

A case study for the Mount Pelion region in Greece

Paratransit systems



Local transport in the Mount Pelion region of Greece is hampered by the sparse road network and difficult mountain conditions. Public transport services are limited and inadequate, a major problem for both residents and visitors to this all-round tourist destination. An innovative 'dial-a-ride' system could be the answer.

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Mount Pelion in Volos is one of the best known national and international tourist destinations in Greece. The region offers pristine mountainous forests, a ski resort for the winter period and attractive beaches for the summer season. However, the high altitude and the steep slopes of the area

make the design and construction of an efficient road system a difficult task and the existing road network is quite sparse. These conditions present the local authorities with one of their most challenging problems: how to operate the existing public transportation system efficiently.

The only public transport system operating in the area is the KTEL of Magnesia (the traditional train of Pelion runs only as a tourist attraction). Services to and from many villages are infrequent (see Table 1) because the large buses have difficulty negotiating the narrow mountain roads.

ITINERARIES	DEPARTURES											
Volos-Agios Lavrentios	06:00	13:45										
Agios Lavrentios-Volos	07:00	14:45										
Volos-Pinakates	06:00	14:00										
Pinakates-Volos	07:00	15:00										
Volos-Agios Vlassios	06:00	12:30	14:00									
Agios Vlassios-Volos	07:15	13:15	15:15									
Volos-Milies-Vizitsa	05:45	06:45	09:00	12:00	13:30	18:00						
Vizitsa-Milies-Volos	07:00	08:00	10:15	13:45		14:45		19:15				
Volos-Zagora	05:15	08:30	14:15 (through Hania)			08:20 (through Neochori)						
Zagora-Volos	08:45	14:30	17:45 (through Hania)			13:55 (through Neochori)						
Zagora-Horefto	07:45	16:45										
Horefto-Zagora	08:15	17:15										
Volos-Neochori	05:15	08:20	12:30	13:30	16:30							
Neochori-Volos	06:55	14:00	17:45									
Volos-Katigiorgis	04:15	10:15										
Katigiorgis-Volos	06:30	15:30										
Volos-Platanias	04:30	10:15	16:30									
Volos-Portaria-Makrinitza	06:15	08:00	10:00	12:30	13:45	14:30	16:30	19:45	20:45			
Makrinitza-Portaria-Volos	07:00	08:45	10:45	13:15	14:30	15:15	17:15	20:30	21:30			
Volos-Agios Ioannis	04:45	13:30										
Agios Ioannis-Volos	07:00	15:30	16:30	15:00								
Volos-Afissos	05:15	11:00	12:30	14:00	16:30	21:00						
Afissos-Volos	07:00	12:00	14:15	15:00	18:15	22:00						
Volos-Kala Nera	04:00	04:15	04:30	04:45	05:00	05:15	05:45	06:30	06:45	08:20	09:00	10:15
	11:00	12:00	12:30	13:30	14:00	16:30	18:00	21:00				
Kala Nera-Volos	07:30	07:40	07:45	08:30	08:40	08:45	09:00	10:45	12:15	14:30	14:45	15:15
	15:30	16:00	16:10	16:50	17:00	18:00	18:45	19:45	20:30	22:15		
Volos-Trikeri	04:00	12:30										
Trikeri-Volos	06:45	16:00										
Volos-Milina	04:30	10:15	12:30									
Milina-Volos	07:30	16:15	16:30	19:30								

Table 1 Itineraries of the KTEL of Magnesia.

The lack of easy access to the villages reduces the attractiveness of the region and creates major mobility problems both for the tourists and the permanent residents of the area.

Past experience indicates that for problems like these a paratransit system can provide a useful demand responsive service. The minibuses often employed by such systems can operate more efficiently on the narrow, steep roads of Mount Pelion. Travel between the villages would be easier, even for handicapped and elderly people, and most journey times would be significant shorter than the services run by KTEL of Magnesia.

DOOR-TO-DOOR SERVICE

The UK and the US were among the first countries to introduce dial-a-ride systems, in the early 1970s, as an element of public transport services in low-density areas.

During the late 1970s, the concept evolved into its present form as a specialised door-to-door service for disabled passengers who are unable to use conventional public transport.

regular taxi (40-80 euros). In Turkey the popular dolmus, while not exactly a door-to-door paratransit service, is more flexible than the bus and more affordable than a taxi or

How to operate the existing public transportation system efficiently?

The most commonly used vehicle is the minibus. Dial-a-ride systems are currently operating in low density areas of the province of Bologna. They are also used extensively in the USA, under the American with Disabilities Act (ADA), and in Canada. Cyprus has a less organised paratransit taxi-based system, mainly for airport service and other intercity trips from 50 to 100 km per trip, which offers a cheaper alternative (10-20 euros) to a

private car. The dolmus service can be described as a privately operated minibus with a capacity of 12 to 14 passengers (but sometimes taxis with a four-passenger capacity) which depart as soon as they are full (dolmus means 'full') and run on predetermined routes with fixed stops.

Many EU countries, including Finland, Sweden, the Netherlands and Belgium,



The vehicle routing problem

One of the most rapidly developing areas of mathematical programming in recent decades has been transport management. This stems from the importance of logistics management in the economy and the great complexity of the related problems. One of the most important transport management problems to attract the attention of both researchers and practitioners in recent years is the vehicle routing problem.

The vehicle routing problem consists of finding a set of optimal routes for a fleet of vehicles to fulfil a set of transportation requests. In general, the objective function takes into consideration the cost of satisfying the requests, which may include a fixed cost per vehicle used, and the transportation cost, which depends on the time or distance travelled. Additional elements may also be incorporated in the objective function, such as the quality of

service provided. Each request is defined by a geographic location and associated with a load. A time window, which defines a time frame for the service of the associated request, may also be specified for each location. There is a static and a dynamic version of the problem, depending on whether the list of requests is fixed or if it is allowed to change over time. All vehicles depart from a start depot and must arrive at a destination depot after they complete their route.

One of the earliest vehicle routing problems studied is the so-called travelling salesman problem. This problem involves a single vehicle without capacity constraints. The objective is to design the shortest possible route that begins at an origin node, visits each node of a given network exactly once and returns to its origin node. In the pick-up and delivery problem, a pick-up and a

delivery node are specified for each request. Among the additional constraints that apply to this problem are the precedence constraints, which state that each pick-up location has to be visited prior to the corresponding delivery location. Pairing constraints restrict the set of admissible routes to those in which both the pick-up and the delivery of each transportation request are by the same vehicle.

Variants of the vehicle routing problem include several important applications:

- 1 Bus and taxi services
- 2 Fleet management for the purpose of collecting or delivering shipments
- 3 Inventory distribution systems
- 4 Door-to-door disabled transport
- 5 Emergency rescue or repair services

have introduced dial-a-ride systems, mainly funded by the European Commission. European experience shows that it is more straightforward to implement paratransit systems in regulated environments because this reduces conflict with other public transport modes.

The UK Government's Transport Ten Year Plan, published in 2000, pledges to remove or at least relax constraints (e.g. route registration) on the development of flexibly routed bus services and promote a greater role for community-based services. In addition, research commissioned by the (then) UK Department of the Environment, Transport and the Regions (DETR) argues that flexible public transport services provided by local authorities and bus operators in partnerships with employers, stores and leisure centres would help to break down social exclusion. Similar findings were reported in Ireland in 1999. The UK Rural White Paper proposals to extend the Bus Service Operators Grant (BSOG) to

community transport were adopted in 2001. More recently, this interest in flexible forms of transport has been backed up by substantial funding from the Rural and Urban Bus Challenge programmes for local authorities to establish demand responsive transport services.

THE DIAL-A-RIDE PROBLEM

Paratransit systems hinge around the 'dial-a-ride problem', in which a fleet of m vehicles must transport n passengers. All vehicles depart from a start depot and must return to a finish depot after they complete their route. The start and finish depots do not need to coincide. For each passenger an origin and a destination location (node) are specified, with a time window for each node within which the passenger must be delivered or picked up. Time windows may also be defined for the start and finish depots. The objective is to satisfy the given requests while optimising an appropriate parameter related to the operation of the system.

Each vehicle may serve more than one person simultaneously, as long as the number of passengers riding on the vehicle at any time does not exceed the capacity of the vehicle. Some passengers may not be taken straight to their destination point, and the inconvenience experienced by the passengers is factored into the problem as a set of constraints, such as the total time or distance passengers may travel before they arrive at their destinations, the total number of nodes each passenger may visit before arriving at their destination, and whether or not the time windows are strictly observed.

Dial-a-ride systems come in many forms. Most try to optimise performance by manipulating the restrictions arising from the specific constraints in each case. Dial-a-ride systems can therefore be classified according to their flexibility: systems with fixed routes and stops; systems that allow a choice from a set of predetermined routes and stops; and systems with no fixed sets of routes and stops, but which can be adapted

REQUEST	PICK-UP NODE	EARLIEST PICK-UP TIME	LATEST PICK-UP TIME	DELIVERY NODE
1 (Anakasia)	1	0	20	21 (Trikeri)
2 (Portaria)	2	20	40	22 (Volos)
3 (Makrinitza)	3	0	20	23 (Portaria)
4 (Zagora)	4	150	170	24 (Tsagarada)
5 (Tsagarada)	5	180	200	25 (Argalasti)
6 (Milies)	6	110	130	26 (Tsagarada)
7 (Neochori)	7	120	140	27 (Platanias)
8 (Argalasti)	8	100	120	28 (Gatzea)
9 (Lafkos)	9	30	50	29 (Milina)
10 (Platanias)	10	40	60	30 (Milina)
11 (Trikeri)	11	40	60	31 (Milina)
12 (Agria)	12	35	55	32 (Kala Nera)
13 (Gatzea)	13	50	70	33 (Afissos)
14 (Kala Nera)	14	65	85	34 (Agios Ioannis)
15 (Afissos)	15	100	120	35 (Agria)
16 (Milina)	16	75	95	36 (Kalamaki)
17 (Agios Ioannis)	17	100	120	37 (Horefto)
18 (Horefto)	18	125	145	38 (Zagora)
19 (Kalamaki)	19	140	160	39 (Promiri)
20 (Promiri)	20	190	210	40 (Lafkos)

Table 2 List of requests.

to the special needs of each user. They can also be classified into one of two ways of processing the requests and designing the routes: the static system, in which all the requests are known in advance and cannot change thereafter; and the dynamic system, in which the requests are allowed to change dynamically over time. Paratransit systems may also operate in an online or an offline mode, depending on whether the system uses new information gathered en route. In an online system a mini-bus would probably

deviate from the planned route if this route was heavily congested.

The paratransit case study for Mount Pelion We designed a paratransit system for the villages around Mount Pelion based on a concept very similar to paratransit systems operating elsewhere in the world. The model presented here is the static case of the problem, without fixed sets of routes and stops, but it can easily be modified into a dynamic system. The challenge is how to modify the general concept to meet the

special needs of the case. The aim is to make the operation of the system as effective as possible and bring the cost of each passenger trip close to the cost of using fixed-route services.

Take a case in which twenty random inhabitants request transport between two given locations in this region. Several physical constraints, which may be related to age, health or time, make it impractical for these people to use the existing public transport system. In our case, the system used for the transportation of the twenty requests consists of three vehicles starting and finishing in the city of Volos, the capital of Magnesia Prefecture. Each vehicle can accommodate at most 6 passengers at the same time. Table 2 lists the origins (pick-up node) and destinations (delivery node) of each of the twenty requests and the specified time windows. Note that these time windows are only specified for the pick-up location of each request. This is not a physical restriction of the problem, but

The intractable nature of these problems means that they become prohibitive for larger scales of operation



[0-3-23-2-12-13-14-32-17-34-18-37-4-38-5-24-25-33-22-41] and [0-9-10-30-29-15-6-26-35-41]. In each of these routes, nodes 0 and 41 are the origin and destination nodes of the three vehicle routes, which is the same location in the city of Volos.

OPTIMAL ROUTES

The map shows the optimal routes. The blue lines correspond to the first vehicle, the green route is for the second vehicle, and the orange route is the third vehicle. All the vehicle routes are feasible and observe the physical constraints of the system: each request is picked up and delivered by the same vehicle; each request is picked up before it is delivered; the capacity of the vehicle is not exceeded at any time; the time windows of each request are observed; the vehicle starts its service as soon as it arrives at a node, and leaves the node immediately after it finishes service.

The total travel time is 299.33 minutes for the first vehicle, 293.21 minutes for the second and 186.06 minutes for the third. This solution is equivalent to the operation of a 6-passenger minibus for approximately 13 hours (= 780 minutes). The total travel times from pick-up to destination for this situation reveal a high level of satisfaction by the passengers. Although the cost of the system is very close to that of a fixed-route service, its performance, as measured by the quality of service provided, is closer to that of a taxi service.

The intractable nature of these problems means that they become prohibitive for larger scales of operation. In recent years researchers have focused on the development of heuristic techniques, which usually provide high quality solutions (close to optimum) even for very large problems. Their main drawback is that in some extreme cases they may provide a solution which is very far from optimal. In general, the complexity of the problem requires a compromise between time efficiency and solution accuracy.

Optimal routes for the Mount Pelion case study.

rather a situation that arises naturally in practice, since each request usually imposes a unique time window, either for the departure from or for the arrival to some location. The road network is symmetric, since transportation is allowed in both directions for each pair of nodes. The direct travel time (in minutes) between each pair of nodes in the network can be easily computed. We assume a service time of 10 minutes at each node of the network for the passengers to board or alight from the vehicle.

The number of possible routes that the three vehicles could follow to satisfy the requests is very large. Our goal is to find the set of routes that optimises some appropriate performance measure (the objective function), while also ensuring that all the

constraints of the problem are satisfied. Because the financial aspect is one of the most important, the most reasonable choice for the objective function is usually to minimise the total cost of the system. Total costs are made up largely of two items: the total operational cost of the vehicles, and the total cost resulting from the dissatisfaction of the travellers. Incorporating additional financial aspects of the problem is a straightforward process.

This is a difficult problem, even for very small networks. It belongs to a special class of vehicle routing problems that require enormous effort to find the exact optimal solution. Using mathematical programming algorithms we found a solution for the three vehicle routes to service the requests: [0-1-11-21-16-31-8-7-19-36-20-39-27-40-28-41],