LIFE Project Number

LIFE15 ENV/GR/000257

LIFE PROJECT NAME or Acronym

LIFE-F4F (Food for Feed)

Action:	B1: Development of the Source Separated Food Waste Collection System
Partner:	HUA
Deliverable:	B1.4. Short listed and selected hotels optimum collection routes

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Introduction

Food residues are generated in the process of daily life, manufacturing, trading, hospitality and other activities. The growth in the standards of living of the population increases both the composition and quantity of wastes produced. Municipal wastes (or similar type waste) are required to be disposed of systemically with the aim of protecting human health and the environment.

The purpose of this report is to demonstrate an optimum routing process for the collection of food residues from hotels sited in the vicinity of the city of Heraklion and the area of Hersonissos in Crete, participating in the programme "Food for Feed: An Innovative Process for Transforming Hotels' Food Wastes into Animal Feed–LIFE-F4F". Optimum routing process is important in order to make the collection system cost effective, making full use of the available resources. To find the optimal route, it is necessary to establish an efficient transit model that enables us to simulate every possible route in advance. In this work, an enhanced algorithm to determine the optimal route is introduced.

The development of the routing process is based on solving the Traveling Salesman Problem (TSP). TSP refers in finding the shortest possible route that starts from a base, visits a given number of places and returns to base. In our stimulation the base is the Waste Pretreatment Unit of Heraklion sited in the south of the city airport and the places that should be visited are 28 hotels participating in LIFE-F4F (figure 1).

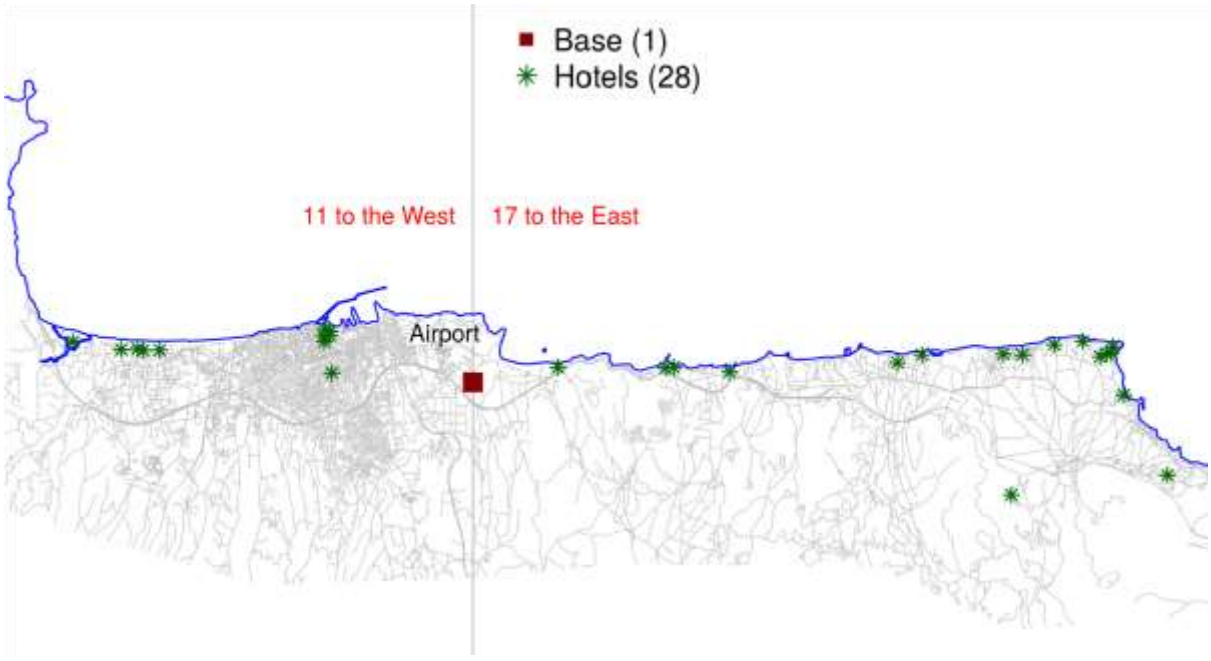

Figure 1: Study area

Routing application

Open data and open source algorithms available to the scientific community were used to minimise the total cost of the management system. Due to it is vast available package ecosystem, high quality graphic exports and interactive visualizations, R programming language was utilized for the purpose. More specifically tools were used from the Open Source Routing Machine project[1] (OSRM), through the corresponding interface for R. OSRM uses open road network data from OpenStreetMap (OSM).

Taking advantage of the shiny package[2], an interactive web application was built that allows the user to select up to 7 hotels from the list of 28, calculate distance and duration for optimum routes to serve them using TSP and visualize all of them on an interactive base map.

Building such an application means that no special knowledge or expertise is required from the end user to calculate routes daily. Additionally, no software installation is needed, and it can be controlled from low spec devices using only a web browser and an internet connection. The cost for the above-mentioned application can be either free with 25 working hours available per month (one hour of use for every day) or 100 USD per year with 100 working hours available per month (four hours of use for every day). The application build is accessible in the link below:

https://veegee.shinyapps.io/heraklio/

Another advantage of this solution is that other programming languages like C, C++, python, Java etc., can be used to build interfaces and take advantage of OSRM API.

The above-mentioned application was tested, and two simulations are discussed below, one with four hotels to be served and one with eight. In these simulations, vehicle capacity has not been considered and it's been considered as capable to serve any weight. A solution for a maximum capacity limit is provided in one of the next chapters.

First simulation (four hotels)

For this simulation the following hotels were chosen and optimum routes and serving order were calculated (figure 2):

"Creta Maris Beach Resort, AQUILA ATLANTIS HOTEL, Galaxy Hotel Heraklion, Olive Green Hotel"

[1] http://project-osrm.org/
[2] https://shiny.rstudio.com/

The calculated duration and speed for every route assumes no traffic at all. Traffic in such a tourist destination as the city of Heraklion is time-varying and hard to be calculated with high accuracy. Even if it could be estimated for a year, there is no guarantee that next year will remain as is. In order to assess the traffic problem three different scenarios were considered with empirically estimations.

- The first scenario assumes that ideally there is no traffic at all and the vehicle is free to travel limited only by the speed limits of the road network (duration column).
- The second scenario assumes that food waste collection takes place in a medium tourism season and that traffic is preventing the vehicle to exceed 30 Km/h even if speed limits allows so (max30 column).
- The third scenario considers high traffic everywhere in the road network and thus the vehicle is not allowed to exceed 15 Km/h of speed (max15 column).

Table 1: First simulation routes with the 4 hotels of the programme.

Start	End	Distance	Speed	Duration	max30	max15
		km	Km.h^{-1}	min	min	min
Base	AQUILA ATLANTIS HOTEL	6.76	21.27	19.07	19.07	27.04
AQUILA ATLANTIS HOTEL	Olive Green Hotel	0.52	12.10	2.56	2.56	2.56
Olive Green Hotel	Galaxy Hotel Heraklion	2.34	20.29	6.92	6.92	9.35
Galaxy Hotel Heraklion	Creta Maris Beach Resort	29.92	60.93	29.46	59.84	119.68
Creta Maris Beach Resort	Base	26.03	44.38	35.19	52.06	104.12
Summary:	Km/ Km.h^{-1}/ min	65.56	42.21	93.20	131.13	262.25

To the above-mentioned duration values in table 1, the model applied considers that the vehicle just passes outside every hotel. The necessary time for the vehicle to enter, the hotel, collect the food wastes and return to the network, is estimated in 10 minutes. So, the above duration values must be modified as in table 2.

Table 2: Scenario duration with 10 min stop for every hotel

Scenario	Time (min)	Time + stall
ideal speed	93.20	133.20
max= 30 km hr^{-1}	131.13	171.13
max= 15 km hr^{-1}	262.25	302.25

Second simulation (eight hotels)

For this simulation the following hotels were chosen and optimum routes and serving order were calculated (figure 3):

"Apollonia Beach Hotel, The Village Heights Golf Resort, Aldemar Knossos Villas, Aquis Bella Beach Hotel, Royal & Imperial Belvedere Hotels, Mitsis Rinela beach resort & spa, LATO BOUTIQUE HOTE, Astoria Capsis Hotel".

Optimum routes and serving order (table 3):

Table 3: Second simulation routes with 8 hotels

Start	End	Distance	Speed	Duration	max30	max15
base	Astoria Capsis Hotel	6.75	31.80	12.75	13.51	27.02
Astoria Capsis Hotel	LATO BOUTIQUE HOTE	0.66	15.64	2.52	2.52	2.63
LATO BOUTIQUE HOTE	Apollonia Beach Hotel	11.67	41.67	16.80	23.33	46.66
Apollonia Beach Hotel	The Village Heights Golf Resort	37.19	68.45	32.60	74.39	148.77
The Village Heights Golf Resort	Royal & Imperial Belvedere Hotels	8.74	29.00	18.08	18.08	34.96
Royal & Imperial Belvedere Hotels	Aldemar Knossos Villas	5.82	17.42	20.04	20.04	23.27
Aldemar Knossos Villas	Aquis Bella Beach Hotel	3.96	14.15	16.80	16.80	16.80
Aquis Bella Beach Hotel	Mitsis Rinela beach resort & Spa	9.35	25.68	21.84	21.84	37.40
Mitsis Rinela beach resort & Spa	***base***	9.08	39.53	13.78	18.16	36.32
Summary:	Km/ km hr^{-1}/ min	**93.22**	**36.04**	**155.21**	**186.44**	**372.88**

Adding the estimated time (10 minutes) that the vehicle stops in every hotel to collect the food wastes (stall):

Table 4: Scenario duration with 10 min stop for every hotel

Scenario	Time (min)	Time + stall
ideal speed	155.21	235.21
max= 30 km hr^{-1}	186.44	266.44
max= 15 km hr^{-1}	372.88	452.88

Conclusions

Considering short delays due to traffic lights, short lunch break for the driver etc., it doesn't seem feasible for a vehicle to serve more than 8 hotels in a single working shift in a high tourism season. Especially when the set of eight hotels includes the opposite extremities of them (far east and far west from the base) that seems impossible.

To assess the problem the below solutions are recommended:

- Overtime working.
- Using a second vehicle and driver.
- Adding a second shift for collection.
- Serve hotels separately East and West from base per day.

Simulation serving separately East-West

Routes for the hotels in the West:

Table 5: West hotels optimum routes

start	end	distance	speed	duration	max30	max15
base	Galaxy Hotel Heraklion	5.81	31.97	10.90	11.62	23.25
Galaxy Hotel Heraklion	AQUILA ATLANTIS HOTEL	1.68	21.38	4.71	4.71	6.71
AQUILA ATLANTIS HOTEL	GDM MEGARON HOTEL	0.28	17.07	0.98	0.98	1.12
GDM MEGARON HOTEL	Astoria Capsis Hotel	1.20	18.30	3.94	3.94	4.81
Astoria Capsis Hotel	Olive Green Hotel	0.22	20.03	0.67	0.67	0.89
Olive Green Hotel	LATO BOUTIQUE HOTE	0.43	14.05	1.85	1.85	1.85
LATO BOUTIQUE HOTE	CANDIA MARIS	5.45	25.19	12.99	12.99	21.82
CANDIA MARIS	Creta Beach Hotel & Bungalows	0.53	13.77	2.29	2.29	2.29
Creta Beach Hotel & Bungalows	Agapi Beach Hotel	0.46	12.08	2.28	2.28	2.28
Agapi Beach Hotel	Hotel Santa Marina	0.56	20.26	1.67	1.67	2.26
Hotel Santa Marina	Apollonia Beach Hotel	1.87	22.28	5.04	5.04	7.48
Apollonia Beach Hotel	base	15.90	52.22	18.27	31.81	63.62
Summary:	Km/Km.h/min	34.41	31.46	65.61	68.82	137.63

Routes for the hotels in the East:

Table 6: East hotels optimum routes

	end	distance	speed	duration	max30	max15
base	AKS Minoa Palace Hotel	3.49	26.29	7.97	7.97	13.98
AKS Minoa Palace Hotel	The Village Heights Golf Resort	18.43	56.81	19.47	36.87	73.74
The Village Heights Golf Resort	Mitsis Serita Beach Hotel	6.30	22.64	16.68	16.68	25.19
Mitsis Serita Beach Hotel	Mitsis Laguna Resort & Spa	1.04	17.19	3.63	3.63	4.16
Mitsis Laguna Resort & Spa	Aldemar Royal Mare	1.55	15.62	5.97	5.97	6.22
Aldemar Royal Mare	Aldemar Knossos Villas	0.65	7.80	5.00	5.00	5.00
Aldemar Knossos Villas	Aldemar Knossos Royal & Royal Villas	0.46	7.72	3.61	3.61	3.61
Aldemar Knossos Royal & Royal Villas	Annabelle Village	0.34	9.16	2.25	2.25	2.25
Annabelle Village	Creta Maris Beach Resort	2.09	15.24	8.24	8.24	8.38
Creta Maris Beach Resort	Royal & Imperial Belvedere Hotels	3.23	20.50	9.46	9.46	12.93
Royal & Imperial Belvedere Hotels	Aquis Bella Beach Hotel	6.82	23.43	17.46	17.46	27.28
Aquis Bella Beach Hotel	Atlantica Caldera Palace	1.30	14.85	5.24	5.24	5.24
Atlantica Caldera Palace	Aquis Arina Sand	4.08	19.05	12.86	12.86	16.33
Aquis Arina Sand	St. Constantin Village	1.59	12.19	7.84	7.85	7.85
St. Constantin Village	Mitsis Rinela beach resort & spa	5.69	22.32	15.30	15.30	22.76
Mitsis Rinela beach resort & spa	Knossos Beach Bungalows & Suites	1.71	24.79	4.13	4.13	6.83
Knossos Beach Bungalows & Suites	Grecotel Amirandes	0.29	17.30	1.00	1.00	1.16
Grecotel Amirandes	base	8.12	40.21	12.12	16.24	32.49
Summary:	Km/ Km.h^{-1}/ min	67.21	25.48	158.26	158.26	268.83

Adding 10 minutes stop for every hotel.

Table 7: Summary for the East-West model

Direction	Hotels	Distance	Duration	max30	max15
West	11	34.4078	175.6117	178.8156	247.6312
East	17	67.2085	328.2567	328.2567	438.8340

Table 7 indicates that serving separately all hotels East or West from base per day is feasible within a typical 8-hour working shift (figure 4). Serving all hotels in one day in both directions is also feasible when enabling overtime working or adding a second vehicle with a second driver. Of course, this solution assumes that the vehicle weight capacity can serve the total weight of food wastes collected on each trip. If the weight capacity of the vehicle used can't serve all the hotels in a single trip, then a solution is provided in the section that follows.

Best hotel combinations

One very important and daily problem that must be solved in order to maximize the efficiency of every route, is to minimise the empty space of the vehicle in every trip. The ideal solution is to select the hotels from which the sum of the food wastes weight to be collected, equals to the transportation capacity of the available vehicle, as it can't be exceeded in any case.

To simulate the problem, we can assume that we must collect food residues from 11 hotels knowing the weight for each one of them (table 8). An approximation for the weight can be accomplished by anyone, using bins of certain volume and the mean weight of the food (Kg/lt). If a fully filled bin weights for example 1.2 tonnes, a half-filled weight 0.6 tonne and so on. The knowledge of the weight to be collected from each of the hotels which is related to the size of them, is a high priority issue for efficient management of the food wastes collection system.

Table 8: 11 hotels with random food residues weight

Hotel	Food waste (t)
Aldemar Knossos Villas	0.50
Mitsis Rinela beach resort & spa	0.20
Mitsis Serita Beach Hotel	0.90
Mitsis Laguna Resort & spa	0.80
Royal & Imperial Belvedere Hotels	1.00
Grecotel Amirandes	0.32
Aquila Atlantis Hotel	0.44
Galaxy Hotel Heraklion	0.61
Creta Maris Beach Resort	0.22
Aldemar Knossos Royal & Royal Villas	0.75
Aquis Bella Beach Hotel	1.20

If the available vehicle can carry maximum 3.5 tons of weight and the maximum number of hotels that can be served in a single working shift is 7, then finding 7 hotels

that the sum of their food wastes weights is below 3.5tn and at the same time is closest to 3.5, is the best combination in order to take full advantage of the vehicle cost.

The code chunk which follows is a implementation of the above method in the programming language R and it can be easily translated to other structural languages such as python, C, C++, Java etc. The problem is known as the "subset sum problem".

```
food.wastes <- c(0.5,0.2,0.9,0.8,1,0.32,0.44,0.61,0.22,0.75,1.2)
names(food.wastes) <- 1:length(food.wastes)
myGroups <- combn(food.wastes, 7)
nms <- combn(names(food.wastes),7,FUN=paste0,collapse=",",simplify = T)
mysums <- combn(food.wastes, 7, FUN = sum, simplify = TRUE)
Results <- myGroups[, mysums < 3.5]
Results.df <- as.data.frame(Results)
sums <- lapply(Results.df, sum)
sums.diff <- lapply(Results.df, function(x) {3.5 - sum(x)})
best.combination <- nms[which.min(sums.diff)]
my.indices <- unlist(strsplit(best.combination, split = ","))
my.indices <- as.numeric(my.indices)
```

The total weight of the best combination is:

```
print(sums[which.max(sums)])
## $V12
## [1] 3.49
```

The hotels (first list) that should be served at the first trip are:

First List
Aldemar Knossos Villas
Mitsis Rinela beach resort & spa
Mitsis Serita Beach Hotel
Mitsis Laguna Resort & spa
Royal & Imperial Belvedere Hotels
Galaxy Hotel Heraklion
Aquis Bella Beach Hotel

The total weight remaining to be collected is:

```
sum(food.wastes) - 3.49
## [1] 3.45
```

The hotels (second list) that remain for the second trip are:

Second List
Grecotel Amirandes
AQUILA ATLANTIS HOTEL
Creta Maris Beach Resort

Aldemar Knossos Royal & Royal Villas

For the above two lists of hotels, the main routing application can be utilised to find the optimum routes and order to serve them, eliminating time and distance as described in the first section.

Monitoring of the identified routes

The following table summarises the results of the real time monitoring of the identified routes with the 4 hotels of the programme.

Table 4: Real time monitoring of the identified routes on with the 4 hotels of the programme

Start	**End**	**Stall (min)**	**Distance (km)**	**Duration (hr)**	**Speed ($km.hr^{-1}$)**
Base (F4F pilot plant)	Olive Green Hotel	05:25.0	6.98	0:26:00	16.11
Olive Green Hotel	Aquila Atlantis Hotel	05:00.0	0.45	0:04:35	5.89
Aquila Atlantis Hotel	Galaxy Hotel Heraklion	06:00.0	1.40	0:10:00	8.40
Galaxy Hotel Heraklion	Creta Maris Beach Resort	35:00.0	29.93	0:41:00	43.80
Creta Maris Beach Resort	***Base (F4F pilot plant)***		24.65	0:51:00	29.00
Travel duration		51:25.0	63.41	2:12:35	28.70
		0.86 hrs. (51.60 min)		2.21 (132.60 min)	
Duration (included stops)				**3.07 hrs. (184.20 min)**	**20.66**

The duration of the identified routes is compared satisfactory with the duration of the actual routes. The only slight “discrepancy” is the total stall time, because of the longer than assumed collection time for one of the hotels (Creta Maris). This does not affect the identified optimum routes and can be easily incorporated in the model.

Figures

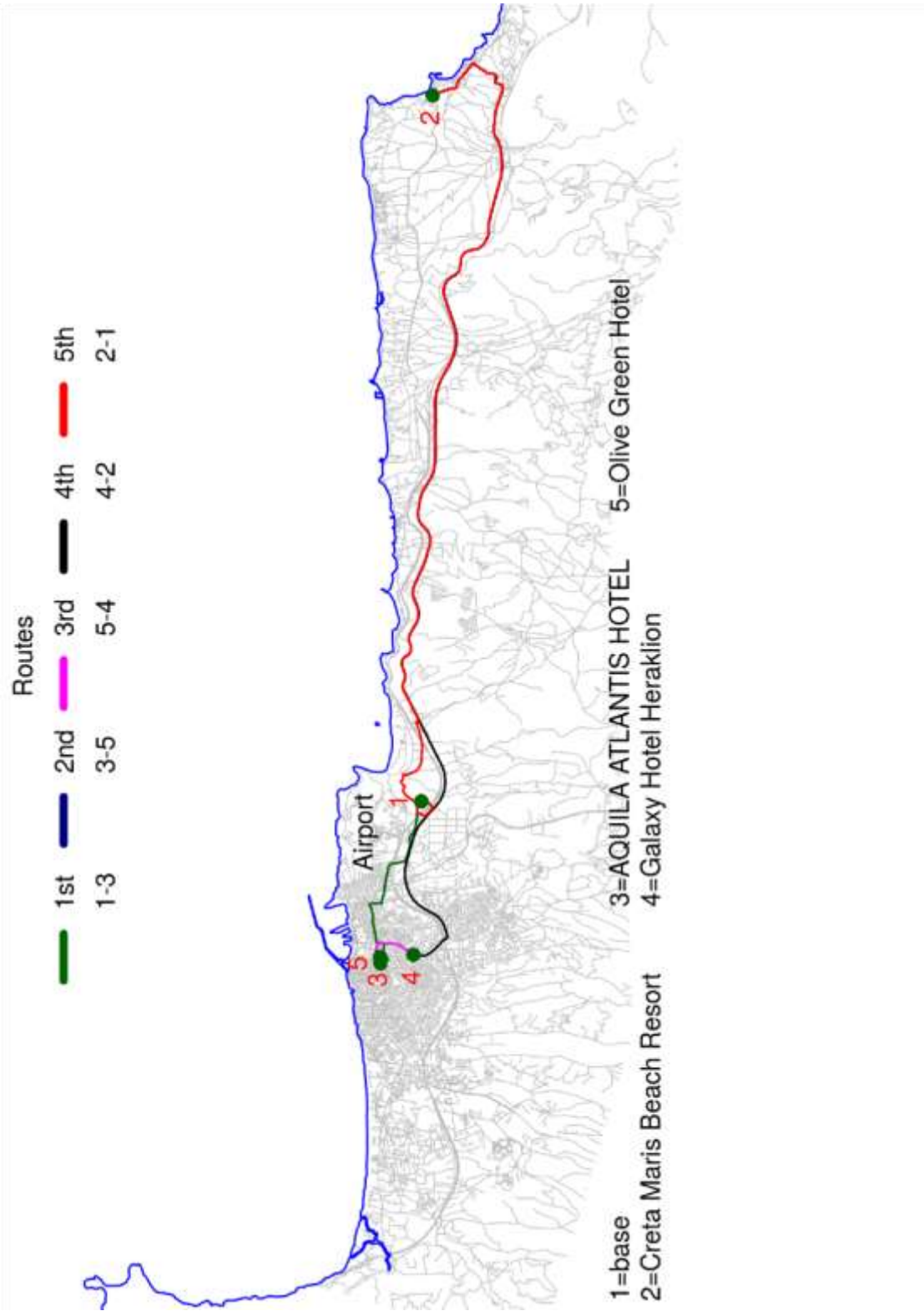

Figure 2: Simulation with the 4 hotels of the programme.

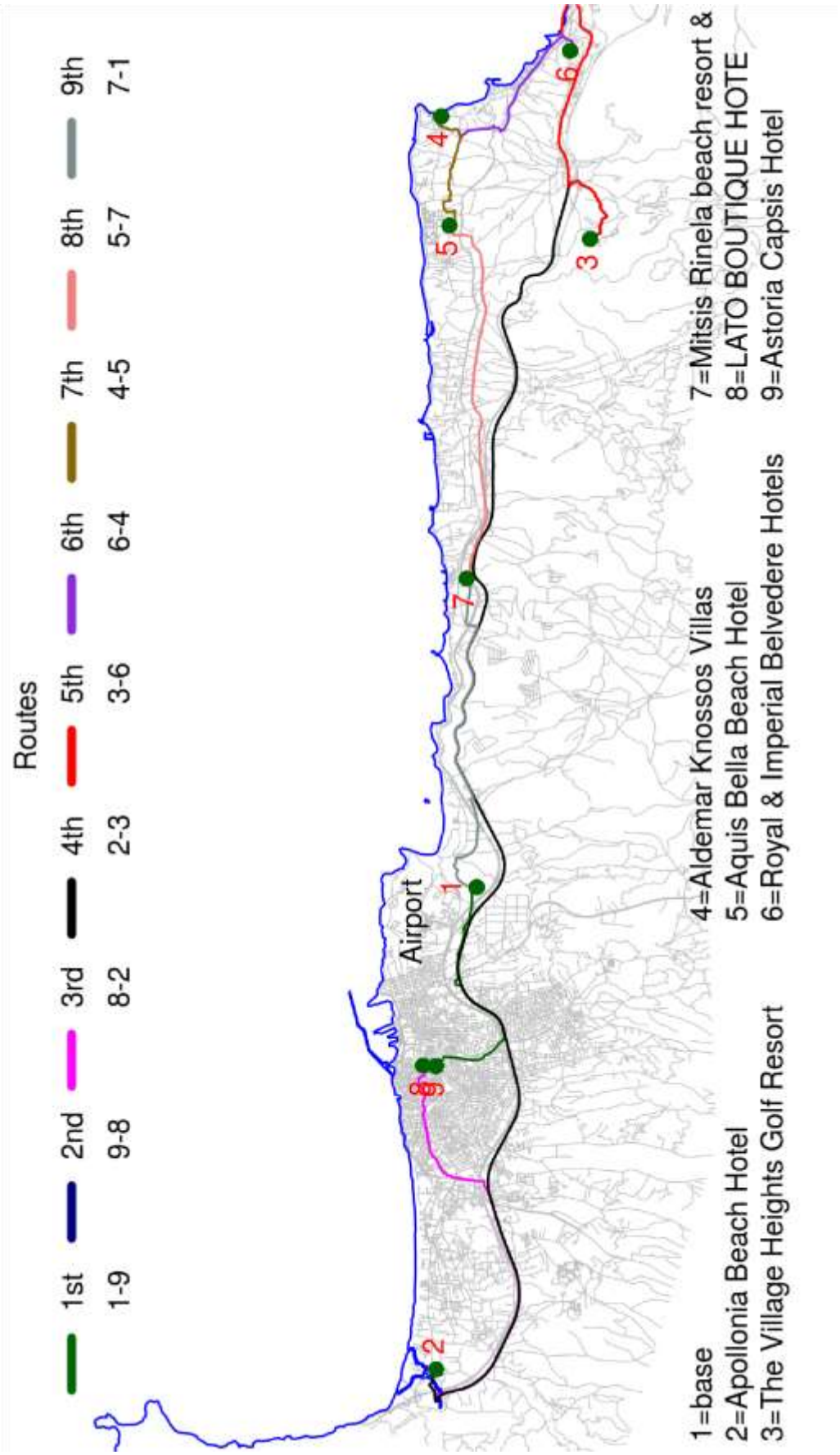

Figure 3: Simulation with 8 hotels

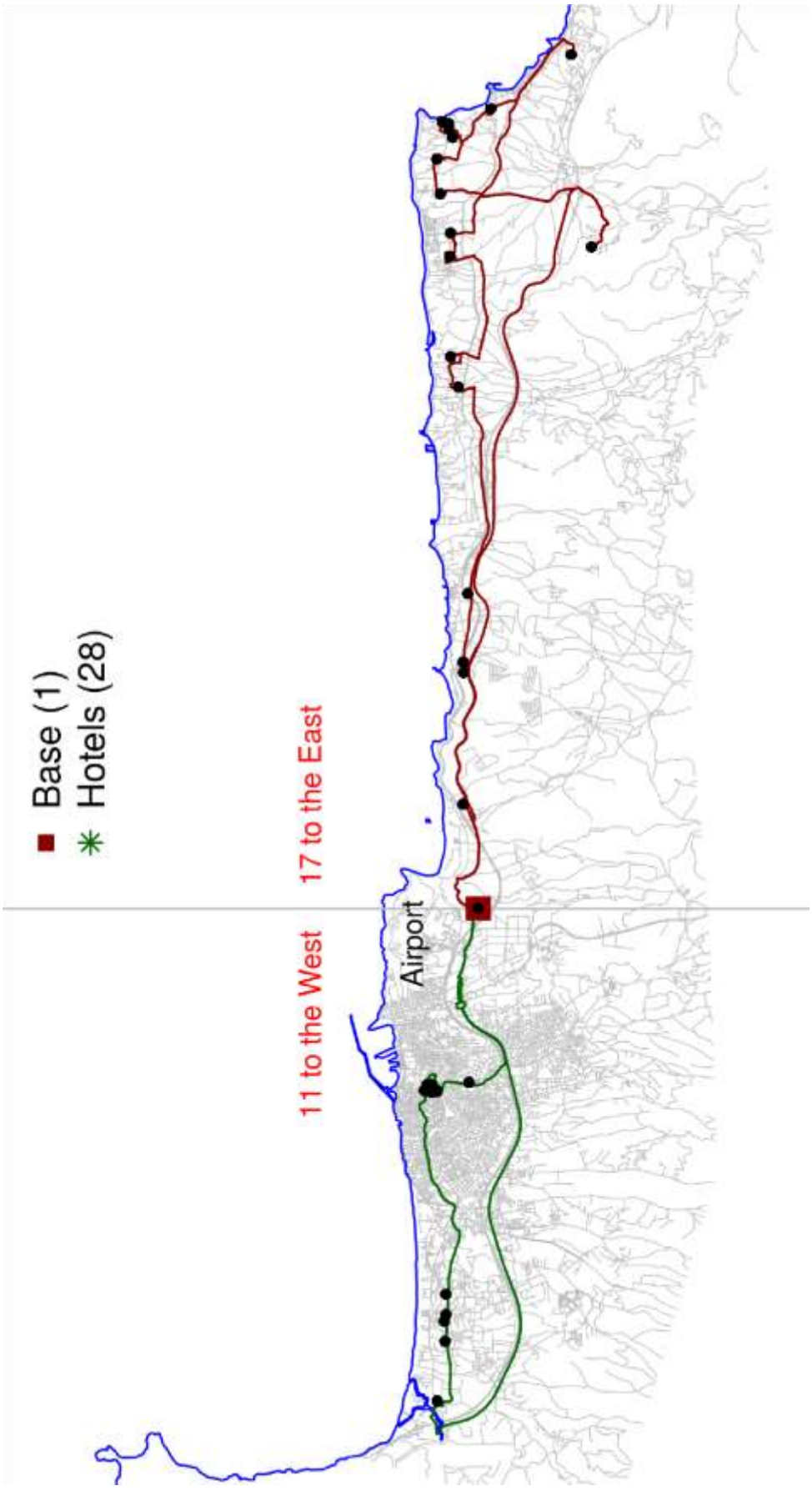

Figure 4: East - West serving model