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A Pilot Study for the Optimization of Routes for Waste Collection Vehicles for the Göçmenköy District of Lefkoşa

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***Abstract*—**A pilot project was carried out in 2007 by the senior students of Cyprus International University, aiming to minimize the total cost of waste collection in Northern Cyprus. Many developed and developing countries have cut their transportation costs – which lies between 30-40% – down at a rate of 40% percent, by implementing network models for their route assignments. Accordingly, a network model was implemented at Göçmenköy district, to optimize and standardize waste collection works. The work environment of the employees were also redesigned to provide maximum ergonomy and to increase productivity, efficiency and safety. Following the collection of the required data including waste densities, lengths of roads and population, a model was constructed to allocate the optimal route assignment for the waste collection trucks at Göçmenköy district.

***Keywords*—**Minimization, waste collection, operations cost, transportation, ergonomy, productivity.

I. Introduction

WASTE collection and transport is an operation necessary to the well being of any country. The cost of this operation cannot be reduced at the expense of low efficiency or minimal service, on the contrary, this type of service should always be made more efficient. Accordingly, the study aimed to make the operations more reliable and efficient and also reduce cost through the conventional means of work study, ergonomics and operations research. Prior to the start of the study, the problems with waste collection were as follows:

1 The routes that were presently being used by the waste collection vehicles were random; this caused a low level of service because of missed collection points and streets.
2 The productivity of the waste workers was very low.
3 The collection workers faced high health risks and proper safety measures were not taken to prevent them.
4 The general city population faced health risks due to uncollected waste.
5 The waste collection vehicles could not be monitored.
6 The shifts of the workers were not fixed which lead to working extra hours with a higher cost.
7 Because of the inefficient waste collection system the tourism inflow and the health of the general student population living on the island was threatened.

The need for such a study is extremely important for Northern Cyprus, whose major sources of income are students and tourists. Both of them need a clean and healthy environment. Therefore, these sources of income should be nurtured by providing them with what they need. The present drop in the number of tourists and students coming to the island can be in part blamed on the low level of services provided by the municipality. Improving and reducing the costs will help the municipality to assign resources and manpower to other projects.

II. Literature Survey

Finding the optimal route for a fleet of vehicles has been the topic of many studies. Optimizing vehicle routes has been classified as Vehicle Routing Problems by Dantzig and Ramser [1], and is basically a variant of the Travelling Salesman Problem with particular constraints. Vehicle Routing Problems are divided into categories which deal with specific constraints such capacity (CVRP), time windows (VRPTW), periods (PVRP) etc.

Teemu Nuortio, Jari Kyto¨joki, Harri Niska, Olli Braysy [2], on the other hand aimed to maximize the efficiency of waste collection vehicle routes for two regions in Eastern Finland. The study provided routes with time windows, hence using the Vehicle Routing Problem with Time Windows or VRPTW (Braysy and Gendreau 2005 a,b). The collection routes were based on the location of waste containers, the vehicles were routed in respect with these co-ordinates. But also, the amount and volume of the waste collected always depended on the density of the population, income level, and Lifestyle, therefore this problem in part becomes a Stochastic Periodic Vehicle Routing Problem with Time Windows and a limited number of vehicles (SPVRPTW). The problem was solved by Guided Variable Neighborhood Thresholding (GVNT) metaheuristic of Kytojoki, Nuorto and Braysy (2004). Average savings due to the implementation of this study was about 2500 km (in Kuopio area), and on average the routes were improved by nearly 46%.

Sandra Cointreau [3] highlights that the total collection costs require from about 0.5% to 2.5% of the total per capita income (as GDP), services only cover from about 30% to 70% of the total urban population and the service is infrequent. Route type, vehicle type, waste type etc should be considered in order to maximize productivity. Results highlight that 5

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person crew had lower cost/tonne then 4 person crew and also that a larger crew can load a vehicle faster than a smaller crew.

Emilie Grellier, Pierra Dejax, Narendra Jussien, Zhiqiang Lu [4] considered a multi-periodic vehicle routing problem for reverse logistics. A logistics network with n stores, warehouses and heterogeneous fleet of vehicles is defined in their case study. The network comprises three different flows: a direct one from warehouses to stores, a reverse one from the stores to warehouses and an internal one between stores and warehouses. The problem of optimization of transport activities and inventory management in a two levels network composed of warehouses and stores is considered.

Many software packages are available that can be used to solve vehicle routing problems, provided that GIS data is available. O. Apaydın and M.T Gönüllü [5] used Route View Pro in their study to find an optimal route for the waste collection vehicles in Trabzon city in Turkey. Optimization was done on a network of 777 waste containers, these containers were distributed in accordance with the population of each area and vehicles were assigned to these areas accordingly, GIS data was integrated with the software and the resulting solutions provided the municipality with a reduction of 24 % in time and 44 % in distance. Fırıncı, Ablay, Khan, Yıldırım, Mütevelli [6], on the other hand, discussed the route assignment system of Nicosia Municipality's waste collection activities, in their study titled "Optimization of Routes of Waste Collection Vehicles of Lefkoşa". In this study, they analyzed the present situation of waste collection at Nicosis and proposed a new methodology, to be discussed in detail.

III. Methodology and Field Studies

The major objective of the study was to provide the waste collection vehicles of the Göçmenköy district with a route that was near optimal which would adequately reduce the time consumed and become more efficient at the same time providing a better environment for the public and the workers. For this objective, a very simple Greedy Algorithm (Minimal Spanning Tree) was used to find the near optimal route. The methodology was broken up into small parts. In this method, the following was carried out to reach the objective:

1. Identify present Geographic location
2. Distribute waste containers based on population
3. Find road distances (measure distance between all waste containers)
4. Implement a Greedy Algorithm to find a route which reduces the distances
5. Once the algorithm is designed, evaluate the present ergonomic conditions of the workers
6. Implement new systems and practices to better the situation

The map of the Göçmenköy district and the divided districts of Nicosia Municipality are given below in Fig. 1 and Fig. 2.

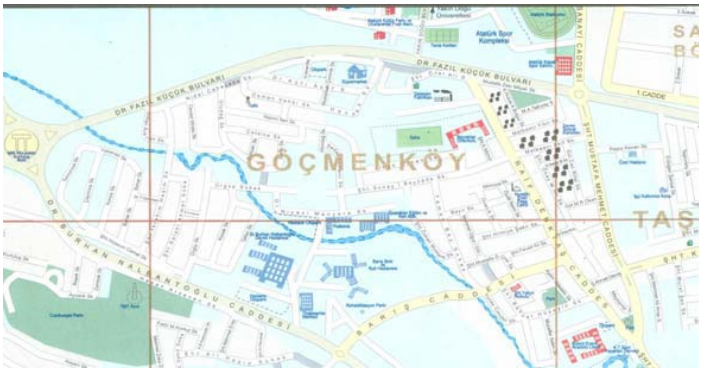

Fig. 1 Map of Göçmenköy district

Fig. 2 Divided districts of Nicosia Municipality

The present system could be viewed as a network with undirected arcs and nodes. Every arc has a weight attached to it, and it is often possible to get from one node to another in more than one ways. Thus, if there are *n* nodes in a network, there must be at least *n-1* arcs that are needed to connect all the nodes with one another. The basic algorithm that will be used over here is as follows:

Step 0: Let M_0= Ø Also K_0= *N*

Step 1: Start with any node, i, in the unconnected network K_0 and Let M_1 = i, which satisfies the condition K_0 = N – I, repeat iteration.

General Form: Select node i, between two nodes, such that d(M_i k_i < M_i k_i), for all i, select this node as permanent node. Go to next node and repeat step. If all the nodes are connected STOP. (**M_i** = Permanently Connected nodes, **k_i =** Nodes yet to be connected).

This problem was represented as an undirected graph, so it should be kept in mind that there should be no cycles or loops. The density of waste was calculated from the study done by Cointreau [4]. The health and safety of the workers were then evaluated by taking into consideration the various practices provided by NIOSH (National Institute for Occupational Safety and Health) and NSWMA (National Solid Waste Management Association).

IV. Results

As is known, reduction of waste collection costs is dependent on the distance travelled by the collection vehicles. Following the implementation of the route assignment model at Göçmenköy and having divided the area into smaller parts, the population density and waste density per zone was effectively determined. According to these data, it was observed that each region in fact generates a waste amount based on population and also the type of population. As highlighted before, the collection of the waste was based on days for different regions. According to the study done by the Municipality, solid waste amount produced per capita in Northern Cyprus is 2.5 kg. This is against the usual norms for developing and developed countries, as their solid waste per capita is approximately 1 kg. There can be a variety of reasons for this, the first and foremost being that there is a large student population living in the Northern side, constituting vast numbers of consumers. Apart from this, the industry of Northern Cyprus is based mainly on food catering industry, which might be another factor contributing to the large amount of waste produced per capita. Container density for each district is given below in Table I.

The number and volume of containers (N_k and V_k) were calculated in accordance with the respective population, obtained from government authorities for respective districts. To carry out the necessary calculations, the following formulation was adopted (Apaydın [6]):

$$N_k = P/P_k$$

where P = Population in area,
P_k =Population to be served by each container

P_k can be derived by:

$$P_k = V_k/V_{RP}$$

where V_k = Volume of Container in m^3.
V_{RP} = Volume of Municipal solid waste per person

V_{RP} can be derived by:

$$V_{RP} = M/W_p$$

where M = MSW amount per person/day
W_p = unit volume per kg in a container, that is density.

Based on the studies and best policies developed by American National Standards Institute, guidelines and policies were developed for the workers on technical requirements, clothing requirements and best practices and policies. Three workers per team were carrying out the collection of wastes in two shifts (morning and evening), starting either at 04:00 am or 24:00 p.m., with the objective of encountering minimal traffic and higher level of safety. For the Göçmenköy district, the average distance travelled was initially 12.2 km. By the application of the greedy algorithm, the optimal route for the Göçmenköy district was found and is presented in Fig. 3. The new distance covered by the new route is 9 km, providing 25 % betterment. This yields reductions both in time and cost.

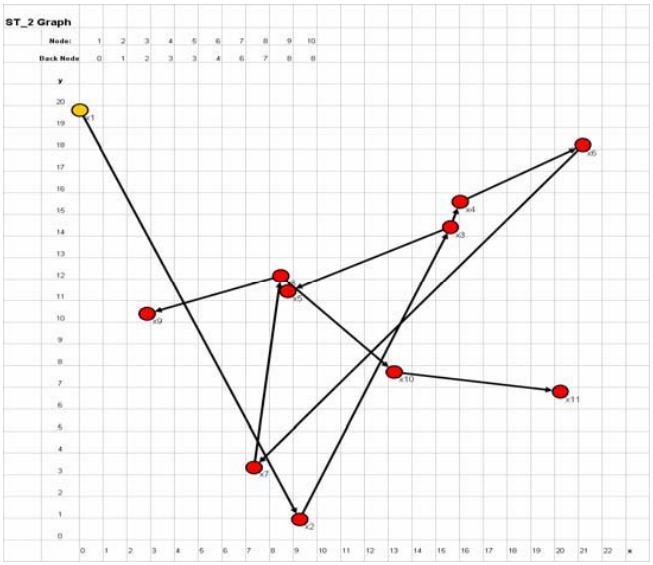

Fig. 3 Optimal route for Göçmenköy district

V. Discussion

This project was undertaken with the aim of studying the current system and providing an element of standardization and cost reduction. This aim was fulfilled to some degree. It is possible that acceptable reductions and cost savings can be acquired with the use of relatively simple algorithms. This paves the way for the future use of more complex algorithms which take into consideration the capacity and time constraints. To conclude, it would be safe to say that the provided route could be implemented in Göçmenköy, bearing in mind the fact that there is a great need to study and improve the system of waste collection in Northern Cyprus. This can be done through various methods, but the implementation of these methods would require both finance and time. The single best option that remains for the Municipality of a country having scarce resources and finances is to move towards systems that rely on scientific observations, in order to improve and utilize the current resources efficiently.

The present working conditions of the employees are appalling to say the least. This needs to be improved if a higher level of productivity is to be expected from them. The only way to improve this is through the application of principles of work study and ergonomy. This will not only increase the productivity of the workers but will also reduce the risks that they face during the work every day. This will directly reflect in the insurance and health premiums paid by the municipality every year.

The present work system cannot be monitored by the management, but after the standardization introduced, it is possible to check whether or not the waste collection requirements in the Gocmenkoy area has been met. In the future it is recommended that the municipality take advantage of a vast array of vehicle tracking software and hardware

available, this would enable the managers to efficiently move the flow of work from one point (with a lower urgency) to a another point (with higher urgency). The proposed system should be considered as a first step in the many more steps that should come in the quest to make the municipality work with 100% efficiency. The pursuit of excellence and perfection is an on going process. It should be kept in mind, that one time betterment of the system will not show any major reductions in cost. The long term and strategic planning however will. Every country should have a waste management system that would satisfy their needs, if not exceed them; the Nicosia Municipality leaves much to be desired in this area.

REFERENCES

[1] Dantzig, G.B.; Ramser, J.H. (1959). "The Truck Dispatching Problem". Management Science 6 (1): 80-91,. Retrieved on 17 April 2008.
[2] Nuortioa, Teemu; Jokib, Jari Kyto; Niskaa, Harri; Braysy, Olli; Improved route planning and scheduling of waste collection and transport, Expert Systems with Applications, pages 223-224, pages 230-231, 2006.
[3] Waste Collection Systems in Developing Countries, pages 1-2, Sandra Cointreau, pp 3-4, pp 10-11, March 2005.
[4] Grelliera, Emilie; Dejaxa, Pierre; Jussiena, Narendra; Lub, Zhiqiang; A Multiperiodic Vehicle Routing Problem in the Context of Reverse Logistics: A Modelling Framework, a Ecole des Mines de Nantes, IRCCyN, LINA 4 rue Kastler, B.P. 20722, 44300 Nantes b Department of Industrial Engineering & Management. School of Mechanical Engineering. Shanghai Jiao Tong University. 1954 Hua Shan Road.
[5] Apaydin, O; Gonullu,M.T; Route Optimization for Solid Waste Collection: Trabzon (Turkey) Case Study, Yildiz Technical University, Environmental Engineering Department, Istanbul, Turkey, published in Global NEST Journal, Vol 9, No 1, pp 6-11, 2007.
[6] Fırıncı, Nergis; Ablay, Talip; Khan, Muhammet Atıf; Yıldırım, Nurcan; Mütevelli, Seçil; Optimization of Routes of Waste Collection Vehicles of Lefkoşa: Cyprus International University Graduation Project, 2007.

TABLE I
CONTAINER DENSITY FOR EACH DISTRICT

District Name	Total	Male	Female	Average Waste/Day (Kg)	Containers
Çağlayan	1413	744	669	**3532,5**	14,13
Göçmenköy	**2946**	**1526**	**1420**	**7365**	**29,46**
Kizilay	2700	1382	1318	**6750**	27
Köşklüçiftlik	3391	1732	1659	**8477,5**	33,91
Kumsal	1770	910	860	**4425**	17,7
Kücükkaymaklı	8054	4243	3811	**20135**	80,54
Marmara	2672	1373	1299	**6680**	26,72
Ortaköy	6277	3322	2955	**15692,5**	62,77
Taşkınköy	6338	3753	2585	**15845**	63,38
Cihangir	929	495	434	**2322,5**	9,29
Çukurova	187	94	93	**467,5**	1,87
Düzova	624	319	305	**1560**	6,24
Hamitkoy	2898	1567	1331	**7245**	28,98
Haspolat	3380	2168	1212	**8450**	33,8
Meriç	546	281	265	**1365**	5,46
Yılmazköy	787	434	353	**1967,5**	7,87
Göçeri	160	88	72	**400**	1,6
Pinarbasi	489	239	250	**1222,5**	4,89
Dagyolu	521	262	259	**1302,5**	5,21
Aydemet	1550	765	785	**3875**	15,5
Dumlupınar	2702	1416	1286	**6755**	27,02
Yenişehir	4156	2135	2021	**10390**	41,56
Total				**136225**	