Designing the Bus Route Network for the City of Heraklion using a Binary Particle Swarm Optimization

George Papadourakis, Mihalis Kalohristianakis, G. Triantafyllidis, Dimitrios Kosmopoulos,

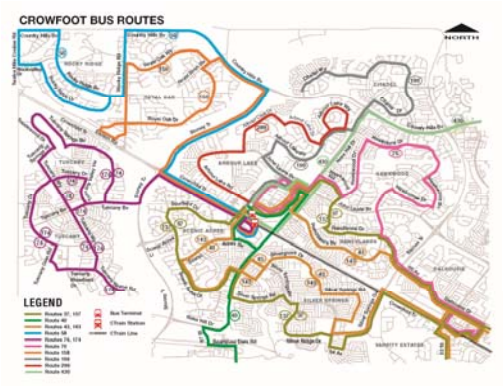
Goal

Optimal design of Public Transportation Systems

Routes of buses

Define

Position of bus stops

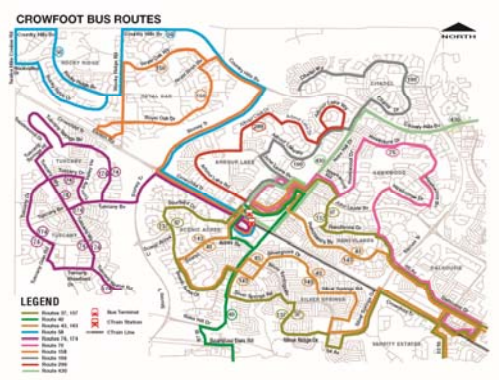


Bus routes

Frequencies

Types of vehicles

Constraints



Structure of street network

Financial resources

Available fleet

Environmental pollution

Customer satisfaction

$$\min Z = \sum_{g=1}^{6} W_g Z_g = W_1 \cdot D_U\left(\underline{LN}, \underline{f}\right) + W_2 \cdot \overline{T}\left(\underline{LN}, \underline{f}\right) + W_3 \cdot e_{h,tot}\left(\underline{LN}, \underline{f}, \underline{G}\right) + W_4 \cdot N_{CS}(\underline{G}) \quad (1)$$
$$+W_5 \cdot V_{req,c}\left(\underline{LN}, \underline{f}, \underline{G}\right) + W_6 \cdot V_{req,c}\left(\underline{LN}, \underline{f}, \underline{G}\right)$$

subject to

$$G_{p,n} \geq G_n \forall n \in \underline{LN} \quad (2)$$

$$L_{\min} \leq L_{n,c} \leq L_{\max,c} \forall n \in \underline{LN} : G_n = 0 \quad (3)$$

$$L_{\min} \leq L_{n,e} \leq L_{\max,e} \forall n \in \underline{LN} : G_n = 1 \quad (4)$$

$$f_{\min} \leq f_n \leq f_{\max} \forall n \in \underline{LN} \quad (5)$$

$$V_{req,c} \leq V_{av,c} \quad (6)$$

$$V_{req,e} \leq V_{av,e} \quad (7)$$

$$S_{x,n,a,a+1} + S_{x,n,a+1,a} \geq 1 \ \forall a = 1 \text{ to } NSL_n - 1,\ 0 \leq x \leq NSL_n - 1,\ n \in \underline{LN} \quad (8)$$

Objective function

Unsatisfied demand

Average travel time

Pollutants emitted

$$\min Z = w_1 D_u(\overline{LN}, \overline{f}) + w_2 \overline{T}(\overline{LN}, \overline{f}) + w_3 e(\overline{LN}, \overline{f}, \overline{G}) +$$

$$w_4 N_{cs}(\overline{G}) + w_5 V_c(\overline{LN}, \overline{f}, \overline{G}) + w_6 V_e(\overline{LN}, \overline{f}, \overline{G})$$

#charging stations

#electric vehicles

#conventional vehicles

The binary formulation

We formulate the solution to the problem as follows:
(a) Fixed number of total bus stops *S* and fixed number of bus lines *L*.
(b) A maximum number of bus stops *s*.

Solution: a binary 2D matrix of *L* rows and *s* columns.

A “1” represents that the respective bus line goes through the respective bus stop.

A vector with $L \times s$ elements.

The formulation

To the previous vector we also have to append bits to encode the following information:

- Frequency of buses per line (number of bits depends on what is the maximum bus frequency)
- Whether the line is operated by electric or conventional bus

The sequence of bus stops is not encoded in the binary vector but can be inferred by running a traveling salesman-like optimization

The PSO

- The continuous PSO
- Assume a number of particles x for each of which:

$$x_i(t+1) = x_i(t) + v_i(t+1)$$

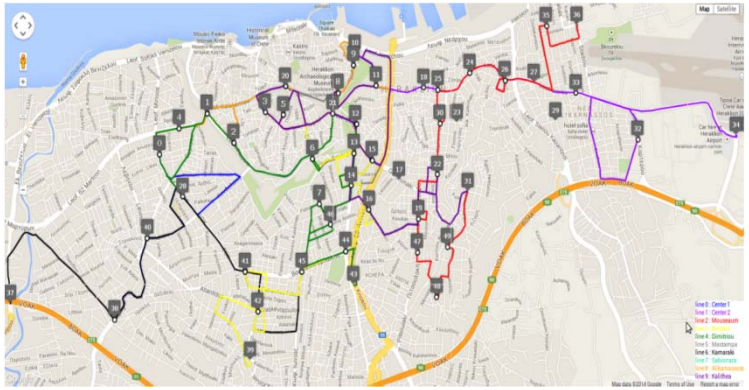
$$v_i(t+1) = w \times v_i(t) + c_1 \times r_1 \times (pbest_i - x_i(t)) + c_2 \times r_2 \times (gbest - x_i(t))$$

- The Binary PSO
- Possible via a sigmoid function

$$T(v_i^k(t)) = \frac{1}{1+e^{-v_i^k(t)}}$$

$$x_i^k(t+1) = \begin{cases} 0 & if \quad r < T(v_i^k(t+1)) \\ 1 & if \quad r \geq T(v_i^k(t+1)) \end{cases}$$

Typical solutions



Conclusions

- Formulation as an objective function which can be optimized via PSO
- Consideration of financial, environmental and human factors
- Next steps: to evaluate and compare to standard genetic algorithm approaches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Thank you