Solving FTP with Multi-Objective Optimization

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Abstract:- In this paper, an approach to solve Freight Transportation Problem is represented. Actually, there are various factors in this problem. There are different ways to consider all effective parameters in the fright transportation problem, but use multi-objective optimization in this paper. We use MOGA (multi-objective genetic algorithm) and AMOSA (multi-objective simulated annealing) to solve presented problem. Although the used algorithms are stochastic and therefor the final results are deterministic in all times, the paper represents a way to consider all parameters simultaneously.

Key-Words:- Freight Transportation Problem, multi-objective genetic algorithm, multi-objective simulated annealing
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1 Introduction

The street patterns and urban layout of modern cities has important role in the developed world. While cities across the developed world grew to accommodate industrial growth, as well as housing needs, the transport system - notably roads, for cars, to support door-to-door mobility - became well planned and played an important role in accessibility, connecting people to jobs, services and facilities. Transport is a function of land uses and that urban traffic can be postulated into three main variables: the standard of accessibility (degree of usage of motor vehicles), environment (degree of freedom from the adverse effects of traffic i.e. danger, accidents, noise, fumes), and the extent of physical alterations (and hence of capital expenditure) for the purpose of accommodating traffic. Since the negative impact of car oriented development became obvious, city planning has been revisited. Certainly the advancing age of the internet and the development of new communication technologies have changed daily life and space. The current urban form, with its gap between the urban center and the per-urban (suburb) is at the centre of discussion, but there are some problems. For example, the fragile balance of energy cost contests the resilience of a city or region. The birth of smart cities is imagined and the ubiquitous rise of smart technologies is expected to shape the 'compact city' / 'new urbanism' movement, to revitalize cities across the developed world. As cities once more reshape, to become smarter and more human in scale, freight emerges as a problem: how can modern cities cope with this most important aspect of life? The objective of this paper is to describe the current situation with regard to freight transportation in cities.

Road hierarchies were introduced in the Buchanan report to Britain's Ministry of Transport (1963), to provide the rationale for managing urban traffic and congestion via economic evaluation, within a capacity, at an environmentally acceptable level. Actually hierarchical approach is useful, it has some problems. First of all, the mentioned approach considers various factors with different prefers, so there is need to set the factors on the levels carefully, but unfortunately preference of factors different in environments and we can't set them forever. Secondly, hierarchical approach assumes the factors are independent from each other, but there is another scenario in the real world. We have some freight transportation factors that influence to each other in realistic and this influence is different in each environment. The main objective of this paper is addressing to this problems.

In this paper, an Evolutionary Multi-Objective Optimization (EMOO) algorithm is introduced. EMOO allows optimize factors simultaneously.

2 Related Works

The Urban Freight Distribution is a growth field with multiple variables. This problem can be modeled with emphasize on time and capacity [1]. The notation in model is as follow:

E_i: Quantity of goods that must be delivered
Q_k: Load capacity 'Q' of vehicle 'k'
$[a_i, b_i]$: Time window to visit node 'i'
S_i: Service time at node 'i'
D_{ij}: Distance between 'i' and 'j'
TV_{ij}: Time to travel along the route of the arc $< i, j >$
T_i: Time to start service at node 'i'
X_{ijk}: Take 1 if the vehicle 'k' traveles from 'i' to 'j'

So the problem is modeled as follow:

$$\text{OPT.} \quad \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} D_{ij} * X_{ijk}$$

The HC12 is a heuristic searching algorithm that represents the results with searching in the feasible area [2]. Same as other heuristic algorithms, the first step of HC12 is generating the first set of solutions. This set is stochastic and binary. In the next step, the new population (solutions) is generated, which is based on the concept of 'space' (such as hamming distance). This step is doing in a loop. In each iteration, the best individual, which is called 'kernel', is chosen as base to generate the population of the next iteration. Then the neighborhood individuals of kernel create the population for next iteration. The degree of locality/globally depends on the size of neighborly. The pseudo-code of HC12 algorithm is as follow:

$M \leftarrow (M_0, M_1, \cdots, M_n)^T$
$a_{opt} \leftarrow \text{Stochastic}$
For $i = 1$ To Max_Iteration Do
  repeat
    $a_{ker} \leftarrow a_{opt}$
    $A \leftarrow a_{ker} \oplus M$
    $a_{opt} \leftarrow \operatorname{argmin}\left(f(\Gamma(a))\right)$
  until $a_{opt} = a_{ker}$
End

Freight vehicles have the critical role in the driving process [4]. It can produce higher crash frequency with tradeoff between its parameters. Travel time, break-taking behaviors, emission, etc., are the major topics that must be considered in research about freight transportation.

Nowadays, most works on the speed prediction models use the operating speed, but this paper applies a deep learning method. The method is used to predict the general condition with road geometry and the temporal evolutions. Drivers choose their driving speed according to the road condition, but designing speed of the road does not necessarily mean the actual driving speed. Operating speed, on the other hand, is a statistical value of the speed dataset. The presented studies use various regression models such as linear regression; log-linear regression, non-parametric multivariate adaptive regression and parametric logistic regression have all shown their adaption in different practical problems. This paper presents a Recurrent Neural Network to predict the driving speed with considering the geometry parameters.

Road transportation has some advantages: mobility and improve the fuel security [5]. In this paper, authors use an economic approach through the operation management viewpoint to solve the mentioned problem. They define a plan with two dimensions to depict the supply chain collaboration. Horizontal line is set for shippers. Thus the paper has three goals: minimizing the transportation cost, minimizing the CO2 emissions and maximizing the number of created job opportunities. The proposed approach is providing the two-echelon location routing problem to decision making according to evaluation of effect of routing and facilities. Therefore some measurements are defined for sustainability: 1-economic, 2-environmental and 3-social. The first element of sustainability is based on the cost/profit. The measurement of CO2 emission (environment factor) can be added to this concept. The formula of environment factor is as follow:

$$e\left(d_{ij}, c_k, x_{ij}^k\right) = \sum_k \sum_i \sum_j d_{ij} * \left[\left(E_{full} - E_{empty}\right) * \frac{x_{ij}^k}{c_k} + E_{empty} * \left\lceil \frac{x_{ij}^k}{c_k} \right\rceil\right]$$

where $e\left(d_{ij}, c_k, x_{ij}^k\right)$ is the CO2 emission.

Authors propose a plan to service for transportation (passenger or freight) through metro line [6]. Thus they introduce some factors such as train capacity, cargo loading cost, and train service frequency. Then they formulate those factors to produce optimal scheduling of transportation. Authors use Variable Neighborhood Search algorithm (VNS) to solve the model. There are some assumptions: 1-In the certain time period, metro train has capacity to transport certain number of cargo. 2-Loading/Uploading good boxes require certain time window. The VNS algorithm has three parts: 1-initial solution, 2-shaking process and 3-variable neighborhood descent (VND) process. Actually the proposed algorithm is equal to other evolutionary optimization algorithms. In other words, number disturbances operators apply on the set of primitive solution and then produce the next solution. This process run until the determination conditions.

Paper focuses on the children health in transportation [7]. For this reason, authors present a mathematical model to spatial lead of distribution. Therefore an equation for the diffusion-advection of transportation is represented. Then the presented equation is calculated using the mean velocity and the mean free path. Authors construct the initial condition of their system according to data on the mixing ratios in 2007 in the Jersey parks.

There are several problems in the transportation which are needed to be solved [8]. There are two goals in this paper: 1-minimizing total train traveling time and 2-minimizing the tardiness of the freight to their destination. In the next step, authors present a formula to consider both objective functions.

Any railway organization needs to maintain high quality to create a competitive way over the other ways of transportation and also to survive between other organizations [9]. The Locomotive Assignment Problem (LAP) is a problem that addresses various factors for suitable transportation service. Decision-making of the railway organization can be viewed in three levels hierarchically (strategic, tactical and operational).

Actually, authors focus on the Indian railway. Indian Railways needs to reduce its operating expenses and increase the profit margin.

3 Problem Methodology

Suppose there a net of stations (nodes). Actually, embarkation and disembarkation is different (costing/timing) in any station. There are links between stations (arcs). Each link has own characteristics such as price, capacity, required time to delivery and so on.

For example, there are 17 stations in Fig. 1 and also 22 links. Stations and links are identified with numbers to easier knowing. In this problem, freighted good is packed in M packets.

notation	description	range
i	number of stations	$1, \cdots, I$
j	number of links	$1, \cdots, J$
k	number of packets	$1, \cdots, K$

Table 1. Range and Description of Notations

Table 1 represents the meaning and the range of each notation in this problem. The optimize path starts from station 1 and finish in station 17. In each station, there is ability to embark and disembark number packets, but the total number of packets in the last station have to be M. Let declare CR, CS, TR, TS. CR is abbreviation for COST-OF-ROAD and includes price (that must be paid) and also the environment pollution for transferring via each link. CS is abbreviation COST-OF-STATION and it means the price for each station. TR is abbreviation of TIME-ROAD and it means the required times for passing via each link. TS is abbreviation of TIME-STATION and it means required time for embarkation and disembarkation in each station.

Table 2 represents the CS and TS for all stations.

Table 3 represents CR and TR for all links.

station	**CS**	**TS**
1	5	6
2	4	2
3	1	6
4	6	3
5	1	6
6	5	6
7	5	5
8	2	4
9	6	4
10	1	5
11	6	3
12	1	2
13	4	4
14	1	2

15	1	2
16	2	5
17	2	1

Table 2. Stations' parameters

link	CR	TR
1	34	29
2	52	60
3	54	20
4	54	30
5	13	38
6	35	53
7	39	52
8	43	27
9	37	19
10	17	25
11	13	34
12	25	10
13	41	36
14	19	10
15	27	16
16	60	27
17	47	60
18	54	44
19	48	50
20	13	17
21	21	52
22	17	48

Table 3. Links' Parameter

Now we are ready to define a formula for this problem.

4 Problem Solving

Let there is a matrix. The first and the second rows of this matrix shows the vertexes of links. The choose path is a sequence of links with following condition. The second vertex of any link in path

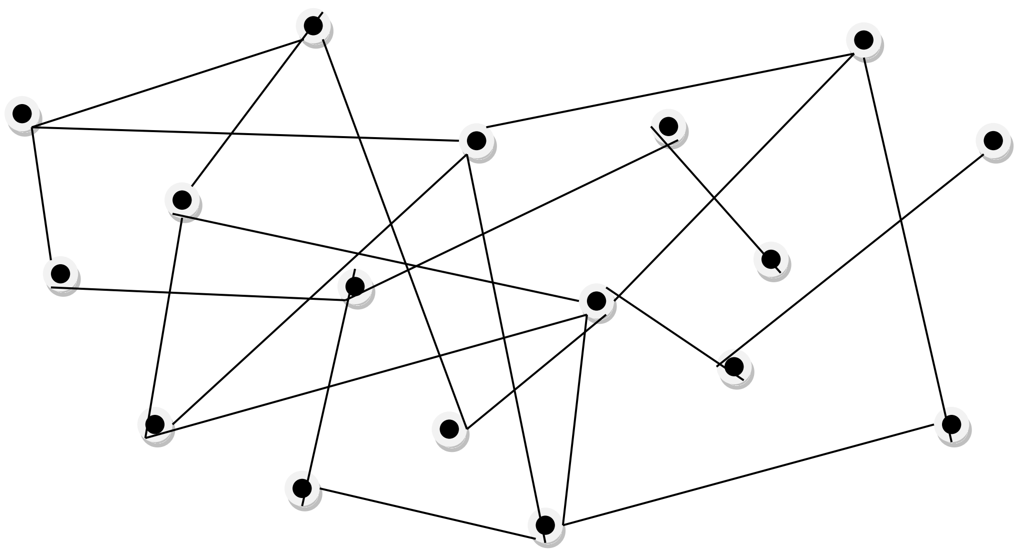

Fig. 1, Paths Net

must be same as the first vertex of the next link. For example, the follow matrix (Fig. 2) represents a path:

1	2	3	5	8	7	6	10	3	11	15
2	3	5	8	7	6	10	3	11	15	22

Fig. 2, Path Example

The main goal is producing the optimum path. According to the previous section, the optimization problem is defined as follow:

$$Opt. \quad P(k) = \sum_i (CS_i + TS_i) + \sum_j \left(CR_j + TR_j\right)$$
(1)

$S.T.$

$$\sum k = M$$

The first part of formula (1) says the cost of the links in the chosen path and the second part says the cost of the stations. Table 4 represents the results when we optimize it with the MOGA (multi-objective genetic algorithm) and ASOMA (multi-objective simulated annealing).

MOGA	AMOSA
356	124
328	168
259	148
431	243
440	144
359	218
522	192

Table 4. Results

5 Conclusion

In this paper, we use MOGA (multi-objective genetic algorithm) and AMOSA (multi-objective simulated annealing) to solve Freight Transportation Problem. Presented approach considers all parameters simultaneously. We repeat these stochastic algorithms (MOGA and AMOSA) 7 times. Due to results, it understand that AMOSA has more ability to solve Freight Transportation Problem.

References

[1]. Andrés Felipe León Villalba, Elsa Cristina González La Rotta, “Clustering and heuristics algorithm for the vehicle routing problem with time windows”, International Journal of Industrial Engineering Computations 13 (2022) 165–184

[2]. Radomil Matousek , Ladislav Dobrovsky, Jakub Kudela, “How to start a heuristic? Utilizing lower bounds for solving the quadratic assignment problem”, International Journal of Industrial Engineering Computations 13 (2022) 151–164

[3]. Thomas H Zunder, Paulus T Aditjandra, Dewan Md Z Islam, Maciej R Tumasz, Bruce Carnaby, “NewRail – Newcastle Centre for Railway Research”, School of Mechanical and Systems Engineering, Newcastle University, Stephenson Building, Newcastle upon Tyne, NE1 7RU, UK, 2016

[4]. Yuren Chen, Yu Chen , Bo Yu, “Speed Distribution Prediction of Freight Vehicles on Mountainous Freeway Using Deep Learning Methods”, Hindawi, Journal of Advanced Transportation, Volume 2020, Article ID 8953182

[5]. Hanan Ouhader, Malika El Kyal, “Combining Facility Location and Routing Decisions in Sustainable Urban Freight Distribution under Horizontal Collaboration: How Can Shippers Be Benefited?”, Hindawi, Mathematical Problems in Engineering, Volume 2017, Article ID 8687515

[6]. Yutao Ye, Junhua Guo , Lixin Yan, “A Metro Freight Plan for Mixed Passenger and Freight Transportation”, Hindawi Journal of Advanced Transportation Volume 2022, Article ID 6602387

[7]. Zhixiong Chen, Yi Ding, Andrew Getz, Bernard Lipat, “Urban Lead: Modeling Its Distribution and Effects on Children”, Hindawi Journal of Applied Mathematics Volume 2017, Article ID 6107430

[8]. Marie Alaghband, Babak Farhang Moghaddam, “An Optimization Model for Scheduling Freight Trains on a Single Rail Track”, Scientia Iranica , DOI: 10.24200/sci.2020.53538.3304

[9]. Prashant Premkumar, P. N. Ram Kumar, “Literature Review of Locomotive Assignment Problem from service operations perspective: The Case of Indian Railways”, IIM Kozhikode Society & Management Review 8(1) 74–86, 2019, Indian Institute of Management Kozhikode Reprints and permissions: in.sagepub.com/journals-permissions-india DOI: 10.1177/2277975218810959