ANÁLISIS E IMPLEMENTACIÓN DEL "HETEROGENEOUS MULTI-TYPE FLEET VEHICLE ROUTING PROBLEM IN FINISHED VEHICLE LOGISTICS" (HVRP-FVL)

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Facultad de Ingeniería
Tesis de pregrado

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Introducción

- Entregas especializadas
- Manejo del tiempo
- Aplicado en envíos.
- Logístico

Objetivos

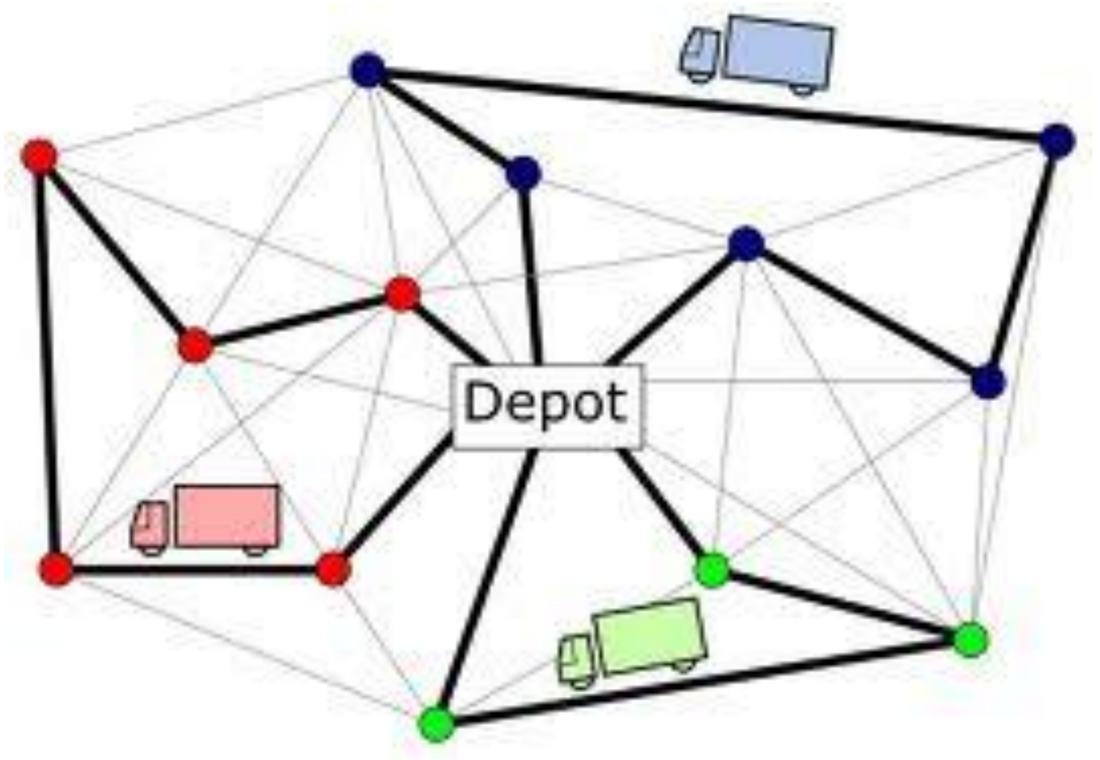
Objetivo General:

- Replicar y evaluar el modelo propuesto para el HVRP-FVL.

Objetivos Específicos:

- Analizar el modelo matemático propuesto.
- Comparar los resultados obtenidos con la información original.
- Probar el modelo de distintas maneras, viendo el impacto en tiempo de ejecución.

HVRP-FVL: Heterogeneous VRP in Finished Vehicle Logistic



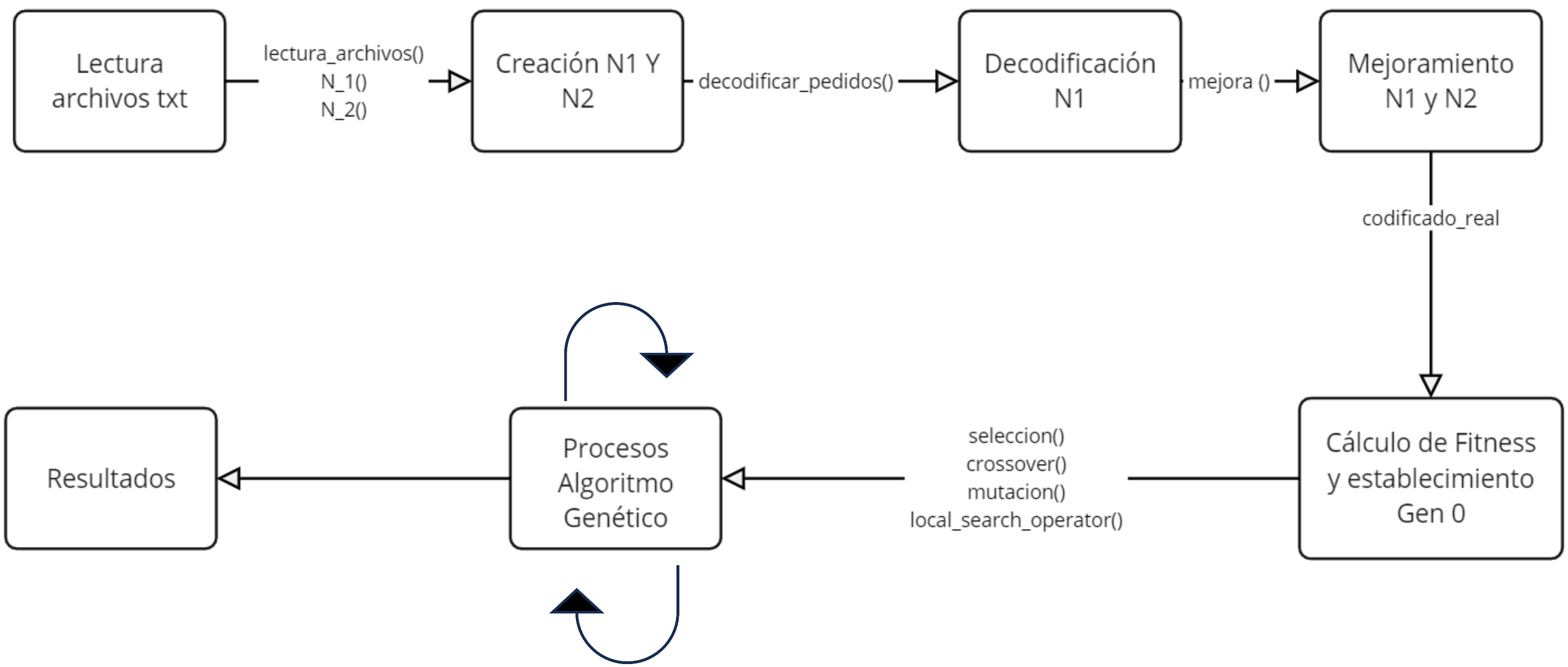
Modelo

Función objetivo y Restricciones	Ecuación
Función Objetivo	$F = f_1 + f_2 + f_3$
Conservación del movimiento	$\sum_{i=0}^{N} x_{iju}^{k} = \sum_{i=0}^{N} x_{jiu}^{k}, \forall j \in N, \forall k \in K; \forall u \in U_k$
Asignación Única	$\sum_{u=1}^{Uk} \sum_{k=1}^{K} y_{iu}^{k} = 1, \forall i \in N$
Restricción de alto y ancho de carga	$y_{iu}^{k}(S-1) = 0, \forall i \in N; \forall k \in K; \forall u \in U_k$
Restricción de capacidad de carga	$\sum_{p=1}^{P} \sum_{i=1}^{N} D_{ip} w_p y_{iu}^{k} \leq G_k, \forall k \in K, \forall u \in U_k$
Restricción de largo de carga	$\sum_{p=1}^{P} \sum_{i=1}^{N} D_{ip} l_p y_{iu}^{k} \leq L_k, \forall k \in K, \forall u \in U_k$

- N: Conjunto de nodos (clientes), donde 0 es el depósito.
- x: Variable de decisión 1
- y: Variable de decisión 2
- Q_v: Capacidad máxima
- K: Flota heterogénea de vehículos K.
- w_p: Demanda del cliente i (en toneladas).
- D_{ip}: Demanda del cliente i de vehículos tipo p.
- G_k, L_k, W_k, H_k: Limitaciones de carga, largo, ancho y alto del vehículo de tipo k.
- S_p^k: Disponibilidad del vehículo de transporte k para el vehículo terminado del tipo p

$$S_p^k = \begin{cases} 1, w_p < W_k \ y \ h_p < H_k \\ 0, caso\ contrario \end{cases} \forall p, \forall k$$

Funcionamiento



Resultados Casos de estudio 1: 21 Clientes

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Optimized Solutions

Ruta n°	Tipo Vehículo	Ruta
1	1	D0→D20→D21→D0
2	3	D0→D19→D18→D15→D0
3	2	D0→D14→D17→D0
4	3	D0→D13→D12→D11→D0
5	2	D0→D8→D10→D0
6	2	D0→D16→D1→D0
7	1	D0→D4→D2→D0
8	3	D0→D3→D6→D9→D0
9	2	D0→D7→D5→D0

Prueba 1

Ruta n°	Tipo Vehículo	Ruta
1	1	[20, 21]
2	3	[19, 18, 15]
3	2	[14, 17]
4	3	[13, 12, 11]
5	2	[8, 10]
6	2	[16, 1]
7	1	[4, 2]
8	3	[3, 6, 9]
9	2	[7, 5]

Comparativa Fitness

	f_1	f_2	f_3	F
Paper	35078	95	32391	67564
Replica desarrollada	43460	374	590913	634749

Resultados Casos de estudio 2: 100 clientes

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Optimized Solutions

Ruta n°	Tipo Vehículo	Ruta
1	3	D0→D46→D22→D93→D0
2	2	D0→D97→D95→D0
3	3	D0→D1→D42→D63→D40→D0
4	3	D0→D67→D26→D34→D0
5	2	D0→D98→D5→D0
6	2	D0→D32→D9→D0
7	3	D0→D92→D7→D54→D0
8	3	D0→D83→D70→D86→D0
9	2	D0→D35→D81→D0
10	2	D0→D37→D2→D0
11	3	D0→D4→D23→D57→D0
12	3	D0→D27→D52→D21→D0
13	2	D0→D80→D24→D0
14	3	D0→D100→D60→D19→D0
15	3	D0→D50→D94→D18→D0
16	3	D0→D85→D43→D53→D0
17	3	D0→D87→D49→D20→D0
18	3	D0→D55→D76→D71→D0
19	1	D0→D96→D90→D0
20	3	D0→D10→D89→D8→D0
21	3	D0→D99→D72→D0
22	3	D0→D65→D11→D13→D0
23	3	D0→D75→D29→D12→D44→D0
24	3	D0→D82→D73→D91→D0
25	2	D0→D78→D48→D0
26	2	D0→D69→D15→D0
27	2	D0→D17→D84→D88→D0
28	2	D0→D61→D45→D25→D0
29	2	D0→D47→D39→D0
30	2	D0→D64→D58→D0
31	2	D0→D31→D6→D0
32	2	D0→D16→D38→D0
33	2	D0→D62→D36→D0
34	1	D0→D14→D0
35	2	D0→D51→D56→D0
36	3	D0→D28→D33→D68→D0
37	2	D0→D41→D79→D0
38	2	D0→D59→D30→D0
39	2	D0→D66→D3→D0
40	2	D0→D74→D77→D0

Prueba 2

Ruta n°	Tipo Vehículo	Ruta
1	3	[46, 22, 93]
2	2	[97, 95]
3	3	[1, 42, 63, 40]
4	3	[67, 26, 34]
5	2	[98, 5]
6	2	[32, 9]
7	3	[92, 7, 54]
8	3	[83, 70, 86]
9	2	[35, 81]
10	2	[37, 2]
11	3	[4, 23, 57]
12	3	[27, 52, 21]
13	2	[80, 24]
14	3	[100, 60, 19]
15	3	[50, 94, 18]
16	3	[85, 43, 53]
17	3	[87, 49, 20]
18	3	[55, 76, 71]
19	1	[96, 90]
20	3	[10, 89, 8]
21	3	[99, 72]
22	3	[65, 11, 13]
23	3	[75, 29, 12, 44]
24	3	[82, 73, 91]
25	2	[78, 48]
26	2	[69, 15]
27	2	[17, 84, 88]
28	2	[61, 45, 25]
29	2	[47, 39]
30	2	[64, 58]
31	2	[31, 6]
32	2	[16, 38]
33	2	[62, 36]
34	1	[14]
35	2	[51, 56]
36	3	[28, 33, 68]
37	2	[41, 79]
38	2	[59, 30]
39	2	[66, 3]
40	2	[74, 77]

Resultados Pruebas 1

N° DE CLIENTES	MÁXIMO POR TIPO	MAXIMO PEDIDO	MÁXIMO FITNESS [RMB]	POS MAX	MINÍMO FITNESS [RMB]	POS MIN	PROMEDIO FITNESS [RMB]
10	1	5	1790595	366	1574258	265	1702690
10	2	5	1325321	834	1116194	14	1199228
10	3	5	1506685	285	1181822	585	1324501
10	4	5	1963758	401	1740316	390	1834954
10	5	5	1384036	290	1211477	655	1259900
10	2	10	3627715	892	3373338	586	3460463
10	3	10	1614419	700	1440215	832	1514930
10	4	10	2391317	108	2302709	203	2331271
10	5	10	2475494	74	2363874	98	2402084
10	3	15	2981463	156	2691281	898	2799263
10	4	15	2926156	820	2894354	682	2899268
10	5	15	3820416	853	3780466	59	3787245
10	4	20	1726367	685	1618486	886	1633998
10	5	20	4782599	789	4558505	3	4642575
10	5	25	3749599	900	3734869	101	3737031

Resultados Pruebas 2

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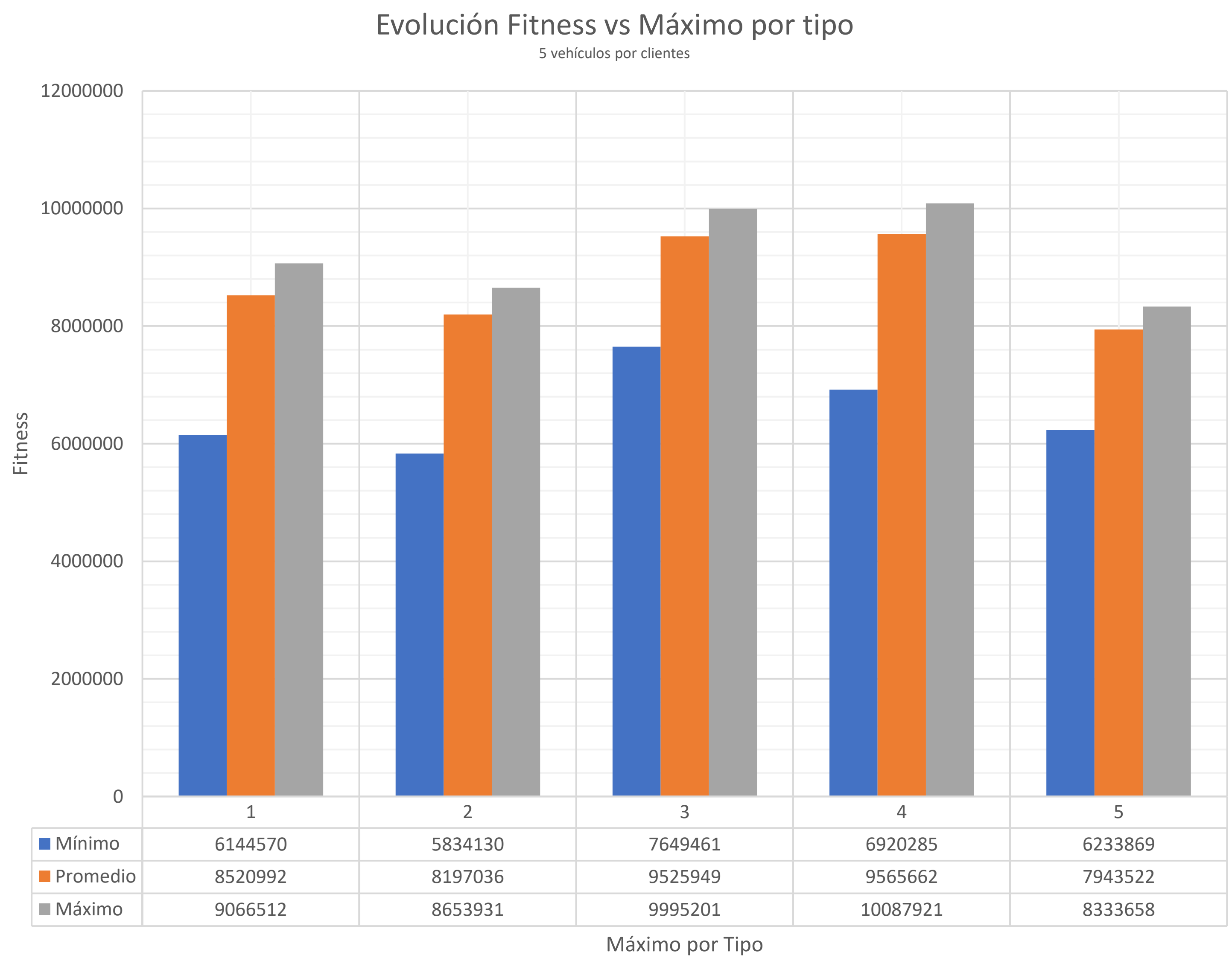
N° DE CLIENTES	MÁXIMO POR TIPO	MAXIMO PEDIDO	MÁXIMO FITNESS [RMB]	POS MAX	MINÍMO FITNESS [RMB]	POS MIN	PROMEDIO FITNESS [RMB]
50	1	5	9066512	476	6144570	2	8520992
50	2	5	8653931	285	5834130	0	8197036
50	3	5	9995201	373	7649461	8	9525949
50	4	5	10087921	828	6920285	0	9565662
50	5	5	8333658	702	6233869	5	7943522
50	2	10	21555158	244	19927002	10	20947410
50	3	10	12243889	855	11252327	6	11907828
50	4	10	11722565	152	10899649	888	11421702
50	5	10	13732886	301	12907263	2	13525151
50	3	15	11917624	852	10347353	2	11523501
50	4	15	14238745	301	13412104	478	13948576
50	5	15	17186591	540	16524785	63	16920851
50	4	20	11563224	320	10980915	858	11337824
50	5	20	24735899	807	23685982	192	24362351
50	5	25	21276489	584	20697539	655	21025788

Análisis



	1	2	3	4	5
Mínimo	6144570	5834130	7649461	6920285	6233869
Promedio	8520992	8197036	9525949	9565662	7943522
Máximo	9066512	8653931	9995201	10087921	8333658

Análisis tiempos

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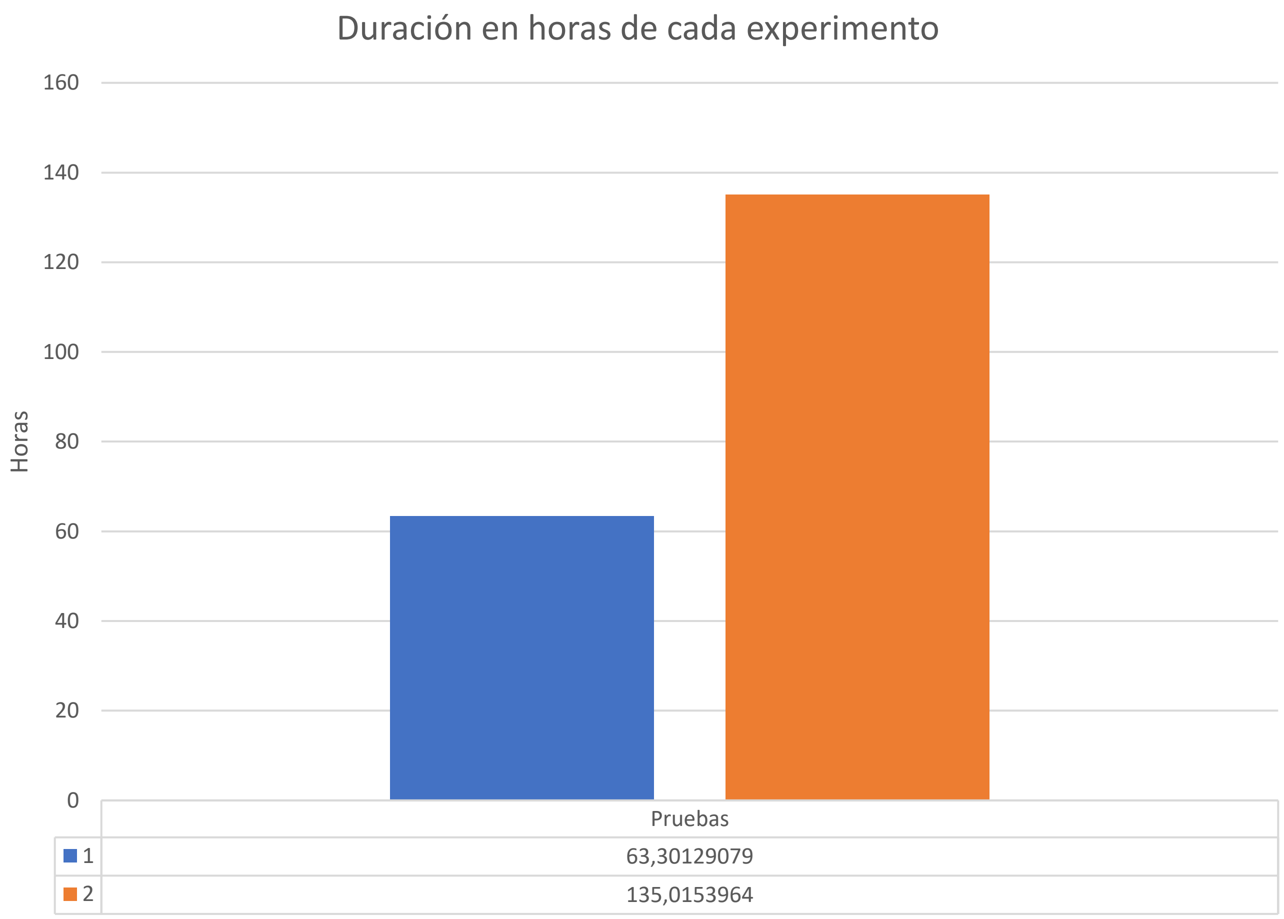
N° de Clientes	Máximo por tipo	Máximo por Cliente	Tiempo HVRP-FVL prueba 1 [S]	Tiempo HVRP-FVL prueba 2 [S]	Porcentaje aumento de tiempo [%]
50	1	5	4289,665489	8863,292754	106,6196718
50	2	5	4652,014741	9827,152655	111,2450884
50	2	10	5182,379978	11283,76387	117,7332406
50	3	5	4710,481986	10245,52741	117,5048633
50	3	10	5899,426592	12469,51236	111,3682096
50	3	15	6090,601832	12291,0346	101,8032854
50	4	5	4636,020566	10047,62368	116,7294888
50	4	10	6388,394864	13668,48969	113,9581222
50	4	15	8195,897773	16311,26067	99,01737573
50	4	20	7415,063356	16944,79479	128,5185436
50	5	5	4733,422256	9892,037916	108,9827905
50	5	10	6612,791518	14424,0091	118,1228465
50	5	15	9381,482415	22051,08302	135,0490258
50	5	20	7162,221347	18947,70408	164,5506634
50	5	25	9893,294857	21077,62579	113,0496068

Análisis tiempos



Conclusiones

- El desarrollo y pruebas hechas han demostrado que el modelo matemático propuesto funciona y puede mejorarse.
- Falto probar casos de mayor exigencia computacional.
- Aunque Python fue el programa elegido, falto probar otros lenguajes para comparar la eficiencia de estos en las mismas condiciones
- Este trabajo puede contarse como uno de los primeros en probar este acercamiento, siendo los predecesores 2 trabajos anteriores, el usado como inspiración y una versión anterior del mismo.

The finished vehicle routing problem with a heterogeneous transport fleet (HVRP-FVL)

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The finished vehicle routing problem with a heterogeneous transport fleet

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Abstract: This paper presents a new variant of the vehicle routing problem, known as the heterogeneous multi-type fleet vehicle routing problem in finished vehicle logistics (HVRP–FVL), which is modeled and solved. The HVRP–FVL considers various transportation costs, such as highway tolls, labor costs, power costs, time penalty costs, and carbon emissions costs. Moreover, the highway toll is charged based on the transport vehicle model, loading weight, and traveled distance, which adds to the complexity of the problem. The objective of the problem is to minimize the total cost of the vehicle fleet. To solve the HVRP–FVL, a metaheuristic is proposed using a genetic algorithm (GA) metaheuristic. The GA incorporates a dual-chromosome encoding method with adaptive crossover, mutation, and climbing operators to improve computational performance. A case study from a logistics company is used to evaluate the effectiveness of the proposed algorithm, and a series of experiments are conducted. The results demonstrate that the proposed approach performs well and satisfies users in practice. The contributions of the paper are the effective modeling and solution of a natural and complex vehicle routing problem in finished vehicle logistics.

1 Introduction

With the rapid expansion of the automotive industry, third-party logistics providers have become more popular for finished vehicle transportation. Finished vehicle logistics can be broadly defined as a series of associated processes from automotive factories to final destinations. Among these processes, the transport cost is a very important economic factor. Third-party logistics companies try to minimize their total transportation cost, which consists of highway toll, labor cost, power cost, time penalty cost, carbon emissions cost, and others. In practice, this is normally done in an ad hoc manner using (and depending on) a manager's experience. With the number of cost factors and a heterogeneous fleet, an ad hoc approach dependent on human expertise needs to be improved upon.

In the classic vehicle routing problem (VRP), it is typically assumed that transport cost is based only on distance traveled. However, in practice, there are different highway toll rates for different loading conditions and geographical areas, which make the problem more challenging. By providing an effective and practical solution approach to this complex finished vehicle routing problem, this paper contributes to the automotive logistics field, both to scholars and to practitioners.

The paper is organized as follows. The next section describes the problem. Section 3 carries out a review of the literature. Section 4 devises a math optimization model for the HVRP-FVL. Section 5 presents a customized GA algorithm. Real test instances and algorithm comparisons are presented in Section 6. Finally, conclusions are drawn in Section 7.

2 Problem overview

Automotive factories produce various types of finished vehicles, such as sedan, pickup truck, and SUV. The set of finished vehicles is initially located at a main depot. A third-party logistics company receives orders from the automotive factories and transports different types of finished vehicles to dealers. The logistics company has its own vehicle fleet consisting of different types of transport vehicles such as 4-axis truck, 5-axis truck, and 6-axis truck. In a typical situation, there are about 100 types of transport vehicles and 600 types of finished vehicles. The dealers can be in different cities and might be far away from each other. Different vehicle transport solutions result in different costs because of the models and numbers of the transport vehicles used. The problem aims to determine a heterogeneous vehicle fleet routing solution to minimize the total cost, which includes toll charge, fuel cost, time penalty cost, and others.

The problem considers a set of ordered items (finished vehicles) characterized by length, width, height, weight, and a set of transport vehicle fleet types characterized by length, width, height, allowable loading weight, and transport cost. The objective is to select the transport vehicles to transport the finished vehicles minimizing the total cost of the transport. We term this problem the Heterogeneous Multi-type Fleet Vehicle Routing Problem in Finished Vehicle Logistics (HVRP-FVL). The HVRP-FVL has its own character different from the classic VRP, which are listed next. (1) Both the shape of the finished vehicles and loading space of the transport vehicles in HVRP-FVL are irregular, which leads to more complex multi-dimensional geometry constraints. The classic VRP mostly consider one-dimensional constraints. (2) Actual highway toll rates are not only based on travel distance, unlike in the classic VRP. (3) Most VRP models simplify the factors that affect vehicle fuel consumption and carbon emissions. Although the HVRP-FVL is found widely in the real automotive supply chain, there are limited related studied in the literature.

Repositorio

https://github.com/Moyaxon/tesis_entrega

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