



Research article

Risk optimization of hazardous materials transportation through differentiated speed limit strategies in mixed traffic networks

Guanxiang Zhang and Haidong Huang*

Department of Electronic Business, South China University of Technology, Guangzhou 510006, China

* **Correspondence:** Email: 202420159457@mail.scut.edu.cn.

Supplementary materials

Algorithm 1 GA with Nested Diagonalization for Speed-Limit Optimization

```

1: Input: Network  $G(N, A)$ , OD demand vectors  $\mathbf{D}_M, \mathbf{D}_H$ , and GA parameters  $\mathcal{P}_{GA}$ .
2: Output: Optimal speed-limit vector  $\mathbf{u}^*$ , equilibrium path-flow vectors  $\mathbf{f}_M^*, \mathbf{f}_H^*$ , equilibrium link-flow vectors  $\mathbf{q}_M^*, \mathbf{q}_H^*$ , and minimum network risk  $R^*$ .
3: Initialize: Generate the initial speed-limit population  $P^{(0)} = \{\mathbf{u}_1, \dots, \mathbf{u}_{PopN}\}$  and set  $R^* = \infty$ .
4: for  $g = 0, \dots, GenN - 1$  do
5:   for each chromosome  $\mathbf{u}_i \in P^{(g)}$  do
6:     Lower-level UE assignment by the diagonalization algorithm:
7:     Initialize  $\mathbf{f}_M^0 = \mathbf{0}, \mathbf{f}_H^0 = \mathbf{0}$ , and  $g_{rel} = \infty$ .
8:     while  $g_{rel} > \epsilon_{diag}$  do
9:       Calculate link flows  $\mathbf{q}_M$  and  $\mathbf{q}_H$  from the current path flows and update link travel times for M-class and H-class users using Eqs. (2) and (3).
10:      Perform all-or-nothing assignment for M-class and H-class users and obtain auxiliary path-flow vectors.
11:      Determine the search directions and optimal step size by line search, and update  $\mathbf{f}_M$  and  $\mathbf{f}_H$ .
12:      Calculate the relative gap  $g_{rel}$ .
13:    end while
14:    Calculate the equilibrium link flows  $\mathbf{q}_M$  and  $\mathbf{q}_H$ , evaluate network risk  $R_i = ComputeRisk(\mathbf{q}_H)$ , and set fitness  $F_i = -R_i$ .
15:    if  $R_i < R^*$  then update  $\{\mathbf{u}^*, \mathbf{f}_M^*, \mathbf{f}_H^*, \mathbf{q}_M^*, \mathbf{q}_H^*, R^*\}$ .
16:  end for
17:  Perform selection, crossover, and mutation to generate  $P^{(g+1)}$ .
18: end for
19: return  $\mathbf{u}^*, \mathbf{f}_M^*, \mathbf{f}_H^*, \mathbf{q}_M^*, \mathbf{q}_H^*, R^*$ .

```

Table S1. Parameters of the Tilburg network.

O	D	Initial speed	Capacity	Population density	Length	O	D	Initial speed	Capacity	Population density	Length
1	2	120, 80	4545	223	4	10	9	80, 80	3200	1107	3
1	12	120, 80	4454	113	5	10	11	80, 80	3200	947	3
2	1	120, 80	4545	217	4	11	5	130, 80	4545	213	4
2	3	120, 80	4545	183	8	11	10	80, 80	3200	956	3
2	7	80, 80	1350	847	4	11	15	130, 80	4545	1617	7
3	2	120, 80	4545	176	8	12	1	120, 80	4454	108	5
3	4	120, 80	4545	153	5	12	13	120, 80	4545	109	6
3	6	80, 80	1350	83	6	13	12	120, 80	4545	102	6
4	3	120, 80	4545	147	5	13	14	100, 80	3800	1793	11
4	5	120, 80	4545	164	4	14	9	80, 80	3200	2812	6
5	4	120, 80	4545	157	4	14	13	100, 80	3800	1811	11
5	11	130, 80	4545	207	4	14	15	50, 50	2400	5386	7
6	3	80, 80	1350	78	6	14	18	80, 80	3200	4217	7
6	10	80, 80	1350	743	4	15	11	130, 80	4545	1588	7
7	2	80, 80	1350	856	4	15	14	50, 50	2400	5413	7
7	8	50, 50	900	1442	1	15	16	130, 80	6553	1864	5
8	7	50, 50	900	1461	1	16	15	130, 80	6553	1847	5
8	9	80, 80	1300	657	6	16	17	130, 80	6553	2193	2
9	8	80, 80	1300	643	6	17	16	130, 80	6553	2211	2
9	10	80, 80	3200	1094	3	17	18	120, 80	6422	3487	1
9	14	80, 80	3200	2791	6	18	14	80, 80	2400	4186	7
10	6	80, 80	1350	756	4	18	17	120, 80	6422	3514	1

Note: Origin (O) and Destination (D) denote the starting and ending nodes, respectively. Initial speed denotes the initial free-flow speeds (km/h) of regular traffic and hazmat vehicles, with the two values listed in that order. Capacity is measured in vehicles/h, Population density in persons/km², and Length in km.

Table S2. Parameters of the Sioux Falls network.

O	D	Initial speed	Capacity	Population density	Length	O	D	Initial speed	Capacity	Population density	Length
1	2	113, 80	25900	54	6	13	24	102, 80	5091	680	4
1	3	115, 80	23403	175	4	14	11	83, 60	4877	1884	4
2	1	113, 80	25900	54	6	14	15	106, 80	5128	1813	5
2	6	89, 60	4958	162	5	14	23	87, 60	4925	1523	4
3	1	115, 80	23403	175	4	15	10	60, 60	13512	2302	6
3	4	84, 60	17111	356	4	15	14	106, 80	5128	1813	5
3	12	115, 80	23403	285	4	15	19	81, 60	14565	1742	3
4	3	84, 60	17111	356	4	15	22	77, 60	9599	1568	3
4	5	101, 80	17783	1043	2	16	8	98, 60	5046	1280	5
4	11	85, 60	4909	1502	6	16	10	81, 60	4855	1979	4
5	4	101, 80	17783	1043	2	16	17	119, 80	5230	1486	2
5	6	88, 60	4948	662	4	16	18	86, 60	19680	1751	3
5	9	93, 60	10000	1838	5	17	10	93, 60	4994	1848	8
6	2	89, 60	4958	162	5	17	16	119, 80	5230	1486	2
6	5	88, 60	4948	662	4	17	19	79, 60	4824	1268	2
6	8	84, 60	4899	530	2	18	7	115, 80	23403	1544	2
7	8	119, 80	7842	891	3	18	16	86, 60	19680	1751	3
7	18	115, 80	23403	1544	2	18	20	115, 80	23403	1224	4
8	6	84, 60	4899	530	2	19	15	81, 60	14565	1742	3
8	7	119, 80	7842	891	3	19	17	79, 60	4824	1268	2
8	9	98, 60	5050	1443	10	19	20	93, 60	4994	970	4
8	16	98, 60	5046	1280	5	20	18	115, 80	23403	1224	4
9	5	93, 60	10000	1838	5	20	19	93, 60	5003	970	4
9	8	98, 60	5050	1443	10	20	21	99, 60	5060	716	6
9	10	67, 60	13916	2329	3	20	22	101, 80	5076	866	5
10	9	67, 60	13916	2329	3	21	20	99, 60	5060	716	6
10	11	93, 60	10000	2293	5	21	22	119, 80	5230	954	2
10	15	60, 60	13512	2302	6	21	24	83, 60	4885	644	3
10	16	81, 60	4855	1979	4	22	15	77, 60	9599	1568	3
10	17	93, 60	4994	1848	8	22	20	101, 80	5076	866	5
11	4	85, 60	4909	1502	6	22	21	119, 80	5230	954	2
11	10	93, 60	10000	2293	5	22	23	93, 60	5000	1150	4
11	12	85, 60	4909	1299	6	23	14	87, 60	4925	1523	4
11	14	83, 60	4877	1884	4	23	22	93, 60	5000	1150	4
12	3	115, 80	23403	285	4	23	24	101, 80	5079	894	2
12	11	85, 60	4909	1299	6	24	13	102, 80	5091	680	4
12	13	113, 80	25900	1098	3	24	21	83, 60	4885	644	3
13	12	113, 80	25900	1098	3	24	23	101, 80	5079	894	2

Note: Origin (O) and Destination (D) denote the starting and ending nodes, respectively. Initial speed denotes the initial free-flow speeds (km/h) of regular traffic and hazmat vehicles, with the two values listed in that order. Capacity is measured in vehicles/h, Population density in persons/km², and Length in km.

Table S3. Hazmat OD demand for the Tilburg and Sioux Falls networks.

Network	Origin	Destination	Demand	Origin	Destination	Demand	Origin	Destination	Demand
Tilburg	1	4	50	1	11	100	1	14	10
	4	1	200	4	13	50	4	18	50
	13	2	150	13	4	100	15	1	400
	17	3	70	17	12	100			
Sioux Falls	1	9	250	1	16	250	1	18	50
	1	20	150	1	22	200	2	4	100
	2	11	100	2	13	150	2	15	50
	2	22	50	4	20	150	5	13	100
	7	13	200	9	20	300	10	13	950
	11	20	300	15	20	550	19	13	150
	22	13	650	23	20	350			



AIMS Press

© 2026 the Author(s), licensee AIMS Press. This is an open access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0>)