Supplementary Materials

A Decision-Centric IoT and Blockchain-Enabled Supply Chain Information System for Demand-Aware Routing: Architecture and Multi-Seed Evaluation

All results are produced by the released code (Software S1); table and equation numbers refer to the main manuscript.

Table S1. Sensitivity of the neural engine to its hyperparameters and reward weights (one factor at a time; 10 seeds, 100 held-out days).

Setting	Cost per 1000 units	Demand satisfaction	Cost vs default (%)	Cost vs demand-aware heuristic, % (seeds better)
Default (Table 7)	0.225	0.553	—	+15.1 (10/10)
Learning rate 3×10^{-4}	0.227	0.552	+0.8	+14.4 (10/10)
Learning rate 3×10^{-3}	0.222	0.553	-1.1	+16.0 (10/10)
Discount $\gamma = 0.8$	0.224	0.553	-0.5	+15.5 (10/10)
Discount $\gamma = 0.99$	0.233	0.552	+3.7	+12.0 (10/10)
Hidden width 16	0.226	0.552	+0.4	+14.8 (10/10)
Hidden width 64	0.226	0.553	+0.6	+14.5 (10/10)
ε decay over 30% of training	0.223	0.553	-0.8	+15.7 (10/10)
ε decay over 90% of training	0.226	0.552	+0.7	+14.4 (10/10)
Demand weight $\alpha_3 = 1.5$	0.228	0.551	+1.5	+13.8 (10/10)
Demand weight $\alpha_3 = 6$	0.224	0.554	-0.4	+15.4 (10/10)
Lateness weight $\alpha_2 = 0.25$	0.223	0.553	-0.9	+15.9 (10/10)
Lateness weight $\alpha_2 = 1.0$	0.227	0.552	+1.1	+14.2 (10/10)

Table S2. Routing with hard time windows and a heterogeneous fleet (10 seeds, 100 held-out days, validation on).

Setting	Method	Cost per 1000 units	Demand satisfaction	Delay (h)	Customers per day	Latency (ms)	Plans rejected
Hard time windows	Demand-aware + 2-opt	0.265	0.554	0.000	9.2	0.81	0
	Neural	0.222	0.549	0.000	8.5	2.37	0
	Neural + 2-opt	0.220	0.549	0.000	8.5	2.40	0
	Neural + rollout	0.198	0.555	0.000	7.9	48.4	0
	ALNS	0.193	0.555	0.000	7.9	467.8	0
	Seeded ALNS	0.190	0.555	0.000	7.9	512.1	0
Hard windows + heterogeneous fleet	Demand-aware + 2-opt	0.258	0.547	0.000	8.8	0.63	0
	Neural	0.215	0.542	0.000	8.0	2.25	0
	Neural + 2-opt	0.212	0.542	0.000	8.0	2.14	0
	Neural +	0.194	0.554	0.000	7.7	48.1	0

rollout						
ALNS	0.188	0.555	0.000	7.7	420.2	0
Seeded ALNS	0.186	0.555	0.000	7.7	480.2	0

Heterogeneous fleet: trip capacities 0.5, 1.0 and 1.5 times the mean, same total capacity. Rollout, K = 4; seeded ALNS, ALNS started from the rollout plan.

Table S3. Byzantine fault-tolerant validation at deployment scale (PBFT simulation with measured processing costs and assumed network delays; median of 100 decisions).

Validators	Tolerated faults	Latency, LAN (ms)	Latency, regional WAN (ms)	Regional WAN, faulty silent (ms)	Latency, global WAN (ms)	Messages per decision	Data per decision (kB)	Processing per node (ms)
4	1	1.4	62	81	246	24	5	1.0
7	2	2.1	65	90	257	84	16	1.9
16	5	4.3	68	104	269	480	78	4.7
31	10	8.1	70	117	273	1860	285	9.2
64	21	16.5	71	129	276	8064	1197	19.2
100	33	25.7	73	135	280	19800	2908	30.1

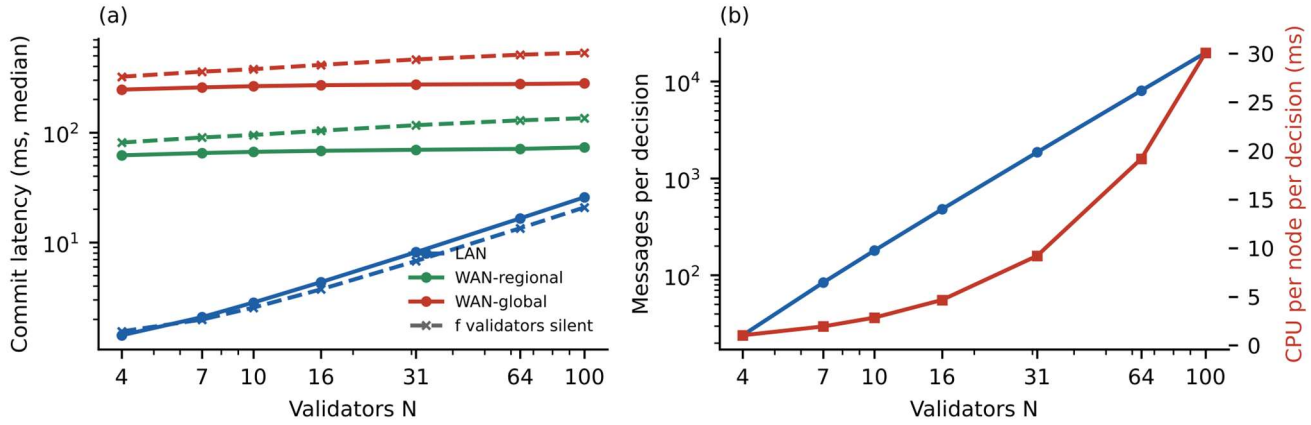


Figure S1. PBFT validation versus validator count: (a) commit latency (dashed: faulty validators silent); (b) messages and processing per node.