Supplementary Information for Resilience Assessment of an Electrified Road Transportation System of Systems Subject to Fast Charging Station Failures

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1. Examples data

The cells representation, consisting of 48 cells, 58 links and 4 O-D pairs, is shown in Fig. 1. Parameters are listed in Tab. 1.

Tab. 1: Cell characteristics of the study network for one lane

Parameters	Values
v_f (m/h)	50
τ (min)	6
L_c (mile)	5
ξ_i	0
δ	1
Number of cells	48
Number of chargers	80
Q_i (v/ τ)	200
N_i (v)	1000
NC_i (v)	20
NP_i (v)	100
$\alpha^t_{i,I}$	4
L_{avg} (mile)	125
L	25
T_d (min)	20

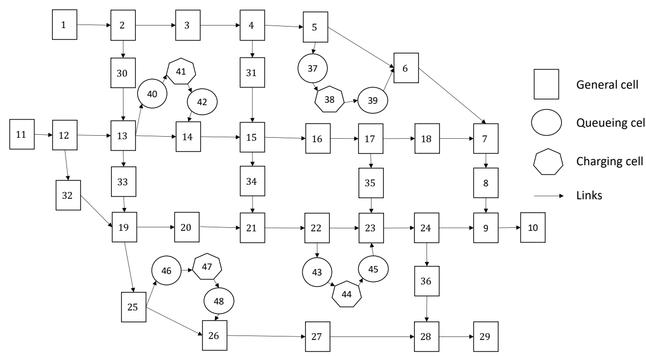

Fig. 1: Cell representation of the studied road network.

2. Computational time

A modified Sioux-Falls (SF) network is considered (Ukkusuri et al., 2012). This network consists of 123 cells, 157 links and 6 O-D pairs. There are three FCSs 590, 591 and 621, which are equipped with 20, 40 and 20 chargers, respectively. Other parameter settings are the same as the Nguyen-Dupuis (ND) Network case. The detailed configuration of this example has been uploaded in https://github.com/lucky105/Sioux-Falls-network-in-cell-representation. All of the experiments have been run on a computer with an Intel Core i7-8700 3.2-GHz CPU with 32 GB of RAM. All of the LP problems have been solved by the commercial software IBM ILOG CPLEX (version 12.6).

We compare the computation time of the proposed SO-DTA-E&C to the classical CTM-based SO-DTA that doesn't consider EV SoC tracking and energy charging. In order to see the extra computational cost that the SoC tracking brings and make it a fair comparison, the initial SoC of all EVs are set to be full in SO-DTA-E&C so that there is no charging demand in both models. As shown in Tab. 2, computation time of the proposed model increases non-negligibly for both SF and ND networks compared to the conventional CTM model. This the cost we must pay for the consideration of tracking EVs SoC.

Tab. 3 reports the computation times for solving the first stage and second stage models in the ND and SF networks. In the SF case, 621 is assumed to be failed. The scenarios with different EV penetrations in the paper are considered to show the minimum and maximum computational

Tab. 2: The CPU times required to solve the SO-DTA problem by two methods

Networks	T_h(time steps)	**SO-DTA-E&C**(sec)	**CTM**(sec)
Nguyen-Dupuis	31	14.42	8.09
Sioux-Falls	33	8.02	1.08

Tab. 3: The CPU times required to solve different scenarios

Networks	Scenarios	First stage		Second stage	
		T_h	Solution time (sec)	T_h	Solution time (sec)
Nguyen-Dupuis	Penetration	36-67	234.41-888.95	36-75	507.28 -3569.78
	Duration	39	316.39	42-56	857.14-1758.38
	Location	39	316.39	39-46	665.25-1064.56
	Combinations	39	316.39	39-46	650.17-1163.2
Sioux-Falls	Penetrations	38-82	93.59-729.95	42-82	901.06-5863.02

time.

The computational times are influenced by many factors, such as the maximum time horizon, traffic demand, topology of the ERN, configuration of the FCSs, EV penetrations and their battery capacities. It should be noted that the proposed models are LPs, which can be solved very efficiently using standard polynomial time algorithms (e.g., the interior point algorithm). Although the calculation time is not low in some extreme scenarios (e.g., 1.6h when the EV penetration is 50%), the computational cost is usually not the main concern of the resilience assessment given that it can be performed offline.

The modified SF network is not a large one in terms of the number of links and intersection nodes, compared to urban level distributor road networks. However, if contains all the relevant aspects of the problem and is, thus, sufficient to demonstrate the performance of the proposed model for the following reasons: 1. Both the ND and SF networks are commonly used in literature (Long & Szeto, 2019; Long et al., 2018; Yu et al., 2020; Zhang et al., 2019; Zhou et al., 2021) to demonstrate the efficacy of traffic models. Both networks capture the important structural characteristics of realistic systems. Our paper focuses on highway networks (trunk roads) with fast-charging stations, which usually have a simpler structure (e.g., fewer intersections) compared to urban level distributor road networks. Therefore, the employed ND and SF networks provide a sufficient level of structural complexity for the problem of interest. Moreover, the road lengths in both the ND and SF networks are modified in our examples. The total lengths (excluding charging cells and queueing cells) of the modified ND network

Tab. 4: The CPU times required of SF network under different time interval scenarios

	$\tau = 6$ mins	$\tau = 12$ mins
First stage	345.81 sec	28.22 sec
Second stage	3698.83 sec	89.08 sec

and SF network are 289.682 km and 917.326 km, respectively. The latter already exceeds the total expressway lengths of many countries, e.g., Ukraine (193km), Norway (599 km) and Finland (863 km). 2. For really large networks, we may use more powerful computing resource, instead of the personal laptop used in our numerical experiment, for a reasonable computation time. Alternatively, we may increase the time interval τ to update the state of the traffic. This could decrease the number of cells in the network, leading to less memory and computational time though at the expense of less fine-grained results. Here, the used SF network in the paper is modified to compare the computation time under different time intervals, where the OD pairs are increased to 26 pairs. The comparison of the computation time is given in Tab. 4. The detailed configuration of this example has been uploaded in https://github.com/lucky105/Sioux-Falls-network-in-cell-representation/tree/main/comparisonTimeInterval.

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