Indices and Sets	
n	Index of transportation network nodes in set, N
l	Index of transportation network edges in set, L
k/m	Index of EVs in set, K
p	Index of picking nodes in set, P
d	Index of delivery nodes in set, D
u	Index of passengers in set, U
c	Index of charging nodes in set, C
st	Index of starting nodes of EVs in set, ST
en	Index of ending nodes of EVs in set, EN
br	Index of bridge for different cars in set, BR
i	Index of the iteration counter, I
$\pi_l^{U,N}/\pi_l^{D,N}$	Set of upstream/downstream nodes of edge l
$\pi_n^{U,L}/\pi_n^{D,L}$	Set of upstream/downstream edges of node n
$\pi_c^{D,L}$	Set of downstream edges of charging node c
π_u^D/π_u^P	Set of pickup/delivery nodes of passenger u
π_k^{ST}/π_k^{EN}	Set of starting/ending nodes of EV k
π_k^{BR}	Set of bridges of EV k
$\pi_{br}^{U,K}/\pi_{br}^{D,K}$	Set of upstream/downstream EVs of bridge br
Variables	
$t_{n,k}^C$	Charging time of EV k at node n (min)
$t_{n,k}^w$	Waiting time of EV k at node n (min)
$t_{n,k}$	Arriving time of EV k at node n (min)
$SoC_{n,k}$	State-of-Charge (%) of EV k at node n
$t_{l,k}^T$	The traveling time of edge l for EV k (min)
$x_{l,k}$	Binary variable of route selection indicator of edge l for EV k; 1 means taken, 0 means otherwise
$f_{u,k}$	Flag binary variable of passenger u pickup and delivery indicator by EV k, 1 means the passenger is served, 0 means otherwise
$f_{u,d,k}^1$	Linearization variable of passenger u delivery time for EV k
$f_{u,p,k}^2$	Linearization variable of passenger u pickup time for EV k
$\overline{R_{c,k,m}}$	Linearization variable of time relationship between EVs k and m at charging station c
$\underline{R_{c,k,m}}$	Linearization variable of time relationship between EVs k and m at charging station c
$\overline{\mathcal{R}_{c,k,m,l}}$	Linearization binary variable of ancillary variables to control charging congestion
$\underline{\mathcal{R}_{c,k,m,l}}$	Linearization binary variable of ancillary variables to control charging congestion

$\partial^C_{c,k,m}/\beta^C_{c,k,m}$	Ancillary binary variables to avoid congestion between EVs *k* and *m* at charging station *c*
η	Ancillary variable representing the objective function of modified master problem
Obj	Ancillary variable representing the objective function of modified Sub problem
ΔV_l	Deviation of traffic flow at edge *l* caused by cyber attack
Parameters	
$\omega_1/\omega_2/\omega_3$	Weighting factors of objective function
M	A sufficiently large number
α/β	Parameters of Bureau of Public Roads function
τ_l	Energy consumption of passing edge *l* (kWh)
ε_n	EV charging price at node *n* ($/kWh)
φ_n	EV charging power at node *n* (kW)
$SoC^{\min}$	Minimum SoC value of EV battery (%)
$SoC^{\max}$	Maximum SoC value of EV battery (%)
E^{max}	Energy capacity of EV battery (kWh)
V_l	Original traffic flow of edge *l*
ρ_l	Capacity of edge *l*
$\gamma_{l,k}$	Free flow time of edge *l* for EV *k*
D_l^S	Distance of edge *l*
ϖ	Budget of cyber attacker for traffic flow tampering (%)
Dual variables	
υ	Dual variable of the objective function
$o^1_{u,d,k}$	Dual variable of passenger *u* delivery time for EV *k*
$o^2_{u,d,k}$	Dual variable of passenger *u* delivery time for EV *k*
$o^3_{u,d,k}$	Dual variable of passenger *u* delivery time for EV *k*
$o^4_{u,d,k}$	Dual variable of passenger *u* delivery time for EV *k*
$\chi^1_{u,p,k}$	Dual variable of passenger *u* pickup time for EV *k*
$\chi^2_{u,p,k}$	Dual variable of passenger *u* pickup time for EV *k*
$\chi^2_{u,p,k}$	Dual variable of passenger *u* pickup time for EV *k*
$\chi^4_{u,p,k}$	Dual variable of passenger *u* pickup time for EV *k*
$\delta_{u,p,d,k}$	Dual variable of passenger *u* travel time for EV *k*
$\overline{\lambda_{c,k}}$	Dual variable of charging time constraint upper bound for kth EV
$\underline{\lambda_{c,k}}$	Dual variable of charging time constraint lower bound for kth EV
$\lambda^{CL}_{n,k}$	Dual variable of charging time limit for EV *k*
$\lambda^{C,min}_{n,k}$	Dual variable of charging time down limit for EV *k*
$\overline{\mu^N_{l,k}}$	Dual variable of arriving time constraint upper bound for EV *k*

$\underline{\mu_{l,k}^{N}}$	Dual variable of arriving time constraint lower bound for EV k
$\mu_{st,k}^{ST}$	Dual variable of time of kth car at start node st
$\mu_{n,k}^{N,min}$	Dual variable of arriving time down limit of kth EV at node n
$\phi_{c,k,m}^{1}$	Dual variable of waiting time constraint for EV
$\phi_{c,k,m}^{2}$	Dual variable of waiting time constraint for EV
$\phi_{c,k,m}^{3}$	Dual variable of waiting time constraint for EV
$\phi_{c,k,m}^{4}$	Dual variable of waiting time constraint for EV
$\phi_{c,k,m}^{5}$	Dual variable of waiting time constraint for EV
$\phi_{c,k,m}^{6}$	Dual variable of waiting time constraint for EV
$\phi_{c,k,m}^{7}$	Dual variable of waiting time constraint for EV
$\phi_{c,k,m}^{8}$	Dual variable of waiting time constraint for EV
$\phi_{c,k,m}^{9}$	Dual variable of waiting time constraint for EV
$\phi_{c,k,m}^{10}$	Dual variable of waiting time constraint for EV
$\phi_{n,k}^{WL}$	Dual variable of waiting time limit for EV k
$\phi_{n,k}^{W,min}$	Dual variable of waiting time down limit for EV k
$\overline{\theta_{l,k}^{N}}$	Dual variable of SoC constraint upper bound for EV k
$\underline{\theta_{l,k}^{N}}$	Dual variable of SoC constraint lower bound for EV k
$\theta_{st,k}^{ST}$	Dual variable of initial SoC for EV k
$\theta_{n,k}^{min}$	Dual variable of SoC upper bound for EV k
$\theta_{n,k}^{max}$	Dual variable of SoC lower bound for EV k
$\xi_{l,k}$	Dual variable of travel time of route l for EV k

$$minimize_{\Omega 1} \quad Obj$$

$$Obj = \omega_1 \sum_{l,k} (D_l^S x_{l,k}) + \omega_2 \sum_{u,p,d,k} [f_{u,k}(t_{d,k} - t_{p,k})] + \omega_3 \sum_{n,k} (\varepsilon_n \varphi_n t_{n,k}^C)\ (v) \tag{1}$$

$$\begin{cases} f_{u,k} t_{d,k} = f_{u,d,k}^1: \\ f_{u,d,k}^1 - M f_{u,k} \le 0\left(o_{u,d,k}^1\right) \\ f_{u,d,k}^1 - t_{d,k} \le 0\left(o_{u,d,k}^2\right) \\ f_{u,d,k}^1 - t_{d,k} + \mathrm{M}\left(1 - f_{u,k}\right) \ge 0\left(o_{u,d,k}^3\right) \\ f_{u,d,k}^1 \ge 0\left(o_{u,d,k}^4\right) \\ \forall u \in U, d \in \pi_u^D, k \in K \end{cases} \tag{2}$$

$$\begin{cases} f_{u,k}t_{p,k} = f_{u,p,k}^2: \\ f_{u,p,k}^2 - Mf_{u,k} \le 0\left(\chi_{u,p,k}^1\right) \\ f_{u,p,k}^2 - t_{p,k} \le 0\left(\chi_{u,p,k}^2\right) \\ f_{u,p,k}^2 - t_{p,k} + \mathrm{M}\left(1 - f_{u,k}\right) \ge 0\left(\chi_{u,p,k}^3\right) \\ f_{u,p,k}^2 \ge 0\left(\chi_{u,p,k}^4\right) \\ \forall u \in U, p \in \pi_u^p, k \in K \end{cases} \tag{3}$$

$$-\sum_{l\in\pi_{st}^{D,L}} x_{l,k} = 1, \forall st \in \pi_k^{ST}, k \in K \tag{4}$$

$$\sum_{l\in\pi_{en}^{U,L}} x_{l,k} = 1, \forall en \in \pi_k^{EN}, k \in K \tag{5}$$

$$\sum_{l\in\pi_n^{D,L}} x_{l,k} \le 1, \forall n \in N/(\pi_k^{ST} \cup \pi_k^{EN}), k \in K \tag{6}$$

$$\sum_{l\in\pi_n^{U,L}} x_{l,k} \le 1, \forall n \in N/(\pi_k^{ST} \cup \pi_k^{EN}), k \in K \tag{7}$$

$$\sum_{l\in\pi_n^{U,L}} x_{l,k} = \sum_{l\in\pi_n^{D,L}} x_{l,k}, \forall n \in N/(\pi_k^{ST} \cup \pi_k^{EN}), k \in K \tag{8}$$

$$\sum_{l\in\pi_d^{U,L}} x_{l,k} + \sum_{l\in\pi_p^{D,L}} x_{l,k} - 2 \ge -M\left(1 - f_{u,k}\right), \forall u \in U, d \in \pi_u^D, p \in \pi_u^p, k \in K \tag{9}$$

$$\sum_{k\in K} f_{u,k} = 1, u \in U \tag{10}$$

$$t_{p,k} - t_{d,k} \le M\left(1 - f_{u,k}\right), \forall u \in U, d \in \pi_u^D, p \in \pi_u^p, k \in K\ (\delta_{u,p,d,k}) \tag{11}$$

$$t_{l,k}^T = \gamma_{l,k}\left(1 + \alpha\left(\frac{V_l + \Delta V_l}{\rho_l}\right)^\beta\right), \forall l \in L, k \in K\ \left(\xi_{l,k}\right) \tag{12}$$

$$-M\left(1 - x_{l,k}\right) \le \sum_{n\in\pi_l^{U,N}} t_{n,k} + \sum_{n\in\pi_l^{U,N}} t_{n,k}^W + \sum_{n\in\pi_l^{U,N}} t_{n,k}^C + t_{l,k}^T - \sum_{n\in\pi_l^{D,N}} t_{n,k} \le \tag{13}$$

$$M\left(1 - x_{l,k}\right), \forall l \in L, k \in K\quad (\underline{\mu_{l,k}^N}, \overline{\mu_{l,k}^N})$$

$$-M\left(1 - x_{l,k}\right) \le \sum_{n\in\pi_l^{U,N}} SoC_{n,k} - \sum_{n\in\pi_l^{D,N}} SoC_{n,k} - \frac{\tau_l D_l^S}{E^{max}} + \frac{\sum_{n\in\pi_l^{U,N}} \varphi_n t_{n,k}^C}{E^{max}} \le M\left(1 - x_{l,k}\right), \forall l \in \tag{14}$$

$$L, k \in K\quad (\underline{\theta_{l,k}^N}, \overline{\theta_{l,k}^N})$$

$$-M\sum_{l\in\pi_c^{D,L}} x_{l,k} \le t_{c,k}^C \le M\sum_{l\in\pi_c^{D,L}} x_{l,k}, \forall c \in C, k \in K\quad (\underline{\lambda_{c,k}}, \overline{\lambda_{c,k}}) \tag{15}$$

$$\partial_{c,k,m}^C\left(t_{c,k} + t_{c,k}^W + t_{c,k}^C - t_{c,m} - t_{c,m}^W\right) \le \partial_{c,k,m}^C\left(1 - \sum_{l\in\pi_c^{U,L}} x_{l,k}\right), \forall k, m \in K, c \in C, k \ne \tag{16}$$

$$m\ \left(\phi_{c,k,m}^{\ 1}\right)$$

$$\begin{cases} \partial_{c,k,m}^{C}\left(t_{c,k}+t_{c,k}^{W}+t_{c,k}^{C}-t_{c,m}-t_{c,m}^{W}\right)=\overline{R_{c,k,m}}: \\ \overline{R_{c,k,m}}-M\partial_{c,k,m}^{C}\le 0(\phi_{c,k,m}^{2}) \\ \overline{R_{c,k,m}}+M\partial_{c,k,m}^{C}\ge 0(\phi_{c,k,m}^{3}) \\ -M\left(1-\partial_{c,k,m}^{C}\right)\le \overline{R_{c,k,m}}-t_{c,k}-t_{c,k}^{W}-t_{c,k}^{C}+t_{c,m}+t_{c,m}^{W} \\ \le M\left(1-\partial_{c,k,m}^{C}\right)(\phi_{c,k,m}^{4},\phi_{c,k,m}^{5}) \\ \forall k,m\in K,c\in C,k\neq m \end{cases} \tag{17}$$

$$\begin{cases} \partial_{c,k,m}^{C}x_{l,k}=\overline{\mathcal{R}_{c,k,m,l}}: \\ \overline{\mathcal{R}_{c,k,m,l}}-\partial_{c,k,m}^{C}\le 0 \\ \overline{\mathcal{R}_{c,k,m,l}}-x_{l,k}\le 0 \\ \partial_{c,k,m}^{C}+x_{l,k}-1-\overline{\mathcal{R}_{c,k,m,l}}\le 0 \\ \forall k,m\in K,c\in C,l\in\pi_{c}^{U,L},k\neq m \end{cases} \tag{18}$$

$$\beta_{c,k,m}^{C}\left(t_{c,m}+t_{c,m}^{W}+t_{c,m}^{C}-t_{c,k}-t_{c,k}^{W}\right)\le\beta_{c,k,m}^{C}\left(1-\sum_{l\in\pi_{c}^{U,L}}x_{l,k}\right),\forall k,m\in K,c\in C,k\neq m\ (\phi_{c,k,m}^{6}) \tag{19}$$

$$\begin{cases} \beta_{c,k,m}^{C}\left(t_{c,m}+t_{c,m}^{W}+t_{c,m}^{C}-t_{c,k}-t_{c,k}^{W}\right)=\underline{R_{c,k,m}}: \\ \underline{R_{c,k,m}}-M\beta_{c,k,m}^{C}\le 0(\phi_{c,k,m}^{7}) \\ \underline{R_{c,k,m}}+M\beta_{c,k,m}^{C}\ge 0(\phi_{c,k,m}^{8}) \\ -M\left(1-\beta_{c,k,m}^{C}\right)\le \underline{R_{c,k,m}}-t_{c,m}-t_{c,m}^{W}-t_{c,m}^{C}+t_{c,k}+t_{c,k}^{W} \\ \le M\left(1-\beta_{c,k,m}^{C}\right)(\phi_{c,k,m}^{9},\phi_{c,k,m}^{10}) \\ \forall k,m\in K,c\in C,k\neq m \end{cases} \tag{20}$$

$$\begin{cases} \beta_{c,k,m}^{C}x_{l,k}=\underline{\mathcal{R}_{c,k,m,l}}: \\ \underline{\mathcal{R}_{c,k,m,l}}-\beta_{c,k,m}^{C}\le 0 \\ \underline{\mathcal{R}_{c,k,m,l}}-x_{l,k}\le 0 \\ \beta_{c,k,m}^{C}+x_{l,k}-1-\underline{\mathcal{R}_{c,k,m,l}}\le 0 \\ \forall k,m\in K,c\in C,l\in\pi_{c}^{U,L},k\neq m \end{cases} \tag{21}$$

$$\partial_{c,k,m}^{C}+\beta_{c,k,m}^{C}=1,\forall k,m\in K,c\in C,k\neq m \tag{22}$$

$$t_{n,k}^{C},t_{n,k}^{W},t_{n,k}\ge 0,\forall n\in N,k\in K\ (\lambda_{n,k}^{C,min},\phi_{n,k}^{W,min},\mu_{n,k}^{N,min}) \tag{23}$$

$$t_{n,k}^{C},t_{n,k}^{W}=0,\forall n\in N\backslash C,k\in K\ (\lambda_{n,k}^{CL},\phi_{n,k}^{WL}) \tag{24}$$

$$SoC_{st,k}=SoC^{max},t_{st,k}=0,\forall st\in\pi_{k}^{ST},k\in K\ (\theta_{st,k}^{ST},\mu_{st,k}^{ST}) \tag{25}$$

$$SoC^{min}\le SoC_{n,k}\le SoC^{max},\forall n\in N,k\in K\ (\theta_{n,k}^{min},\theta_{n,k}^{max}) \tag{26}$$

Dual formulation:

$$1+\nu=0 \tag{27}$$

$$-\omega_{2}\upsilon+o_{u,d,k}^{1}+o_{u,d,k}^{2}-o_{u,d,k}^{3}-o_{u,d,k}^{4}=0,\forall k\in K,u\in\pi_{k}^{U},d\in\pi_{u}^{D} \tag{28}$$

$$-\omega_{2}\upsilon+\chi_{u,p,k}^{1}+\chi_{u,p,k}^{2}-\chi_{u,p,k}^{3}-\chi_{u,p,k}^{4}=0,\forall k\in K,u\in\pi_{k}^{U},p\in\pi_{u}^{P} \tag{29}$$

$$\overline{\mu_{l,k}^{N}}-\underline{\mu_{l,k}^{N}}+\xi_{l,k}=0,\forall l\in L,k\in K \tag{30}$$

$$\theta_{c,k,m}^{1}+\theta_{c,k,m}^{2}-\theta_{c,k,m}^{3}+\theta_{c,k,m}^{4}-\theta_{c,k,m}^{5}=0,\forall k,m\in K,c\in C,k\neq m \tag{31}$$

$$\theta_{c,k,m}^{6}+\theta_{c,k,m}^{7}-\theta_{c,k,m}^{8}+\theta_{c,k,m}^{9}-\theta_{c,k,m}^{10}=0,\forall k,m\in K,c\in C,k\neq m \tag{32}$$

$$-o^2_{u,d,k} + o^3_{u,d,k} - \delta_{u,d,p,k} + \sum_{l\in\pi^{D,L}_d} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{U,L}_d} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{D,L}_d} \underline{\mu^N_{l,k}} + \sum_{l\in\pi^{U,L}_d} \underline{\mu^N_{l,k}} - \mu^{N,min}_{d,k} = 0, \forall k \in K, u \in \pi^U_k, p \in \pi^P_u, d \in \pi^D_u \quad (33)$$

$$-\chi^2_{u,p,k} + \chi^3_{u,p,k} - \delta_{u,d,p,k} + \sum_{l\in\pi^{D,L}_p} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{U,L}_p} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{D,L}_p} \underline{\mu^N_{l,k}} + \sum_{l\in\pi^{U,L}_p} \underline{\mu^N_{l,k}} - \mu^{N,min}_{p,k} = 0, \forall k \in K, u \in \pi^U_k, p \in \pi^P_u, d \in \pi^D_u \quad (34)$$

$$\sum_{l\in\pi^{D,L}_{st}} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{U,L}_{st}} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{D,L}_{st}} \underline{\mu^N_{l,k}} + \sum_{l\in\pi^{U,L}_{st}} \underline{\mu^N_{l,k}} + \mu^{ST}_{st,k} - \mu^{N,min}_{st,k} = 0, \forall k \in K, st \in ST \quad (35)$$

$$\sum_{l\in\pi^{D,L}_c} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{U,L}_c} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{D,L}_c} \underline{\mu^N_{l,k}} + \sum_{l\in\pi^{U,L}_c} \underline{\mu^N_{l,k}} - \mu^{N,min}_{c,k} - \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^4_{c,k,m} + \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^4_{c,m,k} + \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^5_{c,k,m} - \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^5_{c,m,k} + \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^9_{c,k,m} - \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^9_{c,m,k} - \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^{10}_{c,k,m} + \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^{10}_{c,m,k} = 0, \forall k, m \in K, c \in C, k \neq m \quad (36)$$

$$\sum_{l\in\pi^{D,L}_n,} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{U,L}_n} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{D,L}_n} \underline{\mu^N_{l,k}} + \sum_{l\in\pi^{U,L}_n} \underline{\mu^N_{l,k}} - \mu^{N,min}_{n,k} = 0, \forall n \in N/(ST \cup P \cup D \cup C), k \in K \quad (37)$$

$$-\omega_3 \varepsilon_c \varphi_c \nu + \overline{\lambda_{c,k}} - \underline{\lambda_{c,k}} - \lambda^{C,min}_{c,k} + \sum_{l\in\pi^{D,L}_c,} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{D,L}_c} \underline{\mu^N_{l,k}} + \sum_{l\in\pi^{D,L}_c} \frac{\varphi_c \overline{\theta^N_{l,k}}}{E_{max}} - \sum_{l\in\pi^{D,L}_c} \frac{\varphi_c \underline{\theta^N_{l,k}}}{E_{max}} - \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^4_{c,k,m} + \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^5_{c,k,m} - \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^9_{c,m,k} + \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^{10}_{c,m,k} = 0, \forall k, m \in K, c \in C, k \neq m \quad (38)$$

$$\lambda^{CL}_{n,k} - \lambda^{C,min}_{n,k} + \sum_{l\in\pi^{D,L}_n} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{D,L}_n} \underline{\mu^N_{l,k}} + \sum_{l\in\pi^{D,L}_c} \frac{\varphi_c \overline{\theta^N_{l,k}}}{E_{max}} - \sum_{l\in\pi^{D,L}_c} \frac{\varphi_c \underline{\theta^N_{l,k}}}{E_{max}} = 0, \forall k \in K, n \in N/C \quad (39)$$

$$\sum_{l\in\pi^{D,L}_c,} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{D,L}_c} \underline{\mu^N_{l,k}} - \phi^{W,min}_{c,k} - \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^4_{c,k,m} + \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^4_{c,m,k} + \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^5_{c,k,m} - \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^5_{c,m,k} + \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^9_{c,k,m} - \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^9_{c,m,k} - \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^{10}_{c,k,m} + \sum_{m\in\pi^{D,M}_{br}, br\in\pi^{BR}_k} \phi^{10}_{c,m,k} = 0, \forall k, m \in K, c \in C, k \neq m \quad (40)$$

$$\sum_{l\in\pi^{D,L}_n,} \overline{\mu^N_{l,k}} - \sum_{l\in\pi^{D,L}_n} \underline{\mu^N_{l,k}} + \phi^{WL}_{n,k} - \phi^{W.min}_{n,k} = 0, \forall k \in K, n \in N/C \quad (41)$$

$$\sum_{l\in\pi^{D,L}_{st}} \overline{\theta^N_{l,k}} - \sum_{l\in\pi^{U,L}_{st}} \overline{\theta^N_{l,k}} - \sum_{l\in\pi^{D,L}_{st}} \underline{\theta^N_{l,k}} + \sum_{l\in\pi^{U,L}_{st}} \underline{\theta^N_{l,k}} + \theta^{ST}_{st,k} - \theta^{min}_{st,k} + \theta^{max}_{st,k} = 0, \forall k \in K, st \in ST \quad (42)$$

$$\sum_{l\in\pi^{D,L}_n} \overline{\theta^N_{l,k}} - \sum_{l\in\pi^{U,L}_n} \overline{\theta^N_{l,k}} - \sum_{l\in\pi^{D,L}_n} \underline{\theta^N_{l,k}} + \sum_{l\in\pi^{U,L}_n} \underline{\theta^N_{l,k}} - \theta^{min}_{n,k} + \theta^{max}_{n,k} = 0, \forall k \in K, n \in N/ST \quad (43)$$

$$o^1_{u,d,k}, o^2_{u,d,k}, o^3_{u,d,k}, o^4_{u,d,k}, \chi^1_{u,d,k}, \chi^2_{u,d,k}, \chi^3_{u,d,k}, \chi^4_{u,d,k}, \delta_{u,p,d,k} \geq 0 \quad (44)$$

$$\underline{\mu^N_{l,k}}, \overline{\mu^N_{l,k}}, \underline{\theta^N_{l,k}}, \overline{\theta^N_{l,k}}, \underline{\lambda_{c,k}}, \overline{\lambda_{c,k}} \geq 0 \quad (45)$$

$$\phi^{1}_{c,k,m}, \phi^{2}_{c,k,m}, \phi^{3}_{c,k,m}, \phi^{4}_{c,k,m}, \phi^{5}_{c,k,m}, \phi^{6}_{c,k,m}, \phi^{7}_{c,k,m}, \phi^{8}_{c,k,m}, \phi^{9}_{c,k,m}, \phi^{10}_{c,k,m} \geq 0 \quad (46)$$

$$\lambda^{C,min}_{n,k}, \phi^{W,min}_{n,k}, \mu^{N,min}_{n,k}, \theta^{min}_{n,k}, \theta^{max}_{n,k} \geq 0 \quad (47)$$

Strong duality equation

$$\begin{aligned}
&\omega_1 \textstyle\sum_{l,k}(D_l^S x_{l,k}) + \omega_2 \sum_{u,p,d,k}[f_{u,k}(t_{d,k} - t_{p,k})] + \omega_3 \sum_{n,k}(\varepsilon_n \varphi_n t^C_{n,k}) = -\omega_1 \textstyle\sum_{l,k}(D_l^S x_{l,k})\, \nu - \\
&M \textstyle\sum_{u,d,k}(f_{u,k} \mathrm{o}^1_{u,d,k}) - \mathrm{M} \sum_{u,d,k}[(1 - f_{u,k})\mathrm{o}^3_{u,d,k}] - M \sum_{u,p,k}(f_{u,k} \chi^1_{u,p,k}) - \mathrm{M} \sum_{u,p,k}[(1 - \\
&f_{u,k})\chi^3_{u,p,k}] - M \textstyle\sum_{u,p,d,k}[(1 - f_{u,k})\delta_{u,p,d,k}] - \sum_{l,k}\left[\gamma_{l,k}\left(1 + \alpha\left(\frac{V_l + \Delta V_l}{\rho_l}\right)^{\beta}\right)\xi_{l,k}\right] - \\
&M \textstyle\sum_{l,k}[(1 - x_{l,k})\overline{\mu^N_{l,k}}] - M \sum_{l,k}\left[(1 - x_{l,k})\underline{\mu^N_{l,k}}\right] - M \sum_{l,k}\left[(1 - x_{l,k})\overline{\theta^N_{l,k}}\right] - M \sum_{l,k}\left[(1 - \right. \\
&\left. x_{l,k})\underline{\theta^N_{l,k}}\right] - \sum_{l,k}\left(\frac{\tau_l * D_l^S}{E^{max}}\overline{\theta^N_{l,k}}\right) + \sum_{l,k}\left(\frac{\tau_l * D_l^S}{E^{max}}\underline{\theta^N_{l,k}}\right) - M \sum_{c,k,l \in \pi_c^{D,L}}(x_{l,k}\overline{\lambda_{c,k}}) - \\
&M \textstyle\sum_{c,k,l \in \pi_c^{D,L}}\left(x_{l,k}\underline{\lambda_{c,k}}\right) - \sum_{c,k,m}(\partial^C_{c,k,m}\phi^1_{c,k,m}) + \sum_{c,k,m,l}(\overline{\mathcal{R}_{c,k,m,l}}\, \phi^1_{c,k,m}) - \\
&M \textstyle\sum_{c,k,m}(\partial^C_{c,k,m}\phi^2_{c,k,m}) - M \sum_{c,k,m}(\partial^C_{c,k,m}\phi^3_{c,k,m}) - M \sum_{c,k,m}[(1 - \partial^C_{c,k,m})\phi^4_{c,k,m}] - \\
&M \textstyle\sum_{c,k,m}[(1 - \partial^C_{c,k,m})\phi^5_{c,k,m}] - \sum_{c,k,m}(\partial^C_{c,k,m}\phi^6_{c,k,m}) + \sum_{c,k,m,l}\left(\underline{\mathcal{R}_{c,k,m,l}}\phi^6_{c,k,m}\right) - \\
&M \textstyle\sum_{c,k,m}(\partial^C_{c,k,m}\phi^7_{c,k,m}) - M \sum_{c,k,m}(\partial^C_{c,k,m}\phi^8_{c,k,m}) - M \sum_{c,k,m}[(1 - \partial^C_{c,k,m})\phi^9_{c,k,m}] - \\
&M \textstyle\sum_{c,k,m}[(1 - \partial^C_{c,k,m})\phi^{10}_{c,k,m}] + \sum_{n,k}(SoC^{min}\theta^{min}_{n,k}) - \sum_{n,k}(SoC^{max}\theta^{max}_{n,k})
\end{aligned} \quad (48)$$