Evidence-based planning of a fossile-free emergency response fleet

Energimyndigheten project P2023-01441
Joint work of LiU, RTÖG, VTI

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Emergency response

Overall logic of a mission

1. Receive call to SOS & start mission.
2. Repeat until mission complete:
   - 2.1 Dispatch required vehicles:
     - 2.1.1 Identify required vehicle types.
     - 2.1.2 Find / wait for available vehicles.
     - 2.1.3 Send vehicles to mission.
   - 2.2 Recall no longer needed vehicles.
   - 2.3 Monitor mission progress.

↑

We aim to realistically simulate this.

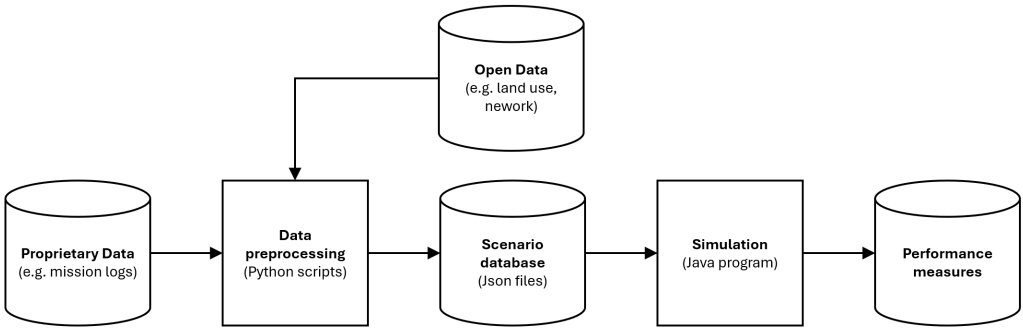
Electrified fleet

- Limited charging speed, battery capacity.
- Driving and mission consume energy.
- Vehicles recharge at dedicated stations.
- Vehicle availability depends on SOC.

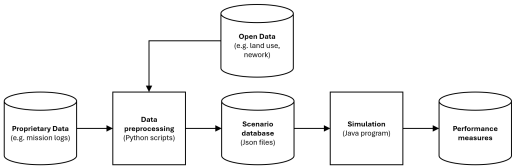
Simplifications

- No limitations on available staff.
- No vehicle failures.
- No en-route obstacles (congestion etc.).

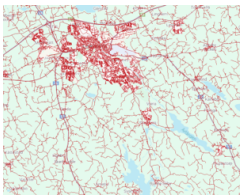
Evidence-based simulation needs data

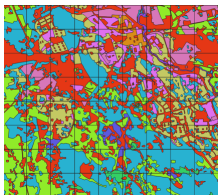


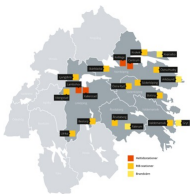
Open data



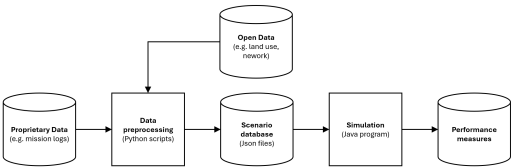
- Road network from NVDB.
- Land use from Lantmäteriet.
- Stations/fleet from RTÖG.
- Electrified fleet – vendor specifications.







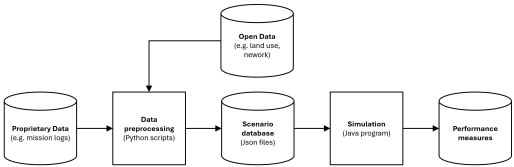
Proprietary data



- Daedalos mission logs (from RTÖG).
- Emergency location, time, type, ...
- Resource logs (vehicles, persons).

Ärende, årsnr	Händelse, typ	Resurs, station	Geo, nord	Resurs, tid klar	Resurs, tid framme	Geo, ost	Resurs, enhet
G2024.129879	Hjärtstopp	242-1000		1900-01-00 00:00	2024-11-06 07:44		242-1065
G2024.129930	Annan bärbar/slp till ambulans	242-2200		2024-11-05 21:36	2024-11-05 21:26		242-2210
G2024.129728	Trafikolycka (väg, terräng, spår, flyg, sjö)	242-2000		2024-11-05 17:54	2024-11-05 17:43		242-2010
G2024.129728	Trafikolycka (väg, terräng, spår, flyg, sjö)	242-2000		2024-11-05 17:54	2024-11-05 17:43		242-2040
G2024.129718	Brand eller brandtillbud i fordon eller fartyg utomhus	242-1000		2024-11-05 17:07	1900-01-00 00:00		242-1010
G2024.129718	Brand eller brandtillbud i fordon eller fartyg utomhus	242-1200		2024-11-05 17:18	2024-11-05 17:18		242-1210
G2024.129708	Trafikolycka (väg, terräng, spår, flyg, sjö)	242-1000		2024-11-05 16:27	1900-01-00 00:00		242-1040
G2024.129708	Trafikolycka (väg, terräng, spår, flyg, sjö)	242-1200		1900-01-00 00:00	1900-01-00 00:00		242-1210
G2024.129707	Hjärtstopp	242-1000		1900-01-00 00:00	1900-01-00 00:00		242-1065
G2024.129697	Trafikolycka (väg, terräng, spår, flyg, sjö)	242-2000		2024-11-05 16:13	1900-01-00 00:00		242-2008
G2024.129697	Trafikolycka (väg, terräng, spår, flyg, sjö)	242-2000		2024-11-05 16:18	2024-11-05 16:17		242-2010
G2024.129647	Automatlarm utan brandtillbud	242-1900		2024-11-05 14:30	2024-11-05 14:16		242-1910
G2024.129569	Automatlarm utan brandtillbud	242-2700		2024-11-05 11:24	2024-11-05 11:08		242-2760
G2024.129569	Automatlarm utan brandtillbud	242-2700		1900-01-00 00:00	2024-11-05 11:11		242-2770
G2024.129569	Automatlarm utan brandtillbud	242-2700		1900-01-00 00:00	2024-11-05 11:10		242-2710
G2024.129472	Annan första hjälpen eller sjukvård	242-3500		2024-11-05 04:51	2024-11-05 04:28		242-3560
G2024.129472	Annan första hjälpen eller sjukvård	242-3500		2024-11-05 04:51	2024-11-05 04:27		242-3570
G2024.129469	Lyfthjälp (inte åt ambulans)	242-3000		2024-11-05 03:13	1900-01-00 00:00		242-3010
G2024.129460	Suicid eller suicidförsök (inte brand, trafikolycka, utsläpp eller drunkning)	242-7000		1900-01-00 00:00	2024-11-05 01:57		242-7010
G2024.129460	Suicid eller suicidförsök (inte brand, trafikolycka, utsläpp eller drunkning)	242-7000		1900-01-00 00:00	2024-11-05 01:57		242-7070
G2024.129460	Suicid eller suicidförsök (inte brand, trafikolycka, utsläpp eller drunkning)	242-7000		1900-01-00 00:00	2024-11-05 01:57		242-7060
G2024.129460	Suicid eller suicidförsök (inte brand, trafikolycka, utsläpp eller drunkning)	242-1000		2024-11-05 02:30	2024-11-05 02:22		242-1080
G2024.129441	Automatlarm utan brandtillbud	242-1000		2024-11-04 23:57	2024-11-04 23:57		242-1010
G2024.129441	Automatlarm utan brandtillbud	242-1000		1900-01-00 00:00	2024-11-04 23:58		242-1080

Scenario database



Processed data

- vehicleTypes.json, vehicles.json, stations.json
- distanceTypes.json, distances.json

Statistical models

- incidentTypes.json, zones.json, missions.json


```
[ {
  "id" : "EV_Car",
  "batteryCapacity_kWh" : 75.0,
  "energyNeed_kWh_per_km" : 0.15,
  "chargingRate_kW" : 50.0,
  "energyNeedDuringMission_kW" : 0.5,
  "maxSpeed_km_h" : 130.0
}, {
  "id" : "EV_Truck",
  "batteryCapacity_kWh" : 300.0,
  "energyNeed_kWh_per_km" : 0.8,
  "chargingRate_kW" : 150.0,
  "energyNeedDuringMission_kW" : 1.5,
  "maxSpeed_km_h" : 90.0
} ]
```

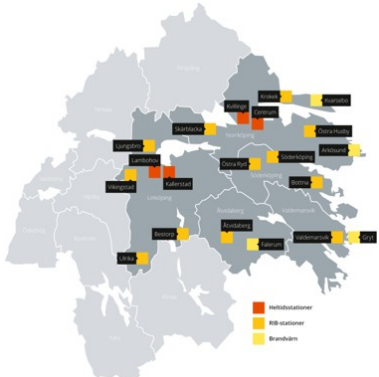
```
[ {
  "id" : "Car_001",
  "typeId" : "EV_Car",
  "stationId" : "NorthernStation"
}, {
  "id" : "Truck_001",
  "typeId" : "EV_Truck",
  "stationId" : "NorthernStation"
}, {
  "id" : "Car_002",
  "typeId" : "EV_Car",
  "stationId" : "SouthernStation"
} ]
```

```
[ {
  "id" : "NorthernStation",
  "zoneId" : "NorthernAmal"
}, {
  "id" : "SouthernStation",
  "zoneId" : "SouthernAmal"
} ]
```

```
[ {
  "id" : "NorthernAmal",
  "incidentTypeId2Intensity_1_yr" : {
    "CarCrash" : 10.0,
    "BuildingFire" : 10.0
  }
}, {
  "id" : "SouthernAmal",
  "incidentTypeId2Intensity_1_yr" : {
    "CarCrash" : 1.0,
    "BuildingFire" : 10.0
  }
}, {
  "id" : "WesternAmal",
```

```
[ {
  "id" : "BuildingFire",
  "season2Weight" : {
    "SUMMER" : 1.0,
    "WINTER" : 1.0,
    "AUTUMN" : 1.0,
    "SPRING" : 1.0
  },
  "typeOfDay2Weight" : {
    "HOLIDAY" : 1.0,
    "WORKDAY" : 1.0
  },
  "timeOfDay2Weight" : {
    "NIGHT" : 1.0,
    "DAY" : 2.0
  }
}, {
```

Östra Götaland case study



→ **Results are not yet validated.** ←

Baseline

- 90 consecutive autumn days.
- Anticipated market standard electrification.
- Ca. 1400 missions in total.

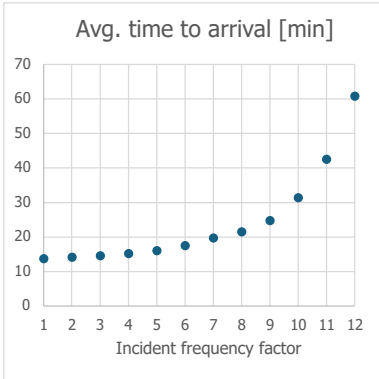
Simulation

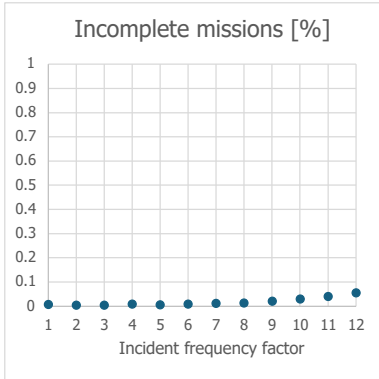
- 100 replications of each scenario.
- consider only system-wide statistics.
- limit statistical analysis to mean values.

Considered scenarios

1. Stress-test: incident frequency.
2. Battery capacity.
3. Charging speed.
4. Minimal SOC for mission-readiness.

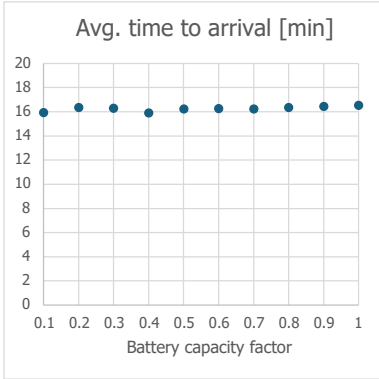
1. Incident frequency

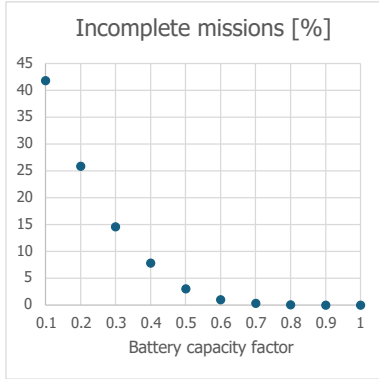




- Battery parameters (capacity, charging rate) at anticipated market standard.
- Vehicles need to be fully charged before entering a mission.
- **Sufficient performance at 500% incident increase.**

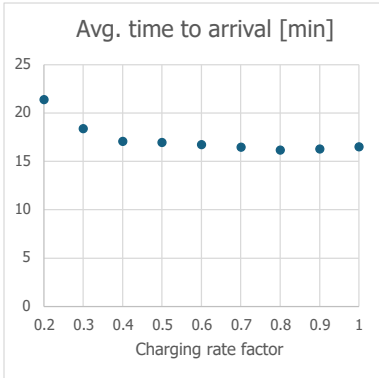
2. Battery capacity

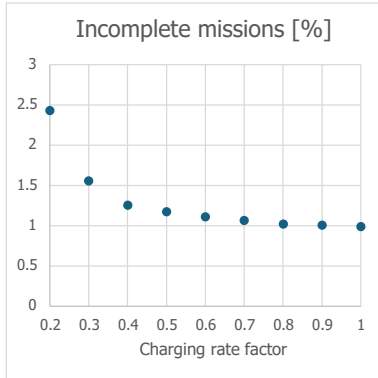




- Stress test: 500% incident increase.
- Charging rate at anticipated market standard.
- Vehicles need to be fully charged before entering a mission.
- **Sufficient performance with 60% battery size.**

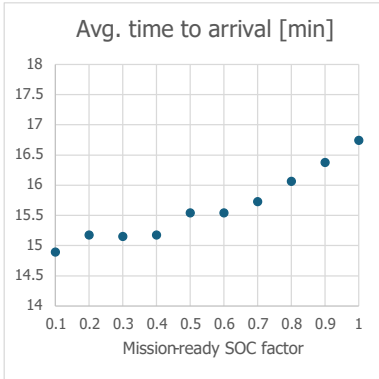
3. Charging rate

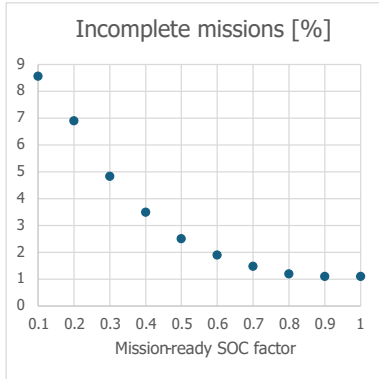




- Stress test: 500% incident increase.
- Battery capacity at anticipated market standard.
- **Sufficient performance with 60% charging speed.**

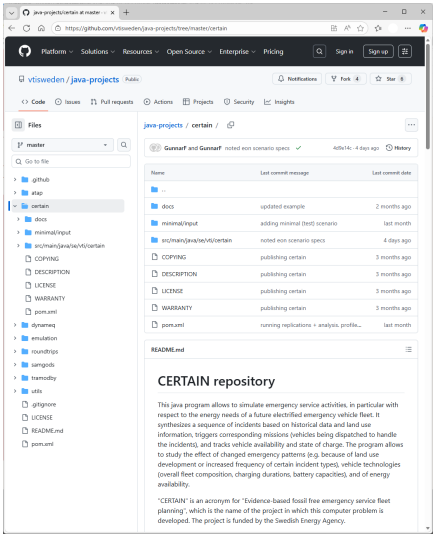
4. Minimal SOC for mission-readiness





- Stress test: 500% incident increase.
- Battery capacity and charging rate at 60% of anticipated market standard.
- **Sufficient performance when dispatching vehicles at 80% SOC.**

Next steps: case studies!



Code:

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