GLS Geospatial Load Modelling and -Forecasting

Anrich Steyn
GLS Consulting

Presentation Overview

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4. Geospatial Network Modelling
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11. Closing Remarks

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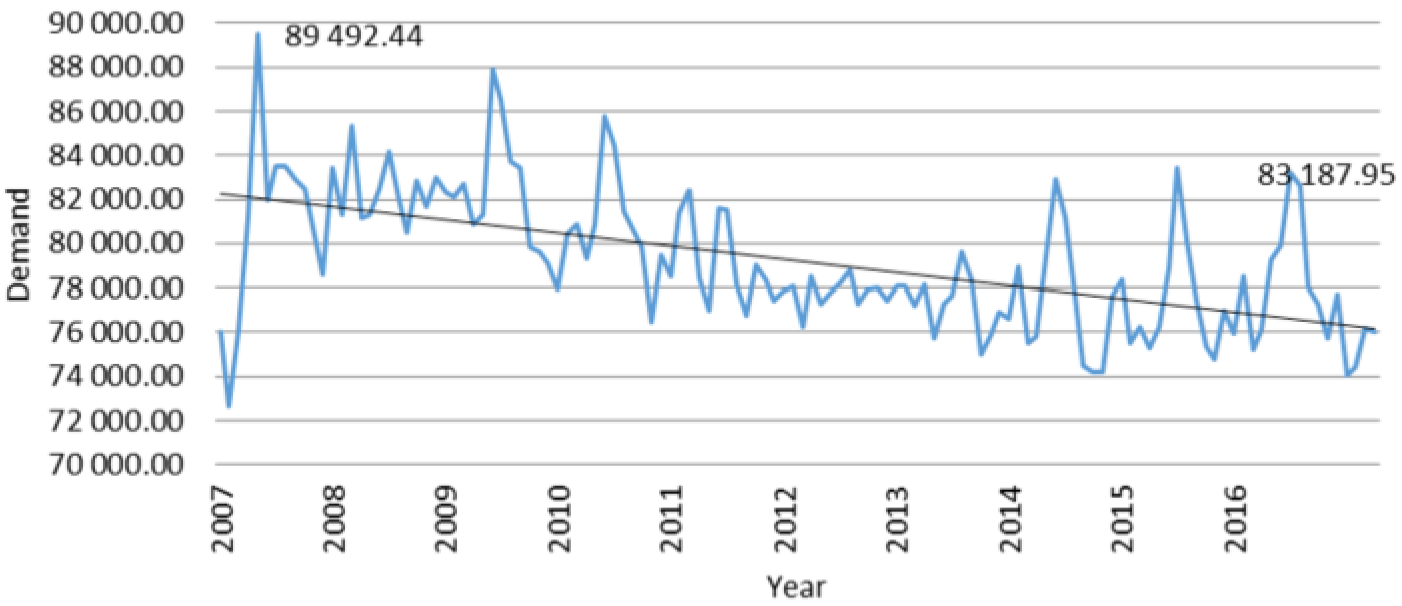
1. Introduction

- Consumer behaviour has changed – EEDSM, load-shedding, electricity prices, DG
- Growth vs. decline
- Necessitates a renewed look at load modelling and –forecasting



2. Tools Used

Two in-house developed software packages:

Swift

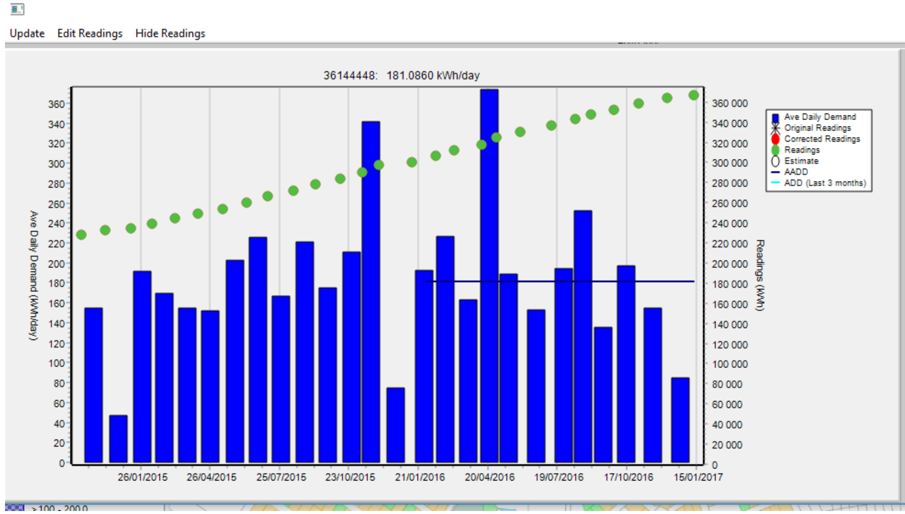
- GIS-based software that performs statistical analysis on utility billing data

Edisan

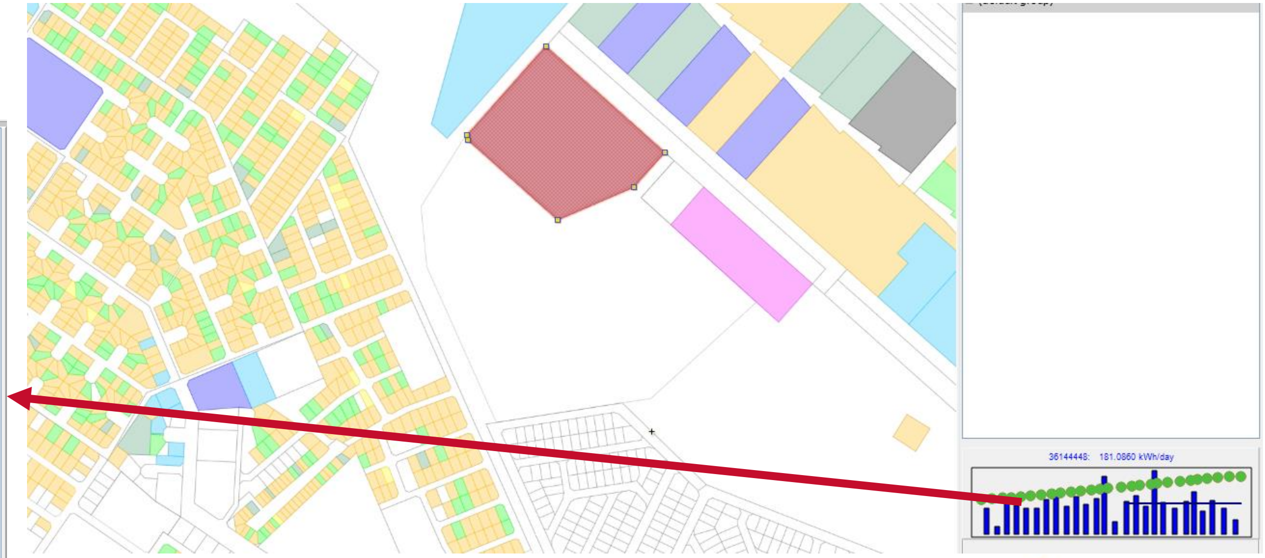
- GIS-based software for integrated and simplified electrical network planning

3. Energy Consumption Analysis

- Populate the Edisan model with electricity sales data from Swift (energy consumption in kWh)
- Populate the Edisan model with per stand land-use data from Swift
- Loss calculations (system input vs consumer usage)
- Revenue enhancement through, for example, visually identifying unmetered stands
- Tariff analysis (& cost of supply)



Date	Reading	Consump	ADD	Cod
12/01/2017	367,070.00			Gewone
08/12/2016	364,119.00	2,951.00	84.31	Gewone
01/11/2016	358,405.00	5,714.00	154.43	Gewone
01/10/2016	352,301.00	6,104.00	196.90	Gewone
01/09/2016	348,234.00	4,067.00	135.57	Gewone
11/08/2016	342,946.00	5,288.00	251.81	Gewone
11/07/2016	336,912.00	6,034.00	194.65	Gewone
01/06/2016	330,791.00	6,121.00	153.02	Gewone
01/05/2016	324,930.00	5,861.00	189.06	Gewone
12/04/2016	317,830.00	7,100.00	373.68	Gewone
07/03/2016	311,973.00	5,857.00	162.69	Gewone
12/02/2016	306,544.00	5,429.00	226.21	Gewone
12/01/2016	300,574.00	5,970.00	192.58	Gewone
01/12/2015	297,462.00	3,112.00	74.10	Gewone
09/11/2015	289,950.00	7,512.00	341.45	Gewone
12/10/2015	284,051.00	5,899.00	210.68	Gewone
09/09/2015	278,270.00	5,781.00	175.18	Gewone
12/08/2015	272,076.00	6,194.00	221.21	Gewone
10/07/2015	266,570.00	5,506.00	166.85	Gewone
12/06/2015	260,261.00	6,309.00	225.32	Gewone
12/05/2015	253,989.00	6,272.00	202.32	Gewone
10/04/2015	249,132.00	4,857.00	151.78	Gewone
12/03/2015	244,656.00	4,476.00	154.34	Gewone
10/02/2015	239,589.00	5,067.00	168.90	Gewone
13/01/2015	234,234.00	5,355.00	191.25	Gewone



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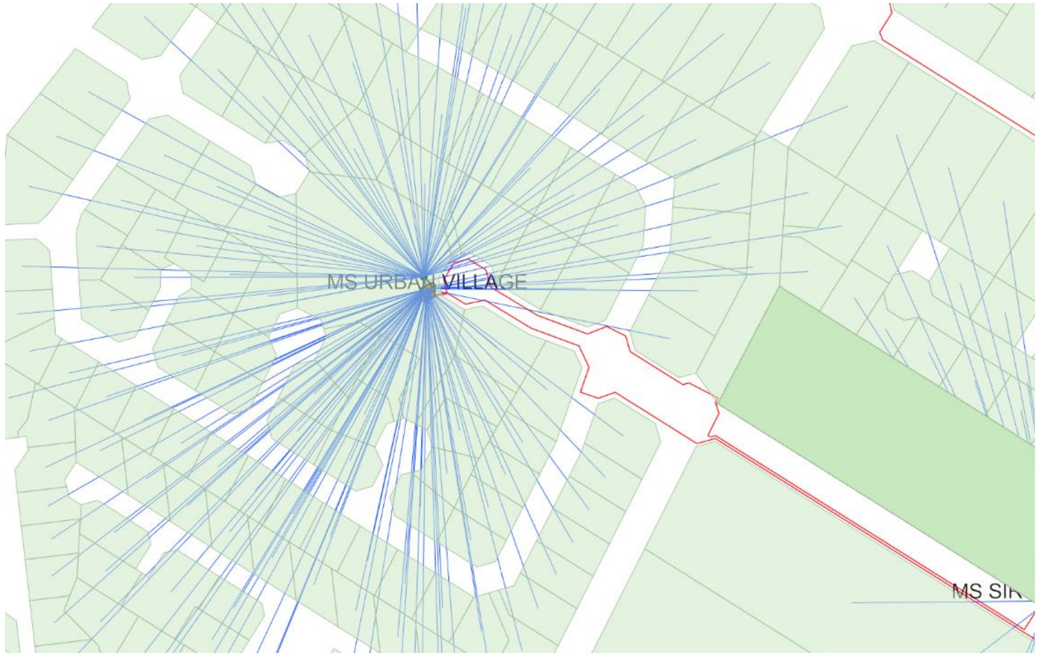
4. Geospatial Network Modelling

Working Principle:

- Consumption & land-use of each stand is imported into Edisan model via Swift
- Spatially tie stand to closest LV kiosk/minisub/substation etc. (model dependent)
- Get per-stand consumption, ADMD* and roll up – kiosk- → transformer- → distribution- →substation zones
- Bottom-up approach from stand to substation

Benefits:

- Have the land-use & consumption on a per-stand basis
- No high-level estimation of load class mix in a load area
- Reduces errors in high-level load class mix estimation
- Identify customers affected by outages
- Ability to view composite load profiles at supply points
- Ability to model LV network



*to be discussed

4. Geospatial Network Modelling

Spatial resolution:

1) **Substation Zone**: Substation supply area

2) **Distribution Zone**: MV switching station supply area

3) **Transformer Zone**: MV/LV transformer supply area (minisubs, ground/pole mounted)

4) **Kiosk Zone**: LV kiosk supply area

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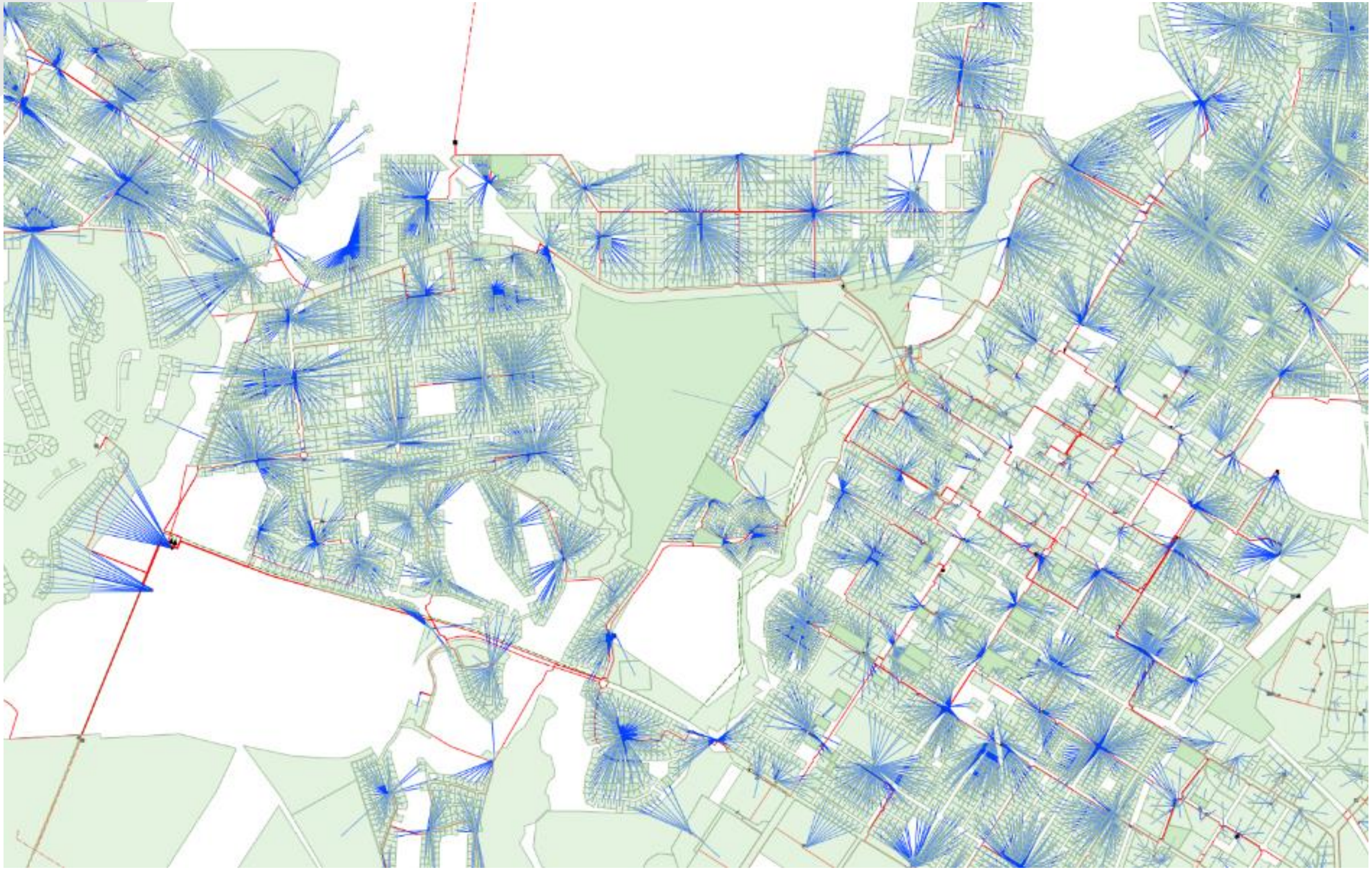
4. Geospatial Network Modelling



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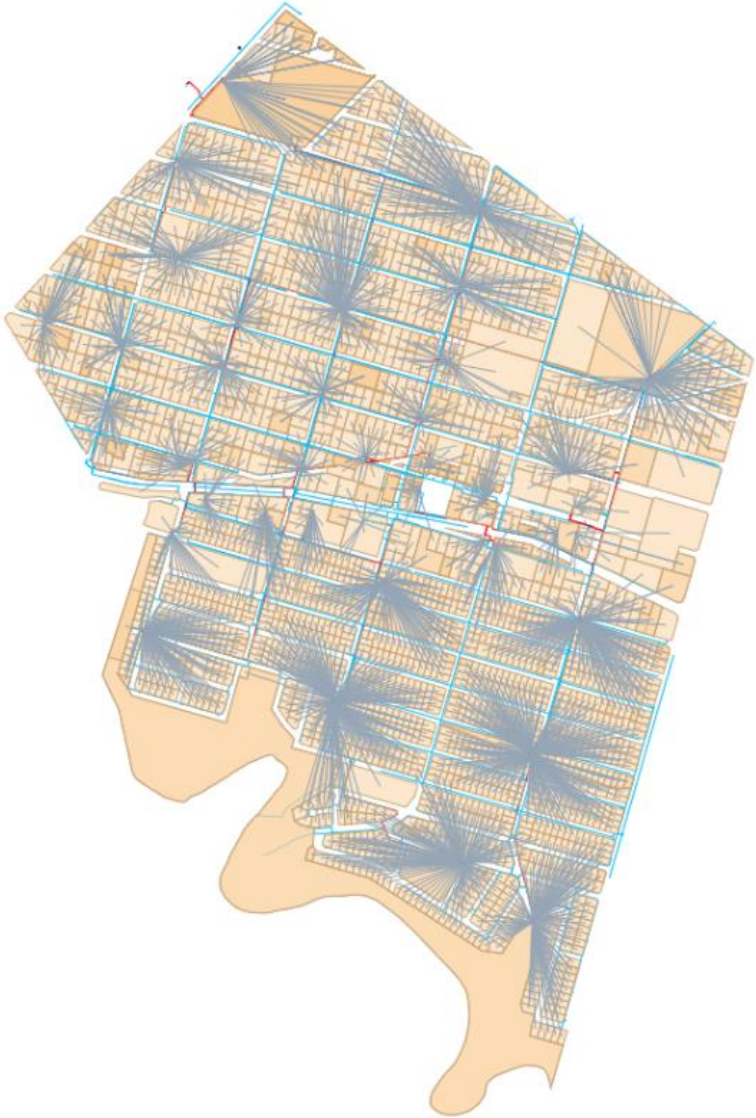

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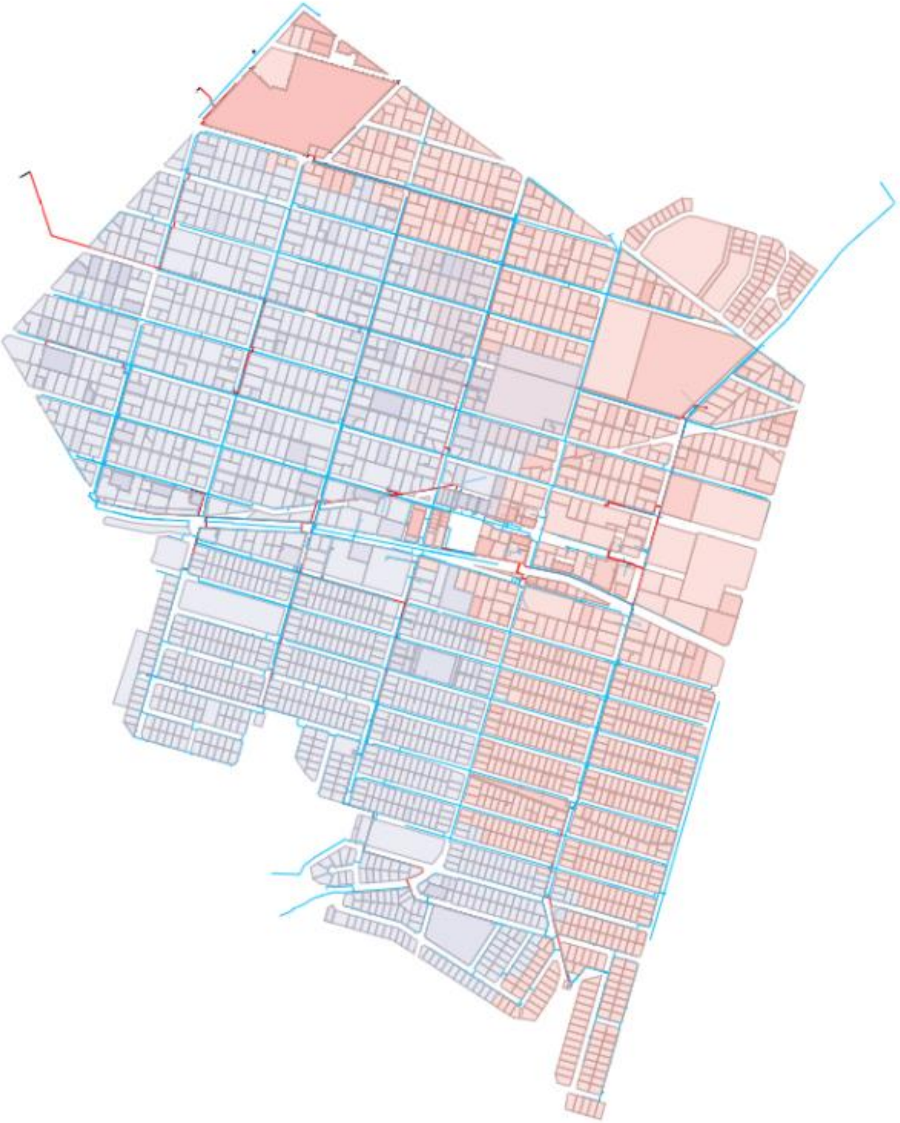

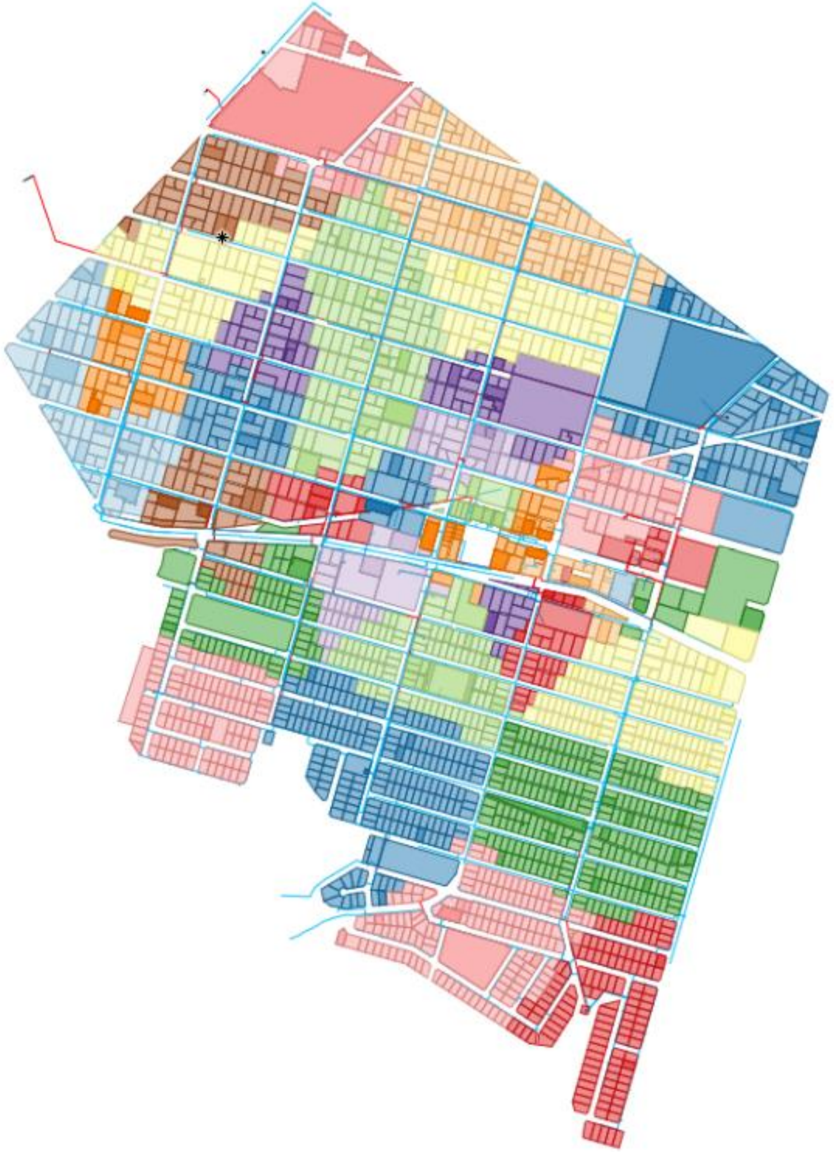

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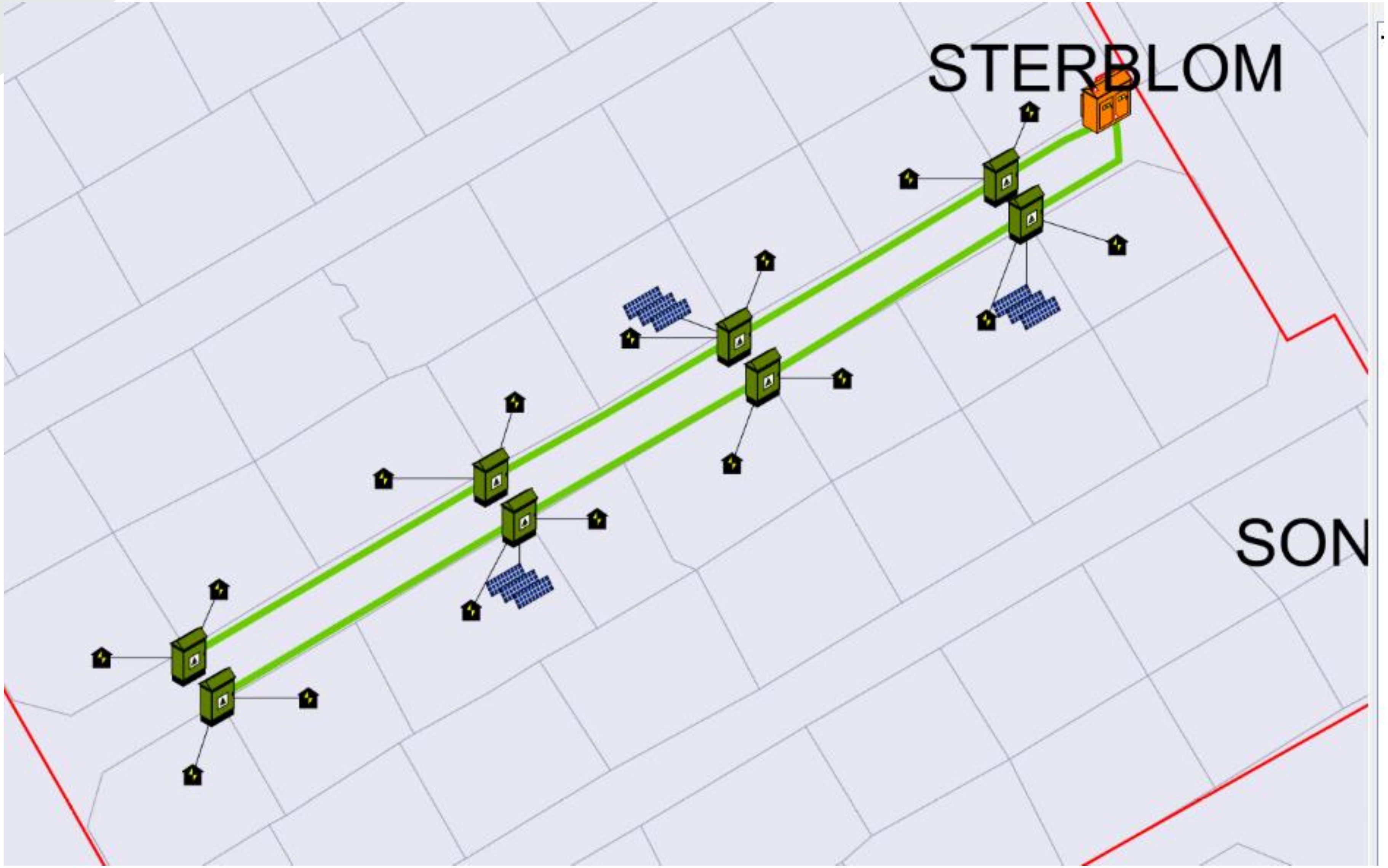
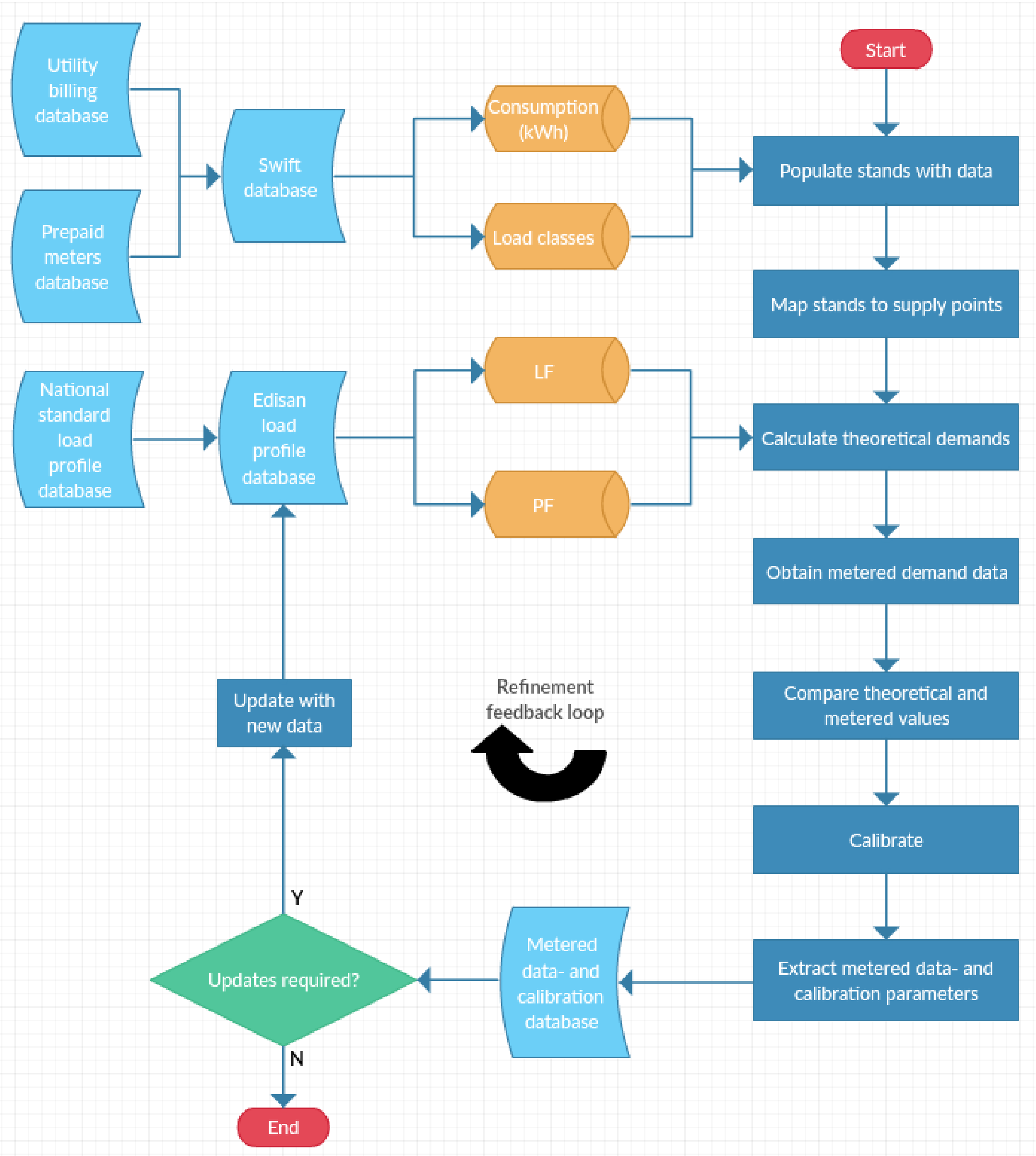


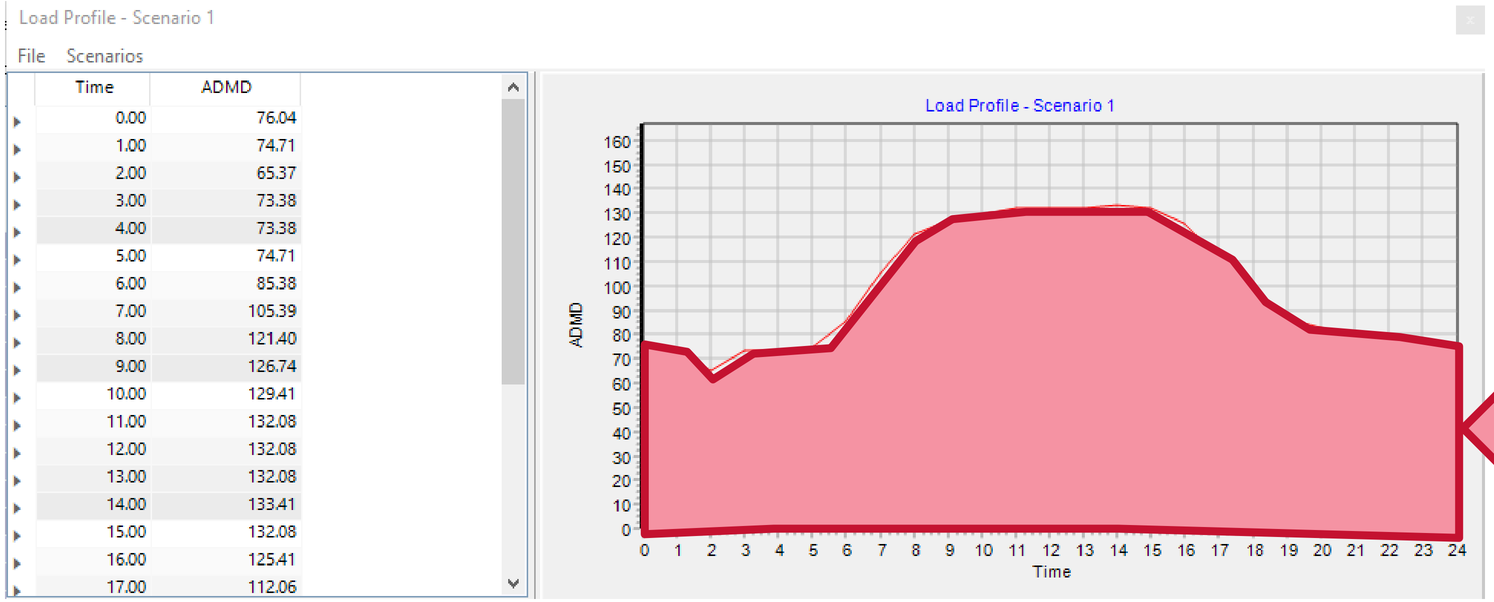
5. Methodology Overview



6. Problem Statement

Energy consumption (known) → How? → MD & ADMD (unknown)

- Load data problem – not readily available downstream of HV/MV substation
- Energy consumption data is readily available through Swift database
- Want to 'predict' MDs and ADMDs from energy consumption



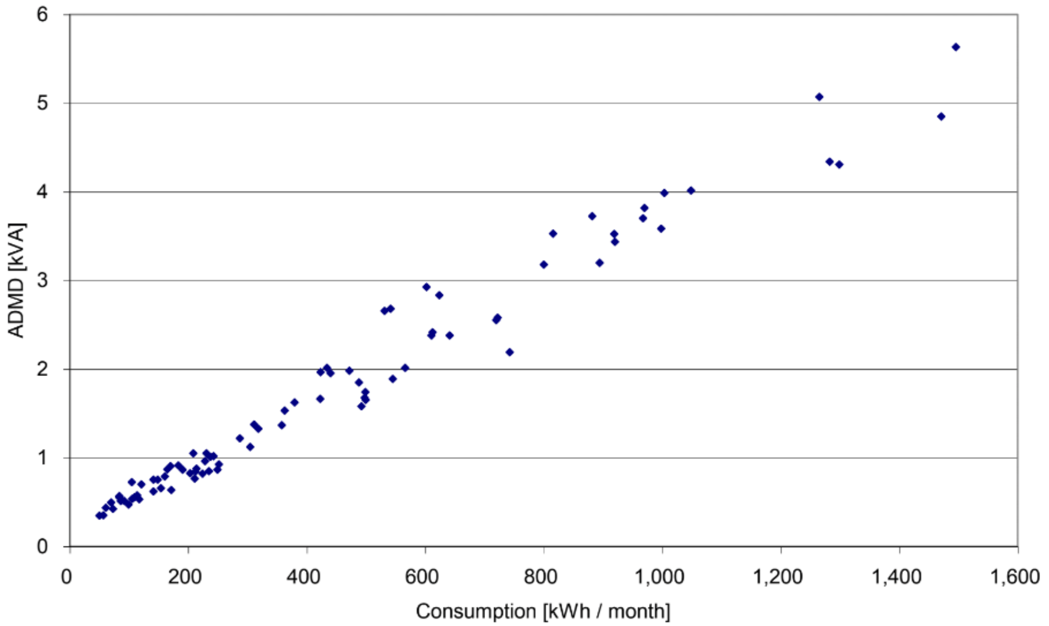
Time	ADMD
0.00	76.04
1.00	74.71
2.00	65.37
3.00	73.38
4.00	73.38
5.00	74.71
6.00	85.38
7.00	105.39
8.00	121.40
9.00	126.74
10.00	129.41
11.00	132.08
12.00	132.08
13.00	132.08
14.00	133.41
15.00	132.08
16.00	125.41
17.00	112.06

Area under curve is $kVAh = \frac{kWh}{PF}$

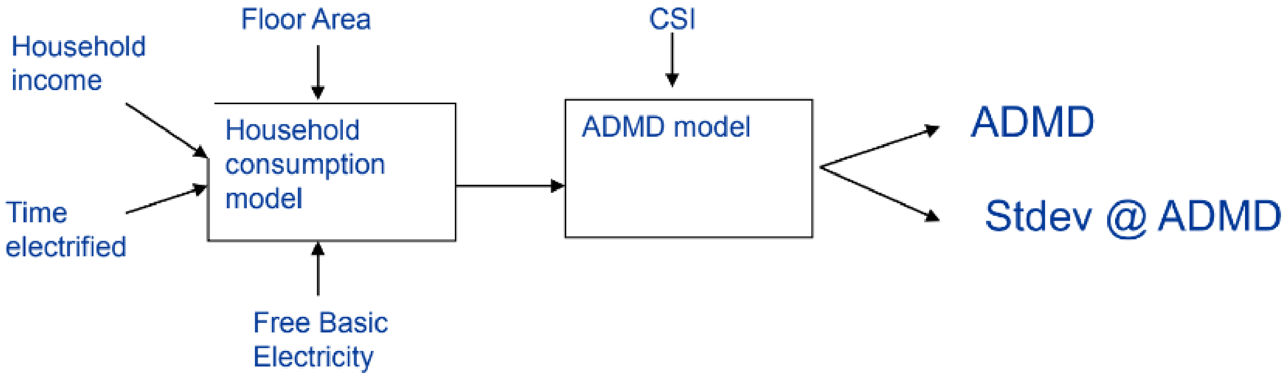
6. Problem Statement

Energy consumption (known) → How? → MD & ADMD (unknown)

Research has shown: Consumption -> useful predictor of demand models



(with thanks to Dr. Schalk Heunis)



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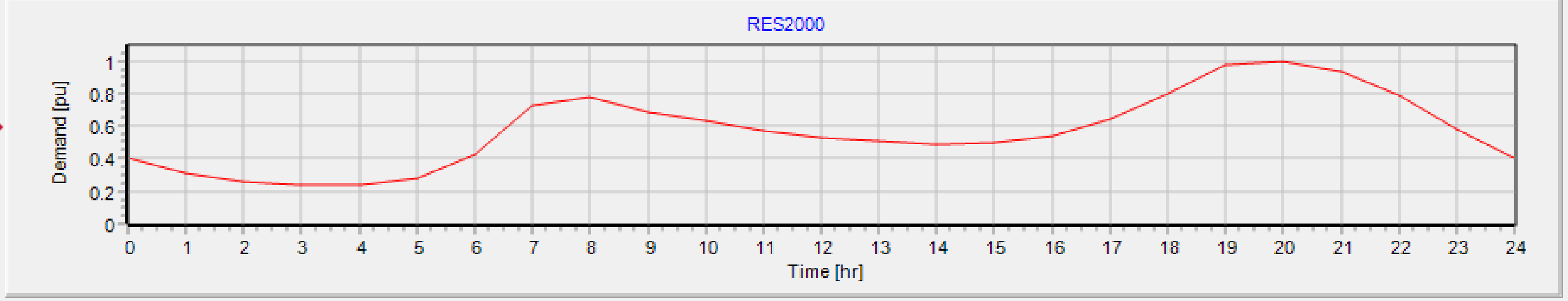
7. Load Profile Database

- Profile types assigned according to land-use imported from Swift into Edisan
- Load profile shapes can be imported, created, and are fully customisable
- Software is flexible, can perform functionality with whatever input it is given
  - Quick and easy testing and verification of different load models can be done

Profile characteristics

Profile	Name	LF	PF	Peak	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour (
BUSCOM	7B-S Warehousing	0.62	0.68		0.35	0.35	0.35	0.35	0.35	
BUSCOM	7D-B Harbour	0.87	0.73		0.79	0.77	0.75	0.78	0.86	
BUSCOM	7D-S Rail	0.93	0.72		0.98	0.93	0.90	0.89	0.95	
BUSCOM	8B Commerce Office	0.75	0.70		0.56	0.49	0.55	0.55	0.56	
BUSCOM	9A Sport	0.88	0.79		0.75	0.74	0.74	0.73	0.73	
GOV	9B Water and Sewerage	0.88	0.75		0.81	0.79	0.77	0.76	0.77	
GOV	9C Hospitals	0.75	0.82		0.57	0.56	0.55	0.56	0.58	
EDU	9C Education	0.76	0.82		0.58	0.58	0.67	0.59	0.66	
GOV	9D Government	0.73	0.83		0.58	0.57	0.56	0.56	0.58	
FLAT	Hostel 4_6	0.52	1.00		0.26	0.23	0.23	0.23	0.27	
RES500	RurRes	0.51	1.00		0.29	0.26	0.24	0.26	0.30	
RES1000	Township 5_6	0.52	1.00		0.26	0.23	0.22	0.22	0.26	
RES1500	UrbEst 10h+	0.74	1.00		0.54	0.51	0.50	0.50	0.51	
RES2000	UrbRes 7l_7h	0.58	1.00		0.31	0.26	0.24	0.24	0.28	
RES9999	UrbTwn 7l_8h	0.71	1.00		0.49	0.45	0.44	0.44	0.46	

Profile shape



7. Load Profile Database

- Profiles normalized with 1 p.u. peak values and do not assume absolute kVA values
  - Same profile shape as national standard assumed, but not necessarily same amplitude
  - Peak value is **calculated** in relation to **actual** consumption data

Profile characteristics

Profile	Name	LF	PF	Peak	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour (
BUSCOM	7B-S Warehousing	0.62	0.68		0.35	0.35	0.35	0.35	0.35	
BUSCOM	7D-B Harbour	0.87	0.73		0.79	0.77	0.75	0.78	0.86	
BUSCOM	7D-S Rail	0.93	0.72		0.98	0.93	0.90	0.89	0.95	
BUSCOM	8B Commerce Office	0.75	0.70		0.56	0.49	0.55	0.55	0.56	
BUSCOM	9A Sport	0.88	0.79		0.75	0.74	0.74	0.73	0.73	
GOV	9B Water and Sewerage	0.88	0.75		0.81	0.79	0.77	0.76	0.77	
GOV	9C Hospitals	0.75	0.82		0.57	0.56	0.55	0.56	0.58	
EDU	9C Education	0.76	0.82		0.58	0.58	0.67	0.59	0.66	
GOV	9D Government	0.73	0.83		0.58	0.57	0.56	0.56	0.58	
FLAT	Hostel 4_6	0.52	1.00		0.26	0.23	0.23	0.23	0.27	
RES500	RurRes	0.51	1.00		0.29	0.26	0.24	0.26	0.30	
RES1000	Township 5_6	0.52	1.00		0.26	0.23	0.22	0.22	0.26	
RES1500	UrbEst 10h+	0.74	1.00		0.54	0.51	0.50	0.50	0.51	
RES2000	UrbRes 7l_7h	0.58	1.00		0.31	0.26	0.24	0.24	0.28	
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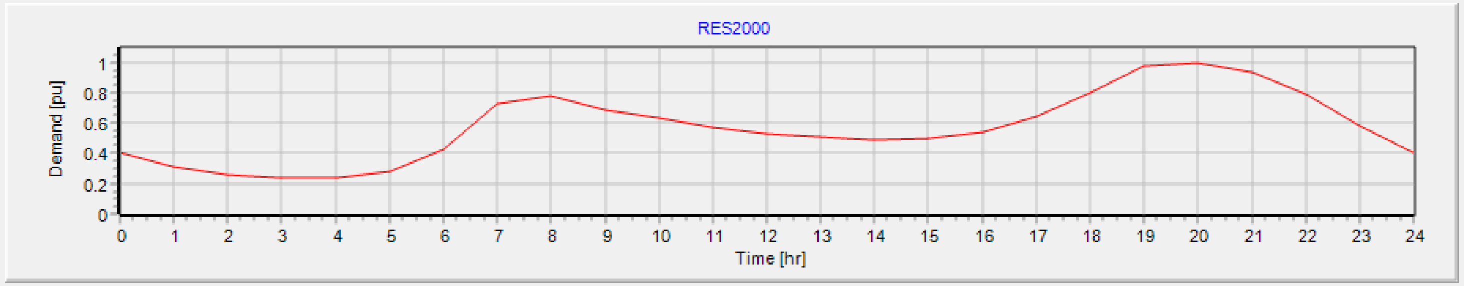
Profile shape



8. Demand Prediction

$$MD_{theoretical}\ (kVA) = \frac{Consumption_{Swift}\ (kWh)}{LF\ x\ PF\ x\ 24h}$$

where

$MD_{theoretical}$ → theoretical maximum demand for a stand
LF → aims to provide compensation for using averaged, as opposed to peak consumption
LF, PF → theoretical values assumed from current national standard load shapes

$Consumption_{Swift}$ input can vary:

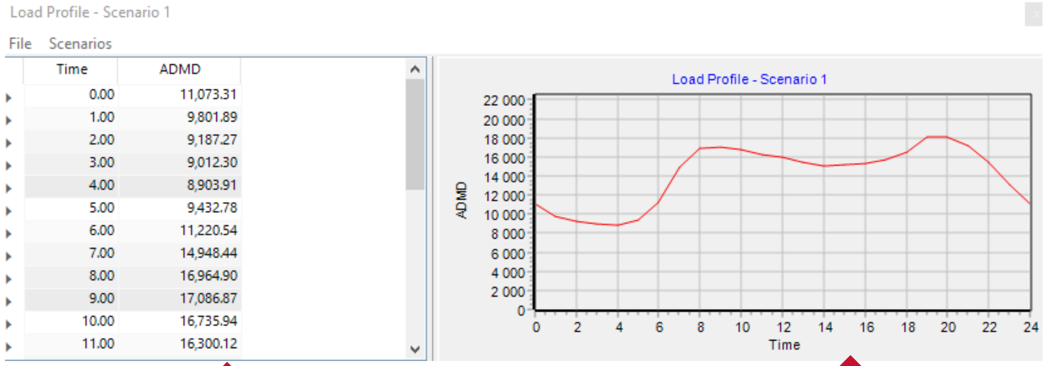
- **Annual *Average Daily*** Consumption (initial method tested)
- **Per Month *Average Daily*** Consumption
- **Peak Month *Average Daily*** Consumption
- **Statistical distribution** of ***Daily*** consumption (reflecting some input variability in demand calculation output)

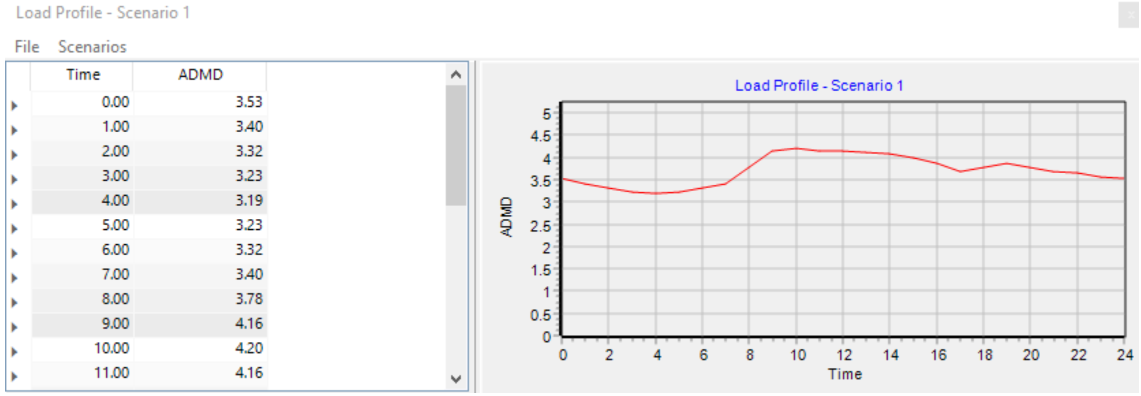
Or

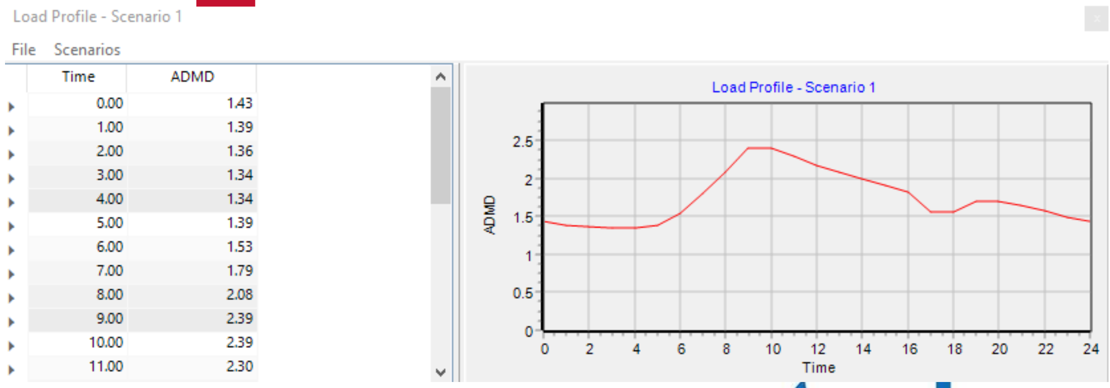
- Consumption can be considered on a monthly basis, with no averaging

8. Demand Prediction

- Substation-, distribution-, transformer- or kiosk zone profile is a summation of all profiles within zone







8. Demand Prediction

GM_0009398 - Scenario 1

Scenario: Scenario 1

Power Factor: 0.82
Load Factor: 0.79
Total AADC : 179235.80

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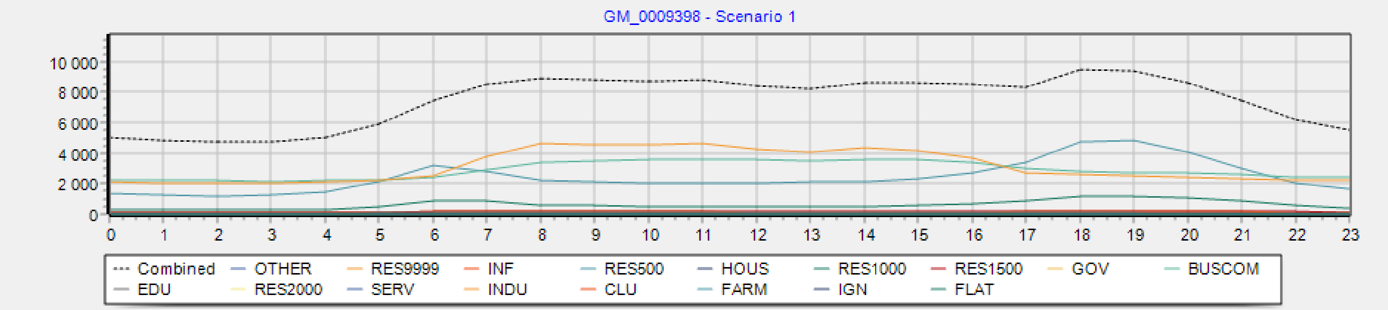
Profile	Count	AADC	MD	ADMD
Combined	8,666	179,235.80	11,606.84	1.34
OTHER	84	1,342.53	99.93	1.19
RES9999	139	3,463.34	204.33	1.47
INF	27	0.00	0.00	0.00
RES500	6,226	58,411.26	4,811.47	0.77
HOUS	14	73.04	4.38	0.31
RES1000	1,146	14,616.94	1,162.84	1.01
RES1500	305	4,047.73	227.27	0.75
GOV	8	232.85	14.68	1.83
BUSCOM	355	47,790.76	3,623.16	10.21
EDU	20	1,020.89	68.08	3.40
RES2000	34	483.30	34.92	1.03
SERV	28	12.27	0.79	0.03
INDU	237	47,451.00	4,653.69	19.64
CLU	1	0.00	0.00	0.00
FARM	5	29.28	1.79	0.36
IGN	34	86.17	6.60	0.19
FLAT	3	174.43	0.00	0.00

Time	AADCpu	MD
0	0.43	5,021.03
1	0.41	4,797.75
2	0.41	4,711.86
3	0.41	4,750.95
4	0.43	5,016.75
5	0.50	5,857.64
6	0.64	7,440.62
7	0.74	8,531.71
8	0.76	8,865.58
9	0.75	8,762.35
10	0.75	8,692.92
11	0.75	8,760.37
12	0.73	8,459.33
13	0.71	8,243.76
14	0.74	8,571.34
15	0.74	8,615.40
16	0.74	8,543.92
17	0.71	8,287.61
18	0.81	9,436.91
19	0.81	9,400.89
20	0.74	8,595.76
21	0.64	7,406.29
22	0.53	6,196.38
23	0.48	5,518.58



Consumption, MD, ADMD breakdown per load class

Combined consumption and MD hourly breakdown

Combined- and per-class load profiles

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8. Demand Prediction

What about non-domestic users?

- ADMD not a useful metric for non-domestic - rather consumption density (kVA/Ha)
- Non-domestic kVA metering database also imported geospatially via Swift
- Facilitates easy comparison of predicted kVA versus metered kVA

Edisan is an integrated database

- Consolidate various datasets into one geospatial network model
- Future datasets
  - Climate data
  - Solar irradiance data
  - Building footprint shapefiles – commercial & industrial demand density metrics (kVA/Ha)
  - Any other relevant metrics that will aid in studying load behaviour

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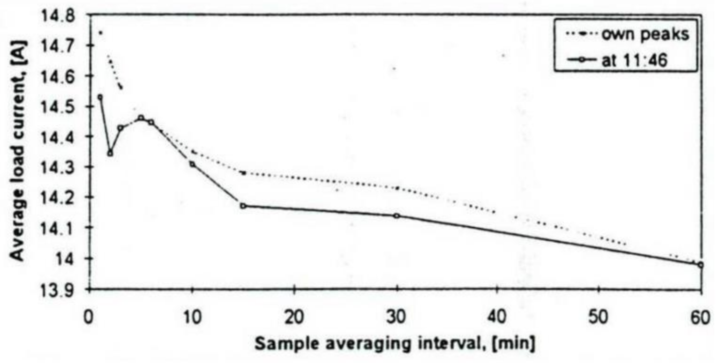
9. Calibration Process

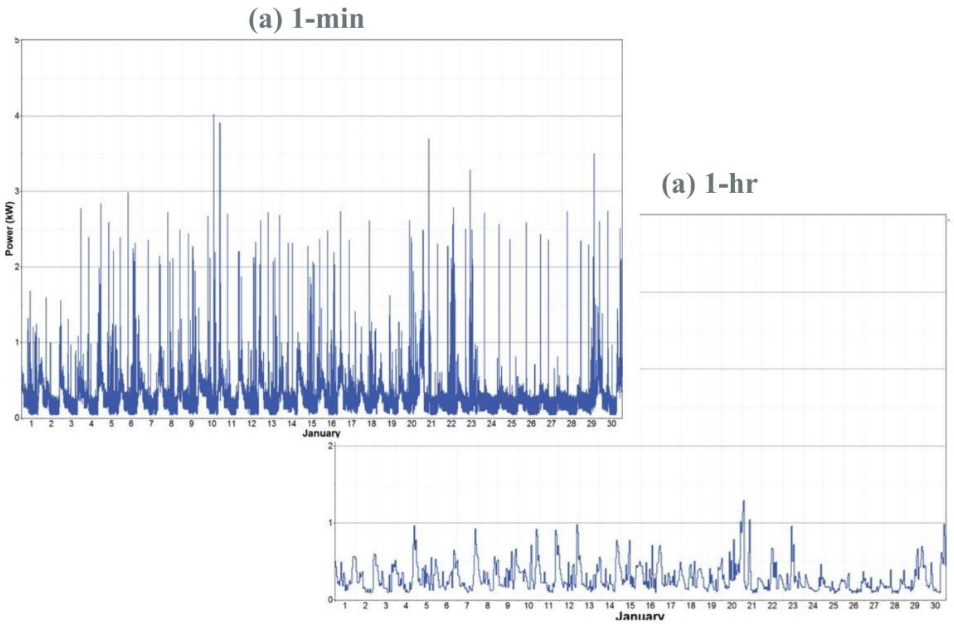
Error is obviously introduced

1) Consumption resolution is per month (and not daily, 30- or even 5-minute)
   - Loss of visibility in the variability of the consumption with increased averaging interval
   - To what extent?
2) Making the jump from energy -> demand introduces error (even with high-resolution, accurate consumption data)
   - To what extent?



Sensitivity of load demand to cadence (Sellick & Gaunt, 1996)

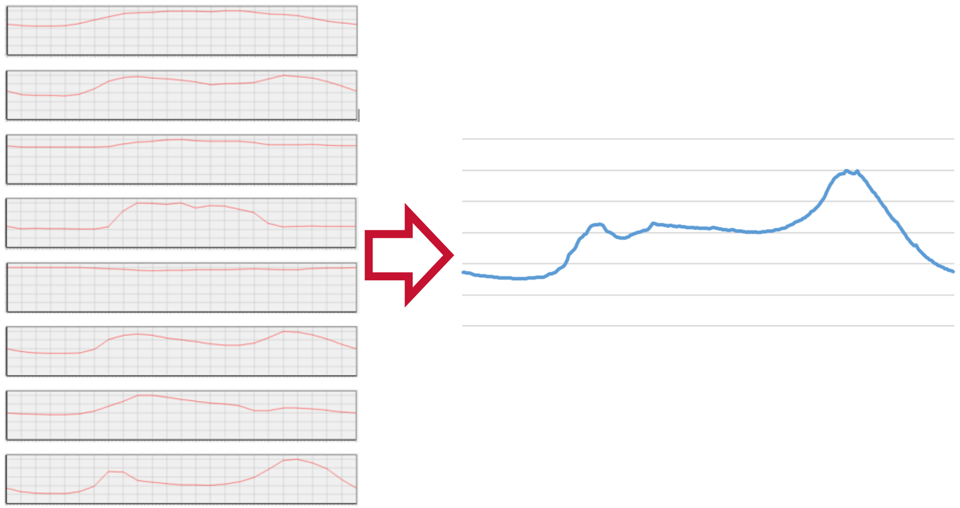
(with thanks to Mr. Justice Chihota)



(with thanks to Mr. Justice Chihota)

9. Calibration Process

- 5/30-minute data at HV/MV substation typically available
  - Currently have strategic minisub metering @ specific client for increased downstream visibility
- Use metered data to calibrate downstream loads
- Automatic load scaling functionality in Edisan, can be applied:
  - Per stand
  - Per load class
  - Per kiosk-, transformer-, distribution- or substation zone
  - Per user selection
- Future: Automated curve fitting algorithm
  - Auto calibration within specified set of rules and limits
  - Peak amplitude calibration vs. shape shifting
  - Different customer groupings?



Important:

Capture calibration information to study the relationship between consumption and demand

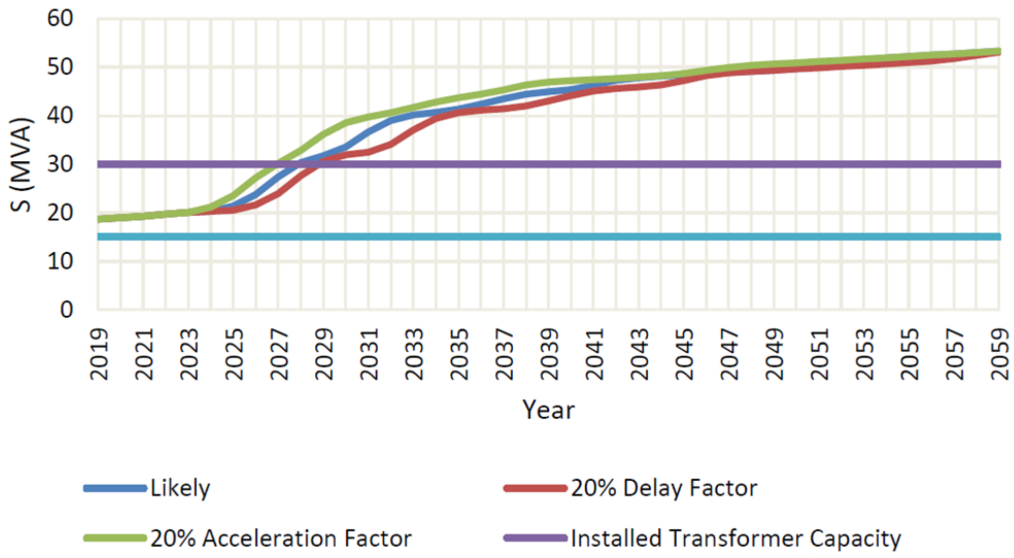
Load Forecast & Future Network

1. Future loads (load growth pockets)
   - Future development geospatial shapefile – **location**, **size**, anticipated **land-use**, priority (**when**) and duration (**how long**)
   - Based on SDF, IDP, House Plans etc. - workshopped with town planners & electrical departments
   - Growth curve – linear, step, s-curve or custom
   - Scenario-based planning between 2 extremes (current situation → saturation)

2. Current loads
   - Change in behaviour (stagnation, growth or decline)
   - Growth curve – linear, step, s-curve or custom

3. Distributed generation

4. Demand-side management strategies



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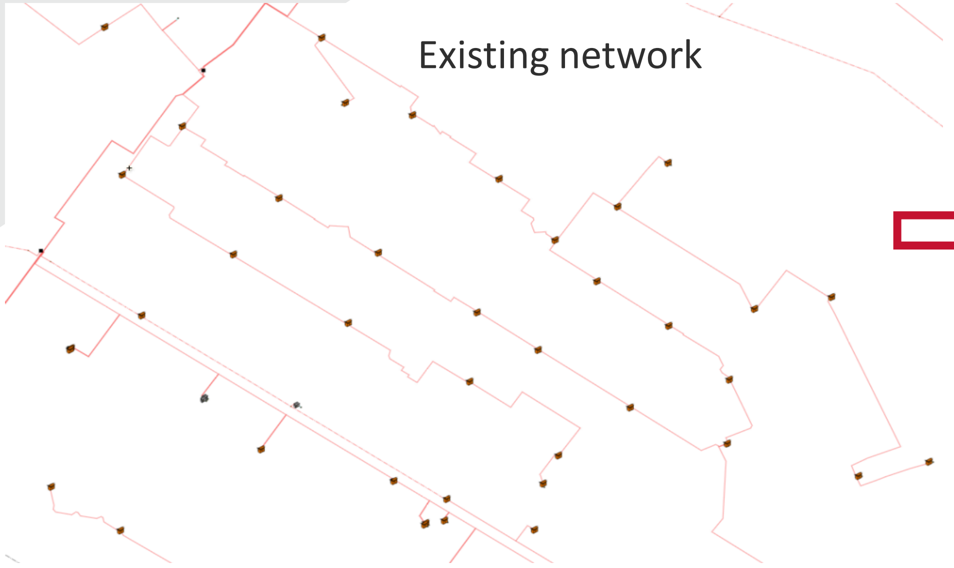
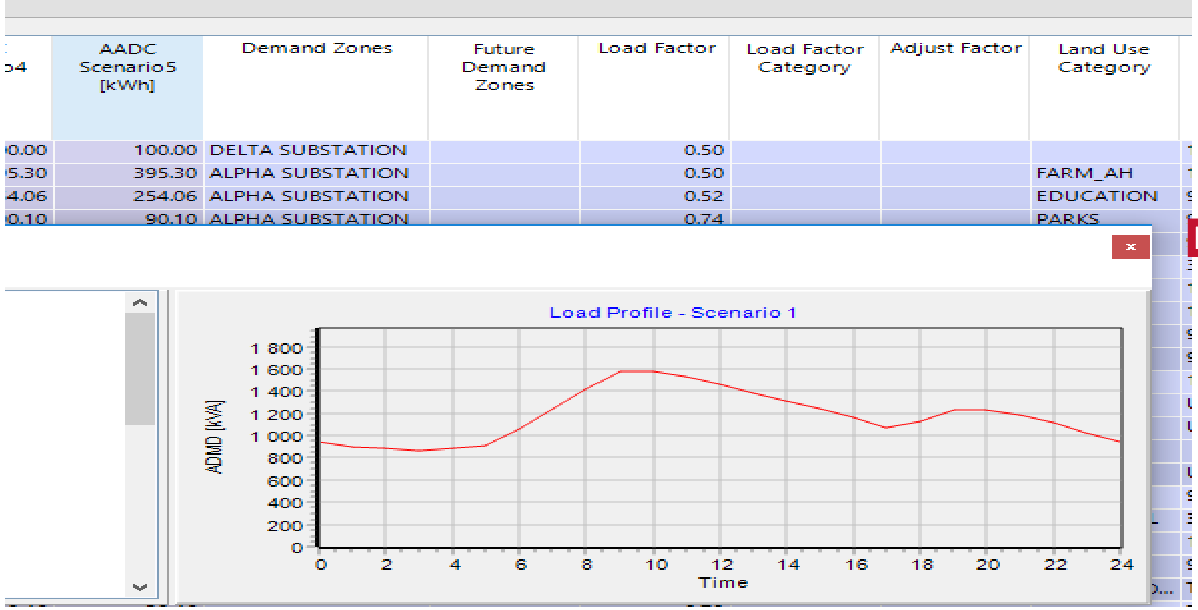
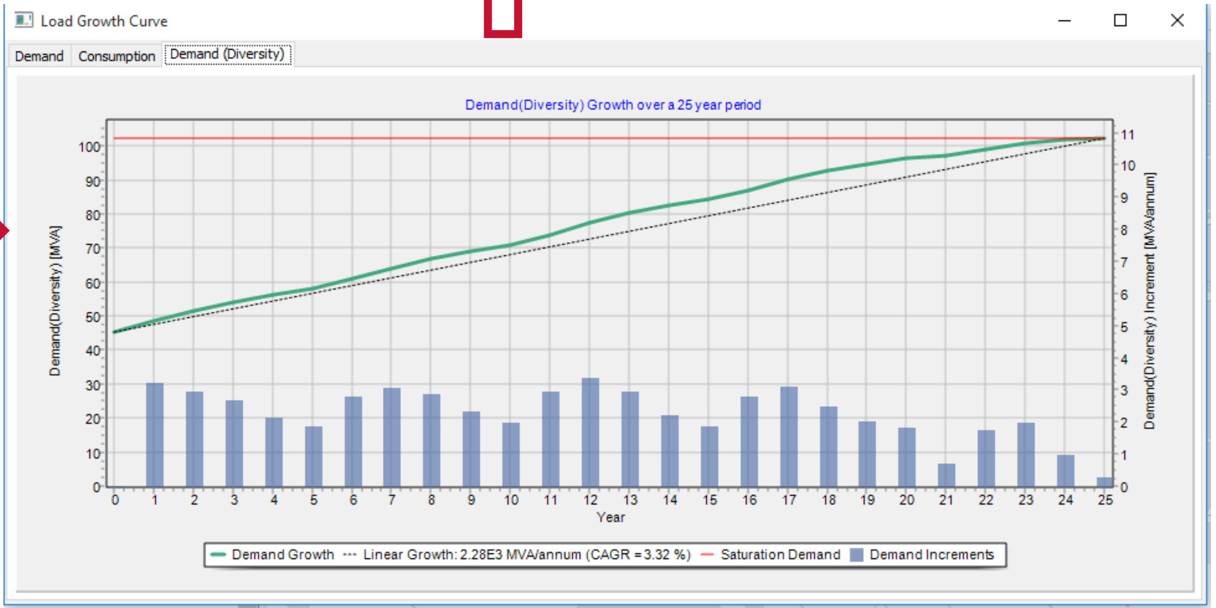
Load Forecast & Future Network

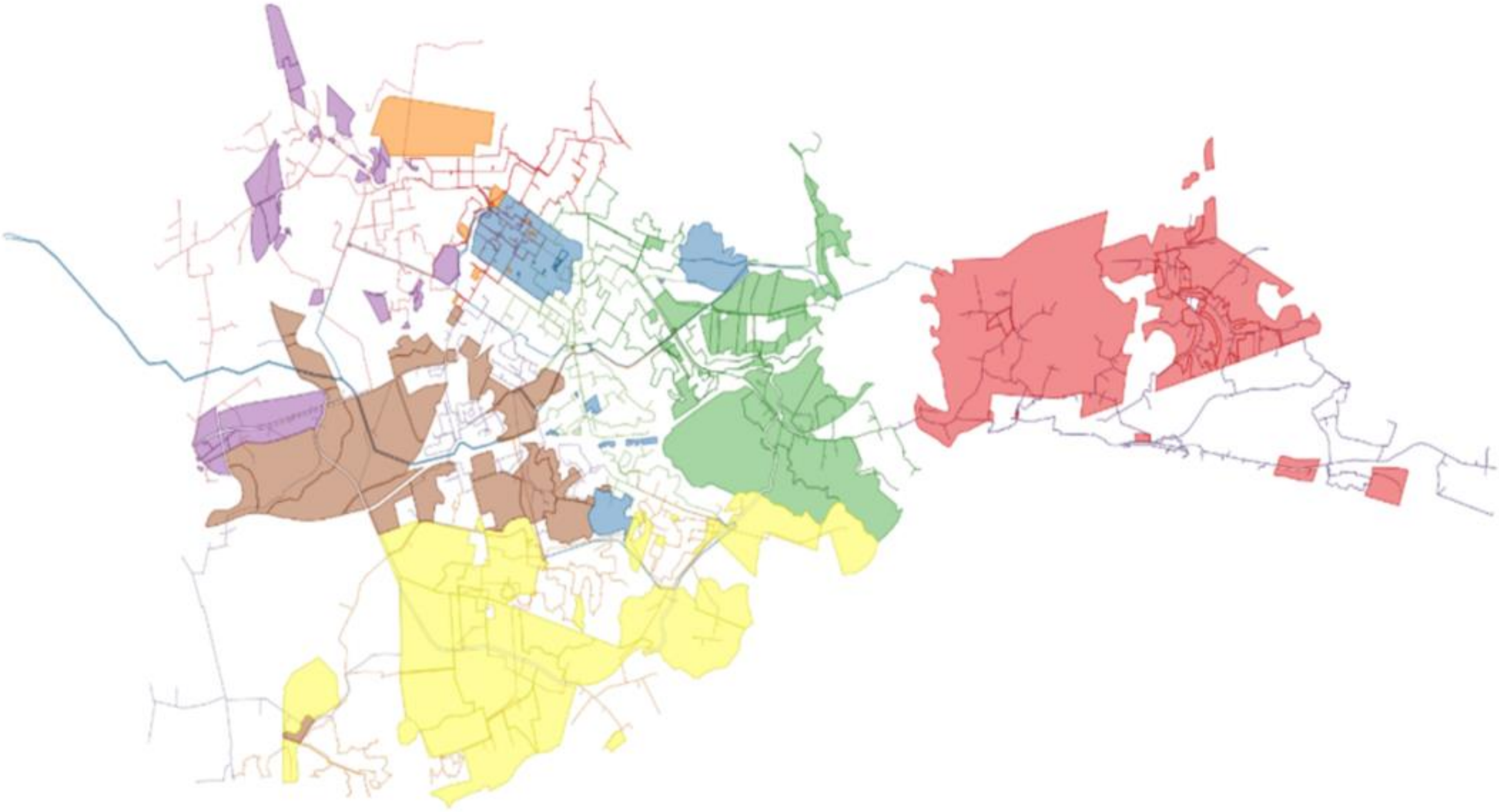




…4	AADC Scenario5 [kWh]	Demand Zones	Future Demand Zones	Load Factor	Load Factor Category	Adjust Factor	Land Use Category
…0.00	100.00	DELTA SUBSTATION		0.50			
…5.30	395.30	ALPHA SUBSTATION		0.50			FARM_AH
…4.06	254.06	ALPHA SUBSTATION		0.52			EDUCATION
…0.10	90.10	ALPHA SUBSTATION		0.74			PARKS



Load Forecast & Future Network



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10. Closing Remarks

- Load behaviour needs to be actively studied to keep trend with status quo
- GLS has powerful tools to support load modelling process
- Available data is limited
  - How do we best use the data that we **do** have?
  - How do we go about sourcing the necessary data we need
- The more times we do this, the more data we will have, and the more informed we will be
  - Refinement process
  - Rinse, repeat, learn, adjust

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Contact

Hilton Baartman (Director): hilton@gls.co.za; 0727153044

Anrich Steyn (Electrical Engineer): anrich@gls.co.za; 0764350190

CONTACT

Contact Details	Postal Address	Street Address
Telephone +27 21 8800388 **Fax** +27 21 8800389 **Email** info@gls.co.za	GLS Consulting (Pty) Ltd PO Box 814 Stellenbosch 7599 South Africa	13 Elektron St Techno Park Stellenbosch 7600 South Africa 33° 57' 52" S 18° 50' 17" E View Map

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