A ticket-based public transport pricing model for Switzerland

Other Conference Item

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A ticket-based public transport pricing model for Switzerland

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Institute for Transport Planning and Systems

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Idea

- Costs for public transport travels are crucial for transport research:
  - Preparation of surveys
  - Analysis of choice experiments
  - Transport simulation

- We would like to:
  - Impute current costs into existing data (Microcensus 2015 !)
  - Extend pricing with future schemes

Current state

- Calculates single trip costs
- Calculates daily costs (like a "check-in" app)

- Includes all public transport authorities (Verbünde) with single/daily tickets or distance tariff, and SBB
- Provides a matching between HAFAS station IDs and transport authority zones

- Does **not** include subscriptions (except Halbtax), special fares (SBB), short distance (Kurzstrecke) and regions with only monthly or annual subscriptions

Model outline

1. Data preparation
   a. Digitalization of T603 (SBB distance tariff)
   b. Digitalization of T651 (Verbundtarife)
   c. Matching of HAFAS station ID to transport authority and zone
   d. Digitalization of tickets

2. Cost calculator
   a. Routing through SwissRailRaptor
   b. Separation of price-relevant trip stages
   c. Combinatorial optimization of potential tickets

Data preparation

Data preparation: T603
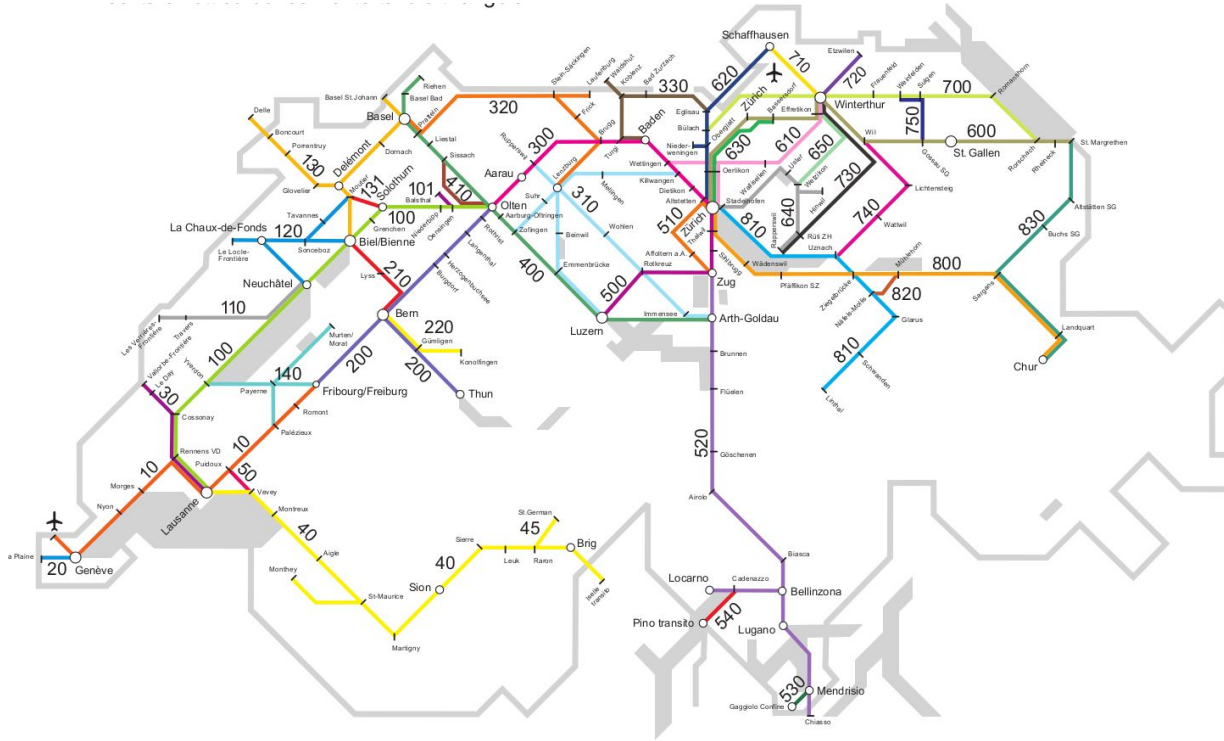
Tariff T603

1. Find triangles
2. Find distance
3. Calculate price

Data preparation: T603
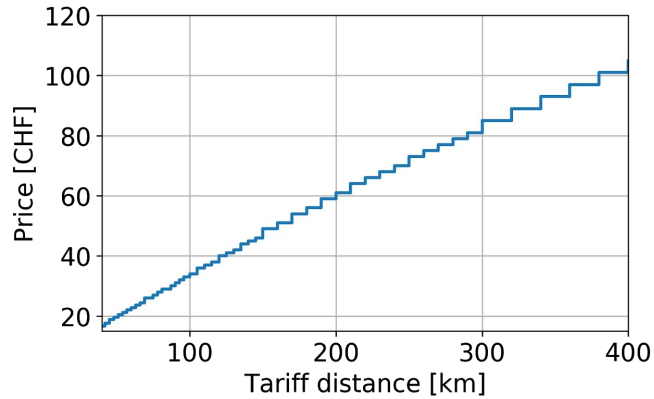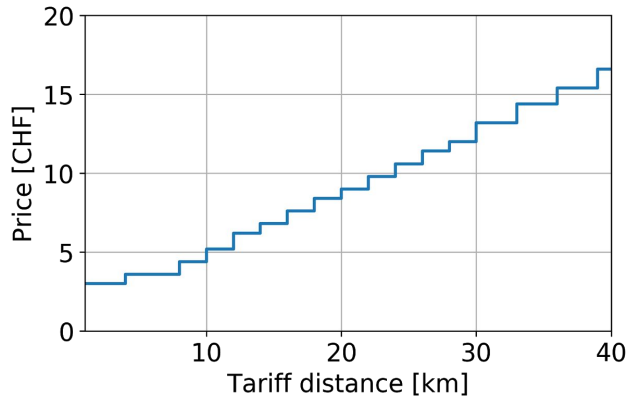
Olten 00218
4 Dulliken 02110
7   3 Däniken 02111
9   5   2 Schönenwerd SO 02112
16   9   6   4 **Aarau** 02113
22   15   12   10   6 Rupperswil 02114
25   18   15   13   9   3 Wildegg 02115
26   19   16   14   10   4   1 Holderbank AG 02128
29   22   19   17   13   7   4   3 Schinznach Bad 02116
36   29   26   24   20   14   9   8   5 **Brugg AG** 00309
40   33   30   28   24   18   13   12   9   4 Turgi 03503
45   38   35   33   29   23   18   17   14   9   5 **Baden** 03504
50   43   40   38   34   28   20   19   16   11   7   2 Wettingen 03505
50   43   40   38   34   28   21   20   17   12   8   3   1 Neuenhof 03511
54   47   44   42   38   32   24   23   20   15   11   6   4   3 Killwangen-Spreitenbach 03506
59   52   49   47   43   37   29   28   25   20   16   11   9   8   5 Dietikon 03508
61   54   51   49   45   39   31   30   27   22   18   13   11   10   7   2 Glanzenberg 03512
63   56   53   51   47   41   33   32   29   24   20   15   13   12   9   4   2 Schlieren 03509
66   59   56   54   50   44   36   35   32   27   23   18   16   15   12   7   5   3 Zürich Altstetten 03001
68   61   58   56   52   46   38   37   34   29   25   20   18   17   14   9   7   5   2 Zürich Hardbrücke 03020
80   73   70   68   64   54   46   45   42   37   33   28   26   19   16   11   9   7   4   2 **Zürich HB** 03000

Tariff T603

1. Find triangles
2. Find distance
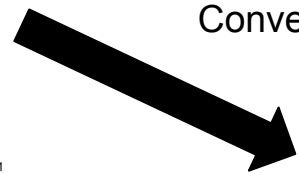3. Calculate price

Source: T603 Tarif, 01.06.2018, ch-direct

Data preparation: T603

Tariff T603

1. Find triangles
2. Find distance
3. Calculate price

* Not 100% exact (difference +/-1 CHF)

Source: T603 Tarif, 01.06.2018, ch-direct

Data preparation: T603

```
Olten 00218
  4 Dulliken 02110
  7    3 Däniken 02111
  9    5    2 Schönenwerd SO 02112
 16    9    6    4 Aarau 02113
 22   15   12   10    6 Rupperswil 02114
 25   18   15   13    9    3 Wildegg 02115
 26   19   16   14   10    4    1 Holderbank AG 02128
 29   22   19   17   13    7    4    3 Schinznach Bad 02116
 36   29   26   24   20   14    9    8    5 Brugg AG 00309
 40   33   30   28   24   18   13   12    9    4 Turgi 03503
 45   38   35   33   29   23   18   17   14    9    5 Baden 03504
 50   43   40   38   34   28   20   19   16   11    7    2 Wettingen 03505
 50   43   40   38   34   28   21   20   17   12    8    3    1 Neuenhof 03511
 54   47   44   42   38   32   24   23   20   15   11    6    4    3 Killwangen-Spreitenbach 03506
 59   52   49   47   43   37   29   28   25   20   16   11    9    8    5 Dietikon 03508
 61   54   51   49   45   39   31   30   27   22   18   13   11   10    7    2 Glanzenberg 03512
 63   56   53   51   47   41   33   32   29   24   20   15   13   12    9    4    2 Schlieren 03509
 66   59   56   54   50   44   36   35   32   27   23   18   16   15   12    7    5    3 Zürich Altstetten 03001
 68   61   58   56   52   46   38   37   34   29   25   20   18   17   14    9    7    5    2 Zürich Hardbrücke 03020
 80   73   70   68   64   54   46   45   42   37   33   28   26   19   16   11    9    7    4    2 Zürich HB 03000
```
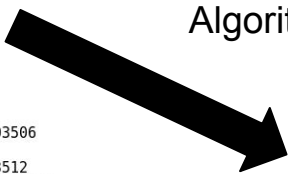
Convert PDF to text (Linux `pdftotext`)

```
Olten 00218
  4 Dulliken 02110
  7    3 Däniken 02111
  9    5    2 Schönenwerd SO 02112
 16    9    6    4 Aarau 02113
 22 15 12 10        6 Rupperswil 02114
 25 18 15 13        9    3 Wildegg 02115
 26 19 16 14 10        4    1 Holderbank AG 02128
 29 22 19 17 13        7    4    3 Schinznach Bad 02116
 36 29 26 24 20 14        9    8    5 Brugg AG 00309
 40 33 30 28 24 18 13 12        9    4 Turgi 03503
 45 38 35 33 29 23 18 17 14        9    5 Baden 03504
 50 43 40 38 34 28 20 19 16 11        7    2 Wettingen 03505
 50 43 40 38 34 28 21 20 17 12        8    3    1 Neuenhof 03511
 54 47 44 42 38 32 24 23 20 15 11        6    4    3 Killwangen-Spreitenbach 03506
 59 52 49 47 43 37 29 28 25 20 16 11        9    8    5 Dietikon 03508
 61 54 51 49 45 39 31 30 27 22 18 13 11 10        7    2 Glanzenberg 03512
 63 56 53 51 47 41 33 32 29 24 20 15 13 12        9    4    2 Schlieren 03509
 66 59 56 54 50 44 36 35 32 27 23 18 16 15 12        7    5    3 Zürich Altstetten 03001
 68 61 58 56 52 46 38 37 34 29 25 20 18 17 14        9    7    5    2 Zürich Hardbrücke 03020
 80 73 70 68 64 54 46 45 42 37 33 28 26 19 16 11        9    7    4    2 Zürich HB 03000
```

Source: T603 Tarif, 01.06.2018, ch-direct

```
Olten 00218
  4 Dulliken 02110
  7    3 Däniken 02111
  9    5     2 Schönenwerd SO 02112  ←
 16    9    6    4 Aarau 02113
 22 15 12 10        6 Rupperswil 02114
 25 18 15 13        9    3 Wildegg 02115
 26 19 16 14 10        4    1 Holderbank AG 02128
 29 22 19 17 13        7    4    3 Schinznach Bad 02116
 36 29 26 24 20 14        9    8    5 Brugg AG 00309
 40 33 30 28 24 18 13 12        9    4 Turgi 03503
 45 38 35 33 29 23 18 17 14        9    5 Baden 03504
 50 43 40 38 34 28 20 19 16 11        7    2 Wettingen 03505
 50 43 40 38 34 28 21 20 17 12        8    3    1 Neuenhof 03511
 54 47 44 42 38 32 24 23 20 15 11        6    4    3 Killwangen-Spreitenbach 03506
 59 52 49 47 43 37 29 28 25 20 16 11        9    8    5 Dietikon 03508
 61 54 51 49 45 39 31 30 27 22 18 13 11 10        7    2 Glanzenberg 03512
 63 56 53 51 47 41 33 32 29 24 20 15 13 12        9    4    2 Schlieren 03509
 66 59 56 54 50 44 36 35 32 27 23 18 16 15 12        7    5    3 Zürich Altstetten 03001
 68 61 58 56 52 46 38 37 34 29 25 20 18 17 14        9    7    5    2 Zürich Hardbrücke 03020
 80 73 70 68 64 54 46 45 42 37 33 28 26 19 16 11        9    7    4    2 Zürich HB 03000
```

Algorithm to read triangles in Python

Digitalized T603
- all stations incl. **HAFAS ID**
- all triangle connections

```
Olten 00218
  4 Dulliken 02110
  7    3 Däniken 02111
  9    5     2 Schönenwerd SO 02112
 16    9    6    4 Aarau 02113
 22 15 12 10         6 Rupperswil 02114
 25 18 15 13         9    3 Wildegg 02115
 26 19 16 14 10         4    1 Holderbank AG 02128
 29 22 19 17 13         7    4    3 Schinznach Bad 02116
 36 29 26 24 20 14         9    8    5 Brugg AG 00309
 40 33 30 28 24 18 13 12         9    4 Turgi 03503
 45 38 35 33 29 23 18 17 14         9    5 Baden 03504
 50 43 40 38 34 28 20 19 16 11         7    2 Wettingen 03505
 50 43 40 38 34 28 21 20 17 12         8    3    1 Neuenhof 03511
 54 47 44 42 38 32 24 23 20 15 11         6    4    3 Killwangen-Spreitenbach 03506
 59 52 49 47 43 37 29 28 25 20 16 11         9    8    5 Dietikon 03508
 61 54 51 49 45 39 31 30 27 22 18 13 11 10         7    2 Glanzenberg 03512
 63 56 53 51 47 41 33 32 29 24 20 15 13 12         9    4    2 Schlieren 03509
 66 59 56 54 50 44 36 35 32 27 23 18 16 15 12         7    5    3 Zürich Altstetten 03001
 68 61 58 56 52 46 38 37 34 29 25 20 18 17 14         9    7    5     2 Zürich Hardbrücke 03020
 80 73 70 68 64 54 46 45 42 37 33 28 26 19 16 11         9    7     4     2 Zürich HB 03000
```

Algorithm to read triangles in Python

Digitalized T603
- all stations incl. **HAFAS ID**
- all triangle connections

Problem: T603 from December 2018 does not include distance triangles anymore!

Data preparation: T651

Tariff T651

- One per transport authority

- Defines zones, ticket types and prices

- Many contain a list of stations and their zones, some don't
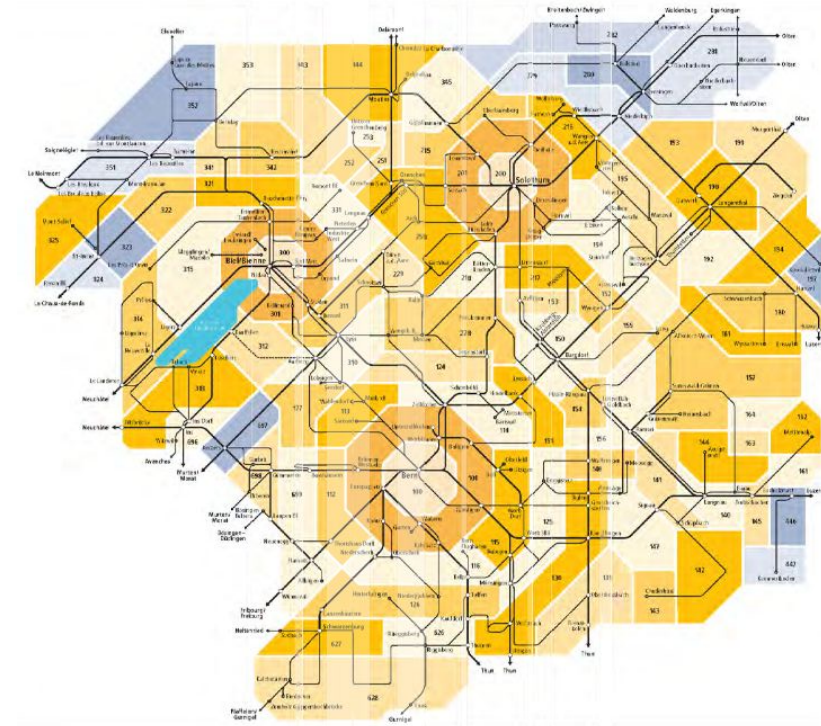
Data preparation: T651

Haltestelle	Zone	Entwerter	Haltestelle	Zone	Entwerter
A	**Zone**	**Entwerter**	Aarau, Tannerstrasse	510	510AaTa
Aarau	510		Aarau, Tellizentrum	510	510AaTe
Aarau Rohr, Gemeindehaus	510	510RoGe	Aarau, Wallerplatz	510	510AaWa
Aarau Rohr, Quellhölzli	510	510RoQu	Aarau, Wasserfluhweg	510	510AaWf
Aarau Rohr, Rigistrasse	510	510RoRi	Aarau, Wöschnauring	510	510AaWö
Aarau Rohr, Salamatt	510	510RoSa	Aarau, Zelglistrasse	510	510AaZe
Aarau Rohr, Unterdorf	510	510RoUd	Aarburg, Alter Friedhof	520	520AaAf
Aarau Torfeld	510	510AaTo	Aarburg, Höhe	520	520AaHö
Aarau, Aarenau	510	510AaAr	Aarburg, Kloosmatte	520	520AaKl
Aarau, Aarepark	510	510AaAa	Aarburg, Längacker	520	520AaLä
Aarau, Achenbergstrasse	510	510AaAc	Aarburg, Stadtgarten	520	520AaSg
Aarau, Allmendweg	510	510AaAl	Aarburg, Städtli	520	520AaSt
Aarau, Alte Badanstalt	510	510AaAb	Aarburg-Oftringen	520/521	
Aarau, Bavaria	510	510AaBa	Abtwil AG, Auwerstrasse	535	535AbAu
Aarau, Berufsschule	510	510AaBe	Abtwil AG, Hofmatt	535	535AbHo

A-Welle

Data preparation: T651

Haltestelle	Zone	Entwerter
A	**Zone**	**Entwerter**
Aarau	510	
Aarau Rohr, Gemeindehaus	510	510RoGe
Aarau Rohr, Quellhölzli	510	510RoQu
Aarau Rohr, Rigistrasse	510	510RoRi
Aarau Rohr, Salamatt	510	510RoSa
Aarau Rohr, Unterdorf	510	510RoUd
Aarau Torfeld	510	510AaTo
Aarau, Aarenau	510	510AaAr
Aarau, Aarepark	510	510AaAa
Aarau, Achenbergstrasse	510	510AaAc
Aarau, Allmendweg	510	510AaAl
Aarau, Alte Badanstalt	510	510AaAb
Aarau, Bavaria	510	510AaBa
Aarau, Berufsschule	510	510AaBe

Haltestelle
Aarau, Tanne
Aarau, Tellize
Aarau, Waller
Aarau, Wass
Aarau, Wösch
Aarau, Zelglis
Aarburg, Alte
Aarburg, Höh
Aarburg, Klod
Aarburg, Län
Aarburg, Sta
Aarburg, Stä
Aarburg-Oftri
Abtwil AG, Au
Abtwil AG, H

A-Welle

Unireso

15.2.0.000	Zone
1	
31 Décembre	10
A	
Acacias	10
Acacias (F)	82
Aéroport	10
Aigues - Vertes	10
Aïre	10
Aire - la - Ville	10
Alpes	10
Amandolier	10
Ancienne	10
Ancienne - Douane	87
Anières - Chavannes	10
Anières - Douane	10
Anières - Foyer	10
Anières - Gravière	10
Anières - Mairie	10
Anières - Village	10
Annemasse Gare	82
Appia	10
Arande	84
Arare	10
Archamps - Centre de convention	84
Archamps - Communauté-Communes	84
Archamps - Pont de Combe	84
Archamps - Technopole	84
Arena - Halle 7	10
Armes	10
Athenaz-Ecole	10
Athenaz - Village	10
Athénée	10

Data preparation: T651

Haltestelle	Zone	Entwerter
A	Zone	Entwerter
Aarau	510	
Aarau Rohr, Gemeindehaus	510	510RoGe
Aarau Rohr, Quellhölzli	510	510RoQu
Aarau Rohr, Rigistrasse	510	510RoRi
Aarau Rohr, Salamatt	510	510RoSa
Aarau Rohr, Unterdorf	510	510RoUd
Aarau Torfeld	510	510AaTo
Aarau, Aarenau	510	510AaAr
Aarau, Aarepark	510	510AaAa
Aarau, Achenbergstrasse	510	510AaAc
Aarau, Allmendweg	510	510AaAl
Aarau, Alte Badanstalt	510	510AaAb
Aarau, Bavaria	510	510AaBa
Aarau, Berufsschule	510	510AaBe

Haltestelle
Aarau, Tanne
Aarau, Tellize
Aarau, Waller
Aarau, Wass
Aarau, Wösch
Aarau, Zelglis
Aarburg, Alte
Aarburg, Höh
Aarburg, Kloc
Aarburg, Län
Aarburg, Stac
Aarburg, Stäc
Aarburg-Oftri
Abtwil AG, Au
Abtwil AG, H

A-Welle

15.2.0.000	Zone
1	
31 Décembre	
A	
Acacias	
Acacias (F)	
Aéroport	
Aigues - Vertes	
Aïre	
Aire - la - Ville	
Alpes	
Amandolier	
Ancienne	
Ancienne - Douane	
Anières - Chavannes	
Anières - Douane	
Anières - Foyer	
Anières - Gravière	
Anières - Mairie	
Anières - Village	
Annemasse Gare	
Appia	
Arande	
Arare	
Archamps - Centre de convention	
Archamps - Communauté-Commun	
Archamps - Pont de Combe	
Archamps - Technopole	
Arena - Halle 7	
Armes	10
Athenaz-Ecole	10
Athenaz - Village	10
Athénée	10

Unireso

Arrêts	Zone	ETC	Oblitération
A			
AREUSE	11	TRN-tn	11Areuse
AREUSE-CHANELAZ	11	TRN-tn	11ARCH
AUVERNIER GARE	10	SBB	AUV
AUVERNIER GARE	10	TRN-tn	
AUVERNIER PACOTTE	10	TRN-tn	
AUVERNIER TN	10	TRN-tn	10auv

Arrêts	Zone	ETC	Oblitération
B			
BEMONT NE RESTAURANT	32	PAG	32Bémon
BEMONT NE SUR-LE-PONT	32	PAG	32SurPo
BEVAIX ANCIENNE POSTE	11	TRN-tn	11BVAP
BEVAIX CENTRE	11	TRN-tn	BVCEN
BEVAIX CHAUVIGNY	11	TRN-tn	CHAUV
BEVAIX GARE	11	SBB	BV

Onde Verte

A-Welle

Haltestelle	Zone	Entwerter
A	Zone	Entwerter
Aarau	510	
Aarau Rohr, Gemeindehaus	510	510RoGe
Aarau Rohr, Quellhölzli	510	510RoQu
Aarau Rohr, Rigistrasse	510	510RoRi
Aarau Rohr, Salamatt	510	510RoSa
Aarau Rohr, Unterdorf	510	510RoUd
Aarau Torfeld	510	510AaTo
Aarau, Aarenau	510	510AaAr
Aarau, Aarepark	510	510AaAa
Aarau, Achenbergstrasse	510	510AaAc
Aarau, Allmendweg	510	510AaAl
Aarau, Alte Badanstalt	510	510AaAb
Aarau, Bavaria	510	510AaBa
Aarau, Berufsschule	510	510AaBe

Haltestelle
Aarau, Tanne
Aarau, Tellize
Aarau, Waller
Aarau, Wass
Aarau, Wösc
Aarau, Zelgli
Aarburg, Alte
Aarburg, Höh
Aarburg, Klo
Aarburg, Län
Aarburg, Stac
Aarburg, Stä
Aarburg-Oftri
Abtwil AG, A
Abtwil AG, H

TVSZ

Unireso

15.2.0.000	Zone
1	
31 Décembre	
A	
Acacias	
Acacias (F)	
Aéroport	
Aigues - Vertes	
Aïre	
Aire - la - Ville	
Alpes	
Amandolier	
Ancienne	
Ancienne - Douane	
Anières - Chavannes	
Anières - Douane	
Anières - Foyer	
Anières - Gravière	
Anières - Mairie	
Anières - Village	
Annemasse Gare	
Appia	
Arande	
Arare	
Archamps - Centre de convention	
Archamps - Communauté-Commun	
Archamps - Pont de Combe	
Archamps - Technopole	
Arena - Halle 7	
Armes	10
Athenaz-Ecole	10
Athenaz - Village	10
Athénée	10

Onde Verte

Arrêts	Zone	ETC	Oblitération
A			
AREUSE	11	TRN-tn	11Areuse
AREUSE-CHANELAZ	11	TRN-tn	11ARCH
AUVERNIER GARE	10	SBB	AUV
AUVERNIER GARE	10	TRN-tn	
AUVERNIER PACOTTE	10	TRN-tn	
AUVERNIER TN	10	TRN-tn	10auv

Arrêts	Zone	ETC	Oblitération
B			
BEMONT NE RESTAURANT	32	PAG	32Bémon
BEMONT NE SUR-LE-PONT	32	PAG	32SurPo
BEVAIX ANCIENNE POSTE	11	TRN-tn	11BVAP
BEVAIX CENTRE	11	TRN-tn	BVCEN
BEVAIX CHAUVIGNY	11	TRN-tn	CHAUV
BEVAIX GARE	11	SBB	BV

Word

Mobilis

Excel

Data preparation: T651

Haltestelle	Zone	Entwerter
A	Zone	Entwerter
Aarau	510	
Aarau Rohr, Gemeindehaus	510	510RoGe
Aarau Rohr, Quellhölzli	510	510RoQu
Aarau Rohr, Rigistrasse	510	510RoRi
Aarau Rohr, Salamatt	510	510RoSa
Aarau Rohr, Unterdorf	510	
Aarau Torfeld	510	
Aarau, Aarenau	510	
Aarau, Aarepark	510	
Aarau, Achenbergstrasse	510	
Aarau, Allmendweg	510	
Aarau, Alte Badanstalt	510	510AaAb
Aarau, Bavaria	510	510AaBa
Aarau, Berufsschule	510	510AaBe

A-Welle

Haltestelle
Aarau, Tanne...
Aarau, Tellize...
Aarau, Waller...
Aarau, Wass...
Aarau, Wösch...
Aarau, Zelglis...
Abtwil AG, A...
Abtwil AG, H...

Unireso

15.2.0.000	Zone
1	
31 Décembre	
A	
Acacias	
Acacias (F)	
Aéroport	
Aigues - Vertes	
Aïre	
Aire - la - Ville	
Anières - Graviere	
Anières - Mairie	
Anières - Village	
Annemasse Gare	
Appia	
Arande	
Arare	
Archamps - Centre de convention	
Archamps - Communauté-Commun...	
Archamps - Pont de Combe	
Archamps - Technopole	
Arena - Halle 7	
Armes	10
Athenaz-Ecole	10
Athenaz - Village	10
Athénée	10

Arrêts	Zone	ETC	Oblitération
A			
AREUSE	11	TRN-tn	11Areuse
AREUSE-CHANELAZ	11	TRN-tn	11ARCH
AUVERNIER GARE	10	SBB	AUV
AUVERNIER GARE	10	TRN-tn	
AUVERNIER PACOTTE	10	TRN-tn	
	10	TRN-tn	10auv

	Zone	ETC	Oblitération
BEMONT NE RESTAURANT	32	PAG	32Bémon
BEMONT NE SUR-LE-PONT	32	PAG	32SurPo
BEVAIX ANCIENNE POSTE	11	TRN-tn	11BVAP
BEVAIX CENTRE	11	TRN-tn	BVCEN
BEVAIX CHAUVIGNY	11	TRN-tn	CHAUV
BEVAIX GARE	11	SBB	BV

Missing: TNW and Arcobaleno

Word

TVSZ

Excel

Mobilis

Onde Verte

Data preparation: T651

A-Welle

Engadin Mobil

Frimobil

Libero

Mobilis

OndeVerte

Ostwind

Passepartout

Transreno

TVSZ

TVZG

Unireso

ZVV

Individual scripts
Mostly regular expressions

Digitalized T651
- names of all stations
- transport authorities of stations
- tariff zones of stations

Data preparation: T651

A-Welle
Engadin Mobil
Frimobil
Libero
Mobilis
OndeVerte
Ostwind
Passepartout
Transreno
TVSZ
TVZG
Unireso
ZVV

Individual scripts
Mostly regular expressions

Digitalized T651
- names of all stations
- transport authorities of stations
- tariff zones of stations

But …
... no HAFAS IDs
... no coordinates!

Data preparation: HAFAS
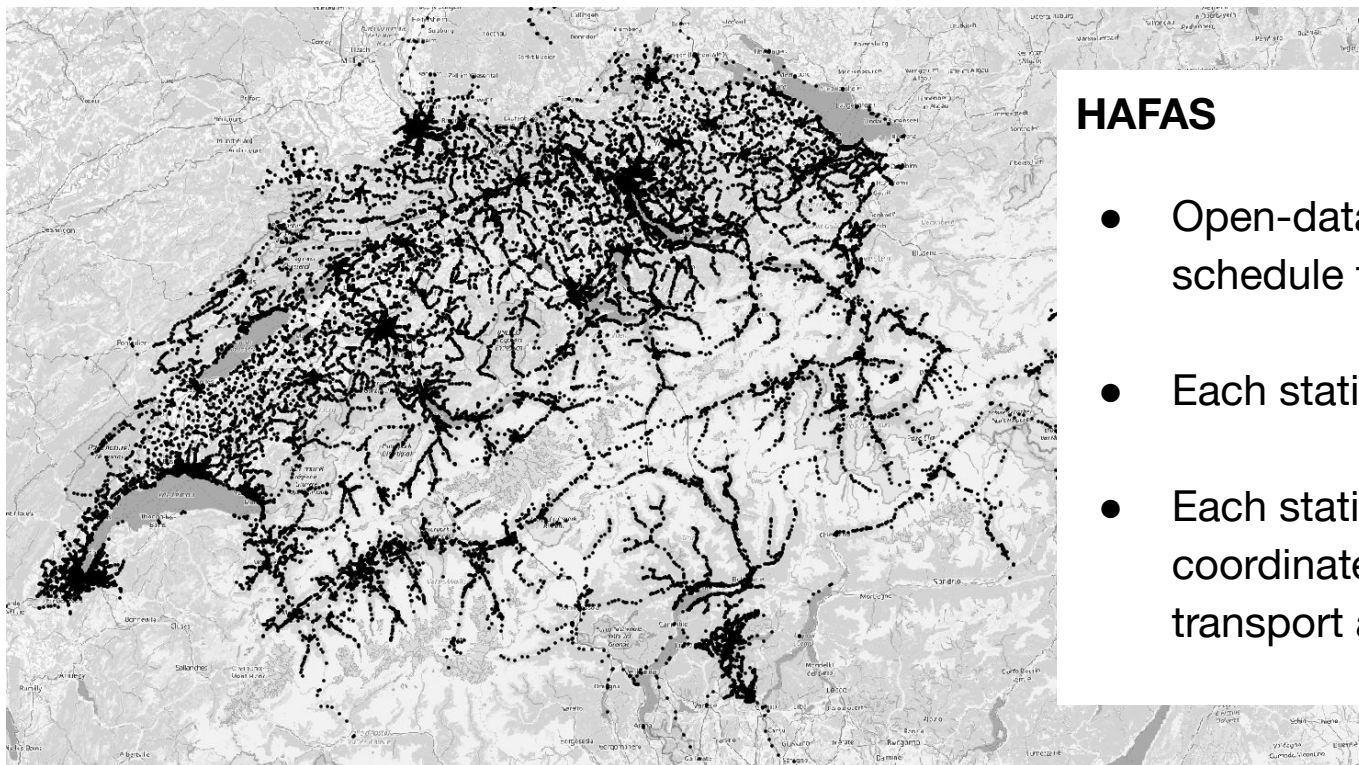
HAFAS

- Open-data public transport schedule for Switzerland

- Each station has unique ID

- Each station has name and coordinate, but no zone or transport authority!

Data preparation: HAFAS Matching
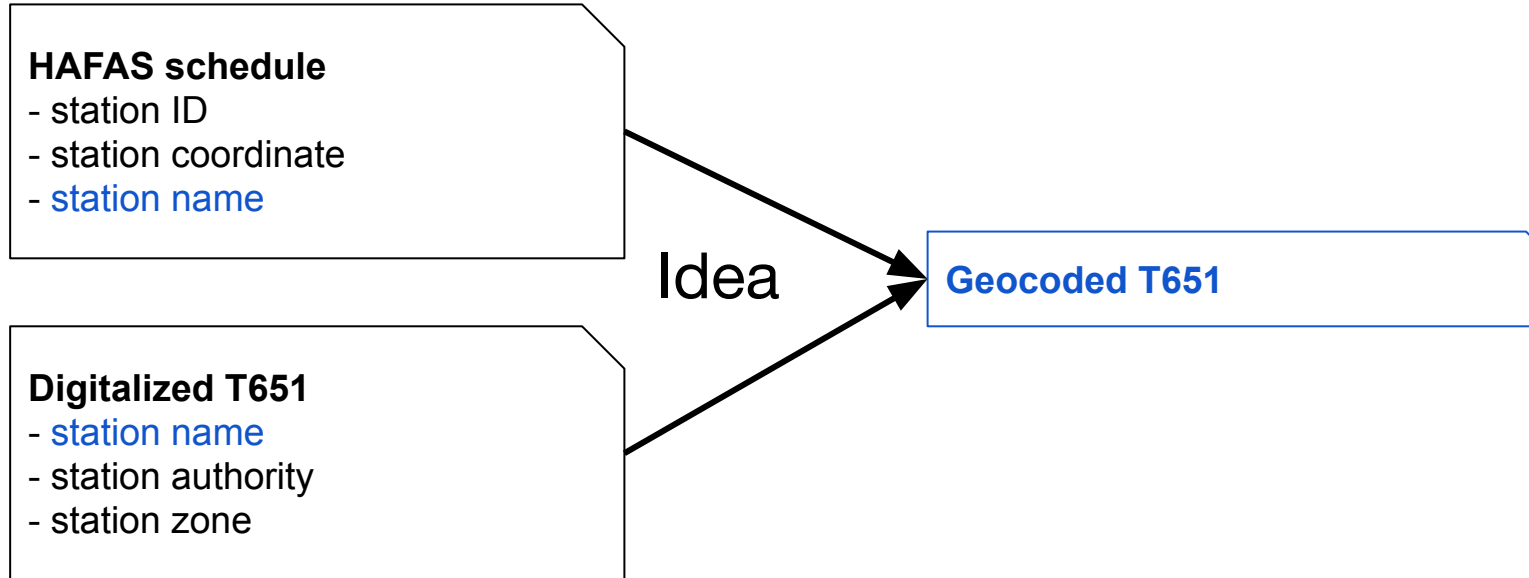
Data preparation: HAFAS Matching

1. Match on normalised names
   - lower case with punctuation removed
   - Matched 60.5% of stations
   - > 10,000 unmatched stations - **too many to match manually**
2. Fuzzy matching
   - In Unireso Tarifverbund remove suburb name - ie. ~~Genève,~~ Nations
   - Token sort ratio
   - Best match taken from matches within 20km of zone centroid where score > 85%
   - 9301 unmatched stations
3. Remaining HAFAS stations matched to nearest HAFAS neighbour within 400m
   - 8177 unmatched stations

Data preparation: HAFAS Matching - manual finishing

1. Identify zone areas using convex hulls
2. Manual allocation of unmatched stations with GIS software - 124 zones
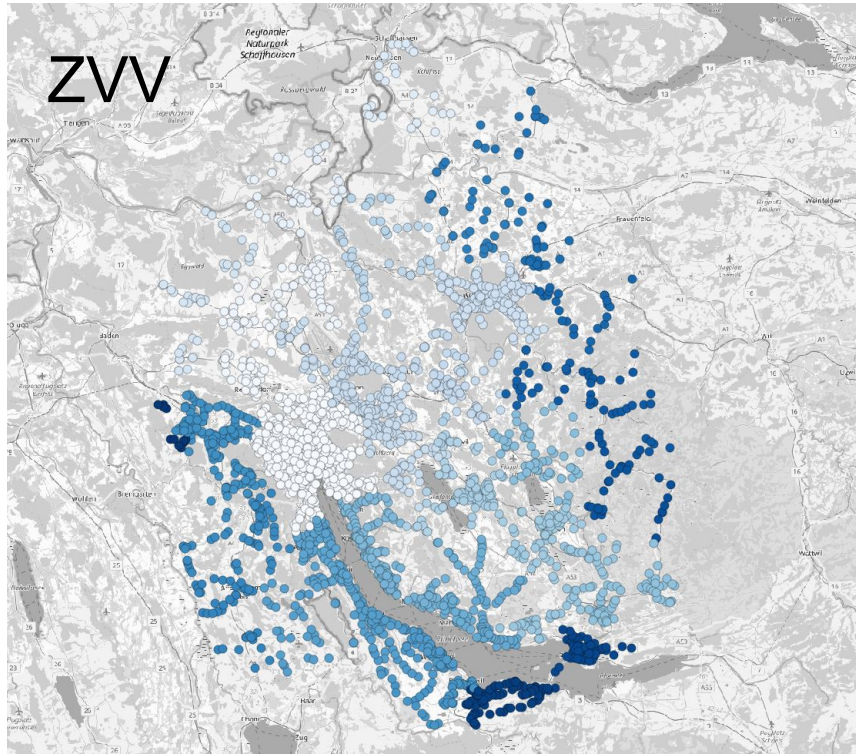3. 8053 remaining stations in non-tariff areas
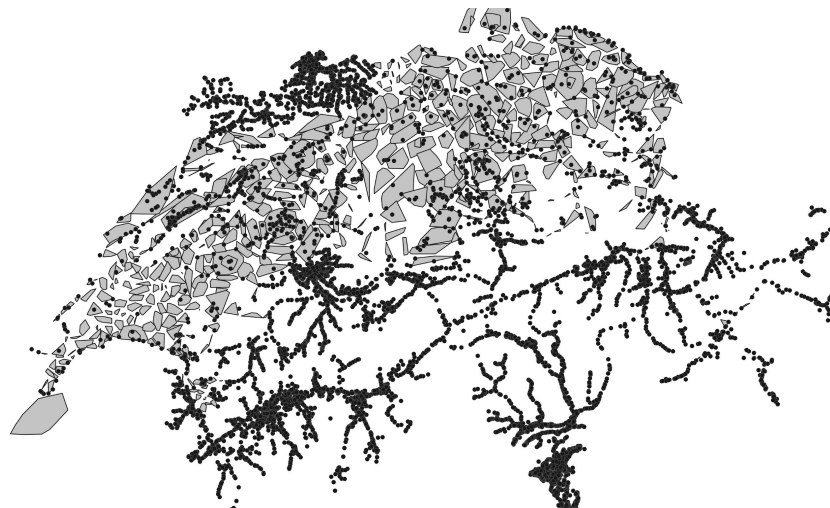
Data preparation: HAFAS Matching

Data preparation: HAFAS Matching

Data preparation: HAFAS Matching

ZVV

Libero
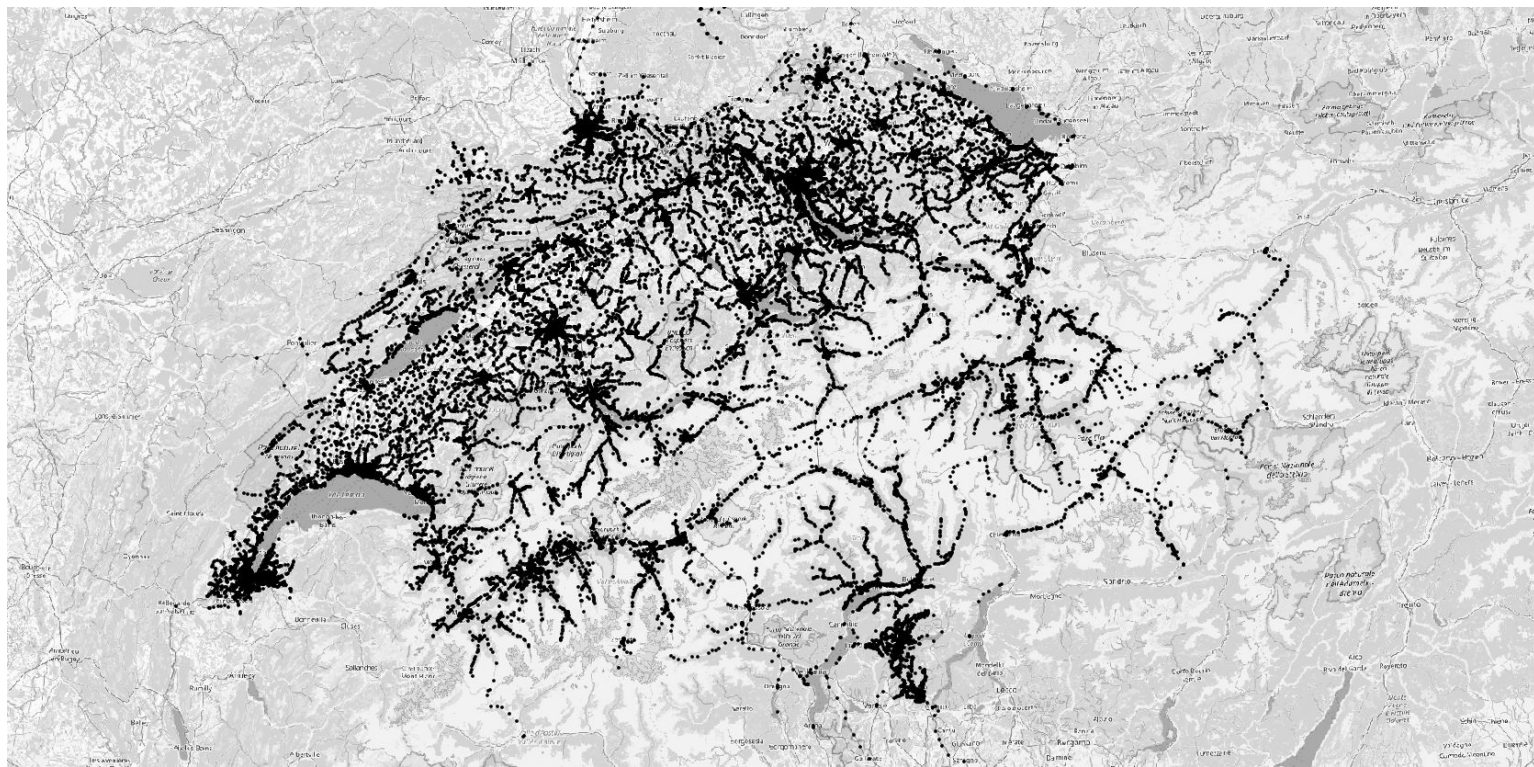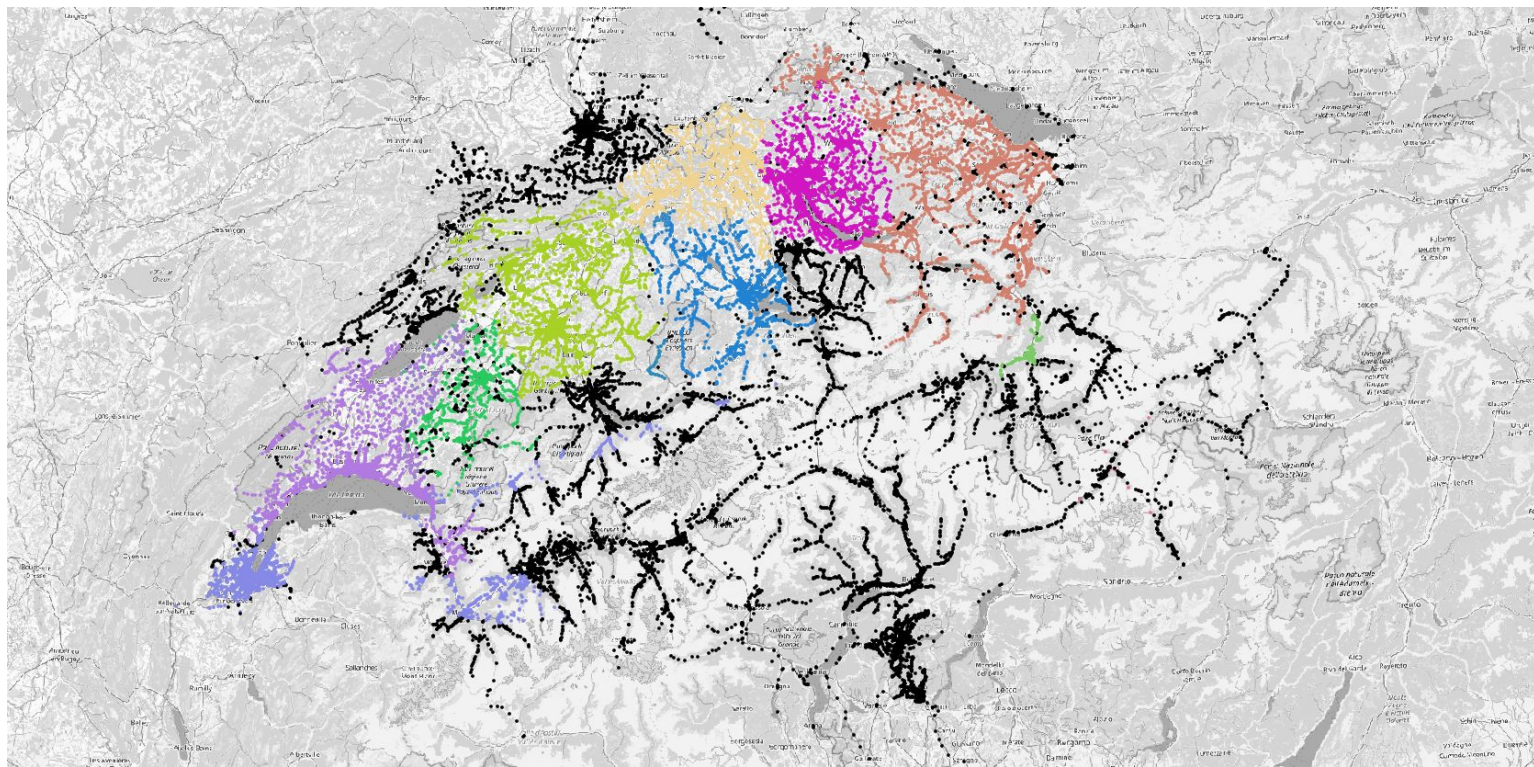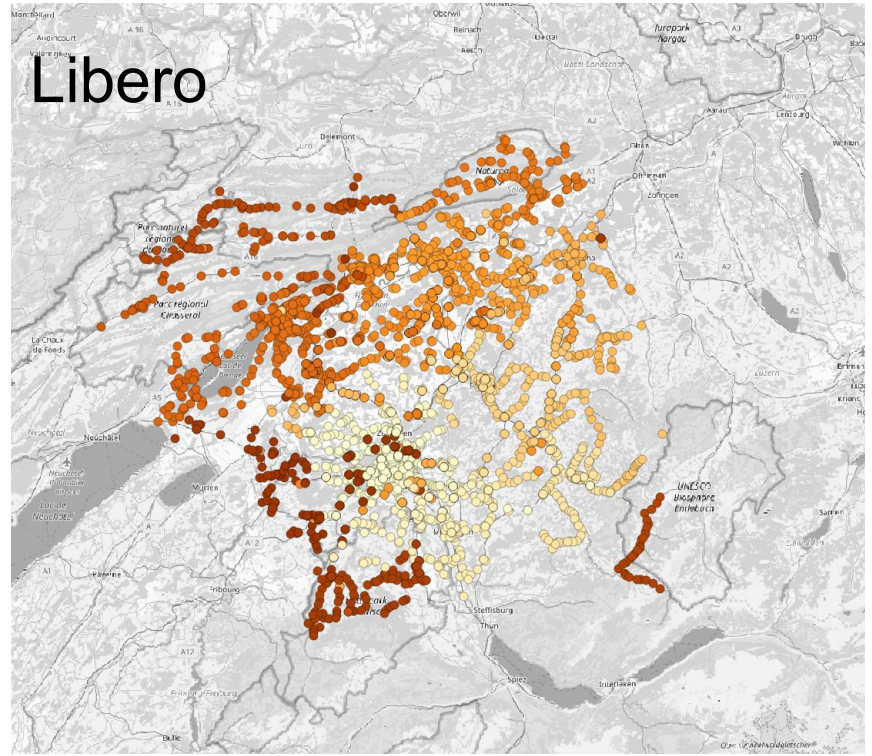
Data preparation: Tickets

Tickets have only small set of attributes:

- **Number of zones** defines for how many zones a certain ticket is valid

- **Validity** defines for how long the ticket can be used
  e.g. 1h, 2h, full day

- **Price** defines how much the tickets costs

➡️ Have been digitalized manually

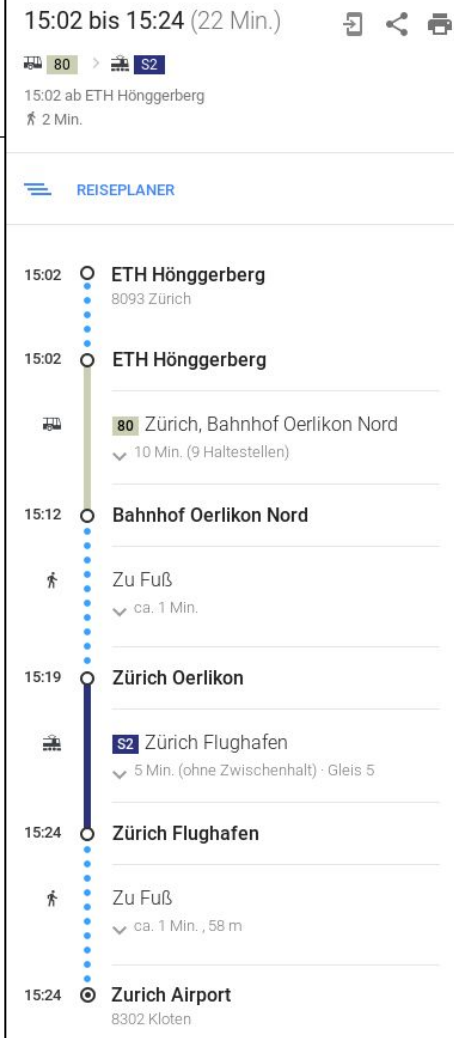|	Gültigkeit	Erwachsene		Halbtax / Kinder ℹ️	
		2. Klasse	1. Klasse	2. Klasse	1. Klasse
Kurzstrecke 210	1/2h	2.40	4.20	2.20	3.80
1 Zone	1h	3.20	5.60	2.60	4.50
2 Zonen	1h	4.80	8.40	2.90	5.10
3 Zonen	1h	7.20	12.60	3.60	6.30
4 Zonen	2h	9.60	16.80	4.80	8.40
5 Zonen	2h	12.00	21.00	6.00	10.50
6 Zonen	2h	14.40	25.20	7.20	12.60
7 Zonen	2h	16.80	29.40	8.40	14.70
8 Zonen	2h	19.20	33.60	9.60	16.80
9 Zonen	2h	21.60	37.80	10.80	18.90
10 Zonen	2h	24.00	42.00	12.00	21.00
11 Zonen	2h	26.20	46.00	13.10	23.00
12 Zonen	2h	28.40	49.80	14.20	24.90
alle Zonen	3h	30.60	53.60	15.30	26.80

Source: Ostwind website

Cost calculator

Cost calculator: SwissRailRaptor

SwissRailRaptor

- Efficient public transport router based on the RAPTOR algorithm
- Developed at SBB for MATSim simulation
- Calculates routes through HAFAS schedule given:
    - Origin coordinate
    - Destination coordinate
    - Departure time

Cost calculator: Ticket selection

1. Find all tickets that potentially cover a certain route

Cost calculator: Ticket selection

1. Find all tickets that potentially cover a certain route

Zone 110 Single
1h, 4.40 CHF

Zone 121 Single
1h, 2.70 CHF

15:02 bis 15:24 (22 Min.)

🚌 80 › 🚆 S2
15:02 ab ETH Hönggerberg
🚶 2 Min.

☰ REISEPLANER

15:02	ETH Hönggerberg
	8093 Zürich
15:02	ETH Hönggerberg
🚌	80 Zürich, Bahnhof Oerlikon Nord
	⌄ 10 Min. (9 Haltestellen)

Zone 110

15:12	Bahnhof Oerlikon Nord
🚶	Zu Fuß
	⌄ ca. 1 Min.
15:19	Zürich Oerlikon
🚆	S2 Zürich Flughafen
	⌄ 5 Min. (ohne Zwischenhalt) · Gleis 5

Zone 120

15:24	Zürich Flughafen
🚶	Zu Fuß
	⌄ ca. 1 Min. , 58 m
15:24	Zurich Airport
	8302 Kloten

Cost calculator: Ticket selection

1. Find all tickets that potentially cover a certain route

Zone 110 Single
1h, 4.40 CHF

Zone 121 Single
1h, 2.70 CHF

Zones 110, 121 Single
1h, 6.80 CHF

Cost calculator: Ticket selection

1. Find all tickets that potentially cover a certain route

Zone 110 Single
1h, 4.40 CHF

Zone 121 Single
1h, 2.70 CHF

Zones 110, 121 Single
1h, 6.80 CHF

Zone 110 Day
8.80 CHF

Zones 110, 121 Day
13.60 CHF

15:02 bis 15:24 (22 Min.)

80 ▸ S2
15:02 ab ETH Hönggerberg
🚶 2 Min.

REISEPLANER

15:02 ⊙ ETH Hönggerberg
8093 Zürich

15:02 ⊙ ETH Hönggerberg

🚌 80 Zürich, Bahnhof Oerlikon Nord
∨ 10 Min. (9 Haltestellen)

Zone 110

15:12 ⊙ Bahnhof Oerlikon Nord

🚶 Zu Fuß
∨ ca. 1 Min.

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🚆 S2 Zürich Flughafen
∨ 5 Min. (ohne Zwischenhalt) · Gleis 5

15:24 ⊙ Zürich Flughafen

Zone 120

🚶 Zu Fuß
∨ ca. 1 Min. , 58 m

15:24 ◉ Zurich Airport
8302 Kloten

Cost calculator: Ticket selection

1. Find all tickets that potentially cover a certain route

Zone 110 Single
1h, 4.40 CHF

Zone 121 Single
1h, 2.70 CHF

Zones 110, 121 Single
1h, 6.80 CHF

Zone 110 Day
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Zones 110, 121 Day
13.60 CHF

15:02 bis 15:24 (22 Min.)

🚌 80 › 🚆 S2

15:02 ab ETH Hönggerberg

🚶 2 Min.

REISEPLANER

Zone 110

15:02 ○ ETH Hönggerberg
8093 Zürich

15:02 ○ ETH Hönggerberg

🚌 80 Zürich, Bahnhof Oerlikon Nord
⌄ 10 Min. (9 Haltestellen)

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🚶 Zu Fuß
⌄ ca. 1 Min.

15:19 ○ Zürich Oerlikon

🚆 S2 Zürich Flughafen
⌄ 5 Min. (ohne Zwischenhalt) · Gleis 5

Zone 120

15:24 ○ Zürich Flughafen

🚶 Zu Fuß
⌄ ca. 1 Min. , 58 m

15:24 ◎ Zurich Airport
8302 Kloten

Cost calculator: Ticket selection

1. Find all tickets that potentially cover a certain route

Zone 110 Single
1h, 4.40 CHF

Zone 121 Single
1h, 2.70 CHF

Zones 110, 121 Single
1h, 6.80 CHF

Zone 110 Day
8.80 CHF

Zones 110, 121 Day
13.60 CHF

- Whole daily chains of trips can be analyzed
- Heuristics are in place to filter out irrelevant tickets
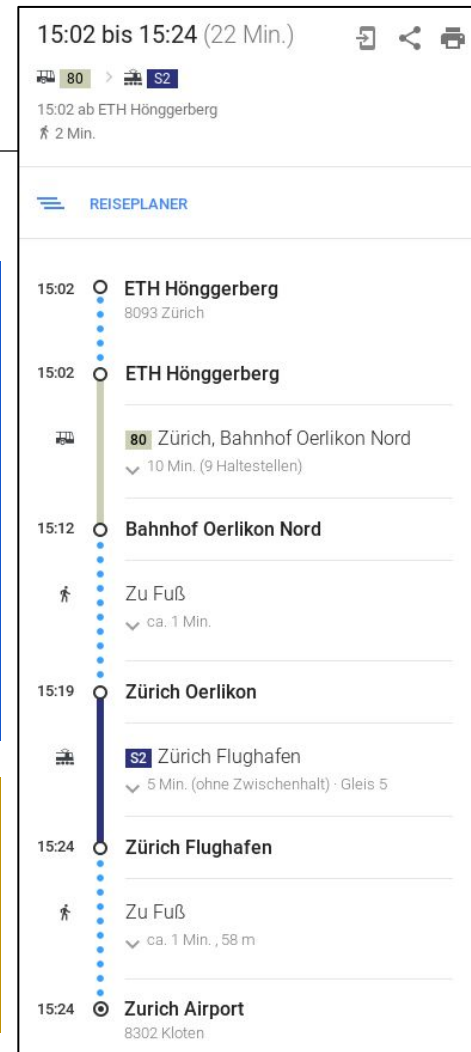
15:02 bis 15:24 (22 Min.)

80 › S2
15:02 ab ETH Hönggerberg
2 Min.

REISEPLANER

15:02 ETH Hönggerberg
8093 Zürich

15:02 ETH Hönggerberg

80 Zürich, Bahnhof Oerlikon Nord
10 Min. (9 Haltestellen)

15:12 Bahnhof Oerlikon Nord

Zu Fuß
ca. 1 Min.

15:19 Zürich Oerlikon

S2 Zürich Flughafen
5 Min. (ohne Zwischenhalt) · Gleis 5

15:24 Zürich Flughafen

Zu Fuß
ca. 1 Min. , 58 m

15:24 Zurich Airport
8302 Kloten

Zone 110

Zone 120

Cost calculator: Ticket selection

2. Solve "cutting stock problem"

Decision variable: Which tickets should I buy?

Zone 110 Single 1h, 4.40 CHF	Zone 121 Single 1h, 2.70 CHF

Zones 110, 121 Single 1h, 6.80 CHF	

4.40 CHF ➡️ Not allowed, second trip is not covered

Zone 110 Day 8.80 CHF	Zones 110, 121 Day 13.60 CHF

15:02 bis 15:24 (22 Min.)

80 > S2
15:02 ab ETH Hönggerberg
🚶 2 Min.

REISEPLANER

15:02	ETH Hönggerberg 8093 Zürich	
15:02	ETH Hönggerberg	
🚌	80 Zürich, Bahnhof Oerlikon Nord 10 Min. (9 Haltestellen)	Zone 110
15:12	Bahnhof Oerlikon Nord	
🚶	Zu Fuß ca. 1 Min.	
15:19	Zürich Oerlikon	
🚆	S2 Zürich Flughafen 5 Min. (ohne Zwischenhalt) · Gleis 5	
15:24	Zürich Flughafen	Zone 120
🚶	Zu Fuß ca. 1 Min. , 58 m	
15:24	Zurich Airport 8302 Kloten	

Cost calculator: Ticket selection

2. Solve "cutting stock problem"

Decision variable: Which tickets should I buy?

Zone 110 Single
1h, 4.40 CHF

Zone 121 Single
1h, 2.70 CHF

Zones 110, 121 Single
1h, 6.80 CHF

13.60 CHF → Allowed, but expensive

Zone 110 Day
8.80 CHF

Zones 110, 121 Day
13.60 CHF

15:02 bis 15:24 (22 Min.)

80 › S2
15:02 ab ETH Hönggerberg
2 Min.

REISEPLANER

15:02 ETH Hönggerberg
8093 Zürich

15:02 ETH Hönggerberg

80 Zürich, Bahnhof Oerlikon Nord
10 Min. (9 Haltestellen)

15:12 Bahnhof Oerlikon Nord

Zu Fuß
ca. 1 Min.

15:19 Zürich Oerlikon

S2 Zürich Flughafen
5 Min. (ohne Zwischenhalt) · Gleis 5

15:24 Zürich Flughafen

Zu Fuß
ca. 1 Min. , 58 m

15:24 Zurich Airport
8302 Kloten

Zone 110

Zone 120

Cost calculator: Ticket selection

2. Solve "cutting stock problem"

Decision variable: Which tickets should I buy?

Zone 110 Single
1h, 4.40 CHF

Zone 121 Single
1h, 2.70 CHF

Zones 110, 121 Single
1h, 6.80 CHF

11.20 CHF ➜ Allowed, but still too expensive

Zone 110 Day
8.80 CHF

Zones 110, 121 Day
13.60 CHF

STRC 2019, May 2019, Ascona

15:02 bis 15:24 (22 Min.)

80 ➤ S2
15:02 ab ETH Hönggerberg
2 Min.

REISEPLANER

15:02 ETH Hönggerberg
       8093 Zürich

15:02 ETH Hönggerberg
       80 Zürich, Bahnhof Oerlikon Nord
       10 Min. (9 Haltestellen)

15:12 Bahnhof Oerlikon Nord

       Zu Fuß
       ca. 1 Min.

15:19 Zürich Oerlikon

       S2 Zürich Flughafen
       5 Min. (ohne Zwischenhalt) · Gleis 5

15:24 Zürich Flughafen

       Zu Fuß
       ca. 1 Min. , 58 m

15:24 Zurich Airport
       8302 Kloten

Zone 110

Zone 120

Cost calculator: Ticket selection

2. Solve "cutting stock problem"
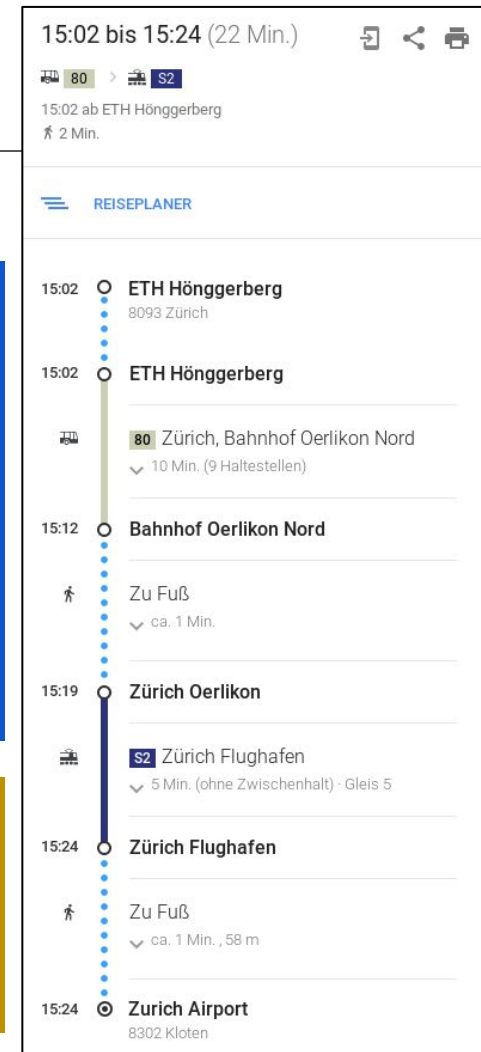
Decision variable: Which tickets should I buy?

| Zone 110 Single
1h, 4.40 CHF | Zone 121 Single
1h, 2.70 CHF |

| **Zones 110, 121 Single
1h, 6.80 CHF** |

6.80 CHF → Allowed, with minimum price

| Zone 110 Day
8.80 CHF | Zones 110, 121 Day
13.60 CHF |

15:02 bis 15:24 (22 Min.)

80 → S2
15:02 ab ETH Hönggerberg
2 Min.

REISEPLANER

15:02	ETH Hönggerberg 8093 Zürich
15:02	ETH Hönggerberg
	80 Zürich, Bahnhof Oerlikon Nord 10 Min. (9 Haltestellen)
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15:24	Zürich Flughafen
	Zu Fuß ca. 1 Min. , 58 m
15:24	Zurich Airport 8302 Kloten

Zone 110

Zone 120

Cost calculator: Ticket selection

2. Solve "cutting stock problem"

$$\text{minimize} \quad \sum_t x_t \cdot p_t$$

$$\text{subject to} \quad \sum_t c_{st} \cdot x_t > 0 \quad \forall s \in \mathcal{S}$$

$$x_t \in \{0, 1\}$$

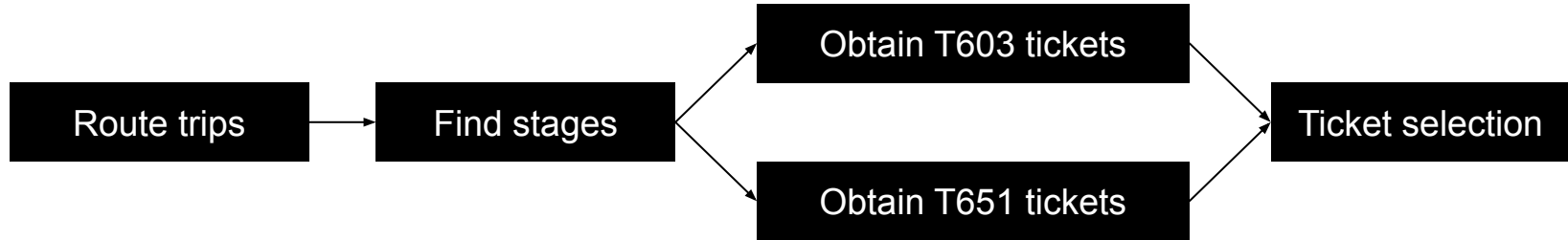$$c_{st} \in \{0, 1\}$$

Variables

- x_t Buy ticket t yes/no ?
- p_t Price of ticket t
- c_{st} Is stage s covered by ticket t ?

➡ Solvable with GLPK (or Gurobi, etc)

Cost calculator: Full process

Validation

- Web interface for testing

- Ongoing - which data sets are available?

Discussion

- Validation is ongoing - Do you have data sets for validation?

- Some parts missing:
    - Short-distance tickets
    - Subscriptions
    - Some authorities: TNW, Arcobaleno

- Outlook: Meta model

- Potential alternative: **NOVA**

NOVA

- Developed by SBB and transport authorities

- Publish open data (but not clear yet, what exactly)

- Several options: Public data, API for researchers, …

- Currently in contact

Packaged up content

- Feel free to ask us for:

  - GeoJSON file mapping all HAFAS station IDs to transport authorities and their zones

  - Imputed per-trip and daily costs for Microcensus 2015 (We'd appreciate any help to validate this!)

  - Routing code, expecting a CSV like
    ```
    plan_id;trip_id;origin_x;origin_y;destination_x;destination_y
    ;departure_time
    ```

Questions?