Data Quality in the Age of AI

Keynote at Guide-AI workshop @SIGMOD 2024

Based on research with Hazar Harmouch, Lisa Ehrlinger, Sedir Mohammed, Divesh Srivastava

June 14, 2024

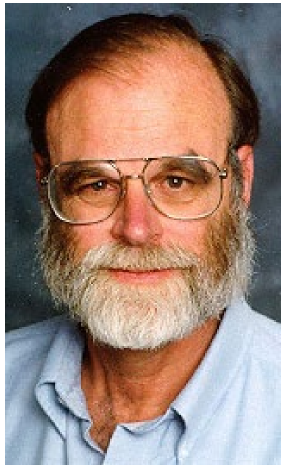
Felix Naumann

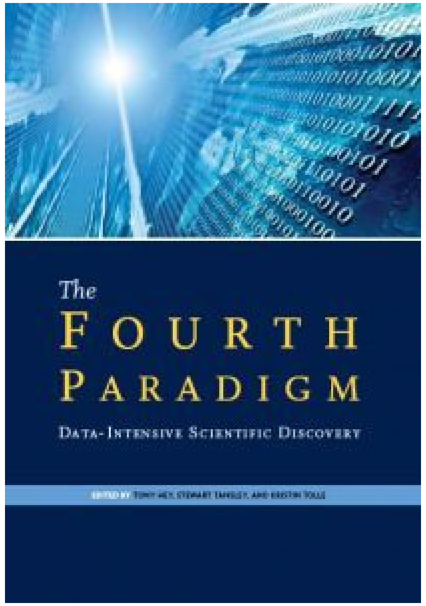
Hasso Plattner Institut
IT Systems Engineering | Universität Potsdam

The Fourth Paradigm of Science

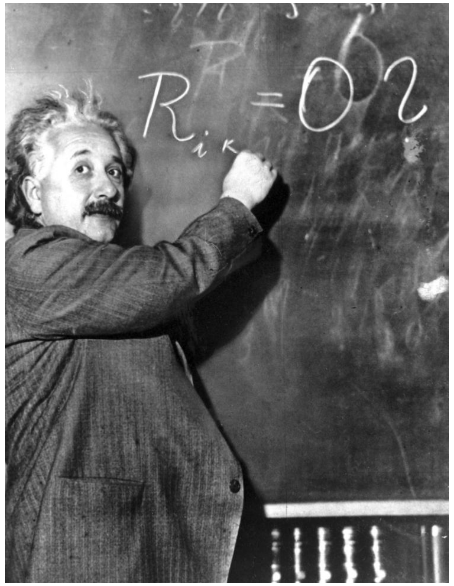
1. Empirical and experimental
2. Theoretical
3. Computational
4. Data-intensive

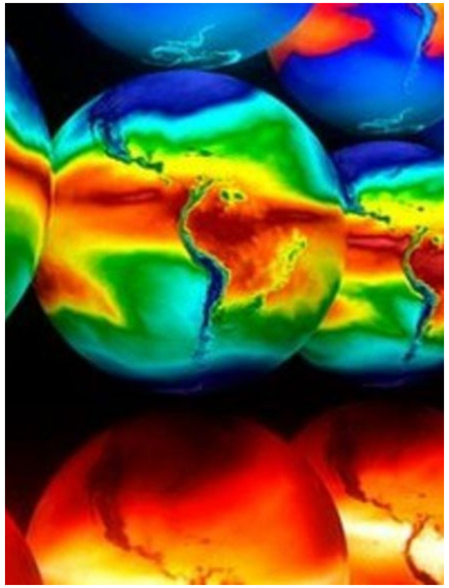
We have to do better producing tools to support the whole research cycle - from data capture and data curation to data analysis and data visualization. Jim Gray

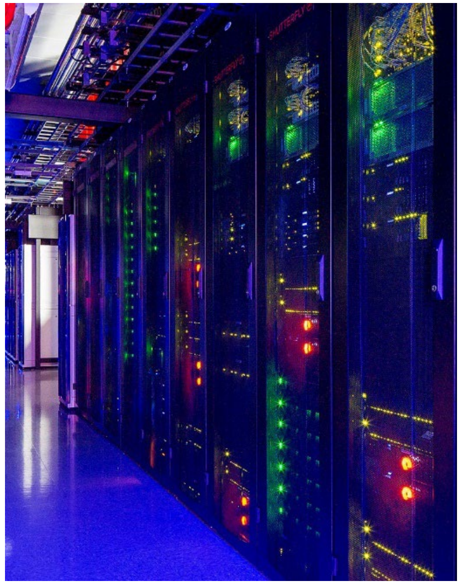




5. Intelligence-driven and knowledge-centric

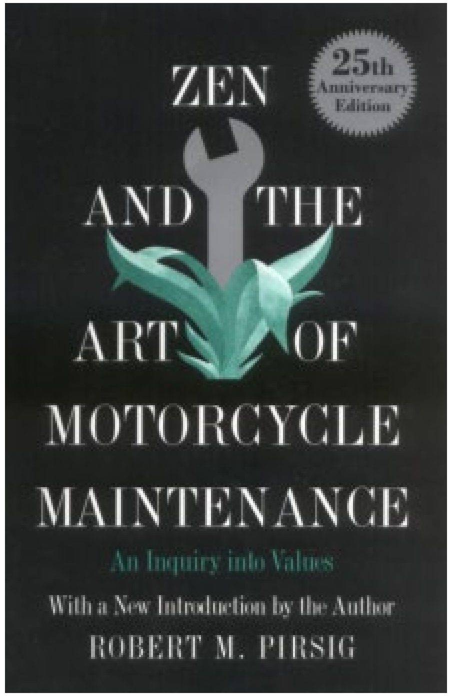






"Even though quality cannot be defined, you know what it is."

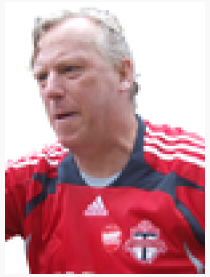
Robert Pirsig



Data Errors for Database Researchers

HPI Hasso Plattner Institut

Vandalism in Wikipedia Tables

No.		Mayor	Took Office	Left Office	Prior Experience	Deputy Mayor
62		Mel Lastman	January 1, 1998	November 30, 2003	Mayor of North York (1969–1997)	Case Ootes
63		David Miller	December 1, 2003	November 30, 2010	City Councillor for Parkdale-High Park (1994–2003)	Joe Pantalone
64		Rob				

```
– |  —Non-Hispanic || 31.7% || 37.9% || 59.0% <ref name="fifteen">From 15% sample</ref> || 91.2%
+ |  —Non-Hispanic || 20.7% || 21.9% || 59.0% <ref name="fifteen">From 15% sample</ref> || 91.2%

  |-
  |-

– | [[African American|Black or African American]] || 32.9% || 39.1% || 32.7% || 8.2%
+ | [[African American|Black or African American]] || 50.9% || 49.1% || 42.7% || 8.2%
```

Example for vandalism in Wikipedia tables: Tampering with the proportions of ethnic minorities. [https://en.wikipedia.org/w/index.php?title=Chicago&diff=prev&oldid=654893961]

Hidden Values / Hidden Value

	Feld						
	Name1	Name2	Name3	City	District	Street	Sum
Mobile phone	41	501	10	0	**2677**	297	3526
Phone	15	98	6	0	**221**	9579	9919
Cost center	283	1112	73	2	**87**	16	1573
Registration ID	11	583	1	1	**0**	3	599
Delivery ID	55	390	9	0	**212**	15	681
Department	3711	**9997**	115	60	**439**	175	14497
Embargo flag	129	143	2	0	**66**	9	349
Deletion flag	1028	442	5	36	**113**	10	1634
Legal form	**131700**	66136	187	6	**64**	57	198150
Credit info	0	100	11	0	**18**	0	129
Commission	216	352	1	2	**36**	10	617
Construction site	2013	3452	42	5	**124**	222	5858
Loading point	2923	3808	94	1503	**958**	3065	12351
Administration	13410	12461	172	19	**295**	7075	33432
Summe	155535	99575	728	1634	**5310**	20533	

Source: Joachim Schmid, FUZZY! Informatik AG

DQ-Problems: Effects

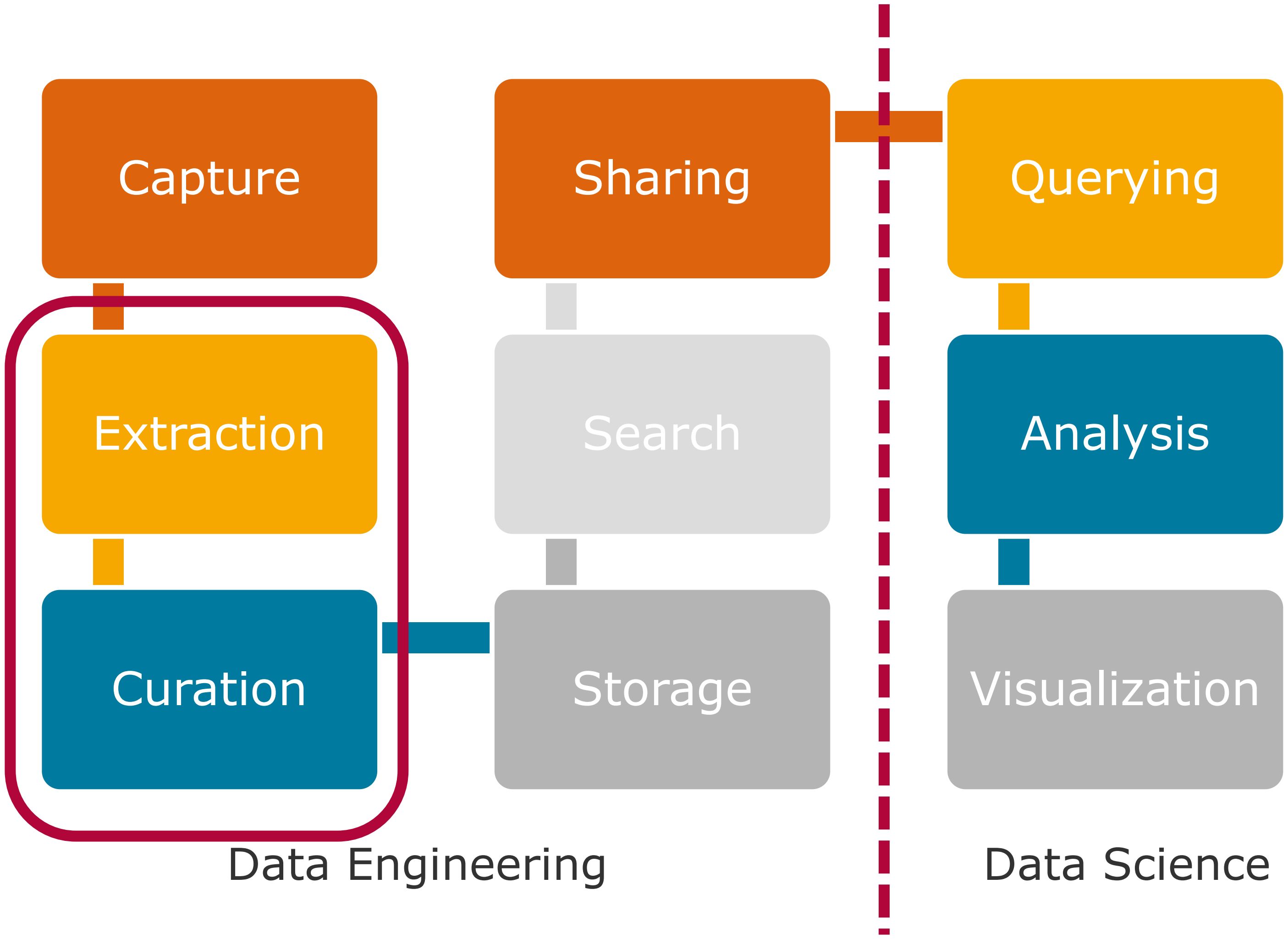
- Incorrect prices in inventory retail databases
  - Costs for consumers 2.5 billion $
  - 80% of barcode-scan-errors to the disadvantage of consumer
- IRS 1992: almost 100,000 tax refunds not deliverable
- 50% to 80% of computerized criminal records in the U.S. were found to be inaccurate, incomplete, or ambiguous.
- US-Postal Service: of 100,000 mass-mailings up to 7,000 undeliverable due to incorrect addresses
- Poor AI system performance

IRS might be after you — to mail you a check

Incorrect addresses stall nearly 1,500 Tennessee refunds

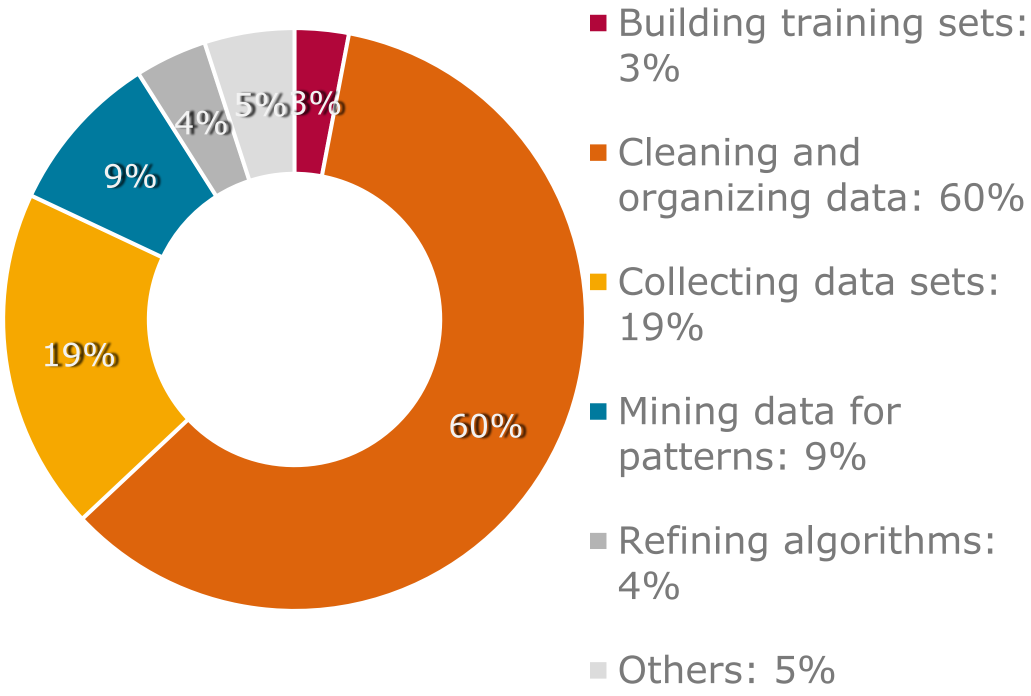
By BONNA de la CRUZ
Staff Writer

Now that Tilcia L. Menifee knows that she'll be getting $500 in a tax refund from Uncle Sam, she can do some Christmas shopping, she said.

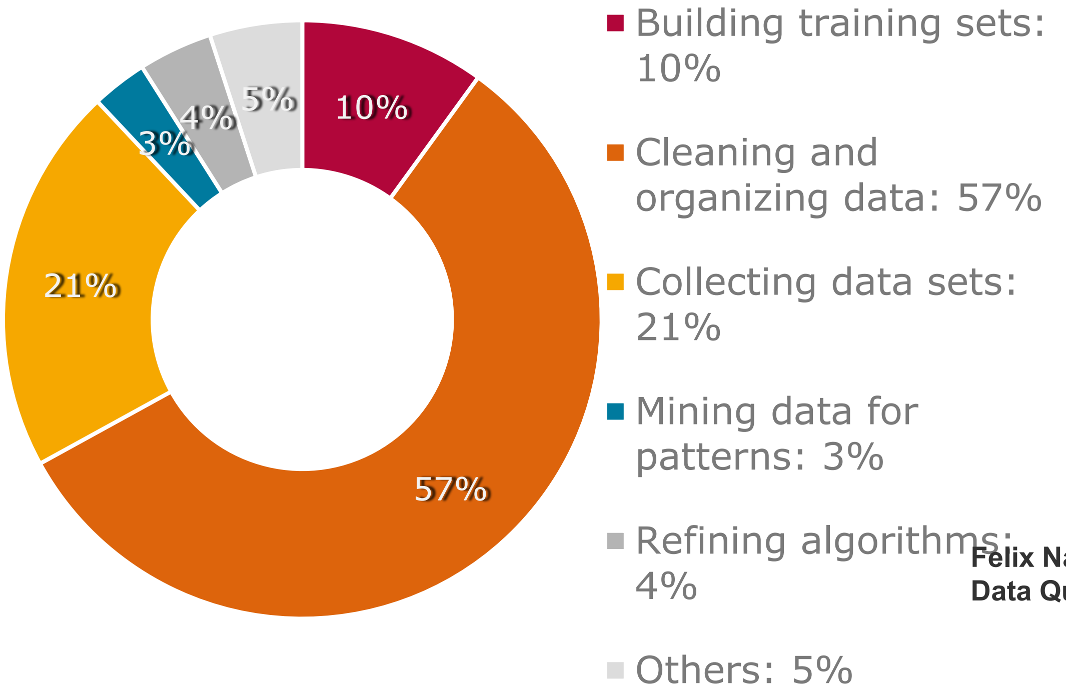

Capture
Sharing
Querying
Extraction
Search
Analysis
Curation
Storage
Visualization
Data Engineering
Data Science

Data preparation in reality

What data scientists spend the most time doing?



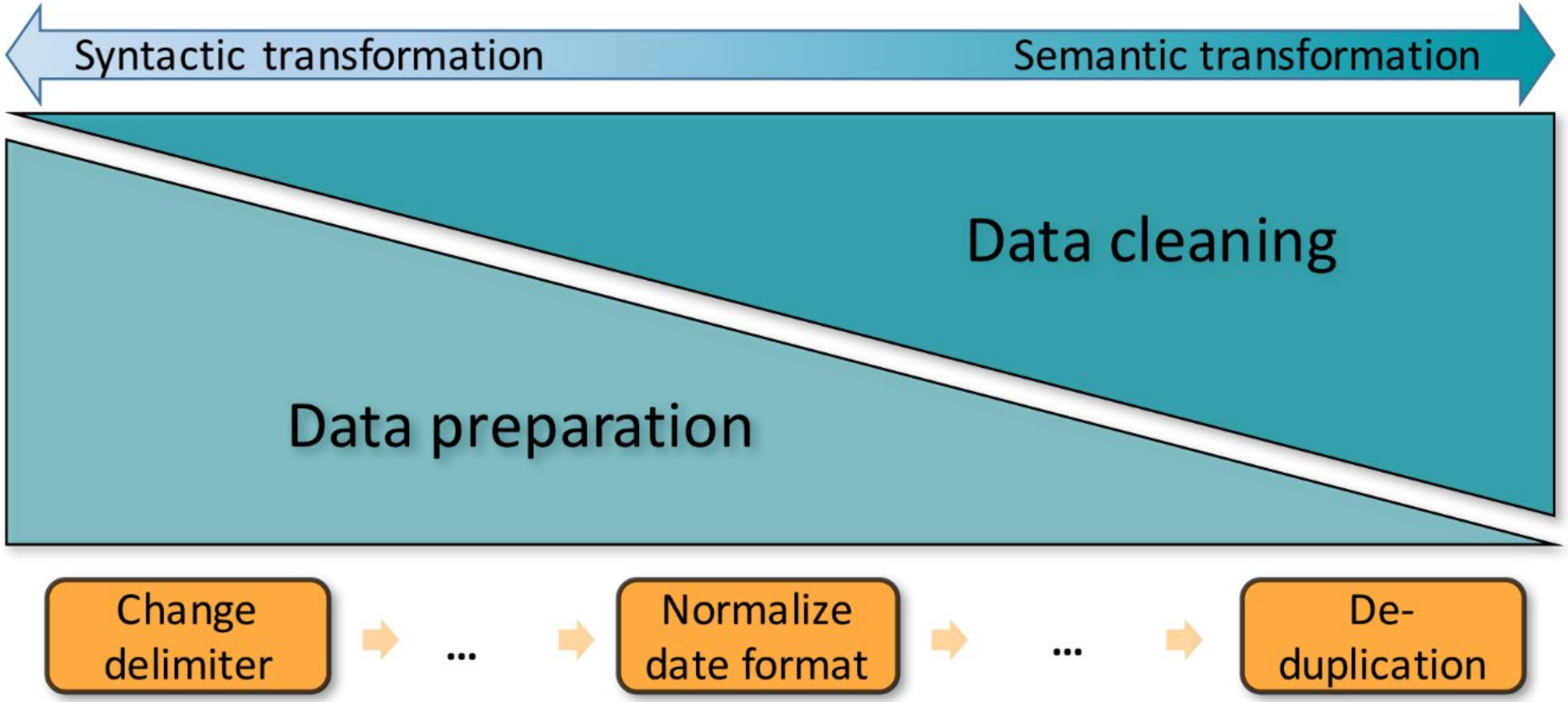
What is the least enjoyable part of data science?



“Cleaning Data: Most Time-Consuming, Least Enjoyable Data Science Task”, Gil Press, Forbes, March 23rd, 2016
http://www.forbes.com/sites/gilpress/2016/03/23/data-preparation-most-time-consuming-least-enjoyable-data-science-task-survey-says/

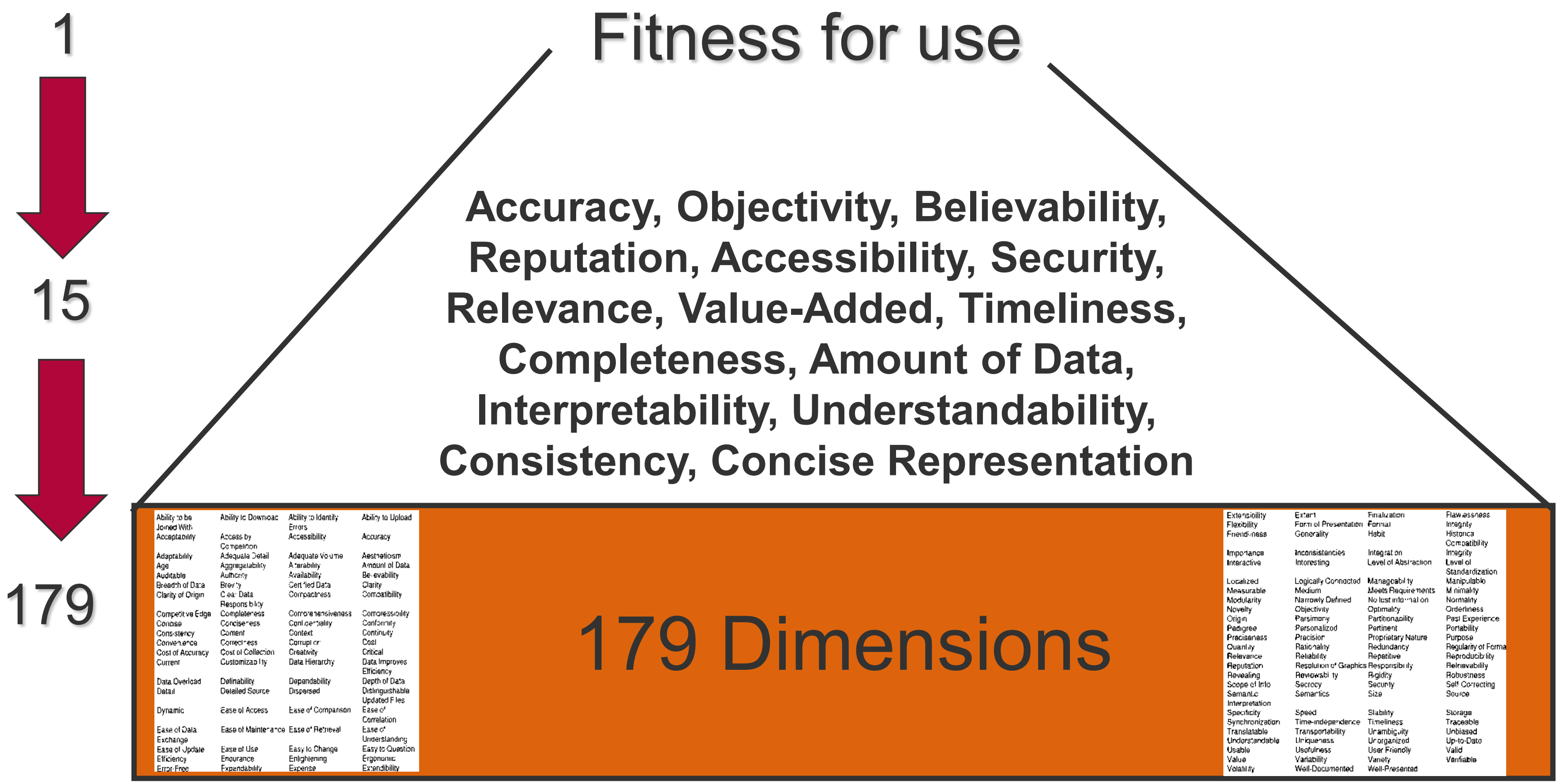
Data Preparation vs. Data Cleaning

- Data preparation adds syntactic and structural value
- Data cleaning adds semantic value



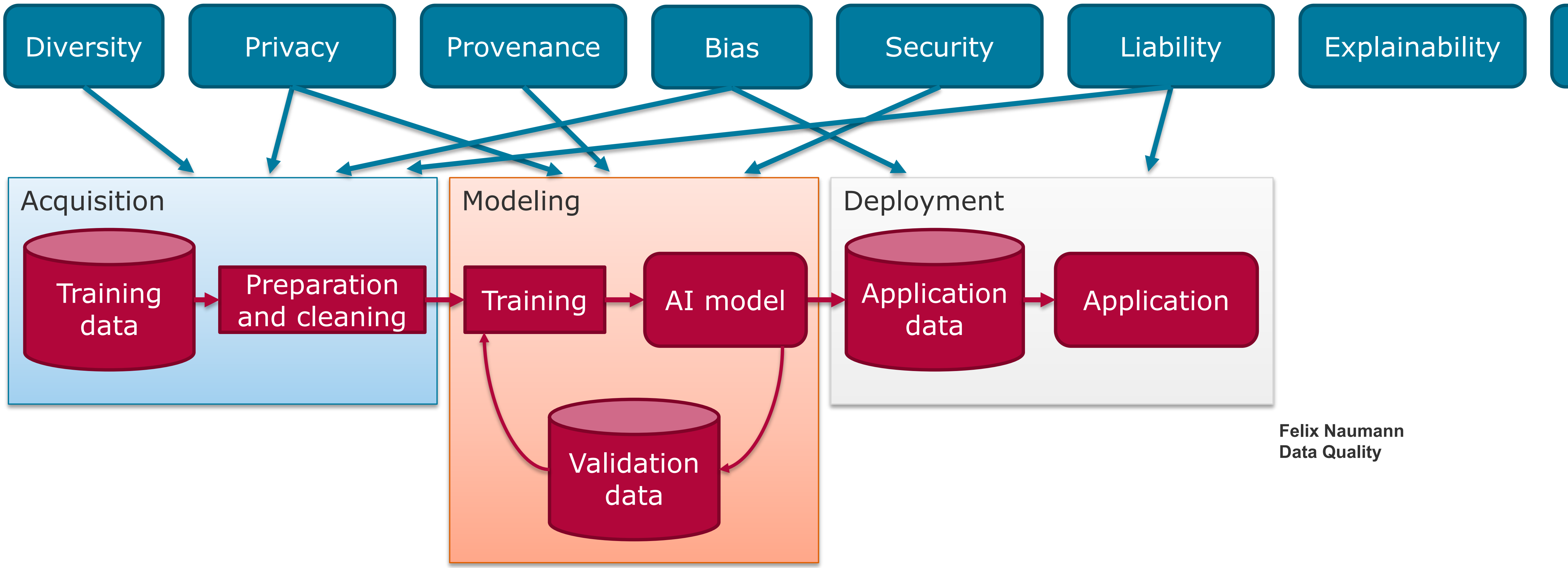
Agenda

1. **Data and Information Quality Research**
2. Data Preparation
3. Data Quality and AI Systems
4. Data Quality Assessment



Wang, R. Y. & Strong, D. M.
Beyond Accuracy: What data quality means to data consumers
Management of Information Systems, 1996, *12(4)*, 5-34

New AI-specific Data Quality Dimensions



28 DQ Dimensions

Uniqueness

Relevance

Privacy

Understandability

Accuracy

Consistent representation

Security

Believability

Added value

Fairness

Precision

Diversity

Representativity

Reputation

Documentation

Transparency

Consistency

Balance

Reliability

Traceability

Completeness

Portability

Accessibility

Amount

Recoverability

Timeliness

Compliance

Efficiency

Ease of manipulation

https://arxiv.org/pdf/2403.00526

Agenda

1. Data and Information Quality Research
2. **Data Preparation**
3. Data Quality and AI Systems
4. Data Quality Assessment

```
"ID,""Name"",""Sex"",""Age"",""Height"",""Weight"",""Team"",""NOC"",""Games"",""Year"",""Season"",""City"",""Sport"",""Event"",""Medal"""
"1,""A Dijiang"",""M"",24,180,80,""China"",""CHN"",""1992 Summer"",1992,""Summer"",""Barcelona"",""Basketball"",""Basketball Men's Basketball"",NA"
"2,""A Lamusi"",""M"",23,170,60,""China"",""CHN"",""2012 Summer"",2012,""Summer"",""London"",""Judo"",""Judo Men's Extra-Lightweight"",NA"
"3,""Gunnar Nielsen Aaby"",""M"",24,NA,NA,""Denmark"",""DEN"",""1920 Summer"",1920,""Summer"",""Antwerpen"",""Football"",""Football Men's Football"",NA"
"4,""Edgar Lindenau Aabye"",""M"",34,NA,NA,""Denmark/Sweden"",""DEN"",""1900 Summer"",1900,""Summer"",""Paris"",""Tug-Of-War"",""Tug-Of-War Men's Tug-Of-War"",""Gold"""
"5,""Christine Jacoba Aaftink"",""F"",21,185,82,""Netherlands"",""NED"",""1988 Winter"",1988,""Winter"",""Calgary"",""Speed Skating"",""Speed Skating Women's 500 metres"",NA"
"5,""Christine Jacoba Aaftink"",""F"",21,185,82,""Netherlands"",""NED"",""1988 Winter"",1988,""Winter"",""Calgary"",""Speed Skating"",""Speed Skating Women's 1,000 metres"",NA"
"5,""Christine Jacoba Aaftink"",""F"",25,185,82,""Netherlands"",""NED"",""1992 Winter"",1992,""Winter"",""Albertville"",""Speed Skating"",""Speed Skating Women's 500 metres"",NA"
"5,""Christine Jacoba Aaftink"",""F"",25,185,82,""Netherlands"",""NED"",""1992 Winter"",1992,""Winter"",""Albertville"",""Speed Skating"",""Speed Skating Women's 1,000 metres"",NA"
"5,""Christine Jacoba Aaftink"",""F"",27,185,82,""Netherlands"",""NED"",""1994 Winter"",1994,""Winter"",""Lillehammer"",""Speed Skating"",""Speed Skating Women's 500 metres"",NA"
"5,""Christine Jacoba Aaftink"",""F"",27,185,82,""Netherlands"",""NED"",""1994 Winter"",1994,""Winter"",""Lillehammer"",""Speed Skating"",""Speed Skating Women's 1,000 metres"",NA"
"6,""Per Knut Aaland"",""M"",31,188,75,""United States"",""USA"",""1992 Winter"",1992,""Winter"",""Albertville"",""Cross Country Skiing"",""Cross Country Skiing Men's 10 kilometres"",NA"
"6,""Per Knut Aaland"",""M"",31,188,75,""United States"",""USA"",""1992 Winter"",1992,""Winter"",""Albertville"",""Cross Country Skiing"",""Cross Country Skiing Men's 50 kilometres"",NA"
"6,""Per Knut Aaland"",""M"",31,188,75,""United States"",""USA"",""1992 Winter"",1992,""Winter"",""Albertville"",""Cross Country Skiing"",""Cross Country Skiing Men's 10/15 kilometres Pursuit"",NA"
"6,""Per Knut Aaland"",""M"",31,188,75,""United States"",""USA"",""1992 Winter"",1992,""Winter"",""Albertville"",""Cross Country Skiing"",""Cross Country Skiing Men's 4 x 10 kilometres Relay"",NA"
"6,""Per Knut Aaland"",""M"",33,188,75,""United States"",""USA"",""1994 Winter"",1994,""Winter"",""Lillehammer"",""Cross Country Skiing"",""Cross Country Skiing Men's 10 kilometres"",NA"
"6,""Per Knut Aaland"",""M"",33,188,75,""United States"",""USA"",""1994 Winter"",1994,""Winter"",""Lillehammer"",""Cross Country Skiing"",""Cross Country Skiing Men's 30 kilometres"",NA"
"6,""Per Knut Aaland"",""M"",33,188,75,""United States"",""USA"",""1994 Winter"",1994,""Winter"",""Lillehammer"",""Cross Country Skiing"",""Cross Country Skiing Men's 10/15 kilometres Pursuit"",NA"
"6,""Per Knut Aaland"",""M"",33,188,75,""United States"",""USA"",""1994 Winter"",1994,""Winter"",""Lillehammer"",""Cross Country Skiing"",""Cross Country Skiing Men's 4 x 10 kilometres Relay"",NA"
"7,""John Aalberg"",""M"",31,183,72,""United States"",""USA"",""1992 Winter"",1992,""Winter"",""Albertville"",""Cross Country Skiing"",""Cross Country Skiing Men's 10 kilometres"",NA"
"7,""John Aalberg"",""M"",31,183,72,""United States"",""USA"",""1992 Winter"",1992,""Winter"",""Albertville"",""Cross Country Skiing"",""Cross Country Skiing Men's 50 kilometres"",NA"
"7,""John Aalberg"",""M"",31,183,72,""United States"",""USA"",""1992 Winter"",1992,""Winter"",""Albertville"",""Cross Country Skiing"",""Cross Country Skiing Men's 10/15 kilometres Pursu
"7,""John Aalberg"",""M"",31,183,72,""United States"",""USA"",""1992 Winter"",1992,""Winter"",""Albertville"",""Cross Country Skiing"",""Cross Country Skiing Men's 4 x 10 kilometres Relay
"7,""John Aalberg"",""M"",33,183,72,""United States"",""USA"",""1994 Winter"",1994,""Winter"",""Lillehammer"",""Cross Country Skiing"",""Cross Country Skiing Men's 10 kilometres"",NA"
"7,""John Aalberg"",""M"",33,183,72,""United States"",""USA"",""1994 Winter"",1994,""Winter"",""Lillehammer"",""Cross Country Skiing"",""Cross Country Skiing Men's 30 kilometres"",NA"
"7,""John Aalberg"",""M"",33,183,72,""United States"",""USA"",""1994 Winter"",1994,""Winter"",""Lillehammer"",""Cross Country Skiing"",""Cross Country Skiing Men's 10/15 kilometres Pursu
"7,""John Aalberg"",""M"",33,183,72,""United States"",""USA"",""1994 Winter"",1994,""Winter"",""Lillehammer"",""Cross Country Skiing"",""Cross Country Skiing Men's 4 x 10 kilometres Relay
"8,""Cornelia """"Cor"""" Aalten (-Strannood)"",""F"",18,168,NA,""Netherlands"",""NED"",""1932 Summer"",1932,""Summer"",""Los Angeles"",""Athletics"",""Athletics Women's 100 metres"",NA"
"8,""Cornelia """"Cor"""" Aalten (-Strannood)"",""F"",18,168,NA,""Netherlands"",""NED"",""1932 Summer"",1932,""Summer"",""Los Angeles"",""Athletics"",""Athletics Women's 4 x 100 metres Relay"",NA"
"9,""Antti Sami Aalto"",""M"",26,186,96,""Finland"",""FIN"",""2002 Winter"",2002,""Winter"",""Salt Lake City"",""Ice Hockey"",""Ice Hockey Men's Ice Hockey"",NA"
"10,""Einar Ferdinand """"Einari"""" Aalto"",""M"",26,NA,NA,""Finland"",""FIN"",""1952 Summer"",1952,""Summer"",""Helsinki"",""Swimming"",""Swimming Men's 400 metres Freestyle"",NA"
"11,""Jorma Ilmari Aalto"",""M"",22,182,76.5,""Finland"",""FIN"",""1980 Winter"",1980,""Winter"",""Lake Placid"",""Cross Country Skiing"",""Cross Country Skiing Men's 30 kilometres"",NA"
"12,""Jyri Tapani Aalto"",""M"",31,172,70,""Finland"",""FIN"",""2000 Summer"",2000,""Summer"",""Sydney"",""Badminton"",""Badminton Men's Singles"",NA"
"13,""Minna Maarit Aalto"",""F"",30,159,55.5,""Finland"",""FIN"",""1996 Summer"",1996,""Summer"",""Atlanta"",""Sailing"",""Sailing Women's Windsurfer"",NA"
"13,""Minna Maarit Aalto"",""F"",34,159,55.5,""Finland"",""FIN"",""2000 Summer"",2000,""Summer"",""Sydney"",""Sailing"",""Sailing Women's Windsurfer"",NA"
"14,""Pirjo Hannele Aalto (Mattila-)"",""F"",32,171,65,""Finland"",""FIN"",""1994 Winter"",1994,""Winter"",""Lillehammer"",""Biathlon"",""Biathlon Women's 7.5 kilometres Sprint"",NA"
"15,""Arvo Ossian Aaltonen"",""M"",22,NA,NA,""Finland"",""FIN"",""1912 Summer"",1912,""Summer"",""Stockholm"",""Swimming"",""Swimming Men's 200 metres Breaststroke"",NA"
"15,""Arvo Ossian Aaltonen"",""M"",22,NA,NA,""Finland"",""FIN"",""1912 Summer"",1912,""Summer"",""Stockholm"",""Swimming"",""Swimming Men's 400 metres Breaststroke"",NA"
"15,""Arvo Ossian Aaltonen"",""M"",30,NA,NA,""Finland"",""FIN"",""1920 Summer"",1920,""Summer"",""Antwerpen"",""Swimming"",""Swimming Men's 200 metres Breaststroke"",""Bronze"""
"15,""Arvo Ossian Aaltonen"",""M"",30,NA,NA,""Finland"",""FIN"",""1920 Summer"",1920,""Summer"",""Antwerpen"",""Swimming"",""Swimming Men's 400 metres Breaststroke"",""Bronze"""
"15,""Arvo Ossian Aaltonen"",""M"",34,NA,NA,""Finland"",""FIN"",""1924 Summer"",1924,""Summer"",""Paris"",""Swimming"",""Swimming Men's 200 metres Breaststroke"",NA"
"16,""Juhamatti Tapio Aaltonen"",""M"",28,184,85,""Finland"",""FIN"",""2014 Winter"",2014,""Winter"",""Sochi"",""Ice Hockey"",""Ice Hockey Men's Ice Hockey"",""Bronze"""
"17,""Paavo Johannes Aaltonen"",""M"",28,175,64,""Finland"",""FIN"",""1948 Summer"",1948,""Summer"",""London"",""Gymnastics"",""Gymnastics Men's Individual All-Around"",""Bronze"""
"17,""Paavo Johannes Aaltonen"",""M"",28,175,64,""Finland"",""FIN"",""1948 Summer"",1948,""Summer"",""London"",""Gymnastics"",""Gymnastics Men's Team All-Around"",""Gold"""
"17,""Paavo Johannes Aaltonen"",""M"",28,175,64,""Finland"",""FIN"",""1948 Summer"",1948,""Summer"",""London"",""Gymnastics"",""Gymnastics Men's Floor Exercise"",NA"
"17,""Paavo Johannes Aaltonen"",""M"",28,175,64,""Finland"",""FIN"",""1948 Summer"",1948,""Summer"",""London"",""Gymnastics"",""Gymnastics Men's Horse Vault"",""Gold"""
"17,""Paavo Johannes Aaltonen"",""M"",28,175,64,""Finland"",""FIN"",""1948 Summer"",1948,""Summer"",""London"",""Gymnastics"",""Gymnastics Men's Parallel Bars"",NA"
"17,""Paavo Johannes Aaltonen"",""M"",28,175,64,""Finland"",""FIN"",""1948 Summer"",1948,""Summer"",""London"",""Gymnastics"",""Gymnastics Men's Horizontal Bar"",NA"
"17,""Paavo Johannes Aaltonen"",""M"",28,175,64,""Finland"",""FIN"",""1948 Summer"",1948,""Summer"",""London"",""Gymnastics"",""Gymnastics Men's Rings"",NA"
"17,""Paavo Johannes Aaltonen"",""M"",28,175,64,""Finland"",""FIN"",""1948 Summer"",1948,""Summer"",""London"",""Gymnastics"",""Gymnastics Men's Pommelled Horse"",""Gold"""
"17,""Paavo Johannes Aaltonen"",""M"",32,175,64,""Finland"",""FIN"",""1952 Summer"",1952,""Summer"",""Helsinki"",""Gymnastics"",""Gymnastics Men's Individual All-Around"",NA"
```

1	**Table rv.03.q: Removals and voluntary departures by country of nationality and type**															
2	Quarter	Geographical region	Country of nationality	**Total enforced removals**	**Total Refused entry at port and subsequently departed**	**Total voluntary departures**	**Total non-asylum enforced removals**	**Non-asylum cases: Refused entry at port and subsequently departed**	**Total non-asylum voluntary departures**	Non-asylum cases: Assisted Voluntary Returns	Non-asylum cases: Notified voluntary departures	Non-asylum cases: Other confirmed voluntary departures	**Total asylum enforced removals**	**Total asylum voluntary departures**	Asylum cases: Assisted Voluntary Returns	As ca No volu depar
237	2011 Q1	Europe	Turkey	**48**	**39**	**79**	**22**	**39**	**74**	0	23	51	**26**	**5**	0	
238	2011 Q1	Europe	Turkmenistan	**2**	**3**	**10**	**1**	**3**	**9**	0	0	9	**1**	**1**	0	
239	2011 Q1	Americas	Turks and Caicos Islands (British)	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	**0**	**0**	0	
240	2011 Q1	Oceania	Tuvalu	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	**0**	**0**	0	
241	2011 Q1	Africa	Uganda	**24**	**3**	**58**	**7**	**3**	**50**	4	8	38	**17**	**8**	7	
242	2011 Q1	Europe	Ukraine	**53**	**63**	**39**	**46**	**63**	**36**	0	12	24	**7**	**3**	2	
243	2011 Q1	Middle East	United Arab Emirates	**0**	**1**	**5**	**0**	**1**	**5**	0	0	5	**0**	**0**	0	
244	2011 Q1	Americas	United States	**14**	**472**	**91**	**14**	**472**	**88**	0	35	53	**0**	**3**	3	
245	2011 Q1	Americas	Uruguay	**1**	**3**	**0**	**0**	**3**	**0**	0	0	0	**1**	**0**	0	
246	2011 Q1	Europe	Uzbekistan	**22**	**1**	**46**	**20**	**1**	**46**	0	8	38	**2**	**0**	0	
247	2011 Q1	Oceania	Vanuatu	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	**0**	**0**	0	
248	2011 Q1	Europe	Vatican City	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	**0**	**0**	0	
249	2011 Q1	Americas	Venezuela	**2**	**45**	**5**	**0**	**45**	**5**	0	3	2	**2**	**0**	0	
250	2011 Q1	Asia	Vietnam	**249**	**24**	**77**	**190**	**24**	**72**	2	10	60	**59**	**5**	3	
251	2011 Q1	Americas	Virgin Islands (British)	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	**0**	**0**	0	
252	2011 Q1	Americas	Virgin Islands (US)	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	**0**	**0**	0	
253	2011 Q1	Oceania	Wallis and Futuna	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	**0**	**0**	0	
254	2011 Q1	Africa	Western Sahara	**2**	**0**	**0**	**2**	**0**	**0**	0	0	0	**0**	**0**	0	
255	2011 Q1	Middle East	Yemen	**2**	**0**	**2**	**2**	**0**	**2**	0	2	0	**0**	**0**	0	
256	2011 Q1	Africa	Zambia	**3**	**3**	**27**	**3**	**3**	**26**	5	6	15	**0**	**1**	1	
257	2011 Q1	Africa	Zimbabwe	**7**	**3**	**73**	**3**	**3**	**35**	1	8	26	**4**	**38**	29	
258	2011 Q2	Total	*Total	**3.456**	**3.963**	**5.156**	**2.130**	**3.963**	**4.488**	154	1.525	2.809	**1.326**	**668**	301	
259	2011 Q2	Africa	*Total Africa	**703**	**611**	**970**	**377**	**611**	**811**	28	357	426	**326**	**159**	62	
260	2011 Q2	Americas	*Total Americas	**343**	**1.367**	**652**	**301**	**1.367**	**643**	55	194	394	**42**	**9**	0	
261	2011 Q2	Asia	*Total Asia	**1.790**	**888**	**2.892**	**1.006**	**888**	**2.526**	61	812	1.653	**784**	**366**	193	
262	2011 Q2	Europe	*Total Europe	**512**	**638**	**356**	**418**	**638**	**318**	9	92	217	**94**	**38**	7	
263	2011 Q2	Middle East	*Total Middle East	**98**	**192**	**240**	**22**	**192**	**144**	1	47	96	**76**	**96**	39	
264	2011 Q2	Oceania	*Total Oceania	**4**	**153**	**38**	**3**	**153**	**38**	0	16	22	**1**	**0**	0	
265	2011 Q2	Other	*Total Other	**6**	**114**	**8**	**3**	**114**	**8**	0	7	1	**3**	**0**	0	
266	2011 Q2	Asia	Afghanistan	**296**	**70**	**69**	**17**	**70**	**4**	0	3	1	**279**	**65**	34	
267	2011 Q2	Europe	Albania	**100**	**187**	**25**	**53**	**187**	**19**	0	11	8	**47**	**6**	2	
268	2011 Q2	Africa	Algeria	**49**	**32**	**42**	**17**	**32**	**21**	0	11	10	**32**	**21**	3	
269	2011 Q2	Oceania	American Samoa	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	**0**	**0**	0	
270	2011 Q2	Europe	Andorra	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	**0**	**0**	0	
271	2011 Q2	Africa	Angola	**7**	**19**	**12**	**1**	**19**	**4**	0	0	4	**6**	**8**	4	
272	2011 Q2	Americas	Anguilla (British)	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	**0**	**0**	0	
273	2011 Q2	Americas	Antigua and Barbuda	**0**	**6**	**1**	**0**	**6**	**1**	0	1	0	**0**	**0**	0	
274	2011 Q2	Americas	Argentina	**4**	**30**	**4**	**4**	**30**	**4**	1	2	1	**0**	**0**	0	
275	2011 Q2	Europe	Armenia	**2**	**3**	**1**	**1**	**3**	**0**	0	0	0	**1**	**1**	0	
276	2011 Q2	Americas	Aruba	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	**0**	**0**	0	
277	2011 Q2	Oceania	Australia	**1**	**120**	**24**	**1**	**120**	**24**	0	8	16	**0**	**0**	0	
278	2011 Q2	Europe	Austria	**2**	**1**	**0**	**2**	**1**	**0**	0	0	0	**0**	**0**	0	

Data Preparation for AI: The Challenge

```
Nov-09,,4,47,35,17,99,32,1055,185,578,16,0,18,16,2,36,5,149,2,47,0,0,16,11,5,32,10,43,5,115,1
Dec-09,,3,41,32,15,89,27,930,145,566,14,0,17,17,2,36,4,131,2,49,0,0,12,10,5,27,8,40,6,106,1
Jan-10,*,3,51,41,17,109,33,799,143,654,19,0,20,18,2,39,5,125,2,52,0,0,14,13,6,33,8,35,5,138,1
Feb-10,,3,46,36,14,96,32,636,133,545,17,0,19,15,1,35,4,97,1,44,0,0,13,12,6,31,8,24,4,113,1
Mar-10,,4,48,36,15,99,29,700,126,550,17,0,19,15,2,36,4,100,2,44,0,0,13,11,6,30,6,19,4,113,1
Apr-10,*,4,57,42,19,119,33,792,157,665,20,0,24,17,3,44,4,115,2,52,0,0,17,15,8,39,7,21,5,141,1
May-10,,3,46,34,18,99,27,629,127,535,16,0,19,13,3,36,4,45,1,42,0,0,12,10,6,28,6,27,5,118,1
Jun-10,,3,43,33,20,97,26,682,132,531,14,0,18,13,5,36,4,55,1,39,0,0,11,10,8,29,6,27,5,115,1
Jul-10,*,5,55,40,26,121,36,1075,182,662,Data are confidential,0,21,16,6,43,5,114,2,51,0,0,11,10,10,31,8,35,5,144,1
Aug-10,,5,43,32,20,95,28,987,165,553,Data are confidential,0,17,11,5,34,4,135,2,46,0,0,10,8,6,24,7,24,5,121,1
Sep-10,,7,48,34,18,100,33,957,158,562,Data are confidential,0,19,13,4,36,5,148,2,46,0,0,16,10,5,31,7,27,5,121,1
Oct-10,*,9,63,44,22,129,49,1191,195,728,Data are confidential,0,24,19,4,47,6,197,3,57,0,1,22,13,6,41,10,29,7,157,1
Nov-10,,7,52,40,18,109,47,1047,183,605,Data are confidential,0,19,16,3,38,6,154,2,47,0,0,14,11,5,29,10,20,4,132,1
Dec-10,**,6,55,42,18,114,41,1065,189,691,Data are confidential,0,21,20,3,43,5,167,3,54,0,0,14,11,6,31,8,20,4,143,1
Jan-11,*,6,60,48,18,126,52,856,190,690,Data are confidential,0,22,20,3,45,6,148,2,52,0,1,16,15,7,38,10,19,4,157,1
Feb-11,,7,47,39,15,101,37,699,156,592,Data are confidential,0,19,16,2,37,4,115,2,48,0,0,14,12,5,32,8,13,2,123,1
Mar-11,,8,51,38,16,105,34,678,137,587,Data are confidential,0,20,16,2,37,4,115,2,49,0,0,13,11,5,29,6,12,2,122,1
Apr-11,*,7,62,46,19,127,37,827,167,683,Data are confidential,0,23,18,4,45,5,118,2,60,0,0,15,12,5,32,7,15,3,143,0
May-11,,5,49,37,19,106,35,655,132,545,Data are confidential,0,19,14,4,36,5,49,2,45,0,0,11,10,6,27,7,17,3,122,0
Jun-11,,5,46,36,21,103,36,749,137,567,Data are confidential,0,17,13,5,35,5,72,2,45,0,0,10,8,6,25,8,21,2,127,0
Jul-11,*,6,56,42,25,123,42,1133,189,728,Data are confidential,0,20,16,6,42,6,137,3,55,0,0,10,8,5,23,9,28,4,151,0
Aug-11,,5,45,34,18,97,34,956,153,594,Data are confidential,0,18,12,4,34,5,133,3,43,0,0,14,8,4,26,7,25,4,121,0
Sep-11,,7,51,36,17,104,40,992,153,621,Data are confidential,0,18,14,2,35,5,144,3,49,0,1,17,9,4,30,8,30,4,127,0
Oct-11,*,8,61,45,18,125,53,1336,216,768,Data are confidential,0,22,20,2,45,8,191,3,68,0,1,20,11,5,36,12,34,5,159,0
Nov-11,,6,50,39,15,105,48,964,165,639,Data are confidential,0,18,16,2,36,6,147,3,59,0,1,13,10,4,27,9,25,4,131,0
Dec-11,,5,42,32,12,85,34,864,153,574,Data are confidential,0,16,16,2,34,5,120,3,56,0,0,11,9,4,24,8,24,2,113,0
Jan-12,*,5,55,45,15,115,46,825,165,721,25,0,20,18,2,40,6,129,2,64,0,0,15,12,5,32,9,23,3,155,0
Feb-12,,6,48,37,12,97,34,658,135,592,19,0,18,15,2,34,4,110,2,52,0,0,12,10,4,27,7,18,3,124,0
Mar-12,,7,49,37,13,99,31,694,130,598,21,0,18,14,2,34,4,108,2,49,0,0,11,9,4,25,6,15,2,124,0
Apr-12,*,5,60,43,17,120,38,803,149,724,24,0,22,16,3,41,5,122,2,58,0,0,15,11,5,32,7,20,3,153,0
May-12,,3,47,34,16,98,32,681,118,583,19,0,18,12,3,34,5,60,2,48,0,0,12,9,5,26,7,23,3,123,0
Jun-12,,3,42,30,17,90,31,668,119,570,19,0,16,11,4,32,5,84,2,49,0,0,10,7,5,22,7,30,2,120,0
Jul-12,*,4,52,38,23,113,45,982,169,744,26,0,19,13,5,38,7,126,2,61,0,0,13,9,6,28,10,41,4,153,0
Aug-12,,5,41,30,17,88,34,892,145,600,21,0,14,10,3,28,5,112,2,52,0,0,13,8,5,26,8,45,3,129,0
Sep-12,,8,45,31,16,91,40,873,143,610,24,0,17,11,3,31,6,123,2,49,0,0,16,9,4,29,10,44,4,128,0
Oct-12,*,9,60,43,19,122,58,1270,212,793,27,0,21,17,3,41,7,142,3,50,0,1,19,11,5,36,14,53,4,162,0
Nov-12,,7,48,36,15,100,49,912,147,672,21,0,16,14,2,33,6,119,2,27,0,1,13,10,4,28,11,41,3,133,0
Dec-12,,6,40,30,12,82,35,917,152,628,17,0,15,14,2,31,5,104,2,23,0,0,12,10,4,26,9,32,3,115,0
Jan-13,*,7,52,41,15,108,48,937,182,762,25,0,20,18,2,40,6,134,2,29,0,1,15,13,5,33,10,31,4,155,0
```

My data won’t load …

… because nobody bothered to use escape symbols.
… because ` is not a proper quotation symbol.
… because the maximum line length is exceeded.
… because there is a header row.
… because there is no header row.
… because the first line is the table-name.
… because some lines are empty.
… because it is encoded in CP-1252.
… because columns are shifted every ten rows.
… because a numeric column contains a string in line 590450.
… because some lines are two fields shorter.
… because Ümlauts are not supported.
… because someone added footnotes.
… because who uses § as a delimiter?
… because the file contains multiple tables.
… because tab and space are not the same thing.
… because someone added a comment in line 3.
… because – is not -.
… because it is split across multiple files.
… because headers are repeated every 80 lines.
… because the file ends mid-row.

Data Preparation: Tasks and Tools

- Data discovery
- Data validation
- Data structuring
- Data enrichment
- Data filtering
- Data cleaning

- And for data scientists
  - Feature selection
  - Feature extraction

Categories	Available features	Data preparation tools						
		Altair	Paxata	SAP	SAS	Tableau	Talend	Trifacta
Data discovery	Locate missing values (nulls)	✓	✓	✓	✓	✓	✓	✓
	Locate outliers		✓		✓			✓
	Search by pattern	✓	✓	✓	✓	✓	✓	✓
	Sort data	✓	✓	✓	✓	✓	✓	✓
Data validation	Compare values (selection and join)	✓	✓	✓		✓	[illegible]	✓
	Check data range	✓	✓	✓		✓	[illegible]	[illegible]
	Check permitted characters						[illegible]	[illegible]
	Check column uniqueness	✓	✓	✓		✓	[illegible]	[illegible]
	Find type-mismatched data		✓	✓		✓	[illegible]	[illegible]
	Find data-mismatched datatypes		✓				[illegible]	[illegible]
Data structuring	Change column data type	✓	✓	✓	✓	[illegible]	[illegible]	[illegible]
	Delete column	✓	✓	✓	✓	[illegible]	[illegible]	[illegible]
	Detect & change encoding					[illegible]	[illegible]	[illegible]
	Pivot / unpivot	✓	✓	✓		[illegible]	[illegible]	[illegible]
	Rename column	✓	✓	✓	✓	[illegible]	[illegible]	[illegible]
	Split column	✓	✓	✓	✓	[illegible]	[illegible]	[illegible]
	Transform by example [13]					[illegible]	[illegible]	[illegible]
Data enrichment	Assign semantic data type				✓	✓	[illegible]	[illegible]
	Calculate column using expressions	✓	✓	✓	✓	✓	✓	[illegible]
	Discover & merge external data	✓	✓	✓			✓	✓
	Duplicate column	✓	✓	✓		✓	✓	✓
	Generate primary key column			✓				✓
	Join & union	✓	✓	✓	✓	✓	✓	✓
	Merge columns	✓		✓		✓	✓	✓
	Normalize numeric values	✓	✓	✓	✓	✓	✓	✓
Data filtering	Delete/keep filtered rows	✓	✓	✓	✓	✓	✓	✓
	Delete empty and invalid rows	✓	✓	✓	✓	✓	✓	✓
	Extract value parts	✓			✓		✓	✓
	Filter with regular expressions							✓
Data cleaning	Change date & time format	✓	✓	✓	✓	✓	✓	✓
	Change letter case	✓	✓	✓	✓	✓	✓	✓
	Change number format	✓	✓	✓	✓	✓	✓	✓
	Deduplicate data	✓	✓	✓	✓		✓	✓
	Delete by pattern	✓	✓		✓	✓	✓	✓
	Edit & replace cell data	✓	✓	✓	✓	✓	✓	✓
	Fill empty cells	✓	✓				✓	✓
	Remove extra whitespace	✓	✓	✓	✓	✓	✓	✓
	Remove diacritics			✓				
	Standardize strings by pattern		✓	✓	✓	✓	✓	✓
	Standardize values in clusters		✓	✓	✓	✓	✓	✓

Selected Data Preparation Projects – Bringing Order to Files

- Mondrian
  - Dissecting multi-table files
- ExtracTable
  - Parsing visually delimited files
- Suragh and Tasheeh
  - Identifying ill-formed records
- Strudel
  - Classify cell-types
- AggreCol
  - Identify aggregation cells

Mondrian: Multitable Spreadsheets

ECONOMIC CALCULATOR FOR FIRM VERSUS NON-FIRM PURCHASE	
Current Hour =	14
Enter Local Generation Avail:	529
Enter Remote Generation:	581
Firm Purchases into EPE:	25
Non-Firm Purchases into EPE:	0
SPS Firm:	0
Reserves:	0
Total Generation for Load:	1135
Enter Total Spin Required:	78
Spin Required:	39
Non-Spin Required:	39
Spin Required + Regulating Margin:	69
*Amount of Spin:	79
Amount of Non-Spin:	50
Total Spin:	129
Spin Available/(Deficient):	40
Enter Firm Price:	$0.00
Enter Non-Firm Price:	$0.00
MWH of Firm Avail./(Deficient):	40
Total Cost of Firm:	$0
MWH of Non-Firm Avail./(Deficient):	40
Total Cost of Non-Firm:	$0

NOTE: * ACTUAL SPIN SHOW MAY BE LESS SINCE UNIT RAMP RATES ARE NOT CONSIDERED.

Next Hour =	15
Projected Control Area Load:	840
PNM Contingent:	41
TNP Firm:	25
IID Firm + Contingent:	150
Firm Sales:	0
Non-Firm Sales:	0
Total Load Next Hour:	1056
PNM Contract:	46
IID Firm Contract:	100
TNP Contract:	25
SPS Contract:	100

Local Avail.	529
Gen.	397
UnLoaded	132

	103
- load	50
	53

Local	529
Copper	69
	598

PV	
IID	80
real/time	80
net/pre	-75
Tep/exc	300
iso	0
	385

(If total goes over 600 EPE has to wheel back)

(Contingent upon units 7 & 8 number automatically feeds from the calculation tab)

Enter Blue Numbers

Lambda =	$47.74
System avg. =	$25.70

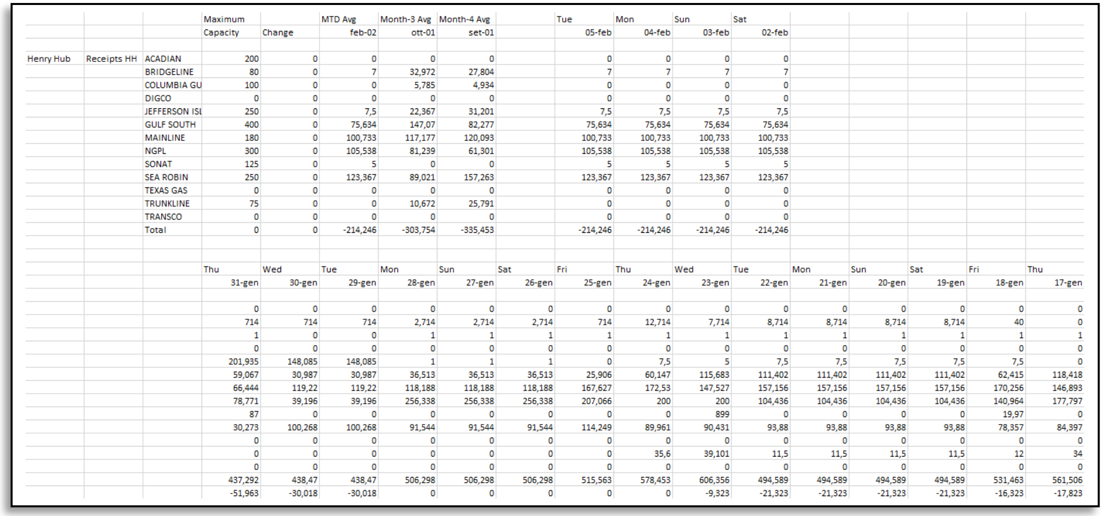
Weighted Avg. Purchase Power Calculator

	MWH	$/MWH		
Firm Block 1:	0	$0.00	$0.00	
Firm Block 2:	0	$0.00	$0.00	
Firm Block 3:	0	$0.00	$0.00	
Firm Block 4:	0	$0.00	$0.00	
Firm Block 5:	0	$0.00	$0.00	
Total:	0	NA	$0.00	$0.00
	MWH	$/MWH		
Non-Firm Block 1:	0	$0.00	$0.00	
Non-Firm Block 2:	0	$0.00	$0.00	
Non-Firm Block 3:	0	$0.00	$0.00	
Non-Firm Block 4:	0	$0.00	$0.00	
Non-Firm Block 5:	0	$0.00	$0.00	
Total:	0	NA	$0.00	$0.00
			$0.00	

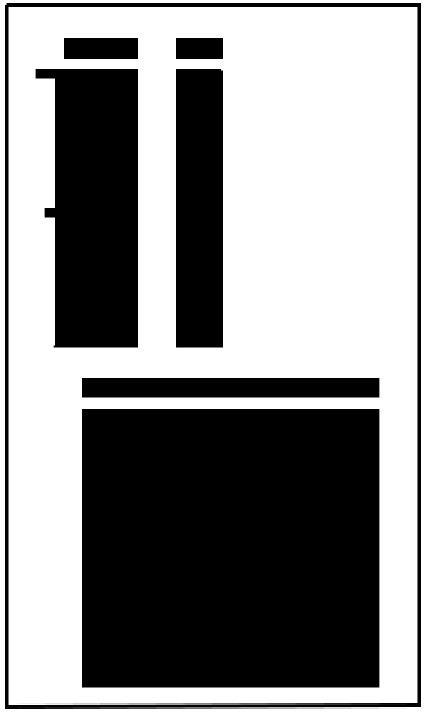
Spin from Ramp rates

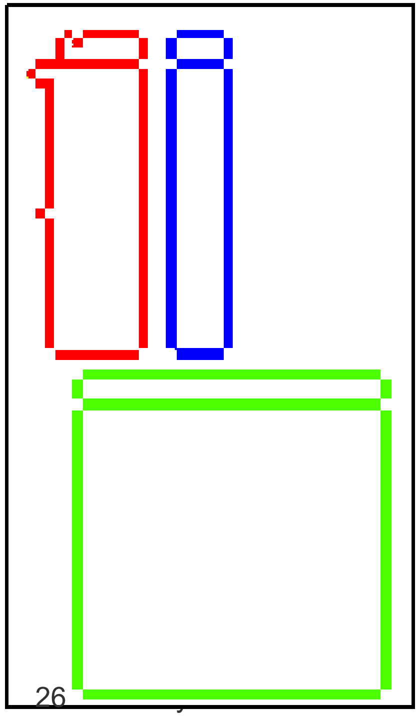
	Output	Highs'	Spin	RR	unloaded
Unit 1	50	80	30	3	30
2	70	82	12	4.5	12
3	0	0	0	5.1	0
GT1	0	0	0	10	0
GT2	0	0	0	10	0
GT1S	0	0	0	3.33	0
GT2S	0	0	0	3.6	0
NM4	148	214	36	3.6	66
Copper	0	0	0	10	0
6	0	0	0	2	0
7	33	33	0	2.1	0
8	96	120	10	1	24
Total	397	529	88		132
FC	49	108			
PV	532	581		Lost Gen.	44
	581	689			

Mondrian: Clustering-based Table Recognition



			Maximum		MTD Avg	Month-3 Avg	Month-4 Avg		Tue	Mon	Sun	Sat					
			Capacity	Change	feb-02	ott-01	set-01		05-feb	04-feb	03-feb	02-feb					
Henry Hub	Receipts HH	ACADIAN	200	0	0	0	0		0	0	0	0					
		BRIDGELINE	80	0	7	32,972	27,804		7	7	7	7					
		COLUMBIA GU	100	0	0	5,785	4,934		0	0	0	0					
		DIGCO	0	0	0	0	0		0	0	0	0					
		JEFFERSON ISL	250	0	7,5	22,367	31,201		7,5	7,5	7,5	7,5					
		GULF SOUTH	400	0	75,634	147,07	82,277		75,634	75,634	75,634	75,634					
		MAINLINE	180	0	100,733	117,177	120,093		100,733	100,733	100,733	100,733					
		NGPL	300	0	105,538	81,239	61,301		105,538	105,538	105,538	105,538					
		SONAT	125	0	5	0	0		5	5	5	5					
		SEA ROBIN	250	0	123,367	89,021	157,263		123,367	123,367	123,367	123,367					
		TEXAS GAS	0	0	0	0	0		0	0	0	0					
		TRUNKLINE	75	0	0	10,672	25,791		0	0	0	0					
		TRANSCO	0	0	0	0	0		0	0	0	0					
		Total	0	0	-214,246	-303,754	-335,453		-214,246	-214,246	-214,246	-214,246					
			Thu	Wed	Tue	Mon	Sun	Sat	Fri	Thu	Wed	Tue	Mon	Sun	Sat	Fri	Thu
			31-gen	30-gen	29-gen	28-gen	27-gen	26-gen	25-gen	24-gen	23-gen	22-gen	21-gen	20-gen	19-gen	18-gen	17-gen
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			714	714	714	2,714	2,714	2,714	714	12,714	7,714	8,714	8,714	8,714	8,714	40	0
			1	0	0	1	1	1	1	1	1	1	1	1	1	1	1
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			201,935	148,085	148,085	1	1	1	0	7,5	5	7,5	7,5	7,5	7,5	7,5	0
			59,067	30,987	30,987	36,513	36,513	36,513	25,906	60,147	115,683	111,402	111,402	111,402	111,402	62,415	118,418
			66,444	119,22	119,22	118,188	118,188	118,188	167,627	172,53	147,527	157,156	157,156	157,156	157,156	170,256	146,893
			78,771	39,196	39,196	256,338	256,338	256,338	207,066	200	200	104,436	104,436	104,436	104,436	140,964	177,797
			87	0	0	0	0	0	0	0	899	0	0	0	0	19,97	0
			30,273	100,268	100,268	91,544	91,544	91,544	114,249	89,961	90,431	93,88	93,88	93,88	93,88	78,357	84,397
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	35,6	39,101	11,5	11,5	11,5	11,5	12	34
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			437,292	438,47	438,47	506,298	506,298	506,298	515,563	578,453	606,356	494,589	494,589	494,589	494,589	531,463	561,506
			-51,963	-30,018	-30,018	0	0	0	0	0	-9,323	-21,323	-21,323	-21,323	-21,323	-16,323	-17,823





1. Render spreadsheet as image
2. Recognize elements
3. Cluster elements into tables

ExtracTable: Bad Files – Worse Files

min	max	num	dist	mean	std	comment
1.8	1.8	1	0	1.5	0	N
20	60	40	1	40	15	cab
0	0	1	0			
0	1	10	2			
0.01	0.01	1	0			
0.009	0.009	1	0			
0.2	7	40	1			
-0.35	-0.35	1	2			
-0.15	-0.15	1	0			
0.5	0.5	1	0			
0.2	0.2	1	0			
0.01	0.01	1	0			
27.947	27.947	1	0			
7.04345	7.04345	1	0			
146.691	146.691	1	0			
1	1	1	0			

```
#   OBIA4RTM config file for setting up Prospect4SAIL
#
#   Typical values (taken from J Gomez-Dans on https://pypi.org/project/prosail/)
#
#   ============================================================================
#   | Parameter   | Description of parameter          | Units         |Typical min  |  Typical max |
#   |-------------|-----------------------------------|---------------|-------------|--------------|
#   |   N         | Leaf structure parameter          | N/A           | 0.8         | 2.5          |
#   |  cab        | Chlorophyll a+b concentration     | ug/cm2        | 0           | 80           |
#   |  caw        | Equivalent water thickiness       | cm            | 0           | 200          |
#   |  car        | Carotenoid concentration          | ug/cm2        | 0           | 20           |
#   |  cbrown     | Brown pigment                     | NA            | 0           | 1            |
#   |  cm         | Dry matter content                | g/cm2         | 0           | 200          |
#   |  lai        | Leaf Area Index                   | N/A           | 0           | 10           |
#   |  lidfa      | Leaf angle distribution           | N/A           | -           | -            |
#   |  lidfb      | Leaf angle distribution           | N/A           | -           | -            |
#   |  psoil      | Dry/Wet soil factor               | N/A           | 0           | 1            |
#   |  rsoil      | Soil brigthness factor            | N/A           | -           | -            |
#   |  hspot      | Hotspot parameter                 | N/A           | -           | -            |
#   |  tts        | Solar zenith angle                | deg           | 0           | 90           |
#   |  tto        | Observer zenith angle             | deg           | 0           | 90           |
#   |  phi        | Relative azimuth angle            | deg           | 0           | 360          |
#   | typelidf    | Leaf angle distribution type      | Integer       | -           | -            |
#   ============================================================================
#
#   You can enter your values below -> make sure not to alter the overall structure of this
#   template -> otherwise bad things might happen
#
#   Further Explainations:
#
#   min: Minimum Value of Parameter
#   max: Maximum Value of Parameter (in case min=max, the parameter will not be retrieved)
#   num: in case min!=max, the number of samples to be drawn for the specific parameter
```

Strudel: Verbose CSV Files

Metadata

Header

Arrest Table						
Arrests for Drug Abuse Violations						
Percent Distribution by Region, 2007						
Drug abuse violations		United States total	Northeast	Midwest	South	West
Total1		100	100	100	100	100
Sale/Manufacturing:	Total	17.5	22.5	18.3	17.1	15
	Heroin or cocaine and their derivatives	7.9	14.2	6.2	7.9	5.5
	Marijuana	5.3	5.7	7.7	4.6	4.7
	Synthetic or manufactured drugs	1.5	1.1	1.1	2.6	0.7
	Other dangerous nonnarcotic drugs	2.8	1.6	3.3	2	4.2
Possession:	Total	82.5	77.5	81.7	82.9	85
	Heroin or cocaine and their derivatives	21.5	22.3	14.7	22.8	22.7
	Marijuana	42.1	44.2	53.1	47.9	29.6
	Synthetic or manufactured drugs	3.3	2.3	3.2	4.3	2.8
	Other dangerous nonnarcotic drugs	15.6	8.6	10.7	7.8	29.9
1 Because of rounding, the percentages may not add to 100.(						

Group header

Aggregation

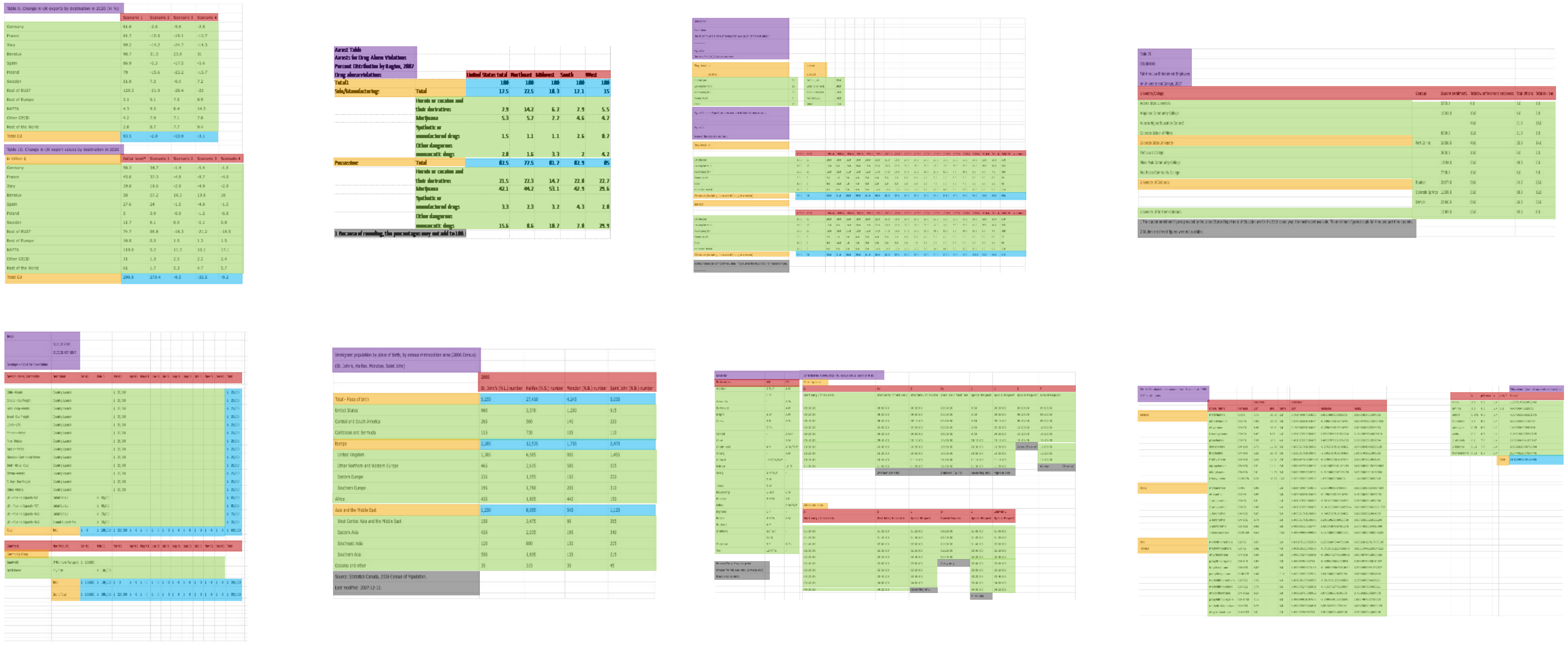
Notes

Data

- Metadata
- Header
- Group header
- Data
- Aggregation
- Notes

Crime In the US (CIUS): https://ucr.fbi.gov/crime-in-the-u.s

Strudel: Structure Diversity in Verbose CSV Files



- Metadata
- Header
- Group header
- Data
- Aggregation
- Notes

AggreCol: Aggregations in CSV Files

$$\%\ \text{Change 2003 vs. 2002} = \frac{\text{FY2003} - \text{FY2002}}{\text{FY2002}}$$

MICROS Systems, Inc.								
Financial Summary								
	% Change							
Income Statement Data	2003 vs. 2002	FY2003	FY2002	FY2001	FY2000	FY1999	FY1998	FY1997
Hardware Revenue	2.2%	$137,013	$134,121	$116,058	$152,186	$155,237	$126,974	$102,816
Software Revenue	17.8%	$71,251	$60,484	$55,873	$66,290	$63,317	$57,744	$45,985
Service Revenue	11.2%	$191,927	$172,558	$154,845	$143,378	$118,525	$97,200	$79,368
Total Revenue	9.0%	$400,191	$367,163	$326,776	$361,854	$337,079	$281,918	$228,169
Memo Item:								
Maintenance Revenue (included in Service Revenue)	13.9%	$113,274	$99,467	$87,007	$65,628	$54,953	$45,908	$37,38
Hardware Gross Profit	2.3%	$38,977	$38,116	$40,683	$51,462	$50,670	$43,947	$39,267
Hardware Gross Profit %	-	28.4%	28.4%	35.1%	33.8%	32.6%	34.6%	38.2%
Software Gross Profit	11.5%	$54,045	$48,457	$46,875	$51,349	$52,138	$47,235	$37,464
Software Gross Profit %	-4.2 Points	75.9%	80.1%	83.9%	77.5%	82.3%	81.8%	81.5%
Service Gross Profit	16.5%	$105,538	$90,564	$76,472	$71,741	$61,367	$46,455	$39,447
Service Gross Profit %	+2.5 Points	55.0%	52.5%	49.4%	50.0%	51.8%	47.8%	49.7%
Total Gross Profit	12.1%	$198,560	$177,137	$164,028	$174,552	$164,175	$137,637	$116,178
Gross Profit %	+1.4 Points	49.6%	48.2%	50.2%	48.2%		48.8%	50.9%

$$\text{Hardware GP}\ \% = \frac{\text{Hardware GP}}{\text{Hardware Revenue}}$$

$$\text{Service GP}\ \% = \text{FY2003} - \text{FY2002}$$

$$\text{Total Gross Profit} = \text{Hardware GP} + \text{Software GP} + \text{Service GP}$$

Ill-formed Records Abort Data Loading

1	NAME	LAST NAME	JOBTITLE	DESCR	HIRE_DT	ANNUAL_RT	GROSS
2	Aaron	Kareem D	Utilities Inst Repair I	A50550	08/27/2018	32470	25743.94
3	Aaron	Patricia G	Office Services II	A03031	10/24/1979	60200	57806.13
4	Abadir	Adam O	Council Technician	A02002	12/12/2016	64823	64774.11
5	Abaku	Aigbolosimuan O	Police Officer	A99094	04/17/2018	53640	59361.55
6	Abbeduto	Mack	Assistant State Attorney	A29011	05/22/2017	68562	61693.59
7	Abbott	Ethan N	Recreation Arts Instructor	A68002	04/11/2018	33280	26156.48
8	AbbottCole	Michelle	Operations Officer III	A90005	11/28/2014	75110	75529.99
9	Abdal Rahim	Naim A	Fire Pump Operator Suppression	A64120	03/30/2011	69595	82132.61
10	Abdi	Ezekiel W	Police Sergeant	A99160	06/14/2007	93284	122992.1
11	Abdul Adl	Attrice A	Radio Dispatcher Sheriff	A38410	09/02/1999	50079	58459.78
12	Abdul Aziz	Hajr E	Swimming Pool Operator	P04002	06/01/2017	28554	15807.64
13	Abdul Aziz	Yaqub M	Swimming Pool Operator	P04002	06/01/2017	28554	6417.9
14	Abdul Saboor	Dana N	Paralegal	A99393	04/13/1998	57857	35715.2
15	Abdul	Jalil	Engineer I	A50101	07/17/2017	64505	65577.5
16	Abdul-Jabbar	Bushra A	Social Service Coordinator	A65028	04/14/2008	46395	46359.55
17	Abdul-Khaliq	Amahl	Recreation Leader II	A04005	06/06/2019	32131	5344.5
18	Abdullah	Beverly A	Office Support Specialist III	A06004	12/01/1986	41757	44522.96
19	Abdullahi	Sharon M	911 Operator	A64604	Wednesday, 6 October 2004	56322	53751.88
20	Abdullateef	Muhammed L	Supt of Public Bldg Repair	A85001	05/09/2019	78000	9000
21	Abdulrahman	Mustafa H	Police Officer Trainee	A99416	12/28/2018	53512	25347.99
22	Abdul Saboor	Jamillah	Printer Library	A75055	07/27/2009	44584	42555.83
23	Abdunafi	Karim	Community Aide	A04015	06/13/2019	24960	9888.55
24	Abdur-Rahman	Diane	Office Services I	A03092	03/27/2017	25363	25649.94
25	Abdurrahman	Saleh Z	Lifeguard I	P04002	06/04/2019	23920	1245.5
26	Abebe	Miraf E	Auditor II	A24002	Saturday, 2 June 2012	67236	60600.92
27	Abend Kollin	Emily L	Fleet Quality Control Analyst	A85301	01/05/2017	47828	49133.11
28	Abid	Amal	Engineer II	A49102	12/02/2013	71774	71630.83
29	Abid	Paula	Recreation Arts Instructor	A04009	06/25/2007	24960	3591.96

Suragh: Row Patterns – Outlier Rows

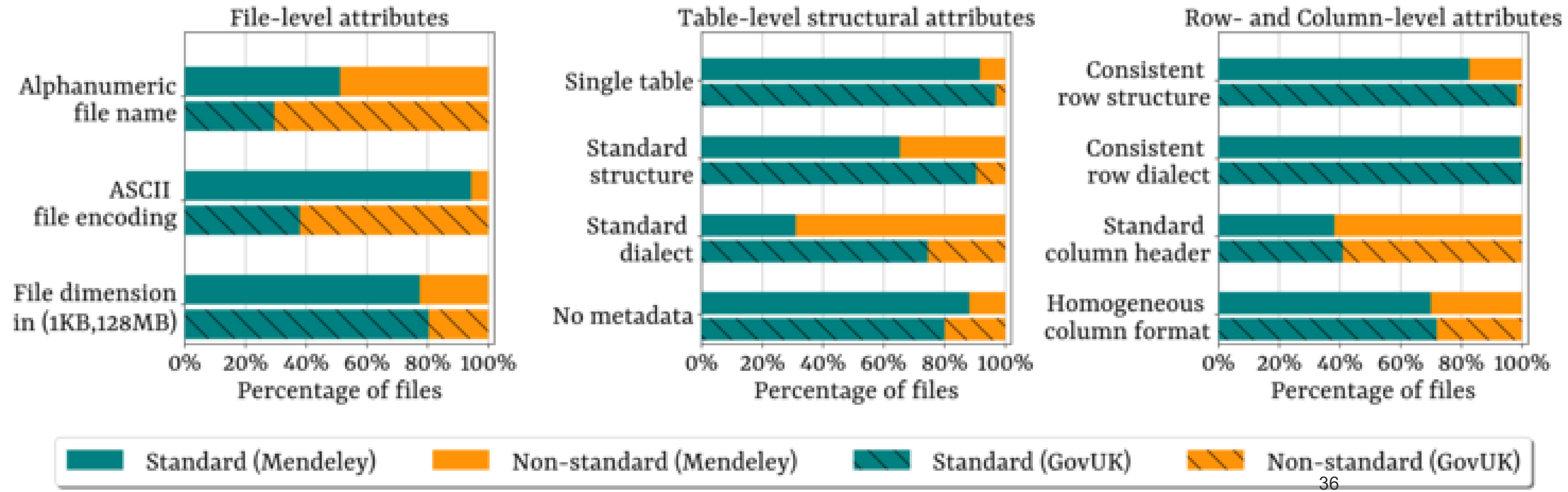
```
SFY,Fund_Source,Age,Total Children Receiving CHDP Services,Total,...
2008-2009,All,0,557757,24.34%,"$21,840,767 ",38.03%
2008-2009,All,1,314994,13.75%,"$7,262,306 ",12.64%
                    ...
2008-2009,All,10,55674,2.43%,"$1,146,066 ",2.00%SFY,Fund_Source,...
2008-2009,All,0,557757,24.34%,"$21,840,767 ",38.03%
2008-2009,All,1,314994,13.75%,"$7,262,306 ",12.64%
                    ...
2008-2009,All,Unknown,1063,0.05%,$0 ,0.00%
2008-2009,All,TOTAL,2291689,100.00%,"$57,436,517 ",100.00%
2008-2009,FFS,0,169699,41.75%,"$14,450,511 ",45.16%
2008-2009,FFS,1,48823,12.01%,"$5,157,938 ",16.12%
2008-2009,FFS,2,29241,7.19%,"$2,019,526 ",6.31%
                    ...
2008-2009,FFS,UNKNOWN,0,0.00%,$0 ,0.00%
2008-2009,FFS,TOTAL,406504,100.00%,"$31,995,243 ",100.00%
2008-2009,GFS,0,91612,33.09%,"$7,363,856 ",31.33%
2008-2009,GFS,1,22723,8.21%,"$2,061,059 ",8.77%
                    ...
```

2008-2009	All	<SEQD>	<SEQD>	<SEQD>.<SEQD>%	"$<NUM> "	<SEQD>.<SEQD>%
2008-2009	<UL><UL><UL>	<SEQD>	<SEQD>	<SEQD>.<SEQD>%	"$<NUM> "	<SEQD>.<SEQD>%

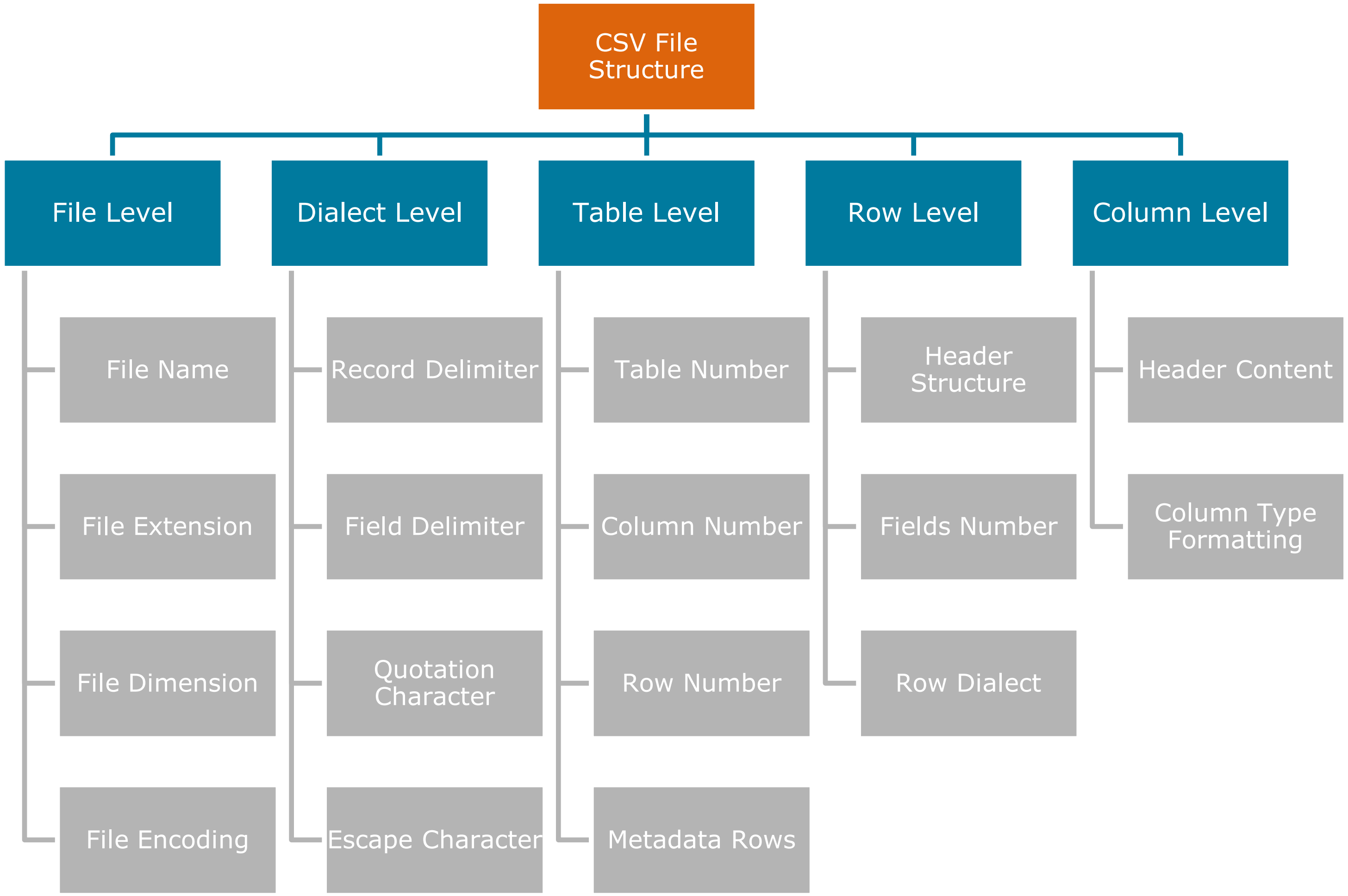
```
Python 3.8.5 (default, Sep  3 2020, 21:29:08) [MSC v.1916 64 bit (AMD64)] :: Anaconda, Inc. on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> import pandas as pd
>>> pd.read_csv("11-708-data-nlss-2009-1.csv")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "C:\Users\User\miniconda3\envs\pollution\lib\site-packages\pandas\io\parsers.py", line 686, in read_csv
    return _read(filepath_or_buffer, kwds)
  File "C:\Users\User\miniconda3\envs\pollution\lib\site-packages\pandas\io\parsers.py", line 458, in _read
    data = parser.read(nrows)
  File "C:\Users\User\miniconda3\envs\pollution\lib\site-packages\pandas\io\parsers.py", line 1196, in read
    ret = self._engine.read(nrows)
  File "C:\Users\User\miniconda3\envs\pollution\lib\site-packages\pandas\io\parsers.py", line 2155, in read
    data = self._reader.read(nrows)
  File "pandas\_libs\parsers.pyx", line 847, in pandas._libs.parsers.TextReader.read
  File "pandas\_libs\parsers.pyx", line 862, in pandas._libs.parsers.TextReader._read_low_memory
  File "pandas\_libs\parsers.pyx", line 918, in pandas._libs.parsers.TextReader._read_rows
  File "pandas\_libs\parsers.pyx", line 905, in pandas._libs.parsers.TextReader._tokenize_rows
  File "pandas\_libs\parsers.pyx", line 2042, in pandas._libs.parsers.raise_parser_error
pandas.errors.ParserError: Error tokenizing data. C error: Expected 25 fields in line 97, saw 27
```

Pollock: Raw Data Survey

- Manual Annotation
  - 1,438 random files from GovUK
  - 2,274 random files from Mendeley



Pollock: Benchmark Dimensions and Results

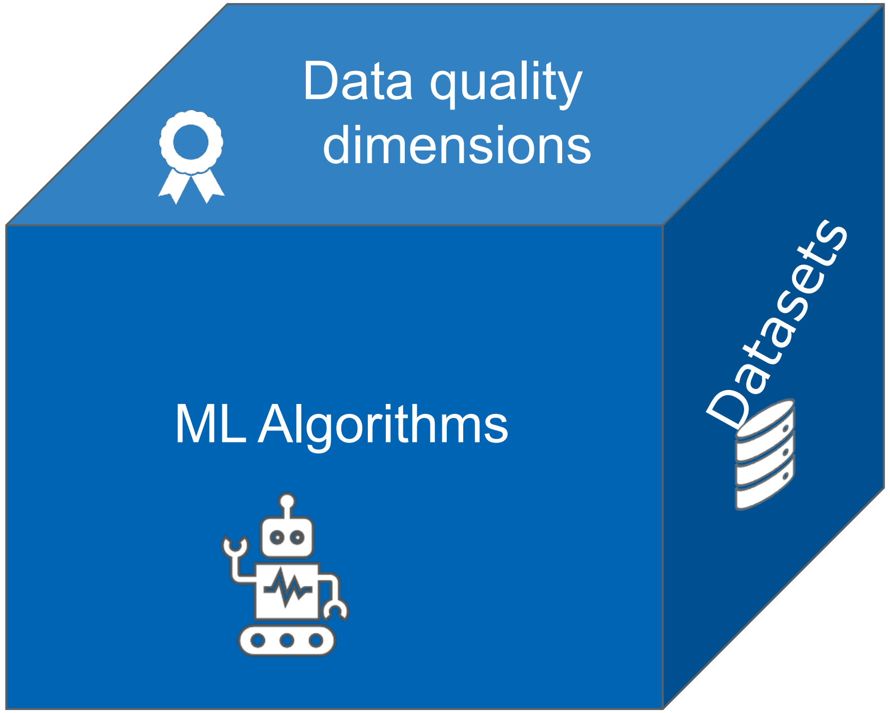


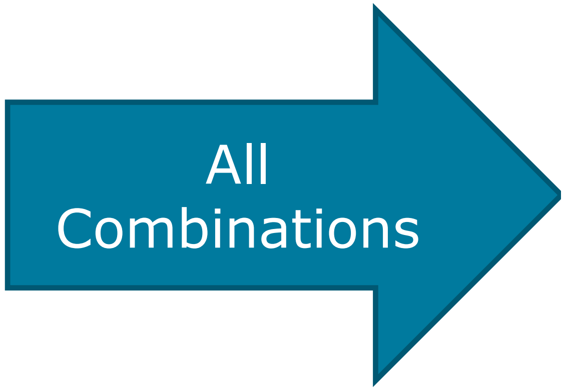
	Pollock score (2 289 +1) files Simple	Pollock score (2 289 +1) files Weighted
CleverCSV 0.7.4	9.05	9.49
CSVCommons 1.9.0	6.63	9.29
Hypoparsr 0.1.0	3.73	4.41
OpenCSV 5.6	6.62	7.80
Pandas 1.4.3	9.88	9.75
PyCsv 3.10.5	9.71	9.47
RCsv 4.2.1	7.78	6.76
Univocity 2.9.1	9.35	7.97
MariaDB 10.9.3	8.81	7.44
MySQL 8.0.31	8.88	7.45
PostgreSQL 15.0	0.14	7.33
SQLite 3.39.0	9.94	9.73
Calc 7.3.6	9.75	7.52
SpreadDesktop	9.79	9.29
SpreadWeb	9.65	9.29
DataViz	4.93	5.51

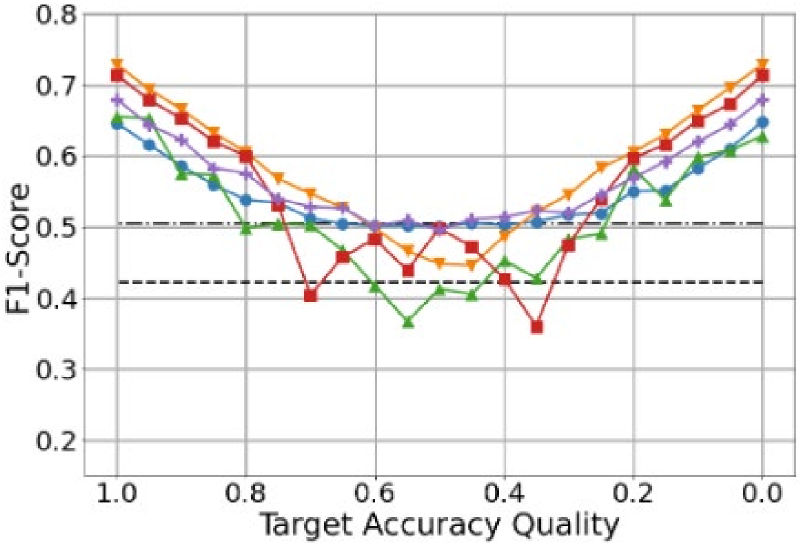
Agenda

1. Data and Information Quality Research
2. Data Preparation
3. **Data Quality and AI Systems**
   - With Hazar Harmouch, Sedir Mohammed et al.
4. Data Quality Assessment

Empirical Measurement of the Effects of Poor Data Quality on ML Results







https://arxiv.org/abs/2207.14529

Measurement Dimensions

Pollutions

- Consistent representation
- Completeness
- Feature accuracy
- Target accuracy
- Uniqueness
- Target balance

Runs

- 5 runs, average

Datasets

- TelcoChurn, GermanCredit, Contraceptive
- Houses, IMDB, Cars
- Bank, Covertype, Letter

Tasks and algorithms

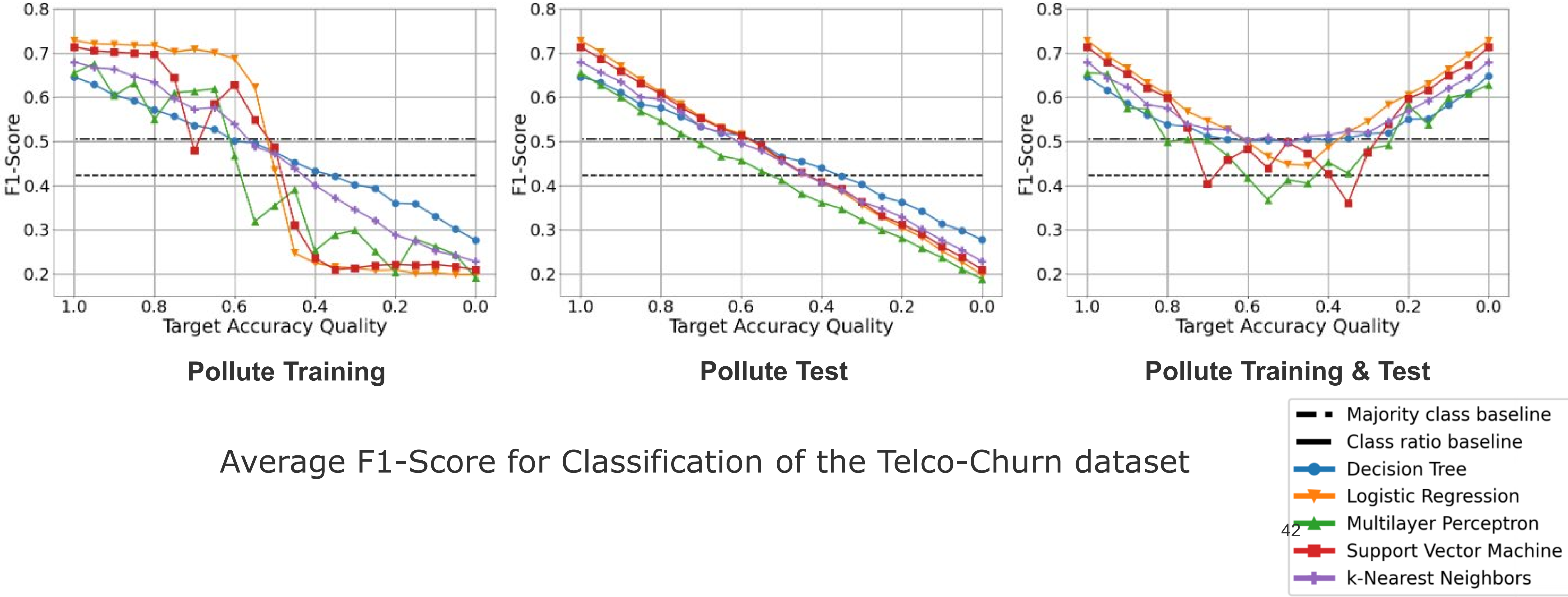
- Classification
  - LogR, SVM, DT, GB, KNN, MLP
- Clustering
  - GM, k-Means, k-Prototypes, AC, OPTICS
- Regression
  - LR, RR, DT, RF, GB, MLP

Scenarios

- Pollute only training data
- Pollute only test data
- Pollute training and test data

Together: 3,780 experiments

Example Results



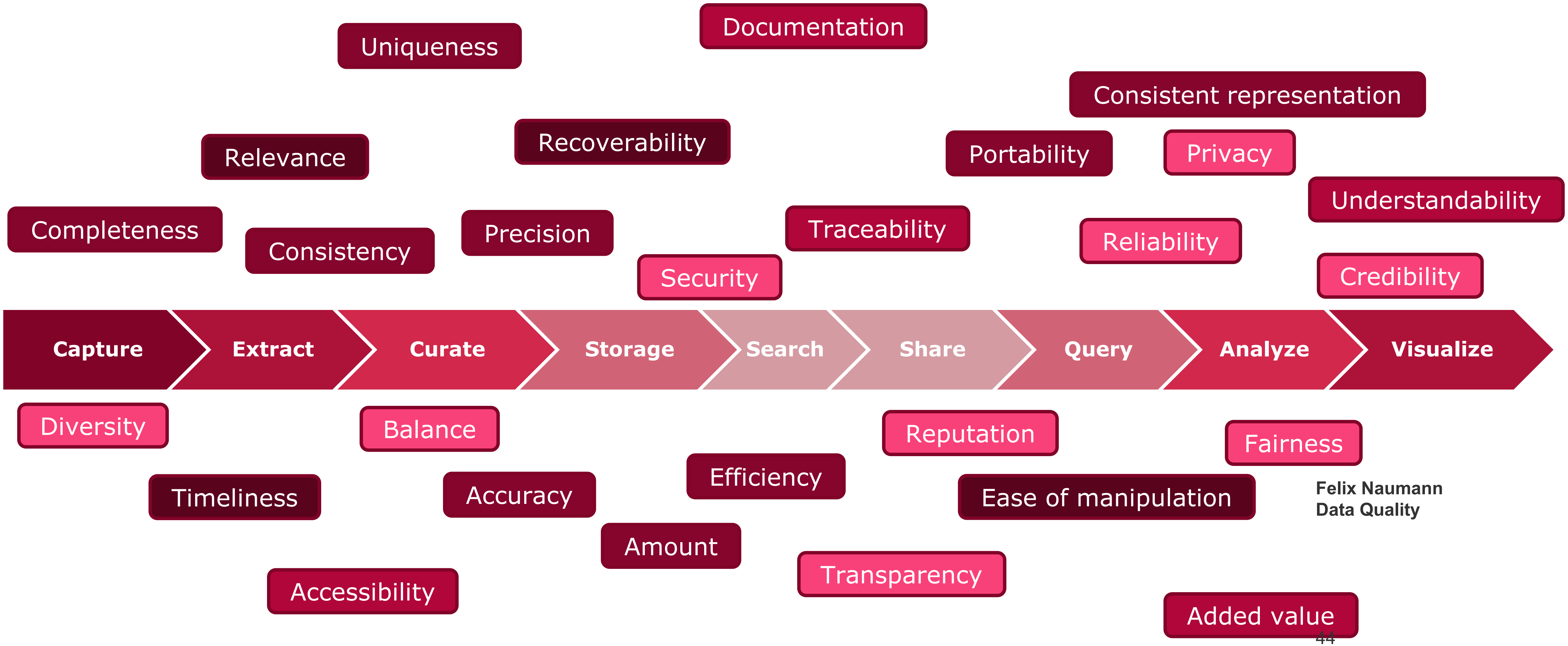
Average F1-Score for Classification of the Telco-Churn dataset

European AI Act Article 10 (3): Data and Data Governance

Training, validation and testing data sets shall be relevant, sufficiently representative, and to the best extent possible, free of errors and complete in view of the intended purpose. They shall have the appropriate statistical properties, including, where applicable, as regards the persons or groups of persons in relation to whom the high-risk AI system is intended to be used.

https://artificialintelligenceact.eu/article/10/

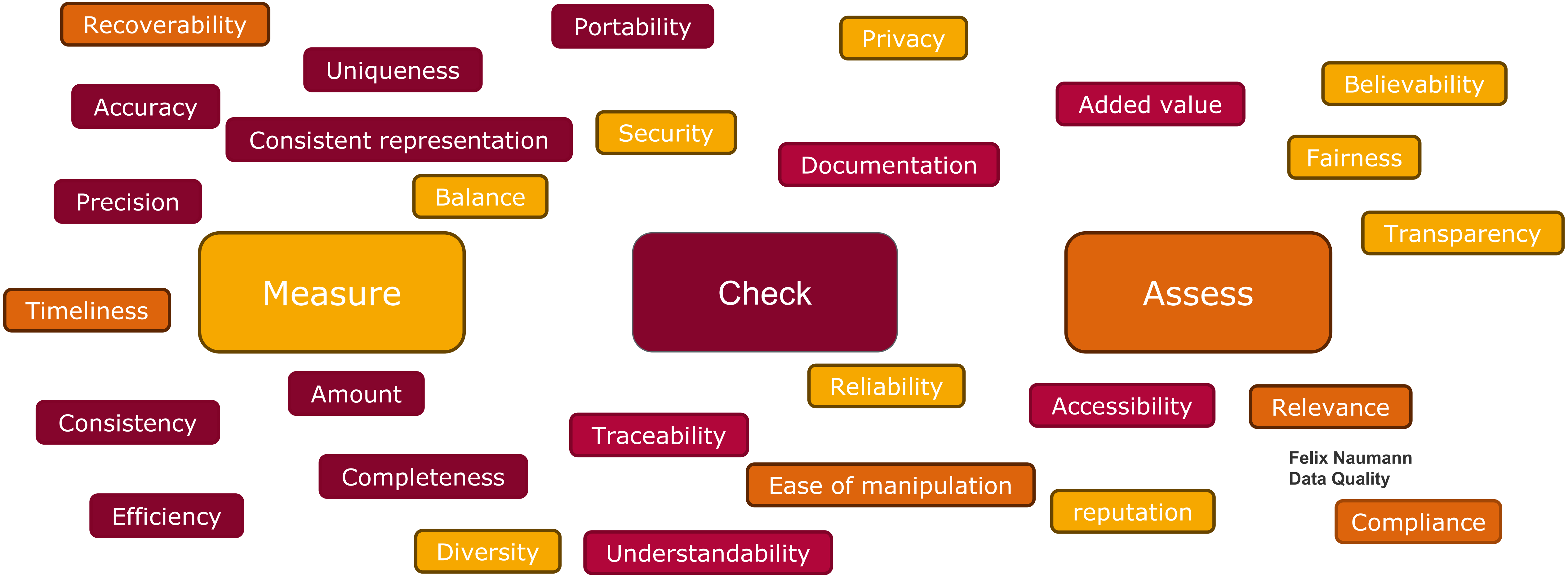
Data Quality along the AI Pipeline



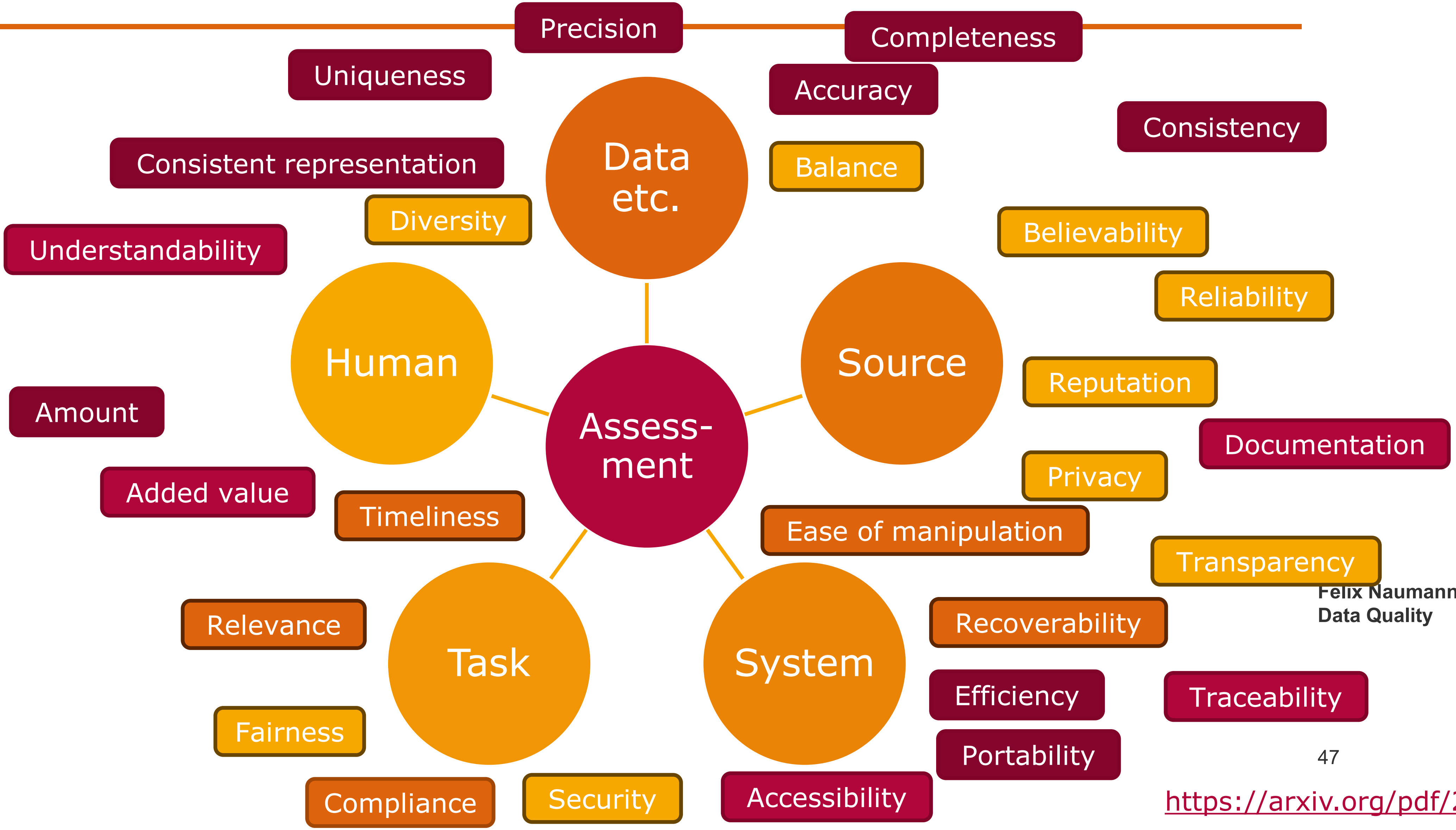
Agenda

1. Data and Information Quality Research
2. Data Preparation
3. Data Quality and AI Systems
4. **Data Quality Assessment**
   - With Hazar Harmouch, Lisa Ehrlinger, Sedir Mohammed and Divesh Srivastava

Assessing Data Quality



Ingredients for DQ Assessment: Five Facets



https://arxiv.org/pdf/2403.00526

Further Challenges for DQ Assessment

- Ambiguity
  - Many attempts to compile and define DQ dimensions
  - Definitions of the dimensions inherently ambiguous
- Explainability
  - Assessment results explainable to consumers
  - Results traceable to their root cause, to improve quality
- Efficiency
  - Assessment effort and time should be low
- Compliance
  - Fulfill organizational data governance processes
  - Comply to a legal framework, e.g., GDPR or the AI Act
- Scoring
  - Aggregate and normalize assessment results to some numeric scale.
  - Allows comparison across datasets and across time
- Adequacy
  - Is the data of sufficient quality or adequate for the task at hand?

Summary

Uniqueness
Relevance
Privacy
Security
Understandability
Accuracy
Consistent representation
Added value
Fairness
Precision
Diversity
Representativity
Reputation
Believability
Documentation
Consistency
Reliability
Completeness
Balance
Traceability
Portability
Accessibility
Amount
Timeliness
Recoverability
Transparency
Efficiency
Ease of manipulation
Representativity
Compliance