HPI Hasso Plattner Institut
IT Systems Engineering | Universität Potsdam

# Bad Files, Bad Data, Bad Results

## Data Centric AI Workshop

Nov. 18 2021

Felix Naumann

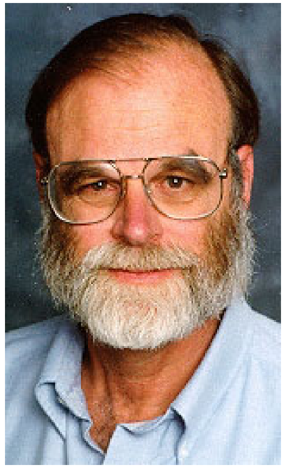
https://www.flickr.com/photos/136315829@N03/27640684175

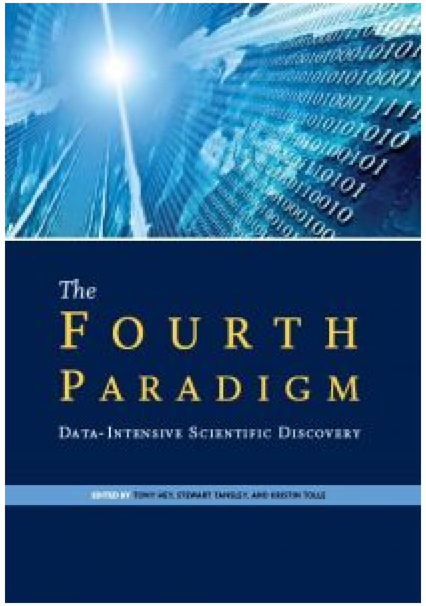
# The Fourth Paradigm of Science

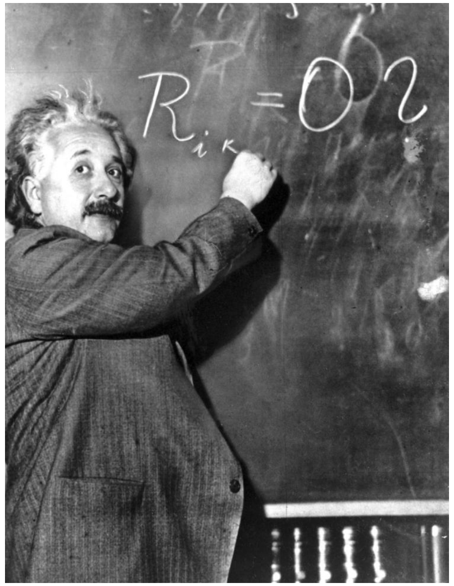
1. Empirical and experimental
2. Theoretical
3. Computational
4. Data-intensive

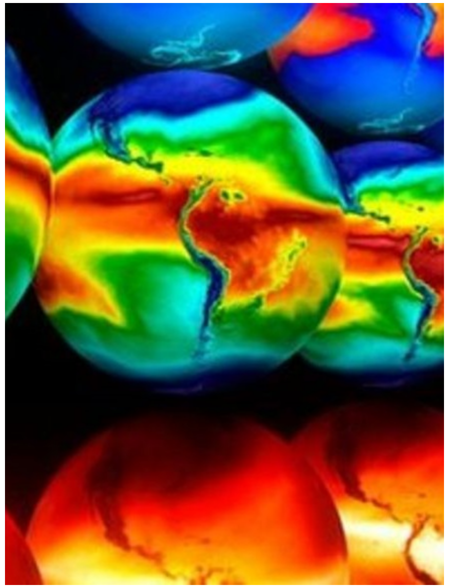
Enabling machine learning and AI

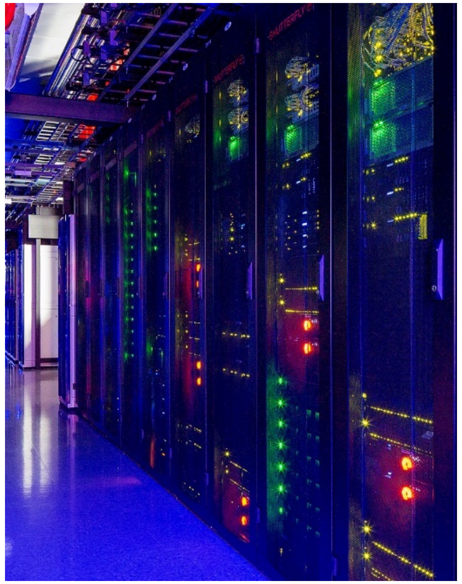
*We have to do better producing tools to support the whole research cycle - from data capture and data curation to data analysis and data visualization.* Jim Gray



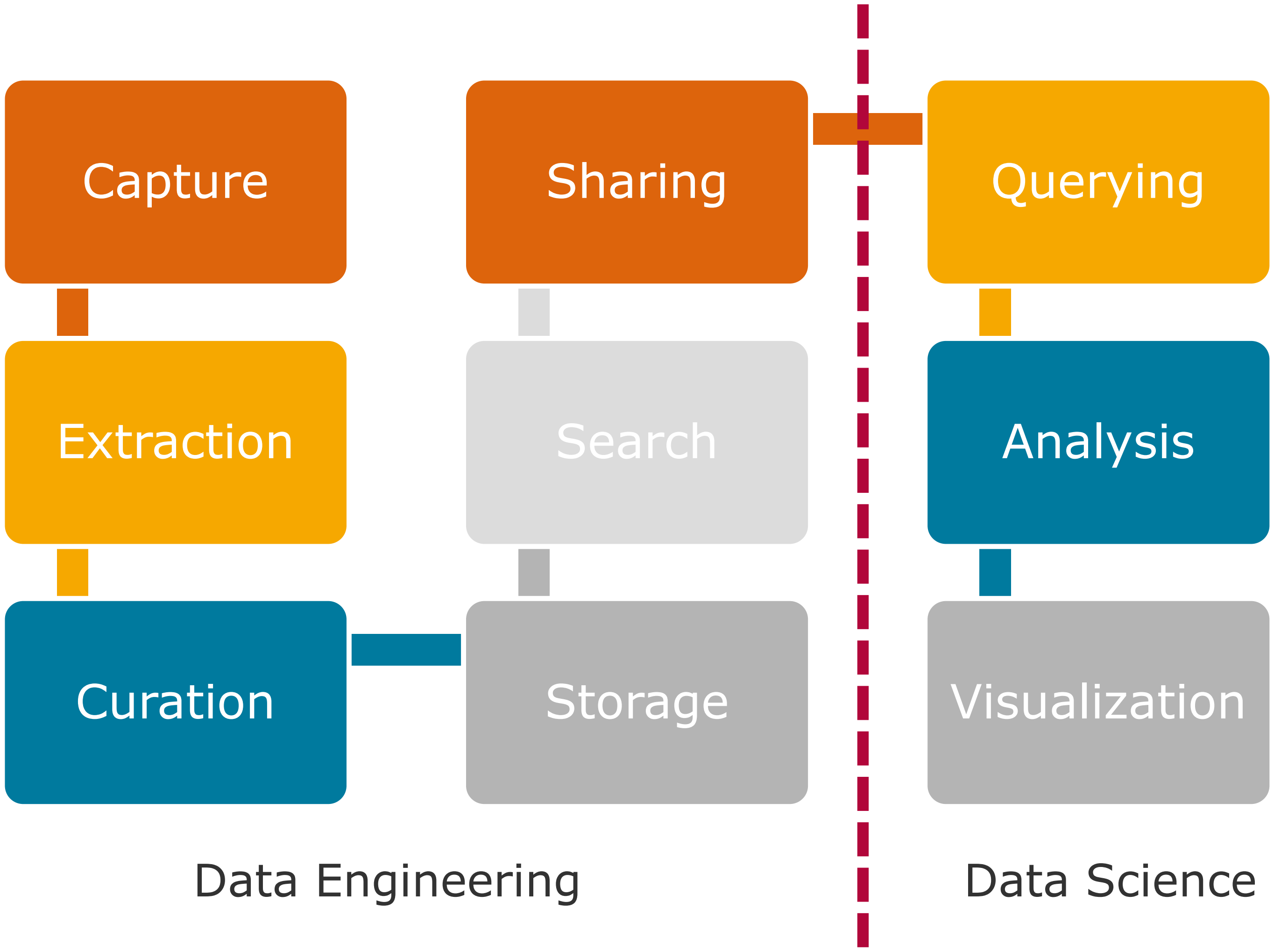




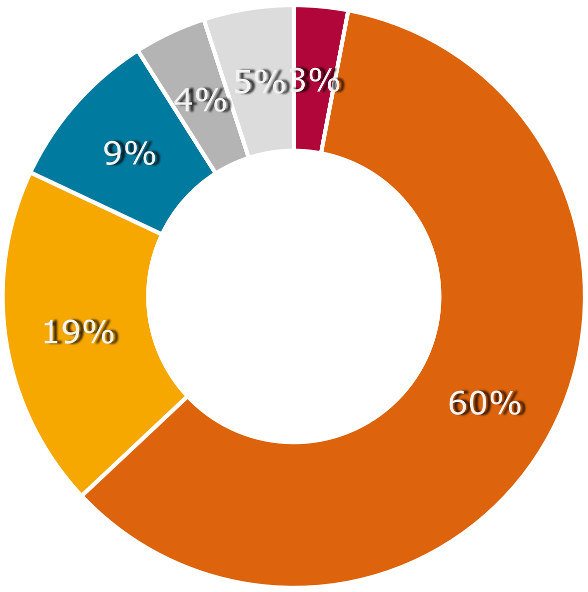


# Data Science Pipeline



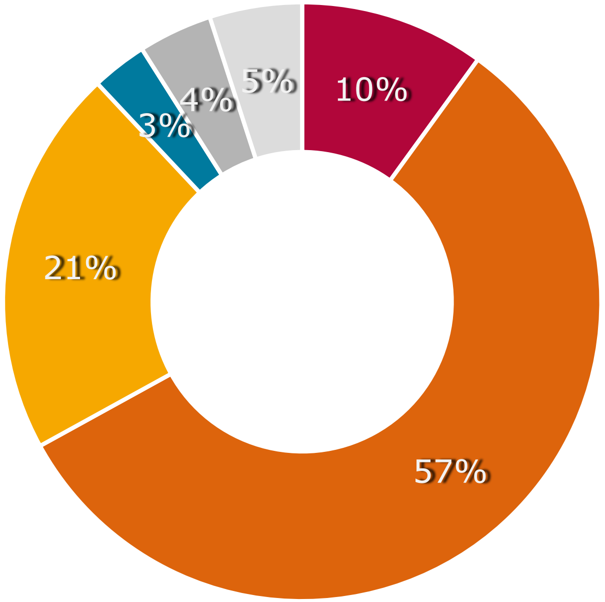
# Data preparation and cleaning in reality

## What data scientists spend the most time doing?




- Building training sets: 3%
- Cleaning and organizing data: 60%
- Collecting data sets: 19%
- Mining data for patterns: 9%
- Refining algorithms: 4%
- Others: 5%

## What is the least enjoyable part of data science?




- Building training sets: 10%
- Cleaning and organizing data: 57%
- Collecting data sets: 21%
- Mining data for patterns: 3%
- Refining algorithms: 4%
- Others: 5%

“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 and Cleaning: Tasks and Tools

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

- And for data scientists
  - Feature selection
  - Feature extraction

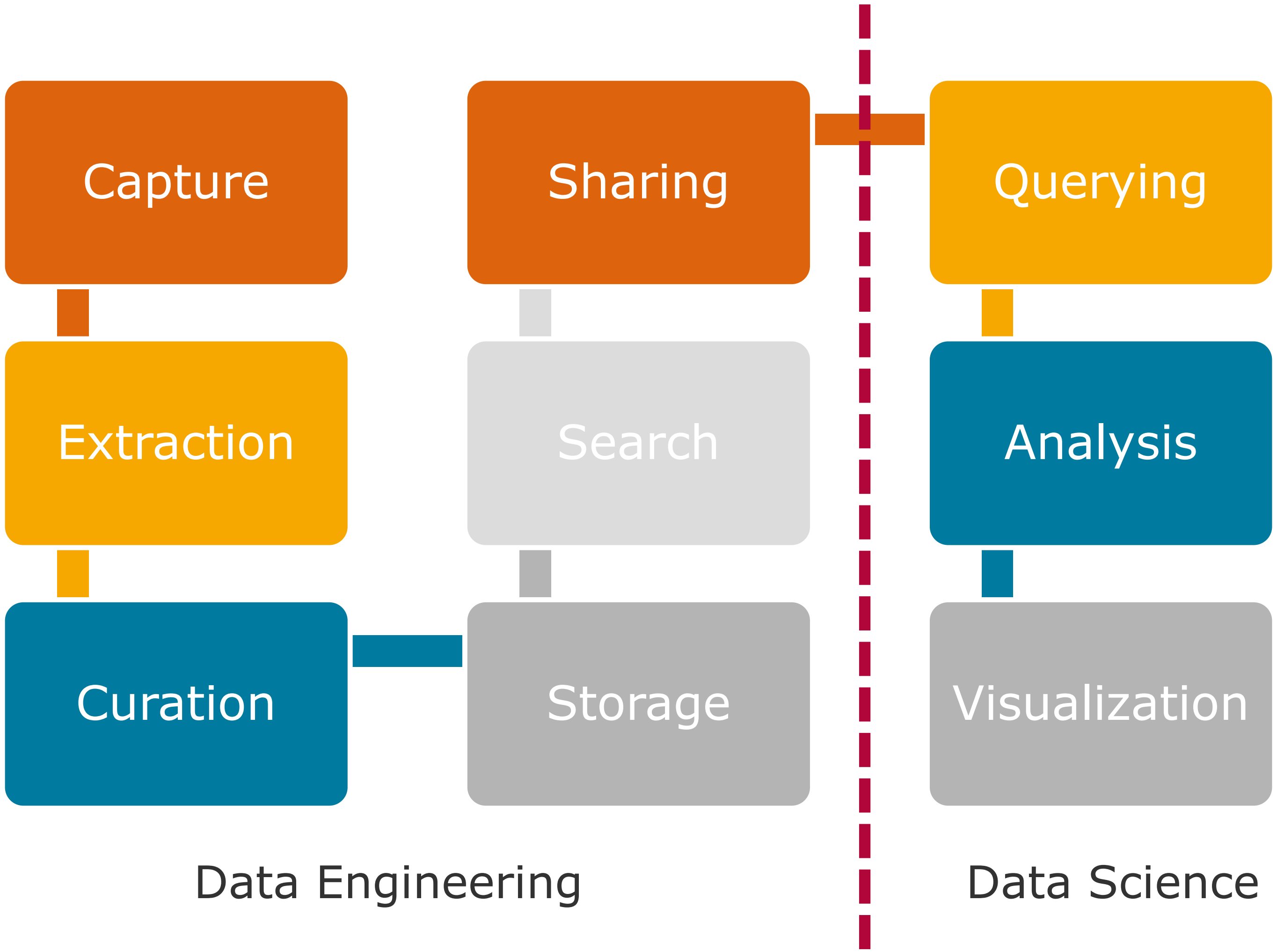
| Categories | Available features | Data preparation tools | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Altair | Paxata | SAP | SAS | Tableau | Talend | Trifacta |
| Data discovery | Locate missing values (nulls) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Locate outliers | | ✓ | | ✓ | | | ✓ |
| | Search by pattern | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Sort data | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Data validation | Compare values (selection and join) | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ |
| | Check data range | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ |
| | Check permitted characters | | | | | | | ✓ |
| | Check column uniqueness | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ |
| | Find type-mismatched data | | ✓ | ✓ | | ✓ | ✓ | ✓ |
| | Find data-mismatched datatypes | | ✓ | | | | ✓ | ✓ |
| Data structuring | Change column data type | [illegible] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Delete column | [illegible] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Detect & change encoding | [illegible] | [illegible] | [illegible] | | | ✓ | ✓ |
| | Pivot / unpivot | [illegible] | [illegible] | [illegible] | [illegible] | ✓ | | ✓ |
| | Rename column | [illegible] | [illegible] | [illegible] | [illegible] | ✓ | ✓ | ✓ |
| | Split column | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | ✓ | ✓ |
| | Transform by example [13] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | ✓ |
| Data enrichment | Assign semantic data type | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| | Calculate column using ex[illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| | Discover & merge externa[illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| | Duplicate column | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| | Generate primary key colu[illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| | Join & union | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | ✓ |
| | Merge columns | ✓ | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | ✓ |
| | Normalize numeric values | ✓ | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | ✓ |
| Data filtering | Delete/keep filtered rows | ✓ | ✓ | [illegible] | [illegible] | [illegible] | [illegible] | ✓ |
| | Delete empty and invalid rows | ✓ | ✓ | ✓ | [illegible] | [illegible] | [illegible] | ✓ |
| | Extract value parts | ✓ | | | ✓ | [illegible] | [illegible] | ✓ |
| | Filter with regular expressions | | | | | [illegible] | [illegible] | ✓ |
| 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 | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

Mazhar Hameed, Felix Naumann: Data Preparation: A Survey of Commercial Tools. SIGMOD Record 49:(3) 2020 (link)

| Tool name | URL |
|---|---|
| **Altair Monarch Data Preparation** | https://www.datawatch.com/in-action/monarch-draft/ |
| Alteryx Data Preparation | https://www.alteryx.com/solutions/analytics-need/data-preparation |
| BigGorilla Data Preparation | https://www.biggorilla.org/ |
| Cambridge Semantics Anzo | https://www.cambridgesemantics.com/ |
| Datameer | https://www.datameer.com/ |
| EasyMorph Data Preparation and Automation | https://easymorph.com/ |
| Erwin | https://erwin.com/ |
| FICO | https://www.fico.com/ |
| Google Cloud Data Prep by Trifacta | https://cloud.google.com/dataprep/ |
| Hitachi-Pentaho Business Analytics | https://www.hitachivantara.com/en-us/products/data-management-analytics.html |
| IBM Data Refinery | https://www.ibm.com/cloud/data-refinery |
| INFOGIX | https://www.infogix.com/data3sixty/analyze/ |
| Informatica Enterprise Data Preparation | https://www.informatica.com/products/data-catalog/enterprise-data-prep.html |
| Looker | https://looker.com/ |
| Lore IO | https://www.getlore.io/ |
| Microsoft Power BI | https://powerbi.microsoft.com/en-us/ |
| MicroStrategy | https://www.microstrategy.com/us/product/analytics/data-visualization |
| Modak-nabu | https://modakanalytics.com/nabu.html |
| OpenRefine | http://openrefine.org/ |
| Oracle Analytics Cloud | https://www.oracle.com/business-analytics/analytics-cloud.html |
| **Paxata Self Service Data Preparation** | https://www.paxata.com/self-service-data-prep/ |
| Qlik Data Catalyst | https://www.qlik.com/us/products/qlik-data-catalyst |
| Quest Toad Data Point | https://www.quest.com/products/toad-data-point/ |
| Rapid Insight | https://www.rapidinsight.com/solutions/data-preparation/ |
| RapidMiner Turbo Prep | https://rapidminer.com/products/turbo-prep/ |
| **SAP Agile Data Preparation** | https://www.sap.com/germany/products/data-preparation.html |
| **SAS Data Preparation** | https://www.sas.com/en_us/software/data-preparation.html |
| Smarten Advanced Data Discovery | https://www.smarten.com/self-serve-data-preparation.html |
| Solix Common Data Platform | https://www.solix.com/products/solix-common-data-platform/ |
| Sparkflows | https://www.sparkflows.io/data-science |
| **Tableau Prep** | https://www.tableau.com/products/prep |
| **Talend Data Preparation** | https://www.talend.com/products/data-preparation/ |
| Tamr | https://www.tamr.com/ |
| Teradata Vantage | https://www.teradata.com/Products/Software/Vantage |
| TIBCO Spotfire Analytics | https://www.tibco.com/products/tibco-spotfire |
| TMMData | https://www.tmmdata.com/ |
| **Trifacta Wrangler** | https://www.trifacta.com/products/wrangler-editions/ |
| Unifi Data Platform | https://unifisoftware.com/platform/ |
| Waterline Data | https://www.waterlinedata.com/ |
| Workday-Prism Analytics | https://www.workday.com/en-us/applications/analytics/prism-analytics.html |
| Yellowfin Data Prep | https://www.yellowfinbi.com/suite/data-prep |
| Zoho Analytics | https://www.zoho.com/analytics/ |

# Overview

1. **Bad Files**
2. Bad Data
3. Bad Results



# Data Sources – Data Formats

- Data lakes
- Open (government) data
- Instrumented processes
- Sensor data
- Experimental output
- Database exports
- Excel

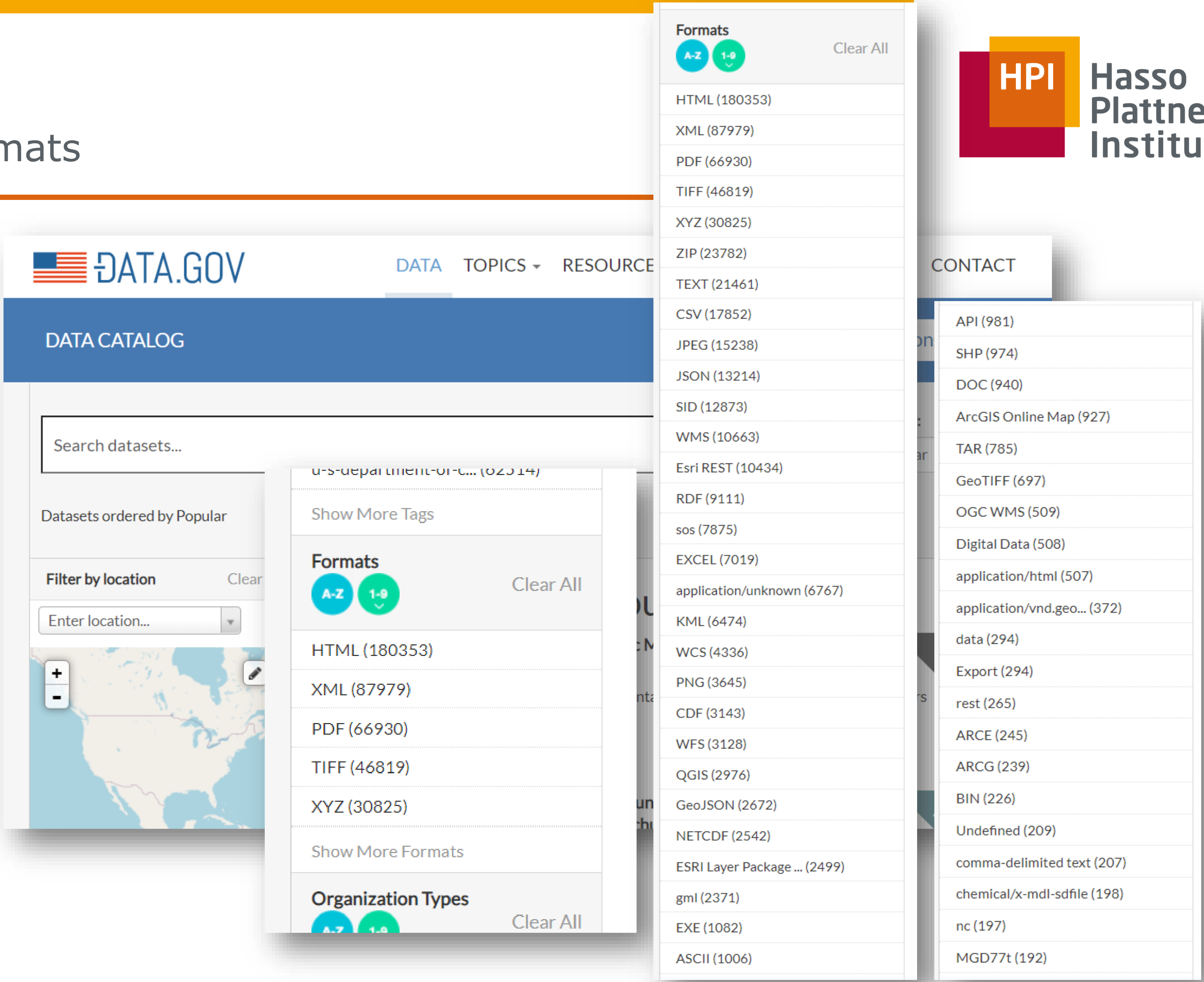


Table rv.03.q: Removals and voluntary departures by country of nationality and type

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 Q1 | Europe | Turkey | **48** | **39** | **79** | **22** | **39** | **74** | 0 | 23 | 51 | **26** | **5** | 0 | |
| 2011 Q1 | Europe | Turkmenistan | **2** | **3** | **10** | **1** | **3** | **9** | 0 | 0 | 9 | **1** | **1** | 0 | |
| 2011 Q1 | Americas | Turks and Caicos Islands (British) | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q1 | Oceania | Tuvalu | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q1 | Africa | Uganda | **24** | **3** | **58** | **7** | **3** | **50** | 4 | 8 | 38 | **17** | **8** | 7 | |
| 2011 Q1 | Europe | Ukraine | **53** | **63** | **39** | **46** | **63** | **36** | 0 | 12 | 24 | **7** | **3** | 2 | |
| 2011 Q1 | Middle East | United Arab Emirates | **0** | **1** | **5** | **0** | **1** | **5** | 0 | 0 | 5 | **0** | **0** | 0 | |
| 2011 Q1 | Americas | United States | **14** | **472** | **91** | **14** | **472** | **88** | 0 | 35 | 53 | **0** | **3** | 3 | |
| 2011 Q1 | Americas | Uruguay | **1** | **3** | **0** | **0** | **3** | **0** | 0 | 0 | 0 | **1** | **0** | 0 | |
| 2011 Q1 | Europe | Uzbekistan | **22** | **1** | **46** | **20** | **1** | **46** | 0 | 8 | 38 | **2** | **0** | 0 | |
| 2011 Q1 | Oceania | Vanuatu | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q1 | Europe | Vatican City | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q1 | Americas | Venezuela | **2** | **45** | **5** | **0** | **45** | **5** | 0 | 3 | 2 | **2** | **0** | 0 | |
| 2011 Q1 | Asia | Vietnam | **249** | **24** | **77** | **190** | **24** | **72** | 2 | 10 | 60 | **59** | **5** | 3 | |
| 2011 Q1 | Americas | Virgin Islands (British) | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q1 | Americas | Virgin Islands (US) | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q1 | Oceania | Wallis and Futuna | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q1 | Africa | Western Sahara | **2** | **0** | **0** | **2** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q1 | Middle East | Yemen | **2** | **0** | **2** | **2** | **0** | **2** | 0 | 2 | 0 | **0** | **0** | 0 | |
| 2011 Q1 | Africa | Zambia | **3** | **3** | **27** | **3** | **3** | **26** | 5 | 6 | 15 | **0** | **1** | 1 | |
| 2011 Q1 | Africa | Zimbabwe | **7** | **3** | **73** | **3** | **3** | **35** | 1 | 8 | 26 | **4** | **38** | 29 | |
| 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 | |
| 2011 Q2 | Africa | *Total Africa | **703** | **611** | **970** | **377** | **611** | **811** | 28 | 357 | 426 | **326** | **159** | 62 | |
| 2011 Q2 | Americas | *Total Americas | **343** | **1.367** | **652** | **301** | **1.367** | **643** | 55 | 194 | 394 | **42** | **9** | 0 | |
| 2011 Q2 | Asia | *Total Asia | **1.790** | **888** | **2.892** | **1.006** | **888** | **2.526** | 61 | 812 | 1.653 | **784** | **366** | 193 | |
| 2011 Q2 | Europe | *Total Europe | **512** | **638** | **356** | **418** | **638** | **318** | 9 | 92 | 217 | **94** | **38** | 7 | |
| 2011 Q2 | Middle East | *Total Middle East | **98** | **192** | **240** | **22** | **192** | **144** | 1 | 47 | 96 | **76** | **96** | 39 | |
| 2011 Q2 | Oceania | *Total Oceania | **4** | **153** | **38** | **3** | **153** | **38** | 0 | 16 | 22 | **1** | **0** | 0 | |
| 2011 Q2 | Other | *Total Other | **6** | **114** | **8** | **3** | **114** | **8** | 0 | 7 | 1 | **3** | **0** | 0 | |
| 2011 Q2 | Asia | Afghanistan | **296** | **70** | **69** | **17** | **70** | **4** | 0 | 3 | 1 | **279** | **65** | 34 | |
| 2011 Q2 | Europe | Albania | **100** | **187** | **25** | **53** | **187** | **19** | 0 | 11 | 8 | **47** | **6** | 2 | |
| 2011 Q2 | Africa | Algeria | **49** | **32** | **42** | **17** | **32** | **21** | 0 | 11 | 10 | **32** | **21** | 3 | |
| 2011 Q2 | Oceania | American Samoa | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q2 | Europe | Andorra | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q2 | Africa | Angola | **7** | **19** | **12** | **1** | **19** | **4** | 0 | 0 | 4 | **6** | **8** | 4 | |
| 2011 Q2 | Americas | Anguilla (British) | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q2 | Americas | Antigua and Barbuda | **0** | **6** | **1** | **0** | **6** | **1** | 0 | 1 | 0 | **0** | **0** | 0 | |
| 2011 Q2 | Americas | Argentina | **4** | **30** | **4** | **4** | **30** | **4** | 1 | 2 | 1 | **0** | **0** | 0 | |
| 2011 Q2 | Europe | Armenia | **2** | **3** | **1** | **1** | **3** | **0** | 0 | 0 | 0 | **1** | **1** | 0 | |
| 2011 Q2 | Americas | Aruba | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |
| 2011 Q2 | Oceania | Australia | **1** | **120** | **24** | **1** | **120** | **24** | 0 | 8 | 16 | **0** | **0** | 0 | |
| 2011 Q2 | Europe | Austria | **2** | **1** | **0** | **2** | **1** | **0** | 0 | 0 | 0 | **0** | **0** | 0 | |

```
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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
```

Hasso Plattner Institut

# 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 |

| | |
|---|---|
| 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

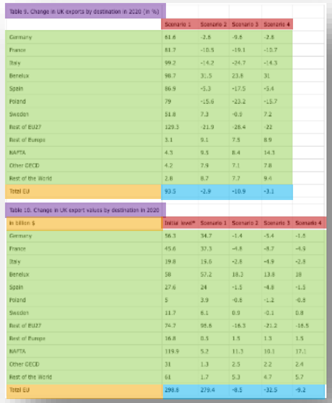
| | MWH | $/MWH | | |
|---|---|---|---|---|
| Firm Block 1: | 0 | $0.00 | $0.00 | |
| Firm Block 2: | 0 | $0.00 | $0.00 | |
| Firm Block 3: | 0 | $0.00 | $0.00 | |
| Firm Block 4: | 0 | $0.00 | $0.00 | |
| Firm Block 5: | 0 | $0.00 | $0.00 | |
| Total: | 0 | NA | $0.00 | $0.00 |
| | MWH | $/MWH | | |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

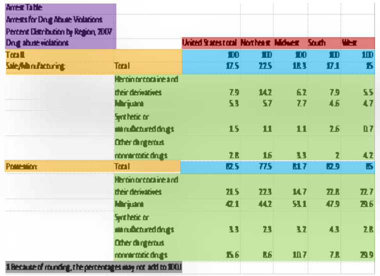
Spin from Ramp rates

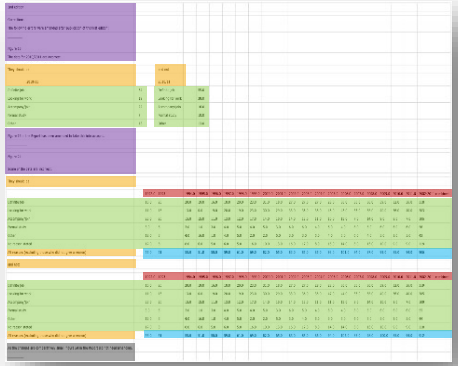
| | Output | Highs' | Spin | RR | unloaded |
|---|---|---|---|---|---|
| Unit 1 | 50 | 80 | 30 | 3 | 30 |
| 2 | 70 | 82 | 12 | 4.5 | 12 |
| 3 | 0 | 0 | 0 | 5.1 | 0 |
| GT1 | 0 | 0 | 0 | 10 | 0 |
| GT2 | 0 | 0 | 0 | 10 | 0 |
| GT1S | 0 | 0 | 0 | 3.33 | 0 |
| GT2S | 0 | 0 | 0 | 3.6 | 0 |
| NM4 | 148 | 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 | | | |

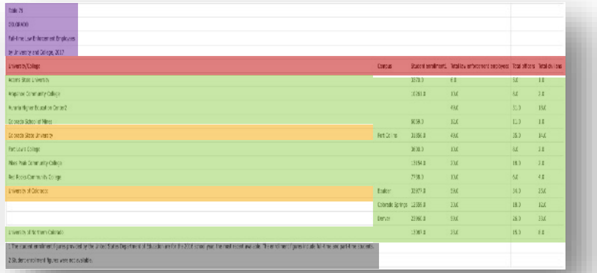
NOTE: * ACTUAL SPIN SHOW MAY BE LESS SINCE UNIT RAMP RATES ARE NOT CONSIDERED.

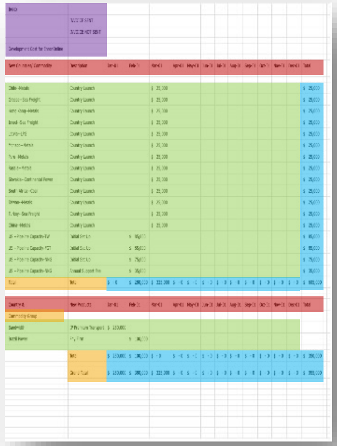
# Structure Diversity in Verbose CSV Files

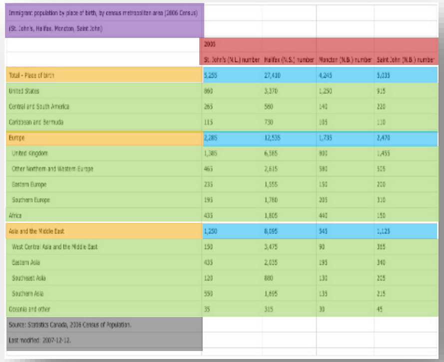


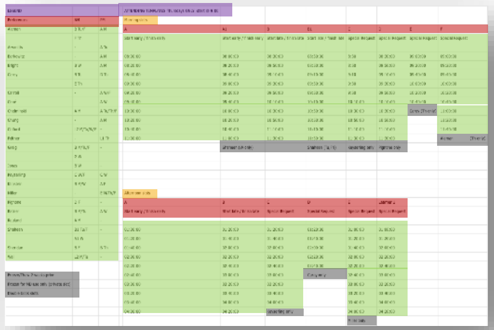


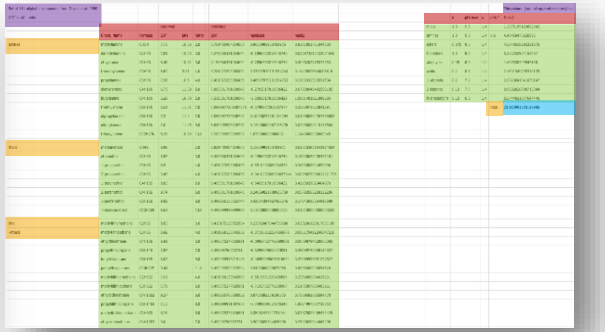












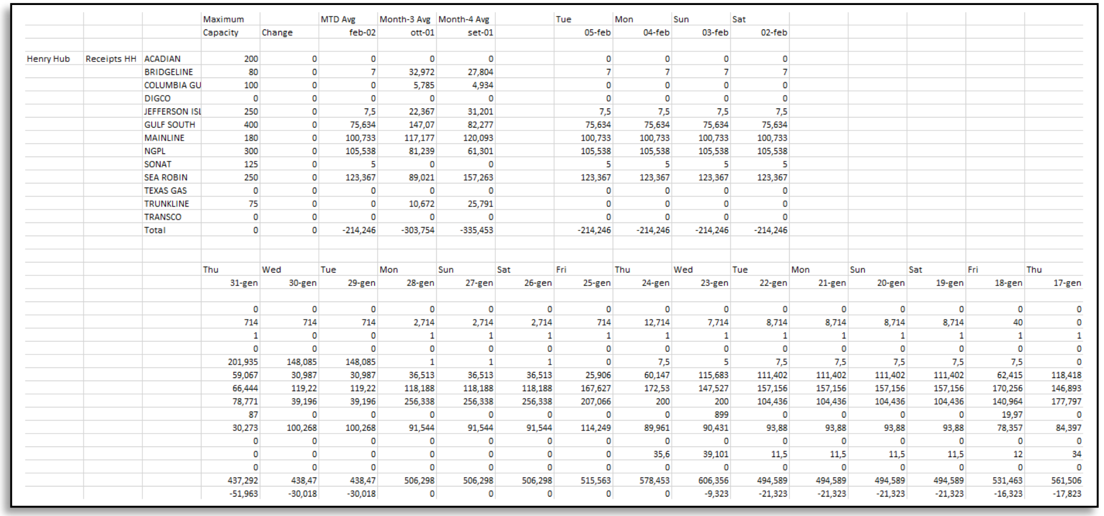
| |
|---|
| Metadata |
| Header |
| Group header |
| Data |
| Aggregation |
| Notes |

# ExtracTable: Bad Files – Worse Files

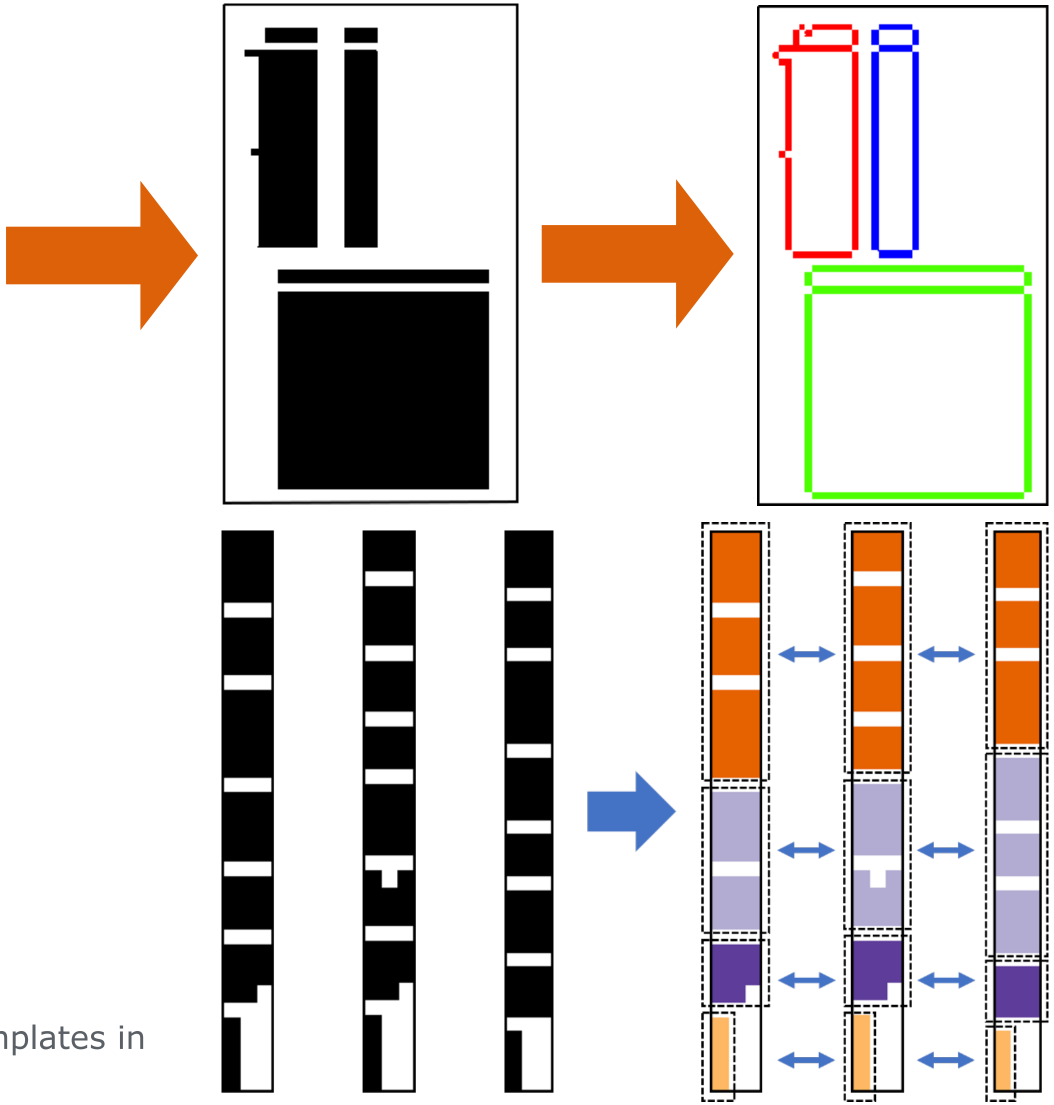
| min | max | num | dist | mean | std | comment |
|---|---|---|---|---|---|---|
| 1.8 | 1.8 | 1 | 0 | 1.5 | 0 | N |
| 20 | 60 | 40 | 1 | 40 | 15 | cab |
| 0 | 0 | 1 | 0 | | | |
| 0 | 1 | 10 | 2 | | | |
| 0.01 | 0.01 | 1 | 0 | | | |
| 0.009 | 0.009 | 1 | 0 | | | |
| 0.2 | 7 | 40 | 1 | | | |
| -0.35 | -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
```

# Automatic 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
4. Cluster files into templates

Gerardo Vitagliano, Lan Jiang, Felix Naumann: Detecting Layout Templates in Complex Multiregion Files. PVLDB vol 15 (accepted)

# Pollock: Benchmarking Ingestion Ability

Systems under test:
- Programming framework (Pandas)
- Spreadsheet software (Libreoffice)
- Database tool (MySQL)
- Data Visualization (Tableau)

```
Python 3.8.5 (default, Sep  3 2020, 21:29:08) [MSC v.1916 64 bi
Type "help", "copyright", "credits" or "license" for more infor
>>> 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: Benchmark Dimensions

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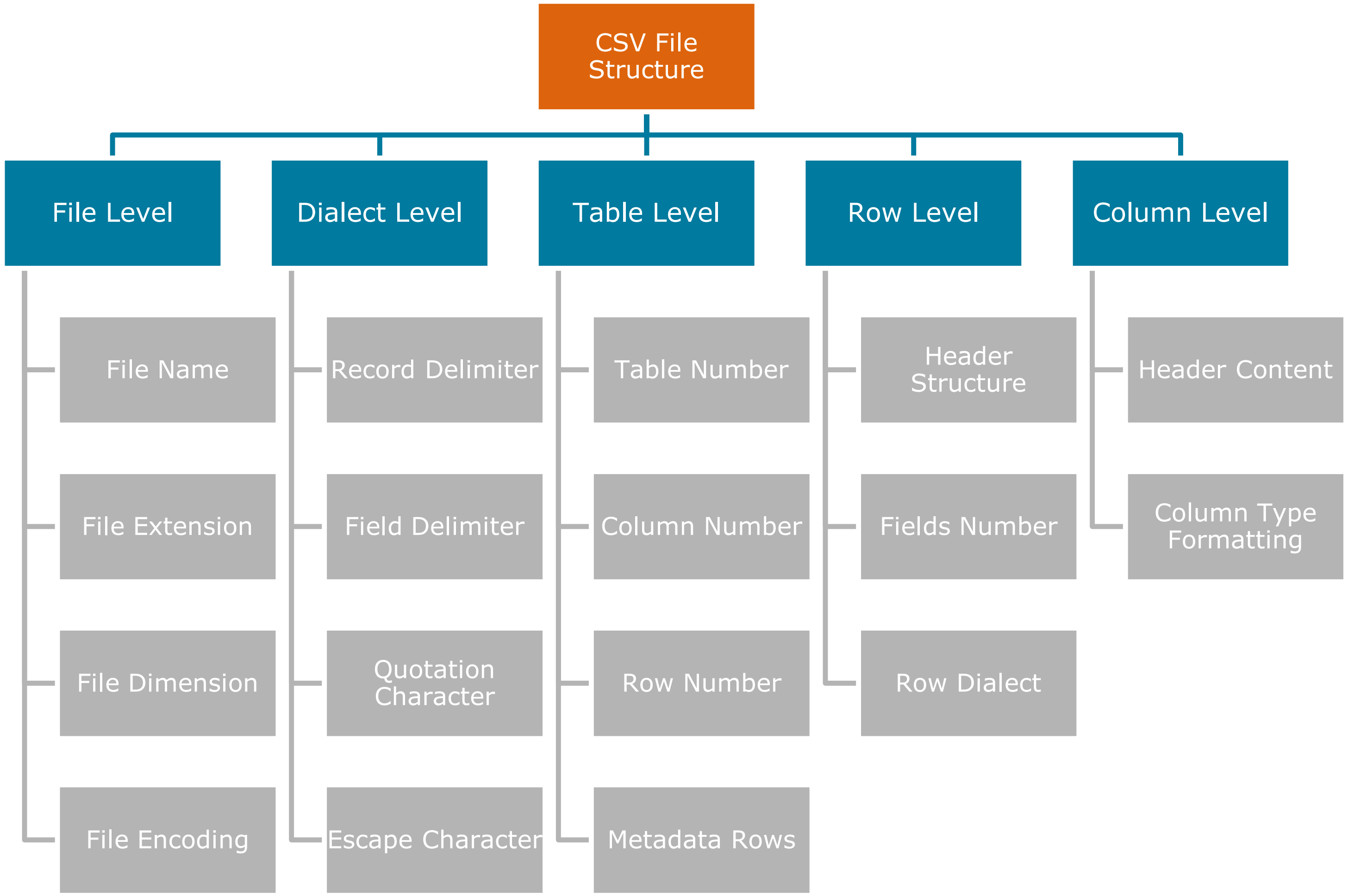
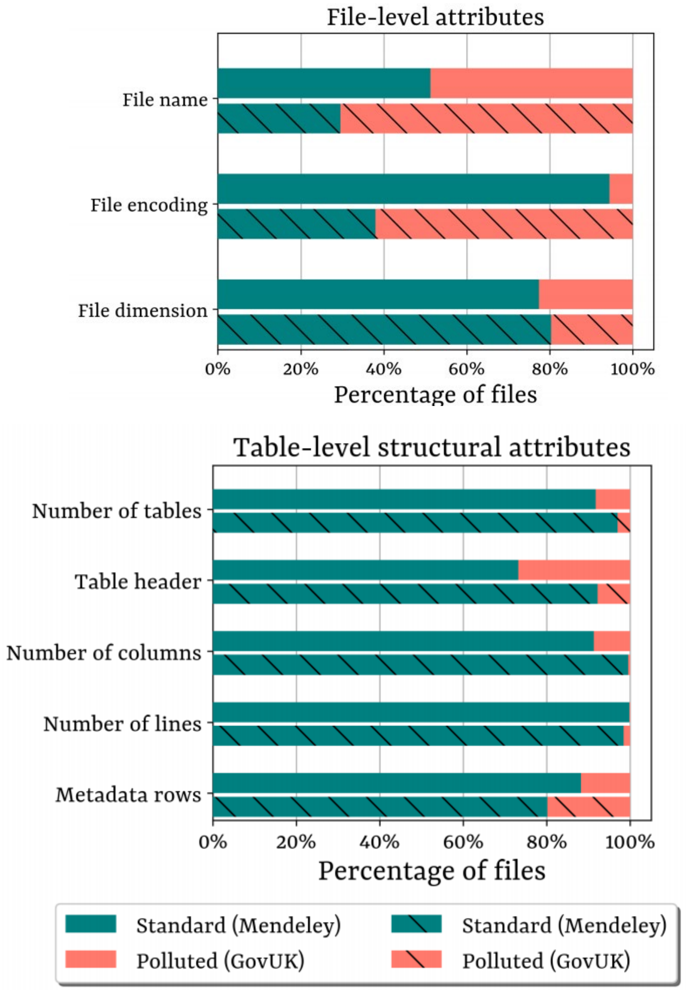


# Data Aggregation Errors in CSV Files

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

| 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 | | | | | | [illegible] | $281,918 | $228,169 |
| | | | | | | | | |
| Memo Item: | | | | | | | | |
| Maintenance Revenue (included in Service Revenue) | | | | | | [illegible] | $45,908 | $37,38[illegible] |
| | | | | | | | | |
| 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% |

**29% of all aggregations have some error.**
**The highest observed error level is 37.5%.**

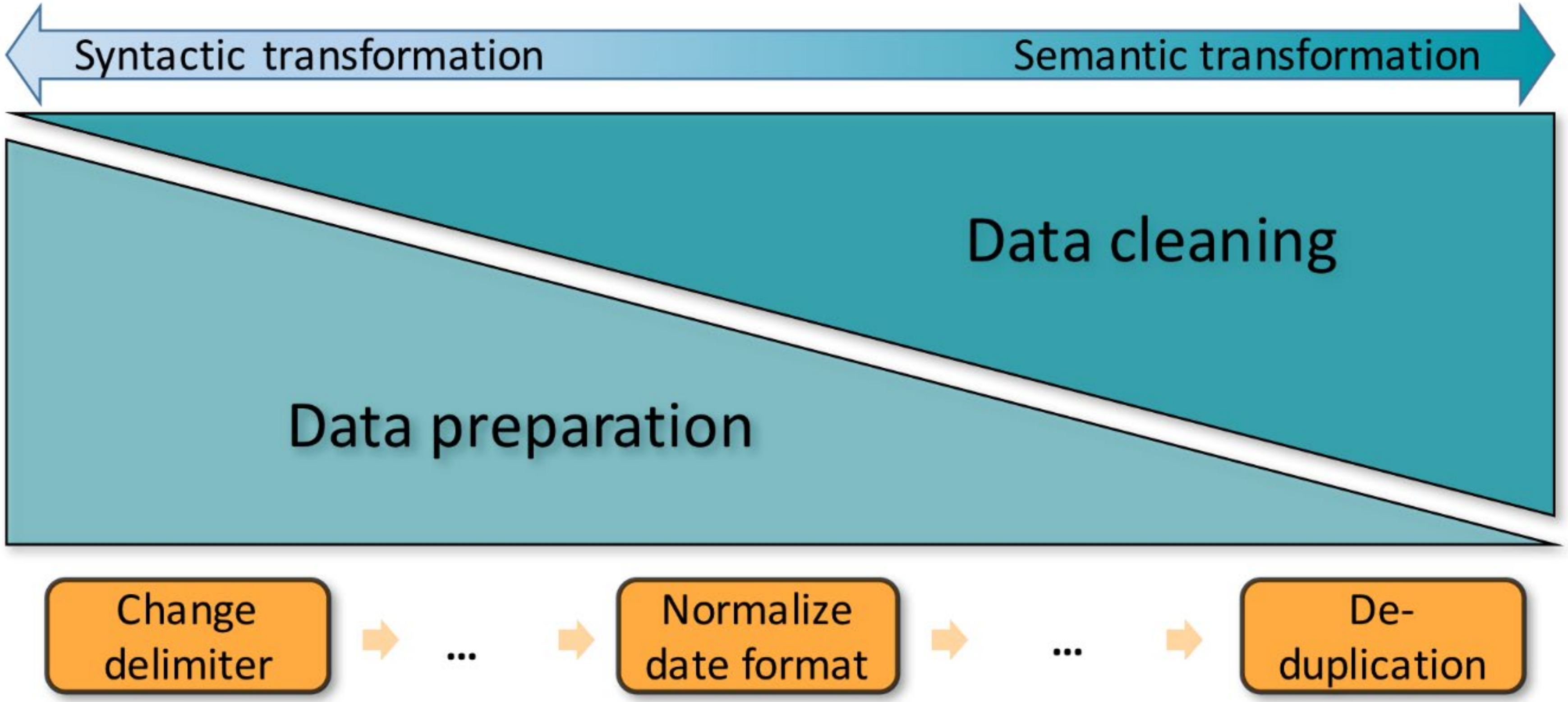
$$\text{Hardware GP \%} = \frac{\text{Hardware GP}}{\text{Hardware Revenue}}$$

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

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

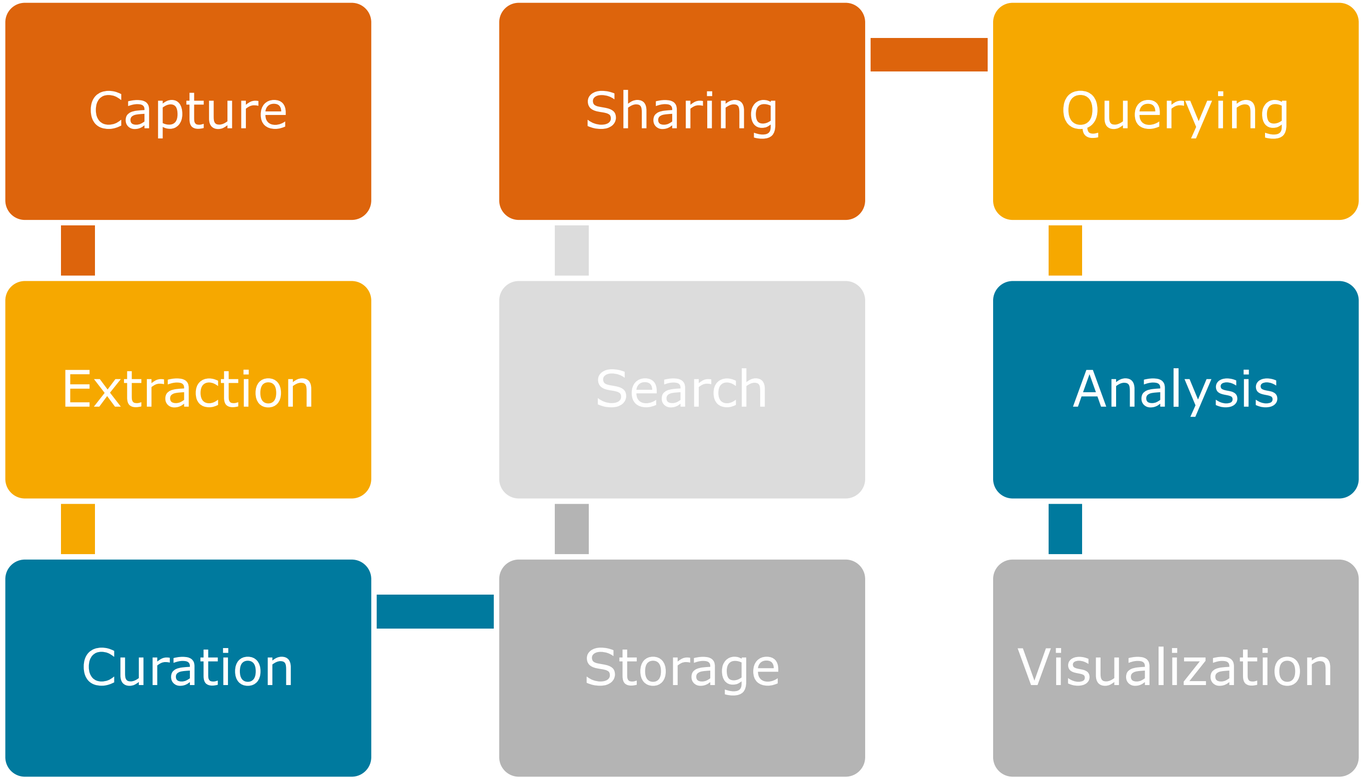
# Data Preparation vs. Data Cleaning

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



# Overview

1. Bad Files
2. **Bad Data**
3. Bad Results



# Real-world data is raw and dirty

| | | | | | |
|---|---|---|---|---|---|
| 488941 britney spears | 29 britent spears | 9 brinttany spears | 5 brney spears | 3 britiy spears | 2 brirreny spears |
| 40134 brittany spears | 29 brittnany spears | 9 britanay spears | 5 broitney spears | 3 britmeny spears | 2 brirtany spears |
| 36315 brittney spears | 29 britttany spears | 9 britinany spears | 5 brotny spears | 3 britneeey spears | 2 brirttany spears |
| 24342 britany spears | 29 btiney spears | 9 britn spears | 5 bruteny spears | 3 britnehy spears | 2 brirttney spears |
| 7331 britny spears | 26 birttney spears | 9 britnew spears | 5 btiyney spears | 3 britnely spears | 2 britain spears |
| 6633 briteny spears | 26 breitney spears | 9 britneyn spears | 5 b | | rs |
| 2696 britteny spears | 26 brinity spears | 9 britrney spears | 5 g | | ears |
| 1807 briney spears | 26 britenay spears | 9 brtiny spears | 5 s | | ars |
| 1635 brittny spears | 26 britneyt spears | 9 brtittney spears | 4 b | | rs |
| 1479 brintey spears | 26 brittan spears | 9 brtny spears | 4 b | | ars |
| 1479 britanny spears | 26 brittne spears | 9 brytny spears | 4 b | | ears |
| 1338 britiny spears | 26 btittany spears | 9 rbitney spears | 4 b | | ars |
| 1211 britnet spears | 24 beitney spears | 8 birtiny spears | 4 b | | ars |
| 1096 britiney spears | 24 birteny spears | 8 bithney spears | 4 b | | ars |
| 991 britaney spears | 24 brightney spears | 8 brattany spears | 4 b | | ars |
| 991 britnay spears | 24 brintiny spears | 8 breitny spears | 4 b | | ars |
| 811 brithney spears | 24 britanty spears | 8 breteny spears | 4 b | | ears |
| 811 brtiney spears | 24 britenny spears | 8 brightny spears | 4 b | | rs |
| 664 birtney spears | 24 britini spears | 8 brintay spears | 4 b | | ars |
| 664 brintney spears | 24 britnwy spears | 8 brinttey spears | 4 b | | ars |
| 664 briteney spears | 24 brittni spears | 8 briotney spears | 4 b | | ears |
| 601 bitney spears | 24 brittnie spears | 8 britanys spears | 4 b | | s |
| 601 brinty spears | 21 biritney spears | 8 britley spears | 4 b | | ears |
| 544 brittaney spears | 21 birtany spears | 8 britneyb spears | 4 b | | s |
| 544 brittnay spears | 21 biteny spears | 8 britnrey spears | 4 b | | ears |
| 364 britey spears | 21 bratney spears | 8 britnty spears | 4 b | | rs |
| 364 brittiny spears | 21 britani spears | 8 brittner spears | 4 b | | ars |
| 329 brtney spears | 21 britanie spears | 8 brottany spears | 4 b | | rs |
| 269 bretney spears | 21 briteany spears | 7 baritney spears | 4 b | | rs |
| 269 britneys spears | 21 brittay spears | 7 birntey spears | 4 b | | ears |
| 244 britne spears | 21 brittinay spears | 7 biteney spears | 4 b | | ars |
| 244 brytney spears | 21 brtany spears | 7 bitiny spears | 4 b | | ars |
| 220 breatney spears | 21 brtiany spears | 7 breateny spears | 4 britneuy spears | 2 baritany spears | 2 britneyh spears |
| 220 britiany spears | 19 birney spears | 7 brianty spears | 4 britnewy spears | 2 bbbritney spears | 2 britneym spears |


LIVE BBC NEWS CHANNEL

Page last updated at 11:45 GMT, Thursday, 19 February 2009

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**The mystery of Ireland's worst driver**

**Details of how police in the Irish Republic finally caught up with the country's most reckless driver have emerged, the Irish Times reports.**

He had been wanted from counties Cork to Cavan after racking up scores of speeding tickets and parking fines.

However, each time the serial offender was stopped he managed to evade justice by giving a different address.

But then his cover was blown.



Poles are Ireland's largest immigrant population

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internet
TOP N
Oma
Sinn
City

# FIFA registration form (2010)





# Hidden Values / Hidden Value

Fitness for use?

| | 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

# From Data Errors (aka. Data Quality) to Data Problems (aka. Information Quality)

Hasso Plattner Institut

| | |
|---|---|
| ■ Incorrect data: | Accuracy |
| ■ Missing data: | Completeness |
| ■ Poor formatting: | Representational consistency |
| | |
| ■ Old data: | Timeliness |
| ■ Unknown data source: | Trustworthiness |
| | |
| ■ Hard to reach data: | Accessibility |
| ■ Slow connection: | Latency |

■ And many more information quality dimensions

## IQ Classification of Wang and Strong

- Intrinsic IQ
  - Believability, Accuracy, Objectivity, Reputation
- Contextual IQ
  - Value-added, Relevancy, Timeliness, Completeness, Amount
- Representational IQ
  - Interpretability, Understandability, Repr. Consistency, Repr. conciseness
- Accessibility IQ
  - Accessibility, Security

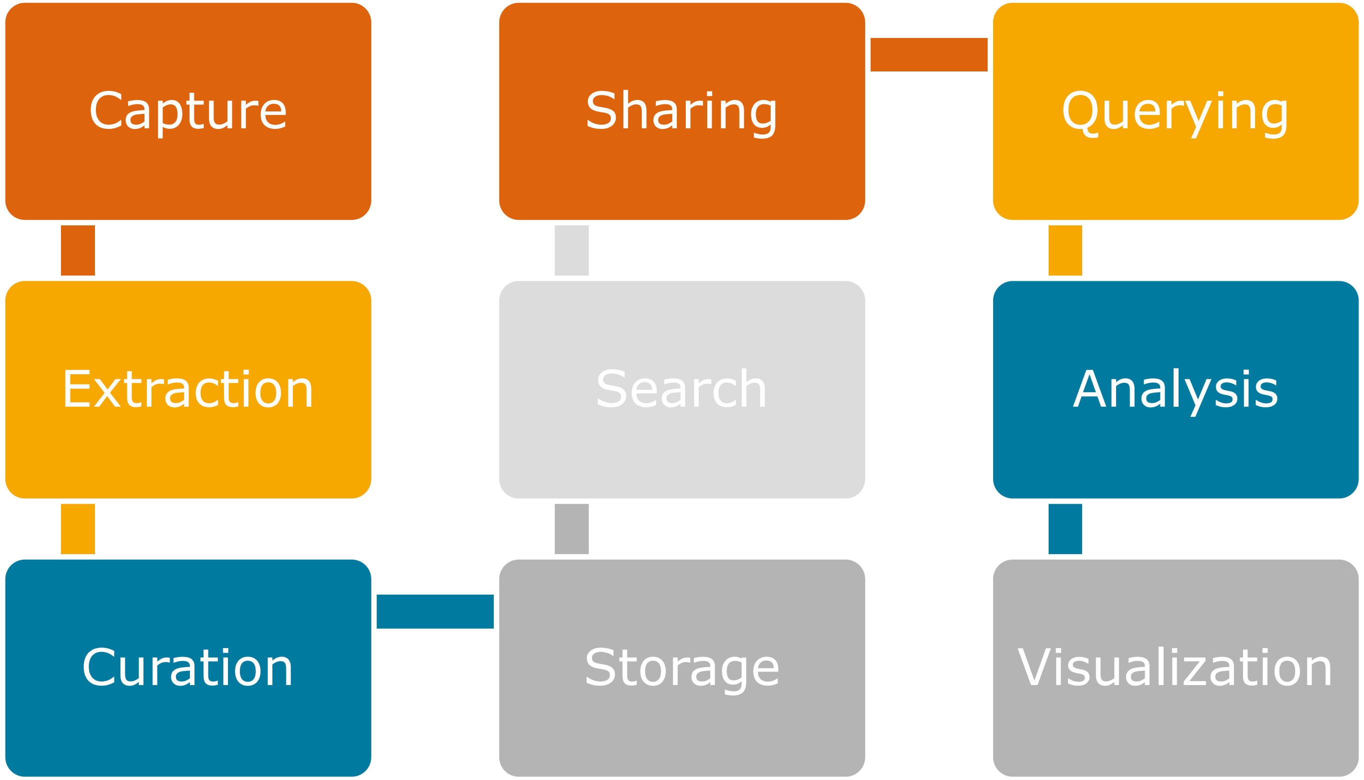
- And more
  - Customer support, documentation, reliability, latency, price, response time, verifiability

Data scientists (might) choose the path of least resistance.

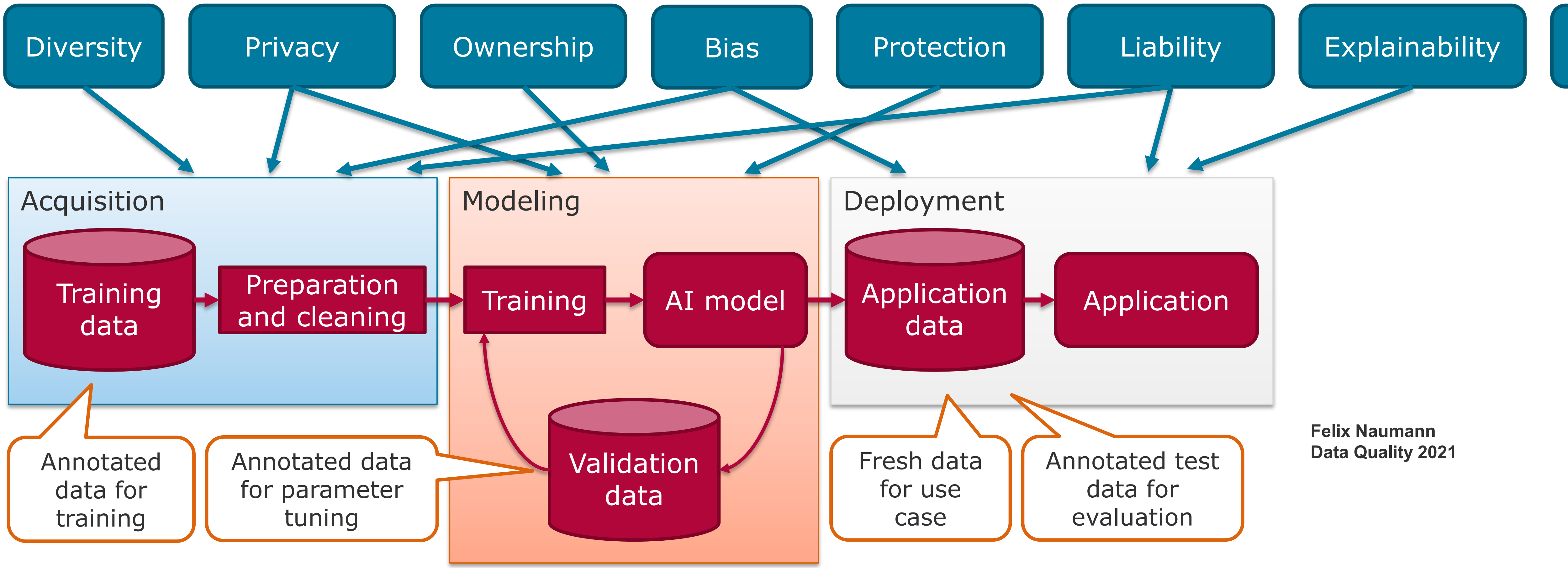
Wang & Strong
Beyond Accuracy: What data quality means to data consumers
*Management of Information Systems*, 1996, *12(4)*, 5-34

# Overview

1. Bad Files
2. Bad Data
3. **Bad Results**



# New AI-specific Data Quality Dimensions and Where to Find Them



# Open Research Questions

- Data quality dimensions
  - Which established dimensions are relevant?
    - Learning task, pipeline stage, domain
  - Which new dimensions are needed?
    - Which are cross-dataset dimensions?
- Assessment and explanation of data quality
  - Which dimensions are (automatically) assessable/testable?
  - Can we efficiently measure data quality?
    - Automatically, manually, domain knowledge
  - Can we correlate model errors with data quality problems
- What are the legal and ethical aspects of data quality?