Variety in Big Data: A Cities Perspective

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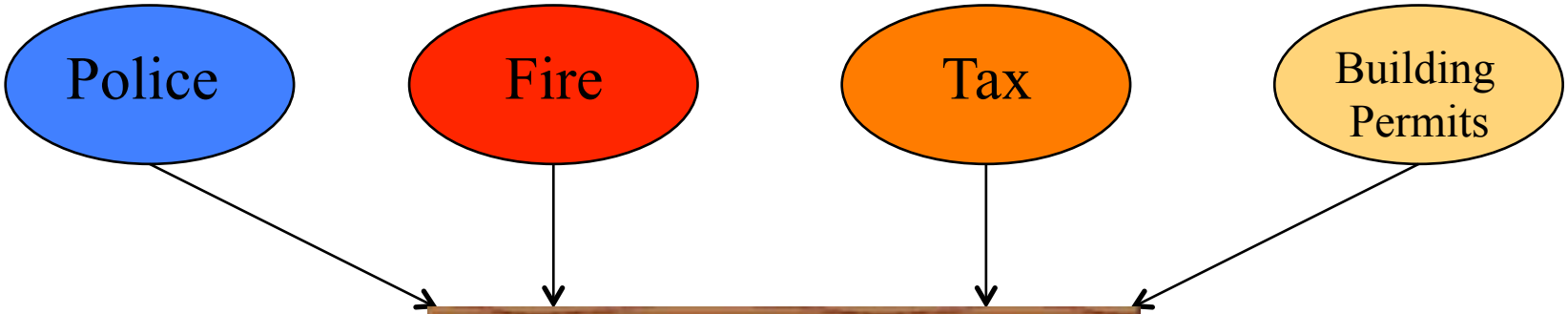
Big Data in the City

- NYC building owners were illegally converting them into rooming houses that contained 10 times the number people they were designed for.
  - Posed a number of problems, including fire hazards, drugs, crime, disease and pest infestations.
  - There are over 900,000 properties in New York City and only 200 inspectors who received over 25,000 illegal conversion complaints per year.
- How to distinguish nuisance complaints from those worth investigating?
  - Current methods resulted in **13%** of inspections issuing vacate orders.

Data From Many Sources

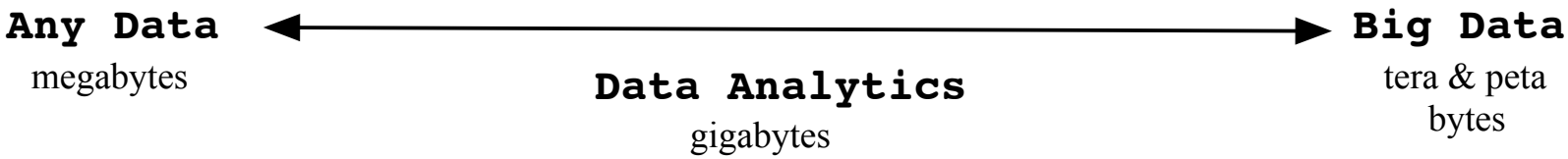


- New York's Analytics team created a dataset combining data from 19 agencies:
  - Buildings, preservation, police, fire, tax, and building permits.

- By combining data analysis with expertise gleaned from inspectors, able to rate complaints such that in **70%** of inspector visits led to vacate orders.

How big is BIG

- Most organizations are making the conversion from gut-based to fact-based decision making, and ***any*** facts will do!



- And the data? It's "not so big".

Big Data = Data Analytics

The Real Bottlenecks

- Assuming you know what data you need
  (Big IF: often we do not know without doing some research, nor can you just dump all the data into a data mining tool and let the algorithm figure it out):
  - Where can I find it?
  - What are the attributes? What do they mean?
  - Are they equivalent to the attributes from other data sets?
  - Is the data correct? Complete? Can I trust it?

Key Distinction

- Over the last 3 months I taught a course titled “Big Data and Global Cities” where each student did a project using data from Global Cities.

- **Data**: A set of values that are created by a repeatable, standardized, calibrated process.
  - Sensors.
- **Information**: A set of values that are created by a process that is inherently uncertain.
  - Determining the number of homeless people,
  - Municipal financial data reporting.

Global City Indicators

A city can be defined as ‘smart’ when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory action and engagement. (Caragliu et al. 2009)

Measurement Gap

- World Bank funded a study, by the University of Toronto, of city performance indicators at 9 cities.

- Belo Horizonte, Brazil
- Bogota, Colombia
- Cali, Colombia
- King County, Washington State, USA
- Montreal, Canada
- Toronto, Canada
- Vancouver, Canada
- Porto Alegre, Brazil
- Sao Paulo, Brazil

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Total of 1100 indicators across 9 pilot cities – only 2 comparable.

World Bank Vision (Hoornweg et al., 2006)

- **Objective**: clear, well defined, precise and unambiguous, simple to understand.
- **Relevant**: directly related to the objectives.
- **Measurable and replicable**: easily quantifiable, systematically observable.
- **Auditable**: valid, subject to third-party verification, quality controlled data (legitimacy across users).
- **Statistically representative** at the city level.
- **Comparable/ Standardized** longitudinally (over time) and transversally (across cities).
- **Flexible:** can accommodate continuous improvements to what is measured and how. Have a formal mechanism for all cities and interested parties to comment on.
- **Potentially Predictive:** extrapolation over time and to other cities that share common environments.
- **Effective:** tool in decision making as well as in the planning for and management of the local system.
- **Economical:** easy to obtain/inexpensive to collect. Use of existing data.
- **Interrelated**: indicators should be constructed in an interconnected fashion (social, environmental and economics).
- **Consistent and sustainable over time**: frequently presented and independent of external capacity and funding support.

Global Cities Institute (U. of Toronto)

Over 100 indicators defined.

City Services

- Education
- Finance
- Governance
- Recreation
- Transportation
- Wastewater
- Energy
- Fire and Emergency Services
- Health
- Safety
- Solid waste
- Urban Planning
- Water

Quality of Life

- Civic Engagement
- Economy
- Shelter
- Culture
- Environment
- Social Equity
- Technology and Innovation

Over 250 cities involved.

Student/Teacher Ratio

2008: **Student/teacher ratio**

World Bank, (2008), "Global City Indicators Program Report: Preliminary Final Report", April 2008.

2012: **Student/teacher ratio**

Numerator: Number of Students

Denominator: Number of Teachers

Global City Indicators Facility: Website User Guide. October 2012.

2014: Student/Teacher Ratio (STR)

- "The student/teacher ratio shall be expressed as the number of enrolled primary school students (numerator) divided by the number of full-time equivalent primary school classroom teachers (denominator).
- The result shall be expressed as the number of students per teacher.
- Private educational facilities shall not be included in the student/teacher ratio.
- One part-time student enrolment shall be counted as one full-time enrolment; in other words a student who attends school for half a day should be counted as a full-time enrolment.
- If a city reports full-time equivalent (FTE) enrolment (where two half day students equal one full student enrolment), this shall be noted.
- The number of classroom teachers and other instructional staff (e.g. teachers' aides, guidance counselors), shall not include administrators or other non-teaching staff.
- Kindergarten or preschool teachers and staff shall not be included.
- The number of teachers shall be counted in fifth time increments, for example, a teacher working one day per week should be counted as 0.2 teachers, and a teacher working three days per week should be counted as 0.6 teachers."

Global Cities Institute (U. of Toronto)

Over 100 indicators defined and submitted to ISO

City Services

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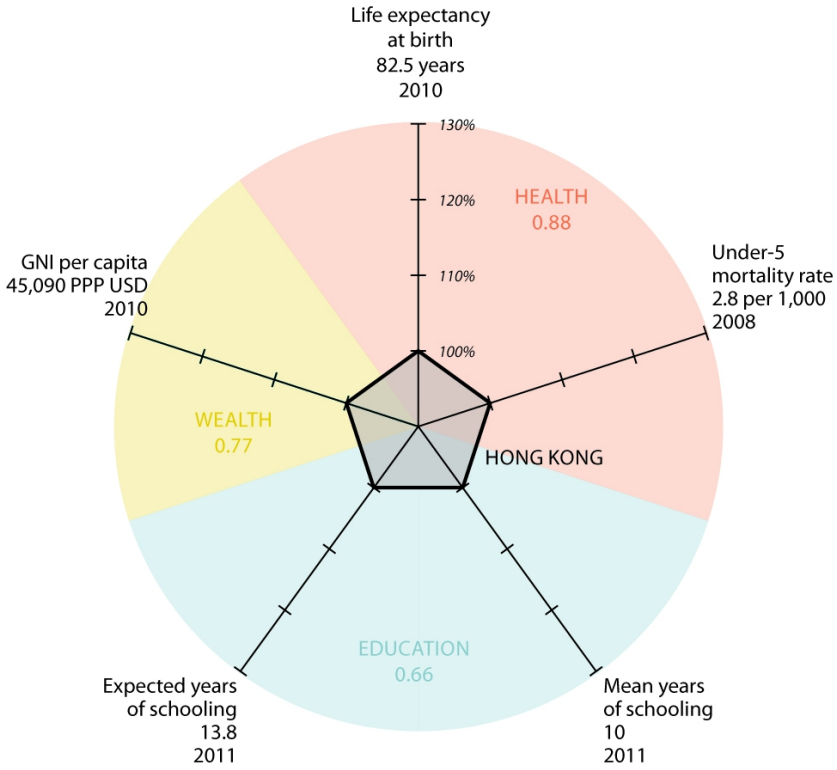
- Technology and Innovation

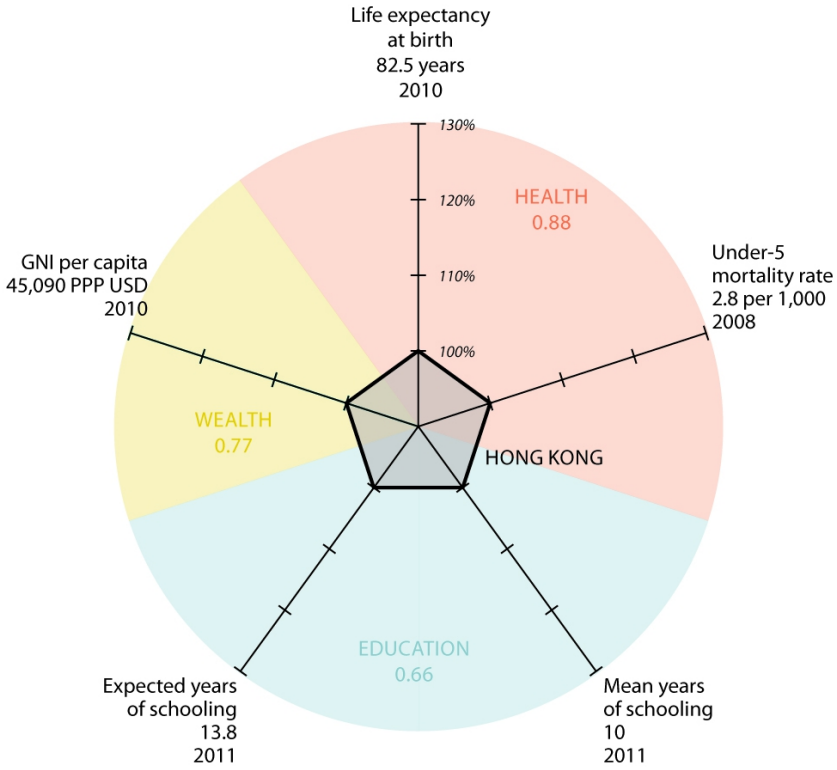
ISO 37120 – Sustainable Development and Resilience of Communities – Indicators for City Services and Quality of Life (under TC268

Computer Science Vision (slightly provocative)



Ontology Engineering Vision

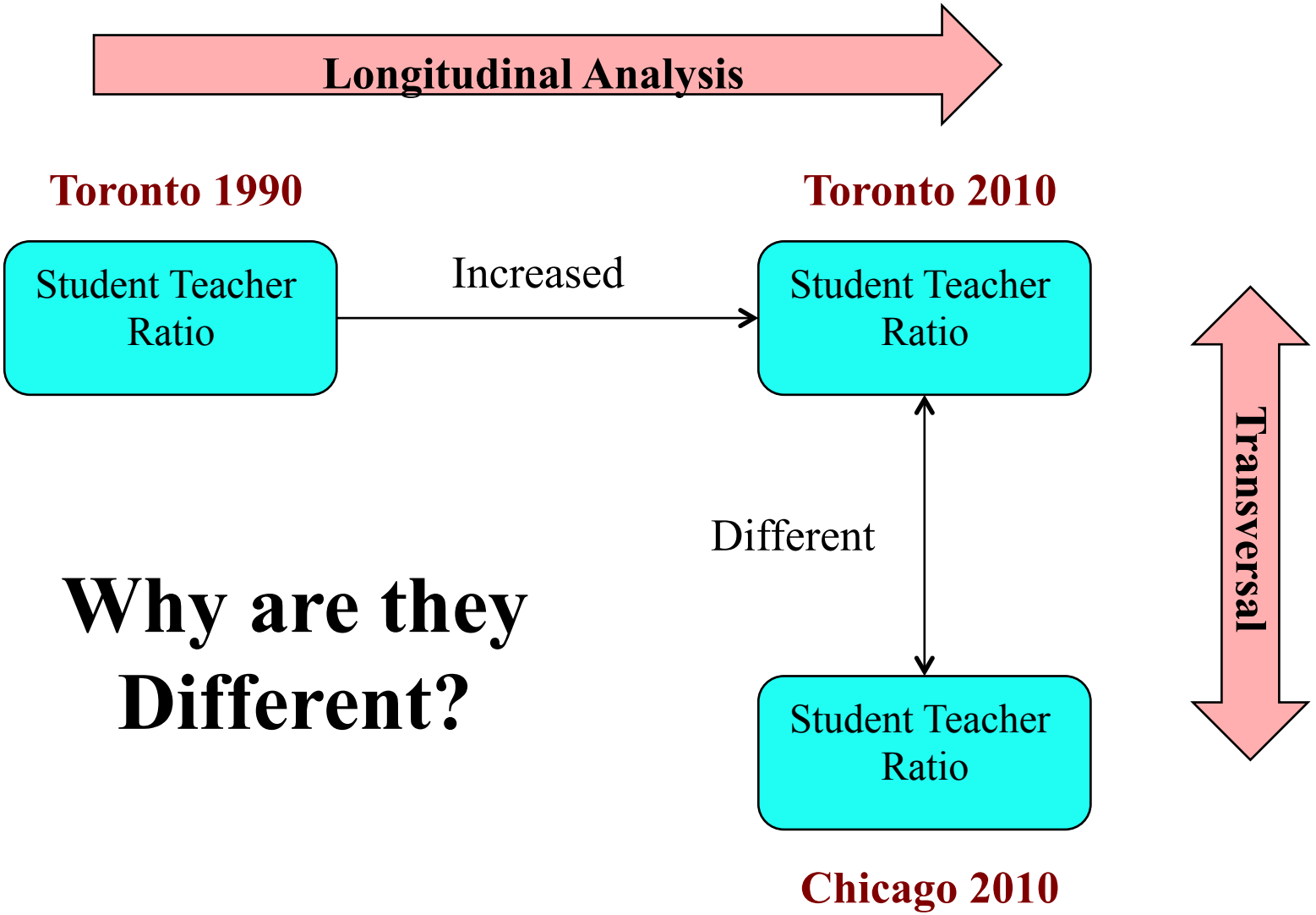
Transition from Visualization to Analysis



- Automate the analysis of city performance
  - Perform **longitudinal** and **transversal** analyses, and
  - Determine the **root causes** of differences,

using data from across the semantic web.

Automated Analysis



Step 1: Providing the Ontologies to Represent City Data

Fox, M.S., (2013), "A Foundation Ontology for Global City Indicators", Global City Institute Working Paper #3,

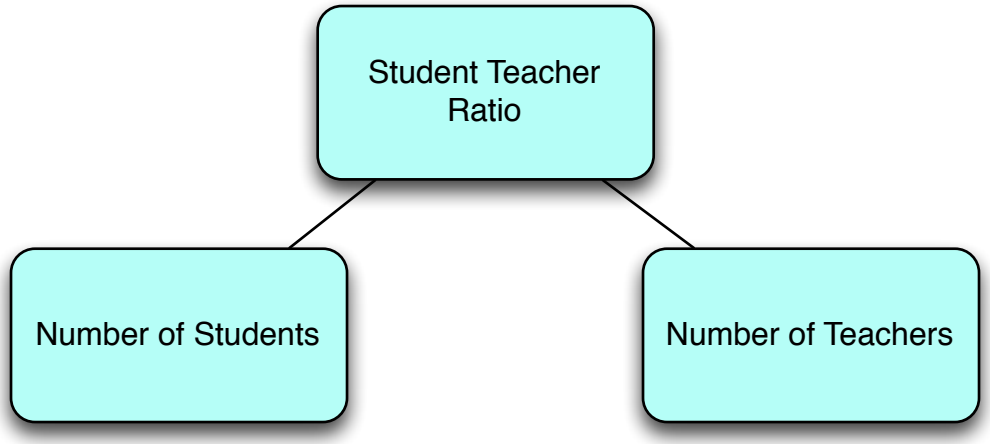
Modeling Gap

- What type of number is a STR?
  - Unit of measurement? Meters? Grams?
  - Ratio, Ordinal, Nominal?
  - Scale? Kilos?

Student Teacher Ratio

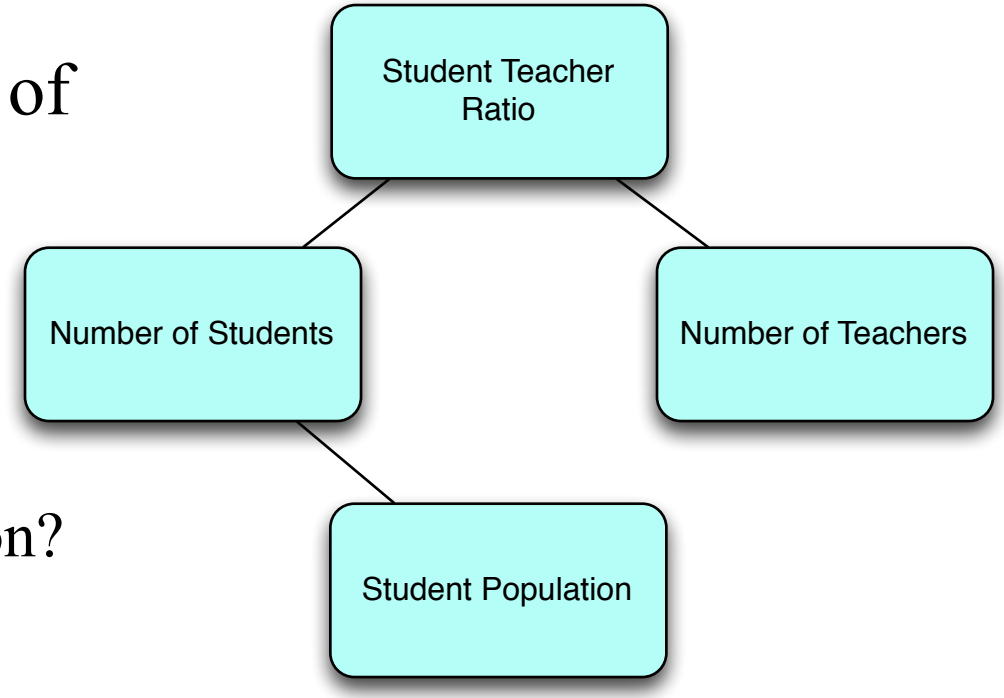
Modeling Gap

- What is an STR composed of?
  - If a "division", what is the numerator? denominator?
- What kind of numbers are these?
  - Ordinal?
  - Units? Kilo?



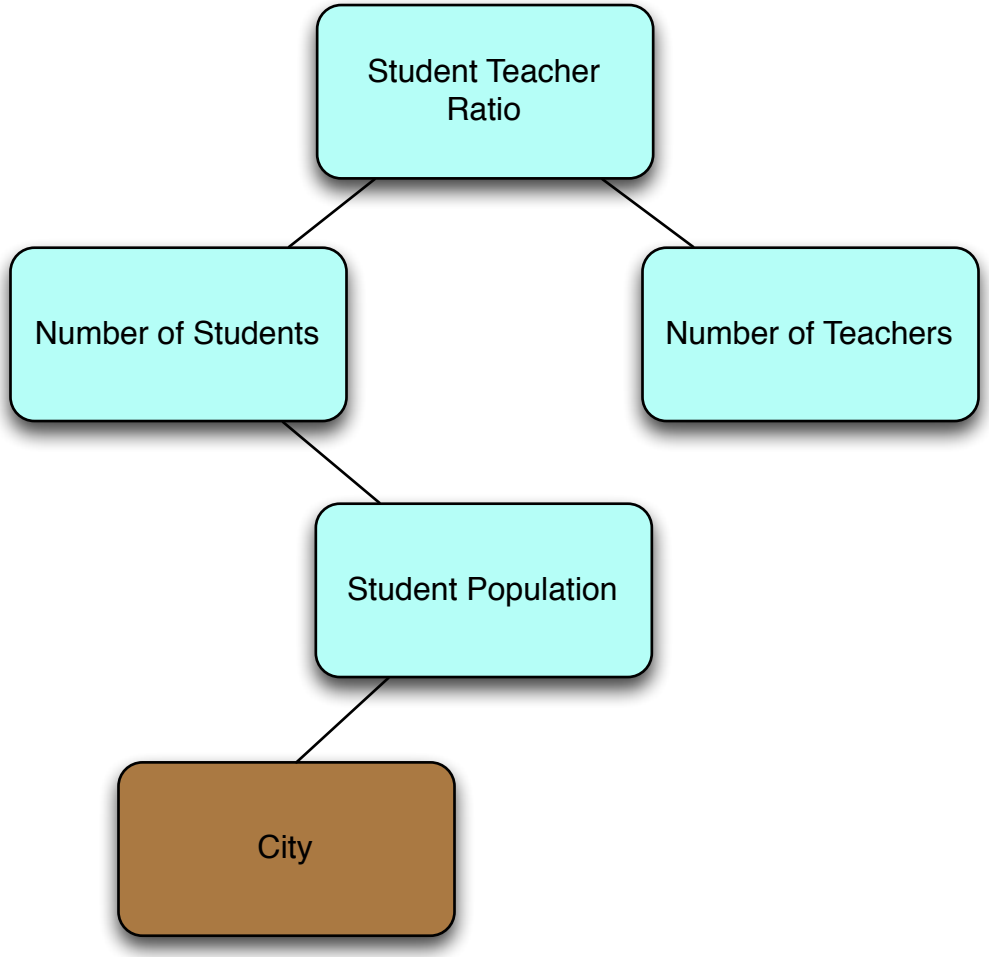
Modeling Gap

- What is the "number of students" representative of?
  - Is it a statistic? Or a property of a set?
  - What is the Population?



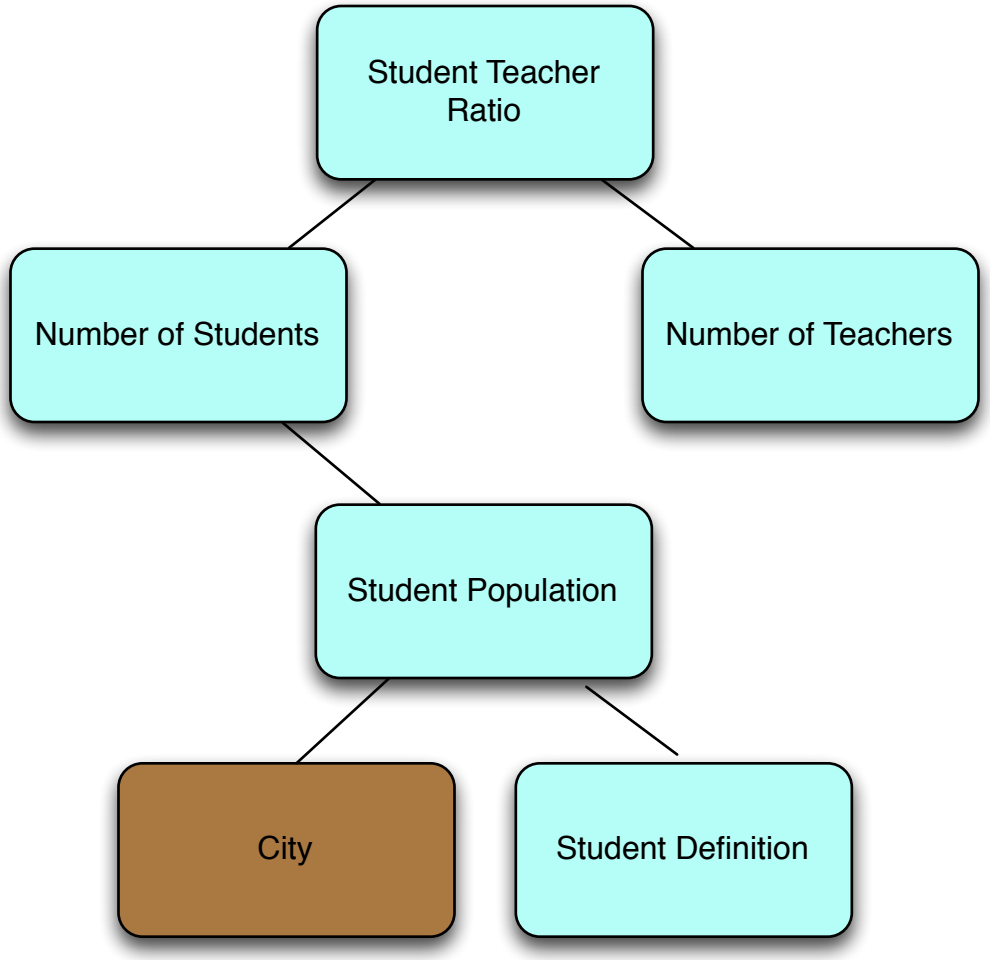
Modeling Gap

- How are members of the Population determined?
  - Where is the population drawn from?
  - Toronto ON? Toronto OH?



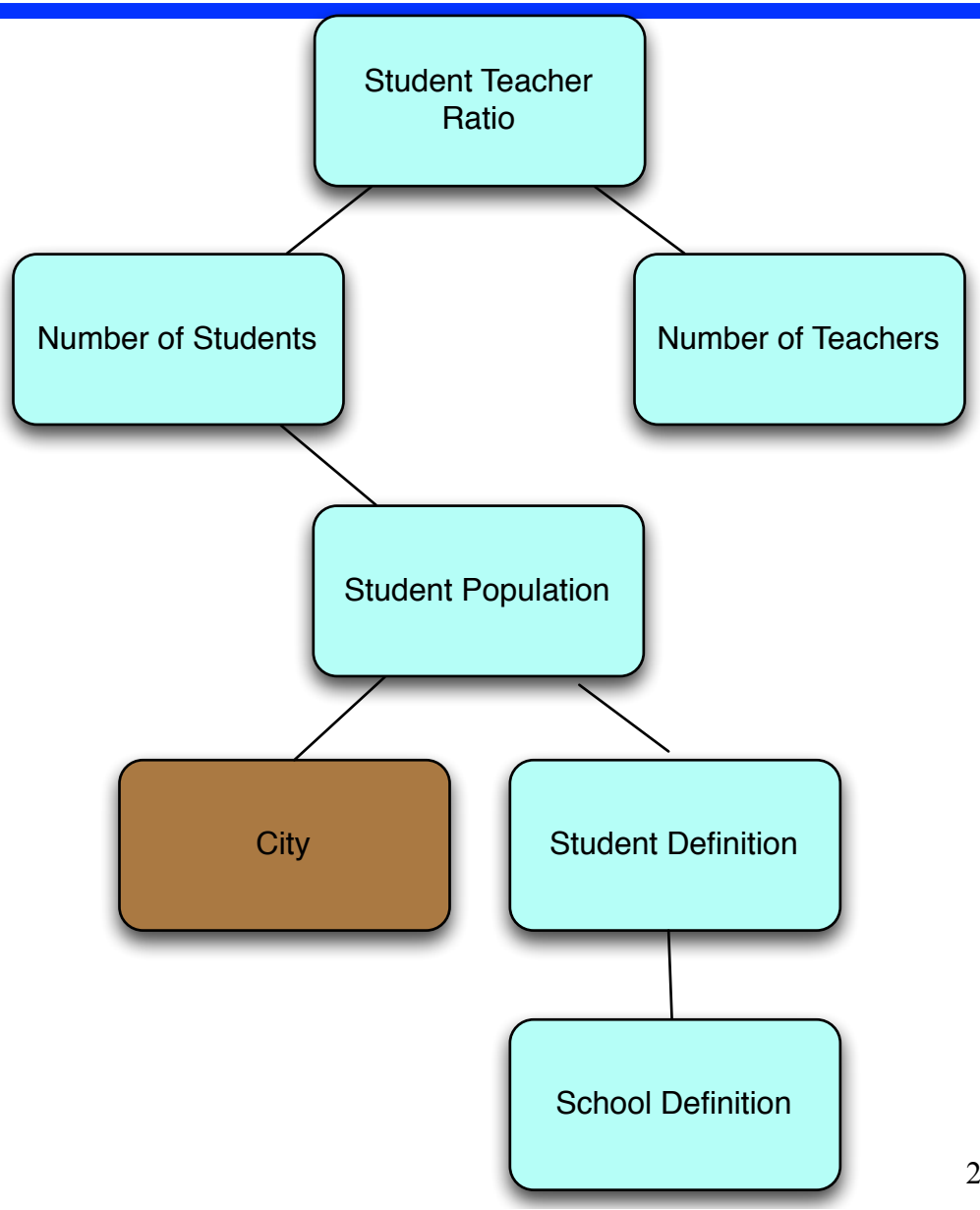
Modeling Gap

- How are members of the Population determined?
  - What is a student?
  - Full or part time?
  - Regular or special?
  - Primary or secondary grades?



Modeling Gap

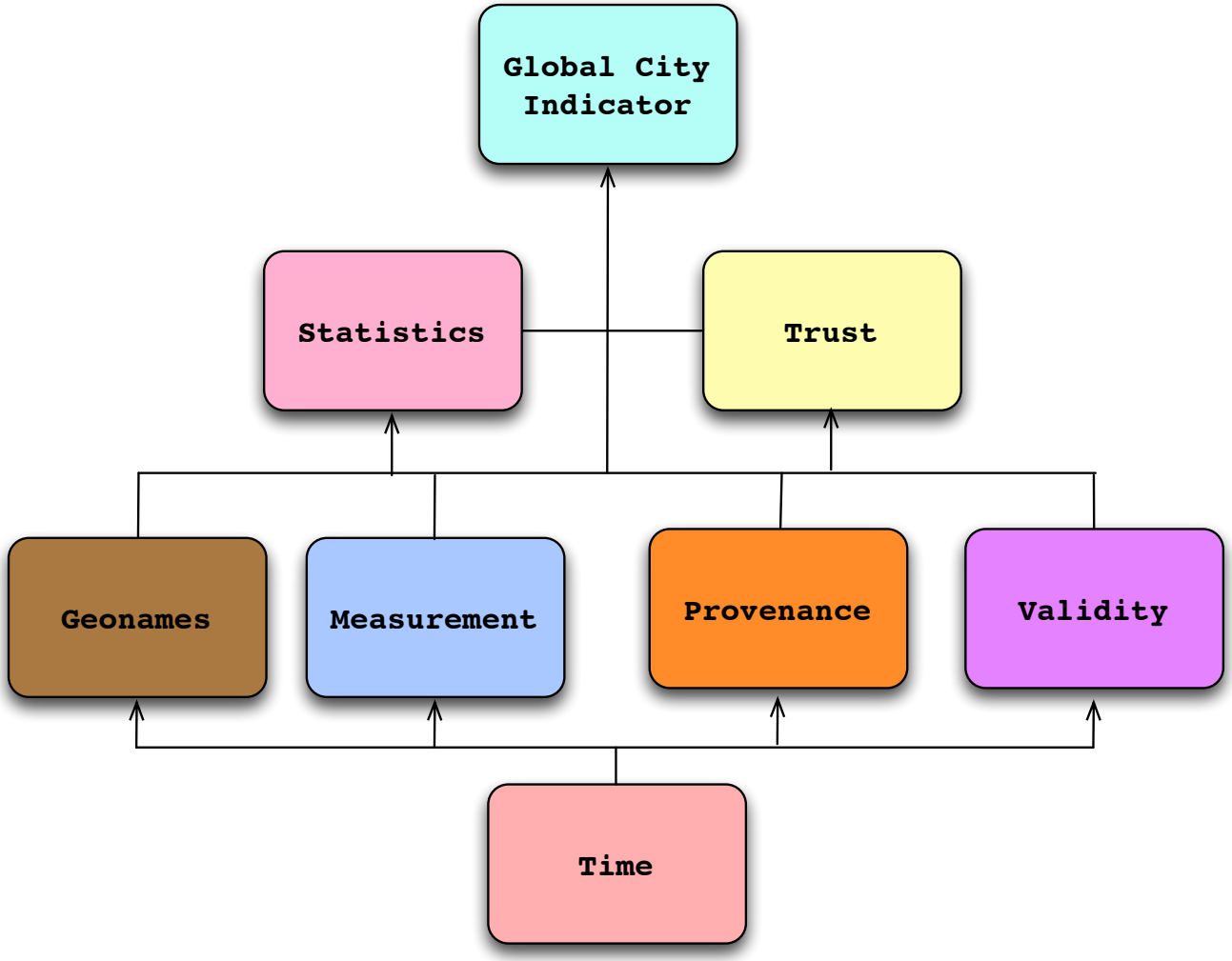
- What schools are included in defining students?
  - Public, Private?
  - What are the primary grades?



Modelling Gap

- **Provenance**
  - Who, when, how
- **Validity & Belief**
  - Effective time period
  - Degree of belief
- **Trust**
  - In the city, organization, individual
  - In beliefs, performance

Consequence



- A single indicator requires the integration of many types of ontologies.

And Includes More Specific Ontologies

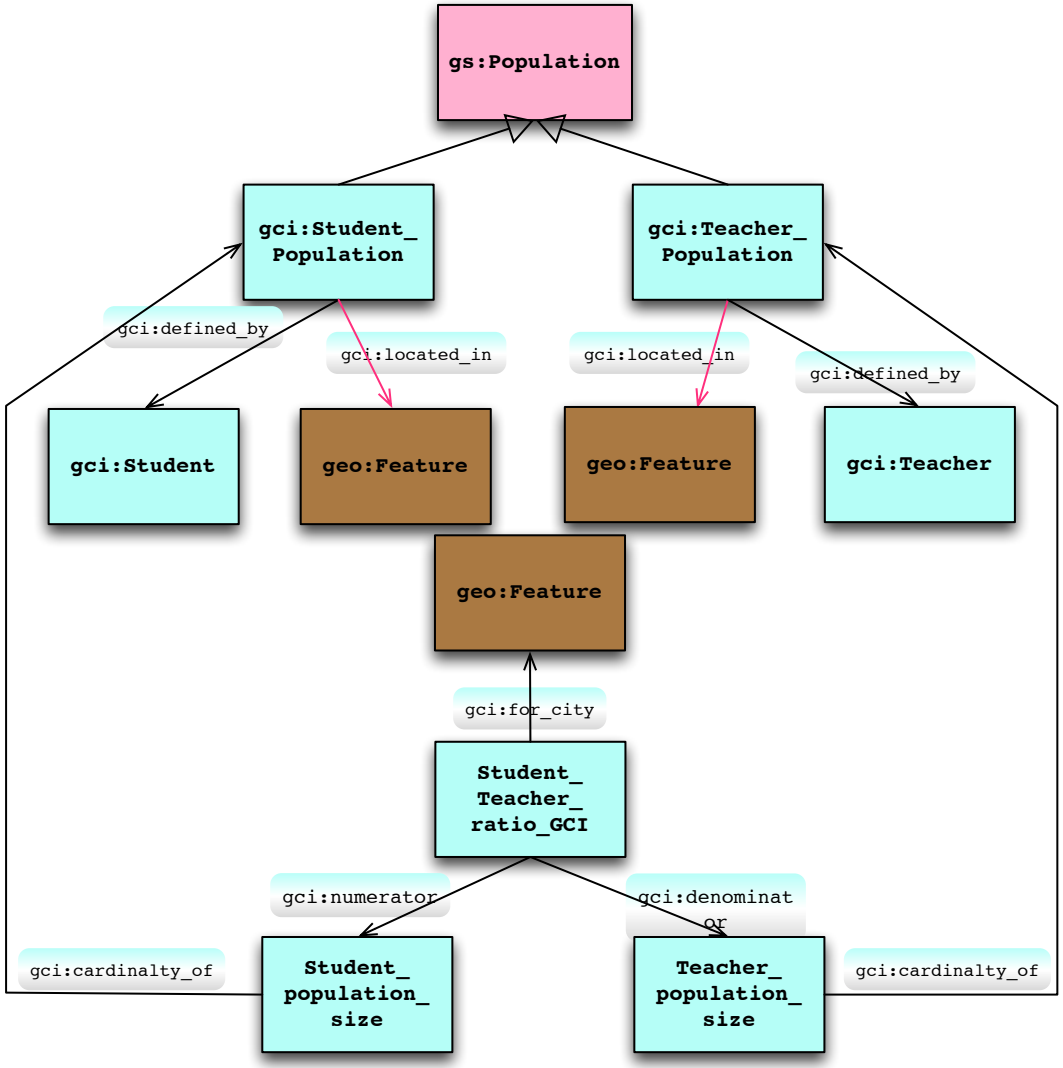
Category	Indicator	3. Placename	4. Measurement	5. Statistics	6. Provenance	7. Time	8. Validity	9. Trust	10. Govt Finance	11. Govt Organization	12. Economics	13. Census	14. Environment	15. City Infrastructure	16. Edu, Tech, Innov	17. Health, Safety, Emer.
Profile Indicators																
Government	Type of government (e.g. Local, Regional, County)	■	■	■	■	■	■	■		■						
	Gross Operating Budget (US$)	■	■	■	■	■	■	■	■	■						
	Gross Operating Budget per capita (US$)	■	■	■	■	■	■	■	■	■						
	Gross Capital Budget (US$)	■	■	■	■	■	■	■	■	■						
	Gross Capital Budget per capita (US$)	■	■	■	■	■	■	■	■	■						
Economy	Average household income [US$]	■	■	■	■	■	■	■			■					
	Annual inflation rate (avg. of last 5 years) [%]	■	■	■	■	■	■	■			■					
	Cost of living [US$]	■	■	■	■	■	■	■			■					
	Income distribution [GINI Coefficient]	■	■	■	■	■	■	■			■					
	Country's GDP [US$]	■	■	■	■	■	■	■			■					
	Country's GDP per capita [US$]	■	■	■	■	■	■	■			■					
	City Product per capita [US$]	■	■	■	■	■	■	■			■					
	City product as a % of country's GDP	■	■	■	■	■	■	■			■					
	Total employment	■	■	■	■	■	■	■			■					
	Employment % change based on the last 5 years	■	■	■	■	■	■	■			■					
	Number of businesses per 1000 population	■	■	■	■	■	■	■			■					
	Annual avg. unemployment rate	■	■	■	■	■	■	■			■					
	Commercial/Ind. assessment as % of total assess't	■	■	■	■	■	■	■			■					
People	Total population	■	■	■	■	■	■	■				■				
	Population density (per sq. kilometer)	■	■	■	■	■	■	■				■				
	% of country's population	■	■	■	■	■	■	■				■				
	% of population that are children (0-14)	■	■	■	■	■	■	■				■				

Step 2: Determine Consistency of Merged Data Using Bridge Axioms

With the integration of information from multiple sources, we need to guarantee that instances are consistent with their definitions and with other instances.

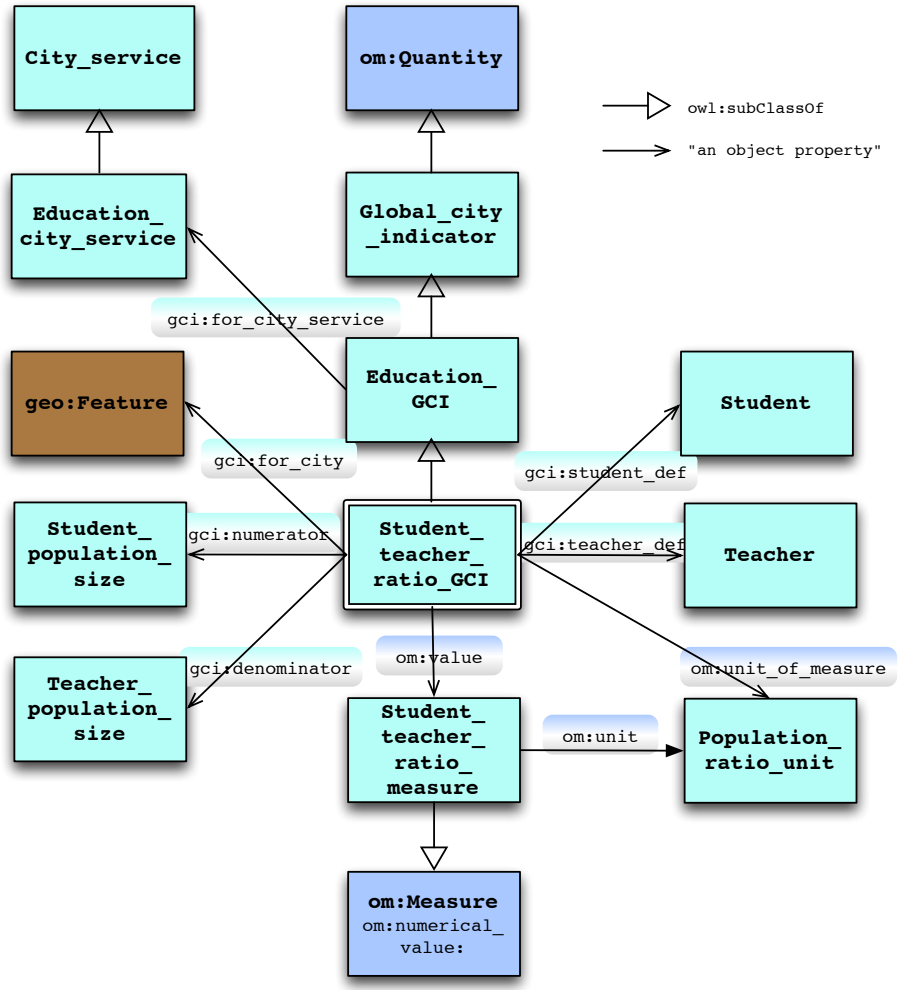
Placename Rules

- **Rule G1:** The city for the STR being measured is the same as the cities where its numerator and denominator are measured.



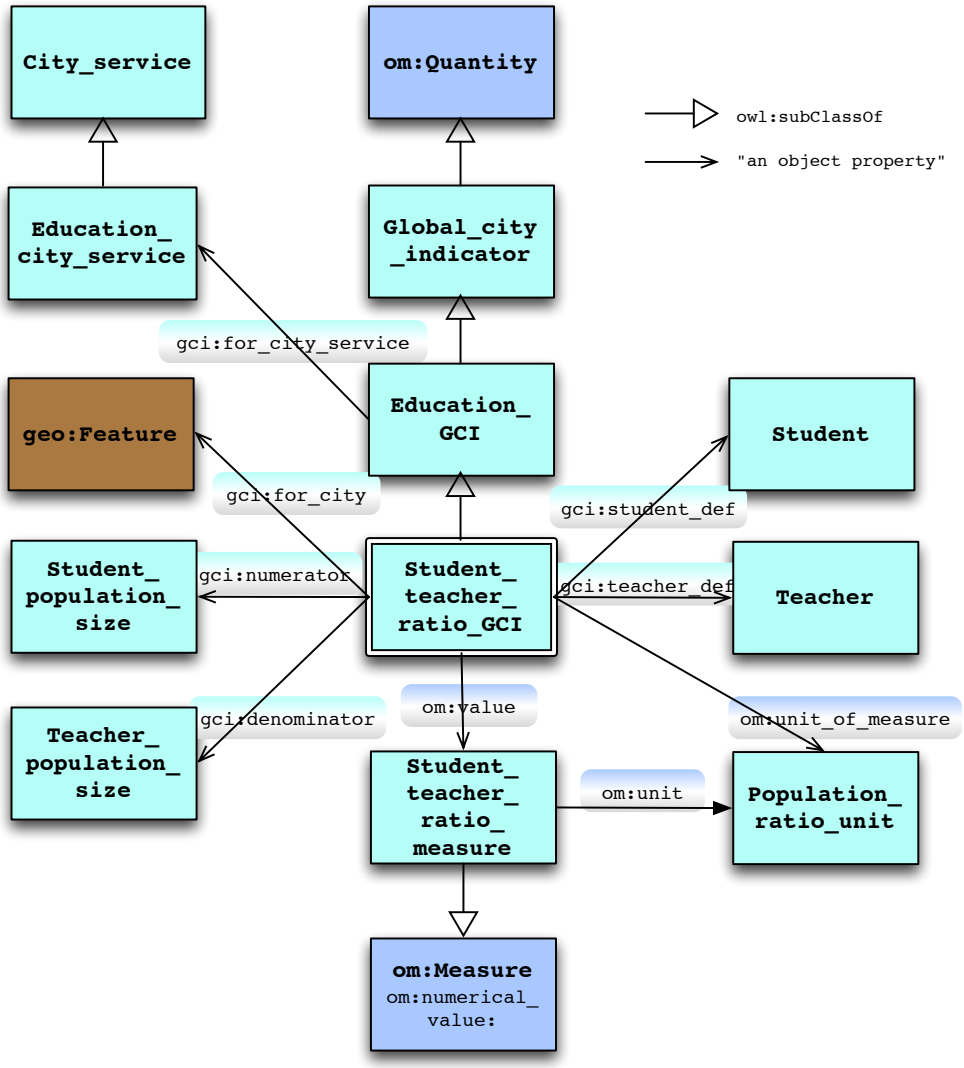
Measurement Rules

- **Rule M1:** The numerator and denominator of a gci:Student_teacher_ratio_GCI are the correct type (as specified by the GCI).
- **Rule M2:** The numerator and denominator of the gci:Student_teacher_ratio_GCI are consistent with the numerator and denominator of its unit of measure.
- **Rule M3:** If the numerator and denominator of a gci:Student_teacher_ratio_GCI are the same type, then they should have the same units (scale).
- **Rule M4:** The units of the actual measurement are the same as defined by GCI it is a measure of.
- **Rule M5:** The value of the gci:Student_teacher_ratio_measure is equal to the value of the gci:Student_teacher_ratio_GCI numerator divided by the denominator.



Population Rules

- **Rule S1:** The definitions of student and teacher for the gci:Student_teacher_ratio_GCI are the same as used by its numerator and denominator.



Meta Information Rules

- **Validity**
  - **Rule V1:** The effective time period for which an indicator is valid is contained within the effective time periods of its numerator and denominator.
  - **Rule V2**: The effective period for an indicator is after the time the indicator was generated.
- **Provenance**
  - **Rule P1:** If two versions of the same indicator exist, then they are inconsistent with each other if different methods were used to generate them.
- **Trust**
  - **Rule T1:** The trustee in a trust relationship is the same as the pr:wasAttributedTo Agent for an indicator.
  - **Rule T2:** The trusted certainty degree of an indicator is less than or equal to the indicator's certainty assigned by its creator.

Step 3: Analysing the Data

Conclusion

- The automated analysis of city indicators requires a high degree of fidelity.
  - *Fidelity refers to the degree to which a model reproduces the state of a real world object, feature or condition. Fidelity is therefore a measure of the realism of a model.*
- Fidelity requires a semantically rich core of both foundational and applied ontologies.
- Sadly, most ontologies are simply vocabularies with limited definitions, hence limiting their value.

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