

Statistical Thinking & Methodology: A Pillar For Quality In The Big Data Era

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Big data era

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Global Partnership for
Sustainable Development Data
(GPSDD)

<http://www.data4sdgs.org/#news>

THE WORLD IS
CREATING
AS MUCH DATA
EVERY TWO-DAYS
AS HAD BEEN CREATED
BETWEEN THE
DAWN
OF CIVILIZATION
AND 2003
(ERIC SCHMITT, CEO, GOOGLE)

Big data era

We live in era of unprecedented volume, availability and access to data.

“Data in the world is doubling every 18 months.”

IBM

<http://www-01.ibm.com/software/data/demystifying-big-data/>

Data gaps

Despite this *data deluge*, there are glaring **data gaps**.

“For example, in low-income countries more than 70% of births – almost 20 million children annually – are not registered.”

Paris21:

<http://datarevolution.paris21.org/the-project>

Data quality

“On September 27th 2015, 193 world leaders committed to 17 Global Goals to achieve 3 extraordinary things in the next 15 years.

End extreme poverty.

Fight inequality & injustice.

Fix climate change.”

Data quality issues

“To reach these Sustainable Development Goals (SDGs), we will need to confront **a crisis** at the heart of solving many of the world’s most pressing issues—a **crisis of poor use, accessibility, and production of high quality data** that is stunting the fight to overcome global challenges in every area—from health to gender equality, human rights to economics, and education to agriculture.

The availability and access to **high quality data** is essential to measuring and achieving the SDGs.”

<http://www.data4sdgs.org/#intro>

Data quality in the Big Data era

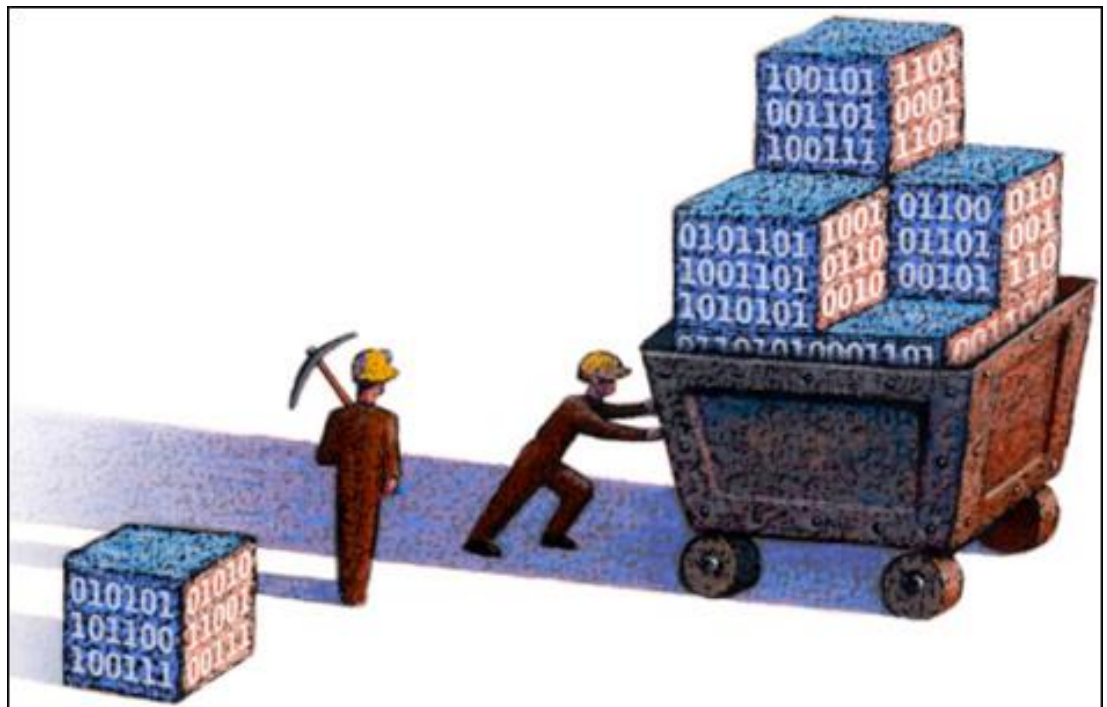
More data does not necessarily mean good or better data!

Many of the data available **lack the quality** required for its safe use in many applications.

Challenges are even bigger with Big Data!

Private sector

The search for competitive advantage demands **more data**, 'intelligence' and **knowledge** extracted from data.



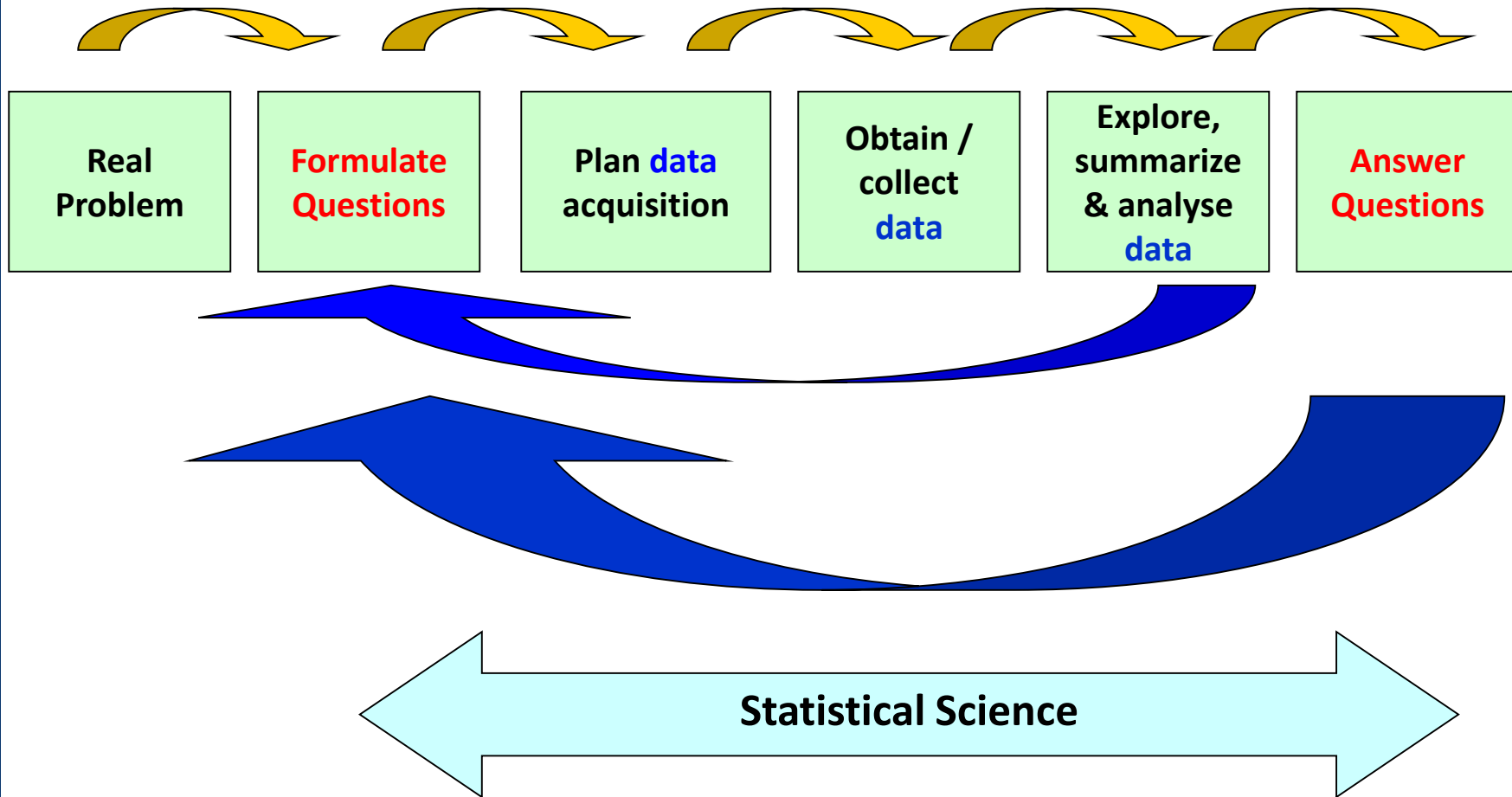
Statistical Science

For all the above reasons, **Statistical Science** has never been in such **evidence** and in such **high demand**.

Statistical thinking & methodology offers the essential guidance to obtaining current, relevant, accurate and cost-effective data.

It also guides the **extraction of useful knowledge** from data, to support decision making.

'Conventional' Knowledge Generation Process



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Offers solutions for research and knowledge discovery via:

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- Formulation and fitting of statistical models to describe data in synthetic form;
- Using fitted models to answer formulated questions (inference); and
- **Creating visual displays of data, summaries and key findings revealed from the data.**

The Core of Statistical Science:

“The Seven Pillars of Statistical Wisdom”

- Aggregation
- Information
- Likelihood
- Intercomparison
- Regression
- Design
- Residuals

Stigler (2015, 2016)

Seven Pillars Core Ideas

- #1 Targeted reduction/compression of data
- #2 Diminishing value of more data
- #3 Putting a probability measure to inferences
- #4 Doing this based upon internal data variation
- #5 Different perspectives give different answers
- #6 The essential role of planning / designing studies
- #7 How to explore in nested families of models

Stigler (2015)

Statistical Science

“These Seven Pillars **are not** *Mathematics* and are not *Computer Science*.

They do centrally constitute the important **core ideas** underlying the **Science of Statistics.**”

Stigler (2015)

Obtaining Data

Methods for careful planning and conducting of cost-effective data gathering studies

- Sampling;
- Design of experiments;
- Design for observational studies;
- Measurement protocols (questionnaires, instruments, etc.)
- Data checking, cleaning, storage and sharing protocols.

Analysis / discovery

Methods for exploratory and confirmatory data analysis:

- Exploratory data analysis;
- Data mining;
- Hypothesis formulation and testing;
- Model formulation, fitting, selection, diagnostics and interpretation;
- Data summarization, presentation & visualization.

Official and Public Statistics

Typical data sources (observational studies)

- **Censuses**

- Data obtained from **every unit** in the target population.

- **Sample surveys**

- Data obtained from **samples of units** in the target population.

- **Administrative records**

- Data obtained for admin purposes, but later used for statistical purposes.

Big Data

- New and emerging **data sources**:

“Big Data are data sources that can be – generally – described as: high **volume**, **velocity** and **variety** of data that demand cost-effective, innovative forms of processing for enhanced insight and decision making.”

UNECE Definition 2013

- Types of sources:

- Social networks (communications; images; searches);
- Traditional business data (transactions; records);
- ‘Internet of things’ (sensor data).

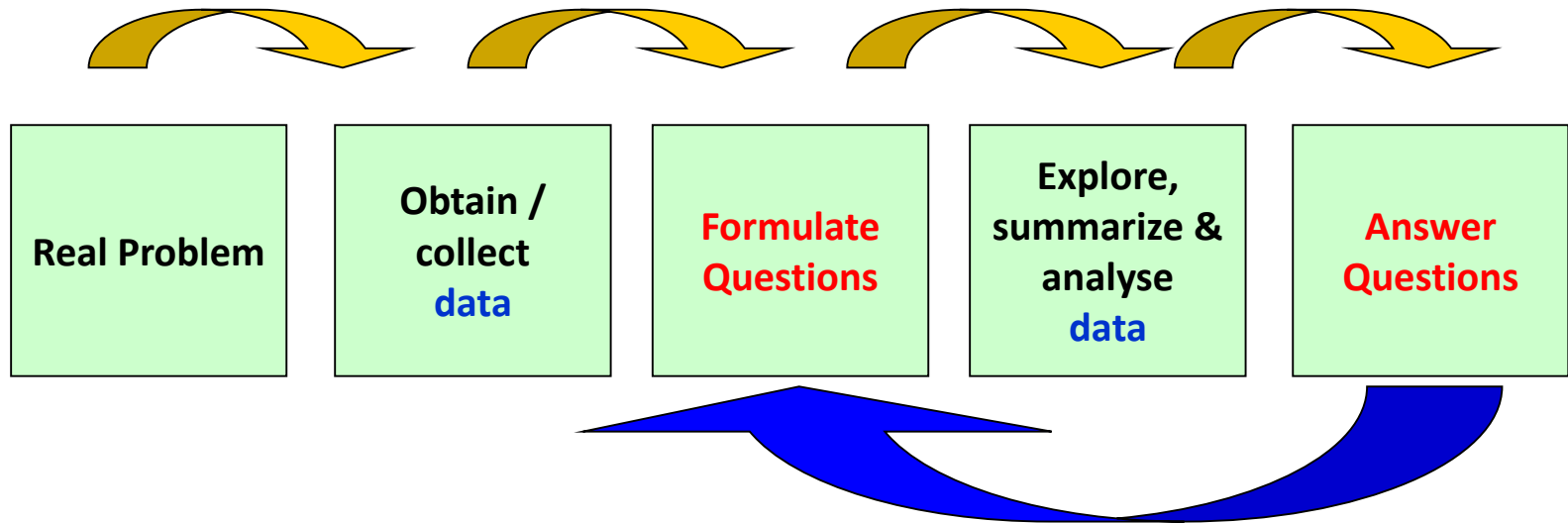
UNECE Classification:

<http://www1.unece.org/stat/platform/display/bigdata/Classification+of+Types+of+Big+Data>

Big Data Quality Issues for Official Statistics

- **Variability or Volatility**
 - Inconsistence and/or instability of data across time.
- **Veracity**
 - Ability to trust that data is accurate and/or complete.
- **Complexity**
 - Need to link multiple data sources.
- **Accessibility**
 - Need to ensure that data is and will be available.

Knowledge Generation Process in the Big Data Era



*A self-monitoring social and economic
eco-system is emerging*

- Designed (or traditional survey) data
 - Data produced to discover the unmeasured
- Organic (or big) data
 - Data produced auxiliary to processes, to record the process

Blending these two types of data is the future.

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GEORGETOWN
UNIVERSITY

Robert Groves

<http://directorsblog.blogs.census.gov/2011/05/31/designed-data-and-organic-data/>

Data quality

- Quality is desirable attribute of all data.
- Data quality derives from **quality of the source(s), measurement instruments & methods.**
- Vague concept: **what is data quality?**
- Must be defined, so that it can be planned, measured and evaluated.

Frameworks for data quality

- Several important organizations have invested in defining frameworks for data quality.
- *'Quality frameworks'*:
 - *US Office of Management and Budget (2006);*
 - *Statistics Canada (2009);*
 - *International Monetary Fund (2012);*
 - *OECD (2012);*
 - *UN (2012);*
 - *IBGE (2013).*



http://www.ibge.gov.br/home/disseminacao/eventos/missao/codigo_boas_praticas.shtm

OECD Quality Framework

Quality Dimension	Description
Relevance	Statistics and data are relevant if they satisfy user's needs.
Accuracy	Refers to the closeness between the values (estimates) provided and the (unknown) true values.
Credibility	Credibility of data products refers to the confidence that users place in those products.
Timeliness	Timeliness of data products reflects the length of time between their availability and the event or phenomenon they describe.
Accessibility	Accessibility of data products reflects how readily the data can be located and accessed.
Interpretability	Interpretability of data products reflects the ease with which the users may understand and properly use and analyse the data.
Coherence	Coherence of data products reflects the degree to which they are logically connected and mutually consistent.
Cost-efficiency	Cost-efficiency with which a product is produced is a measure of the costs and provider burden relative to the outputs.

OECD Statistics Directorate (2012).

Data quality

Two complementary approaches / trajectories
(Lyberg, 2012):

- Models for the **Total Survey Error**;
- **Survey Process & Quality Management** →
continuous quality improvement.

Total Survey Error

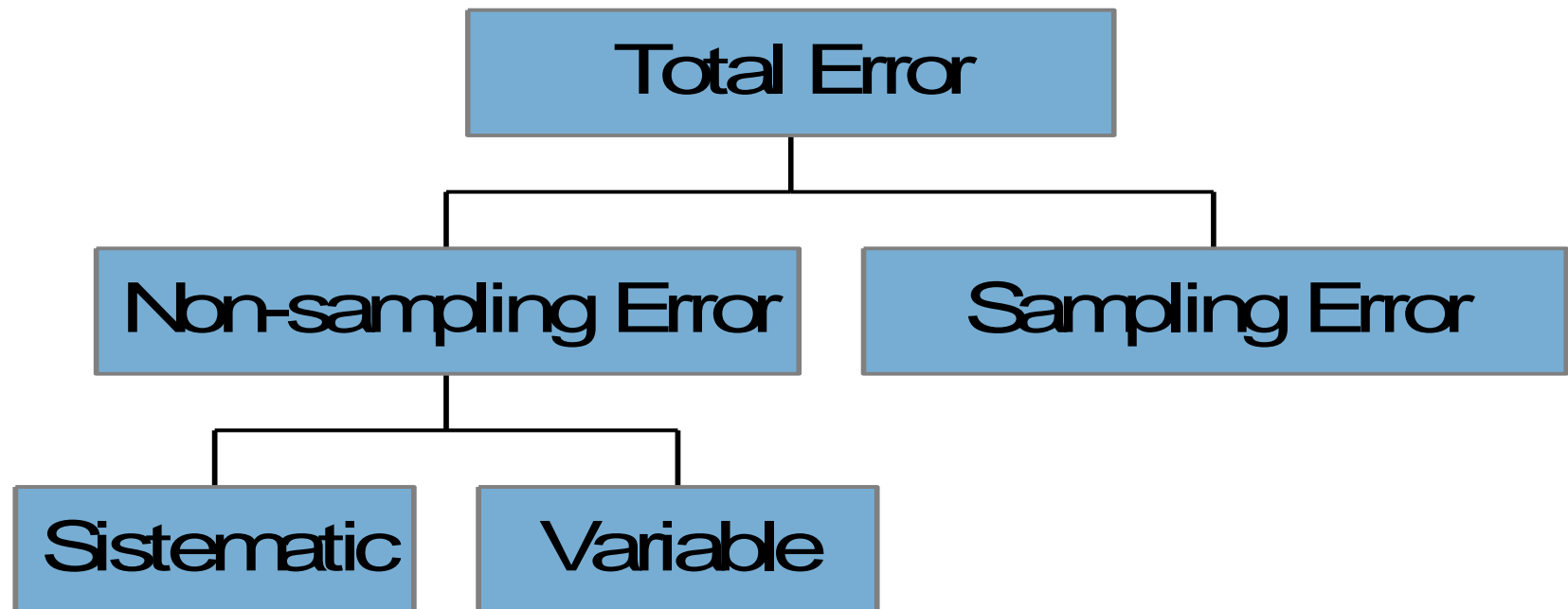
Four principles guiding design, implementation, evaluation and analysis of surveys:

- **Consider** all known error sources;
- **Monitor** main error sources during implementation;
- **Evaluate** key error sources after completing survey; and
- **Study the effects** of errors on key outputs and analysis.

Errors in surveys

“Error” in Estimates

Error = Estimate – True Value



Source: United Nations (2005).

Total Survey Error

Strength:

Survey is planned to control main error sources.

Weakness:

Proper assessment of total survey error is hard and costly to do in practice.

Sampling Error

- Easier to control.
- **Bias** (systematic error) may be avoided → use **probability sampling**.
- **Sample design, sample size** and **estimator** defined to make **variable sampling error** as small as required.

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- **Bias** (systematic error) may be avoided → use **probability sampling**.
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- **With 'Big Data', there may no longer be sampling error in some applications!**

Non-sampling Error

- Two broad classes of **non-sampling errors**.
- Errors due to '**non-observation**':
 - Coverage (frames, populations);
 - Non-response (collection).
- Errors in **observations**:
 - Specification;
 - Measurement;
 - Processing & estimation.

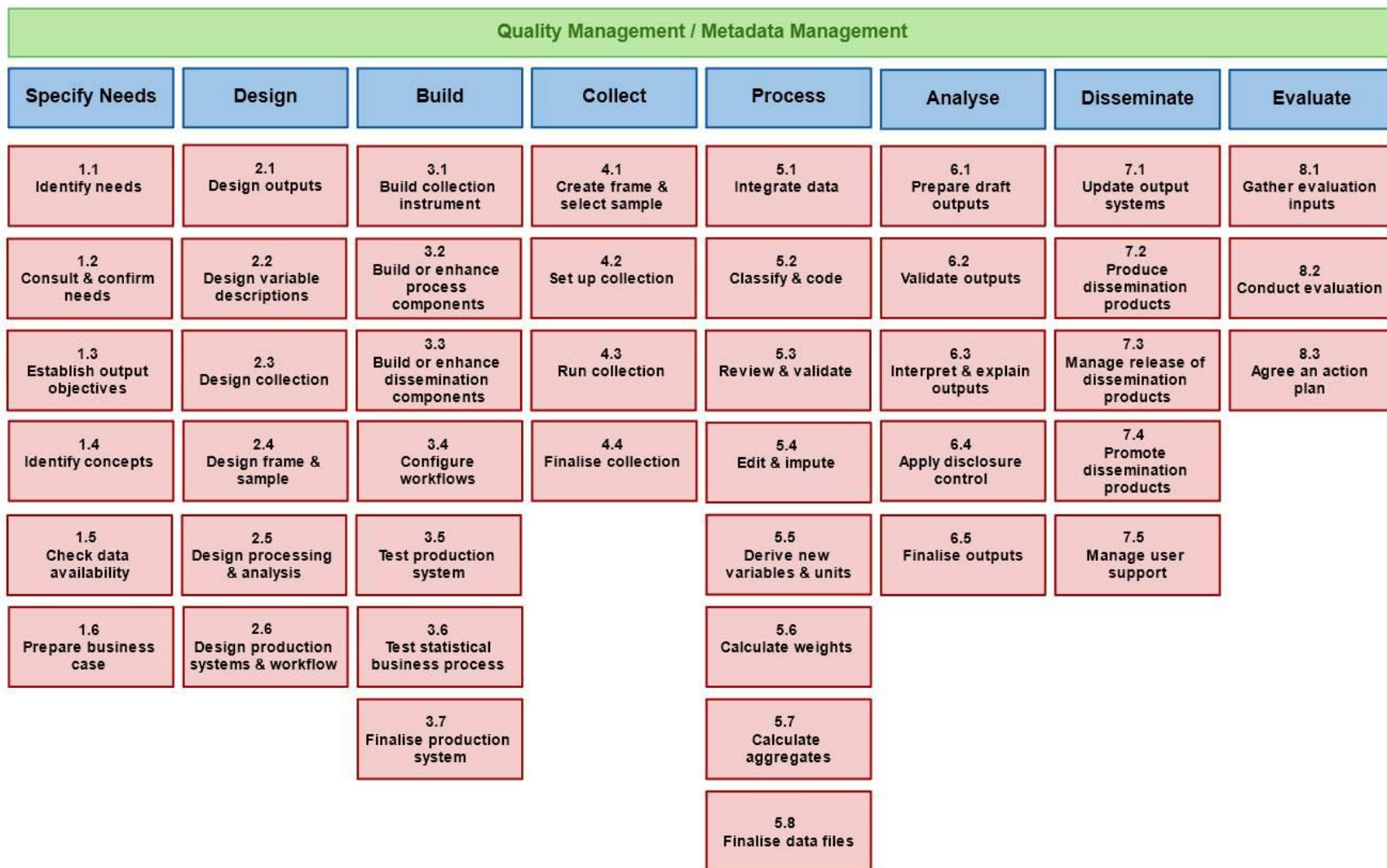
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 - Measurement;
 - Processing & estimation.
- With 'Big Data', non-sampling errors dominate!

Survey Process & Quality Management

- Complex and labour intensive.
- Must be planned, implemented and constantly monitored and adjusted.
- Core assumption / principle:

“**Product quality** depends on **process quality** which depends on **quality of the organization.**”



Source: <http://www1.unece.org/stat/platform/display/GSBPM/GSBPM+v5.0>

Survey quality: planning and analysis

Organization and process quality may be monitored and assessed using:

- Service level agreements;
- Analysis of paradata collected during survey operations;
- Defining and operating ‘quality stations’;
- User satisfaction surveys;
- Organizational assessments, using balanced score cards and other approaches.

UNECE Framework for the Quality of Big Data

- Institutional/business environment (agency providing the data)
- Privacy and Security
- Complexity
- Completeness
- Usability

- Time factors
- Accuracy (selectivity)
- Coherence
- Validity
- Accessibility and Clarity
- Relevance

Summarizing

Data quality remains fundamental concern.

Statistical thinking & methodology is essential pillar for promoting data quality.

Big data era will require **more statistical development**, not less:

- In the past, small n & small p ;
- With Big Data, large n or large p or both!

Thanks for your attention.

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