Design and development of integrated indicators for the Sustainable Development Goals

Report: Senior Expert Meeting

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Executive Summary

As part of the United Nations support to member countries in the development of the Sustainable Development Goals and following on from UNEA Resolution 1/4, UNEP organized an expert workshop on integrated indicators and the data revolution. The main aim was to develop integrated indicators which could support multiple goals and targets, using semantic networks and ontologies, relevant up-to-date information and where needed big data derived from earth observation and mobile platforms.

The multi-disciplinary nature of large-scale monitoring creates a complex collaborative setting characterised by a broad and varied knowledge-base. Ensuring that entities in this environment are clearly represented on a semantic level can greatly enhance the gathering, retrieval, querying, handling, sharing, analysis, and reuse of data by diverse systems and communities, and ultimately the generation of indicators based on a common understanding and set of protocols. The discipline of ontology has much to contribute towards this aim in information-rich systems.

An ontology attempts to systematically identify, in simple (i.e. as 'low-level' or empirical as possible) and precise terms, what the component entities in domains of interest are and how they relate to one another. This is done by creating a defined and logically-structured vocabulary comprising classes and the relations between them. A series of six ontologies were used as a basis for the development of integrated indicators in six environmental areas, air quality, water quality, biodiversity, oceans, chemicals and waste, and land tenure.

Domain	Ontology	Citation or URI
Chemical entities of biological interest	CHEBI	(Degtyarenko et al., 2008)
Human disease	DOID	http://purl.obolibrary.org/obo/doid.owl
Environments and ecosystems	ENVO	(Buttigieg et al., 2013)
Phenotypic qualities	PATO	http://purl.obolibrary.org/obo/pato.owl
Populations and communities	PCO	(Walls et al., 2014)
Cross-species anatomy	UBERON	(Mungall et al., 2012)

The aims of the workshop were to:

i) determine the key semantics, ontologies and definitions for the six areas in order to develop common frameworks for integrated indicators across domains

ii) Identify potential comparable baseline data and statistics for existing indicators and measurements, protocols for their use and where new and/or disaggregated data and statistics would be needed.

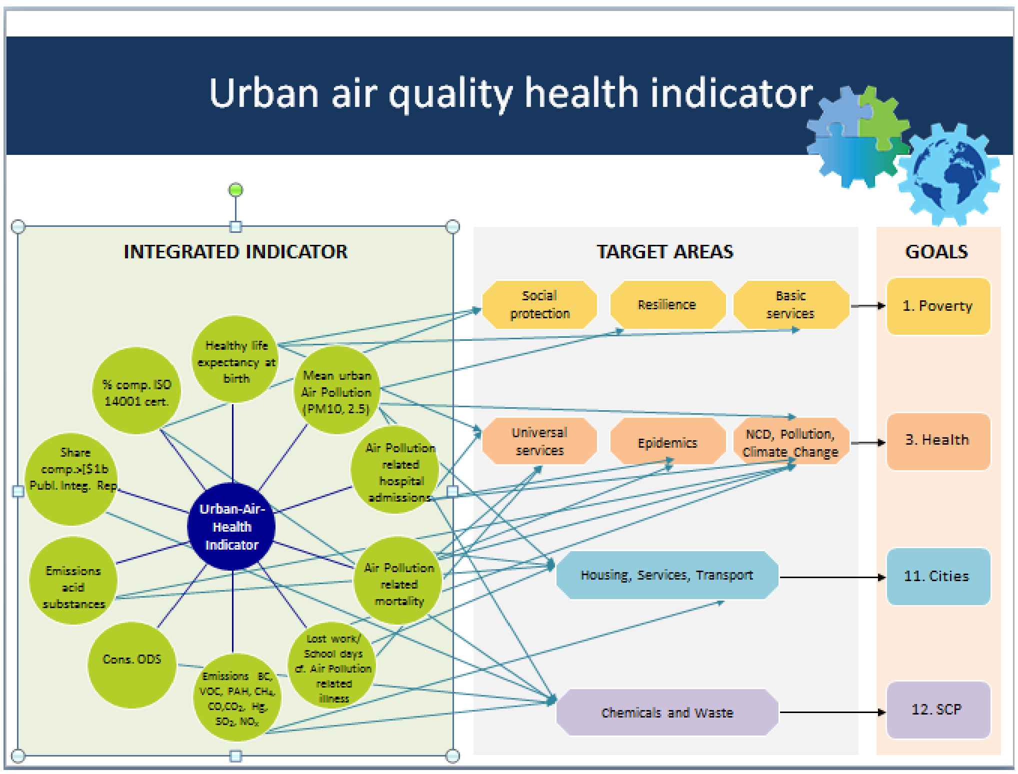
The general conclusions from the meeting were:

- Despite the numerous processes currently ongoing at the global, regional, sub-regional and national levels which aim to promote and support the development and use of indicators, specific work on alignment of domains is needed to be able to develop indicators to measure progress in an integrated and systematic way.
- The six focus areas, air quality, water quality, biodiversity, chemicals and waste, land tenure and oceans, were found to be causally linked to all 17 proposed SDGs, and to underpin their successful delivery.
- The complexity of interactions between thematic areas could be captured through a core set of integrated indicators based on well-aligned domain ontologies.

- To fully support the SDGs, additional ontologies will need to be developed, for example in land and common resources.

Environmental themes

1. **Air quality,** especially in cities, is important to the achievement of all 17 SDGs; the thematic group identified indicative linkages to all SDGs. The overarching SDG objective for air quality can best be achieved through up-to-date assessments of urban emissions, including the estimation of exposures in urban populations and vulnerable groups, and assessments of the short and long-term health impacts. Existing indirect and direct indicators, plus a new design for a global indicator based on an ontology for urban air quality health were identified. The integrated indicator is based on new global data sources derived from satellites and sensor-web enablement to provide air pollution exposure maps for vulnerable groups in cities.



2. For **biodiversity and ecosystem services**, there are numerous processes currently ongoing at the global, regional, sub-regional and national levels that aim to promote and support the development and use of indicators. An analysis of the suite of BIP indicators developed under the CBD framework highlights the relevance of existing BIP indicators to the SDG targets. Of the 60 BIP indicators, 25 are cross-cutting in nature and indicate progress towards multiple SDGs. Key to the development of integrated indicators will be the connection to ecosystem services, resilience and the system of environmental and ecosystem accounting.

3. **Sound management of chemicals and wastes** is essential for sustainable development through its linkages with poverty reduction; gender; water and air pollution, health, agriculture and food safety, industrialization and economic growth.. Sound management of chemicals and wastes provides solutions not only to environmental concerns but also social and economic issues. Proposed indicators are focused under the proposed goals and targets that explicitly mention chemicals, while recognizing that mainstreaming chemicals under the other domains is important in order to capture the complexity of chemicals management and its relationship with sustainable development. The development of

integrated indicators would need to be aligned with the 10 Year Framework Programmes on Sustainable Consumption and Production Patterns (10YFP).

4. Current indicators for **common land and natural resources**, pertaining to rangelands, forests, wetlands, and the natural resources above and below ground, often do not adequately capture the complexity of diverse, flexible and periodic tenure rights and regimes, of the important role that reciprocity and non-marketed goods, services and relationships play, or the voice of users themselves. Data are generally patchy, and definitions and methodologies vary across countries. But the sustainable management of common lands and natural resources can provide substantial benefits to indigenous peoples and local communities (IPLC), to the poor in rural areas, to the health of ecosystems, and downstream benefits such as the water supply of cities. It is therefore urgent to measure progress on this issue in a more systematic manner. There were two types of indicators considered, namely a) those that focus on the existence of IPLC rights, governance, and equitable distribution of benefits, as expressed either in area of land or percentage of people, and disaggregated by gender, ethnicity, age group, land-user group, or other parameters of inequality, both within communities and in comparison with national averages, and b) those that focus on how the rights are exercised and practiced, on the extent of loss or gain of common lands and natural resources, and on how the land and natural resources are used and managed.

5. In addressing **oceans**, a number of issues are highlighted which need to be taken into account more broadly, including the ontology of rights, and benefit sharing. Ocean problems are linked to land-based problems, and experts on both themes need to work together to ensure that these inter-linkages are property reflected in any integrated approach. Connectivity of ecosystem services should also be reflected in the indicators, as well as mainstreaming the value of ocean ecosystem services in national level measures of progress and outcomes. The group developed an approach for developing 4 integrated indicators for the ocean goal: Small-Scale Fisheries; Industrial fisheries (capture fisheries and aquaculture); Coastal and marine Development and Areas beyond national jurisdiction (ABNJ).

These indicators address that address the following issues: Decent work - Food security - Profit and income - Inclusion in decision making - Ecosystem health ("ecological foundation"). Further indicators to be defined include Tourism and Pollution. A revised map of ontologies for Oceans was developed.

6. **Water quality** is relevant to social, environmental and environmental aspects of sustainable development. Water quality is closely linked to all the other environmental themes discussed. These links are partially reflected by the proposed targets, e.g. the sound management of chemicals proposed in target 12.4 that directly relates to eliminating dumping and minimizing release of hazardous chemicals stated in target 6.3. Any indicator development will benefit from using a causal systems framework taking into account functional and contextual relations as defined through well-aligned ontologies such as environments (ENVO), location (GAZ), and populations and communities (PCO). These links need to be considered in future indicator development. A closer collaboration especially with the biodiversity and chemicals & waste communities is necessary. Five proposed core indicators are feasible but their implementation requires additional efforts in terms of monitoring coordination. Ontologies could augment global monitoring systems and indicator application but considerable harmonization work is necessary. Large-scale water quality modelling can help to bridge the data gaps and support indicator application but requires careful analysis and clear communication of model-related uncertainties.

Key Conclusions and Way Forward

1. Integrated indicators, based on universal data and information sources, need to be developed for the SDGs. The indicators will need to be balanced, robust, coherent, comprehensive, accurate and comparable.

2. To ensure the integrity of the SDG indicators it will be crucial that the inter-linkages amongst concepts and classes of processes and entities are clearly defined. This allows data gathered from one

domain to be deployed successfully in another. For example, being able to use sectoral data such as catches from local fisheries in analyses of nutrition and food security.

3. Ontologies are well recognized in this regard. They are widely used in knowledge engineering, artificial intelligence and computer science; in applications related to areas such as knowledge management, natural language processing, e-commerce, intelligent information integration, bio-informatics, education; and in new emerging fields such as the semantic web.

4. The design of indicators based on the use of ontologies and the semantic web avoids the risk of extensive redundancy in data gathering and ensures that different data and statistics standards can be used together.

5. A series of indicator-ontology workshops are currently underway with a view to offering a pilot set of integrated indicators in the areas linked to a minimum level of social and environmental protection, ensuring equity and prosperity within the Earth's life support systems and increasing capital for greater resilience and intergenerational equity. These workshops involve scientists and researchers from all the major disciplines plus ontology engineers, in order to rapidly progress the underpinning framework for the SDGs.

Workshop Details

Facilitators: Jacqueline McGlade, UNEP Chief Scientist, UNEP and Maryam Niamir-Fuller, *Special Advisor to the Executive Director on Post 2015/SDGs, UNEP*

Secretariat: Ludgarde Coppens, DEWA, UNEP

1. Background

As part of the United Nations support to member countries in the development of the Sustainable Development Goals and following on UNEA Resolution 1/4, UNEP has been requested to help establish relevant up-dateable quality assured environmental data flows and indicators. This work is to be undertaken in collaboration with member countries, multilateral environmental agreement secretariats, relevant UN agencies and programmes, centres of excellence, research programmes business and experts, and developed as part of UNEP Live (http://unep.org/uneplive).

UNEP is working with a range of partners to identify ways in which appropriate and integrated measurements can be developed to assess progress on the inter-linkages between environment and other dimensions. Such measurements, whilst challenging to develop and implement, will help to enhance monitoring of the three dimensions of sustainable development, as well as the objectives of the Rio+20 and Post 2015 processes, namely: integration and achieving a transformative and ambitious agenda. Overall, it will require a robust, transparent and multi-stakeholder monitoring and reporting framework to ensure that progress towards meeting goals is effectively tracked and that stakeholders are mutually held accountable for action and delivery.

UNEP's efforts build on existing work with various partners, including inter alia the Climate and Clean Air Coalition (CCAC), the Global Water Assessment, 10 -Year Framework of Programmes on Sustainable Consumption and Production, WAVES and UN SEEA, UN-Oceans, and the Global Call to Action on Community Land Rights. It will draw on and contribute to work being undertaken on indicators for the Post 2015 process, including by the UN Statistical Commission and the Sustainable Development Solutions Network. Eminent scientists and practitioners, UN partners including co-lead Agencies in the UNTST process and the UN Statistical Division, and civil society and private sector partners will be invited to collaborate.

Six areas have been selected because of their inter-linkages across the social, economic and environmental aspects of sustainable development: air quality, water quality, biodiversity, chemicals and waste, land tenure and oceans. The meeting was run as a combination of plenary sessions and parallel working groups.

The aims of the workshop were to support and provide input into the Post-2015 UN-Agency work on monitoring of SDGs by:

iii) determining the key semantics, ontologies and definitions for the six areas in order to develop common frameworks for integrated indicators across domains

iv) Identifying potential comparable baseline data and statistics for existing indicators and measurements and where new and/or disaggregated data and statistics will be needed.

2. The use of ontology in the context of environmental monitoring

Expert: *Pier Luigi Buttigieg, HGF MPG Group for Deep-Sea Ecology and Technology, Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung*

The following introduction is a condensed version of 'A brief encounter with ontology in the context of environmental monitoring', PL Buttigieg, which is available on the UNEP Live CoP (http://uneplive.unep.org/community/groups/profile/5713/integrated-measures-for-monitoring) Please refer to the original paper for references used.

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An ontology attempts to systematically identify, in simple (i.e. as 'low-level' or empirical as possible) and precise terms, what the component entities in some domain of interest are and how they relate to one another. This is done by creating a defined and logically-structured vocabulary comprising classes and the relations between them (*for illustration, see Figure 1*).

A fully realised ontology differs from a glossary, vocabulary (controlled, structured, or otherwise), taxonomy, or thesaurus in several). For example, **classes in ontology represent conceptual rather than textual entities**: the textual representation of a given class is merely a label and alternative labels can be added as synonyms. Class definitions and logical relations to other classes take precedence in identifying their meaning. As long as collaborators agree on the class' position in the conceptual map (*see Figure 1*), they can add and use their own labels while availing of homogenous semantics. Further, **every sub-class inherits all the properties of its super-class**. For example, given a class 'rainforest', the subclass 'tropical rainforest' inherits all the properties of its super-class; however, it is differentiated from other types of rainforests by some property, 'tropical'. This formalism is among several which impose logical constraints on ontological classes which contribute to clear communication both between human and machine agents.

It would be overly ambitious and vastly cumbersome to model the diverse knowledge in this environment with a single, monolithic ontology managed by a single authority. The solution is to **distribute the tasks of modelling** each "orthogonal" (i.e. largely unrelated) domain to several domain-specific expert groups. Each of these groups would follow the same development model and interoperate both on the theoretical and technical level. A workable template for this model has been established in the life sciences in the form of the OBO Foundry (Smith et al., 2007).

Well-aligned domain ontologies can easily import portions of one another to create compound concepts that are, instantaneously, linked to all knowledge models involved**.** To illustrate, consider the environment class 'gut environment'. A class such as 'digestive tract' can be imported from an anatomy ontology such as UBERON (Mungall et al., 2012) and combined with an environment ontology's (e.g. ENVO; Buttigieg et al., 2013) concept of an environment determined by a specific material entity to create a new class, 'digestive tract environment'. The knowledge represented in both ontologies would then be linked and exploitable while the concept stands adequately represented. Similarly, concepts such as 'contaminated soil' or 'heavy metal enriched wastewater' can be constructed using ENVO and CHEBI (Degtyarenko et al., 2008). *Table 3.1* lists a few OBO-Foundry-linked ontologies that are likely to provide good starting points in the development of an application ontology for environmental monitoring. (See the OBO Foundry homepage for more: http://www.obofoundry.org)

Table 2.1: Examples of domain ontologies primarily used in the biomedical sciences

Domain	Ontology	Citation or URI
Chemical entities of biological interest	CHEBI	(Degtyarenko et al., 2008)
Human disease	DOID	http://purl.obolibrary.org/obo/doid.owl
Environments and ecosystems	ENVO	(Buttigieg et al., 2013)
Phenotypic qualities	PATO	http://purl.obolibrary.org/obo/pato.owl
Populations and communities	PCO	(Walls et al., 2014)
Cross-species anatomy	UBERON	(Mungall et al., 2012)

As a welcome 'side-effect' of their logical character, **ontologies – or, at the very least, an ontologically-flavoured development approach – can assist in developing coherent and robust standards which are poised for conversion to machine-readable representations**. Casting knowledge in an ontological form encourages the 'teasing apart' of concepts into their (more or less) empirical parts, which prevents unstructured debate over nebulously-defined, inter-domain inconsistencies when they arise. Further, existing standards can be linked to an appropriate ontology and provide the raw material to extend that ontology. Thus, ontology projects with open membership and development models offer official entities an opportunity to embed their standards into future development.

Table 2.2: Examples of candidate vocabularies

Domain	Instance	Concepts
Biodiversity	Global names architecture GBIF	Institutions, Networks Country nodes, Datasets Search and Metrics
	eCat name parser	Taxonomic names
Ecosystem characterisation	LTER	Organizational units, disciplines, events measurements, methods, processes substances, substrates ecosystems, organisms
Environmental law	ECOLEX/FAOLEX	
Hydrology and inland water sciences	CUHASI	Observations Data Model (ODM) Controlled Vocabulary Registry
	Water ML OGC	OG
Oceanography	Rolling Deck to Repository (R2R)	Controlled vocabulary and ontology
Pollution control	US-EPA Terminology Reference System	
Socio-economics	SEDLAC	

In conclusion, ontologies have great potential to enhance multiple facets of monitoring endeavours by clarifying the semantics of these complex undertakings both for human and machine agents.

3. Environmental Themes

3.1. Air quality

Facilitator: *Jane Akumu, Transport Unit, DTIE, UNEP*

3.1.1. Introduction

Poor air quality is a serious and worsening problem in many rapidly growing cities. According to a March, 2014 report by the World Health Organization (WHO), air pollution is now the world's largest single environmental health risk, and is fast becoming one of the leading causes of illness and death in developing countries. The report estimates that more than 7 million people died prematurely in 2012 due to outdoor and indoor air pollution, one out of eight people worldwide. It is also the poor, young, elderly and sick who are suffering disproportionately from the impacts of deteriorating air quality.

Many factors contribute to increasing air pollution in developing and transition countries: growing vehicle emissions, inefficient industrial technologies, and energy generation are important contributors in urban areas. The use of biomass fuel for cooking and heating in households is another major source of air pollution, particularly in urban poor households and rural areas.

3.1.2. Air quality and SDGs

Improving air quality is vital to the achievement of the proposed SDGs:

Table 3.1: Crosscutting issues in SDGs

Open Working Group proposal SDG		**Indicative Linkages**
Goal 1	End poverty in all its forms everywhere	The poor are more vulnerable to air pollution.
Goal 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Ozone is damaging crops. Mercury can contaminate fish.
Goal 3	Ensure healthy lives and promote well-being for all at all ages	Health and well-being is influenced by air pollution.
Goal 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	Disease caused by air pollution can increase school absences.
Goal 5	Achieve gender equality and empower all women and girls	Women and children suffer more from indoor air pollution than men.
Goal 6	Ensure availability and sustainable management of water and sanitation for all	Air pollution can contaminate water. Volatile liquid effluents in water can