DATA QUALITY AND AVAILABILITY FOR S-LCA

Seminararbeit von
RODRIGO HERRERA

an der KIT-Fakultät für Wirtschaftswissenschaften

eingereicht am	:	29. Juli 2017
Studiengang	:	Wirtschaftsingenieurwesen
Betreuer	:	Andreas Fritsch

Institut für Angewandte Informatik und Formale Beschreibungsverfahren
KIT - Die Forschungsuniversität in der Helmholtz-Gemeinschaft

ABSTRACT

Introduction Social Life Cycle Assessment has, since it's inception, primarily been constrained by the availability of data to conduct this type of studies as well as the quality of said data.

Vision Advances in information technologies as well as the spreading and democratization of access to the Internet, allows us to theorize of how these new technologies could improve the current situation regarding data availability and quality for S-LCA

Moving forward Although the opportunities for improvement are vast and the number of technologies that could be used immense, two particular technologies stood out during while researching for this work, which in the opinion of the author could be of great use for the advancement of the practice of S-LCA. On the one hand the Blockchain could allow the creation of a free, open and verifiable record of S-LCA data collected in a decentralized manner worldwide. Meanwhile the Resource Description Framework (RDF) could provide foundation for a new data architecture for S-LCA databases, facilitating integration of external databases as well as harmonizing the different data sets found, thus facilitating access to S-LCA data.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

S-LCA Social Life Cycle Assessment

RDF Resource Description Framework

E-LCA Environmental Life Cycle Assessment

SHDB Social Hotspots Database

PSILCA Product Social Impact Life Cycle Assessment database

ICTWSS Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts

I/O Input/Output

LCA-HT LCA Harmonization Tool

EPA Environmental Protection Agency

1 INTRODUCTION

The concept of Social Life Cycle Assessment (S-LCA) is a relatively new one, based largely on the idea of measuring how products and services impact social and socio-economical conditions of those involved in the different stages of the supply chain. As stated in the Guidelines for Social Life Cycle Assessment of Products released by the UNEP:

"A social and socio-economic Life Cycle Assessment (S-LCA) is a social impact (and potential impact) assessment technique that aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their life cycle encompassing extraction and processing of raw materials; manufacturing; distribution; use; re-use; maintenance; recycling; and final disposal. S-LCA complements E-LCA with social and socio-economic aspects. It can either be applied on its own or in combination with E-LCA." [Ben010, p. 37]

In these guidelines the methodology for conducting a S-LCA is throughly explained, following the existing ISO 14044 framework, which outlines the phases and requirements for both E-LCA and S-LCA. The phases of a S-LCA study are:

1. Goal and Scope
2. Life Cycle Inventory
3. Life Cycle Impact
4. Interpretation

It is during the the Life Cycle Inventory phase where the data required to perform the study is gathered. One of the most important decisions to be made during this the phase, is when to collect data on site, or when to rely on generic data. Given the nature of social and socio-economical data, this decision can powerfully impact the results of the study.
Data is described as being the driving force behind a life cycle assessment [Curr12]. Yet one of the most pressing challenges which LCA studies face is the lack of databases for conducting the studies, and the high costs and time needed for collecting information on site.

2 DATA IN S-LCA

2.1 SITE-SPECIFIC DATA

"Site specific data refers to data collected for a specific process, occurring in a specific enterprise, in a specific location with those stakeholders involved or affected. Site specific data does not mean that the data is all collected on-site as data might be collected elsewhere (e.g. town office, etc.)."[Ben010, p. 57]
As its name implies, site-specific data needs to be collected at the location where the process being studied is actually taking place. This is usually done through social audits, which may involve:

- Auditing of enterprise documentation (e.g. payrolls, management systems)
- Auditing documentation of authorities and NGOs
- Participative methodologies
- Directed and semi-directed interviews
- Focus groups
- Questionnaires and surveys

[Ben010, p. 61]
Two of the defining characteristics of site-specific data, are the high costs and long time required to collect it. Given that in most cases, collecting site-specific data for every functional unit and every stakeholder, would be prohibitively expensive and time consuming, data collection must be prioritized. Priority setting is often done by considering the sphere of influence of the organizations that requested the study.
Another way to prioritize data collection is through *hotspot assessments*. This means analyzing social hotspots ("unit processes located in a region where a situation occurs that may be considered a problem, a risk or an opportunity, in relation to a social theme of interest"[Ben010, p. 60]) to determine where data collection might be more urgent.
Independently of how the prioritization is done, one of the problem that arises is that in some cases relevant information could be ignored or lead to gathering redundant information. For example, a hotspot assessment could point out, that a certain region should be more closely examined, but the data gathered doesn't reflect the initial suspicion. Meanwhile, another relevant hotspot might have been ignored, given that resources were used to collect data in other location.

2.1.1 *Challenges for site-specific data*

Other than the resources required to gather site-specific data, another important challenges that S-LCA practitioners face for its collection, are the intrinsic bias related to the measurement methods, which should always be discusses when presenting the study and the difficulty of contacting all relevant stakeholders of an specific unit process.

2.2 generic data

"Generic data means data that have not been collected on site (with the stakeholders). Even data that are collected from other manufactures of the same kind of product, in the same country as the one of the life cycle stage being studied, are still considered generic. They may not be representative of the impacts of the particular supply chain. Since behaviors are so important in social impacts assessment, it is important to know the site-specific information."[Ben010, p. 57]
This type of data is usually the one found in most available S-LCA databases, and allows practitioners to fill the gaps they might have, in order to conduct their study.
Another important use of generic data, is allowing S-LCA practitioners to conduct hotspot assessments, in order to prioritize site-specific data collection.
Generic data is collected from secondary sources like the UN or the OECD, the industry or directly using a variety of instruments. (Benoît, Catherine, 2010)

2.2.1 *Challenges for generic data*

One of the main problems when using generic data, is that in many cases secondary data will be needed. However, in most cases, secondary data may have been gathered for other purposes rather than for conduction S-LCA studies.
In the Guidelines for Social Life Cycle Assessment some of the problems that may arise when using secondary data are outlined, including:

- Data may not relate well to the concept being measured.
- The context in which the data was collected may have changed.
- The way the data was collected is no longer available
- The data might have been transformed by those who collected in a way that makes it unusable.

- Persons collecting the data might have committed mistakes.

A good example of such problems is data collected in national censuses:
"A vast majority of social indicators found in international databases are based on information obtained from national censuses. It is well-known that many countries do not have the resources to conduct accurate censuses. No country conducts a yearly national census and some countries conduct them at irregular intervals. Data for the intervening years have to be estimated. Given these and a number of methodological problems, the data tend to be incomparable both between countries at a given point in time and within given countries over time. As a consequence, differences among countries in the values of social indicators are difficult to interpret. Yet, these problems do not provide grounds against the use of social indicators per se, but grounds for attempting to improve their reliability"[McGi06, p. 320]
Other important distinctions that should be made when working with generic data, is whether geographical, temporal or technological differences could play a role in how the data being used relates to the location of the process unit being studied.
Furthermore the credibility of the data sources plays a fundamental role when evaluating generic data.

2.3 DATABASES FOR S-LCA

Databases are one of the most important tools required to conduct S-LCA studies. Given the relative infancy of the field in comparison to E-LCA, and the intrinsic difficulties of measuring and documenting social and socio-economical data, there are few comprehensive S-LCA databases available. Among the most known are:

- SHDB
- PSILCA

2.3.1 *Social Hotspots Database (SHDB)*

The SHDB is a project launched in 2009 and centered at New Earth, a U.S. non-profit focused on information systems for sustainability and currently working with Center for Health and the Global Environment at the Harvard T.H. Chan School of Public Health.
The project looks to provide detailed information on human rights and working conditions along supply chains, in order to assess risks and provide methods to calculate social footprints.
The database is divided in modules which consist of:

1. A Global Input Output Model
2. A Worker Hours Model

3. Data on social risks and opportunities

The activity variable used on the SHDB is worker-hours, which translates into how many worker-hours are involved for each unit process along the supply chain.

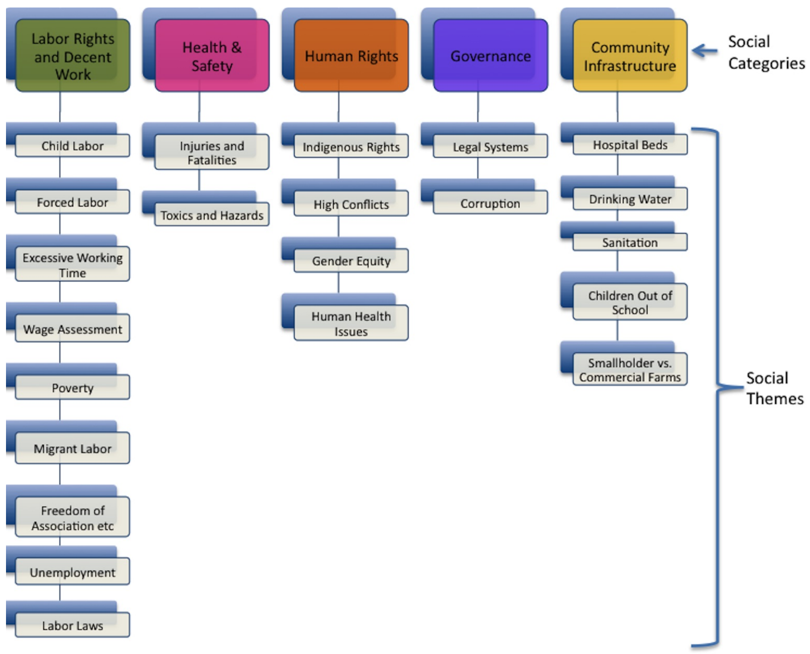

Figure 1: Social Impact categories and themes included in the SHDB [Data17a]

Furthermore the database allows users to easily visualize in a map global sector risks for a specified issue, analyze risks for multiple issues along a supply chain for selected Country-Specific-Sectors and compare Social Hotspot Indexes for country specific sectors. The corresponding interfaces can be seen in the annex 1.

2.3.2 *Product Social Impact Life Cycle Assessment database (PSILCA)*

PSILCA is an innovative, comprehensive database developed by GreenDelta GmbH in Berlin, which seeks to provide a transparent and up-to-date foundation for Social Life Cycle Assessments (S-LCAs).// The database uses uses Eora as its Global Input/Output Model and provides information for 189 countries and almost 15.000 different sectors.
Social indicators are structured in a manner similar to the structure outlined in the Guidelines for Social Lifecycle Assessment of Products, which can be seen in the annex 2.
The database relies on a variety of sources such as:

- reputable statistical agencies such as the World Bank, the International Labour Organization, the World Health Organization, the United Nations among some.
- private or governmental databases like the Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts (ICTWSS) database, the United States Department of Labor, etc.
- various case studies and own investigation.

[Eisf16]
PSILCA uses worker-hours as its activity variable in order to quantify the impacts of a process along a life cycle, although the addition of further variables is currently being analyzed.

2.3.3 *Comparison between SHDB and PSILCA*

The databases mentioned above, are to the date of this work, some of the most known and used among S-LCA practitioners.

	SHDB	PSILCA
I/O Model	v2. GTAP 7	Eora
No. of Indicators	>150	66
Countries represented	225	187
Activity variable	Worker-hours	Worker-hours
Price	1.000 – 5.000 €	3.000 – 14.000 €
Software Compatibility	openLCA, SimaPro	openLCA, SimaPro

Table 1: Comparison between SHDB and PSILCA.

As it can be seen above, thanks to the Global Input/Output (I/O) Model used, PSILCA is more comprehensive than the SHDB. Nonetheless, since the SHDB is built in modules, its I/O can be exchanged for Eora or any other, thus providing more detailed information.
In terms of use, in the current versions of both databases, the SHDB provides information about more countries and more indicators than PSILCA, thus facilitating the execution of hotspot assessments. On the other hand, PSILCA contains data about far more sectors, which in turn eases the workload when conducting S-LCA studies.

2.4 MAIN ISSUES REGARDING DATA QUALITY AND AVAILABILITY

One of the most cited problems among researchers for conducting S-LCA studies is the availability and quality of data. (Benoît, C., 2010, p. 84) (Sala, S et al., 2015, p. 83)
Several factors contribute to the problematic, but all relate to the particular nature of the social impact data needed to conduct S-LCA, which is difficult to measure, collect and evaluate. Biases and errors in the measurement methods often influence the quality of the data. Additionally the data is often semi-qualitative or qualitative, which makes its interpretation ever more challenging.
Compounding to the aforementioned problems, the lack of databases further complicates access to S-LCA data, as well as the fact that the data in said databases was not collected for the purpose of conducting S-LCA studies.

AVAILABILITY	QUALITY
Data collection is both costly and time consuming.	Data might have been collected for other purpose.
Still relatively few available databases.	Data is not always relevant
Most of the information comes from secondary data aggregated by government or international agencies or NGOs.	Measurement methods may no longer be appropriate.
Not enough site-specific data	Data might no longer be valid
	Data might be incomplete
	Data might not well be documented
	Results might be uncertain

Table 2: Main issues regarding data quality and availability

3 NEW TECHNOLOGICAL TRENDS

The basic idea behind life cycle assessment is one that predates many of the information technologies we now count with, but they have nonetheless strongly influenced the field.
As the world became more interconnected and access to the Internet and computers became more ubiquitous, gathering greater amounts of data, analyzing it and interpreting the results became possible, and thus the idea behind fully analyzing the impacts of products along supply chains was finally feasible.
Thanks to the development of databases and the ability to easily access them through the Internet, LCA practitioners have at their disposition a wealth of information that in no other way would be possible to obtain.
Despite this advances, collecting data remains cumbersome and expensive. Furthermore, the structures used for different databases are not always compatible with each other or with certain software packages used for conducting S-LCA studies, thus hindering the access to the information needed.
Yet some promising global technological trends coupled with new information technologies could provide part of the solutions to the problems mentioned before.
On the one hand, the last decade has seen an explosion on the access to the Internet as well as access to smartphones. Although much of this process has occurred in the developed world, where access to data is not as great of a problem as in developing countries, the latter have made huge strides in regards to both metrics in the last decade.

Assuming both of these trends continue their upward trajectory, in a couple of decades the world will find itself in an age of unprecedented interconnectedness, which would give way to far-reaching ways of collecting data and freeing up access to it across the globe.
Two already existing technologies which would benefit from this trend and at the same time help to solve the difficulties regarding data for S-LCA are the **blockchain** and the **Resource Description Framework (RDF)**.
The blockchain has the potential to change the way data is collected and made available for stakeholders to use and validate, while the RDF could potentially greatly simplify of harmonizing diverse databases and incorporating external data sets.

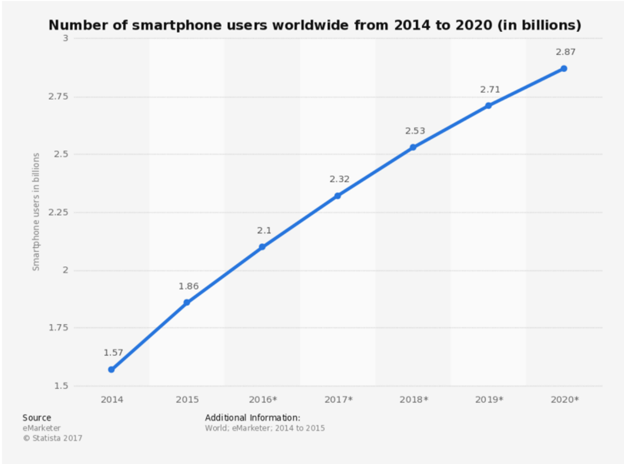

Figure 2: Number of smartphone users worldwide from 2014 to 2020. [eMar17]

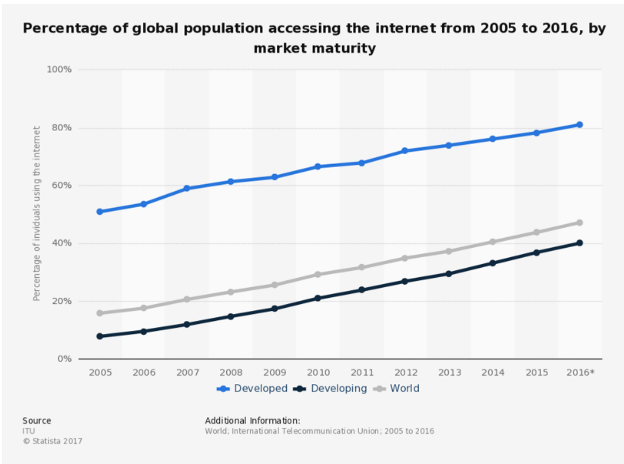

Figure 3: Share of Internet users in the world population since 2006 [ITU17]

4 THE BLOCKCHAIN

4.1 WHAT IS THE BLOCKCHAIN?

Although a great deal of attention is being given to the technology and its potential to upend the way financial transactions are done across the world, several definitions for the concept can be found across the literature. For the purposes of this work, the blockchain will be understood as found in Daniel Drescher's book Blockchain Basics : A Non-Technical Introduction in 25 Steps:

THE BLOCKCHAIN is a purely distributed peer-to-peer system of ledgers that utilizes a software unit that consist of an algorithm, which negotiates the informational content of ordered and connected blocks of data together with cryptographic and security technologies in order to achieve and maintain its integrity.[Dres17, p. 35]

4.2 UNDERLYING PRINCIPLES

Yet just a definition doesn't suffice to fully grasp what the technology does. To further understand how the blockchain works, certain underlying principles must be comprehended.

DISTRIBUTED DATABASE Each party on a blockchain has access to the entire database and its complete history. No single party controls the data or the information. Every party can verify the records of its transaction partners directly, without an intermediary.[IaLa17]

PEER-TO-PEER TRANSMISSION Communication occurs directly between peers instead of through a central node. Each node stores and forwards information to all other nodes.[IaLa17]

TRANSPARENCY WITH PSEUDONIMITY Every transaction and its associated value are visible to anyone with access to the system. Each node, or user, on a blockchain has a unique 30-plus-character alphanumeric address that identifies it. Users can choose to remain anonymous or provide proof of their identity to others. Transactions occur between blockchain addresses.[IaLa17]

IRREVERSEBILITY OF RECORDS Once a transaction is entered in the database and the accounts are updated, the records cannot be altered, because they're linked to every transaction record that came before them (hence the term "chain"). Various computational algorithms and approaches are deployed to ensure that the recording on the database is permanent, chronologically ordered, and available to all others on the network.[IaLa17]

computaional logic The digital nature of the ledger means that blockchain transactions can be tied to computational logic and in essence programmed. So users can set up algorithms and rules that automatically trigger transactions between nodes. [IaLa17]

4.3 the blockchain and sustainability management

Although for many the blockchain would have no other uses outside of the realm of financial transactions and record keeping, the transparent and open nature of a blockchain based registry of records are enormously beneficial for promoting sustainability.
Particularly for the field of Life Cycle Assessment, where products need to be tracked across global supply chains in order to determine the corresponding environmental or social impacts in the different locations and for all the stakeholders involved.
Furthermore the blockchain has the ability to change the way data is collected and stored by allowing to organize data collection in a bottom-up manner.

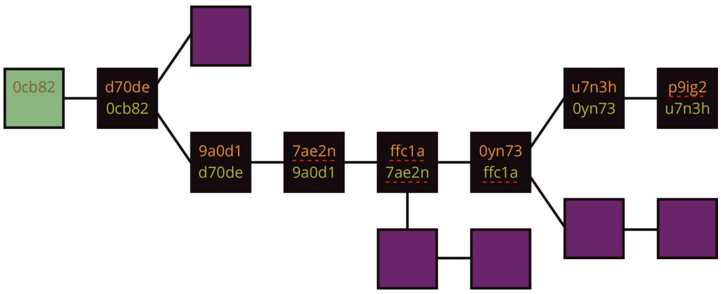

Figure 4: Blockchain formation. The main chain (black) consists of the longest series of blocks from the genesis block (green) to the current block. Orphan blocks (purple) exist outside of the main chain.[blo17a, blo17b]

4.4 tracking products with the blockchain

One use that the blockchain is already being given in the field of sustainability management, yet not to date in S-LCA, is the one of tracking products across the supply chains, and allowing both businesses and consumers to know the origins of the products they are selling or purchasing.
This is being done by a UK based company named Provenance, which developed a platform with the same name, which consists of a blockchain based database, where the different steps of a product along the sup-

ply chain are recorded in the blockchain using smart tags.

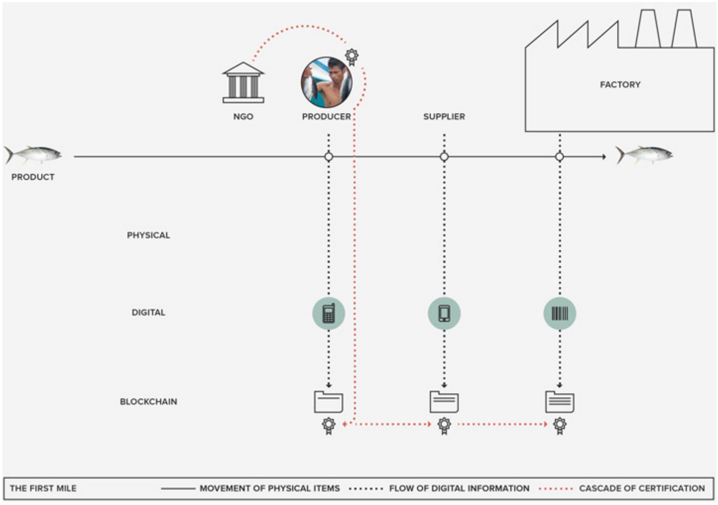

Figure 5: Tracking the tuna along the supply chain. Case study by Project Provenance Ltd. [Bake16]

The company collaborates with NGOs in order to verify that certain standards are being upheld by the different companies (e.g. living wage, health conditions, environmental sustainability), then associating these attributes with the products being tracked and storing this in the blockchain.
Furthermore by recording every step of a product in the supply chain in a unalterable, publicly available database, promotes transparency and ethical behavior on the companies part.
An additional benefit of this use of the blockchain and of special interest for this work, is the wealth of data that could be generated and used for conducting S-LCA studies. By recording the flows of products across supply chains, the work of determining where are the social impacts of a certain product taking place becomes much simpler, as well as allowing to draw larger system boundaries for S-LCA studies.

4.5 BOTTOM-UP DATA COLLECTION USING THE BLOCKCHAIN

A further use that could be theorized for the blockchain in the field of S-LCA, is using its decentralized nature to allow the collection of data by a global network of peers.
The idea could work as follows:

1. Establishing a network of trusted activists and collaborators globally. Determining which organizations or individuals can be considered as trustworthy should fall to a central supervising commission of some form.

2. Using a blockchain-based platform, the collaborators could gather and upload data regarding social indicators of interest in their designated regions on a regular basis. Pseudonimity would help to oversee those uploading information without giving away private information.

3. Validations methods should be put in place to certify that the data being uploaded fulfills quality requirements previously set.

4. S-LCA practitioners and the public in general could then freely access the database. Thanks to the inalterability of the records kept in the database, the information could not be tampered with by outsiders.

4.5.1 *Advantages of a blockchain-based database for S-LCA*

- Costs and time could be greatly reduced given that less planning is needed to organize data collection at specific locations thanks to the network of collaborators.

- The database would be freely accessible and transparent for everyone, thanks to the distributed network of peers which could largely reduce the costs associated with maintaining large growing databases.

- The network could have a large degree of autonomy and function in a decentralized manner, requiring just minimal administrative structures to oversee the basic functioning of the database and certify new collaborators.

4.5.2 *Disadvantages of a blockchain-based database for S-LCA*

- Many of the social and socio-economical indicators used for conducting S-LCA require of some previous knowledge or even advanced training in order to be measured. This could severely limit the number of suitable individuals that could collaborate in the network.

- The network would be almost entirely reliant on the trustworthiness of the collaborators. More rigid control structures to combat this would defeat the purpose of the openness and transparency of the network.

- In many of the most vulnerable locations, data can still be difficult to obtain because of the lack of the proper mobile or broad-band infrastructure needed to regularly upload data to the database.

5 THE RESOURCE DESCRIPTION FRAMEWORK

The Resource Description Framework (RDF) is one of the core components of the Semantic Web, a concept first proposed by Sir Tim Berners Lee, as an extension to the Web. He defined it as "a web of data that can be processed directly and indirectly by machines".
Although his vision has not been fully realized, a potential application of this concept could be providing a new data architecture for S-LCA databases. This idea has been already introduced by Wesley Ingwersen in his article "A new data architecture for advancing life cycle assessment", as well as being put in practice by the U.S. Environment Protection Agency (EPA) with the LCA Harmonization Tool.

5.1 BASIC CONCEPTS

THE RESOURCE DESCRIPTION FRAMEWORK "data model represents information as sets of statements, which can be visualized as node-and-arc-labeled directed graphs."
"In RDF, information is represented in statements, called RDF triples The three parts of each triple are called its subject, predicate, and object. A triple mimics the basic structure of a simple sentence..."[RGIVH13, p. 8]

This idea seeks to replicate to a certain degree how humans reason and connect information themselves. An example of a triple would be:

Carl Benz	was born in	Mühlburg
(subject)	(predicate)	(object)

By combining several triples, "graphs" can be created, an example would be:

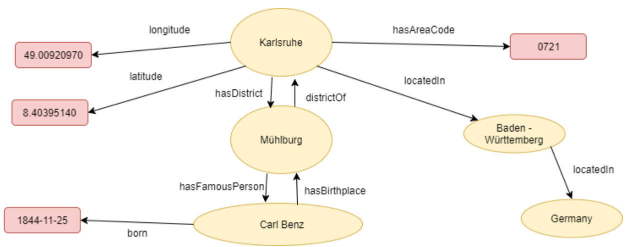

Figure 6: Example of a RDF graph.

By using this structure, data can be easily related and connected. The types of things the data describe and the properties they have are referred to as a vocabulary, sometimes known as an ontology. [IHTM+15]. The Web Ontology Language (OWL) is the standard vocabulary used to describe RDF objects.

WEB ONTOLOGY LANGUAGE is a family of knowledge representation languages for authoring ontologies. Ontologies are a formal way to describe taxonomies and classification networks, essentially defining the structure of knowledge for various domains: the nouns representing classes of objects and the verbs representing relations between the objects.[W3C17]

Although ontologies have certain similarities to the class-hierarchies of the object-oriented programming, ontologies allow a higher degree of flexibility for integrating a rapidly growing amount of data from heterogeneous sources, while class-hierarchies are more static and use less diverse data structures.
Moreover a further advantage of the RDF data architecture is the fact that data relations can be manually determined or automatically inferred through semantic reasoners. [IHTM+15]

5.2 RDF DATA ARCHITECTURE IN S-LCA DATABASES

One of the characteristics of data used for S-LCA is that it usually comes from several sources, who in many cases do not use the same data structure. Integrating this data within the current relational databases required a lot of manual effort and for very large data sets might even be unfeasible.
One of the key advantages that the RDF schema provides, is the ability to easily relate and incorporate external data sets, and making it possible for computers to actually understand what is contained in said data.
In order to implement a RDF-based data architecture for LCA, an ontology needs to be defined, in order to capture its concepts and conventions to effectively describe LCA data, and then using that ontology to appropriately label data in a series of RDF triples. (Ingwersen, W et al., 2015)
In the case of E-LCA, the ECO ontology already provides this step, but there is still, up to the date this work was written, no ontology built for S-LCA. Nonetheless the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Agriculture are currently developing software called the LCA Harmonization Tool (LCA-HT), which would permit to cross match data from different sources using the RDF data architecture and integrate them into a single database.

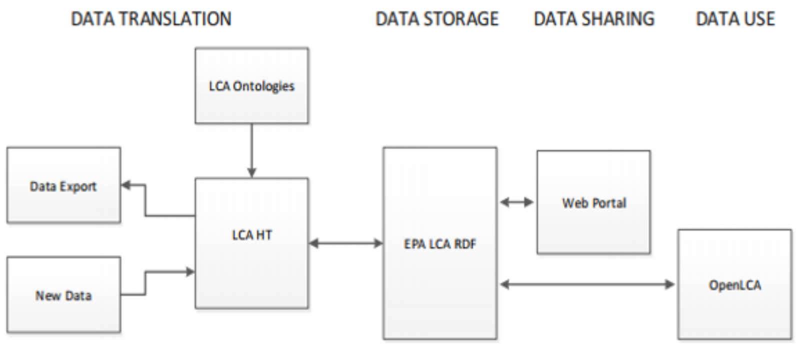

Figure 7: Proposed LCA data flow for EPA LCA data with data translation, storage, sharing, and use phases [IHTM+15]

5.2.1 *Advantages of using the RDF data architecture for S-LCA databases*

By facilitating interoperability between existing S-LCA databases and enabling the integration of non-S-LCA datasets, the RDF data architecture could tackle one of the main problems facing S-LCA practitioners which is the lack of databases.
Moreover, the fact that there are still relatively few databases for S-LCA, means that the adoption of a new data architecture for databases using RDF would be less cumbersome as if there were many.
Also by enhancing the capability to relate data from different sources and in different formats, would mean that practitioners would have easier access to already existing databases, which perhaps are simply not compatible with the software they are using.
Additionally the technology could allow to integrate new data sources automatically using semantic reasoners, thus facilitating the work of maintaining the databases up to date.
By enhancing access and availability of data for S-LCA practitioners, the practice could also be able to expand much faster and encourage adoption on the side of the companies.

6 CONCLUSIONS

Although the challenges being faced by S-LCA practitioners regarding data quality and availability remain strong, and many aspects of the methodology remain unclear, the demand for transparency and accountability for our supply chains remain high. That means, that finding innovative and effective solutions to these problems is an imperative should the practice thrive in the future.
The two information technologies exposed in this work are just ideas and clearly need more refinement before they can be set in practice. Nevertheless they could provide answer to the current challenges being faced by freeing up access to information and making it readily available for conducting S-LCA studies.
Moreover current global technological trends show that access to the Internet and to information technologies will continue to steadily rise, hence the potential impact of both technologies, which rely on access to both resources, could be potentially greater.
Perhaps there are more technologies which could provide solutions to the current difficulties, but in the opinion of the author, the blockchain and the Resource Description Framework could be some of the most easily implemented, given that there are already applications in the field of sustainability management and LCA in general using both of these technologies, allowing the possibility of transfer of knowledge from other fields into S-LCA.

A

ANNEX A

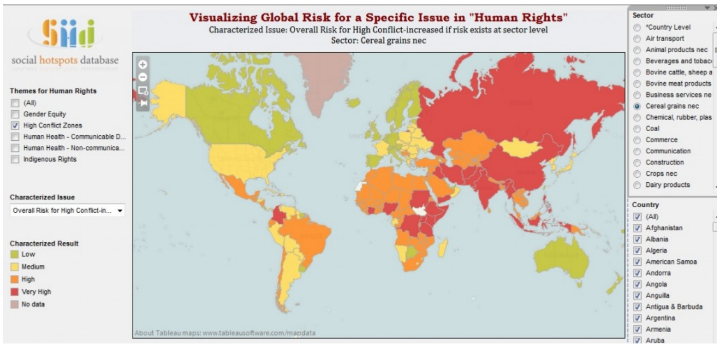

Figure 8: Global Sector Risks Map. [Data17b]

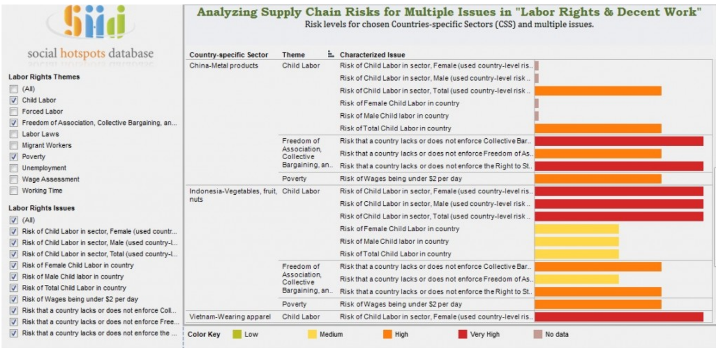

Figure 9: Bar chart showing multiple risks for a supply chain. [Data17b]

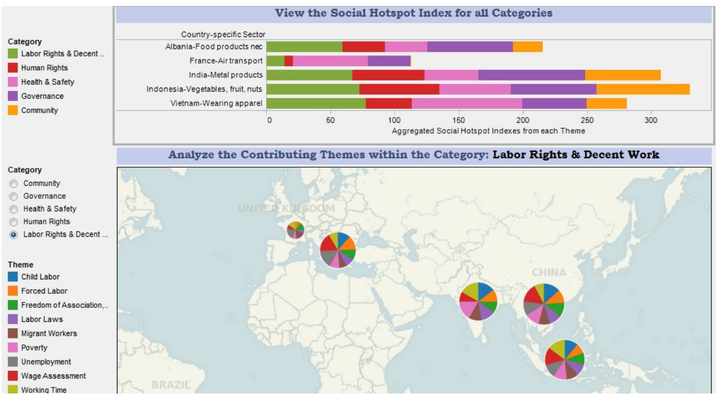

Figure 10: Social Hotspot Index. [Data17b]

ANNEX B

Stakeholder	Subcategory	Indicator	Unit of measurement	Index
WORKERS	Child labour	Children in employment, male	% of male children ages 7-14	W1.1
	Child labour	Children in employment, female	% of female children ages 7-14	W1.2
	Child labour	Children in employment, total	% of all children agess 7-14	W1.3
	Forced labour	Goods produced by forced labour	Number of goods in the sector	W2.1
	Forced labour	Frequency of forced labour	Cases per 1000 inhabitants in the country	W2.2
	Forced labour	Tier placement referring to trafficking in persons	Tier placement	W2.3
	Fair salary	Living wage, per month	USD	W3.1
	Fair salary	Minimum wage, per month	USD	W3.2
	Fair salary	Sector average wage, per month	USD	W3.3
	Working time	Hours of work per employee, per day	h	W4.1
	Working time	Hours of work per employee, per week	h	W4.2
	Working time	Standard weekly hours	h	W4.3
	Working time	Standard daily hours	h	W4.4
	Discrimination	Occurrence of discrimination	Text	W5.1
	Discrimination	Women in the labour force	% of economically active female population	W5.2
	Discrimination	Men in the labour force	% of economically active male population	W5.3
	Discrimination	Gender wage gap	%	W5.4
	Health and Safety	Accident rate at workplace	#/yr	W6.1
	Health and Safety	Fatal accidents at workplace	#/yr	W6.2
	Health and Safety	Occupational risks	Text	W6.3
	Health and Safety	DALYs due to indoor and outdoor air and water pollution	DALYs per 1000 inhabitants in the country	W6.4
	Health and Safety	Presence of sufficient safety measures	OSHA cases per 10000 employees in the setcor	W6.5
	Health and Safety	Workers affected by natural disasters	%	W6.6
	Social benefits, legal issues	Social security expenditures	Social security expenditures as a % of GDP	W7.1
	Social benefits, legal issues	Evidence of violations of laws and employment regulations	#	W7.2
	Workers´ rights	Freedom of association rights	text	W8.1
	Workers´ rights	Trade union density as a % of paid employment total	%	W8.1.1
	Workers´ rights	Right of Association	ordinal 0-3	W8.1.2
	Workers´ rights	Right of Collective bargaining	ordinal 0-3	W8.1.3
	Workers´ rights	Right to Strike	ordinal 0-3	W8.1.4
VALUE CHAIN ACTORS	Fair competition	Presence of anti-competitive behaviour or violation of anti-trust and monopoly legislation	Cases per 10000 employees in the sector	V1.1
	Fair competition	Presence of policies to prevent anti-competitive behaviour	Y/N	V1.2
	Corruption	Corruption index of country	index value	V2.1
	Corruption	Evidence of an active involvement of the enterprises in corruption and bribery	Text	V2.2
	Promoting social responsibility	Presence of codes of conduct that protect human rights of workers among suppliers	Y/N	V3.1
	Promoting social responsibility	Membership in an initiative that promotes social responsibility along the supply chain	%	V3.2
	Supplier relationships	Interaction of the companies with suppliers	Text	V4.1
SOCIETY	Contribution to economic development	Economic situation of the country	Text	S1.1
	Contribution to economic development	Contribution of the sector to economic development	%	S1.2
	Contribution to economic development	Public expenditure on education	USD/yr	S1.3
	Contribution to economic development	Illiteracy rate, male	%	S1.4.1
	Contribution to economic development	Youth illiteracy rate, male	%	S1.4.2
	Contribution to economic development	Illiteracy rate, female	%	S1.5.1
	Contribution to economic development	Youth illiteracy rate, female	%	S1.5.2
	Contribution to economic development	Illiteracy rate, total	%	S1.6.1
	Contribution to economic development	Youth illiteracy rate, total	%	S1.6.2
	Health and safety	Health expenditure, Total	%	S2.1.1
	Health and safety	Health expenditure, Public	%	S2.1.2
	Health and safety	Health expenditure, Out of pocket	%	S2.1.3
	Health and safety	Health expenditure, External resources	%	S2.1.4
	Health and safety	Health expenditure out of the total GDP of the country	%	S3.1
	Health and safety	Life expectancy at birth	Years	S3.2
	Prevention and mitigation of conflicts	Risk of conflicts with regard to the sector	Text	S4.1
LOCAL COMMUNITY	Access to material resources	Level of industrial water use	Text	L1.1
	Access to material resources	Level of industrial water use, out of total withdrawal	%	L1.1.1
	Access to material resources	Level of industrial water use, out of total actual renewable	%	L1.1.2
	Access to material resources	Extraction of material resources (other than industrial water)	Text	L1.2
	Access to material resources	Extraction (total) of fossil fueles	t/cap	L1.2.1
	Access to material resources	Extraction (total) of biomass	t/cap	L1.2.2
	Access to material resources	Extraction (total) of ores	t/cap	L1.2.3
	Access to material resources	Extraction (total) of biomass	t/km²	L1.2.4
	Access to material resources	Extraction (total) of industrial & const. minerals	t/cap	L1.2.5
	Access to material resources	Presence of certified environmental management systems	# of CEMS per 100000 employees	L1.3
	Access to material resources	Description of (potential) material resource conflicts	Text	L1.4
	Respect of indigenous rights	Presence of indigenous population	Y/N	L2.1
	Respect of indigenous rights	Human rights issues faced by indigenous people	text	L2.2
	Respect of indigenous rights	(Company´s) respect of indigenous rights	Text	L2.3
	Safe and healthy living conditions	Pollution level of the country	Text	L3.1
	Safe and healthy living conditions	Contribution of the sector to environmental load	Text	L3.2
	Safe and healthy living conditions	Drinking water coverage	%	L3.3
	Safe and healthy living conditions	Sanitation coverage	%	L3.4
	Safe and healthy living conditions	Management effort to improve environmental performance	Text	L3.5
	Local employment	Unemployment rate in the country	%	L4.1
	Local employment	Work force hired locally	%	L4.2
	Local employment	Percentage of spending on locally based suppliers	%	L4.3
	Migration	International migrant workers in the sector	%	L5.1
	Migration	International Migrant Stock	%	L5.2
	Migration	Net migration rate	Net migration per 1000 persons	L5.3
	Migration	Emigration rate	%	L5.4
	Migration	Immigration rate	%	L5.5
	Migration	Human rights issues faced by migrants	Text	L5.6
CONSUMERS	Health and Safety	Violations of mandatory health and safety standards	#	C1.1
	Health and Safety	Presence of commissions/institutions to detect violations of standards and protect consumers	Y/N	C1.2
	Health and Safety	Presence of management measures to assess consumer health and safety	Y/N	C1.3
	Transparency	Presence of business practices that are deceptive or unfair to consumers	#	C2.1
	Transparency	Presence of certifications or labels for the product/sites sector	#	C2.2
	Transparency	Presence of a law or norm regarding transparency (by country and/or sector)	Y/N	C2.3
	End of life responsibility	Strength of national legislation covering product disposal and recycling	Text	C3.1

Table 3: PSILCA indicators

BIBLIOGRAPHY

[Bake16] J. Baker. From shore to plate: Tracking tuna on the blockchain. `https://www.provenance.org/tracking_tuna_on_the_blockchain`, July 2016.

[Beno10] C. Benoît. *Guidelines for social life cycle assessment of products*. UNEP/Earthprint. 2010.

[blo17a] `https://www.thoughtworks.com/insights/blog/blockchain-under-hood` Retrieved the 22nd of July, 2017, 2017.

[blo17b] `https://en.wikipedia.org/wiki/Blockchain` Retrieved the 22nd of July, 2017, 2017.

[Curr12] M. A. Curran. Sourcing life cycle inventory data. *Life Cycle Assessment handbook: A guide for environmentally sustainable products*, 2012, S. 105–141.

[Data17a] S. H. Database. `http://socialhotspot.org/wp-content/uploads/2013/03/SHDB-Theme-Hierarchy.bmp`, July 2017.

[Data17b] S. H. Database. `https://socialhotspot.org/user-portal-2/portal-info/`, July 2017.

[Dres17] D. Drescher. *Blockchain Basics: A Non-Technical Introduction in 25 Steps*. Apress. 2017.

[Eisf16] F. Eisfeldt. Introducing PSILCA 1.0 – A comprehensive and transparent database for Social LCA. `http://www.greendelta.com/fileadmin/user_upload/GD/Presentation_PSILCA_Webinar_April2016.pdf`, April 2016.

[eMar17] eMarketer. `https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/`, July 2017.

[IaLa17] M. Iansiti und K. R. Lakhani. The Truth About Blockchain. *Harvard Business Review* 95(1), 2017, S. 118–127.

[IHTM+15] W. W. Ingwersen, T. R. Hawkins, T. R. Transue, D. E. Meyer, G. Moore, E. Kahn, P. Arbuckle, H. Paulsen und G. A. Norris. A new data architecture for advancing life cycle assessment. *The International Journal of Life Cycle Assessment* 20(4), 2015, S. 520–526.

[ITU17] ITU. https://www.statista.com/statistics/209096/share-of-internet-users-in-the-total-world-population-since-2006/, July 2017.

[McGi06] M. McGillivray. *Human well-being: Concept and measurement*. Springer. 2006.

[RGIVH13] S. Rudolph, G. Gottlob, H. Ian und F. Van Harmelen. *Reasoning Web. Semantic Technologies for Intelligent Data Access: 9th International Summer School 2013, Mannheim, Germany, July 30–August 2, 2013. Proceedings*, Band 8067. Springer. 2013.

[W3C17] W3C. A Semantic Web Primer for Object-Oriented Software Developers. https://www.w3.org/2001/sw/BestPractices/SE/ODSD/ retrieved the 22nd of July, 2017, 2017.

ERKLÄRUNG

Erklärung hier einfügen . . .
Der Wortlaut der Erklärung ist der jeweiligen Prüfungsordnung (erhältlich auf den Internetseiten der Fakultät unter `http://www.wiwi.kit.edu/serviceDownloads.php`) zu entnehmen.

Karlsruhe, 29. Juli 2017

Rodrigo Herrera