Environmental Engineering

Burkhardt Funk
Peter Niemeyer
Jorge Marx Gómez *Editors*

Information Technology in Environmental Engineering

Selected Contributions to the Sixth International Conference on Information Technologies in Environmental Engineering (ITEE2013)

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Preface

Enabling a sustainable development requires interdisciplinary approaches where computer science can provide the infrastructure for environmental data collection, analysis, simulation, decision support, reporting, and collaboration.

During the past decade methods and technologies at the interface of environmental engineering and information technology made important contributions to the transformation of organizations and processes toward sustainability. Material Flow Management systems, Tools for measuring environmental footprints, and smart grids are well-known examples for innovations in this area.

Since 2003, the conference series Information Technology in Environmental Engineering (ITEE) has established a platform for discussing the progress in the field. During the 6th ITEE 2013 conference practitioners and scientist met at the Leuphana University Lüneburg (Germany) to discuss recent developments, promising ideas, and new challenges in information management for supporting sustainability efforts.

Besides the special focus of this year's conference on information technology as an enabler for green logistics, the authors of the accepted papers cover a wide spectrum of topics from the perspective of different stakeholder groups. This includes topics such as big data, sponsored search advertising, mobile applications, energy consumption, and tools for collaboration.

This conference would not have been possible without many helping hands. We would like to thank all authors and participants of the conference for their contributions. We greatly appreciate the commitment and support of the program committee, namely Witold Abramowicz, Hans-Knud Arndt, Ioannis N. Athanasiadis, João Porto de Albuquerque, Jan Froese, Paulina Golinska, Lorenz M. Hilty, Horst Junker, Kostas Karatzas, Corinna V. Lang, Pericles A. Mitkas, Andreas Möller, Matjaž Mulej, Alexandra Pehlken, Andrea-Emilio Rizzoli, Adenilso da Silva Simão, Frank Teuteberg, Rüdiger Zarnekow. Last but not least, we want to thank the Leuphana team (Martina Darda, Karin Dening-Bratfisch, Madlen Schmaltz, and Norbert Tschritter) for helping at all stages of the conference.

Burkhardt Funk
Peter Niemeyer
Jorge Marx Gómez

Contents

Part I
Research Paper

Influence of Environmental Protection Requirements on Object-Oriented Software Design

Marat Abilov and Jorge Marx Gómez

Abstract The questions of environmental impact that company produce take important place nowadays. The ISO 14064-1 [1] standard specifies principles and requirements for monitor and control the greenhouse gas (GHG) emissions and removals. These requirements can be met by optimizing companies business processes (production, logistic, etc.) and by decreasing the power consumption of the companies' equipments. As side effect of these changes, the total costs of companies can be decreased as well. Companies' data centres and servers consume more than half of total spent electricity power. These servers are mostly used by companies' software systems. Hence, if the software systems require less calculation time, less space, there will be no requirements to keep the big energy consuming servers, and the most of tasks can go in cloud as well. Hence, the environmental protection requirements should be considered in developing software systems for companies. In this paper, we aim to give some literature review and propose the research on the topic.

1 Introduction

Software systems, which support the business processes of companies, are developed by using programming languages and methodologies. The most popular methodology today is Object Oriented (OO) Methodology, which helps to describe different domains using OO models.

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Environmental requirements can influence the software system design process in two ways:

1. They influence the changes in business processes and as the result the changes in software system design as well;
2. Software system by itself should meet these requirements: use less calculation time, and disk space, etc. These requirements can be treated as non-functional requirements (NFR).

In order to explore the problems of integrating these requirements to software design, the literature review of the works in this domain is explained in the following section.

2 Literature Review

2.1 Approaches for Software Power Estimation and Optimization

Hence, the power optimization can be treated as an environmental protection requirement, the review of works that deal with software power optimization and estimation will be provided. According to the review done, the existing approaches mostly deal with embedded software and on very low level.

One approach suggests the usage of symbolic algebra techniques in low power embedded software optimization [2]. The approach works on very low level of code and data types. The idea behind this approach was to optimize block of codes or algorithms of embedded software, so it would need less computation time, and correspondingly the less power. The first improvement over the peace of software is the consideration of moving from float-point to fix-point numbers where possible, because the fix-point ones require less calculation. The second is the energy profiling of code blocks and identifying the routines for optimization. Then these routines can be reformulated using polynomial approximation techniques. After optimization accuracy of produced code should be checked.

Measuring and estimation of instructions in assembly language over RISK processors were done by Russell and Jacome [3]. In this work authors developed power prediction model for low-level assembly program, that gives 99 % certainty with less than 8 % error.

Although the low-level approaches are important as well, in our approach we will consider mostly model-based, on more abstract level problems.

2.2 Approaches for Functional Requirements

The nearest research has been done by the work of [4]. In this work, the author tried to solve challenges existed in software development process with the proposed “Methodological Approach”. This approach has 4 main stages: organizational modelling, purpose analysis, specification of system requirements, and derivation of OO diagrams. On each stage, different artefacts have to be developed. The artefacts from the last stage influence the subsequent software development stages. The most interesting stages, in connection to current research, are the last ones. During the System Requirement stage, “To-Be” Business Process Diagrams (BPD) in the form of EBPD have to be developed, that show how process should occur in organization after software system implementation. After that, the System Requirement Specification (SyRS) has to be developed in the form of Extended Task Description (ETD) templates. This proposed style of SyRS is a combined and improved combination of other approaches: among them are Lauesens Task and Support Descriptions [5], essential use cases [6], Info Case approach [7], and quality requirements from ISO 9126-1 standard [8]. The information presented in these templates is derived not only from BPD, but from previous stage’s artefacts as well. These templates show mainly the functional requirements of the software system. After having the ETD specified, OO diagrams have to be derived from them according to set of rules presented in this work. Rules help to derive two main diagrams: the class diagram, and the state diagram. Among overall contribution of the reviewed work, there are several open issues in connection to current research:

1. This approach can mainly be used in waterfall model of software development, when all work on previous stages should be done in order to proceed to next stage. The connection to iterative, spiral or agile model was not specified in this work.
2. On every stage of this approach the validation is needed to be done by customer stakeholders, other validation techniques were not specified.
3. The process of analysing other non-functional requirements was not formalized and left for system analyzer to consider them in software architecture.
4. In class diagram a rule for specifying the control class was not defined.
5. The problem of parallel works in BPD was not analysed, and rules to consider them in state diagrams were not specified.

Analysis of this work shows that the next ideas can be effectively applied to current research:

- Enriched BPD, as an intermediate model between BPM and OO models.
- ETD templates, as a presentation of the expected behaviour of the software.
- Rules to derive OO diagrams from ETD, as a background, that can be extended to formalize this process for iterative methodology of software development.

In the work done by Loos and Allweyer [9], the authors analysed the Event-driven Process Chain (EPC) diagrams and made connections between then and UML diagrams. Three types of granularity were defined: object internal, object system inside and beyond the scope of an object system. Design of EPC diagrams has also to be conducted in three steps: high-level EPC with connection to information system packages, medium-level EPC with connection to classes, detailed EPC with connections to operations and attributes. The detailed EPC diagrams then can be used to derive the UML class diagrams and the state-chart diagrams of classes. Another UML diagrams were also analysed and relationships from EPC to them were established. Procedural model for applying the integration between EPC and UML was defined. The proposed approach can be used during requirement engineering and software design stages. Although the connection of different level between EPC diagrams and UML diagrams were presented, the concrete guidelines for establishing such diagrams were not specified. In class diagrams the procedure for finding relationships between classes was not specified.

The approach of deriving UML analysis models from use-case models (UCM) is presented in the work of [10].The approach deals with text-based, specified in restricted natural language (NL), UCM (RUCM) [11]. It contains 2 steps:

Step 1: The RUCM models have to be parsed and object model of them has to be generated. At first, the top level objects have to be identified: Use case, Use case specification, actors, brief description, the flows of events, pre- and post-conditions. Then, the sentences, objects are constructed from, have to be parsed by NL parser, the Stanford Parser [12].

Step 2: The UCMeta model have to be transformed into a UML analysis model. The overall algorithm of transformation and the set of rules were specified: for generating overall structure, for generating a class diagram, for generating a sequence diagram, and for validation.

When deriving the class diagram, three types of objects were analysed:

- Boundary objects, that handle interaction between actors and the system
- Entity objects, that are responsible for storing and providing access to data
- Control objects, that control the interaction of participating objects.

In UML these types of classes were specified with stereotypes: ≪Boundary≫, ≪Entity≫, and ≪Control≫. The first set of rules presented in this work deals with deriving this three types of classes and relationships between them. The idea of different stereotypes for classes and rules for deriving them can be found useful in current research.

In the work of [13], the authors presented the Component Bus System Property (CBSP) approach, which helped to connect requirements and architecture. This approach can be used in iterative software development model: the output of the first iteration can be used as an input in the second. In this approach, the decision technique is based on voting among multiple architects or experts. The CBSP process consists of 5 steps:

Step 1: Selection of requirements for next iteration. On this step, the most important requirements have to be analysed and prioritized among 2 criteria: importance, feasibility based on stakeholder decisions.

Step 2: Architectural classification of requirements by the relevance to CBSP dimensions, have to be decided by experts.

Step 3: Identification and resolution of classification mismatches, have to be decided by multiple experts independently. Level of consensus for requirement has to be calculated, and if the level is equal or more than largely then requirement should be accepted.

Step 4: Architectural refinement of requirements. On this step, requirements have to be rephrased and split, redundancies have to be eliminated. Then relevance coefficients of properties for each CBSP dimensions have to be decided among 4 common architectural styles.

Step 5: Trade-off choices of architectural elements and styles with CBSP. On this step requirements have to be refined and rephrased to CBSP model elements in such a manner, that no conflicts exist and all model elements at least largely relevant to one of the CBSP dimension.

Among overall contribution of this work, there are some open issues that are related to current research:

1. Analysed architectural styles are very high level; the derivation of detailed OO was not given in this work;
2. Business process as a type of requirements were not analysed in this work.

In the work of [14], the authors tried to connect OO and process-oriented (PO) models using formal approach. The procedure of translation from OO to PO models has 5 steps:

Step (a) Translation from State Machine Diagrams (SMD) to Heuristics Net using presented algorithm I;

Step (b) Translation from SMD to Annotation Repository using presented algorithm I;

Step (c) Translation from Heuristics Net to Petri Net using presented algorithm II;

Step (d) Creation of a skeleton structure of a process-centric model, using existing conversion plugins;

Step (e) Completion the process-centric model in the form of Yet-Another Workflow Language (YAWL) [15] model.

Obtained PO models are highly detailed. This work can be used to connect two different development approaches, also for analysing OO design from procedure perspective. Here are also some open issues in connection to current research:

1. This approach requires finalized OO models to be translated into PO ones.
2. This approach describes only one-way translation from OO to PO models. Although, the authors promised to start working on backward algorithm.
3. Validation technique was not provided in this work.

The approach, presented in this work can be used as a validation technique for the current research.

2.3 Approaches for Non-functional Requirements

The approach of integrating non-functional requirements and conceptual models: Entity-Relationship (ER), OO model, was done by the work [16]. The approach has several steps: on the first step the Language Extended Lexicon (LEL) [17] has to be developed. LEL registers the vocabulary of a given University of Discourse (UofD) general context, where the software have to be developed or operated [17]. While developing the LEL two principles have to be followed: maximum circularity, and minimum vocabulary. Each NFR has to be detailed using NFR graph, which defines the goal on the root and subgoals on the leaves. Subgoals can contain attributes, which can be general and data ones. General attributes characterize the whole system, while data attributes can be used for deriving ER and OO models. The paper presented the extensions to ER and OO models. In the OO model:

- Additional information, in the form of attached rectangles, was added to the class to show the names of used UofD and NFR.
- To improve traceability, NR_ prefix has to be added to classes, attributes and operations driven from NFR.
- Class names have to by symbols of the LEL.

Some heuristics to integrate the NFR into conceptual models were presented. This heuristics are not showing the straight-forward derivation of models, but the some hints that can help the software engineer in this process. Some ideas in this work can be used in current research:

1. Using LEL to describe the NFR;
2. NFR graph, to explore the influence of the NFR on design and;
3. Traceability idea: to present the name of used NFR and UofD in class diagram, that can be done, by using notes or comments.

The influence of the NFR over the decision of using software design patterns were analysed by the work [18]. For each system there might be multiple NFRs, and some decisions that support one of the requirements can hurt another. To address this problem NFR graph was used, that helps to reflect the decision trees for several NFR. This tree was used to describe the reason of usage of design pattern in the system architecture. The design pattern forces changes in the architecture, so author presented the way of connecting NFR graph with functional decomposition of the system.

3 Open Issues

To summarize the above research, there are several challenges in integrating the requirements as a whole, and the environmental protection requirements as a part into object-oriented software design:

1. Development of software system can be iterative, and not all information about business processes in organizations can be known before the design phase. Therefore, the new proposed approach in this work should be able to deal with incomplete information, and overcome the absence of some details within it.
2. Business processes of organization and non-functional requirements can influence the final design of the software system, so this approach should be able to deal with different types of requirements.
3. Relationships between classes are very hard to determine, and the problem increases when classes can be organized to perform some special behaviour. Some of these organizations are the examples of software design patterns. Design patterns and best practices can be used to solve the problems with software optimization, which as a result will give the less computation time, less power consumption and the less environmental impact as well. As a result, this approach should be able to define any kind of relationships in addition to show what kind of patterns can be applied.

4 Research Methodology

This study will be done by research project following the design research methodology [19]. The design science research contains the next steps [20]:

- Awareness of problem–understand the problem that occurs in practice;
- Suggestion for a problem solution from the existing knowledge base;
- Awareness of problem revisited. Problem can be detailed or generalized;
- Development of possible approach that can partially or fully solve the problem;
- Evaluation of the approach using empirical studies or formal methods;
- Conclusion shows the lesson learned and what influence the approach will have in the practice and science.

Empirical methods can be used in current research for validation the result of the approach. There are several empirical methods that can be used in software engineering context [21]:

- Controlled experiment—investigation of a testable hypothesis where one or more independent variables are manipulated to measure their effect on more dependent variables;

- Case studies—an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident [22];
- Survey research—used to identify the characteristics of a broad population of individuals;
- Ethnographies—help to understand how technical communities build a culture of practices and communication strategies that enable them to perform technical work collaboratively;
- Action research—attempt to solve a real-world problem while simultaneously studying the experience of solving the problem [23].

In most cases several of them can be used simultaneously in order to achieve the more rigidity of the research.

The next tasks are considered as support for answering the above-mentioned research questions:

1. Analyse environmental protection requirements, and their influence on changes in BPM and on non-functional requirements;
2. Analyse the influence of software requirements on the overall software design;
3. Analyse the types of relationships between classes and their derivation from BPM and other requirements;
4. Analyse the types of design patterns and their derivation from BPM and other requirements and
5. Design the approach for derivation OO models from BPM and other requirements that can be used in iterative, spiral and agile models of software engineering.

For the formalization of OO models derivation process, the ETVX (Entry, Task, Verification, and eXit) [24] approach can be used. ETVX is a table with 4 rows:

- Entry row—items required for the execution of the task;
- Task row—details of the activity;
- Verification row—checks and controls for the task;
- eXit row criteria, need to be satisfied in order to consider the task as completed.

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Impact of Design on the Sustainability of Mobile Applications

Hans-Knud Arndt, Bartosz Dziubaczyk and Matthias Mokosch

Abstract Within the context of a consumer, who is anywhere contactable via mobile phone or a mobile access to the internet and his fast changing needs, it becomes more and more important to create a balance in the product-life-cycle. With regard to the design and sustainability of software the requirements to a programmer and the department of information technology in a company are getting higher, especially on mobile Applications (Apps) for mobile devices. The paper aims to explain what makes a good design for Apps and which types of Apps exist. Afterwards a description of the characteristics of a sustainable designed App and a comparison between Apple Design versus Metro Style (was changed due to copyright issues to “Windows 8-style UI”) follows. In connection to the environmental friendliness of Apps it is to be recorded that material and energy have to be saved everywhere it is possible. Developers have the responsibility to create applications in a way that is as efficient as possible. The design of an App can be updated with just one mouse click which is far easier than updating hardware, because hardware can’t be updated and has to be completely exchanged. The update principle is an important step towards sustainability. Software does not really pollute the environment but there is a kind of virtual pollution of the environment.

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1 Introduction

Today markets are characterized by an extremely fast moving and dynamic environment. By the increasingly more mobile consumers and thus rapidly changing customer needs, it is more and more important to create a balanced product life cycle. The contrast between a stationary computer and a small mobile device dis-appears not only with high-resolution display, but mainly by powerful processors and fast, reliable and inexpensive data traffic [1]. Thereby the requirements regarding to the design and sustainability of software, especially applications for mobile devices, are not less. The parameters for optimal functionality, security and usability are more complex for a mobile application than a desktop application [2].

The paper focuses on explaining the situation illustrated by the significant design ethics of the famous German industrial designer Dieter Rams. His design philosophy "Less, but better" represents the focus of this work. This paper aims to discuss based on the ten principles for good design by Dieter Rams, whether it is possible to ensure sustainability of mobile Apps and mobile devices through good product design.

2 Good Design for Mobile Applications

2.1 Braun Design as Creative Director of the Apple Design

Apple's iPhone released in 2007 turn the mobile internet through its innovative interface and its outstanding usability into a new experience. Before that vendors were like Nokia were the global leader in the field of mobile internet. In 2008 the supporting pillar of the app development was the platforms Symbian and Java Platform, Micro Edition. Nowadays, these platforms were hardly discussed. Many companies that specialize in these platforms are trying to develop their systems to the new platforms. The newly introduced platforms, such as Apple's iOS (2007) and Google's Android (2009) have made the breakthrough just by the new technical achievements, easy programming and a playfully easy handling and a new design language. Approximately 60 percent of all applications are developed for Android by which this operating system is considered to be the most popular, closely followed by iOS [1].

It has to be emphasized that mobile apps are not a new invention of Apple, which came with the release of the iPhone in autumn 2007. There were small applications before, but with different formats and on another scale. Java applications belonged to most of these applications. Also the handling was not the same as it is today's. The installation on a mobile device was complicated and time-consuming. In the first step the application had to be downloaded on the pc and in the second step they had to be transferred from the pc to the mobile device. Over the time the thickness of a mobile device approximated more and more to that one of a sheet of paper. Although the data room can't be really expanded it is today possible to obtain millions of options on the display. To control and bundling these data Apple invented the principle of apps, which users could use for playing, communicating, shopping and informing or entertaining themselves. Today there is an App for almost everything. The iPhone takes over a leading role and shows that it is realizable in just a few easy steps to install and start mobile apps in a very simple way [1, 3].

Since the industrialization products were manufactured with a high degree of attractiveness to be able to sell them better. People buy and use more and more industrially manufactured products and endanger the environment. On that score the demand for the future has to be, that not only the designer but also the other areas within the production process have to take care of a lasting production. Unfortunately there are too many "junk products", which were bought and disposed after a little while because of missing functionality. Accordingly an immense demand at new products arises and the product life cycle gets into an imbalance. The great challenge is to produce less of those products, which waste unnecessary resources and strongly pollute the environment. Instead of this the focus has to be on manufacturing products, which fulfil the demands of their functionality and are an enrichment for life [4].

Over decades Dieter Rams, chief designer and member of the board of the company Braun, pursued the central idea of freeing the world from chaos and to redesign it entirely. Already at an early age he strove for a good industry design, which was rarely at that time. For Rams was the concentration on the essential and the simultaneously elimination of irrelevant characteristics aspects for a good design. Primarily the chaos has increased in the mass production in whereas factors like noise and the pollution of the environment are strongly weighted factors [5]. Everything starts in a small way. Also the beginning of new products or its further development begins in a small way for example the optimization of performance characteristics like a new user interface or an easier handling.

"Less but better! Much fewer but much better!" [6]. With these headwords Dieter Rams has changed the design language decisively. Due to the consideration that good design is not quantitatively measurable and that the world is overcrowded with mass market products, within the early 1980s Dieter Rams thoughts to himself what good design means for him. To canonize the bases of his work, he wrote 10 theses in the form of characteristics which distinguish between good and bad design: Good design is innovative, makes a product useful, is aesthetic, makes a product understandable, is unobtrusive, is honest, is long-lasting, is thorough down to the last detail, is environmentally-friendly and is as little design as possible [7].

This thesis arose from years of practice experiences and serves many design-oriented enterprises as a rough guideline to this day. Design is compared with the steady further development of today's technology and culture also a part of it and therefore develops as well [6].

The “10 thesis”, which Dieter Rams strictly followed in his design philosophy, reflect particularly the severe rationality. He put himself in the position of the user intensively, showed great sense of responsibility and was convinced that nothing is left to chance [5].

The German industry designer Dieter Rams was an idol for Jonathan Ive the master designer from Apple on the topic of abstraction and simplification to the necessary. While the creation of each new technical design blue print Apple leader Steve Jobs and Apple designer Jonathan Ive followed Rams main principle “lesser but better” when they thought about how to optimize the product’s design [8]. Steve Jobs developed his preference for a simple and functional design in Aspen, where he participated each year in the “International Design Conference”. Clear lines and forms are a symbol of rationality and functionality. Jobs was a great fellow of the Bauhaus-style, where the functionality and the essence of the products are central and Jobs wanted that Apple products look like the high-tech products of Braun, compact and bright. With this attitude he took the opposite design-pattern to Sony, whose design-pattern more and more became industrial black and heavy. Due to the introduction and evolution of their Walkman and the concept that sometimes “less is more” has a greater use for users. Sony was the first company to be successful on the portable player market. Helpful were the coinstantaneous reduction for the sake of mobility and growing individualisation [9].

Despite the fact that the Apple-products don’t have better technologies than those of their competitive companies and that they are far more expensive, they sell much better. It is agreed upon multiple facts that Apple’s homogeneous, harmonic design with its logically elaborated and user-friendly design-strategy, such as the image-based support campaigns for each single product released by Apple and their costumer-orientated advertising, Apple is put in the good position to have a continuous attractive product line-up [10].

According to the facts shown above, a label defines and separates itself from other labels by its design. The reason to buy an Apple product is based on its high design quality, which creates a significant additional value. Primary the costumers trust in a label is decisive, which can be achieved throughout a good design. This simultaneously defines the design’s additional value. Apple makes it possible for others to recognize its stability by evolving its design value according to its design strength and design continuity, which enables Apple to outdistance its competitors [11].

Dieter Rams, according to the facts already shown, can be called the forefather of the iPhone, which is characterized by its good design. Good design is till today a minority, whereas non-useful things, which have no self-explanatory quality, are far more common in most products. The environmental pollution takes place most likely on the visual plane. Another problem is the optical attrition. Cultures and with them the tastes blend into each other. A conclusion is that there are less different forms and everything becomes more akin [7].

The Meaning of design for Apple as a design-orientated company is not just beauty in its completeness rather than an amalgamation of three parts: The simplicity and honesty of the configuration, the integration of the designer from the very start of the whole product development process and the equalisation of inventor and artist. Through all the diverse, innovative technologies and new challenges arise for the product design. The simplification of electronic devises allowed a better handling and achieved an innovative aesthetic. The maximum purism is not just the default for the outward appearance, but also for design of the surface of the operating system and the software. By pressing the Home-button, the only button the iPhone, the screen is activated and it appears a virtual slider, which requests the user to slide it sideways. On the unlocked screen the user see's just an orthogonal grid of the already installed miniature programmes. This clearly shows that the software is just as consequently simple designed as the hardware and the casing, to make sure that it is understandable and clear for the broad class of customers. Another fact is that the technology and the design must perform in sync, because the design has a huge effect on the company alignment [12].

2.2 Types of App Applications

The Apps are basically divided in two concept groups. Applications that can just be installed on own terminal devices and the existing operating system are also known as native applications. The counter model is the web-applications. These are the solutions, which are based on mobile optimized websites and download the compatible components of the applications from the internet [1].

The most important feature of a native application is the user-friendly handling that allows the immediate one-click-start of the App on the icon and a direct usage. This eradicates to type in long website addresses, the waiting for the website to be ready for usage and the scrolling and zooming if the website is not adjusted for the mobile usage [1]. Native applications are designed according to the criteria of the User Interface Guidelines platform and are developed and optimized for mobile purpose [13]. They are quasi made out of one piece, because the handling and the appearance are better adjusted to the devices than web-applications. Furthermore are device specific functions like the camera, the movement sensor and the Global Positioning System (GPS) useable without problems and allow the inventor the comfortable integration of the functions into the Apps. Last but not least this sort of Apps needs no active internet connection [1].

Another reason for the usage of the native Apps is the easy traceability in the Apps-store [14]. Due to the fact that more and more platforms get on the market, is the development of downloadable and self-installing Apps connected to a great afford and risk in marketing. The disadvantage is its low range, because the developer can't reach the broad masses and have to build an individual App for each of the significant operating systems. This problem does not only affect the support and marketing, but also has a long-term effect that shouldn't be underestimated. This long-term effect is primarily connected to the management of a contemplated evolution after a launch [1]. Even if the major advantage of the native Apps is their independence they must pass through a time consuming and expensive certification process of the platform operator before they have to be distributed on a store.

Aside the native ones there are the browser-based solutions, the so called web-Apps, which more and more take the foreground role in the mobile industry. An elegant universal solution tries to combine all relevant platforms to minimize the development effort and costs [1]. To run a web-application a radio network for it completely acts in a browser. Furthermore do those Apps have no access to functions of the system such as the native Apps have [14]. Mobile web-Apps are controlled over a web-address and that's why they are independent from marketing policies of other companies. In addition do not all terminal devices have the same browser installed. All actually available browsers differ in their handling and quality. Despite that the whole development is cheaper and costs less time than the building and maintenance of a native App for all the today existing platforms [15]. The reason therefore is that a lot of companies are obliged in the software development to convert the content and context of a website to the parameters of a mobile terminal device [1].

In the meantime there appeared temporary solutions which usefully combine the important advantages of both models. Starting point is a hybrid-App that is based on a native-App core and a user-interface primarily based on standard-web-technologies. For the user behavior it means that the App is no longer running in a browser and is instead functioning like a native App.

This was enabled throughout the special frameworks named "PhoneGap" which allocates certain hardware functions via interfaces of web applications to directly activate the needed components. Therefore only the web-based components have to be developed by the company itself, because the native components are already implemented in the frameworks for the particular platform. On behalf of the native application it is possible to influence the individual device functions and the App can be published and distributed in a store. As it is a web application its development isn't too complicated and doesn't cause too much effort. The advantage of a hybrid App is that the problem of the diversification of browsers and operating systems is solved in a practical way [14]. The user has to waive in such a temporary solution the "Look and Feel" of a native App, because the App has to be compatible with many different operating systems [13].

An online survey of the agency "Culture to go" determines another rather surprising development of a prognosticated percentage on the continued existence of Apps of just 15 %. 41 of the 112 asked people said that the native App is just a makeshift for the not yet fully developed browser-based applications. On the other side 44 % think that both basic approaches can co-exist. Pure native Apps do have the right to exist, because of the applications that get more complex like games, navigation systems and they can be easily and targeted merchandised via the main distribution channel the App-Store. On the other side will web-Apps remain, because especially companies will use them based on their evolutionary advantages to be in a future-orientated position and that they can be scalable long-term solution [13].

2.3 Characteristics of Sustainable Designed Apps

Often a costumer asks what signalizes a good App and makes it unique. During the development a main factor was a stable and errorless basis. A good basis pro-vides an excellent usability ajar to the standard-control concept of the respective platform filled with valuable context. As a result the user doesn't need to spend additional time for learning. Furthermore should the App consist of dynamic processes and should be self-explaining in its use via the clear structure of the surface-screen. When the App is an implementation of a website the company has to put their focus not just on copying the content but also to design the App inciting and service-oriented. One of the main aspects in creating an App is the pursuit of a sustainability strategy. To achieve this, the costumer has to have access to updates in regular intervals. These updates should contain bug fixes and feature-extensions (functionality extension of software) [13].

Companies often have to strike up compromises and have to absorb cost and effort for updating their Apps to lead it to success. It has to be mentioned that the usability of today's mobile browsers become more and more similar to those of native apps. The freedom of the internet is an important factor because it allows realizing real time updates grounded on server based App solutions as well as cost reduction. In doing so the platform fragmentation does not matter. Limits for web based applications are adaptabilities of mobile browsers regarding to the navigation. Reason for that is the containing of permanent elements like header and footer. The speed of loading website elements like pictures or stored information of native apps is faster than the speed of web based applications. In addition desired sites, product and user data as well as miscellaneous settings can be stored for offline usage [13].

Altogether devices need a simple surface and a simple interface which allows an easy handling and a fast understanding for the user. But the resolution problem on a small display device is the right balance between information and interface. Too many details overload the interface so that it appears confuse. Too less details cost too much of the user's time to get the information he wants to have. This means that the amount of information shouldn't be reduced, but that the chaos of information and details should be reduced [16]. Good design distinguished with a feeling of safety, confidence and instinct. The familiarity with known things enables the user to develop a relationship to the device. Additionally this familiarity may contain something unexpected for the user [17].

The common run of mankind connects everyday occurrences with familiarity with something and leads to efficiency and usability. Buttons, icons and toolbars can be seen as traffic signs in the App world. Screens without scrollbars need less mental strain and reinforce the illusion of the application to use a physical and not a virtual device. A fixed screen facilitates a feeling of solidity [18].

Today it is hard to sell mobile devices if they have no integrated App-store. That's why Apple integrated the well-known App-store in its new operating system “OS X Lion”. Microsoft tries to do the same with Windows 8. Microsoft’s new store shall offer full screen metro Apps for the start screen [19].

The number of Apps in the App-stores of the particular platform grows daily about 350 Apps [20]. Potential users notice the new Apps often through all known App-stores. The colorful icon is the first thing the user connects with the App. In such an App-store the Apps initially appear with their name and icon. Their occurrence is most important for the visibility in the lists and the sale. The name of an App should fulfill four important criteria. It should be easy to memorize, if possible contain keywords, be unique and be consistent in different stores and lands [21]. The Icon is the face or business card of the App. Today many people get superficial and believe that something that looks good is good. Especially the icon gets in the beginning a lot of attention, because it’s the first thing the costumer sees. To create an economical success and generate a high recognition value, the icon must be connected with a dominating idea and a perfect design [21]. Icons should never be mysterious and instead be colorful and funny. The symbol should directly display what the App is about and contain a unique personality. This can be a visual description of its function, surface, names or its label [18].

3 Apple Design versus Metro Style

In early 2007 the first iPhone was released with a touch-sensible display. The costumers were euphoric, because it was something really new which hasn’t been there before on the market. On its smooth as a mirror glass-display are cent-sized icons. They seem to be old-fashioned and nostalgic. For example the icon for the telephone function was symbolized by a phone. The mail-function is symbolized by an envelope and the settings with three meshing gear wheels. There are also so called pre-digitalized symbols which shall indicate processes. Per slide-movement with the finger on the display pages can be turned over like in a normal book [16].

First, Steve Jobs was strictly against allowing developers of external platforms to develop applications for the iPhone. If this restriction had been realized, a substantial progress in the App word would not have taken place. The fear of infected applications was the main reason why Steve Jobs was against application developing by external companies [8].

The letter “i” is the recognition feature of Apple and is seen as the product-line label. It is in English a term for internet, information, intelligence, interface, identity, individual, inspiration, innovation, etc. The direct translation of “i” is I which proclaims a strong connection between the user and the device [20]. Apple owes its sale records three central main principles of product design. First to name is the principle of simplicity. Following this principle the visual aspect is based on Dieter Rams principle “good design is as less as possible”. Furthermore, Apple’s product design is influenced through the principle of Integration which organizational requires a strong connection between design and technology. Additionally does the principle of obsolescence affect the products of Apple. Here should the marketing limit the lifetime of a product to higher the volume of sale.

With the introduction of Windows 8 Microsoft did the greatest change in the classic Windows-user-interface since Windows 95 and is best prepared for the future. First of all the new surface called Metro is to be mentioned. When windows is started first of all a personalized start screen appears consisting of a user defined grid with interactive colorful tiles. The new tiles serve as a kind of conjunction of the programs starting the "Metro Style"-Apps in full screen mode and show actual update information.

Moreover the tiles of Apps can be customized depending on usage scenarios and customer requirements [19]. Instead of traditional desktop surfaces with windows, taskbar and start menu, Microsoft opened a new interface which is similar to the smartphone operation system Windows Phone 7. The new desktop surface consists of mostly usage-friendly touch tiles. Touching a tile with the finger starts the application immediately in a way that the entire screen can be used without the alongside occurrence of traditional menus and scrollbars [22].

While the operating system Lion from Apple is based on Apps in the form of compact icons of the iOS-attempt, Windows 8 has adaptable tiles which give some space for useful information in a little area. The "Metro Style"-Apps are the focus of this new, consistent and elegant experience. Especially it should be invested in a good tile. A tile is similar to the basic idea of an icon, because it can be found on the start screen too. It has some kind of a private life and is up to date. A tile also facilitates personal information, is present via a miniature picture and therefore arouses the interest of the user [23]. Users shall identify themselves directly with the content and developer shall permanently try to find new interactions. Apps and user perception should become lively by using reasonable animation and intuitive touch gestures to create a feeling of durability [24].

4 Aspects of Environmental Friendliness

Both the design and the designers are forced to make a contribution to protect raw materials and take care of the environment. The physical pollution of nature is just as harmful as visual pollution in the product design [6]. Aim of every design should be handling materials and energies consciously and healthily. Material and energy should be saved wherever it is possible. Normally software does not have any direct impact of nature because it is a non-physical asset. In the last few years the growth of the mobile data use has increased exponentially due to the strongly progressive innovative technologies. In the field of mobile telephone the data volume has tripled every year and in the foreseeable future there is no stagnation visible. Reason for that is the current boom of mobile devices like smart phones, laptops, netbooks or tablet-PC's. This is shown by a report of the federal net agency [1]. The fast and secure mobile internet use was enabled by the strong expansion of the worldwide covering of the mobile communication standard 3G [13].

For today's mobile users, there are two ways of connecting to the internet: cellular and 802.11 WiFi. Thanks to the increasing availability of mobile phones and tablets, the mix of fast connectivity and the explosive spread of applications results in a high performance and users are respond to throughput for each technology. In a direct comparison, it is clear that WiFi offers a clearly superior download performance. In regard to the upload this performance difference is much smaller, but can strongly vary. However, the cellular variant by their relatively predictable performance of some network providers as well as its ubiquity reflects the better option for everybody. With the advent of improved throughput access technologies such as LTE, this will probably be the preferred option for wireless connectivity in the coming years. Finally, the stability and performance of both technologies in the larger markets shows, that through further developments of both sectors, an infrastructure can arise, which could improve the performance in smaller markets [25].

At the development of applications the developers have the responsibility to design them as efficiently as possible. Nowadays developers of mobile applications and operating systems pay more attention at the life time of batteries than to the health of the network. All participants of the network have to share the available capacity of the network. The data checking every 30 s could have negative impact of the network. Hence the broadband demand increases whereas the price is reduced. Many applications need a constant connection to the internet to receive the required data. If the connection cannot be built up, the applications are useless [26]. In connection with the health of the network badly written program code can have negative impact of the data volume, which has to be loaded from the internet. An example is the application "Google Maps" with its navigation function. With this kind of App two aspects of pollution are mentioned at once. On the one hand vast amounts of data are loaded from the internet and on the other hand the environment is polluted indirectly by the users driving.

5 Outlook

The design of an App can be updated with just one mouse click which is far easier than updating hardware, because hardware can't be updated and has to be completely exchanged. The update principle is an important step towards sustainability. Apps that are already distributed in App-stores expire the monetarisation and strain the mobile networks. Furthermore do they deprive from physical mediums like compact discs (CD) and digital video discs (DVD). Software does not really pollute the environment but there is a kind of virtual pollution of the environment as it was already mentioned. Consequently software and hardware has to be considered as a coherent unit and inconsistencies will arise in the future too. It is considered to be proofed that some facts which caused the past success of Apple are going to be more and more a burden. Especially the rising profit of the company in the past years and the high numbers of sale of the iPhone and iPad indicate that both mobile devices will not be much longer seen as luxury goods. It is estimated that in the next three years the tablet-PC market will increase threefold and that it will not only be Apple devices but that there will also be tablets with Windows 8 in the stores.

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Investigating the Promotional Effect of Green Signals in Sponsored Search Advertising using Bayesian Parameter Estimation

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Abstract Over the last years we have observed a remarkable shift of media spendings from offline brand building activities to online performance advertising as well as a noticeable increase in "green marketing" efforts and sustainability communication by companies of various branches. In this paper we bring these two research streams together. We develop and perform a non reactive A/B-test that enables us to evaluate the influence of sustainability information on the customers decision to buy a product by clicking on an ad on a search engine results page (SERP). We analyze campaign performance data from a European e-commerce retailer, apply a Bayesian parameter estimation to compare the two groups, and discuss the implications of the results.

1 Introduction

Internet search engines like Google, Yahoo! or Bing play an undisputed key role in the modern information society. On the one hand they serve the information needs of their users, on the other hand they represent an important source of customer acquisition for companies in a broad variety of industries and sizes [1, 2]. They also provide the search engine companies with significant amounts of their revenues through Sponsored Search Advertising. While still growing rapidly Sponsored Search Advertising already dominates the online media-spendings of companies that advertise on the internet. In this form of advertising, developed in 1998 by Overture, advertisers provide search engines with text-advertisements and a list of keywords, which can consist of one or more terms, they want to be displayed. The advertiser usually also provides attributes to each of these

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keywords, but at the very least the amount of money he is willing to pay for a click on an ad for this specific keyword (CPC_{max}) [3]. Every time a user types in a query the search engine generates individual personalized result pages, depending on the users' location, his search history and other factors. If ads are available that could probably satisfy the need of the user, the search engine displays these ads alongside the organic results. If more than one advertiser is willing to pay for the display of an ad the search engine auctions the position of these ads among all interested players typically based on a Generalized Second Price Auction (*GSP*) [4, 5]. In each auction only the advertiser that wins the auction by getting a click on an ad is charged by the search engine. The effective Cost-Per-Click (CPC_{eff}) is basically the maximum bid of the advertiser with the subsequent highest bid plus a small additional fee. In practice search engine companies use a more robust mechanism to maximize their profits by rewarding keyword/ad combinations that have a high relevance to users (often referred to as the quality score). Although detailed calculations are not disclosed, the key metric is claimed to be the historic Click-Through-Rate (*CTR*) where available, otherwise an expected click probability for the specific advertiser-ad-keyword combination is used.

In the present paper we concentrate on the advertisers' perspective and the direct impact of green signals in text advertisements. We evaluate the probability that a user will click on a given Sponsored Search text advertisement containing the promise of Carbon Neutral delivery versus another one offering generic information on reliable fast delivery and conduct a Bayesian parameter estimation approach to analyze the data.

2 Literature Review

There are two streams in literature which are important for the present research. The first is green marketing. The second studies the various influences on Sponsored Search advertising effectiveness.

2.1 Green Marketing

Green marketing has been a widely recognized trend for international firms over the last years. One can clearly identify strong efforts in the development of sustainable brand images in a number of branches. One trend Leonidou et al. identify in their review of developments in green advertising research and practice from 1988 to 2007 is a strategy shift from communicating environmental aspects within the production process to the communication of sustainable consumption by the customers themselves. An other important expansion of this field is observed in the intensification of efforts by B2C businesses in communicating green messages in their advertising activities [6]. The use of ecolabels is a well known tactic is to provide the potential consumer with independent confirmation of the green efforts of the respective advertiser. In fact Rex and Baumann state that there is still lack of empirical knowledge about the consumers reception in this area [7]. Recent studies indicate that a number of consumers may be willing to pay higher prices for products they identify as environmental friendly [8]. What is still unanswered is the whether these green signals still have an impact direct buying decisions in situations in E-Commerce situations.

2.2 Sponsored Search Advertising

In published research, Online Marketing and Sponsored Search especially has become an established topic with a variety of high quality publications in Computer- and Information Science as well as in the fields of Operations Research and Marketing. Since 2004, Sponsored Search has become a continuously more and more important topic in the Online Marketing research area [2, 9, 10]. Yao and Mela [11] contribute a first comprehensive literature review of Sponsored Search Advertising from the perspective of three stakeholders: (1) search engine companies, (2) advertisers, and (3) users.

Research on auction design with a focus on optimizing the earnings of the search engines [12–14] is at the core of many publications. Fundamental work on this topic deals with the understanding and development of auction designs, mostly based on GSP-like mechanisms [15]. A number of theoretical contributions can be found that develop game-theoretic approaches on equilibrium optimization in GSP auctions [16–20]. For example there are discussions of the introduction of minimum prices [21] or the possible benefits of hybrid auction types. In these auctions the advertisers are given the choice of being charged on a CPC or Cost-Per-Mille (*CPM*) [22] or Cost-per-Action (*CPA*) basis [23]. In practice none of the important players in the search engine market implement such a choice for advertisers as they expect their revenues to decline.

Various authors explore yield optimization problems with special reference to the budget constraints of the bidders in the auction [14, 24–27]. In practice, search engines have to satisfy the user's query by offering relevant results. The quality of the identification of a query intention is important for search engines first of all but also relevant for advertisers as they have to decide for keywords that have a good chance to ultimately lead to a conversion. This indicates the relevance of having algorithms that classify queries [28–32] along the dimensions "navigational", "informational" and "commercial" as well as mixed forms of these. In fact only 38 % of all queries have a commercial background [30] which makes it important for advertisers to correctly identify these terms in order to avoid the waste of expenditure on visitors without any intention to convert into customers. The better these intentions for each individual query session are understood by search engines, the better is the chance that the search engines exactly fit the needs of the current user and are able to display appropriate advertisements.

The search engine auctions the positions of the ads on the Search Engine Result Page (*SERP*) between all advertisers that placed a bid (CPC_{max}) for the given keyword. The ad position is the result of the combined CPC_{max} and so called quality scores of the players. The CPC_{eff} depends on the advertisers bid and the ones provided by the other advertisers in the auction and the quality score of the ad/query combination.

Many publications in this area have an empirical basis. Basically quantitative research is conducted with three types of datasets: (1) Search engine query data (2) aggregated media and e-Commerce statistics and (3) individual user journeys. Search engine query data is the rarest form of available data for researchers who are not directly affiliated to the search engines as it can only be collected by the search engine companies themselves. Although every search engine company generates masses of this type of data, there are only few datasets available for academic use. One of those is the well known AOL dataset. It consists of about 20 million completely non-censored web queries collected from about 650,000 users over a three month period, arranged by anonymous individual IDs. This dataset has been extensively examined since 2006 [33–37].

Aggregated media and e-Commerce statistics are generated by the advertisers themselves during their ad campaigns. One way this kind of data is produced is by the campaigning tool itself (e.g. Google AdWords) or the advertiser's respective software solution. The data is usually aggregated on campaign, adgroup and keyword-level and contains variables like the total number of clicks, impressions, *CTR*, *CPC*, and *CVR* as can be seen in Table 1.

The third sort of available data enables researchers to understand individual user behavior. User journey conversion datasets include information about all measured touch-points that an individual user has with a specific advertiser. These datasets make the development of attribution-models possible where every conversion success can be allocated to the ad-contacts a user has had. Like the other types of data too, user journey data is always subject to several types of bias, such as caused by media discontinuities.

Table 1 Typical dataset from Google adwords (ad level)

Keyword	Clicks	Impressions	CTR (%)	Avg. CPC	Cost	Avg. position	Conversions	Cost/ conversion	Conv. rate (%)
ad 1	132	2,198	6	1.32	174.08	2	16	11	12
ad 2	421	2,893	15	2.32	976.72	3	21	46.51	5
…	…	…	…	…	…	…	…	…	…

2.3 Click Probability

Click probabilities have been widely studied since the early beginning of the advertising format Sponsored Search. However, due the lack of possibilities to observe the user behaviour while using a search engines, a complete coverage of all factors influencing the *CTR* is no easy task.

Evidence suggests that one of the most influencing factors is the ad position within the Sponsored Search results, which depends among other facts on the advertisers CPC_{max} and the so called quality score. The quality score, used by search engines to determine the quality of an advertisement, is based primarily on the historical *CTR*. A large number of studies has shown the correlation between decreasing position and a decreasing *CTR* and vice versa [38, 39]. It should be emphasized, that the highest positions leads to high *CTRs* but not mandatorily to the highest conversion rates. From an advertiser's perspective, a topic of interest is to predict the future *CTR* of sponsored ads. As argued before, the position has a major influence on the *CTR*, called the position bias. In the course of research, several models have been developed to explain the influence of the position bias on the *CTR*.

Crasswell et al. [40] present several models for predicting the *CTR*: (1) baseline model, (2) mixture model, (3) examination model, and (4) cascade model. The findings were originally based on organic search results but, they are applicable to Sponsored Search results as well [38]. The underlying assumption of the (1) baseline model is that a user screens every search result and decides afterwards, which one fits the best to the query. As a consequence, the click probabilities for each individual search result are identically, independently of its position. The (2) mixture model extends the baseline model and divides user behavior into two groups. One group behaves as described in the baseline model, the other group clicks randomly on one of the first search results. The (3) examination model refers to findings from eye tracking studies which state that with declining position, the probability of a click declines as well [41, 42]. The (4) cascade model is, owing to the high degree of explanation by click data, one of the most applied explanation approaches. The basic assumption is that the user scans each search result, beginning from the top to the bottom, comparing the relevance of each ad with the relevance of the ad before. The user continuous scanning the results until the perceived ad relevance reaches a certain level and the user clicks.

As mentioned above one challenge is to predict the *CTR* of keywords or keyword combinations for potential future Sponsored Search ads. One solution that has been proposed is aggregating historical data from similar keywords [43]. Here, the *CTR* is represented as a function of position, independent of a bid. In doing so, the developed models do not focus on a certain advertiser. The same clustering approach can be applied in optimizing the search engines' profit [44]. There are also models taking the quality score into account [45, 46]. A model developed by Zhu et al. [47] called General Click Model focuses on the *CTR* prediction of long-tail queries, based on a Bayesian network. Dealing with the position bias mentioned before, Zhong et al. [48] incorporate post-click user behaviour data from the respective landing page of the clicked ad into the click model to refine the estimation of the perceived user relevance after clicking on a specific ad. A similar approach, using Dynamic Bayesian Networks can be found in Chappelle and Zhang [49]. Several models based on historical click data suffer from limitations in terms of lacking consideration of a possible user learning effect. Taking Gauzente's results as an example, it has been shown that past user satisfaction with Sponsored Search results influences the current click behaviour [50]. Besides the incorporation of position data and the perceived relevance of presented ads, the *CTR* of an advertiser is also affected by the relationship between organic and Sponsored Search results. Listing the results of one company at the same time in sponsored and organic search results leads to a higher *CTR* and vice versa [51, 52].

3 Case Study

This study covers a test period of several days in which a single element in selected Sponsored Search text advertisements hast been alternated for a number of queries that users type into the Google search engine to eventually buy products in the advertiser's online shop as can be seen in Fig. 1. The advertisers' products can be classified as B2C Fast Moving Consumer Goods. The selected keywords include (1) variations of the retailer brand, (2) the brand names of product manufacturers as well as (3) several clear-cut descriptions of selected products in the online-shop. The data was generated directly by Google Adwords as part of the normal campaign evolution of the advertiser.

The test has been carried out in early 2013. The resulting dataset contains a large number of Sponsored Search key performance indicators (*KPI*) for the given period as exemplified in Table 1. The content of the unfiltered dataset as well as the exact dates of the test period cannot be revealed to ensure confidentiality for the advertiser and are of no importance for what follows from here. To ensure that only the impact of the specific text alternation is analyzed and to exclude other factors that would blur the results, especially the strong position effects we describe above, we only analyze the advertisements that were displayed above the organic search results and that were part of the described A/B test. The updated dataset, which is only a small fraction of the advertisers' regular Sponsored Search

Fig. 1 Two variations of an ad, similar to the ones that were used in the A/B test: carbon neutral delivery versus fast and reliable delivery

Fig. 2 Group 1 = CTR for ads advertising carbon neutral delivery, group 2 = CTR for ads advertising fast and reliable delivery

Fig. 3 Posteriors for Bayesian parameter estimation

campaign, includes a total of 105 advertisements of which 52 advertise “Carbon Neutral delivery” while the other 53 advertise “Fast and Reliable delivery” in the third row of the advertisement as illustrated in Fig. 1. It contains a total number of 1,972 clicks. What is used for the analysis is the aggregated *CTR* for each ad over the whole test period.

Analytic approach: Traditionally one makes statements about the magnitude of the difference between two observed groups by using null hypothesis significance testing (*NHST*). Due to drawbacks we apply a Bayesian approach to answer the question whether there is a positive, negative or zero impact of sustainability information in ad texts in Sponsored Search advertising by comparing two groups of users that took part in an A/B test. Even though the applied method possibly influences the behavior of the involved users and could therefore be categorized as reactive in terms of social sciences, it shares common criteria with non-reactive methods since individual users have no knowledge of the investigation of their behavior.

We follow Kruschke and describe the data using mean and standard deviation parameters for t-distributions representing both groups individually and add a normality parameter that is common for both groups. The prior allocation of credibility across the parameters is vague, so that the prior has minimal influence on the estimation, to let the data dominate the inference. Taking the data into account the Bayesian estimation reallocates credibility to parameter values that represent the observed data best. The resulting distribution is a joint distribution across the five parameters, thereby revealing combinations of the five parameter values that are credible, given the data [53]. The two histograms in the top right in Fig. 2 are representations of empirical data and display the two observed groups (group 1 = "Carbon Neutral delivery", group 2 = "Fast and Reliable delivery"), with curves of representative examples of posterior predictive t-distributions. In the left column you will find marginals of the posterior distributions of credible values of means of group 1 and 2 as well as the same for the respective standard deviations and a distribution of credible values for the combined normality parameter. Lower right shows posterior distribution of differences in means and effect size. Figure 3 displays pairwise plots of the parameters for the given study.

4 Conclusions and Outlook

Taking a first look at the data we find a slightly higher empirical mean *CTR* over all ads on ads that advertise "Fast and Reliable delivery" (15.5 %) than on the "Carbon Neutral delivery" ads (14.3 %). These values are not to be confused with those in the top left histograms in Fig. 2 which represent the simulated mean parameters of t-distributions to fit the empirical distribution. So, in the data we observe a 1.2 % lower empirical mean *CTR* for "green" ads which would make us reject the hypotheses that ads with green marketing signals have a higher click probability than their counterparts in the A/B test. In fact we would have to claim the opposite which is that the use of these ads leads to a lower click probability. What is the central question is whether this result is significant and if it enables us to derive inferences about the "real" long-term distribution.

To answer this question a large number of parameter combinations for t-distributions that are credible given the data is generated by Markov chain Monte Carlo simulation (*MCMC*). One gets a good insight by comparing the distribution of credible values for μ_1 which has a mean of 0.124 and a 95 % Highest Density Interval (*HDI*) from 0.0984 to 0.15 with μ_2 which has a mean of 0.134 with a 95 % *HDI* from 0.11 to 0.158. The exact difference $\mu_1 - \mu_2$ is −0.00996 on average as can be found in the plot in the middle of the right column of Fig. 2. One can see that 72.2 % of the 95 % *HDI* for $\mu_1 - \mu_2$ is negative. What is even more relevant for the analysis is that all computed values within the 95 % HDI fall into the Region of Practical Equivalence (*ROPE*) which spreads from −0.1 to 0.1. So, these results imply that there is a 72.2 % chance that the “real” mean of group 1 is smaller than the “real” mean of group 2. Nevertheless the difference of means is so small that there is a high probability that the groups are not credibly different from each other in this aspect. Comparing the distribution of credible values for σ_1 and σ_2 one can see that these groups do not credibly differ too. This can be seen in the respective histogram in Fig. 2 where all computed values for $\sigma_1 - \sigma_2$ are found in the ROPE with 67.3 % being positive and 32.7 % being negative. This suggests that there is a 67.3 % probability that the standard deviation for group 1 is grater than for group 2.

The lower right panel of Fig. 2 shows the distribution of credible effect sizes, given the data. For each combination of means and standard deviations, the effect size is computed. The histogram of 100,000 credible effect sizes has a mode of −0.151 and the zero included in the 95 *% HDI*. 72.2 % of all computed outcomes are negative while 27.8 % are positive.

What can we derive from that? What is true is that there is some probability that there is absolutely no effect caused by the different signals in the advertisements as we do not observe strongly significant unambiguous results. If any effect is presumed, it will have a much higher probability of being negative for “green signals” in Sponsored Search ads, given the observed data. How can this outcome be explained? One argument could be that ad texts do not influence users on SERPs at all. Although we know about various other effects, like the strong position bias described above, that do affect the user there are too many indications that ad texts do have influence on click decisions to let this be true.

In fact, these results need to be interpreted with caution. One possible explanation for this is that users might not be as green in their decisions as marketers would like them to be. In this case the promise of “Fast and Reliable delivery” seams to lead to a slightly higher motivation to click on an ad than the green signals the advertiser sends out to his potential customers. This A/B test should be repeated over a number of various branches before one can derive implications for the whole e-Commerce industry. What is an even more interesting outcome of this paper is that more future research should be conducted on the general impact of texts in Sponsored Search ads considering a variety of branches and containing more diversity in texts to make sophisticated assumptions on the impact of text-details on click probabilities.

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DialogueMaps: Supporting Interactive Transdisciplinary Dialogues with a Web-Based Tool for Multi-layer Knowledge Maps

Paul Drews and Arno Sagawe

Abstract In environmental engineering, experts from different disciplines and with diverse backgrounds and responsibilities need to cooperate. As they tackle problems important to society and practice, this type of cooperation can be characterized as transdisciplinary. In transdisciplinary settings, the actors involved bring together theory, models and knowledge from different disciplines. In order to integrate this knowledge and to create a better understanding of the complex issues under consideration, experts can use methods like knowledge mapping. Compared to other methods used in environmental engineering, knowledge maps are based on a lower degree of formalization. In this article, we derive requirements for a method and a tool for supporting the interactive creation of knowledge maps in groups from theory and from existing methods related to environmental engineering. Based on these requirements, we describe the concept of a new method and a supporting tool called DialogueMaps. This tool is web-based and aims at supporting transdisciplinary interactive dialogues for developing multi-layer knowledge maps.

1 Introduction

Today, the generation and use of knowledge are highly intertwined activities according to several dimensions. First, many of society's 'big problems'—like understanding the climate change [1]—require knowledge from several scientific

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disciplines. Therefore, they need to be addressed in interdisciplinary or transdisciplinary projects. Second, an intertwinement is needed among science and practice within an ongoing process of reciprocal reflection. Third, for tackling global problems, people from different locations combine face-to-face meetings with online collaboration. In environmental engineering, these dimensions do also apply, as actors from different disciplines and knowledge fields need to cooperate. Creating innovative environmental technology and bringing it into the field is often based on interaction of research and practice. Furthermore, many environmental projects act on a global scale or exchange information with other global activities. Hence, environmental engineering needs to address the question of how these circumstances of knowledge processes affect methods of knowledge creation and sharing.

For many years, researchers from different fields created methods like knowledge maps [2]. These concepts aim at supporting the discussion among experts to gather their knowledge and to share it among the participants of a workshop or with other interested people. They are used for summarizing a discussion among experts from different fields and for gathering their knowledge and perspectives on complex issues. Until today, tools supporting these methods are either proprietary, focus on a defined strict modeling method or do not use the latest web technology. This motivates us to rethink the methods and tools used by experts in transdisciplinary projects to establish a common view of issues under consideration by the use of knowledge maps.

In this article, we raise the question of how the potential of IT can be used as a part of a new method which supports the generation, sharing and use of interactive knowledge maps in transdisciplinary contexts like environmental engineering. In a first step, we present the theoretical background of this method and the according tool by drawing on the ideas of transdisciplinarity, communication models and Neurath's ISOTYPE methodology. In the third section, we present and discuss three methods used in environmental engineering which refer to ideas similar to knowledge maps. We use the theoretical background and these methods to extract requirements for the new method and its tool support. In section four, we present these requirements as well as the development approach for the new method and the tool called 'DialogueMaps'. We close with a summary and an outlook in the last section.

2 Theoretical Background

Before we take a closer look at existing methods, we present some theoretical assumptions which serve as a fundament and motivation for our project. First, we consider environmental engineering as a field where the concept of transdisciplinarity provides a platform for integrating knowledge from different academic fields. Second, as we look at cooperating experts in transdisciplinary settings, we draw on Flusser's communication theory and Neurath's ISOTYPE for better understanding and supporting the experts' interaction. Third, knowledge maps are presented as a concept which can be used by expert groups to produce an integrated view on the complex issues which they discuss.

2.1 Transdisciplinarity and Environmental Engineering

During the last decades, a new mode of scientific research has been established. Beside the classical modes of basic and applied research, science has to an increasing degree been involved in problem-oriented research [3, 4]. While basic research focuses on problems generated out of research agendas and paradigms from science, applied research makes use of knowledge generated in science and applies it to problems in practice. In contrast, problem-oriented research addresses social problems. Basic and applied research are mainly guided by the research agendas of scientific disciplines, whereas problem-oriented research does not need to comply with those agendas. It requires transdisciplinary, in which different disciplines work together on a problem which is important to society. In these research settings, establishing a common ground among the involved people and disciplines is not easy. Instead, the participants have to deal with different 'problem definitions, terminologies, methods, and theories' [5]. The starting point for transdisciplinary research according to Pohl and Hirsch Hadorn [6] is a socially relevant problem area (e.g. violence, hunger, poverty, disease, environmental degradation, etc.). The aim of transdisciplinary research is to contribute empirical and practical knowledge for solving, reducing or preventing lifeworld's problems (ibid.). The participatory research with social groups and cooperation across disciplinary boundaries is a way to help solving complex problems. The inclusion of social groups and perspectives of different research disciplines primarily aims at taking the variety of lifeworld perspectives and interests into account. Participatory research is suited to capture the complexity of a problem in a better way.

Beside the financial crisis, which has been pushed into the foreground during the last years, the global environmental problems are considered as being a major threat of mankind. To understand and address this threat, the attention and efforts of political and scientific actors has increased dramatically during the last decades. To tackle the problems of environmental degradation, experts from diverse fields like engineering, biology, chemistry, and architecture needed to cooperate for better identifying and understanding the problems. New approaches have to be developed. Researchers of computer science and information systems contributed to this field by creating new methods and tools for supporting their work. Many of these methods use formalization and calculation methods which can be supported by the use of methods and tools for analyzing material flow, for example, are strongly based on concepts from computer science like petri nets [7].

2.2 Flusser's Circle Dialogues and Neurath's ISOTYPE

When experts come together in transdisciplinary research settings, they need to communicate and to discuss their ideas. The communication philosopher Vilém Flusser defines communication as the process in which information is being transferred, stored and processed [8]. Furthermore, new information is created in communication processes. In his book 'Kommunikologie' Flusser defines different types of communication structures. Among other concepts, he describes theatrical discourses (short: discourse) and circle dialogues (short: dialogue). The theatrical discourse is characterized by the following structure: Sender and receiver are facing each other (class room situation). In this discourse, the receivers are able to respond to the sender immediately. In a circle dialogue, the structure is similar to a 'round table'. All participants are contributing to the dialogue with the information stored in their memories. Then, they try to combine their information to create new information. Though theatrical discourses may be part of interdisciplinary research projects, we will focus on the situation of circle dialogues in the rest of this article as a certain form of cooperation we like to improve.

In these dialogue situations, results are normally captured in text form (cards, protocol, etc.). To challenge this regular way, we draw on the ideas of Otto Neurath's ISOTYPE ("International System of Typographic Picture Education") of iconic reading developed in the 1920s [9]. The non-alphabetic reading, also known as iconic reading, has a long history [10]. The idea of supporting communication by using abstract, graphical objects (icons) is based on the basic science of Otto Neurath. He dealt with the question of how to improve the redistribution of knowledge [11]. His idea was to establish a new relationship to knowledge. The knowledge acquired in science should be made available to its future users [12]. He concentrated on how this communication process can be supported by developing new forms of representation (ibid.). Neurath wanted to visualize social relations in a general form which is easy to understand [13]. The method aims at creating a completely new type of characters, which should be as self-explanatory as possible in relation to the original object [14]. ISOTYPE became an internationally applicable, easily understandable, and cross-cultural (transdisciplinary) image language [15–17]. Today, the independence from spoken language makes ISOTYPE a compass at the crossroads of our globalized and networked society: These icons are used on international airports, in subway stations and bus stops, in tourism centers of cities, as well as for designing graphical user interfaces of computer programs.

2.3 Knowledge Maps as Non-formalized Modeling

Knowledge maps are an instrument of knowledge management used by organizations to visualize knowledge in graphs. Organizations can use these maps to improve the effectiveness and efficiency of work processes [18]. Knowledge maps provide references or links to the knowledge, but not the knowledge itself. They may be used in companies as well as in educational contexts [19, 20]. Compared with geographical maps, knowledge maps can be considered as intellectual environments [21]. According to Eppler, a knowledge map consists of a map base which represents the context of the knowledge which should be mapped. Furthermore, they include an individual layer in which the elements are assigned to the card base (ibid.). To summarize, a knowledge map represents a section of the real or virtual world as a reduced graph on a two-dimensional medium. Each knowledge map has a structure according to its context or topic. The structure is of an abstract nature (e.g. organizational or network schema). This basis is used to place information objects like symbols, colors, forms, texts and images on it. A knowledge map visualizes complex objects and their relations (issues, ideas, concepts, diagrams) in a reduced and abstract form.

For environmental engineering, several methods for modeling complex issues like material flow networks have been developed. For many of these methods, appropriate IT systems for supporting the modeling process are available. However, these tools support modeling tasks referring to methods based on a rather high degree of formalization. The creation of knowledge maps is a method with a rather low degree of formalization. When experts from several disciplines come together to discuss transdisciplinary problems in dialogue situations, they need a tool for supporting the integration of the participants' ideas. In these situations, achieving a higher degree of formalization is often not possible or not wanted. Instead, the participants are seeking to create an overview on a topic as a whole and to identify relations among the objects under consideration. As we have learned from Neurath, reducing complex ideas with simple symbols is a way to improve the transfer of knowledge even to non-expert actors. It is a way to create a language which should not be rooted in the theory or models of the involved disciplines. In a later phase of such projects, further details may be added to the map. These enriched maps may be linked to each other. References in these maps may lead to further information stored in other systems or databases.

3 Existing Methods for Visualizing Complex Facts and Issues in Environmental Engineering

After presenting the underlying theoretical concepts, we compare existing methods used for transdisciplinary research settings in environmental engineering in this section. We selected three methods with the following arguments: For all of them, there is software available which provides functionality needed to fully make use of the method. Two of them (Vester's sensitivity model and IBIS) include a modeling approach or visualizations which are similar to the idea of knowledge maps. The third one (material flow networks) is used to demonstrate the possibility of integrating methods with different degrees of formalization.

3.1 The Sensitivity Model

Frederic Vester propagated the method of networked thinking in several of his publications [22, 23]. Network thinking combines cybernetic and systemic ideas with complexity. Central ideas of network thinking include viewing a system as a network of interrelated effects, leading to emergent behavior of the system as a whole. These networks can be described in different ways (e.g. by using protocols, mathematical networks, computer software, visualizations etc.). Any kind of these descriptions enables the viewer to recognize the positive and negative feedback loops. The described networks can be used as a basis for simulation. It can help to decide the long-term effects of singular measures which manipulate the network. Sensitivity models combine the above-mentioned ideas and can be used in several areas (e.g. corporate strategic planning, technology assessment, city, regional and environmental planning, traffic planning etc.). Sensitivity models have been used since the 1980s in many studies, e.g. by Ford [24] or the UNESCO [25].

The main feature of a sensitivity model is its mediation capacity. Different ways of visualizing the network characteristics of a system are supported. Furthermore, its parts help to put the different interests in the same model to identify their role and mutual influences in a complex pattern. The ability of mediation is supported by the fact that each project participant is able to place his or her own requirements and beliefs in the system's pattern thus recognizing that these are interlinked from the perspective of sustainability.

Sensitivity Model Prof. Vester® (SMPV; today Malik Sensitivitätsmodell® nach Prof. Vester [26]) is a compilation of computerized system tools. The visualization of the Sensitivity Model was used as a basis for the simulation tool, which is recommended for specific scenarios in order to gain some knowledge about the behavior of a system's parts or clusters [27]. The simulation is very well suited for examining an existing model in terms of its behavior through changes. A requirement in the development of SMPV was to make the simulation interactive, allowing the user to react during the runs upon critical developments [27]. But the software does not adequately support the preliminary phase of problem recognition [28]. Although the tool can be extended for group working, this support is related to the functions of controlling and monitoring [29]. Cooperative knowledge maps cannot be created, although Vester provides similar illustrations in his books.

3.2 Material Flow Networks

Material flow networks are based on the methodology of petri nets [30]. They are part of a special modeling approach for mapping material flow systems in a material flow analysis [7]. The material flows of a system and their transformations in production and reduction processes can be modeled as a network. Material flow networks include an ideal basis for a material flow-based costing and special ecological assessment methods, e.g. UBA effective potential method, Eco-indicator 95, CML method (ibid.). Material flow networks are well suited to describe the consumption and the transformation of resources (ibid.). Typically, material flow analyzes are carried out in a project team of members from different disciplines (ibid.). Each team member edits a content delimited region of the system to be analyzed (ibid.). Material analysis and material flow networks are supported by a variety of software products [31, 32]. Using this type of software also requires a pre-created model. To support the modeling of material flow networks, the following requirements apply to the software: A computer-based exchange of information to collect data, the discussion of inconsistencies and missing data, the discussion on the evaluation results with the aim of formal policy and environmental measures, the exchange of texts or text fragments describing the study and the results, including text of the environmental report [33]. Furthermore, the existing software allows simulating changes in the material flow networks. Though these methods and tools do not primarily aim at supporting the creation of knowledge maps, these mapping techniques can be used in a preliminary phase (problem understanding) and for maintaining an overview throughout a project (problem and solution tracking).

3.3 Issue-Based Information System

Issue-Based Information Systems are used for widening the coverage of a complex problem. They "[…] are meant to support coordination and planning of political decision processes. IBIS guides the identification, structuring, and settling of issues raised by problem-solving groups, and provides information pertinent to the discourse […]" [1]. By encouraging a greater degree of participation, particularly in the earlier phases of a project, a designer can try to include other people to receive hints where difficulties of his proposed solution may arise from. Each element of an IBIS is an issue. These issues could be a question that needs to be answered. An issue is associated with alternative positions or possible answers. The answers in turn are associated with one or more arguments. These arguments support or object to a given position or another argument. Since the problem observed by a designer can always be treated as merely a symptom of another higher-level problem, the argumentative approach also increases the likelihood that someone will attempt to attack the problem from his or her point of view. Another desirable characteristic of IBIS is that it helps to make the design process 'transparent'. Transparency here refers to the ability of observers and participants to trace back the process of decision-making. IBIS is also used in issue mapping [34], an argument visualization technique, and as the basis of dialogue mapping [35]. Both methods are very useful to visually monitor the course of a discussion and to structure a complex problem. The IBIS notation is available in a variety of software products. The currently most advanced is Compendium [36]. It allows the creation of advanced IBIS maps (e.g. it is possible to place multimedia content on a map and to use own symbols).

However, the IBIS method shows some shortcomings. First, it is based on a very limited selection of symbols. While this allows participants to easily understand and use these symbols, it does not provide the means for creating rich maps with strong link to the projects' issues. Compared to the relatively high degrees of freedom in knowledge maps, the IBIS method is rather restricted. Furthermore, this method mainly aims at mapping the process of discussion rather than creating an integrated map to foster a common understanding. It is rather a method for discovering topics and to document the process of their discovery. The limitations of the software tools are: Only one person (the moderator) can change the knowledge map at the same time. There is no database connection that can be used for later analyzing or exporting elements of the knowledge maps.

4 DialogueMaps as a Tool-based Method for Supporting Interactive Dialogues with Multi-layer Knowledge Maps

4.1 Requirements

After considering some methods and their according tool support, we now draw on the theory presented in the second section and the strengths and weaknesses of existing methods and tools to conceptualize a new method with integrated tool support. The concept of this method inherently considers the means provided by IT and is not planned to be usable without IT support. This allows us to create a new approach based on innovative potentials of IT like multi-touch devices (tablet computer, smartboards). Referring to the theoretical foundations and the methods above, we derived 13 requirements which the method and the tool should support (see Fig. 1).

There are tools available which support one or several of the requirements listed below. However, we did not find a tool which supports all requirements. Vester's tool for sensitivity analysis provides means for creating maps of important factors and their interrelation. Though, there is no way to interactively add symbols and the method aims at formalizing the interdependencies among variables under consideration. The presentation tool prezi.com is neither based on open source nor does it provide sub-maps or an integrated mode for presentation and editing. Umberto, as a tool for modeling material flow networks, demands (according to the underlying concept of petri nets) a higher degree of formalization than knowledge maps. However, knowledge maps may contain links to more detailed and formalized models like material flow networks.

No.	Requirements: The method and the supporting tool should…
R1	support the communication process within a group to generate a common understanding of a complex issue
R2	allow the interactive creation and refinement of knowledge maps
R3	consider Neurath's ideas and allow adding icons to symbolize complex issues
R4	provide means for navigating on the map (zooming in and out, panning)
R5	make use of detailed sub-maps to 'dive deeper' into certain issues (multiple layers)
R6	include a set of symbols and a way to import own graphics
R7	be usable by multiple users interactively working together on the same knowledge map
R8	allow attaching links, videos, and files to elements on the map to integrate other systems with relevant information (e. g. intranet pages, PDF documents, youtube videos)
R9	support the involvement of participants in a dialogue situation by being compatible with interactive whiteboards (smartboards), tablet computers and notebooks (synchronous editing via diverse devices) but also distributed settings and asynchronous editing
R10	be platform independent and based on open source components to allow modifications and development according to research questions
R11	provide an integrated mode for presentation and editing
R12	consider transdisciplinary and interdisciplinary dialogues with a low entry barrier and by putting great emphasis on the degrees of freedom during the creation of a map
R13	be easy to use, so that it may be used by technically or artistically less skilled people (in contrast to graphic recording which is supported by professional illustrators)
R14	provide means for annotating maps with free-hand drawings
R15	the map, sub-maps and all elements visualized on the map shall be stored in a database which allows import / export of data

Fig. 1 Requirements for a method and a tool

4.2 Method and Tool Implementation

On the basis of the requirements listed in the previous section we started an integrated method and tool development process. In this section, we first describe our revised concept of knowledge maps as the methodological part. This is followed by a description of the tool and its development process. Any knowledge map consists of various elements [e.g. symbols for description from lifeworld situations (R3), free-hand drawings for annotations (R14)]. The elements can be connected with each other through interrelated effects (see Fig. 2). Navigation controls allow zooming (in/out) and panning of the map (R4). Furthermore, each element can refer to a sub-map for a closer look [in a partial region of the life-world situation (R5)]. Elements can also be supplemented with multimedia attachments (R8). The attachments represent collected data (about a part of the lifeworld facts).

For each issue to be discussed, users can load the appropriate icons in the system (R6). By linking knowledge maps, a network is created, which describes the lifeworld facts with different perspectives. The different perspectives can be

Fig. 2 The concept of multi-layer knowledge maps

mapped and discussed by all participants (R7, R9). The result is one integrated knowledge map (R2). This can be used as a further basis for discussion (R1, R11) and can be analyzed via database queries (R15). The application is Open Source (GPL 3.0) and hosted at SourceForge [37] (R10).

To fulfill the requirements and our methodological considerations, we started a research project on evaluating existing software support and ended up in developing a new tool. The research project to develop the tool is design science oriented [38] and uses prototyping [39] and agile development (scrum) [40] as a methodological guide. DialogueMaps was developed as a web-based tool on the basis of Java, Apache Tomcat, and Wicket (server-side) (R10). The client side uses HTML5, Javascript (incl. jQuery), and an SVG canvas (R10). Communication between client and server and persistence are provided by JSON objects, Ajax, Hibernate, and MySQL (R10). Compared to other tools (like prezi.com), DialogueMaps is solely based on open source components and does not use any proprietary software like Flash. It can be used by multiple users synchronously or asynchronously for working together on a single map. The core functionalities have already been implemented. In the next step, the usability will be improved (R12, R13) (Fig. 3).

Fig. 3 A knowledge map from [23] realized in dialogueMaps

5 Summary and Outlook

In this article, we have discussed theoretical foundations of transdisciplinary research, dialogues and Neurath's ISOTYPE. As we have learned from this discussion, this kind of research demands experts from different disciplines to share and integrate their knowledge. The results of these discussions can (synchronously or asynchronously) be captured in knowledge maps which also include references to further knowledge. By looking at methods used in such situations in environmental engineering, we have demonstrated that none of them provides support for creating knowledge maps in interactive dialogues. Instead, they are based on achieving a higher degree of formalization. Especially in early project stages and for providing an integrated overview on a project, these higher degrees of formalization are not always appropriate. Afterwards, we derived requirements for a method and a tool which aim at supporting the dialogues of experts in transdisciplinary research settings. In the next step, we described the development of a method and a web-based tool which fulfill these requirements.

Groups working together on complex knowledge maps do not only occur in transdisciplinary research, but also in education and consulting; we also plan to use and evaluate the method and the tool in these contexts. In education, the tool has already been used and evaluated as a part of 'reflective dialogues'. Until now, the method and the tool as presented here will be evaluated in a real transdisciplinary research setting in the next project phase. As we have argued in the beginning, transdisciplinary projects in the field of environmental engineering would provide a proper field for evaluation.

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The Role of ICT in Green Logistics: A Systematic Literature Review

Volker Frehe and Frank Teuteberg

Abstract This chapter provides a systematic literature review of the field of Green Logistics with a focus on the role of ICT (Information and Communication Technology). It is based on 51 papers in international peer-reviewed journals and conferences. We analyze and cluster the papers in different areas, like Logistics category, ICT category and research methodology. Moreover, we identify different Information Systems used in Green Logistics and extract potential benefits of the use of ICT for Green Logistics and unsolved research problems. With this, information gaps in current research are determined and recommendations for further research are presented.

1 Introduction

Nowadays topics like Green Information Technology (Green IT), Green Information Systems (Green IS) and Sustainability are discussed in different areas. There is a large number of papers analyzing Green Logistics and Green Supply Chain Management (Green SCM). Min and Kim [1] identified 519 papers as well as six journals solely connected to green issues. Furthermore, there are various papers analyzing Green IT or Green IS (e.g. Melville [2]; Chen et al. [3]; Dedrick [4]). Due to environmental legislation (e.g. Kyoto Protocol [5]; ISO [6]) and on grounds of public reputation, the green aspect is discussed in science, practice and mass media alike, thus, plays a major role. Through the mass media, the awareness

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of consumers for (ecological, ethical) transparency as well as their sense of environmental responsibility is increasing [7, 8].

This paper provides an overview of current research in the areas of Green Logistics/Green SCM, with the focus on the use of Information and Communication Technology (ICT) including Information Systems (IS). We have chosen the methodology of a systematic literature review to provide the overview as it is regarded as an important and essential method in science [9, 10].

2 Definition of the Topic

Green Logistics has its roots in Logistics. Christopher [11] defines Logistics as follows:

> Logistics is the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels in such a way that current and future profitability are maximized through the cost-effective fulfillment of orders.

In literature there are different opinions about the differentiation to supply chain management (SCM). In fact, there are several analogies between Logistics and SCM. For instance, Christopher [11] says that SCM is a kind of extension to the logic of logistics, similar to Baumgarten et al. [12], who describe that logistics and SCM supplement each other. As the borders are not clearly defined, in this paper, we will handle both, logistics and SCM.

Wu and Dunn [13] explain why the greening of logistics (and SCM) is important for the industry. Based on the demand for green products, the delivering logistics systems themselves should be "green".

For our paper, we have chosen the formulation 'Green Logistics', despite if it is more a logistics or a SCM topic.

There is some literature, which is discussing rebound effects, especially in the fields of ICT and sustainability [14, 15]. Changes which result in a more sustainable way at the micro level can have an effect at the macro level [16]. While the authors are aware of this effect, it is not possible to examine each described ICT solution in this review referring to its rebound effects.

3 Research Methodology and Framework of Analysis

3.1 Systematic Literature Review and Analyzed Articles

We apply the systematic literature review to analyze the status quo of the role of ICT in Green Logistics as this method has become a key instrument for the efficient analysis of large numbers of sources [17]. According to Dibbern et al. [18],

Table 1 Framework of analysis (cf. Dibbern et al. [18])

Phase	Stages	Research question/content	Section
Motivation	Why?	Why do we analyze the role if ICT in Green Logistics?	1
Scope and applied methods	What?	What is the focus in current research?	4.1
		What kind of ICT is handled?	
		Which Logistics category is dealt with?	
	How?	Which research methods were used?	4.2
Evaluation	Outcome	What are unsolved research problems?	4.3

we created a framework to analyze the articles and to structure objects in predefined work areas. The framework (shown in Table 1) allows narrowing down the field of research, helps to structure the gathered knowledge and to identify further development.

Our review follows the 5-phases plan developed by Fettke [17], which leads to this agenda:

1. **Definition of Review Scope**: This part has already been outlined in Sect. 1.
2. **Definition of Research Topic**: The definition has been carried out in Sect. 2.
3. **Literature Search and Selection**: For the initial keyword search, first, we identified relevant journals by using a mixture from four rankings, namely: the WI (WIRTSCHAFTSINFORMATIK) ranking, the AIS (Association for Information Systems), the MIS (Management Information Systems) journal ranking and the Journal Rankings for Transport, Logistics and SCM (University of Sydney). With the synthesis of rankings, we access top journals in the field of IS as well as logistics. In this research, we only used A-ranked journals, respectively journals ranked lower than 15 in the AIS ranking. This results in a list of 63 journals.[1] We also included three top IS conferences (ECIS, WI, ICIS), based on the ranking of the WKWI (Wissenschaftliche Kommission für Wirtschaftsinformatik).

We used several keyword combinations for the search. Regarding Sect. 2, we chose terms like “green logistic”, “green transport”, “green scm”, etc.[2], whereby we also replaced the word “green” by “sustainable” in all search phrases. Furthermore, we combined these phrases with keywords like “ICT”, “Information System*” and several other ICT relevant keywords.[2] As there were only two papers published in the 1990s, which we, however, did not identify as relevant, only papers dated 2000 or later were regarded. However, white papers, theses etc. were not investigated because for this kind of publications there is often no peer review, which may result in poor quality, whereas articles of high quality are eventually published in journals [19]. The identified papers were used for

[1] The full list of journals can be accessed via http://uwi.uos.de/ICT-GL-Journals.pdf.

[2] The full list of keywords can be downloaded via http://uwi.uos.de/ICT-GL-Keywords.pdf.

backward and forward search. As a result, there were 73 articles which we checked for relevance by reading the abstract. In case no relevance could be identified, the article was cross-read. If still no relation to the topic could be identified, the article was not regarded. Otherwise the article was marked for further analysis and indexed (from 'A01' to 'A51').[3] This index is used to reference the articles in this paper.

4. **Literature Analysis:** In this phase, the kind of ICT and IS, logistics category, research methods and unsolved research problems were analyzed as explained in Table 1. The analysis is carried out in Sect. 4.
5. **Conclusion:** The results were interpreted and are summed up in Sect. 5.

3.2 Related Work

There are several articles dealing with literature reviews in the area of Green Logistics. We used our list of 63 top journals and identified six papers (cf. Table 2).

To the best of our knowledge, our systematic literature review differs from these review articles as it is the first that addresses the role of ICT especially for Green Logistics. By this containment we are able to analyze in which areas of Green Logistics the utilization of ICT is already common. Furthermore, we are able to point out which types of applications are used and what the benefits of this usage are for Green Logistics. As a result we will give an overview of potential future research in this field.

4 Analysis of Results

4.1 Category, Focus and Potential Benefits of ICT Applications

In the following, the reviewed papers will be clustered in different categories. We adapted the model of the logistics areas by Wu and Dunn [13] and the green SCOR model [20] and identified these categories: SCM Strategy, Purchase Logistics, Warehousing, Production Logistics, Packaging, Freight and Passenger Transport, Distribution Logistics und Reverse Logistics (RL) or rather Closed-Loop-SCM. Since a paper may address more than one category the sum of all percentages is larger than 100 %. The results are illustrated in Fig. 1.

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[3] The complete list of the 51 articles and their index can be downloaded via http://uwi.uos.de/ICT-GL-Paper.pdf.

Table 2 Related work

Building sustainability in logistics operations: a research agenda. Dey et al. [24]	
Research objective(s) and results	This paper analyzes the current situation (role and importance) of sustainability in the area of logistic operations. Several recommendations for companies, how to start and implement a sustainable logistics strategy, are identified
Title	A review of the past research and future ideas. Janic [25]
Research objective(s) and results	This paper provides a review of the research on sustainability of transport systems carried out over the last 15 years for the European Union (EU). It concludes that further research is needed to set up a system for more comprehensive monitoring/assessment of the sustainability of transport systems based on an innovative indicator system
An organizational theoretic review of green supply chain management literature. Sarkis et al. [26]	
Research objective(s) and results	This paper reviews green SCM literature under nine broad organizational theories (complexity theory, ecological modernization, information theory, institutional theory, resource based-view, resource dependence theory, social network theory, stakeholder theory and transaction cost economics). Special attention is paid to the adoption, diffusion and outcomes of Green SCM practices. The authors identify four further organizational theories, which, in their opinion, are important for explaining green SCM, but need further investigation. These are diffusion of innovation theory, path dependency theory, social embeddedness theory and structuration theory
Sustainable Urban transport in the 21st century: a new Agenda. Schipper [27]	
Research objective(s) and results	This paper reviews quantitative and qualitative trends in urban transportation and environment. The focus is on developing countries and reviews several efforts. To reverse the unsustainable trends in urban transport different actions (by cities, national government and the private sector) are needed. This must be supported by some political wil
Green supply-chain management: a state-of-the-art literature review. Srivastava [28]	
Research objective(s) and results	This paper clusters the reviewed papers in 3 main categories (importance of green SCM, green design and green operations) and sums up the given information from the corresponding articles. The review contains a sheet where the analyzed papers are mapped to one of the three categories as well as to the used mathematical technique/tool
RFID in reverse logistics—research framework and roadmap. Thoroe et al. [29]	
Research objective(s) and results	This paper reviews RFID literature in the area of Reverse Logistics. It provides a framework of RFID, which organizes the field in definable layers and interconnections. Conclusions are that experiences of the use of RFID in the management of closed loop container systems should be transferred to other areas of reverse logistics
ICT for logistics and freight transportation: a literature review and research agenda. Perego et al. [21]	
Research objective(s) and results	This paper reviews 44 papers from peer-reviewed journals and classifies them by the research methodology and addressed themes. There are many papers addressing 'public transportation', but only a few papers address the 'private transportation'. Most papers are conceptual or empirical studies, whereas simulation and modeling are under-represented

Fig. 1 Examined logistics categories

In the slightly dominant Passenger Transport category, we identified that more than half of the papers address the Land Use and Transport (LUT) System planning, whereas papers analyzing the Passenger Transport from a private point of view play a minor role. This is similar to Perego et al. [21] who identify the same issue for the role of ICT in Logistics in general. On the other hand, public and private points of view are almost equal in the area Freight Transport; half of the papers address Land Use and Transport System planning (public), whereas the other half addresses the firm issues (private).

While the Transport category is well investigated in Green Logistics, other categories are completely under-represented (cf. Fig. 1). Therefore, we perceive great potential for green innovations within these areas. From an ecological and economic aspect, also within innovative purchasing systems, there is still a considerable potential in the optimization of delivery processes. Moreover, by optimizing warehouse structure and configuration, transport routes could further be economized, and intelligent storage systems could control the warehouses themselves in an efficient and sustainable way. Concepts like just-in-time delivery have the potential to green the Production Logistics as they render large warehouses redundant. Using sustainable packaging is another, easy to implement step on the way to Green Logistics.

We recommend research in these areas to prove our suggested benefits.

As a part of this analysis, we want to identify the covered Information and Communication Technology in the analyzed papers. We aggregated the technologies and systems to main categories (e.g. technologies like Bluetooth or Wi-Fi has been aggregated to ‘Wireless Communication’) and mapped them to the kind of ICT (methods and practices, software and applications, technologies). A paper can address more than one of these ICT categories.

As shown in Table 3, more than half of the papers examine the general issue ‘Information Systems’, which was drilled down as shown in Fig. 2 and examined separately. Other frequently mentioned issues are technologies like RFID, Smartphone or the Internet. A deeper analysis has shown that RFID is linked to the category Reverse Logistics, whereas Smartphone is linked with the Passenger Transport. Surprisingly the technology Tracking is under-represented. The established technology GPS is mentioned in 1/5 of the papers, which almost exclusively handle the category Transport (Freight as well as Passenger).

Table 3 ICT categories

Kind of ICT	ICT category	Appearance in paper (%)
Methods and practices	e-Commerce	10
	EDI	8
	e-Payment	2
	Telecommuting	12
Software and applications	CO2 calculators	12
	Driver assistance systems	4
	Enterprise resource planning systems	2
	Information systems (in general)	51
	Network optimization software	2
	Personal travel application	4
Technologies	Barcodes	4
	Internet	37
	RFID/tagging	16
	Sensor technologies	8
	Smartphones	18
	Tracking technologies	6
	GPS	20
	Wireless communication	8

Fig. 2 Examined categories of information systems

19 % of the papers dealing with information systems contain only general thoughts without specifying the information system in detail. Two types of Information Systems are mentioned slightly more frequently than others: Geographic Information Systems (GIS), which often use GPS and are mentioned in papers dealing with some kind of Transportation (Freight, passenger transport) and Decision-Support Systems (DSS). A deeper analysis of the DSS papers shows that they also mainly deal of Freight Transportation and network routing problems. The third most often mentioned systems are the Transport Information Systems (TIS). In fact, the borders between TIS and DSS are not strict because both are equally used for decision making. However, the different applications have only been analyzed separately, thus, an overall holistic approach analyzing the integration among the different systems, is missing. We considered this to be an interesting starting point for future research in the field of Green Logistics.

There are several potential green benefits (i.e. effect of changes entailing a more sustainably acting company) identified. These are listed in an external appendix, which can be accessed via http://uwi.uos.de/ICT-GL-Benefits.pdf. The benefits are clustered by application type. Some of the identified benefits have been realized as the authors of the papers also presented an evaluation. In this case, the evaluation method (S for Simulation and CS for Case Study) is mentioned in brackets. Each benefit is linked to the corresponding paper.[4]

Several papers mention (potential) green benefits deriving from the use of KPIs, benchmarking and monitoring applications. Nevertheless, there is only one paper that investigates the benefits through a case study [A06]. Our recommendation is to analyze the relation between monitoring KPIs and the benefit for Green Logistics, e.g., through field experiments. Another identified issue is the impact of route planning on GHG emissions. As described before, DSS is often used for network optimization problems, but the impact of using such systems on GHG emissions has not yet been specified and approved.

4.2 Research Methods

For the categorizing of the used research methods, a list of IS research methods developed by Wilde et al. [22] has been used. It is possible that one paper refers to more than one research method. However, if the research method was not explicitly mentioned, we assigned at least one method by analyzing the paper in depth. The results are shown in Fig. 3.

The most frequently used research method is Deductive Research. If we cluster the research methods in Behavioral Science[5] and Design Science Research[6] (cf. Wilde et al. [22]), it is noticeable that, by number of total appearances in the reviewed papers, Design Science Research is the dominant research method in current Green Logistics Research. However, a link between the Logistics category as described in Sect. 4.1 and the applied research method could not be made.

To gain a deeper insight into this topic, the underrepresented research methods should be applied more frequently.

Fig. 3 Research methods

[4] The complete list of the 51 analyzed articles of our systematic literature review and their index can be downloaded via http://uwi.uos.de/ICT-GL-Paper.pdf.

[5] Case Study, Cross-Sectional Analysis and Experiment.

[6] Deductive Research, Simulation, Reference Modeling, Action Research and Prototyping.

4.3 Unsolved Problems

While analyzing the papers, we noticed a lot of unsolved problems and ideas that may serve as starting points for further research. We sorted them in an adapted PEST (political, economic, social, technological) scheme from Fahey and Narayanan [23] and added an ecological perspective, whereby we replaced the sentence 'political' by policy. The policy perspective includes any legal or compliant issues as political as well. As the main focus of this paper is ICT, we only outlined the questions referring to our topic in Table 4.

Most of the unsolved problems are of technological or economic nature. Often, the need of an indicator system for benchmarking is mentioned, besides the need of the prototypical implementation of applications like CO2 calculators or information systems to analyze their ecological impact and their acceptance. The results show that the authors of the reviewed papers are consistent with the research areas identified in Sects. 4.1 and 4.2. There are needs to measure the impact of any conceptual method or idea. Furthermore, the acceptance by stakeholders must be analyzed. Prototyping and Behavioral Science methods like Case Study or Field Experiment should be applied for further research.

Table 4 Unsolved research problems)

PEST perspective	Research question/future research requirement
Social	The potential for reducing GHG emissions through e-grocery home delivery services; the actual driving and shopping habits of car owners and none car owners must be measured. [A08]
Technological	Further improvement of the performance of intermodal transport infrastructure (i.e. links, terminals and nodes) including introducing innovative procedures and new automated and robotized technologies. [A14]
	Investigation of possibilities for establishing the compatibility of airline and railway computer reservation systems (CRS) [A14]
	Development, modernization and up-grading information system(s) for supporting integrated transport systems in the broadest sense (passenger and goods transport). [A14]
	Setting up statistics, i.e. creating convenient databases for integrated transport systems, which will be useful for planners, operators and policy-makers of these systems. [A14]
	The effect of innovative communication technologies (e.g. the use of an internet portal for subsuming disassembly firms) to open additional selling markets must be measured. [A01]
	Methods und models must be deployed to benchmark the benefit of RFID in reverse logistics. [A16]
	Low-cost security measures must be developed to increase the customer acceptance of RFID in reverse and forward logistics. [A45]
	The value of sharing data from a personal CO2 transportation application among social groups by using a website should be investigated. [A18]

(continued)

Table 4 (continued)

PEST perspective	Research question/future research requirement
Economic	Improving capacity and efficiency of intermodal terminals and interchanges, setting up criteria for location, investigating the role of fully automated terminals and their technical and commercial perspective. [A14]
	Development of new types of integrated multi-modal transport planning at local–regional level and improvement of communications with potential passengers. [A14]
	Methods and models should be developed to quantify benefits enabled by RFID systems spanning forward and reverse logistics. [A45]
	The impact of ICT on logistics must be analyzed in form of a comparative analysis, which reviews the difference between the impacts of different ICT applications, between actor types, between market segments etc. [A38]
Ecological	A prototype mobile CO2 Calculator should be developed, to investigate the impact on personal transport. [A52]
	Life cycle analysis of different tagging scenarios, incorporating potential ecological opportunities and threats must be done to identify the need of new relevant legislation. [A45]
Policy	The role of the government and how it affects the economic performance in reverse logistics (e.g. regulations as motivation) must be investigated. [A37]
	Creation of an universal integrated ticketing system (urban public transport). [A14]

In *brackets*: analyzed papers (The complete list of the 51 analyzed articles of our systematic literature review and their index can be downloaded via http://uwi.uos.de/ICT-GL-Paper.pdf

5 Conclusion, Implications, Future Research and Limitations

In this paper, we discussed the role of ICT in the field of Green Logistics. The analysis was conducted through a systematic literature review, which was used to identify certain research gaps and under-represented research areas in current literature. These issues are summed up in form of a list of recommendations for future research:

1. **Little investigation has been carried out for several categories of Green Logistics**

   As shown in Fig. 1, there are several under-represented categories in current literature, but we see potential for further investigations in these areas:

- *Purchase Logistics*: The use of an innovative purchase system allows order bundling and therefore the supply can be improved in an ecological way.
- *Warehousing*: Transport routes can be optimized by using efficient structure and configurations (amount, location and size of warehouses). By using intelligent storage systems, the warehouses themselves can act more sustainable.

- *Production Logistics*: The use of just-in-time delivery renders large storage capacities redundant.
- *Packaging*: The use of sustainable packaging materials will result in an overall more sustainable logistic.

Further research to confirm or deny our hypotheses is needed.

2. **There are no studies investigating the integration among different ICT applications for Green Logistics**

All analyzed applications have been examined as a single component (cf. Sect. 4.1). As these applications will be installed in a complex environment, a more holistic approach should be investigated. By the analysis of integrating the different systems in a complex environment, cross- and side effects as well as accumulation can be identified.

3. **Studies which measure the impact of Green KPI measuring/monitoring on Green Logistics are rare**

Regarding Sects. 4.1 and 4.3, there are only few papers analyzing the dependency on or impact of the measurement and monitoring of Green KPIs and the potential benefits for Green Logistics, although many papers identify some benefits. As a next step, we would like to identify firms that use this methodology and execute further research like Surveys, Case Studies and Field Experiments to specify the impact.

4. **Behavioral Science is under-represented in current research**

Most of the analyzed papers refer to the Design Science research, primarily the Deductive Research (cf. Sect. 4.2). As other research methods are far less represented, we suppose research of ICT in combination with Green Logistics still to be in its infancy. Therefore, we recommend further research on this topic, especially in the field of Behavioral Science, e.g., Case Studies or Field Experiments. Regarding Sect. 4.3, also the authors of the examined papers identified this to be a necessary next step.

Our systematic literature review is based on the keyword search in 63 top journals and a constitutive forward, respectively backward search. Although we identified various relevant articles in the leading journals, we cannot exclude the possibility that, based on the restrictions, potentially important publications slipped our search. As the basic literature search was conducted by means of a database keyword search, it is also possible that we did not identify relevant publications, because they do not cover the applied keywords in their title or abstract. Another problem is that the field of Green Logistics and Green SCM includes a large amount of subareas each of them covering different synonyms. Therefore, we cannot be certain that the list of keywords is complete. And even though the analysis of the articles was conducted by two scientists, we cannot completely omit the possibility of false categorization. This could be avoided by including more scientists in the review/analyzing process.

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Green Big Data: A Green IT/Green IS Perspective on Big Data

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Abstract Big Data is recently used as a keyword to discuss technologies and methods which should enable the processing of big, fast growing, in many cases weak structured amounts of data, which cannot or limited be analysed with traditional approaches. This publication is aiming at the analysis of connections between concepts which are relevant in the context of Big Data and those, playing a role in Green IS in order to systematically utilize findings from the field of Big Data for Environmental Management Information Systems. We explore in a Green IT perspective, if already resource-efficient Big Data applications are discussed and in how far Big Data concepts can be applied for the design of resource-efficient business processes.

1 Introduction

In the past years, an increase in the numbers of data sources for data analysis in a business context can be found. Besides transaction data and master data, mass data generated by sensor networks as in production environments, energy management or unstructured data, generated by commercial partners or Web 2.0 processes and social networks come into focus. Concepts and methods for the utilization of these data sources are discussed both in academia and practice using the phrase *Big*

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Data. The goal of this paper is to analyse connections between concepts, applied within Big Data and those used in the Environmental Management Information System (EMIS) community. A theoretical foundation is set up to utilize insights from the field of Big Data for EMIS. In doing so subjects to analysis are (1) if any energy efficient techniques are discussed for Big Data application and (2) in how far Big Data concepts can be deployed for the design of EMIS. While the first questions is searching for a Green IT perspective on Big Data, the second questions discusses a Green IS perspective on Big Data. With regard to the novelty of the phrase Big Data, the explicit referencing of Big Data concepts in publications dealing with EMIS is not to be expected. Therefore we use Topic Models [1] which are suitable to identify relevant subject areas, called topics.

The paper is structured as follows: After a short definition of the phrase Big Data and an overview about the therein contained concepts in Sect. 2, we analyse the thematic development of publications in the research fields Green IS/Green IT in the past 5 years with the help of topic models. We exploit the abstracts of 1055 publications, which have been published since 2008 in a Scopus journal, containing key words from the field of Green IT/Green IS/EMIS. Existing Big Data approaches with regard to Green IT will be presented in Sect. 4, possible applications in the field of Green IS are discussed in Sect. 5.

2 The Concept of Big Data

Initially characterized by practice, Big Data becomes increasingly subject to scientific publications. In scientific databases as Scopus or Web of Science, the number of publications, containing the phrase Big Data in the title, abstract or keywords, is increasing since the year 2000. The light increase was followed by a sharp rise since the year 2010. The publications contain, similarly to other emerging research topics, only occasionally, differing definitions, reasoned amongst others in the ambiguity of the phrase Big Data. The phrase Big Data therefore entails potential misunderstanding as it is used both to describe the size of the processed datasets as well as to describe the Big Data concept. The authors suspect that the sheer breadth and depth of the topic hinders the formulation of a consistent definition. The definitions that the authors selected come both from scientific and practitioner perspectives in order to show different focuses and can be used to derive characterising dimension of the Big Data concept. Dumbill [2], Loukides [3], and Manyika et al. [4] aim at the limited capacities of existing technologies to deal with the increasing amount of data. Therefore, *IT-infrastructure* can be identified as the first dimension. Madden [5] and Laney [6] add the aspect of *data characteristics* in terms of volume, velocity and structure, which can be seen as another dimension. The insufficient allowance of data structure in the definitions is surprising, considering that the combined handling of structured and unstructured data is seen both as a chance for gaining knowledge as well as a challenge with regard to the applied methods and infrastructure. Most of the

Table 1 Definitions and dimensions of big data

Author	Definition	Dimensions
Dumbill [2]	Big data is data that becomes large enough that it cannot be processed using conventional methods	Data characteristics, IT-infrastructure, methods
Jacobs [7]	Data whose size forces us to look beyond the tried-and-true methods that are prevalent at that time	Data characteristics, methods
Laney [6]	Volume, variety, velocity	Data characteristics
Loukides [3]	Big data is when the size of the data itself becomes part of the problem (…) At some point, traditional techniques for working with data run out of steam	Data characteristics, IT-infrastructure
Madden [5]	Data that's too big, too fast, or too hard for existing tools to process	Data characteristics, IT-infrastructure
Manyika et al. [4]	Big data refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyse	Data characteristics, IT-infrastructure

definitions characterise the data volume as the trigger of the Big Data trend, not novel technical capabilities.

In addition, following the definitions of Dumbill [2], and Jacobs [7], the aspect of *methods* which are applied for data analysis purposes can be identified as another characterising dimension. Thus, most authors define Big Data as changes in data characteristics in terms of volume and structure that lead to an excessive demand of the existent IT-infrastructure as well as methods for analysis purposes. The issues mentioned in the dimensions, which results of the changed data characteristics can be found in Green IT/Green IS applications as well, as it will be shown later on. Therefore we discuss in the following section in how far the concept of Big Data can be found directly or indirectly in Green IT/Green IS publications in the past years (Table 1).

3 Development of Main Topics in Green IT/IS

In the previous section we derived characterising dimensions of Big Data by applying a deductive approach, based on existing definitions. The search for the key word "Big Data" combined with "EMIS", "Green IT" or "Green IS" in scientific databases as Scopus results as expected in no suitable matches. Therefore it will be analysed in the following section in how far aspects of the Big Data concept with its dimensions can be found in Green IT/Green IS publications without being named explicitly. For this purpose we use the concept of topic models [8] which is applied to extract relevant topics out of texts, described with words that appear frequently together. The origin of topics models as hierarchical

Fig. 1 Topic model probability function

probability models is in the field of machine learning. Basis for the analysis are usually texts. We use in our example the abstracts of scientific publications. The topics to be identified are represented by probability distributions over the words of the analysed texts. The probability to come across a specific word in a text depends on the topics discussed in the text. A topic is described by a small number of words (in our analysis four words) whose appearance has the highest probability in the probability distribution representing the respective topic. In Fig. 1 especially the words 4, 5, 6 and 7 describe the topic one. In doing so the values of the abscissa represent every word, which can be found in the entirety of the analysed documents, the ordinate assigns a probability of occurrence to each word. Following that, the probability to come upon a word w depends on the respective topic T in the document with z_i as a latent variable, which defines the origin topic of the ith word. Hence applies $(w_i) = \sum_{j=1}^{T} P(w_i|z_i = j)P(z_j = j)$. Consequently $P(w|z)$ represents the relevance of a word for a topic and $P(z)$ describes the appearance of a word of a topic in a document. Different generative models can be found, two of the most popular are the Latent Semantic Analysis (LSA) [9] and the Latent Dirichlet Allocation [1]. Both approaches are based on the described probability distribution over words in the document. Contrary to the LSA the LDA assumes that one word can account for more than one topic, ergo one document can consist of more than one topic. Therefore, following the LDA, a document can be represented by the probabilistic mixture of the topics. With regard to the different dimensions of the Big Data concept and the complexity of Green IT/Green IS, the authors applied the LDA and use the software packages lda [10] and tm [11].

Fig. 2 Topic model results. The number of occupied topics has been optimized depending on the calculated likelihood. Inaccurate topics are results of the partly small number of documents available for the analysis [23]

Aiming at the identification of a potential development towards the topic Big Data in publications from the field of Green IS/Green IT, the abstracts of publications from 2008 to 2012 have been analysed. 1055 documents have been identified for the named period by searching for “EMIS”, “Green IT” or “Green IS” (search field: title, abstract, and keywords) in the database Scopus (www.scopus.com). In preparation of applying the LDA, the authors pre-processed the collected data by removing stop words (e.g. “and” , “the”) and word stemming via Porter’s stemming algorithm [12].

The results of the topic models in Fig. 2 picture the development of the research field for the period 2008 to 2012. The changes can be categorized in two phases from 2008 to 2010 and 2011 to 2012. The first phase is characterized besides EMIS and words concerning energy consumption with natural science related words. These topics, marked by shaded boxes, do not appear in the second phase, therefore we name the first phase the natural science perspective. The second phase is dominated by application-oriented topics. Besides EMIS-relevant words, the aspect of IT-infrastructure combined with the subject of energy consumption becomes increasingly a topic of interest wherein the advancements of the past years in terms of Cloud and Grid can be found. An in-depth analysis of the documents contained in this topics shows that three publications hold an explicit connection to Big Data: [13–15]. As all of these papers refer to the Hadoop framework, an approach for the parallel processing of high volumes of data, Hadoop will be shortly explained in the next section before presenting the Green IT related Hadoop publications.

4 Hadoop: A Green IT Perspective on Big Data

The basis for Hadoop is the programming model MapReduce that was developed originally by Google for concurrent computation. In the course of a performance tests, Google sorted 1 TB data on 1,000 computers in 68 s and 1 PB on 4,000 computers in six hours [16]. Besides MapReduce, the Hadoop project consists primary of the Hadoop distributed file system (HDFS). This java-based framework is designed to run on clusters of commodity hardware, offering a high scalability. The HDFS was originally developed to serve Big Data applications that are typically "gigabytes to terabytes in size" [17]. HDFS uses a master-slave architecture, applying commodity hardware under the assumption of continuous hardware failures. The developers' use of commodity hardware with low acquisition and maintaining costs as a basis, the performance of the system and the continuously development as an open source Apache project has fostered today's widespread distribution. Most IT-companies offering Big Data analytics have at least interfaces to Hadoop or have set up their analytic solutions completely on the Hadoop ecosystem.

Recent Green IT publications which inherit Hadoop as an object of research focus on the lowering of Hadoops energy consumption. Kaushik und Bhandarkar [13] develop an HDFS implementation which tends to a reduction of the energy consumption by applying a specific server-control which led in a test environment to a reduced energy consumption of 26 %. Mao et al. [14] persuade a similar goal by presenting a Hadoop development for the field of bio informatics, which is designed to minimize energy consumption as well. Goiri et al. [15] analyse, in how far data center can be operated with green electricity that fluctuates in its availability. For this purpose they developed a MapReduce implementation called Green Hadoop, which manages upcoming MapReduce jobs according to the availability of green energy in order to reduce the consumption of energy from non-renewable sources.

Based on the findings from the topic models and the related publications it can be shown that Big Data in terms of Hadoop has arrived in the field of Green IT. In contrast, Big Data cannot be found in the field of Green IS. For this reason in the next section it will be shown in how far competences from the field of Big Data can contribute to a future process improvement in the field of Green IS, using as an example the automated calculation of the *product environment impact*.

5 Green IS Perspective on Big Data

From a Green IS point of view it is questioned in how far findings from the field of Big Data can support an ecological oriented sustainability management. Following the results of our literature review in Sect. 3 it exists no study that deals with potential capabilities of Big Data in the EMIS environment. As a first step based on the typical EMIS process, the automated calculation of the product environment impact, we point out to which extend new data sources and their utilization with the help of Big Data concepts can contribute to a process improvement and simplification.

In order to determine the environmental impact of a product, following ISO 14040, the overall environmental impact, starting with the raw material consumption to the delivery (cradle to gate), is aggregated. In doing so all affiliated inputs (resource consumption) and outputs (emissions) during the product life cycle are summed up to the live cycle inventory analysis, which is evaluated with regard to the relevant impact categories. The product carbon footprint as one well-known approach evaluates the live cycle inventory analysis with regard to the impact category *climate effect* which is displayed as the amount of environmental impact equal CO_2 gases [18].

A process for the automated identification of product environment impact is illustrated in Fig. 3 [19]. Based on a customer inquiry for a product, it is initially identified (1) which company-internal production and logistics processes as well as (2) which company-external sourcing processes contributed to the product manufacturing, based on transaction data in the ERP system. In the next step (in Fig. 3 labeled with B) the life cycle inventory analysis for company internal processes that can be assigned to the product is identified. Simultaneously the respective external life cycle inventory analysis which results from previous value-added level is calculated or estimated (in Fig. 3 labeled with A). Finally, both results are aggregated, evaluated with regard to the selected impact category and sent back combined with the life cycle inventory analysis to the customer.

In order to identify the company-internal environmental impact the manufacturing processes have to be analysed. Material-flow models are used for complex processes, for example in terms of petri nets [20]. The high manual efforts which results from the model building are often only accepted if it is enforced by governmental regulations. The utilization of event logs from ERP systems and sensor data from production areas offer Big Data sources that can be partly processed automatically for the logging of source stream nets. The required tools and methods for this are currently developed in connection with the Process Mining Initiative [21]. With the help of Process Mining approaches it is possible to generate business process models based on event data.

In order to apply methods for the generation of material-flow nets, besides regular event data also sensor data from the manufacturing process have to be analysed to extract emissions and energy consumptions of individual manufacturing units.

Fig. 3 Activity diagram: Processing of a customer inquiry for the calculation of the environmental impact. At first the manufacturing processes and corresponding supplies for a product are identified. In box A the environmental impact based on supplies of the upstream chain, in box B the own environmental impact is estimated

For the identification of environmental effects in previous value-added steps new data sources can be utilized as well. Given that suppliers provide relevant information very rarely, external environmental effects have to be estimated. Therefore, numerous national and international environmental databases (e.g. Ecoinvent) provide historical LCA datasets. The automated utilization of these data is difficult due to (1) the lack of universal product classifications which can be used by companies to inquire environmental effects (life cycle inventory analysis) from environment databases. In environment databases as Ecoinvent exist historical ecobalances for a number of intermediate products, final products and services. For the identification a semantic gap between the companies' internal nomenclature for products and the databases nomenclature to identify the matching dataset has to be overcome. After the identification of one matching data record, (2) the needed information are available predominantly in a low structured format. Ecospold as the leading standard contains relevant information in text fields. This problem results from the method-pluralism, persuaded by the LCA-community, which cannot be aligned with a high degree of standardization [22].

Both problem areas discussed are relevant for the Big Data context as well: The allocation of external information to internal objects is basically required for the analysis of weak structured, external data (e.g. for the analysis of blogs and tweets for the evaluation of operational risks). The analysis of texts with regard to contained numerical information and units is a basic problem in the field of text analysis.

The discussion shows that mainly the analysis of sensor data and weak structured external data as well as related methods offer new and improved processes for the design of operational processes.

6 Conclusion

We analysed (1) in how far the recent Big Data discussion offers approaches that persuade a resource-efficient infrastructure and (2) to which extend Big Data concepts can be applied for the further development of EMIS. With the help of a topic models analysis of about 1,000 Scopus publications we analysed the thematic development of the Green IS/IT literature from 2008 to 2012. We identified three publications with a direct link to Big Data concepts that deal explicitly with the Hadoop framework as a promising approach for a Big Data perspective within the field of Green IT. As we could not find any Big Data approaches in EMIS-relevant publications, we outlined exemplary scenarios in which Big Data data sources can be applied for the improvement of existing processes.

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Conceptualizing the Quantification of the Carbon Footprint of IT-Services

Daniel Grimm, Björn Schödwell, Koray Erek and Ruediger Zarnekow

Abstract This paper focuses on conceptualizing the quantification of the Carbon Footprint of IT-Services (CFIS). Initially, the increasing relevance of Carbon Footprint to the IS-community is pointed out. Based on literature review, we present related work that describes underlying concepts e.g. the Carbon Footprint of Products, Life Cycle Assessment as well as IT energy and performance measurement. We apply a transfer-oriented approach (design science) to propose a methodological framework for CFIS that is based on the phases of Life Cycle Assessment, and furthermore provide an example for the calculation. To our opinion the conceptualization of CFIS is an inevitable step to advance Green IS, since it quantifies dependencies between IT-Services, IT energy consumption and related greenhouse gas emissions. Thus, the paper contributes to the IS community by providing an applicable and novel method to IT-Service providers for calculating the CFIS and by identifying further important research directions in this field.

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1 Introduction

Environmental sustainability has become a major concern to the Information Systems (IS) practitioners and the IS research community [1]. All industries face an increasing pressure calling for low carbon footprints of products and services [2, 3]. For manufacturers of consumer goods the Carbon Footprint of Products (CFP) has emerged as an approach to quantify the product's impact on climate change based on product-related greenhouse gas (GHG) emissions expressed as CO2-equivalent (CO2-e) [4]. The Information Technology (IT) industry is also being called upon to deliver environmentally sustainable IT solutions [5], which can be obtained through the production of low carbon IT-Services. The reasons and motivation for IT-Service providers (ISPs) to determine the CFIS are multifaceted. Labeling of consumer products with their CFP is already being realized and used as a marketing measure, e.g. Apple products [6]. However, the quantification and presentation of CFIS is at least an orientation guide for ecological oriented consumers, a possibility to benchmark against competitors and a method to expose carbon reduction efforts. Reference [7] argues that setting boundaries is necessary to draw an imaginary line around the activities that will be used for calculating CF. These boundaries depend on the objective of CF and characteristics of the entity for which CF will be done [7]. Our research questions arising from this are:

- How can the principles of CFP be adopted to IT-Services?
- What specific boundaries need to be considered to define and calculate CFIS?

In order to answer these questions, the paper focuses on the development of a concept for the CFIS that is necessary to quantify GHG emissions induced by the "products" of ISPs. Therefore, the paper is structured as follows. In Sect. 2 we present related work that describes underlying concepts like CFP and Life Cycle Assessment (LCA) as well as IT energy and performance measurement. In Sect. 3 the paper proposes the methodological framework for CFIS based on the phases of LCA. In the context of the research project GreenIT Cockpit funded by German Federal Ministry of Economics and Technology and derived from other case studies, specific energy and performance data of IT resources were collected. These data are used to present an example that calculates the CFIS of an outgoing E-Mail for different scenarios. In Sect. 4 we finally discuss the results, existing limitations of CFIS and further important research directions.

2 Related Work

2.1 GHGs, CFP and LCA

The Green House Gas Protocol defined three Scopes of GHGs in order to differ between direct and indirect emission sources, to improve transparency, and to provide utility for different types of organizations [8]. Scope 1 covers direct GHG emissions occurring from sources owned or controlled by the company, Scope 2 describes indirect GHG emissions from the generation of purchased electricity consumed by the company and Scope 3 accounts for all other indirect emissions from sources not owned or controlled by the company [8]. For conceptualizing CFIS we need to understand the term Carbon Footprint (CF), its origins and related terms. This paper follows the definition of CF as the

1. […] quantity of GHGs expressed in terms of CO2-e, emitted into the atmosphere by an individual, organization, process, product, or event from within a specified boundary. [7]

CF is not a new concept since it has always been the result of the impact category indicator global warming potential (GWP) in LCA [9]. LCA is a more complex approach creating a holistic picture where multiple environmental impact categories i.e. GWP, ozone depletion, acidification, eutrophication, natural resource depletion and aquatic toxicity are assessed [10]. The International Organization for Standardization (ISO) divides the LCA process into the four phases: goal and scope definition, life cycle inventory analysis (LCI), life cycle impact assessment (LCIA) and interpretation [11]. The ISO is recognized as the world's largest and most widely known standards development organization and any new ISO standard in the environmental field will have a sizable influence [12]. Currently, the ISO is developing a specific standard, which includes requirements and guidelines for the quantification and communication of the CFP, which is being used to determine GHG emissions on a product level [3]. The standard is based on principles of LCA and it is now available in second draft ISO/DIS 14067.2:2012 [13]. Because of its expected influence we chose ISO/DIS 14067 for applying a transfer-oriented approach to develop a methodological framework for CFIS.

2.2 Energy Measurement

Real-time measurement of IT energy consumption recently receives increasing attention especially within data centers (DC). The measurement may be established by the ISP following the guidance of The Green Grid and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) [14]. Energy consumption of IT resources can be determined through the deployment of intelligent power distribution units. Moreover, manufacturers successively equip hardware with additional intelligence to log and report energy consumption. It is obvious, that measurement of real-time energy consumption of decentralized equipment distributed in various corporate buildings and for thousands of client devices may be impractical. Alternatively, the ISP may ascertain power profiles of these devices covering off, standby, active idle and peak energy consumption, or may extract energy-related data of manufacturer's specifications.

2.3 Performance Measurement

The measurement of total and IT-Service specific performance of IT resources is necessary to allocate total energy consumption of the IT resources to IT-Services. Simplified, performance may regard:

- in case of servers to the amount of servers used, the utilization of the central processing units or the processed data volume,
- in case of storage to the used storage capacity for active data and input/output operations for backup and archives, and
- in case of network equipment to data volume transmitted (network traffic).

The collection of these data can be instrumented using various tools and protocols like the simple network management protocol (SNMP) and open source monitoring tools such as Nagios or Multi Router Traffic Grapher (MRTG). Measurement during regular operations can be omitted by determining a representative resource consumption profile of the specific IT-Service during experimental load tests as an adequate estimation [15]. Since IT-Service retrieval is usually tracked for accounting purposes, these data can be combined to derive total IT-Service specific performance. In case of client devices average processing time needed to consume the IT-Service may be measured or approximated to assess performance.

2.4 Energy Sourcing and Carbon Emission Factor

A carbon emission factor (CEF) in kilogram CO2-e per kilowatt-hour (kg CO2-e/kWh) is needed in order to determine the CFIS. The CEF converts energy usage rates into carbon emissions [16]. Regional or country-specific CEF for grid electricity can be extracted from non-governmental organizations (NGO) or government's data e.g. the Department for Environment and Rural Affairs (DEFRA) publishes data for the United Kingdom (UK), the Environmental Protection Agency (EPA) publishes factors for the United States of America and Germany-specific factors are provided by Federal Environment Agency (Umweltbundesamt).

3 Methodological Framework

A CF study that applies [13] focusses on the assessment of the GWP of products and uses the four main phases of LCA. These phases form the methodological framework for our CFIS concept as shown in Fig. 1. The framework specifies the process phases of LCA and CFP in order to accomplish a CFIS study.

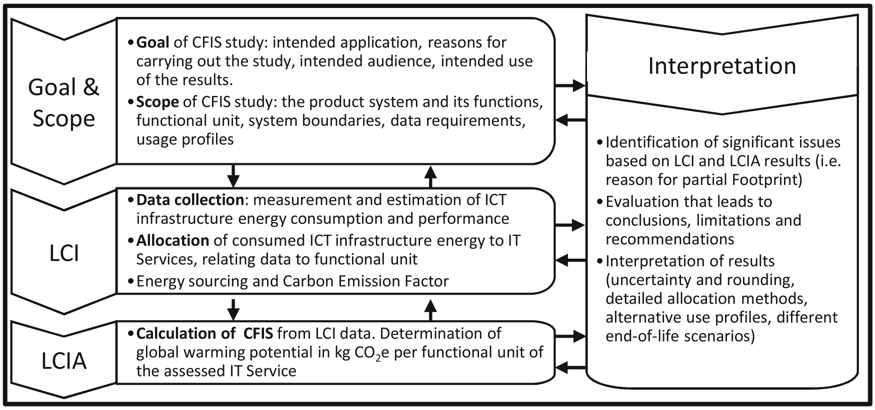

Fig. 1 Methodological framework for CFIS based on ISO/DIS 14067

3.1 Goal and Scope

3.1.1 Goal

By operating IT resources in DCs e.g. server, storage and networks ISPs are able to produce IT-Services. Users consume IT-Service instances as needed by means of workplace related IT resources e.g. desktop PCs, laptops and decentralized networks. This leads to IT related energy consumption on provider and consumer side. A CFIS study aims to allocate this energy consumption to an IT-Service according to an energy-by-cause principle. Using allocated energy a CFIS study quantifies indirect carbon emissions (Scope 2) induced by IT-Services. The result of a CFIS study represents the CF (in kg CO2-e) referring to production and consumption of the assessed IT-Service. The analysis of collected performance and energy data reveals potentials to improve energy efficiency through Green IT measures. The formulated intended use and characteristics of CFIS underline the practical relevance of our concept. With quantified CFISs decision makers are able to indicate the ecological performance of their IT organization's "products".

3.1.2 Scope

The CFIS concept focuses on the product system "IT-Service" which is defined in the Information Technology Infrastructure Library (ITIL) v3 as

> 2. […] a Service provided to one or more Customers, by an ISP. An IT-Service is based on the use of Information Technology and supports Customer's Business Process. [17]

ITIL represents a set of best practices in IT-Service management and is widely accepted as a quasi-standard, which is why we chose the IT-Service definition and life cycle from ITIL for further examinations. Following the proposed definition and its business context, this paper focusses on IT-Services that are simultaneously produced and consumed within an organization. In order to set the scope of any LCA or CF study, it is necessary to identify the assessed subject's lifecycle stages.

Figure 2 shows a conceptual model that combines three lifecycle components representing different perspectives. The lifecycle of workplace-related IT resources is subdivided in classical stages of product life (i.e. raw material extraction, pre-production of components, manufacturing and distribution of end-products, their use and end-of-life treatment). It represents the consumer perspective since workplace-related IT resources are used to consume IT-Services (Fig. 2a). The IT-Service perspective is represented by IT-Service lifecycle of ITILv3. It contains five necessary elements, associated processes, responsibilities and recommendations for strategic placing, design, implementation, production and continual improvement of IT-Services (Fig. 2b). The lifecycle of DC-related IT resources describes the provider perspective. An ISP operates IT resources in their use stage to accomplish all stages of IT-Service lifecycle (Fig. 2c).

Reference [18] identified five issues that need to be assessed using the LCA approach in order to build green information systems. One of the issues is the assessment of

> 3. the energy required in the usage of IT equipment and the overall infrastructure for providing the information services (during both active and idle times), and the corresponding GHG emissions. [18]

To cover this issue, we refined the scope of the CFIS concept by setting boarders. In order to determine corresponding GHG emissions within consumer and provider perspective, CFIS focusses on the quantification of consumed IT-related energy in the use stage of product lifecycle. Beholding the IT-Service

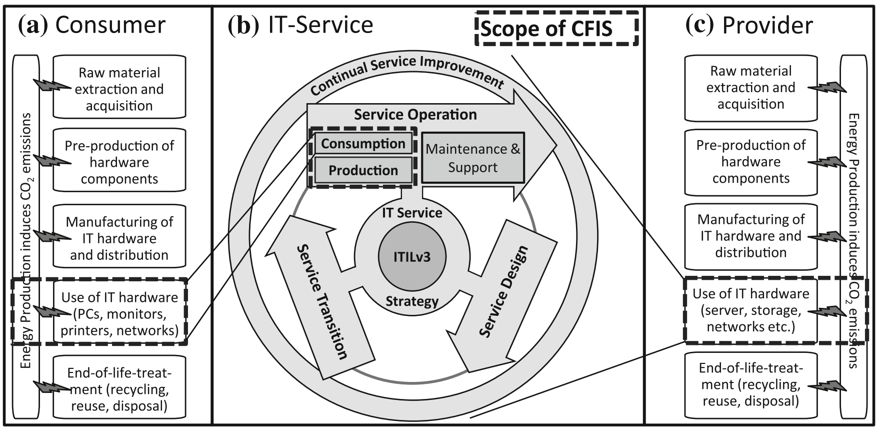

Fig. 2 Scope of CFIS and involved lifecycle perspectives. **a** Consumer perspective. **b** IT-service perspective. **c** Provider perspective

lifecycle, the concept includes the production and consumption of IT-Services, which is accomplished during Service Operation. GHG emissions occurring from activities in other IT-Service lifecycle stages are out of scope for now, since it is difficult to determine consumed energy that is related to design and implementation as well as maintenance and support of IT-Services. The proposed limitations to selected lifecycle stages characterize the CFIS as partial CF [13]. To further refine the scope of CFIS a functional unit (FU) has to be determined. Its primary purpose is to quantify the performance of a product system and to provide a reference to which the inputs and outputs are related [13]. The FU should quantify a specific benefit coming from the output of the assessed product system. Referring to an in-house IT-Service it is necessary to determine its useful contribution to business processes of consumers, which is profound. To simplify this scenario, an IT-Service instance can be chosen as a FU (e.g. one outgoing E-mail). Another issue arising from the FU choice is the fact that instances of an assessed IT-Service can cause different loads of IT resources and thereby different energy consumption. Staying with the example of an outgoing E-mail, its size is the differing factor. One plain-text mail with a few words will cause less IT resource load than one html-mail with an attached video-file of 5 Megabytes (MB). A possible approach would be the use of data amounts (i.e. in Bytes) generated by an IT-Service instance. Further the differing time-related usage of IT-Services especially at consumer perspective needs to be considered. Composing the plain-text-mail might just take a few seconds. Writing and sending a protocol of business meetings to participants can take a few hours. A possible solution would be the definition of different scenarios covering different IT-Service instances or the definition of a mean scenario where for example an average-sized E-mail of 1 MB consumes 2 min of workplace-related IT resources.

3.2 Life Cycle Inventory Analysis

3.2.1 Energy Consumption- and Performance Measurement

Figure 3 represents the IT infrastructure involved in producing and consuming IT-Services, which covers centralized IT subsystems in DC (e.g. server, storage and networks), Ancillary Site Infrastructure (ASI) (e.g. cooling, power and support systems) data networks (e.g. WAN and LAN) and decentralized office devices. An IT subsystem is a combination of multiple IT resources serving the same purpose.

The CFIS determination is based on measurement, respectively calculation of

- total energy consumption of involved IT subsystems,
- total performance (capacity utilization, CU) of involved IT subsystems and
- total performance (CU) of involved IT subsystems induced by the IT-Service.

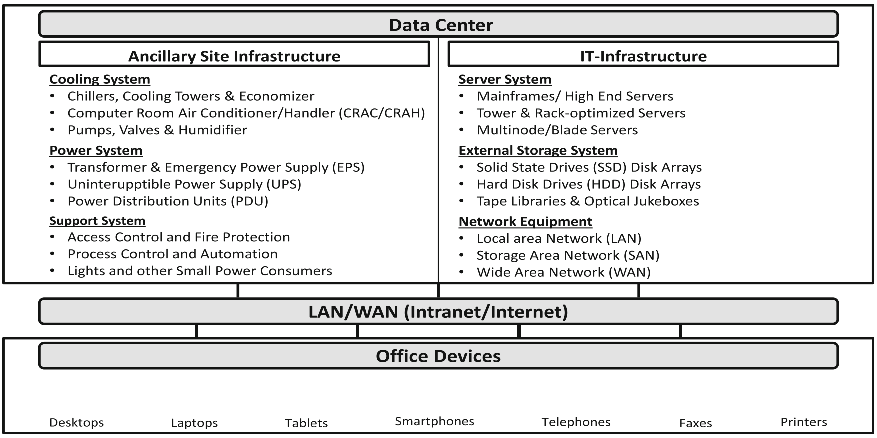

Fig. 3 Involved IT infrastructure

3.2.2 Allocation of Energy Consumption to IT-Services

IT-Services share common DC infrastructure resources during production and consumption. Thus, the allocation of total energy consumption of IT subsystems to the specific IT-Service is necessary to calculate CFIS based on the relative usage of shared resources. The allocation of each IT subsystem's electric energy consumption (EC) to an IT-Service can be realized through performance measurement data collected over a given time period. IT subsystem performance or CU covers server-, storage- and network systems and may refer to volume of data traffic, processing time, quantity of processed or stored data and number of servers used. The equation follows a generic metric.

$$EC_{IT-Service\ X}^{Subsystem\ i} = \frac{EC_{Total}^{Subsystem\ i} \times CU_{IT-Service\ X}^{Subsystem\ i}}{CU_{Total}^{Subsystem\ i}};\ EC_{Total}^{Subsystem\ i} = \begin{array}{c}\text{total energy consumption}\\ \text{of IT subsystem i}\end{array};$$

$$CU_{IT-Service\ X}^{Subsystem\ i} = \begin{array}{l}\text{IT subsystem's i performance (capacity}\\ \text{utilization) induced by the IT-Service}\end{array};\ CU_{Total}^{Subsystem\ i} = \begin{array}{l}\text{total IT subsystem's i performance}\\ \text{(capacity utilization)}\end{array}$$

The energy consumption of all involved subsystems need to be summed to IT infrastructure energy consumption induced by IT-Service X.

$$EC_{IT-Service\ X}^{IT\ infrastructure} = \sum EC_{IT-Service\ X}^{Subsystem\ i}$$

Energy consumption of ASI can be allocated in a proportional manner through the usage of the Power Usage Effectiveness (PUE) metric [19].

$$PUE = \frac{total\,facility\ power}{IT\ equipment\ power} = \frac{IT\ equipment\ power + ancillary\ site\ infrastructure\ power}{IT\ equipment\ power}$$

Applying this relation to our notation and expressions, the energy consumptions of ASI induced by the IT-Service X can be determined.

$$EC^{ASI}_{IT-Service\ X} = (PUE - 1) \times EC^{IT\ infrastructure}_{IT-Service\ X}$$

Overall DC energy consumption related to the production of IT-Service X can be calculated as the sum of IT infrastructure and ASI energy consumption or using the PUE metric.

$$EC^{DC}_{IT-Service\ X} = EC^{IT\ infrastructure}_{IT-Service\ X} + EC^{ASI}_{IT-Service\ X} = EC^{IT\ infrastructure}_{IT-Service\ X} \times PUE$$

The overall DC energy consumption has to be divided by the count of instances of IT-Service X produced during measurement period in order to derive the average energy consumption of DC infrastructure per instance.

$$EC^{DC}_{Instance\ X} = \frac{EC^{DC}_{IT-ServiceX}}{\#instance\,X};$$

$$\#\ Instance\,X = \begin{matrix} count\ of\ produced\ instances\ of\ IT\ Service\,X \\ during\ measurement\ period \end{matrix}$$

3.2.3 Example Scenario

To demonstrate how allocation suggestions and calculation approaches can be applied, we provide an example. The presented data is partially based on case studies. For IT subsystems where no data has been available plausible fictive data was added. An in-house ISP wants to assess GHG emissions induced by an outgoing E-mail. Its DC's year-round PUE is 1.5. During a measurement time period of 7 days the DC consumed 21 MWh (megawatt-hours) of electric energy. Workplace-related decentralized IT resources capable of sending and receiving E-mails consumed 4.25 MWh of electric energy. These workplace-related IT resources which are located in the office environment (OE) of the organization cover 350 desktop PCs including monitors and 150 laptops including docking stations and monitors. Within the measurement period 15.000 E-mails with an average size of 1 MB have been sent and 20.000 E-mails with an average size of 1.5 MB have been received. Network devices in the DC had to handle 10 Terabytes (TB) of internal processed data of which was 2 TB coming from outside and 1.5 TB going out of the organization.

3.2.4 Provider Perspective

The involved DC subsystems that describe the provider perspective can be subdivided into server systems, storage systems, DC network equipment and ASI.

Server Systems

A server cluster consisting of three physical servers operates exclusively to provide E-mail functionality. The cluster consumed 150 kWh of electric energy during the measurement period. The proposed generic formula for the allocation of energy consumption of IT subsystems can be concretized using the data traffic from outgoing E-mails as subsystem's capacity utilization induced by the assessed IT-Service and the data traffic from outgoing and incoming E-mails as subsystem's total capacity utilization.

$$\textbf{\textit{generic;}}$$

$$EC^{Subsystem\ i}_{IT-Servive\ X} = \frac{EC^{Subsystem\ i}_{Total} \times CU^{Subsystem\ i}_{IT-Servive\ X}}{CU^{Subsystem\ i}_{Total}};$$

$$\textbf{\textit{concretized}}$$

$$EC^{EmailServerCluster}_{OutgoingE-Mail} = \frac{150\,\text{kWh} \times (15.000 \times 1\,\text{MB})}{15.000 \times 1\,\text{MB} + 20.000 \times 1.5\,\text{MB}} = 50\,\text{kWh}$$

Further the DC operates another 215 servers of which 5 servers support E-mail functionality by providing Domain Name Service (DNS), Lightweight Directory Access Protocol (LDAP) and Virus Protection. These 5 Servers are summed to the IT subsystem "supporting servers" and totally consumed 250 kWh of electric energy during measurement period. A part of its total energy consumption needs to be allocated to outgoing E-Mails. In our example the allocation is done by using the data traffic from outgoing E-mails as subsystem's capacity utilization induced by the assessed IT-Service and the overall data traffic processed within the DC's LAN as subsystem's total capacity utilization. The latter was chosen because of the assumption that supporting servers are used by all IT-Services.

$$\begin{aligned} EC^{Support\ Servers}_{OutgoingE-Mail} &= \frac{250\,\text{kWh} \times (15.000 \times 1\,\text{MB})}{10\ TB} \\ &= \frac{3.750.000\,\text{kWh} \times \text{MB}}{10.485.760\,\text{MB}} \sim 0.36\,\text{kWh} \end{aligned}$$

Storage Systems

The DC operates active external storage systems which provide an overall capacity of 1.000 TB and totally consumed 2250 kWh. The allocation of storage systems total energy consumption to outgoing E-Mails is determined by the organization's data policy which earmarks the storage of E-mail on active storage for 2 years. This leads to the usage of stored data from outgoing E-mails in 2 years as subsystem's capacity utilization induced by the assessed IT-Service and overall storage capacity as subsystem's total capacity utilization.

$$EC^{Storage\ Systems}_{OutgoingE-Mail} = \frac{2,250\,\mathrm{kWh} \times \frac{2\times 365d}{7d} \times (15.000 \times 1\,\mathrm{MB})}{1.000\,\mathrm{TB}}$$
$$\sim \frac{3.519.642.857\,\mathrm{kWh} \times \mathrm{MB}}{1.048.576.000\,\mathrm{MB}} \sim 3.36\,\mathrm{kWh}$$

DC Network Equipment

The network subsystem in the DC consists of a connecting infrastructure (12 switches and 3 load balancer) that provides Local Area Network (LAN) and an internet gateway (core router, core switch and hardware firewall) that provides connection to the internet (WAN). LAN infrastructure totally consumed 750. Using the data traffic from outgoing E-mails as subsystem's capacity utilization induced by the assessed IT-Service and the overall data traffic processed within the DC's LAN as subsystem's total capacity utilization, the energy consumption of LAN infrastructure induced by outgoing E-Mails can be calculated.

$$EC^{DC-LAN}_{OutgoingE-Mail} = \frac{750\,\mathrm{kWh} \times (15.000 \times 1\,\mathrm{MB})}{10\ TB}$$
$$= \frac{11.250.000\,\mathrm{kWh} \times 1\,\mathrm{MB}}{10.485.760\,\mathrm{MB}} \sim 1.07\,\mathrm{kWh}$$

The WAN infrastructure consumed 200 kWh. Allocation is done by using the data traffic from outgoing E-Mails as subsystem's capacity utilization induced by the assessed IT-Service and the data traffic processed by the DC's WAN infrastructure (incoming and outgoing) as subsystem's total capacity utilization.

$$EC^{DC-WAN}_{OutgoingE-Mail} = \frac{200\,\mathrm{kWh} \times (15.000 \times 1\,\mathrm{MB})}{2TB(incoming) + 1.5TB(outgoing)}$$
$$= \frac{3.000.000\,\mathrm{kWh} \times \mathrm{MB}}{3.670.016\,\mathrm{MB}} \sim 0.82\,\mathrm{kWh}$$

DC's IT infrastructure energy consumption induced by outgoing E-Mails is the sum of allocated energy consumptions of IT infrastructure subsystems.

$$EC^{DC-ITinfrastructure}_{OutgoingE-Mail} = EC^{EmailServerCluster}_{OutgoingE-Mail} + EC^{Support\ Servers}_{OutgoingE-Mail} + EC^{StorageSystems}_{OutgoingE-Mail} + EC^{DC-LAN}_{OutgoingE-Mail} + EC^{DC-WAN}_{OutgoingE-Mail} = 50 + 0.36 + 3.36 + 1.07 + 0.82\,\text{kWh} = 55.61\,\text{kWh}$$

Ancillary Site Infrastructure:

The electric energy consumption of ASI induced by outgoing E-Mails is allocated by using the PUE metric.

$$EC^{ASI}_{OutgoingE-Mail} = EC^{DC-ITinfrastructure}_{OutgoingE-Mail} \times (PUE - 1) = 55.61\,\text{kWh} \times (1.5 - 1) \sim 27.81\,\text{kWh}$$

Data Center

Overall DC electric energy consumption induced by outgoing E-Mails is the sum of IT infrastructure and ASI energy consumption related to outgoing E-Mails.

$$EC^{DC}_{OutgoingE-Mail} = EC^{DC-ITinfrastructure}_{OutgoingE-Mail} + EC^{ASI}_{OutgoingE-Mail} = 55.61 + 27.81\,\text{kWh} = 83.42\,\text{kWh}$$

3.2.5 Consumer Perspective

The involved decentralized subsystems within consumer perspective are client systems and network equipment located in the OE. We considered two scenarios which are concretized by two different types of client systems; first a laptop (LT) workplace and second a desktop (DT) PC workplace. The OE contains 150 LT workplaces as well as 350 DT PC workplaces. Analysis of reference workplaces revealed, that the composition of an average E-Mail consumed 2 min of time.

Client Systems

4.500 E-Mails have been sent from LT workplaces. A LT workplace consumed 700Wh of electric energy during daily operation time and another 17Wh a day during non-operation time due to standby. The allocation is done by using the overall operation time needed to compose all outgoing E-mails as subsystem's capacity utilization induced by the assessed IT-Service and the overall measurement period time as subsystem's total capacity utilization.

$$EC^{LTclients}_{OutgoingE-Mail} = \frac{(150 \times 7 \times 717\,\text{Wh}) \times (4.500 \times 2\,\text{min})}{150 \times 7 \times 24 \times 60\,\text{min}} = \frac{6.775.650.000\,\text{Wh} \times \text{min}}{1.512.000\ \text{min}} \sim 4.48\,\text{kWh}$$

Another 10.50 E-Mails have been sent from DT PC workplaces. A typical DT workplace consumed 1.350 Wh (watt-hours) of electric energy during daily operation time and due to standby of Monitor and PC another 75 Wh a day during non-operation time.

$$EC^{DTclients}_{OutgoingE-Mail} = \frac{(350 \times 7 \times 1.425\,\text{Wh}) \times (10.500 \times 2\,\text{min})}{350 \times 7 \times 24 \times 60\,\text{min}} = \frac{73.316.250.000\,\text{Wh} \times \text{min}}{3.528.000\,\text{min}} \sim 20.78\,\text{kWh}$$

OE Network Equipment

The OE network subsystem consists of 15 switches providing the LAN to connect client workplaces and DC. The OE network totally consumed 200 kWh of electric energy. A switch had to handle data traffic at an average of 500 Gigabytes (GB) during measurement period. Energy consumption of OE LAN induced by outgoing E-Mails is calculated using data traffic from outgoing E-mails as subsystem's capacity utilization induced by the assessed IT-Service and overall data traffic processed by all switches as subsystem's total capacity utilization.

$$EC^{OE-LAN}_{OutgoingE-Mail} = \frac{200\,\text{kWh} \times (15.000 \times 1\,\text{MB})}{15 \times 500\,\text{GB}} = \frac{3.000.000\,\text{kWh} \times 1\,\text{MB}}{15 \times 512.000\,\text{MB}} \sim 0.39\,\text{kWh}$$

Office Environment

IT-related OE electric energy consumption induced by outgoing E-Mails is the sum of OE IT subsystems' energy consumption related to outgoing E-Mails.

$$EC^{OE}_{OutgoingE-Mail} = EC^{LTclients}_{OutgoingE-Mail} + EC^{DTclients}_{OutgoingE-Mail} + EC^{OE-LAN}_{OutgoingE-Mail} = (4.48 + 20.78 + 0.39)\,\text{kWh} = 25.65\,\text{kWh}$$

In order to examine both of the scenarios we need to split the OE electric energy consumption. Therefore we use the proportion of sent emails in both scenarios.

$$EC^{OE}_{OutgoingE-Mail} = EC^{LTclients}_{OutgoingE-Mail} + EC^{OE-LAN}_{OutgoingE-Mail} \times \frac{4.500}{15.000}(4.48 + 0.39 + 0.3)\ \text{kWh} = 4.60\,\text{kWh}$$

$$EC^{OE=Scenario\ 2-DT}_{OutgoingE-Mail} = EC^{DTclients}_{OutgoingE-Mail} + EC^{OE-LAN}_{OutgoingE-Mail} \times \frac{10.500}{15.000}(20.78 + 0.39 + 0.7)\ \text{kWh} = 21.05\,\text{kWh}$$

3.2.6 IT-Service Perspective

IT resources in DC and OE consumed specific amounts of electric energy for the production respectively the consumption of the IT-Service outgoing E-Mails. These amounts need to be summed in order to calculate the overall IT-related electric energy consumption induced by outgoing E-Mails.

$$EC_{OutgoingE-Mail}^{Scenario\ 1-LT} = EC_{OutgoingE-Mail}^{OE-Scenario\ 1-LT} + EC_{OutgoingE-Mail}^{DC} \times \frac{4.500}{15.000}(4.60 + 83.42 \times 0.3)\,\mathrm{kWh} \sim 16.13\,\mathrm{kWh}$$
$$EC_{OutgoingE-Mail}^{Scenario\ 2-DT} = EC_{OutgoingE-Mail}^{OE-Scenario\ 2-DT} + EC_{OutgoingE-Mail}^{DC} \times \frac{10.500}{15.000}(21.05 + 83.42 \times 0.7)\,\mathrm{kWh} \sim 79.44\,\mathrm{kWh}$$

Considering the FU "one outgoing E-mail" the overall IT-related electric energy consumption has to be divided by the amount of produced instances of the assessed IT-Services for the different scenarios.

$$EC_{instanceOutgoingE-Mail}^{Scenario\ 1-LT} = \frac{EC_{instanceOutgoingE-Mail}^{Scenario\ 1-LT}}{\#instancesOutgoingE - Mails} = \frac{29.63\,\mathrm{kWh}}{4.500} \sim 6.58\,\mathrm{Wh}$$
$$EC_{instanceOutgoingE-Mail}^{Scenario\ 2-DT} = \frac{EC_{instanceOutgoingE-Mail}^{Scenario\ 2-DT}}{\#instancesOutgoingE - Mails} = \frac{79.44\,\mathrm{kWh}}{10.500} \sim 7.57\,\mathrm{Wh}$$

3.3 Life Cycle Impact Assessment

Assuming that the organization receives a hundred percent grid-sourced energy in Germany, the estimated CEF for German energy-mix 2011 (559 g CO2-e/kWh) can be used [20]. Figure 4 shows the CFIS of one outgoing E-Mail for both of the scenarios and the combined average. The presented example calculated 3.68 g

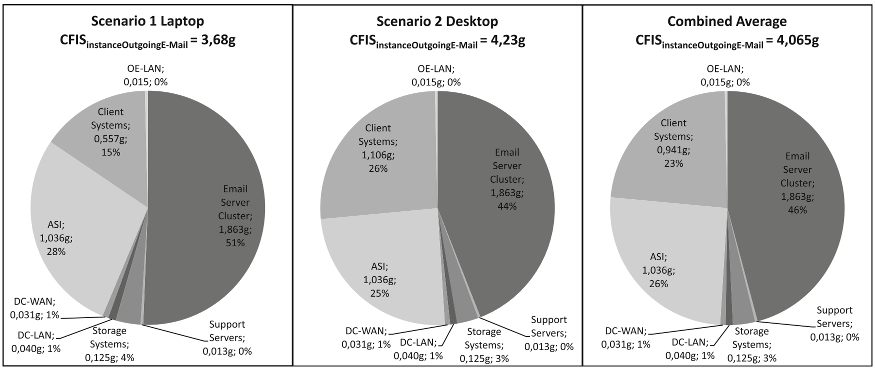

Fig. 4 Carbon Footprint of an IT-Service instance (one outgoing E-Mail) for different scenarios

induced CO2-e emitted due to the energy consumption of IT infrastructure when one average E-mail of 1 MB has been sent from a laptop workplace, 4.23 g for the desktop workplace scenario and 4.065 g as a combined average.

4 Conclusion and Further Research

In practice the CF concept is being used for the declaration and labeling of consumer products to present their impact on global climate change along product's lifecycle. GHG assessment of IT-Services is very rare due to the fact that IT-Service lifecycle is a complex construct as well as IT infrastructures. The paper especially the presented example demonstrates the principles and calculation approaches to assess CFIS in the use stage of IT infrastructure resources. The results of the CFIS calculation have to be evaluated by using real-life data. Therefore we will extend the data collection in context of the research project funded by German Federal Ministry of Economics and Technology in order to substitute the fictive data. The presented methodological framework is based on well-proven methods from LCA and CFP but it still has to proof its practical applicability especially in terms of increasing complexity of allocation due to the growing amount of involved IT devices. Subsequent research will evaluate the concept in case-studies with ISPs and it will be expanded by the assessment of prior and following lifecycle stages of IT resources. A possible approach to consider missing lifecycle stages could be the usage of CFPs of all involved IT resources in order to determine proportional shares based on CFIS in use stage.

Another limitation is the focus on Service Operation within IT-Service lifecycle. To create a comprehensive CFIS, further research has to consider GHG emissions that occur from Service Design, Service Transition and Service Strategy. Thus it is necessary to analyze sourcing processes, software engineering, distribution of IT-Services over the internet and other GHGs scopes (e.g. direct emissions from usage of coolants in DC). In conclusion the CFIS concept is still research in progress with high potential to enhance Green IS.

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Using Key Performance Indicators and Multi-Criteria Decision Analysis to Compare the Sustainability of Mobility

Sven Kölpin, Daniel Stamer and Benjamin Wagner vom Berg

Abstract This work is a result of the increasing social awareness around the term of sustainable mobility. It identifies the mayor problems in current solutions and comes up with a foundation for solving these problems. According to the authors, the basic problem can be found within the increasingly complex and immeasurable system of mobility. A foundation is provided by making heterogeneous alternatives for mobility (transportation modes) comparable in the context of sustainability, while putting heavy emphasis on the ecological dimension of it. The key to a successful comparison of such transportation modes is stated as the selection of semantically suitable key performance indicators (KPI) and a reasonable decision analysis method, which will be covered throughout this work. A healthy set of KPIs is selected by considering various existing indicators, like indicators for measuring resource consumption or air pollution. This work provides a method for comparing the relative sustainability of multiple modes of personal transportation by using key performance indicators and the multi-criteria decision analysis method PROMETHEE II. Some possible practical use cases which are able to create real world added value are introduced by the authors as well.

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1 Introduction

Today companies, governments and the public are recognizing that resources are limited (e.g. oil) and different other problems are occurring in the economic, environmental and social dimension that are resulting from our economic acting and our consumption behaviour [1]. Because of this, sustainability is growing into a major topic for companies as well as for customers.

Especially the energy sector is seeking for alternatives, because it has to deal with huge environmental impacts (hazardous nuclear power, carbon dioxide—CO_2—emissions by fossil burning plants) and upcoming shortages (peak oil). An actual report of the Intergovernmental Panel on Climate Change (IPCC) proclaims that it is possible to produce 77 % of the worldwide needed energy with regenerative power plants like wind energy, solar and others [2].

Mobility has a huge impact in the energy and sustainability context. So 26 % of worldwide CO_2 emissions by combustion of fuel are coming from transport and 35 % of total energy consumption in Europe is coming from transport with 71 % by road traffic [3]. Switching to electric vehicles (EV) seems to have a huge potential for a fundamental change to a more sustainable transportation with less CO_2 emissions and less energy consumption. But also EVs have environmental impacts and furthermore technical shortages. So a 1:1 substitution of conventional cars (CV) by EVs is both not sufficient according sustainability and on basis of today's technology not possible [4].

All of these considerations suggest that there is no such thing as a simple solution to the problem. Furthermore the insufficient substitution of CVs by EVs (without altering the conventional energy mixes) needs to be evaluated so we can provide a better understanding of why this substitution is failing.

In order to provide a base for a possible solution to this problem, we will need to establish a method to compare the competing modes of personal transportation first. This approach follows the well-established management by objectives in its central idea: "What gets measured gets managed" [5].

This work establishes a method for the measurement of mobility in the sense of providing a method for comparing competing modes of transportation among each other. The aim is to find a set of tools, which can be applied on a set of different alternatives for personal mobility. Note that these different alternatives only differ in a limited amount of perspectives; they still transport their common customer from the same common origin to the same common destination in a fixed window of time. The appliance of the mentioned tools will then result in a relative comparison of the alternatives, rating them according to their behaviour in the context of sustainability.

To achieve this we will need to define the terms of 'mobility', 'sustainability' and its composition 'sustainable mobility' at first. This first clarification of relevant terminologies puts emphasis on the well-known term of sustainability and selects a clear definition of what we are referencing in the further sections of this work.

In order to measure alternatives for mobility we must then find a suitable set of key performance indicators (KPI). This work will only focus on assembling sets or systems of KPIs for certain types of vehicles.

After providing the calculatory foundation for measurement, a method for evaluating the different modes of transportation needs to be found. To find a suitable method we need to define the type or class of method at first. Afterwards we can pick the most suitable method from that definition and set it up for use.

Finally this work provides considerations of use cases or appliances in which the assembled set of tools can be used practically. This final section gives numerous insights on how to generate added value by implementing the method.

2 Sustainable Mobility

In this section we will combine the terms of sustainability and mobility. To achieve this we need to cover the definition of these terms for themselves at first. Additionally we want to weight the different dimensions of sustainability for the topic of mobility. Throughout the clarification of these terms we will gather some theoretical foundations for the evaluation of sustainability in further sections of this work.

2.1 Mobility

Mobility is what is commonly referred to as the possibility of movement. The term includes the movement of persons and items, in the sense of moving them in a strictly physical manner. However, persons may also move in a spiritual or social way [6]. The term of mobility is often equated with the term of traffic. To clarify this one must understand that traffic is the actual movement of persons, goods or messages in a fixed system [7]. Therefore, traffic is the result of applied mobility [6]. This concludes that there must be different sets of KPIs for the measurement of traffic and mobility. For example: to measure the amount of mobility in one region one must determine the rate of mobility. This rate consists of the average number of ways which are travelled by one individual in a given amount of time [8]. On the other hand the amount of traffic describes the average number of ways travelled by every individual in a given amount of time.

Traffic is therefore one possible option for realizing mobility. This concludes that one individual must have several other ways to realize mobility, without causing traffic. On the other hand it is possible to create large amounts of traffic without having a large amount of possibilities for mobility. The aim of this work is to provide utilities for the measurement of mobility. These utilities can then be used in future works to reduce the amount of traffic while increasing the possibilities for mobility.

2.2 Sustainability

The usually quoted definition for sustainability is the following one of the Brundlandt commission from the year 1987: "Permanent development is development, which satisfies the needs of the present, without risking that future generations do not satisfy their own needs [9]". This definition makes clear, that sustainability means more than a long-term protection of profits and enterprise maintenance. Sustainable management means to act resource-protective and to take further goals from the social and also the cultural range into focus. To classify the dimensions of sustainability the three pillars of sustainability according the Lower German House of parliament can be differentiated: ecological dimension, social dimension, financial (economical) dimension [10].

2.3 Aggregation of the Terms

The composition of the latterly introduced terms into the term of 'sustainable mobility' can best be described by looking at two existing definitions. The first one by Gottschalk [11] defines sustainable mobility as the following:

> Sustainable Mobility is the ability to meet society's need to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values, today or in the future.

On the other hand Dangschat [12] describes the term a bit differently. Dangschat's definition states that the term 'sustainable mobility' is a collective term for all changes in everyday life, technological development economical system, which allow us to increase the mobility of persons to satisfy the needs of everyday life while decreasing the amount of traffic.

Just like the latterly introduced definition of the 'sustainability' both definitions of the term 'sustainable mobility' share a common idea. All of the definitions reference the need to not exploit the social, economic and ecological resources of future generations by actions taken today. In addition to that, both definitions point out the importance of mobility for the present society. This concludes that there must be a trade-off between the sustainable development of mobility and the requirements on mobility issued by society. This trade-off suggests two options for a possible course of action. A strategy of sufficiency (the abandonment of mobility) is one way to encounter the problem and a strategy of efficiency is the other. The latter option requires sustainable innovations and should be pursued throughout this work. According to Schwarz [13] it is important to find a well balance compromise between the pillars of sustainability. Therefore, it is important to weigh the use of the three dimensions in the further work.

To enable sustainable mobility one must first put heavy emphasis on the ecological dimension of sustainability. This dimension is preferably chosen because its positive effects may also cause positive effects within the social and economic dimension of sustainability. This thesis is underpinned by the Umweltbundesamt and Dalkmann [14].

3 Key Performance Indicators for Sustainable Mobility

Key performance indicators (KPI) are mostly used in managerial functions like controlling. They represent numbers that contain special information for businesses, especially for the management [15]. Indicators are used to inform about the current state of a company. One of the most important characteristics of a KPI is that it makes information quantifiable, which enables the measurability and comparability of situations [16]. KPIs are therefore especially suited to simplify complex issues and to make them comparable.

In this work, general key performance indicators are used to make the sustainability of various means of transportation comparable. The aim is to represent the three pillars of sustainability by various indicators. Because of the reasons pointed out in Sect. 2, the focus of the indicators will be set on the ecological pillar.

3.1 Considered Means of Transportation

The means of transportation investigated in this work are shown in Table 1. The table is based on a report by Lambrecht et al. [17] which was commissioned by the Umweltbundesamt. The focus of this work is on means of transportation that are used in urban areas. The data on the consumption of the car models are average values for urban areas. They also consider the cold-start units. An additional average consumption of 25 % is considered on the consumption of natural gas buses. The emission calculation of a tram and PEV is based on the typical electricity mix in Germany.

Table 1 Considered means of transportation [17, 18]

Vehicle	Energy type	Final energy consumption	Number of seats	Primary energy (kJ/seat-km)
Car	Otto	6–15 l/100 km	5	460–1140
Car	Diesel	3.5–11 l/100 km	5	280–890
Bus	Diesel	40 l/100 km	66	244
Articulated bus	Diesel	55 l/100 km	102	217
Bus	Natural gas	49.7 m^3/100 km	66	327
Articulated bus	Natural gas	68.3 m^3/100 km	102	291
Tram	Electricity	28 Wh/seat-km	n.a.	309
PEV	Electricity	40 Wh/seat-km	2–4	340

The final primary energy consumption of the considered transport in urban areas depends on many different parameters. These include:

- Vehicle-specific parameters (curb weight, air resistance)
- Motor Technical parameters (injection method)
- Equipment (heating, air conditioning)
- Vehicular parameters (wind, flowing traffic)
- Topographic Parameters (flat or hilly terrain).

These parameters are observed only partially by Lambrecht et al. [17]. This is due to the fact that the factors differ from city to city and sometimes even within a city. Therefore, the results presented in Table 1 are only based on expert interviews and literature reviews, but they reflect the reality.

3.2 Making Key Performance Indicators Comparable

The problem of using key performance indicators for the evaluation of the sustainability of different means of transportation is the huge difference between the vehicle types. For example, the carbon emissions of a bus will always be much higher than the emissions of a car because the bus has a higher energy consumption.

This is why the actual utilization rate of a vehicle has to be considered when calculating the concrete values of an indicator. The utilization rate refers to the ratio of available space numbers and actually occupied seats in a vehicle.

By using the actual utilization rate to calculate the indicator values, the differences between the various means of transportations can be compensated and a comparable data basis for the evaluation of the relative sustainability of a vehicle is created.

3.3 Considered Key Performance Indicators

This chapter describes the indicators used for the comparison of different vehicle types. The indicators represent the three pillars of sustainability for mobility.

3.3.1 Indicator for Consumption of Resources

This indicator can be considered as an indicator for the ecologic and economic pillar of sustainability. It is an indicator for the ecologic pillar because the exploitation of natural resources, especially of fossil fuels, does have a huge impact on the environment. Because resource policy does have a massive impact on the national economic, this indicator is also for the economic pillar. The indicator is the basis for the air pollutants which are described next.

3.3.2 Indicators for Air Pollutants

This section covers the most important indicators for the ecologic pillar of sustainability. The indicators represent the most important types of emissions. The selection of the indicators of this section is based on the indicators used in the COPERT-Software which is developed by the European Environment Agency (see [19]).

Greenhouse effect—The most considered challenge in the context of environmental sustainability and traffic is the reduction of the greenhouse effect to prevent the climate change. The influence of a vehicle to the greenhouse effect is measured in carbon dioxide equivalents. In addition to the carbon dioxide emissions, the gases methane (CH_4) and nitrous oxide (N_2O) contribute to the greenhouse effect. The effects of carbon dioxide emissions are not immediately perceptible to humans. This is why this indicator should be considered in its global impact.

Particulates (PM10)—Particulates are dust particles which have a diameter of 10 microns or less [20]. Particulates are especially harmful to humans because they are inhaled unnoticed and may enter the bloodstream. This can result in asthmatics, heart attacks and strokes [21].

Particulate emissions are not only caused by the burning of fossil fuels, but also by dust swirls and abrasion, which for example is caused by braking. Because most of the particulates emissions are caused by traffic, the exposure in urban areas is much higher than in rural areas. Especially heavy vehicles such as buses contribute to the high amount of emissions. For this reason, in 2007, environmental zones have been introduced in many cities in Germany. According to the Umweltbundesamt this caused a reduction in PM-10-emissions by approximately 10 %.

Nitrogen oxides—Nitrogen oxides are created during the combustion at high temperatures. About 96 % of nitrogen oxides emitted can thereby be associated with the transport section [22]. The combustion of diesel fuel creates much more NOx emissions than the combustion of gasoline. The effects of an increase of nitrogen oxides on the environment and the people are different. Especially eutrophication is a major problem. An increase of the nitrogen compounds in the soil can cause chronic damage to the flora and fauna [23]. But also the formation of acid rain and smog, NOx is one of the precursors of ozone, are known issues.

Summer smog—Smog or ozone is not directly caused by vehicles. Ozone gases are formed by sunlight from nitrogen oxides and volatile organic compounds, which in turn are caused by road traffic. Since solar radiation is needed for the formation of ozone, the ozone level usually increases in the summer. This means that the formation of ozone gases is highly dependent on weather and on time.

Ozone gases have a direct impact on human health. The gas irritates the mucous membranes and has negative effects on respiration. In addition, plants can be permanently damaged by ozone gases.

3.3.3 Indicator for Noise Pollution

This indicator can be considered as an indicator for the ecologic and social pillar of sustainability. It is an indicator for the ecologic pillar, because noise is influencing the environment. Also noise pollution can be seen as an indicator for the social pillar, because it influences the life quality of a city which has a huge impact on the demographic composition.

The traffic noise is a permanent disturbance in cities and can have a significant impact on human health. According to the Umweltbundesamt, traffic noise can lead to an increased release of stress hormones and increases the risk for diseases.

Motorised road transport is a major source of noise pollution in urban areas. According to a calculation of the Umweltbundesamt, half of the population is exposed to noise whose level is above 55 dB (A) per day. About one seventh is even exposed to a level of about 66 dB (A).

The calculation of the noise pollution indicator values are based on the computational model CITAIR which was introduced by the Umweltbundesamt. This model allows the calculation of the average sound levels for any traffic situations.

3.3.4 Indicator for Human Toxicity

This indicator measures the impact of road transport on human health. It is thus a measure of the social dimension of sustainability.

This indicator is fully dependent on the already described emissions caused by road transport. Above all, the air pollutants are considered to have a direct impact on the local environment, and thus to humans.

3.3.5 Indicator for Land Consumption

This figure is relevant for both the economic and the social dimension of sustainability. Area is a valuable and very limited resource in a city. The traffic, most of all traffic caused by cars, plays a major role in the space consumption. Increased traffic leads to a higher consumption of space and thus to an impaired quality of life of the urban population.

The maintenance costs for the traffic infrastructure have a high relevance for the economic point of view. Each mode of transport causes an erosion of the transport infrastructure. This condition requires repairs that are often financed with money from public funds which can possibly lead to increased debts.

4 Method for the Comparison of the Relative Sustainability of Vehicles

For a correct evaluation of the relative sustainability of a vehicle, a calculation model that enables the comparison of various alternatives on the basis of heterogeneous criteria and indicators needs to be used. Depending on various parameters, such as vehicle utilization, the traffic situation and even the weather, a ranking for the sustainability of various modes of transportations needs to be created at a specify point of time. Multi-criteria decision support systems (MCDA) provide this exact functionality.

In this work, we used the outranking method PROMETHEE II as a decision support system to create a relative ranking. The PROMETHEE method is one of the outranking methods, which allow a complete ranking of various alternatives based on a variety of criteria [24]. It was developed in 1985 by Brans and Vicke. The advantage of PROMETHEE method is that it takes all available criteria into consideration. All alternatives are compared pairwise and advantages and disadvantages can be considered separately from each other. Furthermore, preference functions can be used during the comparison of alternatives, which allows to model indifferences between the criteria.

In contrast to PROMETHEE I, PROMETHEE II creates a total ranking of alternatives and does not support incomparabilities. In our use case, we want a total ranking of all considered vehicles at a specific point of time. Also incomparabilities, which do not allow a total ranking and can only be modelled with PROMETHEE I [25], are not considered in our use case. This is why the PROMETHEE II method fits best to our multi-criteria decision problem.

As said before, PROMETHEE II allows a total ranking of various alternatives on the basis of various criteria. In the use case of this work, the alternatives are represented by different types of vehicles and the criteria are the key performance indicators explained in Sect. 3.3. This allows us to create a total ranking of the sustainability of all available vehicles at a specific point of time. The ranking heavily depends on the actual utilization of a transport. The Table 2 shows an example of an achievement matrix that needs to be created as a first step. In this simplified example, an actual utilization of five persons per vehicle is assumed.

Table 3 shows the final flow matrix for the example above. It shows that in this trivial example with a utilization of 5 persons, a bus would be the least sustainable transport mode one could use at this point of time, whereas the car with a diesel

Table 2 Example of an achievement matrix for the use case

Alternatives/criteria	Car (Otto) 5 seats	Car (diesel) 5 seats	…	Bus (diesel) 75 seats
Consumption of resources	700 kJ/person-km	620 kJ/person-km	…	3150 kJ/person-km
…	…	…	…	…
Greenhouse effect (CO_2-equivalents)	55 g/person-m	48 g/person-km	…	270 g/person-km

Table 3 Final flow matrix

Flow	Car (Otto)	Car (diesel)	Bus (diesel)
F^+	0.5	0.75	0
F^-	0.25	0	1
F	0.25	0.75	−1

combustion engine would be the most sustainable transportation mode. Note that F^+ describes the aggregated advantages and F^- the aggregated disadvantages of an alternative.

5 Practical Use Case

The assembled set of suitable KPIs in combination with the PROMETHEE multi-criteria decision analysis method can be used to compare different possibilities for mobility according to the context of sustainability.

Such a comparison is very useful for a user, who has a current demand for mobility. It allows the user to compare a set of possible alternatives that would satisfy his current need for mobility. Applying the developed method would result in a relative assessment of the different alternatives, so the user can clearly determine which of the alternatives would be the most sustainable one.

Furthermore, an automated implementation of the method can be very useful within a multimodal route planning software. Such software would typically respond to a specific user request in which the user issues his demand for mobility by specifying several parameters like origin and destination of travel and a desired time frame in which he wishes to travel. The route planning software would then respond with a set of possible alternatives that have the potential of satisfying his demands.

Software like such a route planner could integrate an automated version of the developed method into its result set. It would not only respond with a set of possible alternatives for mobility, but also with additional information on the ecological impacts and consequences that are tied to the actual use of an alternative. This integrated approach would not only eliminate the need of manual calculation by the user but also enhance the user's perception of the implications that go hand in hand with his daily traveling.

The development of a software prototype which focuses on the implementation of the above mentioned possible use case is currently in progress at the University of Oldenburg. The project's aim is to provide a route planning software that stresses the sustainable aspects of the returned results. In addition to that the project tries to implement incentive systems with the goal to influence the users of the software in a way that would push a user towards a more sustainable way of travelling. A similar approach has already been undertaken by a former project which was also located progress at the University of Oldenburg [26].

6 Conclusion

This work shows a method for the comparison of the sustainability of different modes of transportation based on key performance indicators and multi-criteria decision analysis. The used key performance indicators represent the three pillars of sustainability and have a focus on the ecological pillar.

As explained, the introduced method is already used and implemented in practice. At the moment, only key performance indicators that represent the sustainability of a mode of transportation are used. A further idea would be to create more key performance indicators that allow the real time evaluation of other attributes of vehicles such as the costs and the comfort. These KPI-Systems in conjunction with the MCDA-Methods could also be used by software systems that help a user to find the best fitting mode of transportation.

Another further idea is to extend the dynamic aspects of the introduced method. At the moment, only the actual utilization of a vehicle is influencing the value of a key performance indicator. In reality, there are a lot of more parameters, such as the weather, the time or the current traffic situation, that have an impact on the KPI-values. In future these aspects should also be covered by the introduced method.

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Developing a Maturity Assessment Model for IT-Supported Energy Management

Christian Manthey and Thomas Pietsch

Abstract Maturity assessment modelling is a recognised instrument in both academic and business domains which has recently become the focus of discussion in connection with sustainable information and communication technology. At the same time, the acceptance of Corporate Environmental Information Systems (CEMIS) in the corporate world remains modest, and CEMIS continue to be confronted with various problems. Against this background, a maturity assessment model for IT-supported environmental management will be developed with the aim of incentivising companies to deploy CEMIS and thus increase its usage in the corporate domain. The long-term goal is to fundamentally shift the status of environmental management so that it is no longer viewed as being passive, non-integrated and often costly, but rather as being a strategic instrument whose potential can be systematically exploited with the help of a maturity assessment model. The development of maturity assessment models will first be illustrated with the help of a process model. As the development of a maturity assessment model for environmental management in general represents an extremely comprehensive undertaking, application of the model developed here will be explored in the limited context of energy management and planned implementation within a corporate network.

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1 Introduction

1.1 Current Challenges for CEMIS

It is sometimes claimed that the past successes of Corporate Environmental Management Information Systems (CEMIS) are fairly modest, and that the potential of combining ecological and economic success has yet to be fully realised in the corporate domain [1]. An important reason for the lack of implementation might be that reliable studies into the costs and benefits of such systems have not yet been undertaken [2]. This continues to rule out a broad acceptance of CEMIS in corporate practice [3].

As noted in Junker [4], the question of a holistic approach, i.e. the integration of societal factors, also deserves more attention. It has also been stated that a theoretical and conceptual basis for sustainability in information management is still missing, and that most scenarios still lack clear strategies and management concepts from which corresponding sustainability management for the entire IT value chain can be derived ([5], V).

Speaking more specifically in terms of CEMIS, others maintain that these have up until now been developed with remarkably little interest for strategic level corporate activity [6]. The keyword "integration" should therefore also be understood in terms of embedding environmental information into organisational processes beyond just the operational level. As another aspect in terms of integration, the combination of CEMIS and ERP systems remains in its infancy.

Overall, the situation remains unsatisfactory. Firstly, CEMIS are rarely characterised by a holistic approach; secondly, they too often lack a proactive nature; thirdly, there is too little demand for transfer to business practice [1].

1.2 Business Processes from the CEMIS Perspective

Recent years have seen increased discussion of Green Information Systems ("Green IS"). A central aspect of this discussion is "Green Business Process Management" (Green BPM) [7]. "Adding ecological sustainability to business process management as an additional dimension", should therefore be seen as another challenge confronting corporate environment technology [8].

A significant research field of business computing in the future will be to investigate the roles which process changes play in the transformational shift to organisational sustainability [9]. Green IS ought therefore not be seen directly as a "saviour", but instead contribute indirectly to increased awareness regarding interaction with natural resources in the corporate world via the process changes which they about (Fig. 1).

Recently, the publication of the ISO 50001 standard is also driving the opinion in practice that the field of energy management is an essential component of

Fig. 1 BPM's role in IS-supported sustainability initiatives (Seidel et al. [9])

environmental management. The potential for information processing to support energy management business processes will have to be considered more detailed in the on-going research. Here, the challenge is to utilise the potential of BPM to develop a systematic approach for the integration of CEMIS-specific topics into everyday business for SMEs.

1.3 Aim of the Paper and Methodological Approach

This chapter seeks to reveal possible solutions for at least two of the challenges mentioned above by working toward a maturity assessment model for IT-supported energy management. In a highly practice-orientated project which aims to transfer application-relevant knowledge from the CEMIS domain to small- and medium-sized companies (SMEs). As a first step, the participating companies will be equipped to analyse the energy consumption of their production processes with the help of the assessment model. Subsequent steps demonstrate the proactive nature of the proposal outlined: envisaged is a systematic approach with whose help companies are able independently to determine potential actions to be implemented in order to advance to the next level on a path to increased energy efficiency.

Overall aim of the chapter is to describe a way towards a methodological approach for the development of a maturity assessment model for the IT-supported energy management in companies. Following the procedure model as described in Becker et al. [10] the research approach is based on a design science approach [11] and is describes more detailed in chapter "Development of a maturity assessment model for IT-supported energy management" of this chapter. Before that, chapter "Business processes and maturity assessment modelling" provides the basic procedure of process assessment with the help of maturity assessment models and deals with current literature in the field of interest. In anticipation of the results of the research process, we present a first conceptual approach for maturity levels of IT-supported energy management in chapter “Results and future prospects”.

2 Business Processes and Maturity Assessment Modelling

2.1 Process Assessments with Maturity Assessment Models

For a number of years, customer requirements, pressure from competitors or the need to comply with legal requirements have compelled companies to continuously improve their processes with the aim of producing products in shorter times, for a lower cost or in better quality. More recently, these economic factors have been joined by significant ecological aspects; companies now also have to arrange their processes as best they can from this perspective.

Alongside the levelic instruments of business process modelling—analysis and optimisation—maturity assessment of processes has in recent years proved itself a very useful tool. It assesses the performance of processes via a structured, transparent procedure enabling an appraisal of the current situation. Process assessment involves assessors performing targeted investigations into selected processes according to specified criteria. With regard to environmental management issues, these would include efficient energy consumption and, especially in the present context, associated business processes supported by technical equipment (e.g. sensors measuring consumptions and emissions), information technology and software solutions.

The result is a ranking of processes according to their level of maturity on a predefined scale. As well as offering insight into where the company and its processes stand with regard to the energy efficiency criteria specified, the results also represent the basis for subsequent process improvements. This means that a reduction in emissions and the careful use of resources must be actively and specifically pursued in order to elevate processes to a higher level of maturity.

The implementation of maturity assessment is based on international assessment standards for corporate processes such as Capability Maturity Model Integration (CMMI) or Software Process Improvement and Capability Evaluation (SPICE). A company’s processes are tested against a process model (for reference) which is divided into process and maturity dimensions.

The process dimension defines all processes that exist within the area under investigation. Activities and work results (termed inputs and outputs) are allocated to every process. The defined processes are sorted into process categories which each cover one task area. In the maturity dimension, assessment criteria are stored for these processes and allocated to defined maturity levels. Based on these criteria, a decision is made regarding which level of maturity each respective process reaches (see Fig. 2).

The maturity assessment model is a two-dimensional construct. It comprises a processes dimension whose individual processes are organised into process categories. The first dimension shows "what the process does". The maturity dimension defines process attributes which are organised into different maturity levels. They show how mature the process is relative to the criteria model developed. The overall assessment of a process category is dictated by the lowest scoring process in the process category. To reach this result, five phases must be completed which are characteristic of the process of the maturity assessment. Every phase is in turn divided into a series of steps which lead to the respective phase result.

In phase 1 (establish roles), the participants in the maturity assessment are identified and assigned roles.

Phase 2 (initiate project) forms the foundation for the subsequent maturity assessment. Here, all information required for planning is gathered. The steps to be undertaken in these phases extend from acquiring basic data on the organisation to securing required entry and access and to establishing the aspired assessment outputs.

In phase 3 (sequence planning), all resources, schedules, data-gathering measures and instruments required for the implementation are established together with the assessment to be worked through. The results of this phase are documented in a separate assessment plan for each process.

Phase 4 (assessing processes), during which the process categories and processes are assessed and allocated to a maturity level, is the most time-consuming part of the maturity assessment. In order to be able to assess the processes of one's own company, the first step is to create a reference model against which the company's own processes can be assessed. This model must contain all processes with a description of "best practice" as well as all process in- and outputs for an aspired ideal state. The company's own processes are then surveyed and documented in such a manner that they be compared with the ideal process given in the

Fig. 2 Principle and dimensions of the reference model. *Source* Own research reference model. Before the processes can be assessed, the maturity levels, the assessment scale and the process attributes must be defined.

In phase 5 (report completion), the results of the assessment are gathered in a report. This describes the assessment results in terms of strengths, weaknesses and process profiles. Completion of this document signals the end of the maturity assessment. As well as offering insight into where the company and its processes stand with regard to the environmental criteria specified, the results also represent the basis for subsequent process improvement.

2.2 Conducting the Maturity Assessment

The assessment of processes and process categories and assigning of a maturity level is the most time-consuming part of the maturity assessment. First, all processes must be determined and categorised, and an ideal state must be adequately outlined. Before the assessment can be completed, maturity levels, an assessment scale and process attributes must be established. The process attributes form the basis of every assessment.

The maturity levels (i.e. degrees of competence) characterise the performance of the processes. They build on one another consecutively, i.e. entry into a higher level requires that the demands of the previous level are completely fulfilled (i.e. the process is cumulative). Experience with maturity assessment models such as CMMI or SPICE indicates that four to six maturity levels work very effectively for maturity assessment. Applying fewer levels leads to difficulties setting boundaries between respective levels, while applying more than six levels increases workload as a considerably higher number of criteria are required to define each level. Six levels as shown in Table 1 can therefore be recommended.

Process attributes sub-divide and refine the maturity levels so that they can be more accurately described and assessed. This subdivision is standardised and identical for every maturity assessment. The example in Table 2 from a transdisciplinary research project lists attributes that are allocated to the corresponding maturity levels zero to five. Level one and two is allocated to one process attribute

Table 1 Example for maturity levels

Level	Name	Description
0	Non-existent	The process is not implemented or does not fulfil its purpose
1	Initial	The process fulfils its purpose
2	Repeatable	Process implementation is also subject to planning and coordination
3	Defined	Process implementation is standardised
4	Managed	The process is understood and checked in quantitative terms
5	Optimized	The process is continuously optimised and improved

Source Own research based on [10]

Table 2 Defined process attributes

Maturity level	PA ID	Attribute name	Description
0	PA 0	Non-existent	Missing awareness for business processes
1	PA 1.1	Initial process implementation	PA 1.1 assesses whether the purpose and the goal of the process are achieved
2	PA 2.1	Process descriptions	PA 2.1 assesses whether initial results can be repeated for (standard) business processes
3	PA 3.1	Process definition	PA 3.1 assesses the extent to which a standard procedure is maintained in order to support the implementation of a defined process
3	PA 3.2	Process application	PA 3.2 assesses the extent to which a standard process is employed as a defined process and personal responsibilities
4	PA 4.1	Process management	PA 4.1 assesses whether process implementation is managed and checked against quantitative key performance indicators
4	PA 4.2	Process outputs	PA 4.2 assesses the extent to which the outputs generated by the process are further processed
4	PA 4.3	Process measurement	PA 4.3 assesses the extent to which measured results are utilised to ensure that process implementation achieves the pre-defined goals
5	PA 5.1	Process innovation	PA 5.1 assesses the management of process changes emerging from the analysis of process data and innovations and steered by key data for process improvement
5	PA 5.2	Process optimisation	PA 5.2 assesses the management of process changes with regard to their effects (e.g. resources, achieving goals)

Source Example from own research

each (PA 1.1, PA 2.1) while levels three to five are allocated two or three process attributes each).

A four-point scale which has proved itself in process assessment is employed to assess the process attributes listed above. Each of the four scale points corresponds to a percentage range. For identification, each point on the scale is assigned the letter N, P, L or F. The results are clarified in Table 3.

In order to deliver comparable and reproducible results in the assessment, the process attributes are sub-divided into individually assessable techniques. For the assessment of level 1 maturity, the basic techniques described in the process description are compared. From stage 2 upwards generally applicable techniques are tested which are equally applicable to all processes. To this end, techniques and their assessment criteria must be standardised in a table as well as being identical for all maturity assessments.

The individual techniques of each process are then assessed via a 4-point scale. The mean value of all assessed techniques represents the assessment result of a process's respective attributes. The percentage value is then assigned to its respective letter using the 4-point scale.

Allocation in one of the 4 levels is performed according to the judgment of the assessor on the basis of the process maturity of the techniques tested. This allows the assessor some scope: for example the decision as to whether a technique is fulfilled to 85 or 87 % is made by the assessor on the basis of his/her experience. One reason for this lies in the fact that the techniques given in a process description are not specified in every detail. Extremely comprehensive process descriptions could largely eliminate this issue, but experience in practice suggests that a degree of scope for interpretation can actually be extremely helpful.

Table 3 Rating scale based on ISO/IEC 15504

Rating	Percentage	Description
N—not achieved	0–15	There is little or no evidence of achievement of the defined attribute in the assessed process
P—partially achieved	16–50	There is some evidence of an approach to, and some achievement of, the defined attribute in the assessment process. Some aspects of achievement of the attribute may be unpredictable
L—largely achieved	51–85	There is evidence of a systematic approach to, and significant achievement of the defined attribute in the assessment process. Some weakness related to this attribute may exist in the assessed process
F—fully achieved	86–100	There is evidence of a complete and systematic approach to, and full achievement of the defined attribute in the assessment process. No significant weakness related to this attribute exists in the assessed process

3 Development of a Maturity Assessment Model for IT-Supported Energy Management

3.1 A General Procedure Model for the Development of Maturity Assessment Models

A variety of different maturity assessment models already exist which are specifically suited to particular fields of application. However, multiple maturity assessment models also exist for very similar fields of application, which does indicate a degree of arbitrariness regarding their development [10]. The process model for the development of maturity assessment models for IT management demonstrated here seeks to avoid further undesirable developments along these lines. The procedure model is based on a design science approach and is structured in seven steps [10]:

1. Problem definition
2. Comparison of existing maturity assessment models
3. Establishing of development strategy
4. Iterative maturity assessment model development
5. Conceptualisation of transfer and evaluation
6. Implementation of transfer means
7. Implementation of evaluation.

The problem definition phase requires identification of the area concerned and target group for the maturity assessment model and the provision of evidence indicating the need for a new maturity assessment model. As discussed earlier in this chapter, IT-supported energy management in SMEs is to be understood as area concerned and the comparison of existing models can supply important inputs for the model to be developed as it can be based on an existing variant. This allows utilisation of the useful elements of existing models and helps avoid known weaknesses for the model under development. How past models are combined, or whether a completely new development is undertaken, is determined by the development strategy. Step 4 comprises the core of the actual development. Here, the basic architecture and dimensions of the maturity model—as described in chapter "Business processes and maturity assessment modelling"—represent the essential task. This is the most important step in model development, and results must be continuously checked and further developed. After successful development, the results should be made available to interested parties in both academic and practical domains and supported by suitable transfer materials (handbooks, checklists, etc.). The evaluation phase is intended to test the extent to which the maturity assessment model fulfils its intended purpose and thus determine its potential effectiveness.

3.2 Current Discussion on Maturity Assessment Models with Reference to CEMIS

A small selection of current literature will now be used to identify contemporary trends and research within the CEMIS area which could provide important impetus for the further development and expansion of CEMIS. Recently, a number of publications have emerged which deal intensively with business process management, maturity assessment, sustainability and IT.

For example, in Curry and Donnelan [12] a framework for the determination of the maturity of ICT orientated toward sustainability criteria (Sustainable ICT-CMF) is introduced. However, this seems to focus more on the technical level ("Green IT") than on the integration of software ("Green IS") in business processes. Nevertheless, dividing performance into four different categories (strategy and planning; process management; people and culture; governance) might offer a constructive approach to systematically analysing the use of CEMIS in companies and elevating it to a more effective level.

In their work, Cleven et al. [13] also focus on sustainability factors, placing the performance of business processes at the centre of their research. Their "Process Performance Management" model allows the maturity of corporate sustainability to be measured and managed. Maturity assessment models are described as a means of assistance through which organisational performance can be systematically documented and improved.

Morelli et al. [14] describe "sustainable corporate fitness through the measurement of IT support potential in business process maturity modelling". Here, various maturity assessment models for business processes are compared and examined to establish whether the degree of IT support "in adequate form" is considered.

In their work, Stolze et al. [15] maintain that "a comprehensive model for the determination of ecological, economic and social sustainability in IT is yet to become widespread", and lay the "cornerstone" for an integrated maturity assessment model for sustainable IT.

3.3 The Need for a Maturity Assessment Model for IT-Supported Energy Management

This comparison of existing models gives the impression that no adequate maturity assessment models are available for the "Green IS", or CEMIS, domain. In a practically-orientated project, domain-specific software is being developed in cooperation with SMEs which seeks to support energy management in businesses from defined sectors. A maturity assessment model would seem a constructive addition in that it could systematically unlock optimisation potential above and beyond the project itself, as well as driving forward the integration of energy management (or other aspects of corporate environmental management) in the IT landscape and offering a clear example of how the challenges of CEMIS illustrated above can be confronted.

4 Results and Future Prospects

After initial research, no maturity assessment model for IT-support energy management could be found in the published literature. The same is true for comparable models with a holistic approach to IT-supported environmental management. Only in the domain of "Green IT" and sustainable IT management can substantial contributions to the academic discussion be found [5].

An academically rigorous process model can be used for the development of a maturity assessment model for IT-supported energy management [10]. The first step in this process is, however, to prove the necessity of developing a new maturity assessment model by comparing models that already exist. This process is currently underway. The subsequent formulation of a development strategy and the iterative development process of the final maturity model should be carried out in cooperation with multiple corporate networks. Later phases of the process model anticipate the transfer and evaluation of the results.

In advance of a future comparison of existing maturity assessment models and the subsequent phases of model development for the context stipulated in this chapter, a preliminary draft definition of different maturity levels will now be attempted. Here, the scale for IT-supported energy management extends from level 0 (non-existent) to a possible level 5 (optimised). With reference to the Capability Maturity Model (CMM), whose maturity levels also [10] reference with their IT Performance Measurement Maturity Model ($ITPM^3$), the maturity levels are designated 0–6 [10]. Example maturity levels as applicable to energy management can be seen in Table 4. These can function as an initial basis for discussion.

The model offers various potential extensions and refinements. For example, detailed maturity levels can be described which relate to IT-supported management as it is applied for different tasks within energy management (e.g. monitoring and checking energy consumption, standardised action planning etc.). Furthermore, constructive definitions for maturity levels at the level of process attributes and the extent to which they are fulfilled are still to be formulated.

Fundamentally, this type of approach is applicable to all aspects of IT-supported environmental management, i.e. the entire scope of tasks for CEMIS, could be applied. A corresponding expansion of the methodology described here could thus systematically demonstrate how a continual expansion of environmental information's penetration into the IT landscape could be undertaken to support not only energy management but environmental management as a whole. A model which charts this path in single, operationally actionable steps can as such contribute to the formulation of a solution to current challenges for CEMIS.

Table 4 Maturity levels for IT-supported energy management *Source* own research

Maturity level	Description
0-non-existent	Energy management is perceived within the company neither as a task nor as an opportunity
	The potential of IT as a means of assistance is not recognised
1-initial	First measurements are carried out to monitor energy consumption
	Single isolated measures implemented
2-repeatable	Table calculations as means of assistance for recording energy consumption
	Procedural templates exist for repeated measurements and documentation of energy consumption
	Procedural templates facilitate the analysis of energy consumption, i.e. through the creation of diagrams
3-defined	Management energy policy involves IS landscape
	Clear responsibilities with cyclically repeated tasks for individuals
	Comprehensive implementation in line with ISO 50001
	Measures are established systematically
4-managed	CEMIS software solutions are employed
	(IT-supported) benchmarking as input for optimisation measures
5-optimized	Sensor technology supplies constant data to systems
	Continuous controlling of energy data is implemented
	Integration in the software landscape, e.g. ERP systems
	The continuous improvement process (CIP) is supported by proactive management and software integrated into the company's IT landscape
	New tasks are derived from previous measurements and activities in the field of energy management in line with CIP

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Accounting and Modeling as Design Metaphors for CEMIS

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Abstract The terms accounting and modeling both characterize the theoretical background of core components of corporate environmental management information systems (CEMIS). On the one hand, a CEMIS as a computer-based environmental management accounting system; on the other, we emphasize the role of modeling and calculation. With regard to an analysis of materials and energy flows and stocks of organizations and supply chains, accounting and modeling seem to be synonyms. However, in a software development perspective, accounting and modeling can be interpreted as different design metaphors. The aim of this contribution is to design images for computer-based CEMIS in the two perspectives. As a result, an CEMIS should be both a software tool supporting modeling activities and an information system supporting decision making.

1 Introduction

The development and implementation of corporate environmental management systems (CEMIS) is an outcome of basic research in different scientific communities. Often, the paradigms of these communities are not mentioned. The discussion of underlying images and orientations may help to improve the design process. In this contribution the different approaches of the environmental management accounting network (EMAN) and the environmental informatics community are reviewed, in particular the two perspectives "accounting" and "modeling". The aim is to design and development images, which guideline the software implementation of appropriate software solutions.

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The implementation of CEMIS software is a challenge because CEMIS not only a next step in implementing already successful conventional accounting systems like financial accounting and cost accounting. It is not a simple extension of new data fields, evaluation procedures and reports. It seems to be necessary to discuss this special background first. As a result, a CEMIS cannot be implemented as a extension or an replacement of core components of enterprise resource planning systems (ERP systems) only. Rather, a CEMIS has to serve as an office tool (like Microsoft Excel) and as information system component at the same time.

2 Background

This section discusses the upcoming transformation of our industrial metabolism. Industrial metabolism characterizes the physical basis of our economy and society [1]. In 2011 the WBGU (German Advisory Council on Global Change) presented a report about present and future challenges, mainly in industrialized countries [2]. The title of the report "World in Transition—A Social Contract for Sustainability" expresses the most important message of the report: A socio-economic transformation is required. This recommendation is based on the insight that our industrial metabolism is not sustainable. But the consequence is not to change some physical processes (recycling processes, re-use of used materials, introduction of digital products, cleaner production etc.). We have to change our images and orientations how to organize value creation. This is not a technical problem; it is rather a question of the enhancements of our societal institutions. So, not only the industrial metabolism itself is problematic (unsustainable), highly questionable are our images how value creation should take place, the societal orientations and the societal institutions, we have established [3]. The term "transformation" describes the dynamics of future developments: It should be rather a revolution and not a relatively slow evolution.

This is not only a philosophical debate. It has relevant impacts on the successful design of CEMIS. For example, it helps to understand the success of software tools for life cycle assessment and material flow analysis. The hypothesis here is that the success of the software tools is time-dependent: they are useful in the beginning of the transition phase. Later, in a to a large extent sustainable society and economy they will be replaced by powerful ERP system components.

The question is, how we distinguish between transformation phases and the "normal" evolution of our societies. The hypothesis here is that the development and transformation of societal institutions and societal subsystems is based on communication processes of involved stakeholders, whereas in the other phase routinization replaces more and more other types of action coordination (process of rationalization). In a transition phase, stakeholders put unsustainable structures and processes in question, for instance the future of a company with regard to the scarcity of resources, consumption of fossil energy or unacceptable high carbon dioxide emissions. Here come, as one of the most important outcomes of Habermas' theory of communicative action [4], communication and discourse into play: Effective communication in such a situation aims at replacing archaic structures, mechanisms or orientations by new mechanisms and orientations, which are the essence of the communication processes: a new social consensus or contract. In this perspective, the term transformation stands for a communication process.

The consequences for the development of CEMIS are significant. Figure 1 shows the degree of formalization and routinization of organizations, institutions and societal subsystems in time. Normally, the aim of scientific disciplines like business informatics is to contribute to an increase of formalization. However, the discussion about the upcoming socio-economic transformation points out that this is not always helpful. Benefits of CEMIS are different and time-dependent. A CEMIS should integrate at least three different perspectives:

1. Before a transformation phase CEMIS should support the challenges of archaic structures, mechanisms and orientations. They should initiate communication and discourse. With regard to sustainable development, a CEMIS should help the stakeholders to identify challenges of non-sustainability.
2. In the transformation phase CEMIS should contribute to effective communication. They should help to find new (and more sustainable) mechanisms and orientations. In other words, CEMIS should provide an environment for organizational communication and learning and as a result good arguments.
3. Step by step the CEMIS has to support the new consensus by providing new mechanisms, work flows, accounting systems etc.

This makes clear that a CEMIS is not only a software implementation of new accounting systems, in particular environmental management accounting systems. Rather, the accounting system as a design metaphor may help to integrate the three requirements on CEMIS. In the following the basic ideas of accounting systems are presented.

Fig. 1 Degree of formalization and the challenge of transformation phases

3 Environmental Management Accounting

Environmental management accounting (EMA), [5, 6] can be defined as a domain of new accounting concepts in addition to conventional accounting approaches like financial accounting and cost accounting [7]: environmental accounting. The accounting systems have to prepare information for different stakeholders. In case of financial accounting the stakeholders are external parties, in case of cost accounting the management. Cost accounting is a subclass of management accounting systems.

Material flow networks (MFNs) and the underlying Petri nets can be interpreted as mathematical foundations of an environmental accounting system, which allows representing material and energy flows and stocks for a specific time period [8, 9]. The static structure of Petri nets enables specifying a chart of accounts (stocks and flows). Even if Petri nets are developed for a different application domain, the static structure both of Petri nets and accounting systems are very similar. We can apply the logic of double-entry bookkeeping the Petri nets: Double-entry bookkeeping provides information on what financial flows have occurred in a period under review and how the opening inventory has changed after this period. But with regard to environmental accounting, instead of financial flows energy and material flows and stocks are considered. Stocks are assigned to the places and flows to the arcs.

The aim of environmental management accounting as a management accounting approach is to support management planning, control and decision-making [10]. Computer-based information systems provide required information (with regard to environmental management [11]). Even if the application of accounting systems to strategic management is claimed very often, the really successful application domain of accounting systems is still operations management.

However, a CEMIS, which implements accounting approaches only, cannot cover all requirements on CEMIS software mentioned above. The main focus is on the third perspective: EMA should contribute to ensure rationality in management processes [12]. In other words, CEMIS should support eco-controlling. In this perspective, there is a gap between orientations of managers (sustainable company) and appropriate decisions on the one side and on the other side the reality of the industrial metabolism and the role of the company within the industrial metabolism. Instruments like life cycle assessment [13] and product carbon footprinting try to quantify the position and role of the company. Therefore, it is required to include external data about the impact of pre and post chains, the impacts in the use phase and end-of-life impacts (waste disposal and recycling).

But what are the key characteristics of an accounting system as a decision support instrument? In this regard, it should be possible to provide data in different dimensions [9]. For instance double-entry bookkeeping as an approach of financial accounting supports the enterprise balance as well as the profit and loss statement. So, this concept provides information about "stocks" (enterprise balance) and "flows" (profit and loss statement) at the same time.

An environmental management accounting system has to cover different purposes too. With the industrial metabolism in mind, an accounting system should not only present flow data. Stocks are the main problem: the amount of available resources, the scarcity of fossil energy, the concentration of carbon dioxide in the atmosphere etc. So, if we want to draw a picture about future states of the industrial metabolism, we will need a balance (like an enterprise balance) and instruments, which are equivalent to the profit and loss statement: Stocks and the management of the stocks (flows) characterize the state of the industrial metabolism.

Data collection and data entry of the (environmental) management accounting systems seem to be an internal problem of the instruments. Nevertheless, efficient data collection and data processing become major research fields of business informatics. Several approaches are discussed and implemented, for instance the re-use of already existing data sets within ERP systems, an enhanced monitoring of formalized workflows etc.

With regard to EMA systems, this makes sense as part of eco-controlling, in particular to control decisions: The accounting systems provide data, which allow analyzing the gap between expected impacts of decisions and the real outcomes. Here, the accounting system is mainly past-oriented. This makes it possible to collect data by monitoring real business processes. Such a solution is not possible in future-oriented accounting systems [14].

4 Modeling as Indirect Data Collection

Of course, an established cost accounting system is a model. The model represents past or future states and processes of an organization. Methods are applied to derive key performance indicators from the model. A typical example is double-entry bookkeeping. As mentioned above, double-entry bookkeeping results in a consistent model, from which the enterprise balance and profit and loss statements can be derived. The methods behind allow the aggregation of data in a consistent way.

The originally intended way of data collection was "paper-based" with aid of journals and paper-based accounts. Today, computer-based corporate information systems support financial accounting, and the journal is computer-based. The software systems help to collect data sets as efficient as possible and to use them in different ways: as data input of financial accounting, as data input of cost accounting, in invoice processing etc. The idea is that we can derive the data input of the accounting systems from routinized and formalized business work flows.

But such a way of data collection is not applicable in future-oriented accounting systems. In future-oriented accounting systems, manual data collection must be replaced by (more or less sophisticated) simulation models, which draw a picture of future processes and states. These simulation models represent future scenarios, and it is possible to experiment with the models by changing the scenario parameters: assumptions about the development of prices of raw materials and intermediate goods, the market demand, the regulatory framework etc. [15].

A typical example for such a modeling system is process flowsheeting in chemical industry [16]. Process flowsheeting is used to design chemical processes, which consists of several different unit processes like mixers, chemical reactors, flash units etc. The chemical processes are embedded into complex productions networks for chemical substances and products, a so-called "Verbund". Process simulation software determines "the size of equipment in a chemical plant, the amount of energy needed, the overall yield, and the magnitude of the waste streams" [17] by calculating dynamics and in particular steady states of future processes. The financial and ecological impacts can be derived from the models: The process model serves as a data provider of future-oriented cost accounting and life cycle assessment.

As a consequence, a CEMIS, which wants to cover future-oriented environmental accounting, cannot be an enhancement of computer-based accounting systems for financial and management accounting without a modeling component. The first prototype of a software tool, which was based on the material flow network approach, was an accounting system only. Of course, it was passible to calculate eco-balances, but so-called transition specifications were not provided. Such an accounting instrument was useless because of an exorbitant effort for data entry. It is necessary to provide a modeling component, which includes an appropriate user interface [30]. The insights from the first MFN prototype and an analysis of existing material flow analysis and life cycle assessment tools clarify that this is helpful in case of past-oriented environmental management accounting too [18]. The life cycle models include all attached pre and post chains so that the whole product life cycle serves as data input of life cycle impact assessments.

As another consequence, the application domain of future-oriented accounting systems is quite different. Application software in this field can be characterized rather as a "tool" [19]: quick what-if-analyses, experiments, rapid enhancements of the model, by the way model validations. The laptop serves as a workbench for environmental modeling and simulation.

The introduction of a modeling component and an appropriate user interface has remarkable side effects. Data collection is not longer invisible and formalized data processing, which takes place within a software system. Stakeholders are involved, and they interact with the software system to construct and to configure the models. This is not only a special kind of data entry; it is a learning process too. Not only the key performance indicators of the models provide new insights, the modeling process itself does: We better understand the physical processes, the relationship between product output, waste and emissions; we identify possible improvements and analyze them in a special scenario; we learn to interpret the numbers, for example the results of life cycle inventories and impact assessments. The modeling experiences could be the trigger of communication and improvement processes, resulting tables and figures may serve as good arguments, for instance as part of Powerpoint slides.

5 Design Images and Design Metaphors

From a management perspective, CEMIS are management accounting systems and therefore decision support systems. This image in mind, main focus is on "key performance indicators" (KPIs). Data processing within the accounting system takes place on the basis of an underlying accounting approach. In case of environmental management accounting the material flow networks may serve as such an accounting approach. "Accounting" can be interpreted as a design metaphor for a respective software component.

As mentioned, data collection is not a key issue of an accounting system. Here, already established computer-based information systems come into play. To use available data of these systems, a CEMIS component should serve as a data mapper to the respective information system. Here, conventional design metaphors like the "integrated system" [20] can be applied.

However, such a data mapper is not sufficient to cover all requirements on EMA data collection. Typical process specifications in the EcoInvent database for life cycle assessment [21] make clear that each process step has several physical inputs and outputs, which have no market price. Other computer-based information systems like ERP systems do not provide data about these flows.

A CEMIS should provide another software component: a modeling component. The modeling component contributes to close the data gaps by providing (small) models, which allow calculating unknown material and energy flows, e.g. the amount of emissions in a combustion process based on the Diesel input. The modeling tool plays the role of a customizing tool, which links available data of the information systems with databases like EcoInvent.

Moreover, the component is the "workbench" for future-oriented modeling material and energy flow models. The term "tool" may serve as a design metaphor for the component. Figure 2 shows the resulting core components [22, 23] of a CEMIS, which separates accounting from modeling as part of data collection. The framework consists of two important pillars: (1) data entry for past-oriented environmental accounting, and (2) modeling for future-oriented environmental accounting.

5.1 CEMIS as an ERP System Component

The first pillar "(1) Data Mapper ERP System" result in a CEMIS design image, which focuses on an integration into already existing computer-based information systems, mainly ERP systems. In this regard, the CEMIS becomes a decision support system. It serves as a management instrument for eco-controlling. The ideal is a fully integrated information system: the CEMIS should be integral part of ERP systems, no problems with data transfer, no problematic redundancy of data etc. A first step in this direction could be a new CEMIS component as an add-on of

Fig. 2 Core Components of a corporate environmental management information system

already existing ERP systems. The CEMIS becomes an "observer" of all relevant data processing within the ERP system and extracts relevant data. The design images and metaphors of this pillar are in line with expectations, what such an information system should do [24]. Of course, such a component cannot be a stand-alone tool on a laptop or PC.

5.2 CEMIS as a Modeling Tool

The second pillar "(2) Modeling Component" results in a completely different design image. The CEMIS is at first a modeling tool with an appropriate user interface.

The tool helps to model flow sheets or networks of interrelated transformation processes. Users handle with processes, arrows and other graphical elements as the "material" in the design process; they "draw" with aid of the software tool processes and stocks, they link the processes (direct manipulation, [30]); they test the already designed parts of the model etc.

The users do not enter flow and stock data directly. Rather, they regard the processes as sub-models. So, the modeling process is mainly a specification processes. Sometimes fairly sophisticated modeling methods take place, for instance thermodynamic models in chemical industry. The purpose of calculation engines is to compile a consistent material and energy flow model, which integrates all specifications ("the sequential modular approach to flowsheeting" [16]).

The resulting materials and energy flow models serve as data input of appropriate accounting systems. The link to accounting systems can be realized in two different ways. (1) Data mappers transfer the results to data input of the accounting system. This could be a successful approach for already existing simulation models. (2) A second approach integrates the accounting system in a way that the calculated material and energy flows can be used directly as data sets within the accounting component. This requires that the modeling tools adopt the structures, specified in the accounting system, as a flow sheet or network structure of the modeling tool. The software tool Umberto is an example of the second approach.

The second approach avoids data gaps and mapping problems between the modeling tool and the accounting system. Moreover, the integration of modeling method and accounting system approach is prerequisite of an integration of the two different pillars of CEMIS. I will discuss the question of integration in the next section.

5.3 CEMIS Integration

The two pillars of data input of environmental accounting result in different software design images and software implementations. Normally, software frameworks implement a single basic design image only. It seems that we have to decide: the "software tool" or the "integrated system". My hypothesis is that it is possible to integrate these different images: An integrated CEMIS as a software framework [25] should consist of both a local PC-based modeling component and a server-based ERP system component. The accounting system serves as an integration component.

As discussed above, it is recommended that the accounting component provides the static structure of the material and energy flow models. In a stand-alone tool, the two different construction activities are integrated: the design auf the accounts and the relationship between them on the one hand and the specification of processes as sub-models, of feed streams and of scenario parameters on the other hand. But this is not necessarily the case. The accounting system may serve as a template for the specification processes: We "import" the network structure as the structure of the present real scenario [26], specify the processes and may be modify the structure (in a systematic way). As a result, we can calculate a future scenario. The same specifications may serve as a set of material and energy flow and stock accounts, which, as a real scenario, can be filled with data with aid of an ERP system component. The following figure shows a simplified entity-relationship diagram, which shows that it is relatively easy to separate the entities, which are required to represent the specific accounting system, from other entities, which are scenario-specific. This includes not only stock and flow accounts but also process specifications.

Modern technologies like web services and synchronization mechanisms make it possible to integrate local and remote components into a consistent software framework. The modeling components, running on personal computers, serve as a customizing tool for the real scenario and as a modeling tool, which derives future scenarios from the real scenario, provided by the ERP system. The first step of developing a future scenario is to "download" the real scenario from the ERP system (Fig. 3).

Fig. 3 Entity-relationship diagram (simplified) of an MFN-based CEMIS with three scopes: graphical user interface (GraphPlace, GraphTransition), accounting system (Net, Place, Transition) and scenario-related entities (Scenario, Stock, Specification)

6 Conclusions

This contribution discusses several arguments to develop a CEMIS as a software framework that relies on two different pillars: an ERP system component for past-oriented environmental management accounting ("accounting") and a PC-based modeling component, which allows design future scenarios ("modeling"). The consistent integration of future- and past-oriented data facilitates efficient eco-controlling. The PC-based modeling component can be designed as handy and easy-to-use office software. We use such an "App" as we use Excel and Power-point: in office, at home, on a business trip etc.

Decision support is not the only outcome of such a framework. Important are the side effects of using powerful modeling and simulation tools. We can develop and compare different scenarios; we can experiment with the models; we can assess the effects of specific improvements; we can compare different alternatives etc. Moreover, it is possible to find out problematic and unsustainable processes and structures; it is possible visualize possible improvements and differences between the real scenario and possible improvements, for instance with aid of Sankey diagrams [27]. In other words, the modeling component serves as a trigger of improvement processes, which question archaic structures and mechanisms. But as mentioned above, the modeling component does not only trigger improvements on the level of physical flows and stocks. It contributes to necessary communication processes [28, 29] which play a central role the transformation process towards a sustainable economy and society.

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Operational Integration of EMIS and ERP Systems

Florian Nottorf and Andreas Mastel

Abstract The reference architecture of [10] integrates environmental management information systems (EMIS) and enterprise resource planning (ERP) systems in a holistic and long-term oriented environmental manner. Building on this architecture, we developed an extended framework to operationally integrate EMIS and ERP systems. Our proposed framework goes beyond prior specifications as it offers a semi-automatic approach to model ERP information (such as production orders) as a material flow network in which each transition represents an operation of the production process.

1 Introduction

The first scientific publication on "environmental management information systems" (EMIS) appeared in 1989 [1]. Despite or because of its short history, the understanding of the scopes of responsibilities regarding EMIS is controversial. The *traditional* and reporting stream of research focuses mainly on descriptive, passive activities, such as setting up life cycle assessment or other reports [2]. On the other hand, the *process-oriented* stream understands EMIS integrated into the production process and considers substance-feedback between the individual stages of production or supports the implementation of cleaner production concepts [3–5].

The largest category of today's applications of EMIS represents material flow management, which is referred to as the common core element of EMIS [1, 6, 7]. When defining EMIS in an integrated manner with regard to business processes, it seems appropriate to consider the importance of a strategic, long-term integration:

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EMIS are informational systems for systematic collection, documentation, planning and controlling of operational environmental effects, which actively support the (operational and strategic) management control system in its duties. Given this definition, the conceptual integration of EMIS and enterprise resource planning (ERP) systems—as it is developed in this article—can only be a first attempt to successfully fulfill the task of strategic, environmental management.

There are many isolated applications responding to today's environmental business issues that consider economic and ecological problems in an integrative manner. Due to law and regulation floods, EMIS have been virtually plugged by existing systems. In this context, one speaks of "end of pipe" solutions [4]. While those applications can aid companies in reducing emissions, there have been no changes to existing production processes; synergies related to economic aspects continue to be used poorly. Therefore, strictly speaking, these "end of pipe" solutions contradict what has been requested by the commission of inquiry "Protecting People and the Environment" in its definition of the central EMIS-element, which states that material flow management is a "goal-oriented, responsible, holistic and effective influence of material systems, with goals from the ecological and the economic field while considering social aspects" [8]. Junker et al. [4] also require a holistic approach for the development of modern EMIS "which supports the entire supply chain". This harmonization includes both economic and ecological issues equally.

There are positive synergies for the simultaneous pursuit of economic and ecological objectives [9] . To realize these synergies, environmental goals must be specified and integrated into the strategic objective system. Environmental objectives must be defined and quantified to not only make them verifiable, but to also create criteria for success and failure. Additionally, in a holistic perspective, the feedback of multiple target systems needs to be considered. That is, material flow models require information of accounting, production planning and controlling, which often can be found within ERP systems. But, as Teuteberg and Straßenburg [9] point out:

> the developed concepts, reference models and prototypical implementations have not become integral part of business practice and management […], the integration of material flow management system with manufacturing planning and control systems as well as accounting systems is therefore a necessary step that has not yet been taken.

Our work aims to close this gap by proposing an extension of the conceptual framework of integrating EMIS and ERP systems by Funk et al. [10].

Funk et al. [10] present a reference architecture that enables product environmental impact information to be automatically calculated for customer use. The IT architecture aims to provide information on the environmental impact of products and order items for operational decision making. Through their approach, existing systems can be integrated with minimal changes: the architecture requires the ERP system to be linked with various EMIS to integrate job-related environmental information. The central interface forms an integration platform, to which all systems are linked.

Although the reference architecture provides important conceptional insights of how to integrate EMIS and ERP systems in a strategic, holistic manner, important problems remain unsolved, as noted by Teuteberg and Straßenburg [9]: “the integration of material flow management system with manufacturing planning and control systems as well as accounting systems is therefore a necessary step that has not yet been taken”. With regard to the reference architecture of [10], the question becomes: which services and functions need to be defined for ERP systems in conjunction with EMIS to analyze the environmental impact (e.g. of an *order item*) for further automated use?

The remainder of this paper is structured as follows: based on the reference structure of [10], we clarify difficulties that arise when automatically integrating EMIS and ERP systems. By extending the reference architecture, we then present a conceptional framework to operationally integrate EMIS and ERP systems.

2 Operational Integration of EMIS and ERP Systems

2.1 Structure of the Framework

The aim of the framework and its services is to automatically model environmental information in EMIS as material flow networks, based on a company’s present ERP system data model. Compared to the architecture of [10], we add another layer—the EMIS controller—between the integration platform and EMIS (see Fig. 1). That controller is the connector between the integration platform—or the ERP system—and the EMIS. To illustrate its routines, we suppose two stages: one, in which all environmental information for a given product has already been analyzed and stored with all relevant information as a finished scenario in the allocation table within the EMIS controller; and the other, in which there is no environmental information available yet for a given product. For the latter, we will illustrate the conceptional framework of our proposed semi-automatic integration of EMIS and ERP systems in more detail.

Based on a request by the integration platform, the EMIS controller automatically calculates and returns an *order item’s* environmental information to the user in the form of an input/output balance sheet. Therefore, the EMIS controller checks an allocation table for the appropriate order item and whether a fitting scenario has already been stored to the production order of the final product.

In modern EMIS, the entire production process is maintained as a material flow network and saved as a so-called *scenario*. Now assume that all environmental information has already been set up and stored within the EMIS controller. Then, the controller engages the EMIS to calculate the respective product scenarios (’project data’). The final product may contain several modules, which are also present in separate material flow networks. If there are corresponding modules used in the manufacturing process for the final product, each module will be added

Fig. 1 Conceptual framework of integrated EMIS and ERP systems within the reference architecture of [10]. *Source* Own

to the final product in form of an input/output balance. Within the table “material master”, the EMIS stores both the materials of the ERP system and the substances that are maintained manually during the production process.

In the second case, wherein there is no scenario for an order item within the EMIS, the user is prompted to create a material flow network through a GUI. The creation of these material flow networks and their difficulties are discussed in the following chapters.

2.2 Transferring the Manufacturing Processes into Material Flow Networks

The aim of the interface and its services is to model material flow networks, based on the present model of ERP system data, and enrich them with environmental information. The *construction contracts* (including their *bill of materials*, *work plans*, and *material master*) of the ERP come into consideration for this transfer.

Though it is possible to use the work plan events to determine input materials of a material flow network, the difficulties that arise from them and how they can be conjoined is not stored in these work plans. This is due to the data structure of the production planning system. These difficulties are illustrated in Fig. 2.

If there is no scenario related to the product within the mapping table of the EMIS controller, the GUI supports the user in creating a material flow network and an associated scenario. We propose a framework with a three-step semi-automatic process to transfer and connect the information of the ERP system via the EMIS controller into the EMIS.

As a *first step*, a basic network will be developed that models the production process with the construction contract of the final product or its components. This basic network needs to be subsequently enriched with additional environmental information that is not available in the ERP system.

All operations are represented as transitions in a material flow network. Initially, they are not connected to each other. In Fig. 3., the production order is shown in the upper half. Only the operations of the work plans are required to create the initial transitions. This initial process of creating the transitions is fully automatic up to this point: each operation is assigned to one transition. However, it is also conceivable that further transitions can be created manually by the user.

Fig. 2 Difficulties while transferring the manufacturing processes to material flow networks. *Source* Own

Fig. 3 Automated creation of transitions using operations from the production order. *Source* Own

In the *second step*, it is necessary to determine the input points that go into the transitions. As previously noticed, it is not known what materials originate from a process in the ERP system. However, the information—which materials go into those processes—*might* be stored. This information can be used for a semi-automated construction of the material flow network, as these incoming materials are suggested to the user as input points (see Fig. 4).

It is important to notice that the weights of the connection between places and transitions have to be normalized such that the network models the production of one unit.

In the *third step*, the outgoing and connection points of the transitions need to be specified. Within the ERP system, there is no direct mapping between tasks and the resulting outputs. But just as in the previous step, there are certain structures in the ERP system that can be used as suggestions for incoming places. For example, if the previously defined incoming points clearly correspond with all components of a unit list, one might assume that the root element of this bill is the outgoing point of this transition. Furthermore, if there are clear similarities between the output places of one transition and the input places of the next transition, one can assume that these two places need to be combined into a connection place. Thus,

Fig. 4 Automated assignment of materials to the transitions as input. *Source* Own

based on pattern recognition algorithms, a semi-automated process may assist the user for the definition of input places as well (see Fig. 5).

After the output and connection places have been created and connected to each other in the production order, the entire manufacturing process has been modeled as a material flow network. But until this point, the network does not consider the material level, which is essential when assessing the environmental impact. Compared to Isenmann [11], we propose that the material level is taken into account in the material flow networks to keep the data model of the ERP system unchanged. To accomplish this step, the material flow networks are enriched with environmental information on the substance level.

Fig. 5 Semi-automated production of output and connection places. *Source* Own

2.3 Enrichment of Material Flow Networks with Environmental Information

Our proposed solution for automated enrichment of material flow networks with information on a substance level attaches to the fact that work plan operations are always directly connected to machines or workstations. The running time of the machines is measured by the operations and their set-up times, processing times, and idle and transport times. Normally, the costs needed for internal management accounting are derived from the occupational time of the machine to create respective cost rates. This traditional concept leads to the following idea: for each machine in the ERP system, the environmental effects in the EMIS controller are modeled per unit time. This is similar to a cost allocation rate with the difference that "costs" of in- and outgoing materials (and their environmental impacts) will be used instead (see Fig. 6).

Fig. 6 A model of the production's environmental impact, depending on a time scale. *Source* Own

This solution provides that environmental effects can be measured by the machine and stored in regard to time. As the temporal assignment of each machine is defined in the work plans, environmental effects can be installed as proposed values in the network, thereby making it possible to determine the environmental impacts each product or assembly causes.

The environmental impacts that are associated with each machine can be stored in an additional allocation table in the EMIS controller. Maintaining the environmental effects of this table is separate from the process of modeling the material flow network and ideally should be completed beforehand.

3 Conclusion

Based on the reference architecture of Funk et al. [10], we developed a framework to integrate EMIS and ERP systems. The proposed semi-automatic process offers enough flexibility to enrich data from manufacturing processes with environmental information. Compared to Insenmann [11] our approach considers the production process at the operational level. The proposed framework goes beyond prior specifications as it offers an approach to model each production order in a material flow network in which each transition represents an operation of the production process. This high level of detail not only meets the requirement of the reference architecture for Funk et al.[10], but simultaneously can be used for the analysis of additional service processes, as well.

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Enterprise Architectures for Addressing Sustainability Silos

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Abstract A need exists for behaviour change and transparency in modern organisations where the focus needs to shift towards sustainability thinking rather than just sustainability reporting for compliance reasons. The number of organisations which are undertaking Green Initiatives and reporting on sustainability are increasing. However, many of these organisations are not viewing these initiatives strategically. The effect on information requirements and business processes is often not considered and the available tools and technologies are not used to their full potential. As a result, whilst sustainability reports are produced, the underlying infrastructure consists of "sustainability silos" comprising of a lack of integrated systems, inconsistent data and information where the integrity is not reliable. In order to address these issues this study investigates the extent to which organisations consider environmental information requirements and processes when planning their information systems and Enterprise Architecture (EA). The inclusion of Green Initiative strategies into the design of an organisation's enterprise systems and EA is proposed. This will ensure alignment between environmental management and IT planning and result in integrated systems, an improved sustainability reporting process and more effective decision making regarding the environmental impact of organisations.

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1 Introduction

Environmental information is becoming more relevant in organisations today due to legislative requirements such as the Triple Bottom Line (TBL) [1]. Organisations have to report on their impact on the environment in a format known as the environmental (EN) report, which forms one component of the sustainability report. The other two components consist of social effort responsibility and the traditional economic report [2]. The concept of sustainability and sustainability reporting has become an emerging research field as well as a major focus area for organisations [3]. Sustainability reporting is

> the practice of measuring, disclosing, and being accountable to internal and external stakeholders for organizational performance towards the goal of sustainable development. A sustainability report provides a balanced and reasonable representation of the sustainability performance of a reporting organisation – including both positive and negative contributions [2].

In a recent Ernst and Young [4] survey, 66 % of respondent organisations reported that they had an increase in enquiries from investors about sustainability-related issues in the past 12 months. The results also showed that the growth of corporate sustainability of the companies surveyed had moved beyond compliance into viewing sustainability more strategically. The inclusion of sustainability into the strategy and initial plans of an organisation is also proposed by Magoulas et al. [5]. The strategy should include the needs, goals and requirements of Green Initiatives, which will prevent "sustainability silos" and un-integrated systems.

In South Africa, organisations listed on the Johannesburg Stock Exchange (JSE) are legally obliged to submit annual sustainability reports. In addition a number of non-JSE listed organisations are producing sustainability reports voluntarily and reporting in particular, on environmental impact. Research has shown that the challenge to integrate, retrieve, store and present environmental information has existed since the 1960s [6]. This has been confirmed by more recent studies of sustainability reporting in South Africa [4, 7], which reported that the main challenges are finding the right data, assessing its credibility and determining which data is material for reporting purposes.

Other challenges relate to the tools used for producing sustainability reports. The Ernst and Young [4] survey revealed that the tools used are rudimentary, even primitive, compared with those used for financial reporting. Companies cited that spreadsheets, emails and phone calls are the principle tools used to compile sustainability reports. Only one in four respondents used software packages. Despite a number of tools being available for sustainability reporting, these tools are not being used to their full potential.

These challenges can be overcome by viewing sustainability reporting strategically and not as just a legal compliance issue done as an afterthought. The use of Enterprise Architectures (EAs) has been increasingly utilised in organisations to plan the business strategies, information strategies and technologies of an organisation. However designers of these EAs seldom take into account Green

Initiatives which will impact information and reporting requirements. The EA provides the entire view of an organisation and is the repository of the data and complexities in organisations. Klein and Gagliardi [8] define Enterprise Architecture as

> The fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution [9].

The aim of this study is to propose a framework for the incorporation of Green Initiative strategies into an organisation's Enterprise Architecture. The framework includes technology for addressing sustainability reporting challenges; as well as techniques for process re-alignment and green reengineering. The study also makes the following contributions:

An analysis of the relative usage of sustainability reporting in several organisations in South Africa and their perceptions of the process; and

An analysis of the incorporation of sustainability or Green Initiative strategies in the EA of an organisation.

A number of studies have investigated the status of sustainability reporting globally and in South Africa. Selected studies have proposed technical and reference architectures for sustainability reporting systems, however, studies providing a comprehensive framework for the whole process from a strategically and organisational perspective are limited. The layout of the paper is as follows: Sect. 2 states the research objectives and methodology of this study. Section 3 highlights techniques for sustainability reporting and approaches for business and Information Technology (IT) alignment. The results of an investigation into the sustainability reporting process and use of EAs of several organisations are presented in Sect. 4. Section 5 provides recommendations from the results of the literature and survey and discusses the conclusions and future research.

2 Research Objectives and Methodology

This research study will investigate the process of sustainability reporting and of EAs in organisations and will propose a framework for incorporating Green Initiative strategies into an EA. The research also investigates what sustainability reporting issues are most relevant to organisations. The scope of the study will focus on medium to large organisations that operate in South Africa (SA) that do sustainability reporting. The research questions addressed in this study are:

RQ1. What reporting guidelines and tools are used by organisations to support environmental reporting?
RQ2. What are the challenges of environmental reporting?
RQ3. Can an EA be used to address the challenges of environmental reporting and to prevent sustainability silos?

An inductive approach was used in order to derive an EA framework for incorporating strategies for Green Initiatives into each of the four domains of an EA. The framework was designed based on a literature review of research studies in this field. A deductive approach was then followed and a survey of organisations in South Africa was undertaken to determine their usage of environmental reporting guidelines and tools, their use of EAs as well as the challenges they are faced with. The research instrument used in the survey was on-line questionnaires consisting of questions regarding the use of sustainability reporting and Enterprise Architectures in organisations. The questions in the survey address the first two research questions (RQ1 and RQ2). The last research question (RQ3) is answered by a combination of deductive reasoning from the results of the literature review as well as from the results of the survey. More in depth evaluations of the proposed framework are currently being undertaken to further verify and validate the framework.

3 Techniques for Sustainability and Environmental Reporting

Sustainability reporting is becoming a global trend and an obligation in current times and this provides a challenge to managers [10]. One objective of sustainability reporting is to benchmark and compare sustainability performance internally as well as externally in terms of standards and other regulatory factors [11, 12]. Other objectives for sustainability reporting are to [11, 12]:

- Improve communication with stakeholders about sustainability using the sustainability report as a dialogue tool;
- Improve sustainability marketing;
- Initiate programs to eliminate hazardous substances in materials and parts purchased; and
- Increase sustainable use of natural resources (for example, land, forests and animal population).

The Global Reporting Initiative (GRI) is a global network work-based organisation that is renowned as a global standard for sustainability reporting [2]. The principal intentions of the GRI, now known as G3, involve the widespread importance of disclosure on the environmental, social and governance aspects of their performance by entities. A global consultative process which is based upon a multi-stakeholder approach is responsible for creating the G3 guidelines. The GRI produces a wide-ranging framework that is extensively applied by entities on a worldwide basis. Three out of four of the participants in the Ernst and Young [4] survey cited that they followed the GRI reporting framework.

The Guidelines for Sustainability Reporting (the Guidelines) outlines the content to be included in a sustainability report (the Report), Standard Disclosures consisting of Performance Indicators as well as guidelines for reporting on technical topics in the Report. An environmental (EN) report should include all the information regarding the processes of an organisation's impact on the environment whether positive or negative [2]. The G3 guidelines assists companies to identify what information is needed in an EN report which forms part of the sustainability report. The guidelines classify the information for an EN report into categories, known as EN indicators. These indicators are grouped into sections of the EN data applicable for an EN report. The sections are: materials, energy, water, biodiversity (the inputs) as well as emissions, effluents and waste (the outputs).

Rea's [13] report shows that the primary challenges faced by South African companies are those connected to environmental impact namely: water scarcity, increase in electricity demand and increasing fuel prices. The five environmental indicators in Rea's [13] report which were reported as having the most challenges for South African organisations are, in order of ranking from highest to lowest:

- EN16: Total direct and indirect greenhouse gas emissions by weight;
- EN4: Indirect energy consumption by primary source;
- EN3: Direct energy consumption by primary energy source;
- EN8: Total water withdrawal by source and
- EN18: Initiatives to reduce greenhouse gas emissions and reductions achieved.

Organisations wanting to improve on their environmental impact have adopted many Green Initiatives [12]. This leads to the challenge of storing, obtaining and retrieving sustainability information effectively and efficiently in order to be able to report on it [13, 14]. Sustainability reporting in many organisations satisfies legal compliance, but is often accompanied by sustainability "silos", un-integrated systems and inconsistent information. In order to report on environmental information several systems, tools and technologies have been developed. However, the Rea [13] report shows that whilst organisations doing sustainability reporting are increasing, the approaches, techniques and tools they use to do this are still lacking. Speshock [12] recommends the alignment of an organisation's strategy or mission with work processes, decisions, information and technology (Fig. 1). Work processes and decisions can be classified as part of the operational area, whilst information and technology form part of the technological area of an organisation. In order to make the most effective use of technologically available tools, business strategy and IT must be aligned [12, 15, 16]. Velitchkov [15] further proposes the use of EAs for closing the gap between strategy definition and execution and between business and IT at strategic and operational level.

Techniques for sustainability reporting can be therefore classified into the three process levels of an organisation: strategic, operational and technological. At the strategic level, an EA plays a critical role in supporting and informing the strategic decisions made within the organisation [17]. EA is defined by the Open Group Architecture Framework (TOGAF) EA as comprising of four domains [8], namely:

The **business architecture** defines the business strategy, governance, organisation, and key business processes.

The **data architecture** describes the structure of an organisation's logical and physical data assets and data management resources.

Fig. 1 Alignment of IT with an organisation's strategy (Adapted from Speshock [12])

The **application architecture** provides a blueprint for the individual application systems to be deployed, their interactions, and their relationships to the core business processes of the organisation.

The **technology architecture** describes the logical software and hardware capabilities that are required to support the deployment of business, data, and application services. This includes IT infrastructure, middleware, networks, communications, processing and standards.

An EA includes the plans for how an organisation will build, deploy, use, and share its data, processes and IT assets [18]. Green Initiatives should be included in an organisation's strategy, therefore one way of ensuring alignment of a Green Initiative and business strategy with IT is to make use of an EA. Additional strategic techniques for Green Initiatives include balanced scorecards and strategy maps [7, 12]. The use of a balanced scorecard can result in a clear picture of the relationship among sustainable practices, corporate strategies and profitability [19].

At an operational level business process integration and improvement is critical for Green Initiatives and sustainability reporting, which in turn will improve information quality [12]. The foundation for execution of the EA includes core business processes and IT infrastructure [17]. Business Process Reengineering (BPR) are techniques which can help organisations fundamentally rethink how they do their work in order to dramatically improve customer service, cut operational costs and become world-class competitors [12]. Green reengineering is defined as

> The application of BPR concepts that consider environmental impact, by, for example, proactively redesigning and radically improving manufacturing, packaging and distribution processes to become more sensitive to the natural environment.

At a technological or application level, the Internet and Web 2.0 technologies can vastly improve the difficult task of providing sustainability information to stakeholders. These tools can assist organisations with improving the effectiveness and quality of their environmental information and reporting processes.

4 Proposed EA Framework for Environmental Reporting

The proposed framework is based on the incorporation of Green Initiatives into an organisation's IT strategy as recommended by Magoulas et al. [5] and [12] and is classified into three levels, namely strategic, operational and technological. Secondly the framework incorporates business strategy and IT alignment through an organisation's EA as proposed by several studies [15, 16]. This alignment is then mapped to the four domains of an EA proposed by the TOGAF framework, namely: business, data, application and technology architecture (Fig. 2). Organisation's must view sustainability strategically, and include their Green Initiatives in their EA. The strategy must be incorporated into the business architecture domain of the EA, and includes the setting of strategy and objectives for all three elements of sustainability, namely: environmental, economic and social. Managerial processes are considered here.

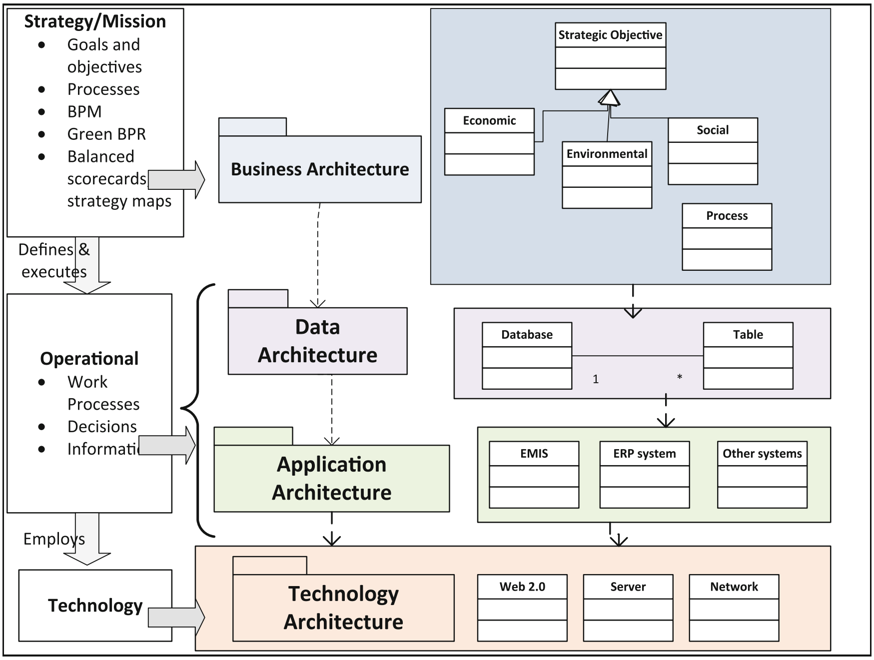

Fig. 2 Framework for integrating green initiative strategies into enterprise architectures

At the operational level, the application and data architectures must be considered. At this level, the business processes which are impacted by these strategies will therefore be taken into account using green reengineering which will result in improved process design and management. The data and application architectures must be designed based on the strategies identified in the business architecture. Examples of applications include internal information systems, Enterprise Resource Planning (ERP) systems as well as those designed specifically for environmental information management, such as Environmental Management Information Systems (EMIS). The technological architecture must also be aligned with the business architecture. Whilst several architectures for EMIS such as STORM [20] and AISLE have been proposed [21], these studies focus on technical architectures and not on the alignment of existing EAs with an organisation's environmental strategy.

5 Research Findings

Several organisations were contacted and requested to participate in survey with on-line questionnaires. A number of participants from several different types and sizes of organisations were willing to participate (Sect. 5.1). The results were analysed and several findings were made (Sect. 5.2).

5.1 Participant Profile

A survey approach was used whereby management reported on the status of sustainability reporting and the use of EAs in their organisations. Twenty one organisations were included in this study and were from a range of industries from mining and resources, to insurance to transport (Table 1). Three major role players in the automotive manufacturing industry participated, as well as three large insurance companies. Nine of the organisations are not listed on any stock exchange and therefore not required by legislation to do sustainability reporting. The respondents ranged from IT managers and Enterprise Architects to sustainability reporting managers.

In order to establish content validity, a pilot test of the questionnaire took place. Based on the results of the pilot study several changes were made to improve the questionnaire. The closed-ended questions were all statements which had to be rated using a 5-point Likert scale where 1 represents *Strongly Disagree* and 5 represents *Strongly Agree.*

Table 1 Participants profile (n = 21)

Company	Industry	Listing status	Number of employees
A	Agriculture	Not listed	101–500
B	Accounting and audit	Not listed	51–100
C	Assurance	Not listed	500+
D and E	Automotive manufacturing	Listed	500+
F	Automotive manufacturing	Not listed	101–500
G	Aviation	Listed	500+
H	Banking and financial services	Listed	500+
I	Broadcasting	Not listed	101–500
J	Consumer goods	Not listed	101–500
K	Energy and utilities	Not listed	500+
L	ICT	Not listed	1–10
M, N and O	Insurance	Listed	500+
P, Q and R	Logistics and transportation	Listed	500+
S	Paper and paper packaging	Listed	500+
T	Pharmaceuticals	Listed	500+
U	Telecommunications	Not listed	500+

5.2 Survey Results

Of the organisations surveyed, 52 % (n = 11) practice sustainability reporting both externally and internally (Table 2). Only one of the participating organisations was found to not report on sustainability. This organisation is a non-JSE listed organisation in the broadcasting industry, who only report on economic and social issues, and not on environmental impact (Table 3).

One of the questions related to whether or not an organisation considers the information and reporting requirements of sustainability or Green Initiatives when designing their EA. Only 43 % (n = 9) of the organisations surveyed do take into account environmental information when designing their EA program (Fig. 3).

Participants rated several objectives for adopting an EA program (Table 4). The objective that was ranked highest was *"To improve risk management"* ($\boldsymbol{\mu}$ = 4.29), while *"Include/Improve environmental concerns"* ($\boldsymbol{\mu}$ = 3.29) was rated second lowest. This confirms the earlier result where more than half of the participants stated that they did not include environmental information concerns in their EA.

Participants rated their inclusion of sustainability reporting in their organisation's processes (Fig. 4). Economic reporting had the highest frequency for Strongly Agree (n = 18), with social reporting the second highest frequency

Table 2 Organisations status of sustainability reporting (n = 21)

Status of sustainability reporting	n	%	Listed (n)	Unlisted (n)
Does not report on sustainability	1	5		1
Practises sustainability reporting internally only	9	43	4	5
Practises sustainability reporting internally and externally	11	52	7	4
Total	21	100	11	10

Table 3 Status of enterprise architectures (n = 21)

Status of EA program	n	Percentage (%)
Has an EA program	12	57
Expanding our EA program	5	24
Thinking about adopting an EA program	1	5
No specific EA program	3	14
Total	21	100

Fig. 3 Integration of environmental information into EA

(n = 16) and environmental reporting rated lowest (n = 12). This confirms that economic reporting still takes priority in most organisations and that environmental reporting is not always included in an organisation's processes.

Participants were asked to list any challenges that they are experiencing with environmental reporting which relate to the information required. One respondent stated that one challenge was "*Capturing the data and information for reporting and auditing purposes*". Another respondent stated that *"In our organisation—like*

Table 4 EA program objectives (n = 21)

Objective	Mean (μ)	SD
Improve risk management	4.29	0.85
Improve enterprise decision making	4.19	1.17
Business efficiency/transformation	4.14	0.79
Increase effectiveness of audit compliance	4.14	1.12
Support system integration	4.10	1.00
Improve IT governance	4.10	1.00
Improve data integrity	4.10	1.26
Reduce operating costs	4.05	1.12
Improve technical integrity	4.05	1.02
Ensure continuity of organisational knowledge	4.00	0.89
Promote technical infrastructure	3.90	1.34
Reduce technical complexity	3.81	1.25
Include/improve environmental concerns	3.29	1.35
Support outsourcing initiatives	3.19	1.25

Fig. 4 Inclusion of sustainability reporting in an organisation's processes

many other ones in SA—there is no overlap between EA and Environmental issues, and in any case the interest in the latter is minimal unfortunately." Access to information and getting data on time were two other challenges cited. The cost of collecting all the necessary information for environmental reporting was an issue reported by one respondent. The respondent from the aviation industry stated that environmental reporting is not being given the priority that it should be.

Fig. 5 Sustainability reporting tools used

An analysis of the results showed that MS-Excel is the most commonly used tool for sustainability reporting (Fig. 5). In the *"Always"* category, MS-Excel had the highest frequency count (n = 17) and internal Information Systems (IS) had the second highest the *"Always"* category (n = 12). Sustainability reporting systems and Web-based reporting tools are not widely used within these organisations. This confirms the Ernst and Young [4] and Rea [13] studies showing that the tools available are not used to their potential.

The top five EN indicators as ranked by participants were the same as the top five indicators identified by Rea [13], confirming the primary challenges as being energy, greenhouse gas emissions and water problems. However, the two studies had slight differences in the order of the five indicators. The top five ranked indicators in this study were, in order of ranking:

- EN3: Direct energy consumption by primary energy source ($\mu = 3.71$);
- EN18: Initiatives to reduce greenhouse gas emissions and reductions achieved ($\mu = 3.52$);
- EN8: Total water withdrawal by source ($\mu = 3.29$);
- EN16: Total direct and indirect greenhouse gas emissions by weight ($\mu = 3.29$); and
- EN4: Indirect energy consumption by primary source ($\mu = 3.14$).

6 Recommendations, Conclusions and Future Research

In this paper the researchers presented and discussed results from a review of the relevant literature as well as from an investigation of organisations doing sustainability reporting. From an in depth literature study it was revealed that there is a need for management to address Green Initiatives and the related environmental information requirements and process issues at a strategic level. The survey of South African organisations confirmed other studies that whilst JSE listed companies are doing sustainability reporting they are not addressing it at a strategic level. The investigation of this study provided several contributions not provided in other studies. Firstly, the results of the survey revealed that most of the participant organisations are almost always using MS Excel spreadsheets to assist them in the process of monitoring and managing their sustainability reporting endeavours and are not using the more sophisticated tools available. Secondly, the study investigated the type of EAs used in these South African organisations, as well whether or not organisations incorporating their Green Initiative strategy and business processes in their EA. The results showed that organisations are still not viewing sustainability strategically and environmental issues are not regarding as having the same priority as financial issues. As a result systems and information are not integrated and several sustainability silos exist.

Sustainability reporting will gain more importance in South Africa, as resources are depleted and government regulations are implemented. It is important for more South African organisations to adopt Green Initiatives and start reporting on sustainability matters especially if the organisations' processes have an impact on the environment. This study has highlighted the need for management to address sustainability reporting at a strategic level. The proposed framework incorporates Green Initiatives into an organisations' EA in order to align IT with these strategies and result in integrated systems and avoid sustainability silos. This framework can assist managers with the process of producing sustainability reports more effectively and efficiently, thereby improving their competitiveness and corporate governance.

This study was limited by the number of organisations willing and available to participate. Future research into evaluations of EA frameworks for Green Initiatives and sustainability reporting is needed, particularly with more organisations. Studies which investigate the implementation of such architectures would be beneficial to the research community. More in depth investigations of organisations in South Africa and in other countries could be undertaken in order to be able to investigate approaches to environmental reporting from both a local and global perspective.

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Municipalities and Sustainable Tourism: Challenges, Requirements and Added Value

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Abstract Municipalities as well as companies are currently addressed by their stakeholders to report their (environmental, social and economic) impacts. If municipalities are following the ideas of the Agenda 21, that are based on the results of the United Nations Conference on Environment and Development in Rio de Janeiro (1992) when focusing on sustainable tourism, they are facing a gap due to missing indicators focusing on topics in the field of sustainable tourism and boundaries of the sustainability report. The analyzed sustainability reporting guidelines, such as the Global Reporting Initiative 3.1 or the United Nations Global Compact, lack to support municipalities due to missing indicators and support in defining the sustainability report's boundaries. This chapter will indicate challenges, requirements and added value for municipalities with respect to sustainable tourism, by extending current sustainability guidelines based on a literature analysis and interviews done in the project "Next Generation CEMIS for Environmental, Energy and Resource Management" (IT-for-Green).

1 Motivation

In recent years, sustainability and sustainability reporting as a dialog between companies and stakeholders became a major topic. Currently, more than two-thirds of listed companies state out that sustainability is an important topic—in 2003 it was only about 40 % of them. According to a survey by Sustainable Business

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Institute [1], founded by the Federal Ministry of Education and Research, interviewed companies agreed with the statement that “sustainability means long-term economic success” (over 86 %).

The growing public interest on sustainability reporting shows, that environmental awareness in Germany is increasing, since environmental protection was mentioned as the third important topic after labor market policy (first place) and economic and financial policy (second place) in a representative public survey done by Borgstet et al. [2]. Environmental protection is one topic in the field of environmental aspects discussed in the triple bottom line of a sustainability report following Elkingtons’ approach [3] which focuses on the relationships between environmental, social and ecological aspects.

Therefore, municipalities following the ideas of the Agenda 21 based on the results of the United Nations Conference on Environment and Development [4], are facing different challenges caused by the number of guidelines and principles. As a result, they demand for more information.

First steps towards such a guideline for a municipality (without the focus sustainable tourism) were done by municipalities on their own. On state level, such as the sustainability report of the town of Ladenburg, Germany, which is based on an indicator-based guideline for a locally agenda 21 developed by several environmental ministries in south of Germany (2009) gives an example.

The agenda 21 is one of the most discussed outcomes of the United Nations Conference on Environment and Development. In paragraph 28 local authorities such as municipalities are invited to follow the agenda 21 and adopt it to locally requirements:

> 28.3. Each local authority should enter into a dialogue with its citizens, local organizations and private enterprises and adopt [4].

The agenda identifies objectives, activities and means to support such a development but—at the same time—it lacks a guideline for approaching a dialogue with stakeholders. To our opinion, sustainability reporting as one part of environmental communication within business communication can be such an entry point.

However, all research done by non-governmental organizations, research institutes, universities and enterprises in the field of sustainability reporting guidelines are lacking support for municipalities. An adopted framework, indicator set or principals to highlight what should be included into an sustainability report of an municipality focusing on sustainable tourism is missing.

The focus of our approach is to extend sustainability reporting towards a reporting from a sustainable tourism point of view and to highlight impacts on the environment and local culture. The chapter will present the results of a literature analysis of guidelines and sustainability reports such as Ladenburg, Germany, and will extend the results by expert interviews done in the project “Next Generation CEMIS for Environmental, Energy and Resource Management” funded by the European regional development fund in the north region of Germany. The chapter will present a research in progress and will be summarized in a catalogue of indicators and an approach to determine the boundaries and indicators for a reporting municipality focusing in sustainable tourism.

2 State-of-the-Art of Sustainability Reporting

Municipalities as well as companies are currently addressed by their stakeholders to present their environmental, social and economic impacts. Currently, no standard for sustainability reporting exists but the "quasi" standard for European companies and non-governmental organization: The Global Reporting Initiative (GRI) with their guideline GRI G3.1. The European Commission recommends the Global Reporting Initiative G3 guideline [5] as quasi-standard for corporate responsibility reporting [6] for enterprises with more than 500 employees to report in a triple-way. On this account, we will focus on the local agenda 21 and GRI G3.1 for our analysis. Other guidelines and standards are not analyzed in detail. For further reading see e.g. [7] who summarizes different guidelines and standards with their strengths and weaknesses.

The GRI G3.1 guideline represents an indicator-based approach extended by reporting principles and profile of the organization. It focuses on statement, quantity and quality indicators such as statement from the most senior decision maker of the organization CEO or water consumption as indicator.

The GRI G3.1 guidelines are structured as shown in Fig. 1, here the sustainability report and the process of generation is separated into the following parts:

Fig. 1 Global Reporting Initiative G3 reporting framework [5]

- Principles and guidance defining the following inputs
  - Report content
  - Report quality
  - Boundary setting
- Standard disclosures generate the following outputs for sustainability reports
  - Company/organization profile
  - Management approach
  - Performance indicators

Performance indicators are partitioned into standard disclosure and sector supplements. Performance indicators from the standard disclosure can be located in every company e.g. energy consumption. The sector supplements are indicators which are added to the performance indicators of the standard disclosure to exposure impacts not covered and which are characteristic for a sector such as mining or the mineral sector which adds performance indicators for land use payments and local workforce, or management.

A further approach is an activity-based approach as United Nations Global Compact which is built on ten principles in the topics: labor, human rights, environment and anti-corruption. Each topic except anti-corruption is divided into several parts and is described with examples such as "Increasing worker productivity and retention" for human rights by United Nations [8]. The United Nations Global Compact is based on a voluntary basis. However, by participating as member in the program one has to publish every year a so called "Communication on Progress (COP)" to have the status "active" otherwise after one year the status will be changed to "non-communicating". And after one further year with no new COP, a company will be ejected. If the level of transparency has not been reached or any errors in the COP have been discovered, a 12 month time period is granted as "learner grace period" to fulfill all requirements. COP is focusing on the impacts of companies in the topics labor, human rights, environment and anti-corruption. The requirements of a municipality focusing on impacts towards sustainable tourism (environmental, social and economic) are not covered or in any way supported by the United Nations Global Compact principles. According to Leipziger [7], the strength of United Nations Global Compact is the motivation and dissemination by the support of the United Nations Secretary-General to involve countries and companies which are new to the corporate social responsibility and sustainability reporting. The ten principles are on one hand a strength and a weakness due to the coverage of a broad range of companies but are on the other hand not supporting certification or benchmarking due to the definition of missing defined indicators.

Another guideline in the field of corporate social responsibilities (CSR) by Sustainability Accounting is the standard SA8000. In contrast to United Nations Global Compact SA8000 is designed as certification standard. The SA8000 requires from companies to integrate a management system in the IT landscape and business processes to handle the information flow and business process exemplary by well-defined training, and management of communication issues. The standard focuses on process and performance along all three pillars of sustainability. The requirement of a management system is seen as strength and weakness because not all companies want to adjust their business process to cope with demands from the management system or the investment which is necessary if no management system exists in the company. On the other hand the strength of SA8000 with management system will influence business processes and thus support companies in daily business on the long run.

Another approach is given by the International Standard Organization (ISO) 26000. Guidance on Social Responsibility consists of seven clauses covering:

- Scope,
- Terms and definitions,
- Understanding social responsibility,
- Principles of social responsibility,
- Two fundamental practices of social responsibility,
- Social responsibility core subjects and
- Integrating social responsibility throughout an organization.

The seven clauses are enriched by the tools and orientations mentioned in the references of the ISO 26000 guidance. The German version of the Guidance on social responsibility (2011) has 175 entries in the reference list.

Any organization or company following the ISO 26000 guidance has to accept the social corporate responsibility of their organization's impact and to identify and include stakeholders in the process of reporting. The next step is to expose activities and recommend processes to improve the impacts of the organization in the core topics of ISO 26000: organizational governance, human rights, labor practices, environment, fair operating practices, consumer issues, community involvement and development.

The international labour office (ILO) as specialized agency of United Nations focuses on a "Tripartite declaration of principles concerning multinational enterprises and social policy", and encourages companies to make economic and social progress announced to interested stakeholders. The guidelines focus on labor conditions and multinational enterprises. However, labor conditions could be one topic in sustainable tourism by hiring workers from the local employment market instead of hiring people from around the world. This would support the local market and community and lead to decreased daily travelling by workers [9].

A criteria catalog focusing on municipalities in the topic of the "Local agenda 21" is developed by the Ministry of the Environment, Climate Protocol and the Energy Sector Baden-Württemberg, Germany, and other governmental organizations and research institutes (2009). The criteria catalogue focuses on the topics environment, economy, social issues and participation (each topic has six criteria). As an example: "A1 Minor amount of waste" is supported by activities or services such as municipal waste collections in order to decrease material flows or the usage of natural resources. The criteria catalogue defines scope and aim of each criterion that is included in a local agenda of a reporting municipality.

An extension as result of the cities council Baden-Württemberg by Landesanstalt für Umweltschutz Baden-Württemberg [10] identifies 24 new criteria in five topics to enrich the existing catalogue:

- Nature protection and biodiversity
- Environment and health
- Energy and climate protection
- Transportation and mobility
- Waste and residual water

Further initiatives in the topics sustainability and CSR focus on a sector or are mentioned in the annex of the ISO 26000 guidance [11] as comprehensive initiative. We will indicate challenges, requirements and added value for municipalities with respect to sustainable tourism, by extending current sustainability guidelines based on a literature analysis and interviews done in the project "Next Generation CEMIS for Environmental, Energy and Resource Management" (IT-for-Green).

3 Sustainability Reporting Guidelines for Sustainable Tourism

3.1 Challenges

Municipalities following the ideas of the Agenda 21 are reporting their impacts by the indicators following "Local agenda 21" by the Ministry of the Environment, Climate Protocol and the Energy Sector Baden-Württemberg [12].

The University of Innsbruck and the County of Tyrol have generated a benchmark to analyze the current state of sustainability of municipalities which indicates challenges that have to be faced in the process of generating a sustainability report. Therefore the European Foundation for Quality Management excellence model and a "Tiroler Unternehmenscheck" (Tyrol company check) are combined to benchmark the current state. Figure 2 shows an excerpt from the Tyrol company check (only available in German) [13].

The Tyrol company check as survey uses a list of economical, ecological and social questions and are subdivided into following sections:

- Management
- Processes
- Results

In the survey the colors (green, yellow, orange and red in the company check) show answered questions and indicate if the municipality is currently acting in a sustainable way. In total, thirty questions are in the economical part, thirty-six in the social part and in the ecological 25 questions. The scale in the result part is as follows:

Fig. 2 Tyroler sustainable check [13]

- Green: Sustainable orientation of a municipality is visible. No actions necessary.
- Yellow: Sustainable orientation visible but optimization potential is visible for the next years.
- Orange: Orientation visible but municipality on the first stage towards sustainability. Most sections could be optimized.
- Red: Currently the municipality does not fulfill necessary activities to be called sustainable.

The benchmark (as self-survey) supports the identification of gaps in the sustainability strategy by evaluating the triple bottom line aspects of management and processes. The main challenge of a guideline for sustainability reporting for sustainable tourism are the missing indicators. The municipalities are not able to identify which data is necessary for analyzing their sustainable impact without technical support.

Another challenge is to adopt the boundaries of the sustainability reports. Travelling of tourists is an impact to be reported in the sustainability report which starts outside the municipal but is influenced by services and offers of the municipal to handle e.g. luggage it tourist come by train or anything else. The service is not carried out by the municipal but by other companies such as Deutsche Bahn AG.

3.2 Requirements

A first draft for an indicator catalogue supporting municipalities was created in the project by the Ministry of the Environment, Climate Protocol and the Energy Sector Baden-Württemberg, Germany, and other governmental organizations and research institutes (2009) which involves several environmental ministries in south

Germany. The indicator catalogue enfolded 24 indicator in the topics: ecology, economical, social and participation (each topic has six indicator). The guideline with the current 4th version is updated consistently and further indicators extend topics with 18 additional indicators such as “municipal environmental indicator”. The challenges for municipalities focusing on sustainable tourism are that indicators of sustainable tourism are missing e.g. what is the impact of water and energy consumption done by tourist compared to the totals, what travel preferences are the tourist using or how many workers are hired from the local workforce to reduce travelling from home towards their workplaces?

Analyzing the sustainability report of the municipality of Ladenburg [14], Germany, based on the 24 criteria currently requires methods and techniques to handle criteria such as biodiversity. The criteria catalogue misses to support municipalities with documents and tools to support gathering and accessing data to analyze the current state of biodiversity. Such indicators are not covered.

Another requirement would be to adopt boundaries of the sustainability report if travelling is provided by external services (e.g. Deutsche Bahn AG) but influences the impact. Currently 24 % of the energy consumed by Deutsche Bahn [15] will be provided by renewable energy sources and in 2050 the railways will use only energy from renewable energy sources. Currently, if the municipality increases the percentage of their tourists using the railway, the emission of carbon dioxide will decrease compared to the usage of cars caused by the current 24 % of energy from renewable energy used by Deutsche Bahn AG and other factors.

The analyzed guidelines lack support for municipalities and especially municipalities focusing on sustainable tourism. The mentioned indicator catalogue which is focused on municipalities is not able to handle necessary boundaries of a sustainability report. Sustainable tourism requires that employees are hired from the local employment market to support the local community and to decrease environmental emissions coming from daily travelling of employees.

In the IT-for-Green project (http://www.it-for-green.eu) interviews with personal from a municipality in the north-west of Germany with the focus of tourism indicates that following criteria (see below an excerpt) or data should be contained in a sustainability report from their point of view:

- Data from the municipality
- Data from companies belonging to the municipality
- Data from companies located in the municipality which influences the impacts (social, economical and ecological)
- Tourism requires travelling of their guest
  - Public transport
  - Train
  - Ferry
  - Parking Areas (with and without costs)

Sustainable tourism begins with travelling tourists that should be supported by special offers from the municipality such as handling of luggage by using public transport. Therefore, the guideline should be able to be enriched and adopted towards sustainable tourism. The guideline United Nations Global Compact which is activity oriented by ten principles does not describe indicators required to adopted the basic principles towards sustainable tourism.

3.3 Added Value

Current environmental communication enriched by social and economic data, which are the three pillars of sustainability following [3], to present corporate social responsibility is done by generating sustainability reports. The shift of chapter-based sustainability reports towards internet-based sustainability reports following [16] enables a more complex and stakeholder-oriented reporting. More and more indicators and extensions of sustainability guidelines are available. Voluntary reporting focusing on marketing causes a demand for the inclusion of several information sources and databases from the company or municipal IT landscape.

The inclusion of the environmental impact generated e.g. by travelling of guest increases the reliability of a sustainability report. Reliability is a main principle to be supported in sustainability reports. The travelling practice of spa guest and employees influences social, economical and ecological aspects. Increased usage of public transport decreases the request of parking areas, decreases emissions from individual transport and offers new prospects such as handling of luggage, transport of spa guest with carriage or electric cars. In the case of the interviewed municipality all spa guests have to use a ferry due to that the municipality is an island which also holds true for the transport of the waste from the island.

Another criterion which is influenced dramatically from tourism is energy and water consumption as seen on islands in the Mediterranean Sea which has to be covered in the sustainability report without discouraging potential spa guests. Several islands require transporting drinking water by ship to overcome shortages routed in the amount of spa guests. Others like the municipality in the IT-for-Green project may cover all required water from a fresh water bubble under the island which requires careful usage.

A sustainability reporting focusing on sustainable tourism would increase the transparency of the impacts of each guest. An example of the requirements for one guest should be calculated to highlight the impact of decisions and activities each guest could personally influence. Another benefit will be the reliability of the activities of the municipality which will be assisted by a sustainability report covering all activities, services and impacts generated by tourists.

4 Summary and Outlook

Analyzing in detail GRI3.1 and Local Agenda 21 and a basic analysis of the other guidelines such as United Nations Global Compact, Sustainability Accounting 8,000, ISO 26000 or International Labour Office, we found that the guidelines and standards are not covering indicators and further requirements for tourism.

The indicator catalogue and the handling of boundaries have to be extended to be able to support the generation of a sustainability report with focus on sustainable tourism.

We presented the research in progress in the field of sustainability reporting as part of environmental communication. Current sustainability guidelines lack the possibility to set boundaries of reporting. Especially the field of sustainability reporting requires to set borders of reporting independent from the level of influence e.g. different approaches for borders of sustainability reporting following [17–19]. Sustainable tourism starts with the choice of travelling of each spa guest which can be influenced by the municipality by offering service bundles to support sustainable offers such as traveling by train and use of an electro automobiles to transport luggage of spa guest or guest to their place of stay.

The chapter identifies the lack of support in sustainability reporting guidelines and standards. The guidelines only support reporting influenced directly by the reporting company. Trends as GRI 4th version of guidelines called G4 are showing that supply chain disclosure is one main trend in upcoming reports due to the networks and relations between companies. This has to be included into sustainability reports focusing on sustainable tourism.

The identified added value of sustainability reporting mentioned above has to be extended in a next step towards a sector supplement following the structure of GRI. This is part of the ongoing research which will support the research on corporate environmental management information systems as done in the Next Generation CEMIS for Environmental, Energy and Resource Management.

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The Green Product Lifecycle and Services: Is There a Gap?

Timo R. H. von der Dovenmühle and Klaas Schmidt

Abstract IT Products are often bundled with services. One reason is the development of business structures within the industry nations. The Service enhance by its significance, while the production is transferred to other countries. This change has a great impact to the lifecycle of products. It is an open question, if this development has a positive effect to sustainability or if new problems arise. This chapter discusses alterations to the Product Lifecycle in order to consider the impact of Services to sustainability.

1 Introduction

The idea of services had a great impact to the economy. Regions, decades ago characterized by industrial production of goods, nowadays are dominated by the service industry. For instance, services cause 66.7 % of the gross domestic product (GDP) in 2009 in European union (EU) [1]. Kondratieff, who labeled this stage of development as the fifth Kondratieff cycle, predicted this development. Information technology (IT) is part of the sixth Kondratieff cycle [2], p. 91. The main difference to the past cycles is the increased interdependency of formerly autonomous economic regions and/or markets.

Many Companies outsourced the production to original equipment manufacturers (OEM). It is a prospective development based on expected consolidation effects, that OEMs will undertake the design and engineering in the future, as well. If OEMs does the steps of design, engineering, and production, the client company

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itself fulfills just the task of blending a product with their brand. While this could be acceptable for a well-established company, this would prevent new companies from getting into the competition. There is the risk of competition by OEMs as well, as market shares of formerly pure manufacturers like those that Asus illustrate [3], p. 33.

As a result, consumers lose sight of companies as a product provider. They are now service providers, which are capable to handle versatile aspects of IT operation. Following this strategy is not a disadvantage for the companies. Consumers expect the full range of benefits regarding a product. The combination of physical goods and supporting services drives the customers' perception aspired by the provider. Beside consumer expectations, the development of market places let providers accept new challenges:

- Within the industrial nations, the market is saturated. Existential needs of consumers are generally settled.
- Many product categories reached a level of development, where a product-based separation from the competitive environment is difficult to achieve. The outcome of this is that provider loses their physical product as a unique selling point.
- In a saturated market the entrance for new providers is a much greater challenge, while established participants fight with low price elasticity of supply due minor product differentiation.

With the exception of new product categories, which can affect the market share of vendors almost immediately, these characteristics are typical for industrial nations. The IT market faces further additional changes: In contrast to other technology markets, like the automotive sector, decline in prices avoids to prevent monetary losses. There are only limited possibilities to recover potential loss of sales, while defend the share of the profit during declining prices. Enhancements of the IT technology and productivity as well had a negative impact on achievable prices. As a result, even in a growing market with increasing sales, the profits not following the growth of sales at the same level.

2 Services and Consumer/Professional Demand

It is a challenge to merchandise services, if the offered product includes goods of high quality and/or the construction type of them minimize the customers need for support. In other words: if a product does not attract attention by malfunction, the customer will not notice a high-grade support service. A well-designed User Interface without great demands to customer skills is not helpful, if the main business model is selling training courses. Derived requirements to a good from a first level supplier imply a good (hardware) design, which supports service merchandising without being suggestive of inferior quality. In practice, casing quality directly noticed by customers would outweigh internal quality or maintenance and repair capabilities.

If the first level supplier is not representing the face to the customer, this tightens the development. The Mobile Communications Marketplace uses the service of subsidized replacement phones to defend shares within a saturated market. As consequence customers replaces their phones based on a regular time span. In this situation, a long-life operation phase of the phone is no demand of the customer. The service of a regular phone replacement shortens the expected useful life to e.g. 24 month.

Within the Consumer Market with short replacement time spans, (internal) quality of a good is even less important. This is reflected in product designs, like non-exchangeable battery packs', targeting planned obsolescence and/or maintenance service needs that resulting into nondurable goods. At first glance, this should be an obvious downside of a product. From a consumer's viewpoint, this product design combined with excellent support seems without prejudice. A malfunction that appeared two times repaired on guaranty could appear even as surplus. The professional service is easier to notice and to communicate than a product with no malfunctions at all.

Within the Business Market, this is not true. Computer and communication equipment are asset investments. As a result, economic criteria outbalance subjective ones. The period of use is the main criteria to calculate the cost fraction of an asset in relation to its usefulness, also referred to as cost/utility optimization. One mayor element to determine the period of use is the wear out. This factor is considered by accountancy regularly. In Germany, typical time spans for depreciation are 36 month (e.g. IT equipment) to 50 years (e.g. buildings). This time spans are based on experience and admitted by fiscal authorities for the determination of taxable income.

An important fact is the extended time span of utilization within the IT sector over the last ten years. User-requirements under-achieve the exchangeable hardware performance. Requirements defined by software did not follow developments within the hardware sector. A coexisting factor is the extended life cycle of software products. The Operating system Windows XP product lifecycle ends on April 8th 2014 [4]. The launch of this software was at October 25th 2001 [5]. This means, based on 36 month of expected depreciation, ten more years of utilization are possible. It is self-evident, that the hardware infrastructure would not last that long. Nevertheless, the hardware performance requirements are comparatively stable. From a customer's perspective, as strive a long usage time span is an economic requisite, utilization time advancements are the main objective.

3 Challenges

As illustrated, IT industry faces altering basic economic conditions. In the past, the market demand continuously surpasses supply. The advancements in hardware platform technology were not able to fulfill requirements generated by new software and use cases. Nowadays, computers have computing capacities far beyond the average requirement of users. Hardware is not running by its limit, but rather has power reserves within many ranges of applications. In consequence of this, the lifecycle of deployed IT infrastructure increases. Without a lack of capacities, there is no customer demand. Furthermore, there is only a reduced demand for advances in technology that could legitimate replacement purchases.

This trend is positive, if stated based on green indicators. A longer lifecycle implies lower raw material consumption. Reduced production expenditures are a positive result, as well. It is obvious that an economic valuation from the supplier position differ from this rating. Probably additional services are able to clear financial losses or even exceed the overall profit of a provider. It is a point of principle, if these economic driven services fulfill the goals of Green IT.

4 The Influence of Services to the Product Lifecycle Management

Product lifecycle management (PLM) implements a holistic view about the different phases a good is going through. Figure 1 follows the general idea like published in countless publications (e.g. [6], p. 245, [7], p. 157, [8], p. 165).

There are two mayor reasons to question this model. First, there is no recycling of goods. It appears that assuming the disposal of a good at the end of utilization has a great impact to the Design and Development phase. Second, customers are not waiting after phasing-out a good until all the phases through Production are done. As a result, the cycle is not really a circle. Why is that important? Within a circle, the lessons learned from a Recycling phase (respectively the Disposal phase) are an input for the new Concept phase. This assumption is not valid in the

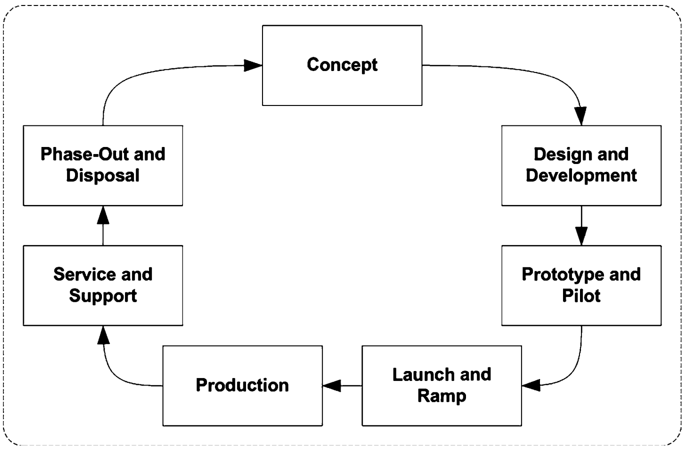

Fig. 1 Generic product lifecycle

real world, because the phases have different time spans. For example, the service induced time period of utilization within the sector of mobile devices is 24 month. The product lifecycle from a producers view is much shorter—it is common to work with time spans of about 6 month until the introduction of the next generation of products/goods. As a result, the phases Design and Development to Service and Support passed through asynchronous to the Concept phase.

Figure 2 follows a linear model. The main difference, despite the fact that it is not a circle anymore, is in phase Phase-Out and Disposal/Recycling. Instead of assuming a disposal of the product, a recycling phase is introduced [9], p. 83 f. This is the first step to a Green PLM. *S7.1* is an information path (dotted), while *S7* represents the process path (solid). A cycle is completed after finishing *S7*, while *S7.1* is optional. Evidently, there is no way to get information back to a previous phase. This means, we need communication links back to previous phases of the product lifecycle. This link is introduced in Fig. 3.

Every link back is expensive, because modifications to a product design can have great impact to following phases. The relationship between the actual phase and resulting costs of a modification is visualized in Fig. 4. Concisely, it is way less expensive to modify results of phase Concept or phase *P2: Design and Development* than modify results e.g. in phase *P5: Production* [6], p. 245. It is obvious that results of phase *P7: Phase-Out and Disposal/Recycling* within a

Fig. 2 Generic product lifecycle sequence

Fig. 3 Green product lifecycle sequence

Fig. 4 Cost sum within a product lifecycle

Green PLM have to be an input for the requirements defined in phases *P1:Concept* and *P2: Design and Development*. The impact of phase *P6: Service and Support* is an input for phases *P1: Concept* and *P2: Design and Development*, if we enhance the relevance of Services for the product.

This model prevents the possibility of going backward the process, because otherwise there is the risk, that modifications would not be observed at earlier phases. In a worst-case scenario, the modification is unknown in phases Concept as well as in Design and Development. The result is higher costs at later stages, based on the cost curve in Fig. 4.

Figure 5 illustrates a Product Lifecycle considering the effects of the phases Service & Support as well as Phase-Out & Disposal/Recycling in the beginning of a cycle.

- *P1*: Concept—Determination of requirements and specification contract.
- *P2*: Design and Development—of the new product based on the specification from *P1*.
- *P3*: Prototype and Pilot—Validation of producibility.
- *P4*: Launch & Ramp—Built and start of the production line.
- *P5*: Production—of the product.
- *P6*: Service and Support—Services after sale. Product is delivered to the customer.
- *P7*: Phase-Out and Disposal/Recycling—After usage, services regarding disposal of the product and support for replacement purchases.
- *S0*: Conception—Requirements from *P7* can be considered from earlier generations of a product or as actualization of the current product. The additional requirements from *P7* reveal green criteria. Information from *P6* can underscore this, because shortened period of use or high maintenance costs could be an

Fig. 5 Service influenced *green* product lifecycle indicator for adversely product concepts. Within *P1*, lessons learned from former projects/product generations will be assimilated.

- *S1*: Specification—the specification includes the requirements defined in the product concept. Like in *S0*, information from *P6* and *P7* will be used to optimize the specification. The main difference is that the findings will affect the actual product while within *S0* they have their main impact to the requirements of a new product. Optimizations will affect the actual generation and the updates/facelifts of it.
- *S2–S6*: Implementation—no changes to the generic product lifecycle.
- *S6:1*: Operating experience—Operating experiences like maintainability, and/or device failures have to be documented in order to affect the requirements within the Concept phase.
- *S6:2*: Operating experience—Information regarding the basic conditions of the product, design based on operating experiences, will be used to enhance the lifetime of *S6*.
- *S7*: Product termination—No changes to the product life lifecycle.
- *S7:1*: Recycling experience—While *P1* and *P2* consider future recycling process requirements, further developments could change actual recycling rates. This long term collected data enhance requirements of the next cycle concept.
- *S7:2*: Recycling experience—Maintainability is a crucial factor within *S6:x*. It also has an impact to the recycling process, because the efforts taking apart a product correspond with its maintainability. Challenging aspects of an actual design should affect *P2* via *S7:2* in order to enhance *P7* Recycling results.

5 Results and Discussion

This chapter is following the assumption, that a product equals the combination of goods and supporting services. As outlined above, there is more than one participant representing the supply of the product. Chances are that each actor within this supply chain acts opportunistic to increase their own share in profits. The profit rate for the first level supplier, the face to the customer, is mainly bound to the ratio good versus service. A product with low value in goods enhances their profit chance.

An enhanced Lifecycle realized via extended operation periods will have a positive effect to the product sustainability within the professional sector. Resource utilization will be increased without having a negative economic impact to the provider or the customer, either. This result is valid as long as the provider role will be seen holistic over all entities within the production chain. Individual entities have different interests and the expected opportunistic actions have to be minimized in order to fulfill non-economic goals. Nevertheless, in the consumer market the goals of consumers as well as Face to the Customer-Providers are to decrease the operation time. New devices beat ecologic aspects.

The connection between maintainability and recycling is not clear. While it seems to be like a fact that the recycling process is strongly affected by maintainability, new developments in chemical separation could dissolve this connection.

Another open question is the positive impact of more energy efficient product designs. In general, every criterion that allows reducing the energy consumption of a product is seen positive from an ecologic viewpoint. Therefore, within the last decades, the focus was lowering the energy consumption. However, since a couple of years, one condition changed: the percentage of renewable energy within the energy mix continuously increased. As a side effect, the eco footprint of products in operation improved, because of the lowered emissions of the used energy. It is to expect, that this development will be continued in the future. If raw materials are nonrenewable resources, it is highly questionable, if it is a prospective behavior to invest these materials to save renewable energy. In the past, lowered energy consumption was a valid reason to shorten the operation time spans of products by swapping to Green Products. Future trends could call the validity of that into question.

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Part II
Logistic Workshop

Service Quality Versus Sustainability: A New Conflict of Objectives

Wolf-Rüdiger Bretzke

Abstract Sustainability cannot be obtained at no charge. This is the first and most fundamental goal conflict we are exposed to after accepting sustainability as a new substantial requirement which all our future decisions and actions will have to fulfill. This article deals with a further goal conflict which is more specific and arises in the field of logistics. The fact that demanding service requirements can restrict our efforts to promote sustainability (and vice versa) is not obvious and has not yet been scrutinized in depth up to now. The article delivers an analysis of the drivers of this conflict and the barriers which have to be removed in order to advance sustainability.

1 Basic Definitions for the Analyses

1.1 The Concept of Sustainability

The term "sustainability" has become much overused in everyday language. As a consequence, this significant concept leaves too much room for hollow public "commitments" and management activities that do not go far beyond mere "green washing". A typical indicator for this conceptual aberration is the frequent debates about "green logistics". Whereas sustainability must be understood as a definite condition of a system, green is merely a color. This is unsatisfying both for scientific research and for practitioners looking for a sound basis and a mental guideline for their respective work.

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In accordance with [1], I classify a system as being "sustainable" if it is adapted to a set of actual or foreseeable future conditions, determining factors and requirements in such a way that it can reach and/or maintain its desired state and requires no further adaptation as long as these conditions hold. Vice versa, I define a system as being "unsustainable" if it has left important adjustments unresolved and is thus bound to miss its targets. Admittedly, this is a rather abstract definition, which is not limited to the evaluation of systems in the field of logistics. (It can, for instance, also be applied to social security systems facing an aging population, or to a banking sector carrying leverage effects to an excess.) Yet this is rather an advantage than a shortcoming, because it supports debates across different disciplines and fields of action on the basis of a common understanding of a basic issue concerning the future of mankind.

Usually the notion of sustainability is closely associated with the three-pillar model (people, planet, profit) introduced by Elkington [2]. Often this "magical triangle" is even treated as an indispensable part of the definition (see e.g. Ott and Doering [3] and their reference to the preambles of the EU treaty). As logisticians cannot do much against social inequality or child labor, I drop that respective pillar and substitute it by the task of maintaining mobility in our increasingly congested traffic infrastructure. Bearing in mind that mobility is an outcome variable, the third reference system of sustainability is therefore freight traffic (the critical measuring unit being the reachability of places within an acceptable time frame). Mobility is threatened by the congestion of our traffic infrastructure, which in turn essentially results from an insufficient utilization of vehicles.

1.2 The Meaning of Service

In many industries, competition has shifted away from the original (hardware) products, which have become more and more interchangeable, towards an increasingly differentiated and more demanding delivery service. A fair number of manufacturers have seized the opportunity to turn into service providers who carry out production. But even the service sector itself yields some examples of highly developed service promises, which the respective vendors hope will be of advantage to them in their own markets.

Without a clear definition of this notion, service can neither be managed nor explored by scientists. Therefore we have to remove all colloquial vagueness from the term "service" and provide a more concise definition with regard to the field of logistics. Following [4], service can thus be defined as *supporting customer processes by means of supplier capacities and processes*. This definition appears to be self-evident, but it has a serious consequence: in order to enhance the service profile of a company, one has to gain a deep understanding of the customer's processes that need to be supported or even replaced.

Within the field of logistics, service has a lot to do with the management of time. For instance, short lead times enable a customer to reduce inventory days of reach (safety stocks) or—with regard to spare part distribution—to minimize a machine's downtime. Very often, service is based on an exchange. The supplier accepts higher costs or reduced efficiency in order to help his customer save time and money. Wholesalers in the pharmaceutical industry who deliver drugs to pharmacies several times a day are a concrete example of such a trade-off. Furthermore, this example gives us a first indication of the existence of a conflict of objectives between the promotion of sustainability and the expansion of delivery services.

2 The Impact of Demanding Service Requirements on the Pursuit of Sustainability

2.1 The Point of Departure: Service and Sustainability as Mutual Restrictions

Within the design of logistical networks, service profiles act as requirements and as restrictions which provide an orientation, while at the same time scaling down the space of acceptable solutions (for a more detailed discussion, see [5]). In principle, the requirements of sustainability can be categorized likewise. Whatever we plan or do in the future: the consequences of our actions must not interfere with the conservation of the scarce resources we have to pass on to our descendants and the goal of restricting global warming to the politically accepted limit of two degrees Celsius. "Sustainable development is development that meets the needs of the present without comprising the ability of future generations to meet their own needs" [6]. Moreover, Diamond [7] already confronted us eight years ago with the accurate diagnosis that "the world society is presently on a non-sustainable course". So mere conservation might possibly not be enough. Transforming our economy into a sustainable system is a very challenging task, and this applies to all its subsystems, including logistics.

The fact that demanding service requirements can restrict our efforts to promote sustainability (and vice versa) is less obvious. This goal conflict is new on our agenda and has not yet been scrutinized in depth. The best way to illustrate this is by providing concrete examples. The classic grand delusion of German traffic policy is the promise to shift a considerable amount of freight traffic from road to rail. Although this could reduce greenhouse gas emissions by more than 80 %, the modal split has not changed within the last twenty years. When analyzing the reasons for this perseverance, one will soon realize that the service which the railroad operators can offer does not match the requirements of short and flexible lead times, which have become a standard in many of our industries (especially those that have to deal with a large product variety and short product lifecycles). We have unlearned the ability to wait and, while striving to have all we need at our disposal within the shortest amount of time, we pay the price in the form of pollution levels that are clearly higher than needed and are therefore fostering global warming and congested roads. Service requirements can limit the pursuit of sustainability.

The latter would not happen if the requirements of sustainability functioned as harsh restrictions in a similar way, limiting our scope of permissible actions. For historical reasons, the constraining impacts of sustainability on service appear to be less rigid. Our traditional understanding of common goods (such as the climate, the oceans, biodiversity, freshwater systems) as resources that can be used free of charge has prevented us from accepting that there are limits that should not be exceeded if we want to preserve our planet. This will change to the extent that governments act as the owners of these common goods and charge money for their usage with prices reflecting their scarcity. The best example for the effects of such an internalization of external effects is the market for emission certificates, which follows the principle of "cap and trade". (For a more detailed explanation of this model, see [8]). If the amount of tradable pollution rights is adjusted properly, companies will have to choose whether to accept the costs of reducing their emissions or buy their way out. In both cases, this will increase the price of all activities affecting the environment and reduce the demand for the respective products and services. Markets regain their steering function.

For instance, the transport of prawns from Hamburg to Morocco for shelling will be eliminated, because this unnecessary strain on both the environment and the traffic infrastructure was only acceptable as long as external costs remained uncompensated, transportation prices did not reflect the true costs and there were no eco balances and carbon footprints in place to make this environmental insanity transparent. Nevertheless, it remains to be seen whether these changing conditions will be strong enough to reduce service levels to a sustainable level. Seeing as everybody has gotten used to them, there is the danger of nobody daring to make the first step.

At any rate, it is harder to neglect the way in which increasing bottlenecks in our infrastructure constrain logistical systems and services. If mobility goes down, the individual feedback is immediate. (However, the estimation of the social costs of traffic jams is beset with some uncertainty. According to a position paper of the European Conference of Ministers of Transport [9] presented in Sofia, Bulgaria, in 2007, the economic costs of traffic jams across Europe amount to about 1 % of the GDP and thus wipe out parts of our economic growth.)

2.2 The Root Causes of the Rising Competition Against Time

Anyone who is supplied by slower modes of transport such as the railroad—which, on top of everything else, are also bound by invariable cycle times where the latest possible pick-up time is concerned—must be able, at a relatively early stage, to say what they (or their customers) are going to need in the near future, at the same time as taking precautions for the risk of error, which could be minimized by means of "quick response" models. Longer transport times not only require the recipients of the goods to make firm commitments with regard to resource and material needs at an earlier stage, but also make planning in logistics more relevant and aggravate problems related to predicting demand, which is essential for the cross-company synchronization of supply processes and for defining the required volume of safety stocks. In a world of uncertain needs and demand, early commitments represent a more or less hidden form of risk transfer from the senders to the recipients, which in turn explains why clients prefer to order from suppliers who offer short response times: they relieve them of risks.

The only downside that the Kraft Foods Company complained about with regard to the eco friendly shift of green coffee transports to the railroad on the route from Bremen, Germany, to Vienna, Austria, is that they could no longer make changes to their predefined weekly needs—and it is to be noted that with a product like green coffee, issues such as a broad range of different variants and short product lifecycles, which tend to be drivers of need-related uncertainties, are rather insignificant. (For more information on this example, see [10]).

"Time is the secret weapon of business. Progress in response times can compensate for all the other differences that are essential to a company's overall competitive advantage"—such were the words of Stalk and Hout even as early as 1990 [11]. And the supply chain experts Simchi-Levy et al. assess that "the importance of lead-time reductions cannot be overestimated" [12]. Since then, two of the main drivers of complexity and dynamics, namely product proliferation and the reduction of product lifecycles, progressed even further and brought something into being which I call the "complexity trap".

Part of this trap is attributed to the fact that the interplay of complexity and dynamics leads to a problematic time divide in management and to a conflict between the objectives pursued by customers and suppliers (see Fig. 1, taken from [13]). If complexity grows, many companies will potentially need greater response times in order to adapt to unexpected changes, because they cannot be prepared for everything. On the other hand, growing dynamics lead to increasing uncertainty, and, as a result, customers tend to call for ever shorter response times (thus trying to shift complexity to their suppliers). Such developments bring about evermore rigidly coupled processes, which, in the end, are no longer capable of absorbing potential disruptions.

Fig. 1 The complexity trap as a time divide

The consequences are as follows: there is strong pressure to respond to the increasing unpredictability of sales (which can no longer be controlled by other means) by switching from push principle to pull principle, thus consistently replacing plan-based activities by reactive, order-driven processes, keeping both delivery times and delivery frequencies short and centralizing stocks, which consequently leads to sending small transport batch sizes over long distances and permanently having express freight operations up one's sleeve as a "requisite variety" for emergencies. Obviously, the shift of competition from hardware products to services and the counter bidding on ever shorter lead times was not always voluntary. But it had destructive effects on both the environment and on our overstressed traffic infrastructure each time.

2.3 Unconsidered Side Effects of a Rigid "Lean Management"

Occasionally, you will hear that the drivers of complexity mentioned above are said to be an inevitable consequence of a switch from sellers' to buyers' markets (which would mean that the marketing managers fostering the individualization of products are "managed" by said circumstances to at least the same extent as they themselves believe to manage said circumstances). What cannot be denied is the fact that "lean management" is a modern concept, which especially logisticians are proud of and implement on purpose. Initially, this concept applies to production processes rather than to delivery services. But on the one hand, one of the key messages of this concept is a strict orientation of all activities towards the needs of customers. And on the other hand, the consequent elimination of all buffers and time reserves leads to a rigid coupling of activities, making supply chains prone to risks, which can affect customers directly. What logisticians have overlooked in the past are the spillover effects, which this concept can generate with regard to sustainability.

The term "lean management" generally refers to a consistent minimization of throughput time, which ultimately has a positive effect on liquidity as it leads to minimal cash-to-cash cycles. Compelling as that may seem, potential side effects were often neglected completely, although they might turn out to have a major impact—and not just with regard to sustainability. If consistently implemented, combining a strict demand orientation approach (pull), a rigid coupling of processes and an intense time compression leads to an increase in transport frequency accompanied by a reduction of transport batch sizes, narrows down the room available for balancing utilization levels, increases the necessity to use express freight transports to make up for time lost due to disruptions, and consequentially tends to destroy transportation and traffic route capacities. (Courier transports normally do not qualify for or are not capable of finding any return freight). Paradoxical as it may seem, at the end of the day we will have to accept that part of the efforts made to regain lost time by adopting lean management concepts have been in vain, as traffic congestion will eat up the extra time gained, and we will see processes slowing down and capacities going to waste, even though our original intention was to speed processes up and eliminate waste of any kind. We will fall victims to the previously unheeded side effects of our own actions and come to realize that our competition on service went too far.

2.4 Aggregation, Deceleration and Organizational Slack as Means to Promote Sustainability

The concepts listed in the above headline have one important thing in common: beyond their positive effects on the environment, they can help to boost the utilization of the means of transportation in use (thus contributing to a relief of our overburdened traffic routes), and they only become accessible if we are ready to loosen the service requirements delineated above. Instead of delivering an all-embracing theoretical approach, I will explain this principle using some informative and representative examples.

The first examples relate to milk run tours with respect to local deliveries. Within open transportation networks, this leg of transport is also called the "last mile," and it is common knowledge that the final delivery of goods entails disproportionate costs and emission levels. "The average small van (1.5 t) generates around 4.6 times more CO_2 per tonne-km than larger vehicles," as observed by Edwards et al. [14] regarding delivery vehicles such as the ones used by parcel services. The first loss of efficiency which deserves closer attention results from the tendency to individualize services to the greatest possible extent. If all recipients of shipments grouped into a daily tour are granted the option of arranging individual delivery time slots, this concession generates suboptimal routes and corresponding unbundling effects in the shipment density of these tours (less stops per tour).

The second loss of efficiency is related to the volume delivered per stop. In the past, it has been observed that in different industries the frequency of regional supply tours has been raised considerably. Fast food chains have switched to a daily supply of their restaurants, car manufacturers replenish their dealers with spare parts on at least a daily basis, and, as mentioned above, we consider it normal for pharmacies to receive deliveries from their wholesalers several times a day. This service enables the affected partners to allocate inventory on a higher stage in the supply chain (in general, regional warehouses), where pooling effects create increased turnover rates and greater product availability. Yet on the other hand, the utilization of vehicles decreases, which means that we need more of them to achieve the same output. When reassessing these secondary effects against the background of sustainability, such services are put into question. Figures 2 and 3 illustrate this effect.

Fig. 2 Order-driven milk runs

Fig. 3 Daily quantities in case of fewer deliveries

These figures show order volumes per delivery during one week. While Fig. 2 reflects order-driven day-to-day supply in its most original state, Fig. 3 illustrates the situation when switching to a two-day rhythm (with an anticipated aggregation of the quantities required over the course of two consecutive days). In this case, the resulting key parameters provide especially valuable insights. Changing supply intervals results in a slight consolidation and brings down the variation coefficient (the ratio of standard deviation and median) from 0.23 to 0.09, meaning that the capacity needs are decoupled from fluctuations in daily order intake, thus producing a considerable capacity-balancing effect. If the vehicle capacities available in both cases are equivalent to the capacities required to satisfy peak demand, utilization would then go up from 74 to 88 %.

Lead time extensions can work in two different ways. If the lengthened lead times include time reserves, these buffers can be used to smooth the demand for transportation capacities. Figure 4 presents an idealized simplification of the fluctuations in daily order intake. (Bear in mind that a distinct oscillation is the unavoidable consequence of the pull principle, one of the core ideas behind lean management.) Aligning capacity planning (dotted line) with the peaks in demand

Fig. 4 Pull principle including time reserves

would ensure both minimal throughput time and perfect delivery date adherence, yet ruin the company as a result of an unacceptably low degree of average capacity utilization or due to excessively high prices. Without the buffers, reducing the capacity limits would occasionally result in pending orders.

Substituting service quality assurance based on *capacity buffers* by a utilization optimization scheme based on *order buffers*—a form of redundancy that would be more cost-effective from the supplier's perspective—would allow capacity operators to shift occasional peaks in demand to subsequent low-demand periods (arrows), thus "leveling the load". The result would be a problematic lead time variance, the average lead time being lower than in the first case. Obviously, in both cases customers would have to accept a reduction in service quality in order to enable their suppliers to foster sustainability.

Demand aggregation and load leveling can be achieved within the same mode of transport. Yet there is still another option for exploiting lead time extensions for the sake of sustainability: a change in the modal split. As mentioned above, in the past, shippers have widely neglected the services offered by railroad operators, because these offers did not fit into the clocked time cycles of their supply chains. In the foreseeable future this will change, because trucks will lose their competitive advantages to the same degree that they lose time and reliability on congested roads.

Nevertheless, we will not be able to make logistics sustainable without a deceleration of processes. Figure 5 illustrates the logic behind this assertion, while at the same time pointing to the root causes which have destroyed our ability to produce reliable demand forecasts in the past. In logistics, no single idea is so strong that it cannot be foiled by exaggeration. The mantra of strict vertical integration and rigidly coupled activities, which weaves its way through supply chain management literature like a golden thread, is precisely one of these ideas. Slimness (a moderate form of lean management) is healthy. Anorexia is not.

Fig. 5 The logic of deceleration

"In lean supply chain thinking, inventory is regarded as one of the seven wastes" [15]. The requirement of sustainability forces us to correct this view. Buffers cannot only increase the resilience of supply chains, they can also enable us to make a better use of transportation capacities, thus reducing greenhouse gas emissions and lightening the burden weighing down on our traffic infrastructure. The latter outcome can be regarded as a positive external effect. In principle, a change in the amount of emissions can be calculated with the help of tools that are publicly available (though in this case it might turn out to be difficult to trace them back to their root causes). The effects of an unburdened infrastructure can hardly be estimated or measured at all. As a consequence, one will find it hard to offset positive external effects against the additional costs which customers may have to bear as a result of a reduction of service levels.

2.5 Winners and Losers of Lowered Service Promises

When such service is reduced, we can clearly observe an outcome that is very common in this type of situation: there are three direct winners and one loser. The winners are the service provider (who saves money), as well as the environment and the mobility on our traffic routes. The losers are the customers, who make a contribution to environmental protection at the cost of longer waiting times. If, for instance, Volkswagen were to eliminate the second daily workshop supply tour in national spare parts distribution (which is the main reason why the company is able to exceed its competitors' service level and deliver on the same day as the order arrives), the elimination of this tour would have to be explicitly advertised as a contribution to environmental protection. Ultimately, however, the workshops and their customers would also have to pay the price in the form of occasionally prolonged throughput times in vehicle repair services. This uneven distribution of financial costs and benefits between different economic units adds complexity to the further development of our concepts and models and their transformation into systems that deserve to be rated as being "sustainable."

3 Summary and Outlook

Sustainability cannot be obtained at no charge. When you cut back on your own service in favor of the environment, you involve your own customers and force them to adapt their own systems (and thus perhaps to bear additional costs). This conflict can be mitigated by either offering a discount on the poorer service, or by showing your customers the reduction of the carbon footprint they allowed for, thus motivating them to play along. Neither measure tackles the root causes for the time pressure exerted on our logistic systems in the recent past.

The correlation between shortened product lifecycles and product proliferation on the one hand and sustainability on the other, a link to be forged by a deceleration of delivery processes, may not be obvious straight away. But it does exist. Within the near future, there will be no such a thing as a "green transportation." For that reason, sustainability will remain inaccessible as long as we remain unable to decouple traffic growth from economic growth. Within this context, we will have to find a new answer to the question of how much service we really need.

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A Standardisation of the Calculation of CO_2(e) Emissions Along Supply Chains: Challenges and Requirements Beyond EN 16258

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Abstract European countries are expected to reduce their total annual Greenhouse Gas (GHG) emissions by at least 20 % by 2020 and by 60–80 % by 2050, compared to 1990 emission levels. In order to achieve such reductions of emissions and thus to optimise their efficiency and effectiveness, it is necessary to be able to compare different supply chains. Standards for the calculation of CO_2 emissions are a prerequisite for such comparability. In the past, different organisations, corporates and interest groups have developed approaches for a CO_2 emission calculation standard. Given the diverse background and motivation of these players the resulting calculation approaches often are not compatible or complementary. With EN 16258 a first step towards a European standardisation has been taken. This research analyses in how far EN 16258 is able to build a basis for a global CO_2 emission calculation standard. Furthermore, it reflects how currently on-going work and efforts worldwide can lead to a further convergence of existing emission calculation tools.

1 Introduction

European countries are expected to reduce their total annual Greenhouse Gas (GHG) emissions by at least 20 % by 2020 and by 60–80 % by 2050, compared to 1990 emission levels (cf. [1], p. 12). With the current transport system being powered by 95 % petroleum products, it contributes about 23 % of global

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anthropogenic CO_2 emissions. The transport system therefore significantly contributes to the emissions associated with global climate change (cf. [2], p. 279; [3], p. 5). As a consequence, the reduction of $CO_{2(e)}$ emissions from transport plays an important role in the context of the realisation of the targets set by the EU council. Furthermore, more and more organisations, commercial as well as non-commercial, aim for a reduction of their $CO_{2(e)}$ emissions, as these emissions are directly related to the organisations' energy consumption. With energy costs on the rise, reduced emissions are usually related to a reduction of the organisations' operational costs. Furthermore, the growing environmental awareness of customers encourages organisations to try to reduce their environmental impact results. In this context, green logistics is becoming an important topic for more and more companies and many producers, shippers and logistics service providers. Many of them already follow a green strategy and calculate their $CO_{2(e)}$ emissions in order to identify the emissions' sources and to reduce their energy consumption. To effectively control and reduce $CO_{2(e)}$ emissions though, a reliable and clearly defined emission calculation method is needed to compare emissions over time as well as between different organisations, routings, transport modes etc.

In the past, no regulations or standards for carbon footprint reporting were available. Tools and methods were developed on the basis of individual needs and requirements. They were set up by different organizations independently, served different purposes and were developed with different intentions. As a consequence they differed in their approach, using different logic, data sources and calculations.

Many of these currently used tools have valuable starting points. The use of diverse methodologies and tools for emission calculation in different companies leads to incomparable and incompatible results though and, subsequently, to a lack of transparency. A comparability of the calculated results over time as well as between different organisations is needed as it builds the basis for the analysis of efficiency and effectiveness of different supply chains. Moreover, with an augmenting internationalisation of supply chains, most supply chains on global and on European but also on a national level are based on the co-operations of several transport and logistics service providers. To improve $CO_{2(e)}$ emissions of these multi-player chains, it is therefore, necessary that the calculations of the various supply chain elements are compatible and comparable; only than it is possible to calculate a carbon footprint on a product level as the carbon footprint is defined as "the sum of greenhouse gas emissions and greenhouse gas removals of a product system, expressed in CO_2 equivalents ($CO_{2(e)}$)" by the International Organization of Standardization (ISO) (see Fig. 1: Reasons for the development of a CO_2 emission calculation standard). Hence, a standardisation of the calculation of $CO_{2(e)}$ emission is required.

Fig. 1 Reasons for the development of a CO_2 emission calculation standard

2 Efforts to Establish an Emission Calculation Standard: A Short Overview

Initial efforts to address the problem of incomparability have been taken through standardisation initiatives such as ISO which established the environmental management standard ISO 14064-1. Another standard is the Green House Gas (GHG) Protocol (I-III), announced by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). These standards provide for guidelines for the calculation of greenhouse gas emissions on company level and they enable companies to calculate their Corporate Carbon Footprints on a general level. As a part of their general recommendations they also include the topics of transport and supply chains. Another standard currently prepared by the International Standardization Organisation, the ISO 14067, includes a standard with a focus on the Carbon Footprint of products. The stated draft version covers goods and services e.g. transport and will be announced in the middle of 2013. Besides ISO, WRI and WBCSD, the European Committee for Standardisation (CEN) applied itself to the topic of carbon footprint of transport. With the development of the EN 16258 the CEN/TC 320/WG 10 delivered a European norm for the calculation of energy consumption and for the calculation of the carbon footprint of transport services. Besides a standard for the calculation of CO_2 emissions, the EN 16258 covers the greenhouse gases N_2O (nitrous oxides), CH_4 (methane), and hydro fluorocarbons. The standard was published in December 2012 and mainly aims with its guidelines at companies of the transport and logistics sector, but it also addresses shippers and consignees. At this point in time none of these standards is enforced by law or regulations and their application is limited to voluntary use. France though is one of the first countries to introduce the legal requirement for the reporting of emissions as per 01.10.2013 and the calculation of these emission reporting will have to be in line with the EN 16258, according to the law. It is to be expected that other countries will follow suit, whether they all will apply the EN 16258 is not certain though. Beyond these standards, the following groups of activities for the calculation of emissions along supply chains can be clustered (cf. [4], p. 5):

- **Carbon footprint methodologies**: These offer guidelines and frameworks for how to calculate the carbon footprint along a supply chain, usually in the format of the previously mentioned standards; other standard-like guidelines and guidebooks include e.g. Cenex Guidelines (cf. [5]), the DEFRA guidelines published by the British Government (cf. [6]), PAS 2050 or the EU ETS for aviation (cf. [7]), even if their scope is usually limited to specific countries or regions and may not include all forms of transport. Furthermore, industry-led programmes and schemes that focus on a harmonisation within specific industries and which are based on voluntary application and compliance can be included into this group of carbon footprint methodologies.
- **Carbon footprint calculation tools**: Including web-based commercial, public and company specific tools, instruments, software and algorithms to calculate a carbon footprint; typical examples are SEMBA (cf. [8]) or EcoTransIT (cf. [9]). These carbon footprint calculation tools are often publicly available, free of charge and they cover all modes of transport, offering worldwide, regional or national coverage. Similar to the aforementioned standards though, and despite the fact that several of these tool include transportation specific aspects such as load factors and empty trips, they tend not to cover all processes of the transport chain and usually some of the supply chain elements remain uncovered.
- **Emissions factor databases**: This group covers public and commercial collections of greenhouse gas emission data that is needed in order to calculate carbon footprint.
- **Other activities and initiatives**: Including research projects, forums, awareness raising initiatives and communication channels to the topic of carbon footprint.

3 Challenges Towards the Development of a Standard

The impulses for all these developments derive from different sources (see Fig. 2: Reasons for the calculation of emissions along supply chains): some of them arise from a need within the transportation industry to raise the efficiency of energy consumption in order to reduce costs or to improve the image towards the customers. These initiatives aim for a calculation of emissions over entire transportation networks and want to derive a supply chain calculation from the network perspective. Achieving high load factors even if these may lead to detours from the

Fig. 2 Reasons for the calculation of emissions along supply chains

shortest way for the individual shipment. Other initiatives are rooted within the group of end-users or shippers. As a consequence their main focus is on the calculation of shipment and product related supply chain as they aim for an improved footprint of the individual product. This focus aims for the shortest, most effective transport.

As a result the databases, tools and methods are not all compatible with each other. Developments towards a standard for the calculation of emissions along supply chains are started but not realised yet. Beyond the different motivations and perspectives for approaching such a standard, various gaps within the coverage of the supply chain still exist. These gaps can regard single supply chain elements (see. Fig. 3: Example of an international transportation chain) as well as methodological aspects be related to the emission calculation of the supply chain as a whole.

4 Current Gaps in Standardisation

Even though the ISO (draft) 14067 and the GHG Protocol maintain requirements regarding the carbon footprint of products they do not focus on transport directly. Therefore, their regulations about the accounting of transport are not specific and remain ambiguous (cf. [10], p. 12). In contrast, the EN 16258 focusses on transport and logistics. As aforementioned, not only does it describe a method for the calculation of GHG emissions but it also gives advices on which data sources can be used for calculating. The vehicle operation system (VOS) remains a vague issue within the guideline though. The term is not further defined and specified.

Fig. 3 Example of an international transportation chain

Different transport modes have different characteristics; in consequence companies are left with a lot of room for interpretation. Due to this insufficient clarity in respect of VOS the standard suffers precision. Another weakness of the EN 16258 is the missing coverage of terminals and warehouses leaving companies without guidance on how to calculate the handling and storage of goods in the process of transport and logistics. This gap is particularly poignant in regards to the transport of temperature controlled goods. Furthermore, with more and more handling processes being outsourced to logistics providers, the complexity of handling processes increases and it is to be assumed that also the emissions related to these processes is increasing.

Another issue not solved yet is the inclusion of subcontractors. The calculation of their emissions needs to be captured and integrated within the supply chain. This is often causing challenges though as their tours and routings are not planned by the logistics provider who is delegating the consignment and hence such shipments cannot be seamlessly tracked and traced. In these cases emission calculations depend on accurate and reliable data being forwarded by the subcontractor. This is often difficult and data requirements as well as quality standards are neither defined nor can they currently be monitored reliably.

Despite the fact that a full well-to-wheel analysis is acknowledged, upstream energy processes are not reached by tools and databases yet and also input of the manufacturers of products is not yet considered within EN 16258 and definition for their calculation is missing. Most approaches for the calculation of emissions concentrate on the transport operations as performed by a specific actor; Transport performed by other actors or non-transport logistics operations are often neglected. Furthermore, differences often exist between modes regarding the level of precision and most databases and tools are geographically limited, focusing on the national context. To get the full carbon footprint of a product, different approaches, databases, methods have to be combined therefore at the moment. This further adds to the ambiguity of calculation results. Even when the same databases and methods or tools are applied for the calculation of the elements of a supply chain, the space for interpretation is usually so vast that different results can be obtained easily. Comparisons between different supply chains are therefore often misleading or impossible.

EN 16258 is the most encompassing and detailed official standard for the calculation of CO_2 emissions along supply chains. Apart from the aspects mentioned, it is to be taken into consideration that it is a European standard and therefore can substantially contribute to a harmonization of calculations of emissions within Europe. Many supply chains are international supply chains though. In how fare EN 16258 will establish itself beyond Europe as a standard is difficult to predict. As next steps it would therefore be important to ensure that any remaining gaps are covered, that all ambiguities which allow different calculation approaches are eliminated and that the efforts of standardisation are accepted on a global level. In the following the EU co-funded project COFRET is presented which aims at contributing to these necessary next steps.

5 Beyond EN 16258

The project Carbon Footprint in Freight Transport (COFRET) which is co-funded within the 7th framework programme of the EU and focuses on a further harmonization of existing tools and methodologies with a special emphasis on the first standardisation approaches of GHG Protocol Scope 3, EN 16258 and ISO (draft) 14067. COFRET analysed over 100 existing items (see COFRET project D2.1) that deal with calculation of the carbon footprint as far as transport and logistics is concerned and evaluated them (see Table 1: Top-level findings of COFRET analysis of calculation items).

The evaluation not only reflected the vast number of carbon footprint calculation tools and data sources but also the wide differences in quality, coverage and originality. It was ascertained that among the existing methods, tools and databases suitable elements for the calculation of carbon footprint of transport and logistics along supply chains exist but that a harmonised framework is currently still missing (cf. [11], p. 7).

A “white spot analysis” of gaps still to be found within the three existing standards in relation to the requirements of an entire supply chain is one of COFRET’s central elements, with the EN 16258 being the point of reference. Using real case scenarios, it will be investigated to which extend calculation results can differ if the various standards are applied to the same supply chain. It will also be analysed for which supply chain elements there are still no or ambiguous calculation approaches available within the EN 16258. A central aim of

Table 1 Top-level findings of COFRET analysis of calculation items (cf. [12])

Item name	Strengths of item
ARTEMIS	Detailed annual emissions database. Includes all modes except air. Manoeuvring and internal transport also included
Bilan carbone	Includes calculations on vehicle level, yet also offers a tonne kilometre approach
Carbon footprint for metro group logistics	Includes information on nodes and other supply chain elements. Private tool
CENEX	High level of detail. Company or vehicle level calculations
Clean cargo working group (CCWG)	Important emission database. Only direct short sea, transhipments, reefer container and idling are included
COPERT	Contains useful data for road transport
DEFRA	Contains allocation strategies and relevant data
DSLV	Based on EN16258, focus on road transport
EcoTransIT World	Includes a detailed and accurate database. Vehicle level
EMEP/EEA (CORINAIR)	Database distinguishes equipment types. Focus on air quality
EN16258	Published as a European standard in late 2012. Methodology includes imbalance and allocation
GHG protocol	Well structured, rather simple, widely accepted, very well known
GREET fleet	USA data, yet not primarily focused on transport
HBEFA	Widely accepted detailed database for road transport, valid for a limited number of countries
IPCC	Very complete, but on national level
JEC well-to-wheels analyses (WTW)	Good database on fuel production emissions (WTT). Can be combined with TTW emission data sources
LIPASTO	Detailed TTW data source
Map & guide	Example of how to implement EN16258 using HBEFA data within a calculation tool
NTM	Widely accepted yet private calculation tool, aims to cover all logistics operations
Smartrans—grønngods transport	Only road transport. Includes methodology for calculations on shipment level. Includes vehicle utilisation and gradients
SmartWay	Based on USA data for road transport, based on fuel consumption
Spin-Alp	Detailed road freight emissions, taking vehicle utilization and different route profiles into account
TREMOD	Compares companies to national emissions inventories. Not directly suitable for single vehicle or shipments
TREMOVE	Based on other sources. Regional level
Versit +	Detailed emission factors for road transport, different vehicle types and roads
World ports climate initiative (WPCI)	Widely accepted tool. Includes short sea, deep sea and terminals
Zicht op CO_2 stappenplan & emissiescan logistiek	Guideline on how to develop an emission calculation tool

COFRET is, to identify which of these gaps have to be filled and to make transparent to which extent the mentioned standards are compatible or complement each other.

With the vast number of various initiatives for the development of a calculation method existing already, one of the most important parts of the COFRET project is the close engagement of researchers and users on one side and the close cooperation with other on-going initiatives on the other side.

6 Conclusion

The analysis of existing methodologies has shown that important first steps towards a harmonisation as well as towards a standardisation of CO_2 emissions along supply chains have been taken. The development of EN 16258 is an important and necessary step forwards and towards achieving the needed transparency in calculating CO_2 emissions. This standard is a European standard though and there is no global organisation that can enforce its usage. The lack of transparency in regards to measuring approaches therefore will continue to exist for the moment and further work will be needed before a global standardisation will be achieved. Main challenges are to develop a standard which covers identified still existing open points and which at the same time is flexible and simple. Providing input for such a next development can be achieved by the means of independent, international projects such as COFRET, which aims to contribute to the input for an extended EN 16258. Furthermore though, it is important that a global alignment of efforts and activities can be achieved because supply chains often are international co-operations. On the communication side an international coordination and support of standardisation developments is therefore required beyond EN 16258. On the technical side it is important to ensure that all supply chain elements are covered and that all ambiguities that still might leave space for interpretation in regards to calculation are avoided.

7 Outlook

Initial steps to foster global collaboration, prompted by COFRET and other initiatives, are now underway. The established dialogue and partnership with existing initiatives needs to be further enhanced and developed as they are the basis for a convergent development of standardisation efforts. A close cooperation between research and industry is important to striking the right balance between the trade-off between accuracy and simplicity and practicality. In a first approach, it seems to be reasonable to find a solution that is applicable and straight forward so that comparable calculation results can be obtained. Such a form of comparability will enable the identification of best practice for supply chain solutions between different approaches. In a mid- to long-term perspective, though, it is important to also aim for accuracy of the calculation of emissions. Comparison will generate relative values. For being able to understand the entire impact of supply chain emissions and, subsequently, that of production processes, reliable absolute values for supply chain emissions will be needed. As no international body or organization is there to enforce the application of an emission calculation standard, the dialogue and exchange between the key industry players and international initiatives needs to take place on an international level to insure that the global potential for the successful development and implementation of a common approach is maximized.

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Information and Process Requirements for Electric Mobility in Last-Mile-Logistics

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Abstract E-vehicles are expected to become increasingly important in the logistics sector. Global use of delivery vehicles with combustion motors causes a significant percentage of total emissions and is responsible for climate change, shortage of fossil fuels and pollution in urban areas. Simultaneously, cargo volumes are increasing, especially in urban regions due to for example e-commerce developments. The purpose of this research contribution is to investigate the critical information and process requirements that logistics service providers and retailers are facing in their daily operations by using e-vehicles for last mile distribution. The main objectives are to identify these factors for the usage of e-vehicle in the last mile distribution and to analyze different parameters. The analytical hierarchy process (AHP) is applied to determine the importance and weighting of these criteria. Methodically, the AHP sorts competing factors by assigning percentage points to these factors and helps to sort each factors into a ranking. So getting clear statements the AHP is a very useful tool to indicate the priority and the importance of relevant success factors influencing the use of electric vehicles for last mile distribution. The value of this chapter is to provide guidance for further research as well as a framework and ranked criteria checklist for practitioners who are interested in gaining information in preparation of adding e-vehicles to their existing transport fleet.

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1 Introduction and Research Approach

Extreme weather, melting glaciers and an increasing sea level annually up to 3.7 mm are phenomena that are due to the influence of humans on the global climate. Because of the progressive globalization, rising supply chain shipment volumes [1] and the need for efficient logistics systems the carbon dioxide emissions of the logistics industry are at a high level [2]. A shift to sustainable business activities in context of green logistics concepts is also forced by the increasing scarcity of fossil fuels [3]. The pressure to innovate in the logistics industry is growing [2]. Regarding these various changes an adaptation for resource-saving measures seems to be useful. In the wake of this statement electric vehicles are expected to play a greater role in the future [4].

The usage of electric vehicles is slowly increasing. In the year 2020 shall be a million electric vehicles in use in Germany—this is the plan of the German government [5]. The technological progress here also includes the commercial vehicle sector. The applicability of this sector's innovations is currently tested by logistics companies. Restrictive parameters such as limited range or poor infrastructure are responsible for a today very limited usage for commercial purposes [6]. In this context electric delivery vehicles that are used in the field of last-mile distribution perform a niche function. During their daily tour, these vehicles have a range of about 100 km. Therefore, it seems to be suitable to use them for urban supply and disposal service [7]. In the present technological state-of-the-art, the usage of electric delivery vehicles as part of the last-mile distribution seems to be possible for logistics companies. In this case the progress, which has been done in the technical sector, is enormous and a result of research in engineering.

But the question of required *business process changes* in order to operate economically is still misrepresented in research. In particular small and middle-sized companies in the logistics industry and in trade have to deal with this problem. For them it is difficult to evaluate the purchase of electric vehicles because these companies have no prior knowledge regarding necessary operational changes. Concerning this problem, it is important to investigate the critical information and process requirements that logistics service providers and retailers are facing in their daily operations by using electric delivery vehicles for last-mile distribution.

The proposed research deals with an assessment of different operational changes in logistics in case of usage of electric delivery vehicles. To fulfil this aim the possible *operational change areas* were ranked in a hierarchy and evaluated as part of an expert survey. Methodically the survey implemented the *Analytical Hierarchy Process* (*AHP*). The aim of this research is to show the importance of individual operational parameters regarding a switch to electric delivery vehicles within logistics processes. The value of this research is to provide information for companies who are interested in converting their transport fleet or parts thereof to electric delivery vehicles and making it possible to consider economic parameters regarding this strategic decision.

2 Lack of Information and Potential Risks

With regard to a green logistics concept many companies align their strategies to sustainable development. In this case companies decide to restructure their own transport fleet and to upgrade it with environmental friendly propulsion technologies. As a result of technical innovation the usage of electric delivery vehicles becomes possible. Especially the progress in battery technology and operation optimization by using intelligent navigation systems and modern software for route planning are significant.

Vehicle ranges are specified by manufacturers by up to 150 kilometres [7]. Logistics companies such as Deutsche Post DHL and others successfully test appropriate vehicles [8]. Regarding these strategic decisions technical restrictions are still significant. The question of required business process changes in order to operate economically as well as the logistics processes must be considered too.

The conversion to environmental friendly propulsion technologies is new for many companies. Due to the novelty of this strategy as well as a low state of research, with regard to necessary operational adjustments, companies can rely on little information in this area. There is a lack of information. But information is an important attribute to efficient decisions processes [9]. Due to the lack of information the purchase of electric delivery vehicles is difficult to calculate. Especially for small and medium-sized companies limited information is a high risk because of their scarce resources to compensate possible economical errors [10].

Various parameters must be considered in the planning and transition of logistics processes including electric delivery vehicles. Companies who integrate these new processes cannot rely on best practice solutions. In terms of continuous improvement, process modifications are reasonable during normal operation, but basic problems can be solved with difficulty. For this reason it is important to be well informed and to solve possible problems as early as possible.

The possible operational top process areas due to the change of operational processes are shown in Fig. 1 on next page and can be found in the second level of the presented hierarchy of operational changes.

3 Case Study

In the context of this case study it was important to determine which operational changes have to be done to ensure economic logistic processes by using electric delivery vehicles in last-mile-distribution. The required collection of information was part of an expert survey. Methodically this project will be evaluated by using the Analytical Hierarchy Process (AHP). The AHP sorts competing factors by assigning percentage points to these factors and helps to put each factor into a ranking [11]. The aim is to get a hierarchical weighting of operating areas in which process changes are necessary when using electric delivery vehicles. This result can be used as guidance for companies.

Fig. 1 Hierarchy of operational changes

3.1 Empirical Process

First, possible change parameters were identified by executing a brainstorming and research in specific sources. For showing the connection each criteria was structured and sorted into a hierarchy (Fig. 1). By using these data, a questionnaire was designed.

This questionnaire was divided in two parts. In the first part personal data have been collected. In the second part a survey of the individual top- and sub-segments were conducted. 10 logistic experts were addressed in the survey, 9 of them sent back the completed questionnaires within the predetermined time. This is a return rate of 90 %. The analysis of the questionnaires was carried out in two steps. The personal data of the first part were collected and processed in an Excel Chart (section Experts Characteristics). By using the software Expert Choice the information requested in the second part were reviewed (section AHP Results). Expert Choice is a tool to manage complex issues, which is based on the query system of AHP. With the help of this software it is possible to conduct an individual rating after entering several criteria. The arrangement of these criteria is similar to the setting within the questionnaires. After completing the data entry Expert Choice calculates the weighting of each parameter. For getting a clearly arranged overview the data can be shown in separate charts.

3.2 Experts Characteristics

In the first part of the survey the personal data were determined to show the qualification and experience of each respondent. The reason for this is to indicate problem-related knowledge of the respondents and to prove their significance due to the survey. Category groups such as industry and logistics business as well as experience have been interrogated. 8 of 9 participants are experts in the field of logistics. All selected respondents have a basic knowledge in logistics. This understanding for logistics processes based upon activities as operational or strategic staff of logistics companies or with respect to activities in the field of scientific logistics research. Their experience is fundamental to a meaningful result. None of the participants work less than three years in their profession. Working experience of 4 experts exceeds more than 10 years. These data show the vast experience and knowledge in the field of logistics. 5 of 9 respondents currently work as employees in a logistics company which is a further evidence for this statement.

3.3 AHP Results

With the usage of Expert Choice all paired comparisons were finished. The weighting of all operational changes are shown in Fig. 2.

Processes and product performance were identified as main process areas with the greatest impact on operational changes by using electric delivery vehicles. With a weighting of 31.66 % the criterion product performance was assessed on the first place. The factor processes were weighted with 29.20 % on the second place. The difference between product performance and processes is 2.46 % points. Due to this small gap between product performance and processes, both criteria are equipollent. This is also illustrated by consideration of the sub-segments according to this. Due to sub-segments weighting of processes it is conspicuous that dispatching with 39.43 % and transportation with 36.39 % were prioritized similar. Dispatching and transportation add up to 75.92 % and exceed the most important product performance criterion (transport goods) of 24.64 % points. Overall the weighting of the product performance is higher than the weighting of processes. That is why the sub-segments, transport goods, dispatching and transportation are equal to each other. As part of the supply chain these processes build the core disciplines [12] and are fundamental for the feasibility of the logistic chain. One result of this survey is that logistic core disciplines are strongly influenced by using electric delivery vehicles. In this case the meaning for business decisions can be highly classified. Possible reasons for this vote are related identified problems in range problems or large-sized batteries which limit the transport capacity. Especially logistics providers whose core capabilities are related to these processes should check these parameters.

Fig. 2 Hierarchy of operational changes

With a weighting of 17.39 % the criterion plant was assessed on the third place. In this context the sub-segment vehicle fleet was identified as the most important factor with a weighting of 55.49 %. Due to the purchase of new electric delivery vehicles fleet mixture changes and homogeneity is no longer given. This has an influence regarding fleet management. A higher administrative expense and related expenses are conceivable. Changes in the operating area were weighted by 20.54 %. For additional electric vehicles a larger surface and more space for charging stations have to be provided. This step can reduce the surface for traffic routes within the company. In this context legal requirements concerning escape routes for fire brigades have to be considered.

The criterion education and training needs has been elected with 12.76 % on fourth position. Education and training needs for drivers with 48.35 % and dispatcher with 22.99 % were identified as the main factors by this election. These results form a synergy with the results of the sub-segments dispatching and transportation. This finding leads to the statement that the more drivers and dispatchers are trained in handling and planning with electric vehicles, the merrier it is possible to execute the core processes in logistics. In this context driver can be trained in respect to the special requirements by using electric vehicles. Dispatcher can be trained in the field of tour and route planning as well as with regard to modern planning and navigation software [6].

With a weighting of 8.99 % security has least relevance. In terms of this safety sub-segments play a subordinate role. For example constructions for power cables and ventilation systems or the storage and disposal of new and used batteries should be considered anyway.

4 Results

The use of electric delivery vehicles as part of the last-mile distribution causes a lot of operational changes. The results of the presented AHP survey show that especially logistics core services should be considered to ensure a continuation of logistics services. This statement is demonstrated by the high weighting of the main criteria *processes* and *product performance*. This corroborates the presented research hypothesis, that within a change process towards including electric vehicles in distribution fleets an analytical focus has to be directed towards operational performance as main part of any economically justifiable investment decision. Combined with training especially for drivers and dispatchers synergies were created. These synergies have a positive impact on process performance. Security relevant criteria, which seemed to be important, got quite a low weighting and have only a small impact on operational changes by purchasing electric delivery vehicles due to the experts' perspective.

For future research an additional cost analysis validation of this study can improve the practical business implication of such research. To further increase the explanatory power of this study it also makes sense to extend it further to a larger group of persons with expertise in the area of logistics. These results are the basis for further efforts in logistics research.

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Key Factors for Measurement of CO_2 Emissions

Case Study: Container Terminal

Indah Lengkong and Jens Froese

Abstract Along with the rapid growth of seaborne traffic volumes and rising public concern about environment, transport and logistics services are experiencing increasing pressures not only to improve their operational efficiency and reduce costs but also to minimize their environmental impacts. The requirement to become more sustainable is also inevitable for seaports and terminals, as significant nodes in the intermodal transport chain. A number of approaches on calculating and documenting carbon footprint are available for transport and logistics services, and many major ports and terminals have also started adopting them. The selection criteria of which methodology to be applied would finally depend on what a company wants to achieve. Nevertheless, it is crucial that the methodology should allow identification and focus on areas of improvements in order to develop an efficient energy saving and reduction measures and allow fair allocation of emissions. The objective of this chapter is to develop an applicable carbon footprint measurement framework for ports and terminals to serve three principals: a transparent and standardized CO_{2}-equivalent -measurement method, a consistent reporting scheme and an effective management system for ports and terminals. To achieve this, an assessment on selected existing methodologies and identification of key factors for calculation of carbon footprint at a container terminal will be performed and elucidated.

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1 Driving Factors for Carbon Footprint Measurement

Rise in energy costs and stricter environmental policies have led port industry to look at innovative and sustainable solutions to reduce and control their energy consumption, and hence their emissions as well. Requirements for port industry to measure and report their carbon footprint, also to develop energy saving and reduction action plans are increasingly asked by their clients, financing institutions and authorities. Meeting these requirements definitely will be a challenging task for many port and terminal operators, especially for those which still need to focus on improvement of their operational efficiency and cost reduction to become more competitive. However, reduction of energy consumption will not only provide environmental, but also financial benefits.

Numerous research projects and studies were more focused on estimating emissions of transport services, not individually identifying ports and terminals operations, probably due to their small carbon footprint contribution across the whole chain. It is estimated that emissions produced by port handling activities account for less than two percent of the entire transport chain, e.g. from Asia to Europe [1, 2]. In fact the port emissions, especially those of CO_2 and particulate matters, may have significant regional impacts because of the concentration of ships.

For a terminal operator who wants to perform benchmarking, there is no simple way to compare terminals, since every terminal to a certain extent is unique. Comparing emissions of terminals required detailed information on e.g. type of processes, equipment and operations, geographical boundary and climate [3, 4]. Currently, it is not very common to continuously capture all energy consumption data in correspondence to equipment and operations. Knowledge of terminals operation processes is a prerequisite to identify sources of emissions, to evaluate operations performance indicators of energy consumption and carbon footprint and to identify problems and opportunities for improvements. Moreover, it is important to meet a balanced set of technical, operational and attitude oriented measures in order to define most cost effective improvements [5].

The key deficiencies in ports and terminals are

- Lack of detailed consumption data allocated to equipment and processes
- Lack of a standardized method to measure consumptions
- Lack of key performance indicators to allow for benchmarking and control.

This chapter will contribute to development of a fair and transparent carbon footprint calculation methodology for ports and terminals by assessing some selected standards and identifying key measurement factors for calculation of carbon footprint based on a case study of a container terminal. The following chapters will discuss three selected methodologies and criteria which are deemed to be relevant for port and terminal carbon footprint measurement framework as well as improvements of their energy efficiency.

2 Overview of Carbon Footprint Methods and Standards

Existing calculation methods, standards and reporting guidelines range widely from corporate to product level and from general to specific approaches. Difference in quality, coverage and originality (i.e. data quality is difficult to assess) may lead to incomparability and non-transparent carbon footprint results [6]. A large number of international standards, related to environmental subjects for the port sector, e.g. the ISO 14000 family, are partly overlapping, which make it very difficult for practitioners to navigate through. Most standards also focus only on accounting and reporting of emissions but do not provide framework for measurement and verification. The ISO in general are categorized to technical and management standards and can be organized in two groups: (1) *system-oriented*, aiming at implementing a management structure to cater for desired results such as quality, security or sustainability but do not assess results by e.g. key performance indicators (KPIs), and (2) *result-oriented*, focusing on measurements and calculations to achieve measurable results [7]. Therefore, when selecting the appropriate method or standard to be applied, it is important to understand the purposes and requirements of each method/standard and then set up criteria, which match the company's strategic goals. An applicable carbon footprint measurement standard for ports and terminals should provide clear guidelines on what, where, and how to measure and report emissions and how to effectively manage the operational system in order to continuously reduce the carbon footprint.

A widely recognized and used standard for carbon footprint measurements both on corporate and product level is the Greenhouse Gas (GHG) Protocol which provided the basis for ISO 14064-1, a technical and system-oriented standard, which provides an applicable methodology to identify what and where to measure. The GHG Protocol and ISO 14064-1 complement each other, where ISO 14064 identifies "what to do" and GHG protocol explains "how to do it" [8]. First step to develop a transparent emission inventory is by identifying physical, organizational, and operational inventory boundaries [9]. The physical boundaries basically refer to the geographical area where the company's physical operations are located. The organizational boundaries are where the company is responsible for emissions from operations and where they have control [10]. Second step is the inventory of GHG emissions, according to the GHG Protocol, mainly through: (1) identification of emissions sources according to operational boundaries, (2) selection of measurement methodology, (3) data collection, and (4) calculation of GHG emissions. Three main scopes of emissions determined by the protocol: operation-related direct emissions (scope 1), operation-related indirect emissions (scope 2) and other indirect emissions related to the operation but not under the responsibility of the company (scope 3—optional), including extraction and production of purchased materials and transportation of purchased fuel.

The European standard CEN 16258—a technical and result oriented standard, provides a guideline how to measure and allocate the energy consumption and GHG emissions, especially developed for transport services. This standard elucidates a more detailed and systematic approach to calculate and report both energy consumptions and GHG emissions and it is beneficial when measuring the product carbon footprint. The standard requests transport companies to proportionally allocate the emissions in CO_2-equivalents to the individual shipment. The application of this standard is currently still restricted to transport carrier services (goods and passenger transport) and does not yet cover cargo distribution center and terminal operations. It is planned to extend the standard in the future to also become applicable to such type of transport nodes [11].

According to CEN 16258, the transport services must take into account not only their consumption and emissions produced due to fuel consumed of transport vehicles, “tank-to-wheel”, but also include the CO_2-equivalent from production, transport and distribution of fuel used in order to capture the “well-to-wheel” carbon footprint. This means that the CO_2-equivalent does not only depend on the local fuel consumption but also on the origin of the fuel and the different types of fuel. The calculation method appears to be rather complicated to apply in order to achieve comparable results and it does not well match with ISO 14064-1, therefore, further investigation on this standard and its role within the related standards deals with environment, especially for application in port and terminal, is necessary [7].

Table 1 summarizes the differences and similarities between ISO 14064 and CEN 16258. In order to be able to generate a complete view of the company’s GHG emissions, application of CEN 16258 should be in combination with ISO 14064. On the other hand, when a company and its clients want to know the emissions of each shipment, CEN 16258 provides appropriate measurement methodology.

Calculation of carbon footprint is the first step in order to get a clearer picture of the energy consumption and to define strategic measures for reduction. In order to reduce and continuously improve energy performance, the ISO 50001—management and result oriented standard—provides a systematic management framework to allow company continuously improving energy performance, e.g. among other things by (1) measuring energy use, (2) identifying areas of improvement, (3) establishing an energy baseline to allow comparison of energy performance during a specified period of time and (4) determining appropriate energy performance indicators and targets, and (5) developing and implementing an energy action plan [12].

3 Defining the Boundaries of Container Terminal Emissions

A clearer view on source of emissions of container terminals will indeed help terminal operators to create strategic measures to manage their emissions. Energy consumers of container terminals in general include (1) operational equipment and vehicles used to handle containers, (2) office buildings, canteens, showers and maintenance and repair workshops, (3) reefer (refrigerated containers) plugs, and

Table 1 Differences and similarities between ISO 14064-1 and CEN 16258

	ISO 14064-1	CEN 16258
Target users	All type of companies	Transport services
Boundaries	Direct emissions (scope 1) Indirect emissions (scope 2 & 3), including office building, maintenance workshop, lighting, cold store, handling equipment, business trips, staff commuting and third party services	Direct emissions: transport mode/vehicles Indirect emissions: production and transportation of purchased fuel used for transport mode/vehicles
GHG emissions sources	Scope 1, 2, 3	Tank-to-Wheel/TTW (vehicle processes), Well-to-Wheel/WTW (energy processes)
Measurement methodology	Direct measurement, published emission factors, default fuel use data	Specific measured values, Transport operator vehicle-type or route-type specific values, Transport operator fleet values, Default values
Activity data	Scope 1: fuel consumption Scope 2: purchased energy and supplier specific, local grid or other published emissions factor Scope 3: reported energy use or published third party emissions	Fuel consumption Actual distance Weight of shipment Energy conversion factor (WTW and TTW) Emissions conversion factor (WTW and TTW)

Source GHG protocol, ISO 14064 and CEN 16258

(4) lighting the terminal area, to name the most important ones. However, with relation to ISO 14064, scope 3, which currently is optional, the total emissions figure also needs to consider emissions from other indirect sources related to the terminal activities although they cannot control these. The three scopes of emissions, as defined by ISO 14064, for a container terminal, are:

- Scope 1: Direct GHG emissions. Emissions from sources that are controlled by the terminal, for example: emissions from combustion of handling equipment and own vehicles.
- Scope 2: Electricity indirect GHG emissions. Emissions from the production of purchased energy which are consumed by the terminals (e.g. electricity, heat, steam and cooling), for example purchased electricity for electric power handling equipment, facilities and workshops.
- Scope 3: Other indirect GHG emissions. Emissions which occur from sources not under the control of the terminal but a consequence of the terminal's activities. For example, vessels berthed at the terminal, external trucks, locomotives, supply vessels/barge, supply trucks, staff commuting and staff business trips. Also, extraction, production and transportation of purchased equipment and transportation of purchased fuel [10].

The following Table 2, which is not an exhaustive list, provides a general overview of energy consumers and the allocated scope of emissions. Category of process domains and their general processes of container terminal operations were adopted from GREEN EFFORTS project report [13].

4 Measuring Scope 3 Carbon Emissions of a Container Terminal

The scope 3 emissions are often the biggest source of emissions, therefore they hold a large potential for emissions reduction [15]. According to published reports from ports which have conducted carbon footprint calculation, it can be seen the scope 3 emissions contribute the largest proportion of the total emissions of a port [16, 17]. In general, a significant source of emissions of container ports is due to berthed vessels. An estimation performed by Gothenburg Port Authority in the year 2010 showed that their scope 3 results were mainly due to berthed vessels, accounting for 93 % of the total emissions [16]. The same was reported by Jurong Port in Singapore, where more than 80 % were emissions from berthed vessels and tug boats operations [17].

Reporting of scope 3 emissions according to GHG protocol is optional for a company. However, having the whole picture of emissions generated due to the company's operation will give better understanding on the emission pattern and enable the company to develop strategic measures that will eventually bring long term benefits for the company [15]. Scope 3 from definition looks simple and clear, however, clear standards to set boundaries of scope 3 in a comparable way is still lacking. Therefore, before performing calculation of scope 3 emissions, there are principle questions to be considered:

- To what extent a life cycle based calculation should be done and how this will fit to their emission reduction measures? According to GHG protocol and CEN 16258, emissions of extraction and production of purchased materials and transportation of purchased fuel are included in scope 3. This would mean, besides emissions of vessels, trucks and other earlier mentioned emissions scope 3, emissions due to production and transportation of their handling equipment as well as transportation of purchased fuel for the equipment need to be included in the calculation.
- What sort of information and where to find reliable and accurate information sources? Reliable and accurate data, needed for calculation of scopes 1, to some extent, are documented by port/terminal, and for scope 2, the terminals may use local grid or other published emissions factor. However, they might face some uncertainties when collecting data and information for scope 3. In many cases, there is a lack of reference materials and data and information are not available or they can only be obtained from third party sources, which either might not be willing to do so or not at a sufficient quality level.

Table 2 List of energy consumers according to processes domains of container terminals

Container terminal process domains	Meta processes	Processes	Energy consumers/emissions sources	Emissions scope		
				1	2	3
(1) Berth operations			Berthed vessel/barge			✔
	Vessel services	Vessel supply	Bunker vessel/barge			✔
			Fuel truck			✔
		Waste services	External truck			✔
			Vessel/barge			✔
		Ship repair/maintenance	External truck			✔
			Vessel/barge			✔
(2) Quay operations	Loading/unloading container		Quay crane		✔	
			Mobile harbor crane	✔		
		Move twist lock boxes	Forklift	✔		
(3) Marshalling/ apron area	Horizontal transport	Move container from quay to stacking area	Terminal truck/tractor	✔		
			Van/straddle carrier	✔		
			Automated guided vehicle (AGV)	✔	✔	
		Move container from quay to gate	External container truck			✔
(4) Stacking/yard operations	Stacking containers	Place/pick-up/shuffling/pre-stowing container	Van/straddle carrier	✔		
			Rubber tyred gantry (RTG)	✔		
			Fully electric RTG		✔	
			Rail mounted gantry (RMG)		✔	
			Automated stacking crane (ASC)		✔	
			Reach stacker	✔		
			Empty container handling (ECH)/ forklift	✔		
	Reefer/temperature controlled container storage		Reefer plugs		✔	

(continued)

Table 2 (continued)

Container terminal process domains	Meta processes	Processes	Energy consumers/emissions sources	Emissions scope		
				1	2	3
(5) Interchange operations	Truck handling	Move containers from stacking to truck interchange area	See move container in stacking area handling equipment list			
			External container truck			✔
	Train handling	Move containers from stacking to train interchange area	See move container in stacking area handling equipment list			
			Terminal truck/tractor	✔		
(6) Gate operations	Truck gate	Gate building	Check in/out		✔	
(7) Equipment maintenance	Maintenance	Workshop building	Electricity for maintenance		✔	
	Repair	Workshop building	Electricity for maintenance		✔	
	Refueling		Fuel truck			✔
(8) Administration	Staff office	Office building	Space heating		✔	
			Cooling		✔	
			Lighting		✔	
			Refrigeration		✔	
			Water heating		✔	
			Office equipment		✔	
	Client office	Office building	See office building energy consumer list			
	IT services		Server		✔	
	Yard lighting		Lighting		✔	
	Parking place lighting		Lighting		✔	
	Security	Security check in terminal area	Car	✔		
(9) Staff services	Canteen		Canteen building, cooking		✔	
	Shower		water heating, lighting		✔	

(continued)

Table 2 (continued)

Container terminal process domains	Meta processes	Processes	Energy consumers/emissions sources	Emissions scope		
				1	2	3
	Shuttle service	Move staff within terminal	Bus	✔		
			Car	✔		
(10) Off terminal storage	Container Freight Station		Transport vehicles and handling equipment (e.g. Terminal tractor, Truck, forklift, Reach stacker)	✔		
	Inter Terminal Transport		Transport vehicles and handling equipment (e.g. Terminal tractor, Truck)	✔		
(11) Special services	Container	Repair	Workshop building energy consumers		✔	
		Flexi (container) tank	Workshop building energy consumers		✔	
	Container/cargo storage	Cross-docking (including e.g. stuffing, stripping)	Warehouse building energy consumers		✔	
	Terminal visitors		Bus			✔
	Custom facilities	Office building	See office building energy consumer list			✔
(12) Staff Commuting			Car			✔
			Train			✔
			Public transportation			✔
(13) Staff business travel			Car			✔
			Train			✔
			Airplane			✔

Source Own elaboration of emissions scope allocation with input from GREEN EFFORTS process map [14]

- What measurement methodology would be the most appropriate for estimating the scope 3 emissions? Actual data measurement requires extra staff and other resources. Take an example of calculating emissions of external trucks during terminal operation, while waiting for picking up/dropping off containers and on port operation, when entering and exiting the port area. Some useful parameters for emissions estimation from truck operations on terminal are type of external trucks, gate operating schedules, average speeds on terminal, time duration and distance travelled on terminal and time spend idling/queuing time at the entrance and exit gate and on port activities including average of round trip distance between entrance and exit gate ([3] and [18]). For distance travelled, it can be estimated based on port and terminal layout, however, other information mentioned above can be captured during the operation with support of information systems attached to vehicles. This will be cumbersome efforts for the terminal, however, the measurement can be realized only through collaboration and exchange information with truck operators. Another measurement methodology is by utilizing published default values, e.g. average fuel use and published third party emissions.

5 Variables for Carbon Footprint Calculation at a Container Terminal

Different companies may use different input variables, which have a major influence on the results of calculations, therefore, to allow comparison of the results, input variables need to be specified. In this chapter, important activity data, as input variables to calculate the carbon footprint from general to more details perspectives (process-based and activities-based variables) are introduced.

To provide a general idea, the absolute CO_2 emissions at a container terminal could be based on total emissions in relation to the volume of standard containers (TEU) handled per year. This would result in a unit of tons of CO_2 equivalent/TEU. Total emissions then can be derived from the total energy consumption per year from the total energy bill per year taking into account relevant emission factors for e.g. electricity and fuel combustion. This general approach, however, will not be suitable for those terminals which handle significant amount of reefer/temperature controlled containers and, project cargos which must be treated separately.

Sources and level of emissions of a container terminal will also depend on the terminal layout and operations design, which determining type of handling equipment. Geerlings and van Duin [1] developed a process-based approach and introduced some variables to estimate the emissions at a container terminal. This includes modal split; types of equipment and to which processes or modalities it is served; terminal layout to estimate the distances travelled by each type of handling

Table 3 Example of activity based variables according to ISO 14064 and CEN 16258

ISO 14064	CEN 16258
Fuel consumption, travelled distance, utilization factor, operating hours, TEU throughput, rated power, load factor, speed	Fuel consumption, weight, travelled distance, volume, loading meres, number of pallets, number of TEU, number of stops, utilization factor, speed

equipment to each served mode, i.e. sea, barge, road, rail and inter-terminal transport. This approach allows terminals to estimate total emissions from their operations according to usage of terminal equipment serving specific modalities.

Estimation also can be performed by direct measurement of energy consumption of handling equipment according to its operating hours. The World Port Climate Initiatives (WPCI)'s guidance document includes some additional activity data such as rated power and average load factors (fraction of available power) while operating for different types of equipment giving more details estimation [3].

Table 3 summarizes some of the input variables which can be used by container terminals. Certainly, there are many other equipment attributes or operational methods, which could influence the level of CO_2 emissions and which need to be considered in order to provide a comprehensive and accurate estimation of container terminals emissions. For example, stay duration of a container, speed of horizontal transport (e.g. of straddle carriers or terminal tractors) moving from quay to yard, driving habits, method of movement of container (e.g. single trolley quay crane or double trolley quay crane), and method of stacking of containers on the yard. Also, there are other sources of emissions worth to be considered such as consumption of office buildings, staff services, yard lighting, standby consumption of equipment, and reefer containers. As the next step, determining appropriate performance indicators relevant to energy and environmental, without compromise operational performance, will be performed.

6 Conclusion and Future Outlook

There are many existing carbon footprint calculation methodologies to support companies to understand and manage their emissions. To allow for a development of an efficient energy saving and emissions reduction action plan, the first step is to identify sources of emissions in order to allow a terminal to be more focused on potential areas of improvement to be followed by continuous measurement of the emissions. It is necessary to capture consumption data from all related energy consumers in relation to terminal operation in order to achieve transparency data to qualify for a fair benchmarking. A standardized calculation model with appropriate input variables and performance indicators for energy efficiency will allow measurement of emissions performance between container terminals in comparable basis.

The objective of this chapter is to develop an applicable carbon footprint measurement framework for ports and terminals to serve three principals: a transparent and standardized CO_2 e-measurement method, a consistent reporting scheme and an effective management system for ports and terminals. It is proposed that the standard measurements for carbon footprint at a container terminal shall be done according to ISO 14064 for scope 1 and 2, which later might become extended to scope 3 (estimations and lump sum considerations). Here the following approach is recommended:

- CEN 16258 as a methodology how to measure the energy consumption and the GHG emissions and proportionally allocate emissions to each transported unit. Application of the CEN 16258 standard is currently restricted only to the transport service, which is not sufficient to provide a broader view of emissions on company level. Therefore, the combination with ISO 14064 is recommended.
- ISO 14064 to identify where and what to be measured (scope 1–3).
- ISO 50001 as a management framework.

For further research, it is important to understand how to allocate the appropriate proportion of total emissions to each unit or container or customer and to develop integrated processes for a consistent implementation of those recommended standards to ports and terminals.

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Environmental Impacts in the Liner Shipping Industry

The Hapag-Lloyd Online tool EcoCalc Reveals Emissions Arising from Container Transportation

Simone Ziegler

Abstract The liner shipping industry is the most environmentally friendly way to transport goods around the world volume wise. However, since worldwide business continues to grow the environmental strains have to be kept to a minimum. Regulatory measures demand this by claiming the environmental footprint of a transport. And customers are increasing their requirements as well. In order to meet all these expectations and requirements for sustainable transport solutions Hapag-Lloyd implemented an online tool to reveal emissions in 2011, the Hapag-Lloyd EcoCalc.

1 Emissions in the Liner Shipping Industry

Liner shipping is the most environmentally sound way to transport large volumes of goods around the world. It produces less greenhouse gases per tonne kilometer compared to any other mode of transport (Table 1).

Vessels carry approximately 90 % of the traded goods by volume [1] however, according to various independent sources this accounts only for some 2.7 % of global greenhouse gas emissions [2]. The shipping industry is generally aware of the impact that transport services have on the environment such as greenhouse gases, noise, waste etc. The environmental strain of the transport and all supporting activities should therefore be kept to a minimum. The worldwide reduction of environmental impacts from shipping is a significant challenge for the industry as the global fleet continues to grow with the increase in worldwide trade.

Great potential for reducing environmental impacts lies in the reduction of vessel's fuel consumption. Emissions are directly related to the amount of fuel

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Table 1 Average CO_2 Emissions for cargo transport within Europe[9]

*Hapag-Lloyd own data

burned as they result from the combustion of marine fuel when operating vessels. Carbon dioxide (CO_2) emissions are those directly depending emissions from fuel combustion and can therefore easily be calculated. Obviously less fuel consumption leads to reduced emissions.

Carbon dioxide is the dominant greenhouse gas worldwide. Transport is the only sector in the EU in which CO_2 emissions have risen in the last few years. In addition, it is the main greenhouse gas in terms of emitted volume and noxiousness to humans and to the environment [3].

Due to the significant environmental impact and the external requirements from customers or regulatory bodies CO_2 emissions are often reported by many companies.

2 Goals for Implementation

Hapag-Lloyd decided to indicate emissions when transporting a container along the whole container transport chain or door-to-door transport. This is what an intermodal calculator offers. Consequently Hapag-Lloyd decided to present its own intermodal calculator—in line with the saying: “You can only manage what you measure!”

Data for the seaborne part have been available in-house since Hapag-Lloyd had calculated emissions for its seaborne transportation in the past according to the

Clean Cargo Working Group Methodology.[1] However, comprehensive emission figures for the pre- and on-carriage were still needed.

Key drivers for the implementation were:

- ensure stronger customer relations with better value proposition
- improve corporate image
- spearhead green developments in the container shipping industry
- meet legal requirements such as the European Standard DIN EN 16258 as well as the French decree no 2011-1336[2]
- gain competitive advantage.

3 Requirements of the Software Tool

Many intermodal calculators which indicate emissions within the supply chain were available on the software market. These tools employ different approaches from carbon accounting for the whole company as well as environmental auditing.

The tool Hapag-Lloyd wanted to offer needed to meet certain requirements.

The tool must offer comprehensive data for the pre- and on-carriage that unfold emission figures for different modes of transport such as truck or rail transportation. All sources of data behind these figures had to be reliable and profound. For example a container transport by truck in Germany causes other emission values

[1] This calculation model projects CO_2 emissions especially for shipping in an effort to improve transparency and comparability.

Parameters used in this model for CO_2 calculation are:

- Actual fuel consumption
- Actual distance sailed
- Number of days vessel was deployed
- Total TEU (nominal capacity)
- Number of reefer plugs

The CCWG [4] will include recent consolidated findings of the DIN EN 16258 in enhancing the calculation model with regard to vessel utilization and upstream emissions as from 2013 on. The CCWG basic calculation model takes the specific factors deriving in the container shipping industry into account.

As from 2010/2011 ocean carriers were asked to independently verify their calculation process according to the CCWG method including data gathering and actual calculation to independently proof the correctness of the data.

[2] In 2013 the European Standard DIN EN 16258 [5] as well as the French decree no 2011-1336 of 24 October 2011 [6] come into force.

The voluntary DIN EN 16258 provides a homogeneous “Methodology for calculation and declaration on energy consumptions and GHG emissions in transport services”. For liner shipping allocation rules have to be obeyed.

The French decree no 2011-1336 requires the delivery of carbon emission data for each transport service (goods and passengers transport) carried out in France.

than a truck transported in China. Thus it is essential to investigate how these distinctions between countries, continents and within modes of transport are considered by the different tools in order to reach this imposing goal.

Additionally, the methodology needed to be independently checked to facilitate trustworthy and reliable data. Possibilities of customizing and access to the Hapag-Lloyd IT-systems has to be checked beforehand as well. The implementation costs and the costs for the tool itself needed also to be considered.

4 Development and Implementation

Hapag-Lloyd decided to use EcoTransIT (Ecological Transport Information Tool) because it is currently the most sophisticated software tool in the transport industry offering a comprehensive database [7]. EcoTransIT provides an online tool to calculate emissions and energy consumption per transport worldwide and for different modes of transport such as truck, rail etc. This is exactly what Hapag-Lloyd was looking-for. The methodology of EcoTransIT was developed by the internationally recognized Institute for Energy and Environmental Research (ifeu) Heidelberg and the Institute for Applied Ecology in Berlin, and it already fulfills the requirements of the future European CEN-Standard 16258. More information and the scientific basis behind EcoTransIT are provided on the project's website [7].

The project: "Implementation of an online Hapag-Lloyd Emission Calculator" was led by the department Sustainability Management that involved various departments besides the EcoTransIT and customer input:

- IT for the technical work infrastructure and web support
- Global Sales equipped and trained the sales colleagues all over the world with the necessary background knowledge
- PR developed the logo and led the media relations
- Legal department checked the contracts and disclaimer
- Sustainability department led the project team, coordinated the project tasks and acted as point of entry for external parties such as our supplier EcoTransIT and selected customers who were involved in testing EcoCalc procedures.

A key task was to customize the EcoTransIT's product in order to develop a Hapag-Lloyd online emission calculator. Hapag-Lloyd implemented specific values such as trade lane specific CO_2 values and the port layer into the EcoTransIT product.

There were regular project meetings every two weeks to discuss project plans and developments. The work plans were adjusted accordingly.

Key actions were to find a dependable way of implementing the Hapag-Lloyd tradelane specific CO_2 values into the EcoTransIT database and to decide which parameters to use for the background calculation. Some actions arose during the execution of the project for example which transport mode to use in the background calculation when showing pre- and on-carriage.

In summary the implementation of the EcoCalc worked quickly by the excellent cooperation and support through all members of the project group.

5 The Online Calculator EcoCalc

Since October 2011 the online tool EcoCalc is publically available on the Hapag-Lloyd website [8]. EcoCalc calculates the environmental impact of freight transports worldwide based on data independently verified and scientifically sound. Evaluated emissions are Carbon Dioxide (CO_2) Nitrogen Oxide (NO_x), Sulphur Dioxide (SO_2), and Particulate Matter (PM_{10}).

Although most attention is paid to CO_2 and SO_2 emissions with regards to transport, there are also NOx and PM emissions arising during transportation. Both emissions are publically more and more discussed. Hapag-Lloyd also provides these emission data for reference.

6 Conclusion

This project to implement an online intermodal calculator was a great success for Hapag-Lloyd. Customer and stakeholders have been included in the project at an early stage in order to develop a sophisticated web-product to match their requirements.

1, 5 years after its launch the Hapag-Lloyd EcoCalc still enjoys a frequent usage by our customers who determine their environmental footprint with this online calculator.

In summary we have indentified four main success factors:

1. The EcoCalc is compliant. It fulfills the rising regulatory framework for logistic providers: the requirements of the European CEN-Standard 16258 and the French decree no 2011-1336 of 24 October 2011 coming into force this year.
2. The EcoCalc methodology is reliable. Data and methodology from EcoTransIT are scientifically based. In 2013 the Germanischer Lloyd has verified the data submission provided by Hapag-Lloyd.
3. The EcoCalc is complete. It allows to calculate the emissions of a container transport from the beginning to the end of its journey—the complete door-to-door transport.
4. The EcoCalc is comprehensive. It reveals relevant emissions of Carbon Dioxide (CO_2), Nitrogen Oxide (NO_x), Sulphur Dioxide (SO_2), and Particulate Matter (PM_{10}).

Further enhancements of the functionality of EcoCalc are planned and aim to improve its usability for customers as well as the accuracy of the data.

The EcoCalc has made emissions more transparent and has increased the awareness for ecological-friendlier logistics. The industry has come a long way in reducing emissions, but need to cut them even further as well as to lower the overall environmental impact of transporting goods.

This requires a variety of different measures such as:

- Technical enhancements of the equipment of ships
- Operational measures in the daily vessel operation
- Emission-reducing activities ashore
- Reduce the environmental impact of the container production.

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