What constitutes EMIS for sustainability reporting? A classification approach, using a systematic literature review

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Abstract

Due to an extensive amount of environmental impacts by industrial processes, the demand for information about firm's caused environmental impacts increases by different stakeholder groups. An uprising and sophisticated form of environmental performance information distribution is sustainability reporting (SR), although it is a complex task. Information and communication technologies (ICT) are supposed to support and enable SR, however the adoption and diffusion of specific EMIS for the task of SR is rather low. One reason may be that scholars missed their chance to provide tangible and precise definitions for EMIS as well as features and characteristics of this class of IS. In order to understand and define what really constitutes EMIS for SR, we first use a well-known IS classification pattern to find general features of IS. We then use this classification pattern in a systematic literature review and analyze present knowledge for characteristics of EMIS for SR. The outcome is twofold. First we derive an EMIS for SR specific classification pattern. Second, we point out what is already known about EMIS for SR and which topics should be addressed in further research.

1. Introduction

Due to an extensive amount of environmental impacts by industrial processes, the demand for information about firm's caused environmental impacts increases by different stakeholder groups [1]. A sophisticated form of environmental performance information distribution is sustainability reporting (SR), which includes information about the environmental, economic and social performance of a firm [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" [7]. As sustainability reporting is a complex task, information and communication technologies (ICT) are considered to be able to support the process of sustainability reporting in a comprehensive manner [5]. An information system class which is discussed to support the process of sustainability reporting is environmental management information systems (EMIS) [12; 9]. EMIS have the objective to obtain, process and make environmental relevant information available in a systematic manner [12] to enable decision-making and knowledge creation within and outside of organizations [15]. While IS scholars conducted research on EMIS since the early 1990s, the adoption and usage of EMIS in general and also for sustainability reporting purposes in practice is rather low. One reason for this situation is that the field misses its chance to provide tangible and precise definitions for EMIS as well as characteristics of this class of IS [8], wherefore other scholars call for action [10; 17; 15]. First attempts have been made to gather more detailed characteristics of the general class of EMIS [6]. However, EMIS for SR are still understudied, undefined, and uncharacterized while representing an important subclass of EMIS. For this reason, we intent to reach two goals with this paper: First,

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we want to know what are the relevant features and characteristics that represent and describe EMIS for the task of sustainability reporting comprehensively. Second, we intent to point out what is already known about EMIS for SR and which topics should be addressed in further research.

In this paper, we first provide a short overview of the used methodology in section two and proceed to the results of our systematic literature review. Ongoing, we discuss the results and propose a classification pattern according to the results. Finally, we provide a short conclusion.

2. Methodology

To characterize EMIS for sustainability reporting in more detail, we draw on an IS systematization pattern by Schumann [13] and Mertens [11]. The used pattern (Figure 1) defines relevant aspects of information systems in general and comprises seven IS features to be analysed. These features are the supported processes, the subject-specific methods, the comprising capabilities and its implemented algorithms. Furthermore, the necessary data as well as the degree of automation and integration are relevant to describe information systems.

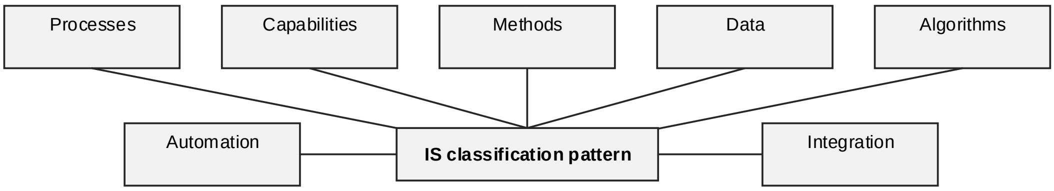

Figure 1: IS classification scheme [13, p. 10]

To classify EMIS for SR, we linked this basic schema with EMIS for SR domain specific features and characteristics that are known from prior literature on environmental informatics and the uprising field of Green IS. To provide a complete overview as well as detailed insights into present knowledge, we further conducted a systematic literature review according to [18] and [16]. Therefore, we used search terms comprising of “sustainability reporting” and “(environmental management) information systems”, their abbreviations as well as their German equivalents. Within the search process we used the search engines EbscoHost, SpringerLink, ScienceDirect, EconBiz, the AIS library and the “Gemeinsamer Verbundkatalog” (GUV).

3. Results of systematic literature review

The systematic literature review revealed 993 articles in the first search process iteration. After an initial inspection of titles and abstract, we were able to reduce the amount of articles to 84 (available in online appendix; http://www2.as.wiwi.uni-goettingen.de/getfile?DateiID=725) that found to be relevant for describing features and characteristics of EMIS for SR. We classified the provided content of these articles according to the proposed pattern and analysed them topic-centred according to Webster and Watson [18]. The resulting analysis framework, which comprises the basic pattern by Schumann [13] and known literature from the field of EMIS is shown in Figure 1. Furthermore, the framework draws on knowledge from [2] and [14], describing the reasons of SR by institutional theory as well as the perceived usage of SR by knowing organization theory [4].

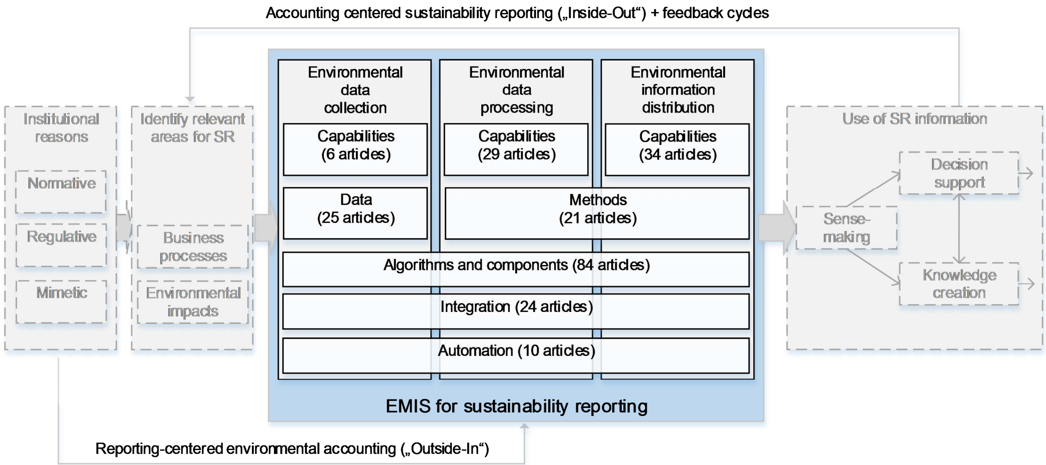

Figure 2: Analysis framework and topic-related results

The topic-related amount of relevant literature that resulted from the analysis can be depicted as follows: We captured knowledge about relevant capabilities in terms of environmental data collection (6 articles), processing (29 articles), and the subsequent information distribution (34 articles). Knowledge about algorithms and components has been described by 84 articles. Moreover, we were able to gather knowledge about the necessary data (25 articles), sustainability and environmental accounting methods (21 articles), the degree of automation (10 articles), and integration (24 articles). According to these results, the identified papers will be discussed and ordered by aspects of IS classification pattern. Due to coherence of capabilities and algorithms these aspects will be discussed together. Furthermore, we will connect the aspect of automation and integration as they are connected by horizontal and vertical integration.

3.1. Capabilities and algorithms

We found 69 papers in our systematic literature review that discuss capabilities of EMIS for SR and 84 papers that provide specific algorithms and components that implement functionalities. First, SR requires *environmental data collection* [101], [41] and [65]. For instance, Gösling et al. [41] discuss that EMIS for SR need a structured data collection of in- and output data in order to enable environmental reporting, while Jensen & Norup [65] point out that comprehensive monitoring is especially necessary for regulative purposes, e.g. for the GHG emission trading act. In the field, the environmental data collection is supposed to be fulfilled by *interfaces* with other business IS [102], [40], [99] and [59]. Wohlgemuth & Page [102] connect the LCA tool Umberto to an environmental simulation tool, Gomez & Amelang [40] propose an interface that is capable to read out environmental data by XML (Extended Markup Language). Wohlgemuth et al. [99] use the standardised data exchange format PAS 1025 in order to read out environmental data from business IS. According to Watson et al. [17], *sensor networks* can be used to obtain environmental data. In literature, only few scholars provide solutions that actually use sensors for data collection. Wohlgemuth et al. [101] suggest to use sensor networks, while Hentz et al. [45] propose a system design, where sensors within the operative machine logging system are used to collect environmental information in production processes. Collected data need to be stored in *databases*. Isenmann et al. [59] use MySQL to store environmental data in order to provide a persistent data storage. Petrini & Pozzebom [84] propose to use a data warehouses for this task. Bischof & Winkler [25] conceptualize a system, using a data warehouse, which is implemented by Thies [96] with a SAP BW system.

Furthermore, environmental data *aggregation* is a relevant capability of EMIS for SR [12]. Gräuler et al. [6] for instance found this requirement in the context of Green IS, stating that the level of abstraction has to be selectable. In order to enable (dis-)aggregation of environmental data, *models* of activity and environmental data flow are necessary, as this capability also enables life cycle analysis [39], [85] and [75]. Additionally, *calculation algorithms* are used to compile environmental indicators [19], [21] and [41]. Ahmed & Sundaram [19] present a prototype that is able to calculate environmental data, Arco et al. [21] use algorithms in case of missing data based on neuronal networks and case based reasoning. Gösling et al. [41] propose a calculation algorithm that is able to provide environmental indicators. Another algorithmic component that is found to be necessary in literature are *workflow mechanisms* as they supports the process of SR [46] and [91]. Hrebieciek et al. [19] argue that the workflow of persons that collect data should be supported as well as auditing processes.

Document management has been revealed as another important capability of EMIS for IS [23], [46] and [53]. For instance, Arndt et al. [23] developed a document management system for environmental related content. Hribicek et al. [46] use XML-based document management systems and XSLT (Extended Stylesheet Language) for the distribution of SR in different formats, e.g. PDF. The usage of XML and XLST has also been shown by several publications of Isenmann. In this context, the *historization* of sustainability reports is also an important feature of EMIS for SR [39] and [68]. Kuryazov et al. [68] conceive a revision and historization control for IS for SR, using delta calculations.

According to literature EMIS for SR also need to be capable of the *visualization* of environmental data in terms of graphs or sankey diagrams [39] and [40]. Cencic & Ruchberger [32] point out that environmental indicators in time series or in relation to source of origin enable decision-making in SR. *Simulation* also has been analysed extensive in prior literature [12], [100], [82] and [71]. Wohlgemuth [100] simulates environmental impacts in case of missing data in time series, Pawleski & Otamendi [82] propose the use of suitable programming frameworks (e.g. EcoSimPro; DESMO-J) and software products (JADE). Lee et al. [71] developed a simulation prototype, using DES (discrete event simulation) for determine the environmental impacts of production programs.

Finally, EMIS for SR need to be able to provide sustainability *reports* in different distribution forms [93], [44], [74], [56] and [92]. While reports can be provided as classical PDFs, they can be distributed on *web portals*, which have *interactive* features. Solsbach and Gomez propose the use of web portals for SR distribution, which has been shown by Grünwald [44] in terms of a prototype. Also Lopez Abad & Meyerholt [74] showed the development of a portal for SR as a prototype. Isenmann and Kim [56] propose a concept of interactive sustainability reporting, having feedback mechanisms. Solsbach et al. [92] developed a prototype called “iStorm” that uses a shopping cart-feature to enable stakeholders choosing information according to their needs. The usage of XML and XSL enables to *export* sustainability reports in a desired format [26]. The characteristics for capabilities and algorithms / components are summarized in Table 1.

Feature	Characteristics (n)								
Capability	Data collection (6)	Aggregation (2)	Modelling (13)	Analyze (5)	Visualize (7)	Historize (1)	Simulate (7)	Report (30)	Interact (3)
Algorithm / components	Sensor networks (1)	Import interfaces (18)	Databases (6)	Calculation algorithms (6)	Workflow algorithms (10)	Document management algorithms (10)	GUI (31)	Export interfaces (25)	

Table 1: Features and characteristics of capabilities and algorithms / components

3.2. Data

The aspect of data integration has been addressed by 25 papers. While 21 mentioned the type of data, 14 papers reflect on data collection methods and 15 papers consider data quality. Funk et al.

[34] use material flow data from ERP systems for SR and calculate resulting environmental impacts. Also Wohlgemuth et al. [100] use *activity flow data* from existing business IS for environmental impact determination. Lee et al. [72] analyse the occurrence of environmental impact data at a Korean car manufacturer, finding that *resource consumptions* can be determined only by hand as this data is not available in present IS. Grünwald [44] developed a prototype of a reporting system and found that environmental data sources at a German car manufacturer can only be found rarely. Cencin & Rechberger [32] conclude that environmental data calculations result in high uncertainties, wherefore decision support is not possible. Hentz et al. [45] propose a concept on how to use sensor data in production processes, gathering primary *environmental impact* data. Schlund et al. [89] claim that environmental data should be gathered directly, using sensor systems in order to increase data quality. However, the literature shows that environmental data is often *calculated* or *estimated*. We found only two papers that address *direct measurements* of environmental impacts, while seven papers propose to calculate and six papers to estimate data. Also Melville & Whisnant [77] conclude that necessary data for SR is often 'not digitzed' wherefore *primary data* is missing. Thus, external databases are used that provide *secondary data* sources. Solsbach et al. [91] and Gräuler et al. [6] state that data sources and the collection of environmental data is a major problem in SR. The identified characteristics of EMIS for SR are summarized in Table 2.

Feature	Characteristics (n)		
Type of data	Resource consumptions (14)	Environmental impacts (1)	Process activity data (5)
Collection method	Directly measured (2)	Calculated (7)	Estimated (6)
Data quality	Primary data (6)	Secondary data (7)	

Table 2: Features and characteristics of environmental data

3.3. Methods

In terms of adequate methods for SR, we found 21 papers that address this issue, mainly proposing environmental accounting methods. Konrad [66] shows in an empirical study that *environmental indicators* and LCA (*life cycle analysis)* are suitable methods for SR. Möller & Viere [80] point out that physical and monetary representations of environmental impacts should be considered, wherefore also *environmental cost accounting* needs to be considered. Funk et al. [35] analyse carbon footprints on product level as an adequate method for environmental impact information distribution. Eun et al. [33] also point out the importance of a product level view in SR. Petrini & Pozzebom [84] analysed the integrated usage of environmental indicators, which is determined as the most suitable method for SR by Löschner [75]. Specific solutions have been shown by Wohlgemuth & Page [102], Gomez et al. [40], Cencic & Rechberger [32], Personn et al. [83] and Gösling et al. [41]. Wohlgemuth & Page [102] showed how IS can be used to provide LCAs, while Gomez & Amelung [40] used Umberto for demonstration. Cencic & Rechberger [32] developed a prototype called STAN (substance flow ANalysis) that uses environmental accounting methods to calculate environmental impacts in production processes. Personn et al. [83] use the material stream method as a derivate of value material flow method to determine material and resource consumption flows. Table 3 shows the identified characteristics.

Feature	Characteristics (n)		
Methods	Life cycle analysis (13)	Environmental indicators (8)	Environmental cost accounting (3)
Related object	Environmental impact of products (10)	Environmental impact of processes (7)	Environmental impact of company (11)

Table 3: Features and characteristics of method

3.4. Automation and integration

The systematic literature review revealed ten papers about the degree of automation and 24 papers about the integration. In terms of automation, Rapp & Bremer [87] analysed current EMIS for IS and found that the degree of automation is low, as most of these IS do not support an automated data collection, but rather are *partly automated* IS. These IS only support the environmental data collection by hand or by using Excel imports. According to Scheide et al. [88] these manual tasks increase the chance of errors in data collection. Also Hrebicek et al. [46] conclude that the current state of EMIS for SR does not feature automated tasks in the process of SR. However, they state that EMIS for SR should support automated data collection from existing business IS. Bracher [27] provides a concept for *automated* ad-hoc reports, using a RESTful (Representational State Transfer) web service, gathering the necessary data from existing IS.

In terms of a vertical integration the distribution of environmental relevant data in *real-time* is stated by Isenmann & Lenz [57] and Thies [96] as an important requirement. However, due to the rather low availability of data most IS work with *batch processing*. Petrini et al. [84] show empirically that there is a lack in real-time environmental reporting, Eun et al. [33] and Schlund et al. [89] state this topic as a research gap. Bischof & Winkler [25] point out that a continuous data flow from operative to top decision-making IS is necessary for a real-time integration, showing this vertical integration by a SAP business intelligence concept. The vertical integration of EMIS for SR is also analysed by existing research. According to Möller & Viere [80] EMIS are stand-alone or integrated IS. However, Isenmann & Rautenstrauch [58], Möller et al. [78] and Möller & Michelsen [79] describe that a vertical integration with other IS is important. For instance, Möller & Michelsen [79] show the necessity of vertical integration of IS for flow management with production planning systems *within the company*. Gräuler et al. [6] found empirical evidence for a vertical integration, which has also been stated by Freundlieb & Teuteberg [37]. Funk et al. [35], Isenmann [53] and Bublitz et al. [29] point out the relevance of *inter-company* integration, especially in terms of supply chain integration. Bublitz et al. [29] integrate environmental impacts from supply chain partners, using estimated values from an external life-cycle database. The characteristics of automation and integration are summarized in Table 4.

Feature	Characteristics (n)	
Automation	Partly automated (9)	Automated (1)
Vertical integration	Real-time processing (6)	Batch processing (13)
Horizontal integration	In-company (21)	Inter-company (4)

Table 4: Features and characteristics of automation and integration

4. Classification of EMIS for SR

A qualitative analysis of the relevant literature has been used to reveal detailed characteristics of the analysed features in the previous chapter. We use this knowledge to systemize the characteristics of EMIS for SR. The results of this classification are shown in Table 1. Understudied characteristics and thus research gaps are highlighted in Table 1 and will be discussed in the following.

The analysis of literature revealed research gaps in the field of primary data sourcing and collecting of environmental impacts as well as for IS capabilities in supporting this task (e. g. by using sensor networks). While several articles treat data collection topics, they do not provide comprehensive solutions for this task. Import interfaces are defined but further analysis shows that data are not present in an adequate quality in current IS. Therefore, secondary average data from life cycle inventory databases is used, resulting in high uncertainties of environmental information. Thus, knowledge about relevant environmental data types and adequate data collection methods is missing as well as their support by information systems [17]. Furthermore, the aggregation and analysis of gathered data as a basis for decision making and knowledge creation hasn't been investigated in detail by prior research. Our analysis reveals that this is influenced by the quality of environmental data. As secondary data sources provide average values with high uncertainties, further detailed aggregation and analysis has not been possible in the past. Thus, data aggregation and disaggregation also hasn't been investigated in detail so far. The automation and real time data supply hasn't been studied sufficiently too, while found to be relevant to improve decision making processes, enable process and behavioural changes, and subsequently contribute to sustainable development. The horizontal integration has been discussed in literature for intra- and inter-organisational sustainability reporting. However, comprehensive artefacts are missing for the integration of supplier's and other network partner's information about environmental impacts.

Feature	Characteristics								
Data type	Resource inputs	Environmental impacts	Activities						
Data collection method	Measurement	Calculation	Estimation						
Data quality	Primary data	Secondary data							
Methods	Environmental life cycle assessments	Environmental performance indicators	Environmental cost calculations						
Scope	Product impacts	Process impacts	Company impacts						
Functionalities	Collect	Aggregate	Model	Analyze	Visualize	Historize	Simulate	Report	Interact
Algorithms and components	Sensor-networks	Import interfaces	Data-base	Calculation algorithms	Workflow algorithms	Document management algorithms	GUI	Export interfaces	
Automation	Partly automated	Fully automated							
Vertical integration	"Real time" supply	„Batch" supply							
Horizontal integration	Intra-company	Inter-company							

Table 5: Systematization of EMIS for SR

Based on the gained knowledge about features and characteristics of EMIS for SR, we propose a research agenda according to [16] based on the identified research gaps as the second outcome of this study (see Table 2).

Research agenda	
Data sources	(1) What is an adequate level of data granularity for sustainability reporting? (2) Which primary environmental data sources can be used to decrease uncertainties in sustainability reporting?
Capabilities / algorithms and components	(3) How can innovative information systems and technologies be used to gather environmental impacts at the causing business entities? (4) How can environmental impact analysis and aggregation functionalities be designed to enable improved decision-making and knowledge-creation?
Automation / Integration	(5) How can EMIS for SR be designed to enable real-time data collection, processing and distribution of environmental impact information?
	(6) How can supply chain partner's IS be integrated with EMIS for SR to enable environmental impact data collection from up- and downstream partners?

Table 6: Research agenda

5. Conclusion

In conclusion we sought to seek a more detailed, precise and improved systematization of EMIS for SR than provided by prior research. Furthermore, we aimed to understand the state of current knowledge about EMIS for SR. Therefore, we used an IS classification pattern which was adapted to the field of investigation. A systematic literature review has been used to gather relevant characteristics for the subclass of EMIS of SR and revealed research gaps. Finally, we provided an agenda for further research, paving the way for more relevance and rigor in the field of environmental informatics and Green IS, especially for the class of EMIS for SR.

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