Measuring the Carbon Footprint of Business Processes

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Jan Recker
University of Hamburg

Michael Rosemann
Queensland University of Technology

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Jan Recker, Michael Rosemann, and Ehsan Roohi Gohar

Information Systems Discipline, Queensland University of Technology
126 Margaret Street, Brisbane QLD 4000, Australia
{j.recker,m.rosemann,ehsan.roohigohar}@qut.edu.au

Abstract. While many corporations and individuals realize that environmental sustainability is an urgent problem to address, the academic community has been slow to acknowledge the problem and take action. We contribute to the emerging academic discussion by proposing a new approach for engaging in the analysis of environmentally sustainable business processes. Specifically, we propose an approach for measuring the carbon dioxide emissions produced during the execution of a business process, and apply this approach in a real-life case of a Direct Invoicing process at a Corporate Services provider. We show how this information can be leveraged in the re-design of "green" business processes.

Keywords: sustainability, process analysis, carbon footprint.

1 Introduction

The increasing awareness for the necessity of sustainability in living and working has put "green" or "sustainable" practices on the radar screen of organizations. Environmental constraints are increasingly imposed on organizations, and demand new levels of operational compliance.

In this context, colloquial terms such as Green IT [1] have emerged to acknowledge information systems and the surrounding business processes as contributors to environmental problems as well as potential enablers of green, sustainable solutions. Yet, while organizations around the globe increasingly realize the demand and potential of the transformative power of information systems [2], to date, few examples of such approaches have been reported in studies.

In this paper, we contribute to the emerging body of research on sustainability by discussing an analysis approach for measuring the carbon footprint of business processes. Our approach extends activity-based costing approaches [e.g., 3] towards the consideration of greenhouse gas emissions alongside the activities of a business processes. Thereby, it facilitates the consideration of environmental sustainability consideration in the improvement or re-design of business processes.

Following this introduction, we review existing research on sustainability. Then, we briefly discuss existing approaches to measuring carbon footprints in organizations. Next, we suggest an approach for measuring the carbon footprints of business processes. We apply our approach to the case of a Direct Invoicing process at an Australian Corporate Services provider. We then conclude this paper with a review of contributions and implications.

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2 Background

With our research we seek to contribute to the development and improvement of sustainable business practices. Sustainability is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [4]. Our interest specifically is on environmental aspects of sustainability. The most important environmental sustainability challenge is known as the problem of *global warming*, the increase in the average temperature of Earth's near-surface air and oceans. Global warming is primarily caused by greenhouse gas (GHG) emissions, in particular through Carbon Dioxide produced collaterally through human-triggered actions, such as business travels, paper production, manufacturing and others. We believe that these actions manifest especially in the execution of organizational business processes.

Of course, we are not the first to examine environmental issues and organizational performance. Contributions on environmental quality, lean production, regulatory mechanisms, environmentally benevolent activities and sustainable initiatives have been made in operations research [5] or econometrics [6], to name just two. Yet, few contributions exist that examine the contribution of an organization's business processes to environmental sustainability.

We believe that Business Process Management can assist in the endeavor to extend our perspective on processes and the wider organizational performance. This is because Business Process Management tools and techniques assist organizations in their efforts to (re-) design the organizational processes in light of compliance regulations, operational agility, or other business imperatives such as time, quality or costs [7]. The dedication of BPM approaches to eliminate waste under the "paperless office" paradigm indicates its potential for making processes more environmentally sustainable. We believe that it is possible to extend and adopt Business Process Management tools such that they also allow organizations to manage and improve the organizational processes in light of environmental considerations.

This work is an important move forward because, nowadays, global warming has raised attention about so-called eco-friendly business activities, defined as those processes that produce less carbon dioxide as a main cause of global warming. In this context, it is often referred to the *carbon footprint of business processes* as a measure for the carbon dioxide production alongside organizational operations such as paper-intensive processes (e.g., a bank's mortgage process), fuel consuming processes (e.g., business travels) or a process that produces waste materials and unnecessary power sources (e.g., defect processes, quality rectification processes).

Carbon footprint is commonly understood as the amount of carbon dioxide (CO2) emitted through the combustion of fossil fuels during daily activities – in the case of a business organization, the amount of carbon dioxide emitted either directly or indirectly as a result of its everyday process operations. It is expressed as grams of CO2 equivalent per kilowatt hour of generation (gCO2eq/kWh), which accounts for the different global warming effects of other greenhouse gases.

To facilitate the improvement of the carbon footprint of business processes, it is firstly required to facilitate the documentation and measurement of the carbon dioxide emissions alongside a business process. We discuss some relevant approaches in the following.

3 Carbon Footprint Calculation Approaches

Carbon footprint measurement has become a topic of interest to many business organizations, and has led to the development of several measurement approaches to calculate the footprint of a business as an organizational entity (see, for instance, http://www.carbonfootprint.com/).

Calculating the carbon footprint of an organization can be done via three approaches [8]: bottom-up, based on Process Analysis (PA) or top-down, based on an Environmental Input-Output (EIO) analysis, or through a combination of both. We briefly review the three approaches in the following.

3.1 Process Analysis

Process analysis (PA) is a bottom-up method, which has been developed to understand the environmental impacts of individual products over its lifecycle from cradle to grave [9]. In a process-based Life Cycle Assessment (LCA), one itemizes the inputs (materials and energy resources) and the outputs (emissions and wastes to the environment) for a given step in producing a product.

The bottom-up nature of process-based LCA means that they suffer from a system boundary problem – typically, only on-site and first-order, sometimes second-order impacts are considered. If PA-LCA is used for deriving carbon footprint estimates, a strong emphasis therefore needs to be given to the identification of appropriate system boundaries, which minimize this truncation error. A PA-based LCA runs into further difficulties once carbon footprints for larger entities such as government, households or particular industrial sectors have to be established. Even though estimates can be derived by extrapolating information contained in life-cycle databases, results will get increasingly patchy as these procedures usually require the assumption that a subset of individual products are representative for a larger product grouping and the use of information from different databases, which are usually not consistent.

3.2 Environmental Input-Output Analysis

Environmental Input-Output (EIO) analysis [10] provides an alternative top-down approach suitable to carbon foot printing. Input-output tables are economic accounts providing a picture of all economic activities at the meso (sector) level. In combination with consistent environmental account data they can be used to establish carbon footprint estimates in a comprehensive and robust way taking into account all higher order impacts and setting the whole economic system as boundary. However, the suitability of environmental input-output analysis to assess micro systems such as products or processes is limited, as it assumes homogeneity of prices, outputs and their carbon emissions at the sector level. Although sectors can be disaggregated for further analysis, bringing it closer to a micro system, this possibility is limited, at least on a larger scale. A big advantage of input-output based approaches, however, is a much smaller requirement of time and manpower once the model is in place.

3.3 Hybrid-EIO-LCA

The combination of the above methods in a hybrid approach [11] allows preserving the detail and accuracy of bottom-up approaches in lower order stages, while higher-order requirements are covered by the input-output part of the model. Such a Hybrid-EIO-LCA method, embedding process systems inside input-output tables, is the current state-of-the art in ecological economic modeling [11]. Still, this approach is focused on understanding input-output relations on a broader institutional or economical level. We argue that an understanding of carbon emissions on a business process level would create further opportunities on a meso and micro level to make quick and effective adjustments to an organization with a direct impact on its environmental image. Our argument rests on a tight linkage between carbon emission measurement and the facilitation and implementation of principles associated with Business Process Management.

4 Activity-Based Emission Analysis

Through Business Process Management [12], an organization can create competent processes, which function cost efficiently, with greater precision, reduced errors, and improved flexibility. This is because by using Business Process Management, an organization can enhance its processes in each of the lifecycle stages planning, development and implementation of processes, by identifying errors, bottlenecks and, indeed, waste, before it affects other processes and overall revenue [13]. While typically, process management has focused on the documentation, analysis and improvement of performance objectives such as cost, time, quality or flexibility [7], we will in the following extend a typical process management tool, Activity-Based Costing [3], towards the inclusion of environmental measures in an approach we call *Activity-based Emission (ABE) Analysis*.

4.1 Approach

Activity-Based Costing (ABC) is a collection of financial and operational performance information dealing with significant activities of the business [3]. Key to this approach is the consideration of actual usage of equipment and resources (e.g. machinery, human resources) in the activities that constitute a business process. This approach takes a stance, therefore, on the operational level of a business process, which, through multi-level process architectures, thereby allowing for composition of the measures to a meso- or macro-organizational level.

Based on ABC Analysis, we argue that Activity-Based Emission (ABE) Analysis can be conducted for a process to determine the emission of CO2 for each activity as well as the overall process. ABE allows the calculation of CO2 emission more accurate than LCA or EIO approaches by focusing on every step of a business process, by identifying the so-called *emission drivers* and by considering the impact of alternative resources that facilitate the process execution. In fact, by estimating and measuring the CO2 outturn of each activity, the CO2 emission of all services and products across all business processes of an organization can be calculated. In turn, ABE analysis can provide a more precise and specific insight into the actual processes, activities and resources within, that directly contribution, positively or negatively, to the carbon emission of an organization. This is because ABE helps to distinguish operations and resources based on their CO2 emissions, and thus allows embedding an environmental view in the decision-making related to process (re-) design.

Further benefits from an ABE approach include that it can also be used within other business analysis tools such as Pareto analyses, to further examine the relation between cost, time and emission of CO2 for a business. We foresee the combination of ABE with other analysis tools as a key step in defining organizational areas which require an improvement in light of sustainability considerations.

4.2 Stage Model

Similarly to a regular ABC analysis, an ABE can be conducted within five main steps:

1. **Identify the product or service to be considered.** This step is typically supported through business or service modeling activities at a strategic level.
2. **Determine all the resources and processes that are required to create the product or deliver the service, and their respective CO2 emission.** To that end, typically, semi-formal graphical models of the business process are considered as documentations of the tasks that have to be performed, the actors and other resources that are involved in the execution of these tasks, relevant data and sources (papers, forms, systems and technology) of the data, and the business rule logic that describes the logical and temporal order in which tasks are to be performed [14]. To measure the CO2 emissions, data will have to be collected, at least, about three important CO2 emission factors, *consumed electricity, consumed paper,* and *consumed fuel.* Arguably, there could be other emission factors that could also be taken into consideration.
3. **Determine the "emission drivers" for each resource.** To that end, in late 1997, the World Resources Institute and the World Business Council, developed the Greenhouse Gas Protocol (GHG Protocol) for Sustainable Development (www.ghgprotocol.org). The GHG Protocol is providing series of accounting tools to understand measure and manage green house gas emissions. In this protocol, three scope levels are defined to define organizational boundaries to enable differentiating between GHG emitting activities that are owned by organizations, and those that are not. These scope boundaries categories owned emitting activities in to three different scopes which is distinguishes between direct and in direct GHG emitting activities:

   - *Scope1: direct GHG emissions* – emissions that occur from sources that are owned or controlled by the company. Examples include emissions from boilers, vehicles, electric generators and so forth.
   - *Scope2: electricity indirect emissions* – emissions that originate from consuming electricity, heat or steam purchased by the company.
   - *Scope3: other indirect GHG emissions* – emissions that are the results of the activities of the company but arise from sources not owned or controlled by

the company. These include emissions from product materials produced by suppliers (newsprint/paper, ink, etc.), contractor delivery vehicles, employee commuting to/from work and business air travel.

4. **Calculate CO2 emission for each activity by gathering Activity Data for each process and resource and define the emission factor for each Activity Data.** The GHG Protocol enables the calculation of the CO2 emission for each defined source in step 3 through GHG Protocol calculation tools. Examples for the three selected emission drivers include the following:

   - *Fuel (scope3):* For calculating the CO2 emission of scope3 activities (e.g., business travel between two offices), the GHG protocol provides the formula*: Distance travelled × emissions factor incorporating default fuel efficiency value = CO2 emission*
   - *Paper (scope3):* For calculating the CO2 emission of scope3 activities (e.g., transporting paper forms between two offices), the GHG protocol provides the formula*: Weight of paper × emissions factor for manufacture of paper = CO2 equivalent emissions*
   - *Electricity (scope2):* CO2 emission of purchased electricity can be calculated by using the GHG Protocol calculation tool for purchased electricity, which is based on the formula*: KWh of electricity used by organization × emission factor = CO2 emissions*

5. **Use the data to calculate the overall CO2 emission of the process.** This is achieved by summing up all CO2 emissions across all activities and scope levels. This analysis will then enable a sixth step (out of scope for this paper) - the actual act of making eco-aware process re-design decisions, and selecting those process and resource variants that help to reduce the carbon footprint during run-time execution.

5 A Case Study: The Direct Invoicing Process

5.1 Case Description

We applied our approach in a case study with Seamless Service Provision (SSP), an Australia-based organization that offers financial and human resource services to organizations in the private and public sector. One of these services is the payment of so-called direct invoices for its clients. A direct invoice is an invoice without a corresponding purchase order.

SSP receives between 15,000-25,000 paper-based invoices per month. The invoices arrive in the incoming mail centre in the city centre (Office 1). Invoices are screened, entered into a system and then forwarded to Data Entry Officers at Office 2 in the north of the city (10 km distance from Office 1). Incomplete or incompliant invoices (10% of all invoices) are sent back to the client via postal mail with the request to complete the invoice.

The data entry officers Attach vendor master records to the invoices. The internal mail collects these forms and takes them to the master data entry department. The master data entry department creates SAP master data (takes 1-5 days) and then the invoice is ready to be entered in the SAP system by Data Entry Officers.

Validation Officers sort the invoices and print a 10-page report per 100 invoices (60 minutes for a batch of 100 invoices). Invoices are now ready for payment. The Payment Office runs a payment process every week. This is a highly automated process, at the end of which a report is generated. This report will be sent via mail to the individual clients to inform them about the successful payment of the invoice. Also, it will be sent to SSP's Accounts Receivable Department at Office 3 located 3km away from Office 2. This department generates monthly invoices for SSP's clients. Third, the payment report will be sent to the Registry (same building). The employee in the Registry selects the paper-based invoices that have been paid and archives the invoices. Sometimes, vendors or clients have an issue with the payment and in these cases it is required to track down the original paper-based invoice together with all information on the invoice entry form. Such requests occur approx. 5-10 times per month.

5.2 ABE Analysis

To calculate the carbon footprint of the direct invoicing process, we firstly created a process model of the process, modelled in BPMN [14]. The model details the process in terms of 43 individual activities, 10 involved departments within SSP, plus required data, paper, forms and other inputs to, and outputs from, the process. We omit the detailed BPMN model from this paper but note that we developed dedicated BPMN notation extensions to capture and illustrate the flow of CO2 along the processes. The model is available upon request.

In a second step, we selected three CO2 emission drivers of the process, viz., **fuel** (for delivering invoices between different offices), **paper** (Invoice, Invoice entry form, etc.) and **electricity** (regular office use). We note that our approach can also be used for other emission drivers. In step three, we then identified the sources for each of these three emission drivers (again, other sources are imaginable):

- Fuel: Depends on travelled distance to deliver the invoices between different offices.
- Paper: Depends on number of invoices.
- Electricity: Depends on the overall process cycle time.

In step four, we then calculated the CO2 emissions alongside the process, the three identified resources, using the three scope levels of the GHG protocol (www.ghgprotocol.org). Due to space restrictions we cannot provide full details about the analysis and results (this information is available from the contact author upon request). Instead, we discuss some exemplary analyses in the following.

For instance, to be able to calculate CO2 emission from purchased electricity, we firstly gathered data about office electricity consumptions per month (viz., office 1: 5,000 kwh per month, office 2: 2,500 kwh per month, office 3: 10,000 kwh per month). We then used a calculation tool provided in the GHG protocol to estimate the total electricity consumption (see Table 1). Then, by dividing CO2 emission for each office in a relative fraction per seconds, the emission per seconds for each office can be calculated (Office 1: 4,603,000kg / 748,800 second = 6.15 kg per second; Office 2: 2,301,000kg / 748,800 second = 3.08 kg per second; Office 3: 9,205,000kg / 748,800 second = 12.3 kg per second).

Table 1. Calculation of SSP purchased electricity

The Greenhouse Gas Protocol Initiative
The foundation for sound and sustainable climate strategies

Facility information				Consumption data				Emission factor (kg GHG/ KWh)			Emissions			
Facility description	% of electricity used by the facility	Country	Region (if available)	Year	Fuel mix	Amount	Units	CO_2	CH_4	N_2O	CO_2 (tonnes)	CH_4 (kg)	N_2O (kg)	CO_2e (tonnes)
Office 1	100	Australia		2006	All	5,000	kWh	0.920527			4.603			4.603
Office 2	100	Australia		2006	All	2,500	kWh	0.920527			2.301	0.000		2.301
Office 3	100	Australia		2006	All	10,000	kWh	0.920527			9.205			9.205
											16.109	0.000	0.000	16.109

To calculate the paper consumption, we assumed that all the consumed papers in company are in same size and weight, and estimated the weight of each paper as 0.03 kg. The emission factor for 1 kg of paper in the SSP company is 10 kg, therefore, each invoice or consumed sheet of paper in the Direct Invoicing process produces 300 gram of CO2.

Last, we used a calculation tool provided in the GHG protocol to estimate the fuel consumption for delivering invoices and paperwork between offices, assuming company-owned cars with one driver only (see Table 2). The GHG Protocol calculation tool for mobile combustion fuel consumption shows that for each 100 km travelling with a car 24 kg CO2 (0.024 kg per 1 km) are produced by SSP.

Table 2. Calculation of SSP fuel consumption

The Greenhouse Gas Protocol Initiative
The foundation for sound and sustainable climate strategies

Total GHG Emissions, exclude Biofuel CO2 (metric tonnes CO2e)	0.024
Biofuel CO2 Emissions (metric tonnes)	0

Activity Data

Status	Source Description	Region	Mode of Transport	Scope	Type of Activity Data	Activity Data				
						Vehicle Type	Distance Travelled	Gross Weight	# of Passenger	Unit of Distance
	Delivery between offices	Other	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	100			Kilometer

Add Row

Error Messages	GHG Emissions			
	Fossil Fuel CO2 (metric tonnes)	CH4 (kilograms)	N2O (kilograms)	Total GHG Emissions, exclude Biofuel CO2 (metric tonnes CO2e)
	0.024			0.024
Total (metric tonnes CO2e)	0.024	0	0	0.024

Based on these results, in a last step, we calculated the overall CO2 emission of the Direct Invoicing Process, as described in Table 3. As can be seen, the current paper-based process, considering both direct and indirect emissions, produces over one billion kg of emissions due to its paper-intensive mode, which in turn presents a strong plea for the importance of the “paperless office” paradigm.

Table 3. ABE Analysis of SSP Direct Invoicing Process

Process/process variants		Description	Number of process instances per month	CO2 emission per process instance (kg)	CO2 emission per month (kg)
Complete invoices		95% of received invoices are complete.	19,000	**5233.81**	99,442,390
Incomplete invoices		5% of received invoices are incomplete.	1,000	**861.6**	861,600
Non-compliant invoices (10% of received invoices are non-compliant)	clarified by experienced SSP staff	50% of non-compliant invoices are clarified by experienced SSP staff.	1,000	738	738,000
	completed by calling the customers	25% of non-compliant invoices are completed by calling the customers.	500	738	369,000
	sent back to the customers for completion	25% of non-compliant invoices are sent back to the customers for completion.	500	**1,077.15**	538,575
Invoices for which vendors numbers are not in the SAP system		5% of all invoices do not have a SAP vendor number.	1,000	**863.9**	863,900
Invoices with payment issues that are tracked down		5-10 invoices require the track down of the invoice together with the invoice entry form.	2	7,380	14,760
Total emission per month(kg)					**1,028,282,225**

6 Conclusion

Our work denotes an important step forward towards the eco-friendly management of business processes. By being able to measure the environmental impact of a business process, analysts and managers are empowered to account for environmental information in their decisions to execute or change business processes. Our measurement approach works for as-is as well as for to-be scenarios and can therefore be used to make informed decisions about "green" processes and the improvement of the processes towards environmental as well as classical business objectives.

Our research has some limitations. Notably, we reported on a first exploratory case, and more empirical study is required. We focused on selected emission drivers and emission sources and acknowledge that a different focus could yield different results. Last, we note that the office energy consumption calculation does not take into account the use of office space for multiple processes. Therefore, a split of energy consumption would deliver improved results.

Our research as well as the related studies in this area [15] demand complementary future studies in a number of areas. For instance, we are working towards a process documentation notation that captures carbon footprint drivers, emissions and consequences. Similarly, our research calls for increased attention for approaches that facilitate truly paperless processes, through appropriate digitized information and artifact flow alongside a process. Typical process improvement strategies (e.g., TRIZ, reference modeling, Six Sigma, to name just a few) should be reviewed, to investigate how these techniques allow for an inclusion of environmental data, and how potential goal-conflicts (e.g., costs versus environmental impact) can be resolved.

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