Capturing Environmental Impacts of Business Processes with Camunda and the SOPA Framework

Finn Klessascheck[1,2,*], Yannic Seibert[3] and Luise Pufahl[1,2]

[1] *Technical University of Munich, School of CIT, Heilbronn, Germany*
[2] *Weizenbaum Institute, Berlin, Germany*
[3] *Technical University of Munich, School of CIT, Munich, Germany*

Abstract

Organizations are progressively interested in reducing the environmental impacts of business processes, to contribute to a *sustainable* future. *Green Business Process Management* has developed approaches to aid organizations in this. Previously, we have presented the *SOPA framework* for holistically assessing and redesigning business processes for their environmental impact. So far, SOPA has been implemented for *simulated* event logs. While SOPA can also assess *executed* business processes based on real-world event logs, relevant information is rarely captured as is required by SOPA. Therefore, we extended a business process engine, Camunda, so that this information can be specified *during* business process execution.

Keywords

Sustainability, Green BPM, LCA, SOPA, Business Process Engine, Camunda

1. Introduction

In light of continuing environmental degradation, it is increasingly important for companies to make their business practices more environmentally *sustainable* [1] by reducing their impact on the environment [1, 2]. For this, the discipline of *Business Process Management* (BPM) [3], and in particular *Green BPM* [4], which provides techniques for assessing, improving, and monitoring business processes for their environmental impact, has been positioned as useful for companies in this regard [2]. As one concrete approach positioned in Green BPM, the *SOPA* framework [5], which provides mechanisms for *holistically* assessing and re-designing business processes for their environmental impact (i.e., without focussing on a limited set of environmental indicators, but instead aggregating a broad range of dimensions of environmental impact into a single, unit-less indicator [5]) via *Business Process Simulation* [6] and *Life Cycle Assessment* (LCA) [7], can help companies to analyse and improve the environmental impact of their business processes in a data-driven manner. While SOPA can calculate environmental impacts either 1) via business process simulation based on a process model and simulation configuration that specify how activity executions incur environmental impact, or 2) via event log data that directly captures environmental impacts holistically, the latter option has only been conceptually proposed and not yet implemented. However, real-world business process execution systems rarely store the holistic information SOPA would require [8]; therefore, we see the need to provide practically applicable tooling to facilitate SOPA analyses based on event logs, and to overcome the lack of readily useable data.

For addressing this shortcoming, *Business Process Engines*, i.e. information systems that are responsible for supporting the execution of business processes by orchestrating tasks, process participants, data, and applications [9, 10], are well-situated to allow enrichment of event data *during* business process execution (as opposed to ex-post enrichments, see e.g. [11]) with information about environmental impacts. Therefore, to overcome the existing limitation of SOPA and its implementation, and to allow companies to capture business process executions so that information about environmental impacts

Proceedings of the Best BPM Dissertation Award, Doctoral Consortium, and Demonstrations & Resources Forum co-located with 23rd International Conference on Business Process Management (BPM 2025), Seville, Spain, August 31st to September 5th, 2025.
*Corresponding author.
finn.klessascheck@tum.de (F. Klessascheck); yannic.seibert@tum.de (Y. Seibert); luise.pufahl@tum.de (L. Pufahl)
0000-0001-6961-1828 (F. Klessascheck); 0000-0002-5182-2587 (L. Pufahl)

is stored in a way useable by SOPA, we: 1) extended one particular business process engine, being *Camunda 7*, with concepts of the SOPA framework, and 2) extended an existing implementation of SOPA to allow comparing actually executed and simulated business processes for their environmental impact. In particular, we made the following extensions of our previous work [5, 12, 13]: It is now possible for end users to dynamically specify *environmental cost drivers* (i.e., entities, products, and services [5]) *during* business process execution, and *parametrise* them (e.g., regarding quantity, weight, or distance). This is a further extension of the static ex-post analyses supported by existing implementations of SOPA, which helps in reducing the gap between environmental impacts calculated with SOPA and those actually occurring in the real world. The resulting event log can then be further used to compare it with simulated business process executions in *SimuBridge* [12, 13], a tool for creating, managing, and executing business process simulation scenarios. Possible analyses could be e.g. assessing further potential for reduction in environmental impact, or checking whether a business process re-design has led to such a reduction when being implemented.

Figure 1 shows the main concepts and capabilities of integrating concepts of SOPA into Camunda. In the following, we present the extension's features and its components; we also describe its application and outline potential future work.

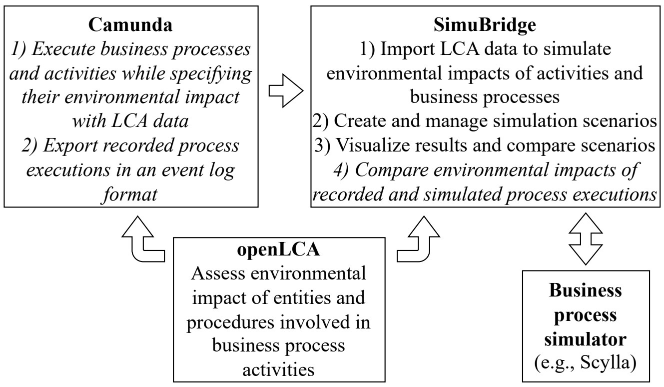

Figure 1: Features of our integration of the SOPA framework and SimuBridge with Camunda, adapted from [12, 13]; extended features are shown in *italics*.

2. Tool Description

2.1. Features

Our implementation, available on GitHub,[1] now offers the following features to process analysts:

1) Parametrised execution. For every execution of a *user task* of a business process deployed to Camunda, a user can now select *abstract* cost drivers (i.e., a grouping of concrete cost drivers, such as "packaging material", without yet being concrete enough for calculating its environmental impact), and select a corresponding *concrete* cost driver. These concrete cost drivers represent *concrete* entities, products or services, for which an environmental impact can be calculated. In addition, the end user can specify *parameters* relevant to the specific concrete cost drivers, such as weight, distance, or quantity. For this selection and parametrisation to be possible, these abstract and concrete cost drivers need to have been modelled beforehand in *openLCA*, which is a tool for LCA analyses. To this end, openLCA allows integrating various existing LCA databases (see [14]) for simplifying the modelling and analysis of *product systems*, i.e. entities, products, services, or materials [13], which in our case are used to represent concrete cost drivers.

Note that, while emerging approaches support conducting LCAs directly on event log data without the need for relying on ex-ante analyses with e.g. openLCA that are then used to enrich an event log

[1] https://github.com/INSM-TUM/Camunda--SOPA-Extension [Accessed: 23/06/2025]

(e.g. [15]), we have found that relevant data is (as yet) rarely present in relevant information systems [8]; hence, relying on expert-conducted and/or LCA database-supported analyses for modelling cost drivers is in our view nonetheless a step towards supporting sustainable business practices.

2) Extraction of event log. After executing one or more instances of a business process with Camunda, end users can extract event logs that record information about these instances in XES format [16]. For this, the configured concrete cost drivers and their parameters of activity instances are used to calculate the environmental impact of activity and process instances using openLCA. The process analyst can select any impact calculation method as long as it is present in the used openLCA installation, and supports aggregating environmental impacts into a single score.

3) Import into SimuBridge. Finally, the resulting event log can be uploaded to *SimuBridge*[2] [12], which we also extended with SOPA concepts in previous work [13]. There, a previously implemented dashboard can be used to visualize the results and compare them with the environmental impact of simulated business process executions. Further, SimuBridge can be used to discover and configure simulation scenarios based on the recorded business process executions, although abstract and concrete cost drivers would have to be configured again for simulation — this is due to the fact that so far, the tool used for simulation scenario discovery is not yet aware of SOPA concepts, specifically, the notion of environmental cost drivers. However, with these two capabilities, end users can now assess I) whether the recorder business process executions show potential for improvement of environmental impact in line with the SOPA framework, and II) whether the recorded business process executions, in case they have been previously simulated and used for business process re-design, have actually led to a reduction of environmental impact.

2.2. Structure

For offering the described features, we have extended Camunda and SimuBridge in several ways, which we describe in the following. Figure 2 provides an overview of the components we implemented or extended significantly.

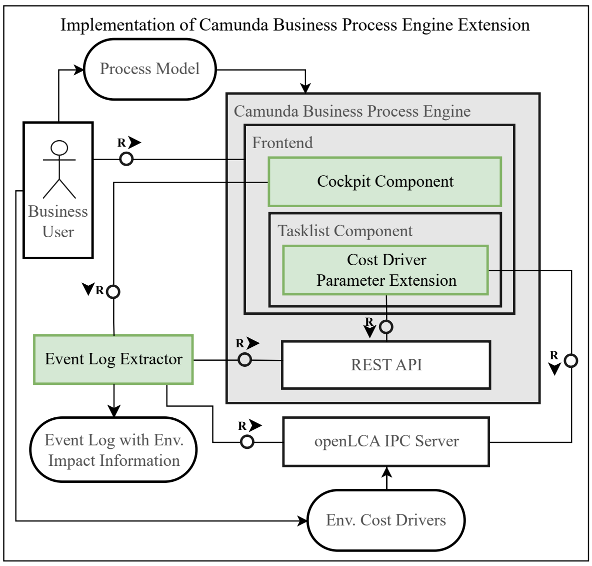

Figure 2: FMC diagram [17] of extension's architecture, with extended component shown in green.

The *tasklist* component of Camunda 7[3] now provides a form for each *user task*, where users can select

[2]https://github.com/INSM-TUM/SimuBridge--SOPA-Extension [Accessed: 23/06/2025]
[3]https://camunda.com/platform-7/ [Accessed: 23/06/2025]

for each activity instance they are executing the relevant abstract and concrete cost drivers, as well as parametrizing them further. For this, Camunda fetches data about the configured abstract and concrete cost drivers via a REST API[4] from openLCA. After completing an activity instance, the configured cost drivers and parameters are stored internally.

After business process execution, an external *event log extractor* tool, written in JavaScript, can be called from within Camunda's *cockpit component* to extract XES event logs from Camunda for a specified business process. Using Camunda's REST API, activity instances and process instances are collected; for those activity instances that provide cost driver information, their environmental impact is calculated using openLCA's IPC Sever and REST API, and a pre-defined calculation method. This method aggregates environmental impacts of the cost drivers into single numeric scores [7, 14], that in our case represent the environmental impact incurred by a single activity instance through the entities involved in its execution. The result is an event log with additional information about the environmental impact of process and activity instances, as described by the SOPA framework (see [5]).

This event log can be uploaded to SimuBridge [12] (a web-based application written in TypeScript that interfaces with tools for process simulation scenario discovery, e.g., [18], and process simulators, e.g. [19]), where we have extended the *dashboard* originally used to compare environmental impacts of different simulation scenarios. Now, a comparison of actual executions with simulated executions regarding the average, median, maximum, or minimum environmental impact of process instances or activity instances is possible.

3. Demonstration and Future Work

For demonstrating our implementation, we show a realistic example of how process executions can be tracked and analysed in the screencast.[5] However, we are again unable to make the underlying LCA dataset available due to licensing issues (cf. [13]); instead, we make a synthetic abstract version of the dataset, as well as the BPMN process model of a logistics process which we used, available online in the implementation's repository. Further, the repository contains additional deployable BPMN diagrams (of a hiring process and a pizza delivery process, adapted from [13]) that can also be used with the synthetic dataset.

For *future work*, there are several interesting angles we want to pursue further in order to contribute to Green BPM research and practice: First, extending the discovery of process simulation scenarios (see in particular [18]) so that cost drivers and their parameters can be detected from event logs and be related to those configured in openLCA during scenario configuration would be a valuable extension. Second, extending calculations so that for cost drivers, where *duration* is a parameter, the duration of activity executions is automatically used as a parameter would also be promising. Third, for *script* tasks, execution times and hardware information could similarly be used to automatically derive their environmental impact in addition to involved cost drivers.

Maturity We evaluated this implementation with three synthetic business processes in the area of logistics, HR, and food delivery, and several scenarios, for which we used concrete cost drivers derived from real-world LCA datasets. This allowed us to specify and parametrize the environmental impact of process executions holistically while executing each process, and to compare it after the fact with simulated executions of the same process. The implementation of SOPA on which we built has been presented at a related conference [13], where we also first sketched the need for the parametrization of cost drivers presented herein.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

[4]https://greendelta.github.io/openLCA-ApiDoc/ [Accessed: 23/06/2025]
[5]https://doi.org/10.6084/m9.figshare.29382653 [Accessed: 20/07/2025]

References

[1] A. Fritsch, J. von Hammerstein, C. Schreiber, S. Betz, A. Oberweis, Pathways to Greener Pastures: Research Opportunities to Integrate Life Cycle Assessment and Sustainable Business Process Management Based on a Systematic Tertiary Literature Review, Sustainability 14 (2022) 11164.

[2] D. Couckuyt, A. Van Looy, A systematic review of Green Business Process Management, Business Process Management Journal 26 (2019) 421–446.

[3] M. Weske, Business Process Management: Concepts, Languages, Architectures, Springer, 2024.

[4] S. Seidel, J. Recker, J. Vom Brocke, Green Business Process Management, in: J. vom Brocke, S. Seidel, J. Recker (Eds.), Green Business Process Management, Springer, 2012, pp. 3–13.

[5] F. Klessascheck, I. Weber, L. Pufahl, SOPA: A framework for sustainability-oriented process analysis and re-design in business process management, Inf. Syst. e-Bus. (2025).

[6] M. Dumas, M. La Rosa, J. Mendling, H. A. Reijers, Fundamentals of Business Process Management, Springer, 2018.

[7] W. Klöpffer, B. Grahl, Life Cycle Assessment (LCA): A Guide to Best Practice, Wiley-VCHVerlag GmbH & Co. KGaA, 2014.

[8] D. Schäfer, F. Klessascheck, T. Kampik, L. Pufahl, Can we leverage process data from ERP systems for business process sustainability analyses?, in: A. Delgado, T. Slaats (Eds.), Process Mining Workshops, Springer Nature, 2025, pp. 764–777.

[9] K. Traganos, M. Adams, A. Hense, A. H. Ter Hofstede, J. Mangler, S. Rinderle-Ma, P. Grefen, Business process management engines, in: P. Grefen, I. Vanderfeesten (Eds.), Handbook on Business Process Management and Digital Transformation, Edward Elgar Publishing, 2024, pp. 103–137.

[10] A. Ter Hofstede, M. Dumas, W. van der Aalst (Eds.), Process-Aware Information Systems: Bridging People and Software through Process Technology, Wiley-Interscience, 2005.

[11] M. L. van Eck, X. Lu, S. J. J. Leemans, W. M. P. van der Aalst, Pm^2: A process mining project methodology, in: J. Zdravkovic, M. Kirikova, P. Johannesson (Eds.), Advanced Information Systems Engineering, volume 9097, Springer, 2015, pp. 297–313.

[12] L. Bein, F. Klessascheck, S. Nepeina, C. Warmuth, T. Kampik, L. Pufahl, SimuBridge: Discovery and Management of Process Simulation Scenarios, in: Demonstration & Resources Track, Best BPM Dissertation Award, and Doctoral Consortium, 2023.

[13] F. Klessascheck, L. Bein, L. Pufahl, Simulating Environmental Impacts of Business Processes with SimuBridge and the SOPA Framework, in: J. D. Weerdt, G. Meroni, H. van der Aa, K. Winter (Eds.), Doctoral Consortium and Demo Track at the International Conference on Process Mining, 2024.

[14] G. Finnveden, M. Z. Hauschild, T. Ekvall, J. Guinée, R. Heijungs, S. Hellweg, A. Koehler, D. Pennington, S. Suh, Recent developments in Life Cycle Assessment, J. Environ. Manag. 91 (2009) 1–21.

[15] N. Graves, A. Fritsch, R. Hensen, I. Koren, W. Aalst, Object-Centric Process Mining for Semi-Automated and Multi-Perspective Sustainability Analyses, in: ICT4S, IEEE, 2025.

[16] IEEE Standard for eXtensible Event Stream (XES) for Achieving Interoperability in Event Logs and Event Streams, 2023.

[17] A. Knöpfel, B. Gröne, P. Tabeling, Fundamental Modeling Concepts: Effective Communication of IT Systems, J. Wiley & Sons, 2005.

[18] D. Chapela-Campa, O. López-Pintado, I. Suvorau, M. Dumas, SIMOD: Automated discovery of business process simulation models, SoftwareX 30 (2025) 102157.

[19] L. Pufahl, T. Y. Wong, M. Weske, Design of an Extensible BPMN Process Simulator, in: E. Teniente, M. Weidlich (Eds.), Business Process Management Workshops, Springer, 2018, pp. 782–795.

A. Online Resources

A screencast showcasing the tool presented herein is available online at https://doi.org/10.6084/m9.figshare.29382653; the implementation and a demo dataset are available at https://github.com/INSM-TUM/Camunda--SOPA-Extension.