GRL for Representing the Sustainability Reference Model

Birgit Penzenstadler

Department of Computer Engineering and Computer Science
California State University Long Beach
birgit.penzenstadler@csulb.edu

Abstract. [**Context**] Goal modeling is an important method to get a grip on fuzzy concepts, to understand the relations between objectives, and to reason about trade-offs. One of the concepts that is currently discussed with often fuzzy arguments is sustainability. In previous work, we developed a reference model for sustainability in order to be able to break it down into more specific goals and relate those to activities and indicators. [**Problem**] Even though sustainability is now captured and differentiated in a reference goal model, it has no standardized notation that would provide a means for formal reasoning. [**Contribution**] This paper proposes to use GRL to represent our sustainability reference goal model and shows first results. [**Impact**] By using the more wide-spread notation technique based on i* for the sustainability reference model, we hope to facilitate the discussion and application of the model. Integrating the model with a standard technique allows for a broader understanding of how to decompose and handle sustainability as a major objective for systems' development, as well as a formalized basis for reasoning. We hope to engage in community discussion.

1 Introduction

Why consider Software Engineering for Sustainability? How is current SE not sustainable? Current SE practice aims at making systems faster and more encompassing, which can lead to exponential growth in resource consumption. That is unsustainable as we only have limited natural resources available. However, this is driven by the business behind the software and, therefore, the economy. To include sustainability as a concern in the businesses, the added value for the costs caused by sustainability has to be proven, for example improvements of the company image, which is primarily the responsibility of the business analysts. However, as software engineers we are responsible for the long-term consequences of our designs [1].

In previous work, we presented a sustainability goal reference model [10] that helps to break down the abstract concept of sustainability into more tangible goals by means of dimensions and values. It is used as a checklist for software engineers who want to include the goal of sustainability into their development. As the original model didn't have a standard notation and didn't provide means

for formal reasoning, we chose to remodel it in the Goal-oriented Requirement Language (GRL) that allows for reasoning with qualitative and quantitative data. In its new form, the reference model is more accessible (due to a better know notation) and provides more means for guidance and analysis.

2 Background and Related Work

This section explains the background of sustainability and its relation to software engineering, our own preliminary work on a reference goal model for sustainability, and presents an overview of the most relevant related work.

Background: Characterization of Sustainability. The first known European use of the word Nachhaltigkeit ("sustainability") occurred in 1713 for "sustained-yield forestry" [4]. Since then, sustainability has been defined as, inter alia: (i) "The capacity to endure" [13], indicating simply endurance over time. (ii) "Preserving the function of a system over an extended period of time" [6], to serve as a starting point for scoping in systems analysis. (iii) "Ethics expanded in space and time" [7], adding the notion of ethics and values. (iv) "The possibility that all forms of life will flourish forever" [3], adding a notion of prosperity and quality of life that includes non-human forms of life. The first ones ([13] and [6], without the notion of values) are domain-independent, and the latter ones ([7] and [3], the ones that refer to values) are domain-dependent and therefore specifically relevant for the application domain context. To define what sustainability means for any kind of system, exact scoping needs to be performed by answering the questions of what to sustain, for whom, over which time frame, and at what cost [13].

Prior work: Reference Goal Model for Sustainability. To analyze sustainability in detail, we decompose it into five different dimensions [10], see top of Fig. 1. Most concisely, the dimensions of sustainability are characterized as follows: *Individual* sustainability refers to maintaining human capital (e.g., health, education, skills, knowledge, leadership, and access to services). *Social* sustainability aims at preserving the societal communities in their solidarity and services. *Economic* sustainability aims at maintaining capital and added value. *Environmental* sustainability refers to improving human welfare by protecting the natural resources: water, land, air, minerals and ecosystem services. *Technical* sustainability refers to domain-independent longevity of systems and infrastructure and their adequate evolution with changing surrounding conditions. The reference goal model, shown in an excerpt in Fig. 1, structures sustainability by its dimensions, which are represented by a set of values, which can be contributed to by activities and are approximated by indicators (details see [10,11]).

Related Work. There are two works related to sustainability and goal-oriented modeling that are the most important related work for the paper at hand. *Cabot et al.* [2] modeled sustainability goals focusing on conference organization, and

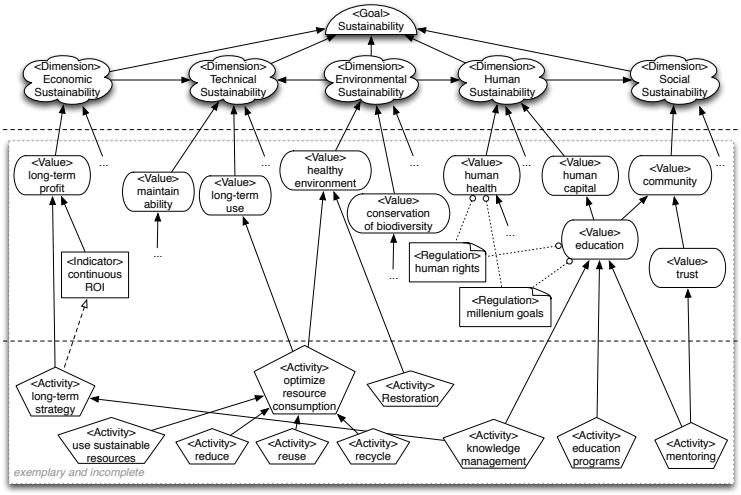

Fig. 1. Old Notation of the Reference Goal Model for Sustainability

their sustainability taxonomy was one of the original inspirations for our sustainability goal reference model [10]. *Mussbacher and Nuttall* [8] modeled sustainability in GRL and related it to time cost, thereby combining quantitative and qualitative data for a richer analysis. Because of that support for indicators and reasoning, we chose to use GRL for our model. Their work is an example case for a sustainability goal model, though, as opposed to a reference model.

3 The Reference Model in GRL

The sustainability reference goal model introduced in Sec. 2 is now represented in its new GRL form in Fig. 2. The elements visible in the figure are the same ones as in the excerpt in Fig. 1 plus a few more activities. While the actual mapping takes place on the level of the meta model, we could not include a figure of the meta model in this paper due to limitations of space, but it is available in [10].

The mapping of the concepts and their visual representation is as follows: Overall goal, Dimensions, and Values are mapped onto Soft goals with metadata for differentiation and preservation of knowledge.

(Sub-)Goals become Goals, Activities become Tasks, and Regulations become Resources.

Indicators remain Indicators, and Contributions remain Contributions.

This now "standardized" representation in a better known notation provides for the possibility to perform richer analyses and reasoning with qualitative and quantitative data.

IV

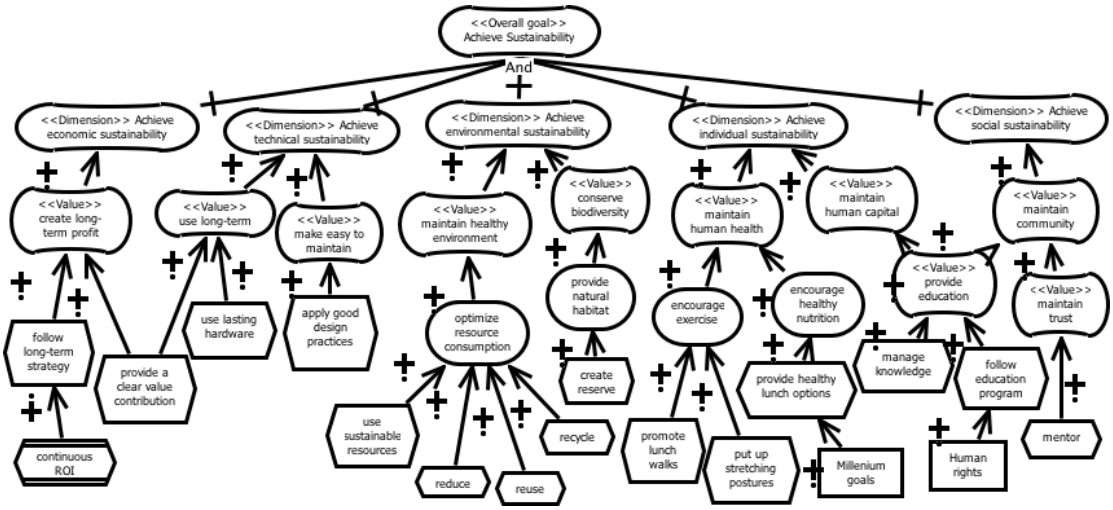

Fig. 2. New GRL Version of the Reference Goal Model for Sustainability.

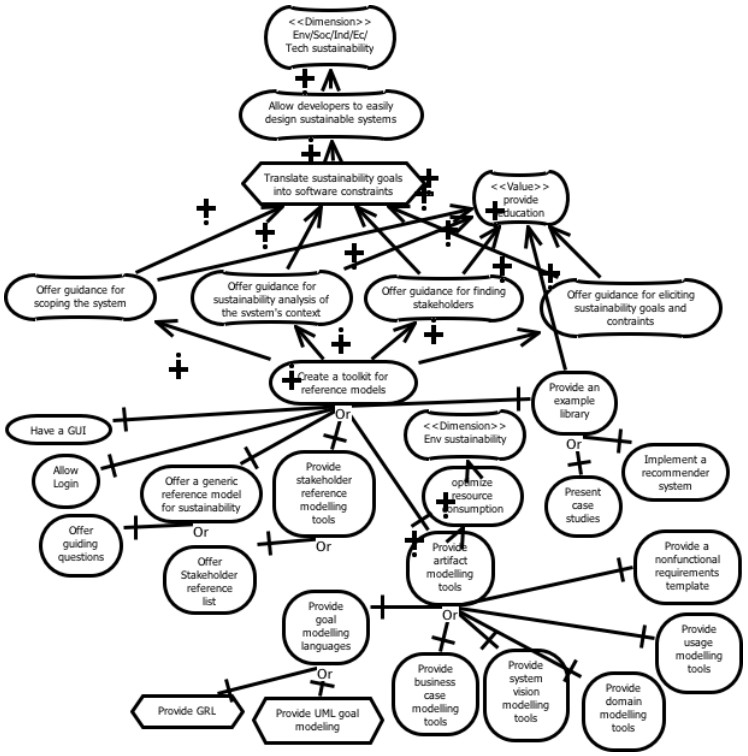

Fig. 3. Goal Model for the Toolkit.

Further Application and Usage. The reference model is intended to serve as a checklist for a systems engineer who tries to integrate sustainability as a major goal into her development context. That means, a goal model is developed while consulting the reference model as one additional input source, because sustainability often lacks explicit stakeholders. The toolkit goal model shown in Fig. 3 is one example where the sustainability goal reference model was considered. It is for a toolkit that helps developers use sustainability reference models (for different artifacts in RE) [9]. When taking a critical look at Fig. 3, there is the *toolkit goal* acting as the only contribution to the four guidance goals. However, this is a known problem in goal modeling. Consequently, the model might be improved in different ways, but it was helpful for progressing with the tool development. The *Values* that the respective *Goals* are related to are referenced in the metadata, which is not visible in the figure. Only for illustrative purposes we have added the example of the $<< Value >>$ *Provide Education* in the upper half and $<< Dimension >>$ *Environmental Sustainability* in the bottom half of the figure.

4 Discussion and Conclusion

Choice of GRL Notation. We use GRL because of its direct support for indicators, which is missing in i*, KAOS, and Tropos, making it difficult to capture real-life measurements from the sustainability assessment in the goal model and then reason about them in the goal model. We could have used BIM [5], which includes *indicators* and *situations* but it is more complex than needed for our purpose.

Expressiveness of New Model. GRL provides a better known notation and simplified the model. Due to this simplification, there initially occurred some information loss during the mapping, for example, that the *dimensions* are now simply *soft goals* as opposed to having a separate concept. However, this was mitigated by using the metadata available in GRL that allowed for adding $<< Dimension >>$ back in.

Analysis and Reasoning. Qualitative and quantitative reasoning are both possible using GRL, and the combination of the two will provide for a richer analysis. That way we are now able to perform a weighting of the goals and by approximating qualitative values to the level of least precision of the quantitative values, we can do first overall assessments.

Future Work on Actors. We chose to show representations without actors in this paper in order to keep things simple for the initial discussion of the sustainability reference model in this notation. One of the steps for future work is to extend the model with views per actor, where the actors are common stakeholders, for example users, project managers, requirements engineers, etc. We plan to extend our previous work on stakeholders for that [12].

Future Work on Tooling. We are currently building a tool (based on jUCMNav) to make this model available as online reference model that can be instan-

tiated and related to other requirements engineering artifacts. For details, see the tool vision in [9].

Take-away Message. This paper presented a sustainability goal reference model in GRL that allows for reasoning with qualitative and quantitative data. It is intended to serve as guidance and checklist for software engineers who want to include the goal of sustainability into their development.

Acknowledgments. We thank Bertrand Ithurburn for his work on the toolkit model, Jennifer Horkoff for a helpful discussion and feedback on a draft version of the model, Gunter Mussbacher for feedback on an earlier version of the model, and Daniel Mendez and Leticia Duboc for feedback on the draft paper. Furthermore, we would like to thank Reviewer 1 for detailed feedback and suggestions for improvement.

References

1. C. Becker, R. Chitchyan, L. Duboc, S. Easterbrook, B. Penzenstadler, N. Seyff, and C. Venters. Sustainability Design and Software: The Karlskrona Manifesto. In *Proceedings of the International Conference on Software Engineering*, 2015.
2. J. Cabot, S. Easterbrook, J. Horkoff, L. Lessard, S. Liaskos, and J. Mazón. Integrating sustainability in decision-making processes: A modelling strategy. In *31st Intl Conf on Software Engineering*, pages 207–210. IEEE, 2009.
3. J. R. Ehrenfeld. The roots of sustainability. *MIT Sloan Management Review*, 46(2):23–25, 2005.
4. R. Heinberg and D. Lerch. What is sustainability? *The post carbon reader: managing the 21st century's sustainability crises*, 2010.
5. J. Horkoff, D. Barone, L. Jiang, E. Yu, D. Amyot, A. Borgida, and J. Mylopoulos. Strategic business modeling: representation and reasoning. *Software & Systems Modeling*, 13(3):1015–1041, 2014.
6. L. Hilty et al. The relevance of information and communication technologies for environmental sustainability. *Env. Mod. & Softw.*, 21(11):1618 – 1629, 2006.
7. S. Mann, K. Costello, M. Lopez, D. Lopez, and N. Smith. An ethical basis for sustainability in the worldviews of first year students. In *ICT for Sustainability 2014 (ICT4S-14)*. Atlantis Press, 2014.
8. G. Mussbacher and D. Nuttall. Goal modeling for sustainability: The case of time. In *Model-Driven Requirements Engineering Workshop (MoDRE), 2014 IEEE 4th International*, pages 7–16. IEEE, 2014.
9. B. Penzenstadler. A toolkit for SE for sustainability - a design fiction. In *Proceedings of the HCI International 2015*, 2015. accepted for publication.
10. B. Penzenstadler and H. Femmer. A Generic Model for Sustainability with Process- and Product-specific Instances. In *First Intl. Workshop on Green In Software Engineering and Green By Software Engineering*, 2013.
11. B. Penzenstadler and H. Femmer. RE at 21: Time to Sustain! In *2nd International Workshop on Requirements Engineering for Sustainable Systems, RE, Rio*, 2013. CEUR-WS.org/Vol-995.
12. B. Penzenstadler, H. Femmer, and D. Richardson. Who Is the Advocate? Stakeholders for Sustainability. In *2nd International Workshop GREENS*, 2013.
13. J. Tainter. A framework for sustainability. *World Futures: The Journal of General Evolution*, 59(3):213–223, 2003.