Integrating Sustainability Awareness Analysis and BPMN-Modelling

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Abstract

All enterprise information system changes need to take the sustainability effects of a reengineered business area or organisation into account. The way to analyse sustainability effects is not clearly related to standard enterprise modelling approaches, and this position paper tries to motivate further discussion on possible ways of linking these types of methods by suggesting an integrated meta-model of SusAF and BPMN.

The proposal is explored through the use of an example and discussed in relation to the quality of modelling language integration. The example illustrates one way this might be done, but also that there might be other ways of integrating sustainability awareness techniques and enterprise modelling that are worth pursuing. We are currently experimenting with additional links between sustainability analysis and enterprise modelling to provide further results at PoEM 2025 and beyond.

Keywords

Sustainability analysis, BPMN, SusAF

1. Introduction

PoEM 2025 focuses on Enterprise Modelling for Sustainable Reindustrialisation. Sustainability has been recognised as central to information systems and software engineering for at least the last decade [3, 10]. In [6], it is concluded that sustainability should become a key concern in the next generation of engineered systems. [6] focuses specifically on the critical role of modelling in this regard. ICT plays a vital role in assuring both social, environmental and economic sustainability. The need for the ICT field to address sustainability has been acknowledged for some time in areas such as Information systems [19], HCI, and software engineering [4, 13].

There are several approaches to evaluating and creating awareness of sustainability. One of these, the Sustainability Assessment Framework (SAF) [13], structures the effects of software systems into four dimensions. Three of them have been incorporated into several sustainability models since the 1980s, following the Brundtland [7] framework, which encompasses the economic, environmental, and social dimensions. To this, SAF adds the technical dimension.

The Sustainable Awareness Framework (SusAF) [4, 5] also has a separate individual dimension. In both frameworks, effects are classified as direct, enabling, or long-term (systemic) [11]. [15] extends this to four levels of effects, differentiating between direct and indirect effects. In a review study of techniques to incorporate sustainability into requirements engineering [2], SusAF is the most frequently discussed approach; however, these publications are primarily from the team that developed the original framework. Beyond what is described in this literature, the application of the framework is limited [2], although some other works are reported [8].

Whereas both SAF and SusAF are attempted to be used as inputs to software requirements and design, the link between sustainability analysis and enterprise business processes is less explored. In this paper, we report on the first attempts to bridge this gap, an approach that we are currently experimenting with in a course in information systems at the university.

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Thus, our research question is

- RQ1: How can sustainability effects be related to business process models?

In the next section, we will provide further background on SusAF. In Section 3, we describe the main result, and in Section 4, we give an example of the integrated use of SusAF and BPMN [17]. These results are discussed in Section 5, before we conclude in Section 6.

2. Background and Related Work

As mentioned above, five dimensions have traditionally been used in the development of a model for sustainability evaluation of ICT projects [4, 14], utilising SusAF, where the model is referred to as the 'sustainability analysis diagram' (SusAD). Specifically, SusAF is composed of the SusAD, the chart for visualising potential sustainability effects of a (software) system, and five question sets for guiding exploration of the five sustainability dimensions [14]. Effects are on different levels. Direct effects, such as energy consumption, are what Hilty et al. [11] denote first-order effects. Second-order enabling effects include the consequences of processes being changed. Third-order structural effects are seen as long- and medium-term change in behaviour.

The five dimensions can be described in the following way [4, 14]:

- The environmental dimension covers the use and stewardship of natural resources. It includes material and resources, waste and pollution, biodiversity, and energy usage.
- The technical dimension covers the ability to maintain and evolve artificial systems (such as software) over time, including aspects of maintainability, adaptability, security, and scalability.
- The economic dimension covers financial value, customer relationship management, supply chain, logistics, governance and innovation.
- The individual dimension covers health, lifelong learning, privacy, usability, universal availability, safety, and agency.
- The social dimension covers relationships between individuals and groups. This includes a sense of community, trust, inclusiveness, diversity, equity, participation and communication [9].

In addition, we have added a sixth dimension that covers compliance with rules and regulations, both in the short term and to ensure future-proofing for upcoming regulations. This is in view of the large number of regulations emerging, particularly in the EU, with the AI Act being just one of many, although specifically important due to the significant role AI plays in digitalization and sustainable development [18]. The renewed framework is illustrated in Figure 1.

Aspects within these dimensions are often interlinked, so that an effect in one area can have a positive or negative effect on another effect in the same or different dimension, possibly on another level, as will be illustrated in the example in Section 4.

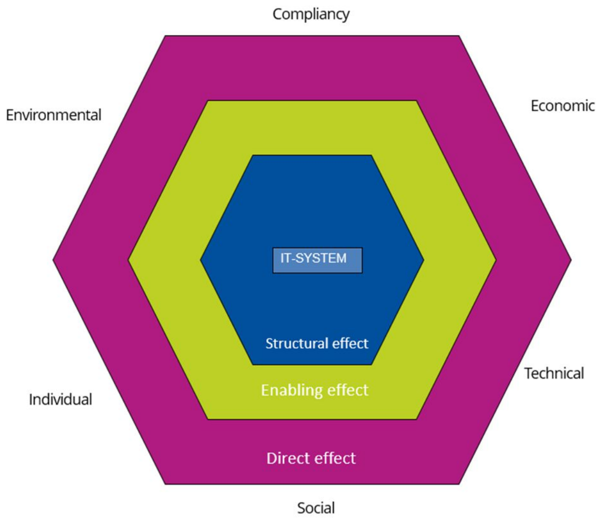

Figure 1: Extended SusAD.

In enterprise modelling, we aim to support the modelling of effective enterprises, including good business processes. A *good* business process produces its products or services by optimising one or more of a set of quality features. The value of a process to be optimised is not only the economic return, but also a broader set of possible objectives, as listed in Table 1, further explained below.

Table 1
Dimensions of value of business processes

Dimension of value	What is wanted
Time	Timely
Quality	Right
Cost	Low
Flexibility	Sufficient
Resource-usage	Sustainable
Unwanted side-effects	None
According to regulations	Compliant
Reproduceable	Trustworthy
Improvable	Possible

- Time: Time from the start to the end of the process. Based on the expectations, it should be on time (or faster), i.e., be timely.
- Quality: The quality of the resulting product is as expected (or better).
- Cost: Direct monetary costs as expected or lower.
- Flexibility: Often relates to how one can treat discrepancies with the normal path of the process. The required flexibility varies significantly for different types of processes.
- Resource usage: This can relate to several areas. When it comes to employees, they would not like to work in a process where they experience that they are exploited. When it comes to natural resources, Green BPM as part of Green information systems [19] has emerged as an area where one examines the overall carbon footprint of the process or any other type of pollution resulting from it.

- Unwanted side-effects: Some examples are a process that jeopardises the security of the customers (think of an internet bank with too poor security) or privacy, or the reputation of the company (using child labourers to produce their products, for instance, or for a public service to be biased against certain groups of citizens). The process should not have unwanted bias.
- According to regulations: In most areas, both in the public and private sectors, you have to act according to the regulations in the area (usually country) that you operate. You can also consider the situation where you are certified according to a specific process or at a certain maturity level, which may be necessary to be allowed to deliver a particular product or service. This can also be important to be regarded as a sufficiently good provider in a supply chain or digital business ecosystem.
- Reproducible: The level of service can be redone, and does not deteriorate, e.g. because of being supported by unmaintainable IT-solutions, or too dependent on individuals in the company.
- Improvable: It is possible to gauge the level of service, and not only keep this up, but potentially improve it by introducing, e.g., new technology.

The dimension of process-value is related to the dimensions of sustainability in the following ways:

- Time and cost -> Economic impact
- Resource – usage -> Environmental impact
- Improvable -> Technical impact
- According to regulations -> Compliance impact
- Unwanted side-effects -> Social, individual or technical impact
- Flexibility -> Individual impact
- Reproduceable -> Technical impact

Quality can thus have an impact on any of the sustainability dimensions.

3. Approach to Integration

A way of bridging SUSAF with requirements and process modelling in an information system context is suggested below, where concepts from SusAF are linked to (process) modelling and quality of business processes. The figure is described in more detail below:

A *system* can have specific *effects*. The system can be an *existing* system (as-is analysis), or a new system *planned* for development (to-be analysis) and is often either a software system or an information system (including also a set of business processes and an (re)organisation in addition to the technical software system). Our focus here is (enterprise) information systems. The effects have an *impact* (low/medium/high) if they occur, and a *likelihood* of occurring (low/medium/high). The effect itself can be regarded as *positive* or *negative.*

To achieve a positive effect, or avoid a negative effect, one has parts of a process (activities that might utilise a software system). The business process can be depicted, for example, in BPMN. Another possible approach (not shown here) is to link effects to goal models (that an effect will achieve a goal more or less likely). In this paper, we focus on the integration with process models. Process metrics are as listed above.

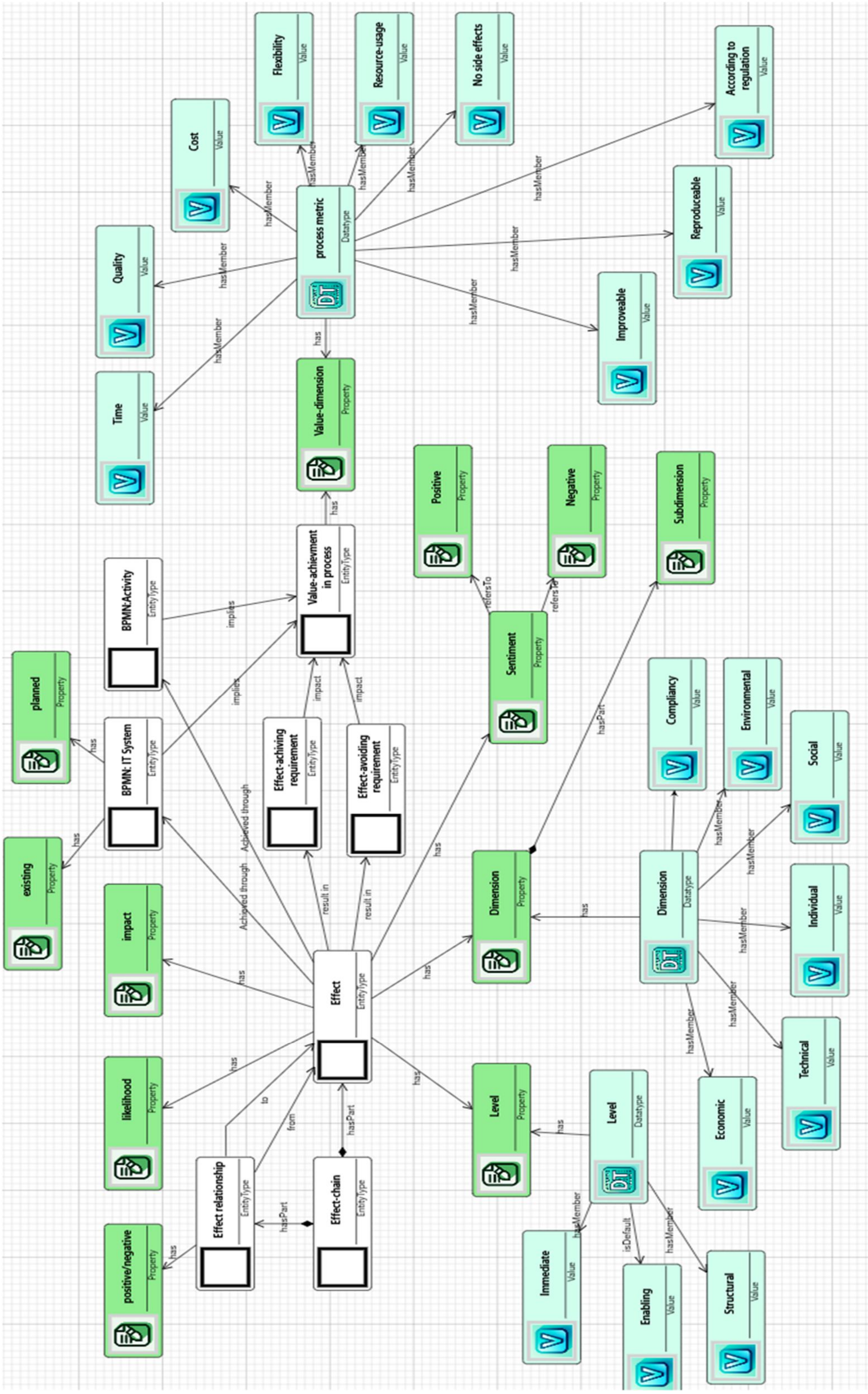

Figure 2: Metamodel of extended SusAF and process value in BPMN

Effects can be part of an *effect-chain*. In these cases, one effect might have a *positive or negative* influence on achieving another effect. Effects are categorised according to the levels (immediate (direct), enabling, structural) and dimensions (economic, technical, individual, social, environmental, and compliancy) as previously described. Sub-dimensions as found in [14] are not depicted in the diagram.

4. Example Application of the Approach

The following example illustrates the possible connection between sustainability concerns and a new procurement process in a public sector agency. Figure 3 is a high-level, simplified BPMN model of the first part of such a process.

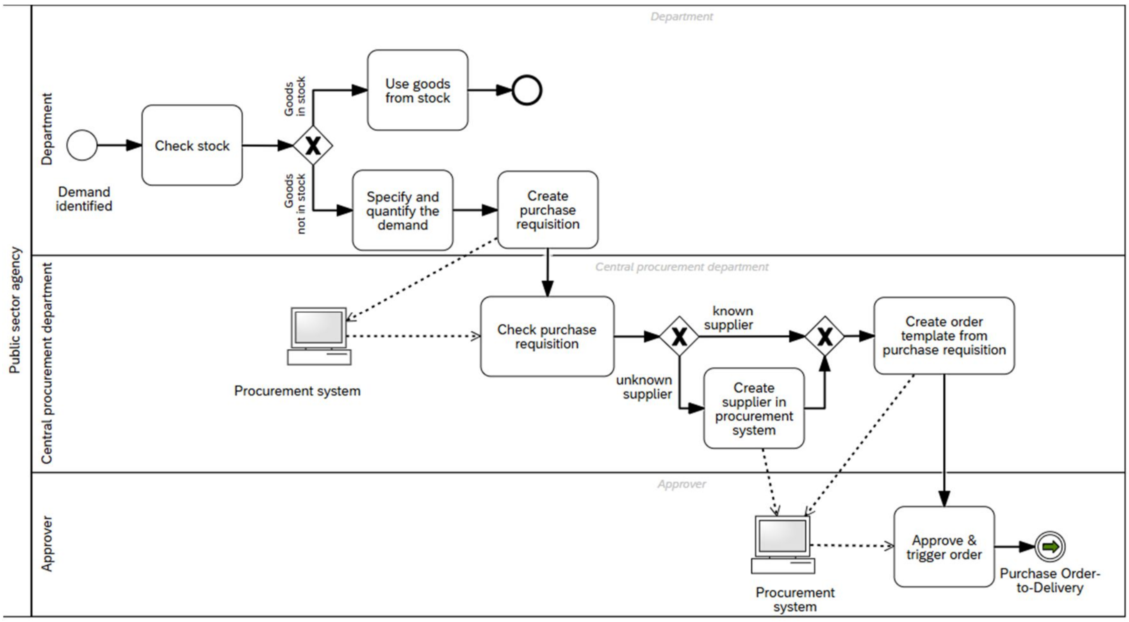

Figure 3: Public procurement process

The process begins when someone in a department within the agency identifies a demand (Event: Demand identified). If the product is locally available, one uses the good from stock. If not, the demand is further described, and a purchase requisition is made. A worker in the central procurement department checks this. If the supplier is known, an order is made. If not, the new supplier is registered in the system first. Finally, an approver triggers the actual order to the supplier.

The organisation aspires to have a more sustainable procurement process. Several possible sustainability effects at various levels are illustrated in Figure 4 (described further in Table 2), partly inspired by the example found in [4].

Note that this relates to the whole procurement process, as it is supported in the technical procurement systems (bottom right).

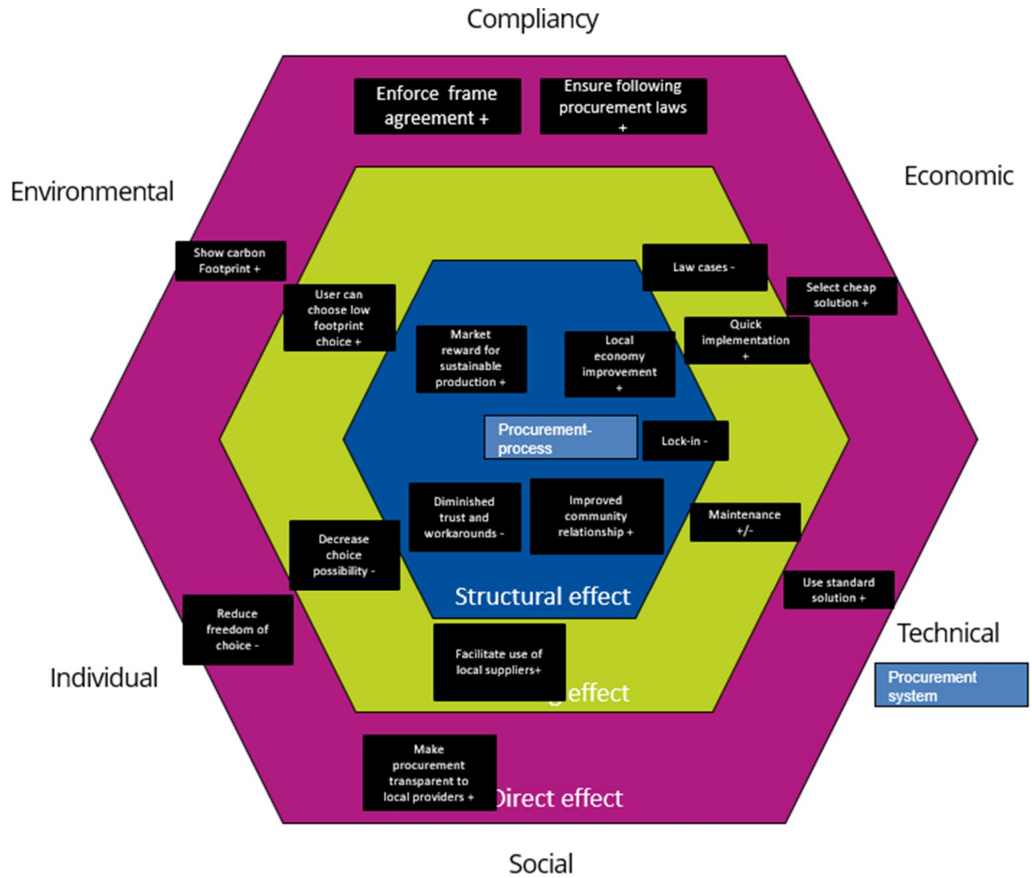

Figure 4: Sustainability effects in the procurement process.

Below is a listing of the effects found in Figure 4, before we list the relationships (effect chains). The +/- indicates a positive or negative effect, the first digit represents the level of effect, and the second digit represents the dimension.

Some connections among effects[2]

- +D.T.1 -$^{+}$> +E.T.1 or – E.T.1: The use of a standard procurement solution will potentially save money for evolution and maintenance, given that it supports the process wanted by the organisation well. On the other hand, if numerous local changes are required, the evolution and maintenance activities may become more extensive. (thus, the effect can be both positive and negative).
- +D.T.1 -$^{+}$> +E.EC.1: A standard solution can be quick to implement, and thus one can enforce a new process quickly. A bespoke solution may be slower to implement, but it will be better equipped to accommodate specific needs. On the other hand, it may necessitate different types of maintenance needs that would have been addressed in a standard solution.

[2] -$^{+}$> is a positive connection (i.e. that one effect make the other effect more likely),
-$^{-}$> is a negative connection (i.e. that one effect is expected to dampen another effect)

Table 2
Sustainability effects

Level/Dimension	**D**irect effect	**E**nabling effect	**S**tructural effect
Environmental	+ D.EN.1 Show carbon footprint in system	+ E.EN.1 Enable choice based on carbon footprint	+S.EN.1 Market reward for sustainable production
Individual	- D.I.1 Reduce freedom of choice	-E.I.1 Decrease choice possibility	-S.I.1 Diminished trust and workarounds
Social	+ D.SO.1 Make procurement transparent to local providers	+ E.SO.1 facilitate use of local providers	+ S.SO.1 improved community relationship
Technical	+ D.T.1 Use standard solution	+/- E.T.1 system maintenance	- S.T.1 Lock-in
Economic	+ D.EC.1 Select a cheap IT solution	+ E.EC.1 Quick implementation of the system -E.EC.2 Law cases	+ S.EC.1 local economy improvement
Compliancy	+ D.C.1 Ensure following procurement laws + D.C.2 Enforce frame agreement		

- +D.T.1 $-^{+}>$ +D.C.1: A standard solution is probably made in a way that enforces following the existing procurement laws.
- +D.C.1 $-^{-}>$ - E.EC.2: Following the procurement laws will minimise the risk of being sued by providers from erroneous procurement (and thus reduce the risk of losing lawsuits).
- +D.4.1 $-^{-}>$ +D.EN.1: If the standard procurement system does not include information about carbon footprint, it will be hard to support this. Similar to other ways of supporting sustainability (e.g., the enforcement of local suppliers).
- + D.C.2 $-^{-}>$ + E.SO.1: The enforcement of frame agreements might make it more challenging to use some local suppliers.
- + D.C.2 $-^{+}>$ - E.I.1: The enforcement of using frame agreements can make the possibility of individual choice less, thus enforcing this potentially negative effect.
- +D.1.1/+2.1.1 $-^{+}>$ S.EN.1: If information on carbon footprint is available, and many use this opportunity, in the long term, it can influence the market to provide more sustainable options and thus have a long-term positive effect on environmental sustainability, especially if it influences the standard procurement solutions.

As we understand, there are a number of connections and trade-offs to be made, which can be discussed based on this analysis. Additionally, the influence of this on the process can be illustrated in the process model, which is here supplemented with comments, as there is no suitable notation in BPMN for sustainability effects. Whereas some aspects are on an overall system level (choice of standard or bespoke system), other elements are closely related to where in the process different aspects are enforced.

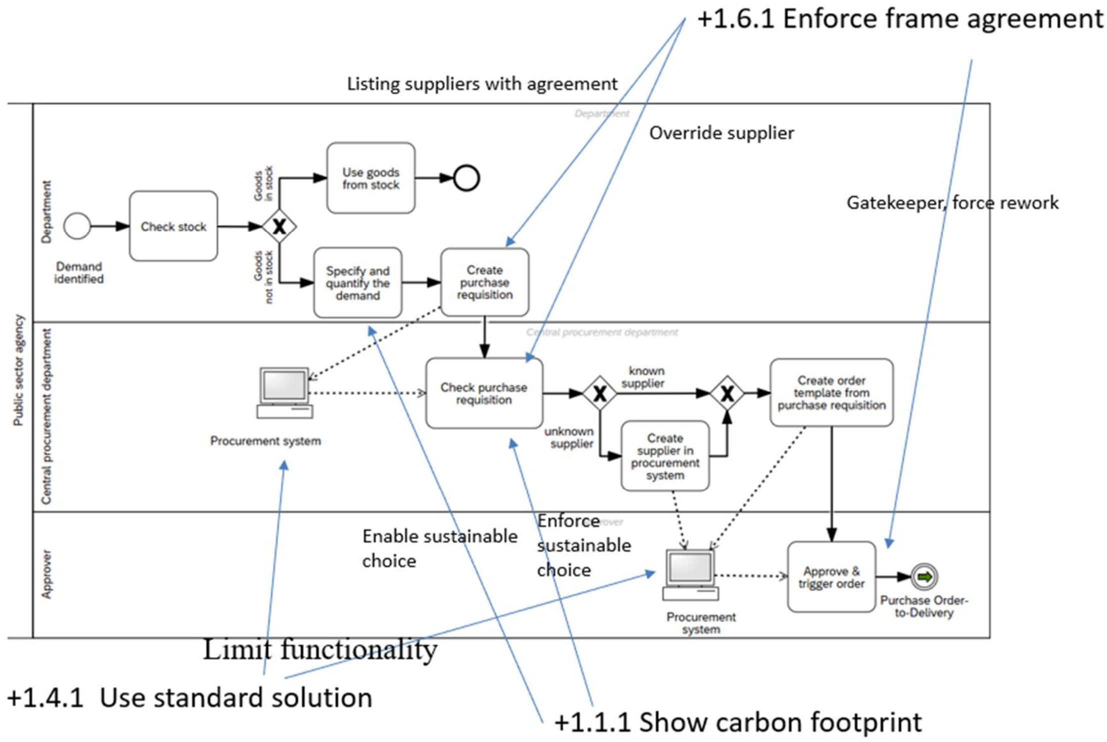

Figure 5: Public procurement process model annotated with sustainability effects.

In Figure 5, we illustrate some of the links that can also influence the overall time used for procurement, from the time a need is identified until a purchase order is sent.

- Is the standard solution to be used for all steps, or is this only used for the formal part, whereas one might add specific wishes in the initial purchase requisition?
- Is the frame agreement enforced in all steps, thus almost disallowing selecting new suppliers, or is it first implemented by the procurement department or the final approver (with the possible need of restarting part of the process, e.g. needing to update the process model)?
- Is it possible to see the carbon footprint by the initial procurement request and make a choice based on this , or is this first taken into account by the procurement department?

5. Discussion

Different dimensions of sustainability are increasingly becoming critical in how we are evolving organised activities. In enterprise modelling, we have several approaches to provide an overview of current and future situations, supporting the analysis and development of new information systems. Many workshop-oriented approaches, such as SAF and SusAF, exist to identify the sustainability effects of systems, and links to software requirements [2] and design [13] have been developed; however, they are currently underutilized in practice [1, 5].

Returning to our research question **RQ1**: "How can sustainability effects be related to business process models? ", we have in this paper provided an example of one possible way this can be done. We admit, though, that this is so far weak anecdotal evidence which provide important risk to validity.

The example presented, although simple, illustrates several novelties:

- In addition to the five traditional dimensions of sustainability effects, we have introduced a compliance dimension, which proved helpful to illustrate the laws, regulations and standards that influence the overall system, which also will affect the process model.
- A meta-model of the extended version of SusAF is provided, also illustrating one way that sustainability effects can be linked to parts of the process models and requirements and, through that, to the achievement of process value.

Although the example illustrates that it is possible to link sustainability effects to business process models, the link is not immediately apparent, and much of the reasoning behind the resulting business process is not easily illustrated in the existing BPMN language, apart from as comments/annotations. That said, this applies to all process value deliberation; the 'why' aspect of the process model is poorly represented in standard BPMN, indicating a need to link the sustainability diagrams to more comprehensive enterprise modelling notations, such as ArchiMate or 4EM [16] which also include goal modelling.

6. Conclusion and Further Work

In this position paper, we have begun to explore the possible integration of a sustainability awareness framework and process modelling using BPMN, aiming to take sustainability more consciously into account in process improvements. This can be supported more concretely in BPMN models as part of enterprise process modelling.

The example provided in this paper, is to our knowledge, the first attempt to establish such a link on the modelling language level. A suggestion for the main parts of a combined meta-model is presented, although only a limited part of a BMPN-metamodel is provided. The overall approach is currently tested by student groups in an advanced Bachelor course with around 150 students. Based on the learnings we will update the overall approach. The next step is to design a better tool that supports this by integrating it with a BPMN meta-model found in other tools.

We plan to do this using the Mimris-environment[3], and also devise a better notation, taking into account aspects of quality of modelling languages [12]. Using this we plan to perform additional experiments, both as for the usefulness and usability of such language, being studied as being used in industrial cases. The possibility of parallel modelling and meta-modelling supported in Mimris will make possible further extensions of the meta-model of the approach through use. We will also investigate the integration of sustainability effects with goal-oriented modelling, such as found e.g., in 4EM [16]. A more detailed evaluation is planned for Autumn 2026 linking to the course in which we are currently piloting the approach.

Declaration on Generative AI

During the preparation of this work, the author did not use AI tools, but only built-in services in Microsoft Word in order to do grammar and spelling check.

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