Modelling Sustainability in a Procurement System: An Experience Report

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***Abstract*—Sustainability is one of the main driving forces in our society. IT can also contribute to sustainable development, which goes beyond the energy consumed to produce and run the software product. The development of social-technical systems can have a significant impact on the sustainability of its surroundings. A particular type of system with considerable sustainability impact are procurement systems. They normally affect the three pillars of sustainability: social, economic and environmental. This paper describes an experience on using goal modelling to incorporate sustainability into the procurement system of a large multinational energy company. The study highlights the advantages and challenges of introducing sustainability into private procurement systems, as well as the suitability of the technique for such a purpose. We believe this experience and its resulting model can be useful to other companies wishing to implement sustainable procurement processes.**

I. Introduction

Sustainable development is defined as "the ability to meet the needs of the present without compromising the ability of future generations to satisfy their own needs" [1]. Sustainability has become a driving force in our society. Concerns about the impact of human activities have been increasing, accompanied by worldwide efforts to achieve sustainable development [2]. These concerns have started to reflect in organizations. Some find themselves obliged to comply with regulations in order to operate, such as organizations that exploit natural resources [3]. Others have begun to understand the importance of having a public image for "sustainable organization", as consumers are increasingly preferring products and services that have a sustainable character [4].

A survey with around 1,000 CEOs in 2010 [5] showed that their majority (93%) reported sustainability to be "important" or "very important" to the success of their business and that it should be fully incorporated into strategies and operations (96%), implemented by boards (93%), and integrated in the supply chain (88%). In 2013 [6], the survey showed similar results: again 93% of the CEOs regarded sustainability as key to success. Nevertheless, a deeper analysis of the data in this latest survey reveals that business efforts on sustainability may have reached a plateau instead of continuing for a new peak, perhaps reflecting the current economic climate. In spite of the doubt about the pace of change and the scale of impact, the survey also reveals that "the corporate sustainability movement is broadening, with a deeper awareness and commitment evident in every quarter of the world" [6].

IT has an important role to fulfil in sustainable development. First, IT systems are large consumers of resources, not only when they are operating, but also considering their whole life cycle [7][2]. Second, IT is at the heart of many areas critical to sustainability and can be crucial in creating awareness for sustainable practices, as well as in facilitating the implementation and monitoring of strategies for sustainability.

A particular type of IT system that considerably impacts on the three pillars of sustainability (social, economic and environmental) are procurement systems. Such systems can be used by both private and public organizations to support the processes for purchasing products and contracting services. Usually, these systems are not big energy consumers, yet they can have a considerable influence on the sustainable development of the communities around them.

Governments are normally interested in promoting sustainable development, which led to the creation of international guidelines for sustainable public procurement [8][9]. Even though such guidelines are followed by a number of government agencies worldwide, we are not aware of studies on software engineering to incorporate these guidelines into public companies' procurement systems. In the private sector, companies are increasingly aware of the advantages of maintaining an "green" public image [4]. Procurement systems offer such an opportunity, as it allows companies to publicize a sustainability-related initiative. Also, by using sustainable raw materials, companies may eventually advertise so directly in the label of their products. Finally, sustainable procurement can bring financial gains [9][4].

In this paper, we report on the experience of modelling sustainability into the procurement system of one of the leading energy companies in the world. Due to a non-disclosure agreement, the anonymity of the company must be preserved; thus, a fictional name is used: Oil.Br. The system supports the process of purchasing products and services for part of the company in Brazil, including the request, approval, quotation, order submission to suppliers. The system aims to ease the acquisition of products and services, while ensuring that Oil.Br's suppliers meet compliance rules. It also optimizes for price, payment conditions and delivery times. This paper

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describes the experience of adding the sustainability dimension to this optimization criteria. Our driving question is: "Is it possible to make procurement systems more sustainable? If so, how can this be made?". Although this answer is addressed in the context of Oil.Br, the experience described in this paper can be valuable to other organizations, in both private and public sectors, wishing to implement procurement systems (or to augment their systems) with sustainability.

Our proposition was to adapt the guidelines for sustainable public procurement [8] [9] to Oil.Br's system, which raised an important concern: How to ensure the incorporated guidelines are aligned with Oil.Br's business goals and yet create a shared responsibility for sustainability within the company? In order to choose the technique to model sustainability into Oil.Br system, we started from the premise that sustainability can be considered as a software quality matter [10], so we focused on techniques that treated non-functional requirements as first-class entities, such as goal modelling. In this context, we opted for the KAOS framework [11]. As it is discussed later, the advantages of dealing with sustainability using goal modelling include the alignment with high-level business goals, the trade-off analysis, and the distribution of responsibility among agents. The methodology for the study consisted of (i) interviewing stakeholders at Oil.Br, (ii) building a preliminary model using the KAOS framework and the heuristics in [11], (iii) studying the literature on sustainability-related norms and guidelines for sustainable public procurement, (iv) incorporating sustainability goals into the system, and (v) evolving the model based on stakeholder feedback.

The contribution of the paper is two-fold. First, it strengthens the body of knowledge on sustainability and software engineering, by describing and analysing the application of a requirements engineering technique to incorporate sustainability to a large real-world system. Such need was recognized by other authors [12][13][14][15]. Second, the reported experience and the created model can help other organizations to implement sustainable procurement systems. The paper also highlights the advantages and challenges of introducing sustainability goals into a private procurement system.

This paper is organized as follows: Section I describes how IT, in general, and procurement systems, in particular, can contribute to sustainable development. Section II introduces the key concepts underlying this work, namely sustainability, sustainable public procurement guidelines, and KAOS. Section III presents the real-world procurement system to which sustainability should be incorporated. Section IV describes how this system was modelled, include an adaptation of the guidelines for sustainable public procurement. Section V shows a critical evaluation of this experience. Finally, Section VI reports on related work, and Section VII highlights the main points of this paper and lists future work.

II. Background

A. Sustainability

Sustainable development rests on three pillars: social, economic and environmental. Social sustainability includes human rights, as well as rights of justice, labour, equality, diversity, health, democracy and governance. It refers to a set of actions to improve the quality of life of our society [1][16]. Economic sustainability refers to the economic growth and productive efficiency of public and private sectors, including the profit that companies get, in a sustainable manner, through the distribution and consumption of goods and services [1][17]. Environmental sustainability refers to meeting the needs of the society without exceeding the capacity of ecosystems nor diminishing biological diversity [18].

Like on many other areas, Information and Communications Technology (ICT) has an impact on sustainable development. On one hand, it can implement and monitor sustainability strategies, raise awareness of the impact of actions, or even augment ordinary systems so that they achieve their business goals in a more sustainable manner. On the other hand, ICT can negatively impact sustainability by increasing energy consumption and electronic waste disposal or by creating unexpected rebound effects, for example. With respect to the environmental impact, Berkhout and Hertin [19] define the following three orders of effects caused by ICT:

First order impact: Environmental effects directly caused by the production and use of ICT, such as the resource usage and the pollution associated with the production of infrastructure and devices, power consumption of hardware, and the collection of electronics disposal;

Second order impact: Environmental impact indirectly related to the effect of ICT on the economy, production processes, products and distribution systems;

Third order impact: Indirect effects on the environment, mainly through increasing consumption and economic growth caused by the adoption of ICT.

Even though Berkhout and Hertin were concerned with environmental impact, these orders also could be thought in the context of social and economic impact.

B. Sustainable Public Procurement

Government expenditure can represent between 15% and 30% of the Gross Domestic Product [20]. Sustainable procurement aims to incorporate aspects to reduce social and environmental impacts into the process for purchasing goods and hiring services, while generating savings to the public administration [8][9]. This solution integrates social and environmental considerations through actions such as buying what is really necessary and making decisions based on the circumstances in which a product was made.

Sustainable procurement can bring many benefits. For instance, by choosing a product that has low power usage and low water consumption, for example, organizations can significantly reduce their costs during the product life cycle [9]. A key point of sustainable procurement is that it cannot result in significant additional expenditure [8].

Besides profitability, a sustainable procurement policy can bring a number of benefits not only to organizations, but also to the government and the society in general [8][9]:

- Improve organization's image, given thatcaring about the environment normally leads organizations be better regarded by the society and government agencies;
- Improve local community's quality of life, e.g. through the use more energy-efficient and less polluting means of transport;
- Contribute to global sustainability, by reducing greenhouse gases and deforestation in regions beyond the location
- Encourage suppliers to innovate products and to make them more sustainable, promoting a greener and more inclusive economyand also increasing the number of jobs;
- Improve organizational efficiency, allowing better decision making on procurement and contracting;
- Achieve higher levels of sustainability with the same capital due to the offset of costs during the products life cycle.

Among the different methodologies that help the government agencies to implement sustainable procurement, the best known and most used one is ICLEI's Procura+ [8][9]. This methodology defines the following important guidelines:

Watch continuous improvement: The decision criteria of purchases and contracts should go beyond price, time and quality, also assessing aspects such as the replacement of polluting sources, waste reduction and recycling, water and energy savings, combating of slave labour, social inclusion and improved relationship with communities;

Watch the product: Evaluate the product life cycle, analysing the money spent and the social-environmental impacts arising from the acquisition, use, maintenance, transportation and proper disposal;

Watch the buyer: Purchasing staff must be aware of the company's sustainability strategy and must be trained on the sustainability criteria and best practices. Furthermore, buyers need the support of an sustainability expert;

Watch the supplier: Criteria of sustainability in purchases and contracting must be checked. Dialogue must be established with suppliers to exchange ideas and receive feedback.

According to Biderman et al. [9], even though sustainable procurement is normally adopted by government agencies, it can also be adapted to the private sector, bringing benefits such as the ones mentioned previously.

In order to perform this work, we have also investigated the ISO 14000 family, which defines guidelines for environmental management [21], and some models on sustainability indicators [22] [23]. Because these addressed sustainability in general, adapting the guidelines for sustainable public procurement [8][9] was more suitable to the characteristics of the system and needs of the organization.

C. KAOS

KAOS is a goal-oriented framework for requirements engineering. Its main model, the goal model, is concerned with "why" the system needs a given functionality and "how" this functionality can be obtained. We chose the KAOS modelling because the goal model fits the needs of sharing responsibility for sustainability and aligning to high-level goals. Another influencing factor for this choice is that sustainability can be considered as a software quality matter [10], and other techniques such as user stories and use cases are not intended to handle non-functional requirements.

The goal model's main concepts are: goals, agents, requirements, expectations and domain assumptions [11]. Goals may be formulated at different levels of abstractions, ranging from high-level strategic concerns to low-level technical concerns. Goals may also be functional, describing the services to be provided by the system, or non-functional, associated with quality of service. In a goal model, goals are interrelated by AND- and OR-refinements. An agent is an active system component that is responsible for satisfying a goal. Agents may belong to the system environment or to the software system itself. Goals should be refined until they can be assigned to a single agent. A requirement is a goal under the responsibility of a single agent in the system-to-be, while an expectation is a goal under the responsibility of an agent in the environment. Finally, a domain assumption is a descriptive statement about the environment that is expected to hold true regardless of the system behaviour.

III. OIL.BR'S PROCUREMENT SYSTEM

Oil.Br uses an in-house developed procurement system to purchase goods and to contract services. This is a large system, implemented mostly using Oracle technology. In this paper, we refer to such system as *IProc - Integrated Procurement System*. IProc aims to reduce costs, to ease the process of purchasing and contracting, and to ensure compliance rules.

In order to hire services or buy products, these must be previously registered in the system. Examples of services are maintenance, painting, health and security services. Products, in turn, are classified direct or indirect. The former are used directly in the products sold by Oil.Br; examples include base oils, additives, and packaging for lubricants. The latter are all other products used by Oil.Br's employees during processes, such as computers, paper and pens.

Both products and services must be supplied by registered companies who have passed Oil.Br's approval process, which normally consists of attesting that the supplier is reliable and has the capacity to provide what is being requested. However, there are services and goods that require certain certifications from the supplier, such as environmental management (ISO 14001 [24]) and occupational health and safety (OHSAS 18001 [25]). Examples of these are the services that require specialized equipment, and products that require especial care for waste disposal. In such cases, the corresponded certification is also verified in the approval process.

The IProc system assumes that products, services and suppliers have been previously registered. For convenience, we refer to both the purchasing of products and the hiring of services as the purchasing of items.

Oil.Br's procurement system encompasses three types of purchases: ordinary, directed and urgent. The first represents the main purchasing process. In the direct purchase, there is a pre-selected supplier this is justifiable when there is only one licensed supplier of an item. The urgent purchase is a quicker

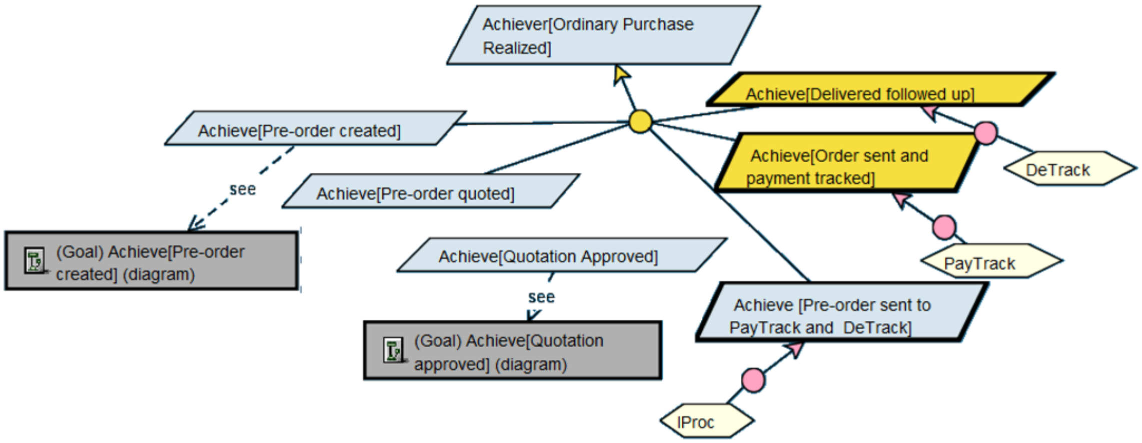

Fig. 1. Excerpt of the goal model for Ordinary Purchase.

process due to an urgent need for a product or a service, such as the replacement of a broken production equipment. The model includes the three types of purchases, but due to space constraints, only the first one is discussed in this paper.

In summary, the ordinary purchase starts when an employee (requester) asks for items, which must be approved by his assigned superior (approver). Upon approval, the system creates a pre-order and send it to the registered suppliers for quotation. Then, suppliers inform the prices of the requested items, payment conditions and delivery times. After the quotation, a supplier is chosen and the system sends the pre-order to two external systems, referred to as *PayTrack - Order Payment Tracking System* and *DeTrack - Order Delivery Tracking System*. PayTrack is responsible for issuing the purchase order to the supplier, as well as following up its payment. DeTrack controls the delivery of the product or the execution of the service. Requested items can be cancelled at any time.

In addition to the presented process, the IProc system has three other aspects of interest: (i) it keeps track of all purchases, including information of who ordered or approved a particular item and which items were associated with the same purchase; (ii) it ensures that all requesters and approvers are registered in the system, along with their respective restrictions, such as the family of items that an employee can request or approve; and (iii) it allows users to request modifications to the system on the IT team, subject to approval.

IV. Incorporation Sustainability

As described in Section I, after interviewing stakeholders, a goal model was created to Oil.Br's system. The subsequent step was to extend that model to include sustainability goals. The extended model contained 13 agents and 137 goals, from which 43 were requirements and 41 were expectations.

A. *Modelling the system-as-is*

A list of the agents in the system-as-is model and their main responsibilities are given as follows:

- `IProc`: Oil.Br's software system to pre-order products and services (items);
- `PayTrack`: Oil.Br's software system to issue orders and track their payment;
- `DeTrack`: Oil.Br's software system to track the delivery of products and execution of services ordered;
- `Requester`: Employee requesting an item;
- `Approver`: Employee approving a request;
- `Supplier`: A registered provider for an item.

One of the main high-level goals of the system is `Achieve[Purchase process automated]`, which contributes to the top-level goals `Minimize[Purchase time]`, `Maintain[Compliance with regulation]` and `Improve[Ease of the purchase process]`. In order to satisfy the goal `Achieve[Purchase process automated]`, the system must allow purchases to be made and cancelled, as well as the history of all purchases. As explained before, there are three types of purchase processes, represented by the goals `Achieve[Ordinary purchase realized]`, `Achieve[Directed purchase realized]` and `Achieve[Urgent purchase realized]`. Due to space constraints, the full goal model is not shown. The most important excerpts of this model are presented as follows.

Figure 1 shows the refinement of the goal `Achieve[Ordinary purchase realized]`. To satisfy this goal, a pre-order for the item is created and sent to the suppliers for quotation. Once the quotation is approved, the pre-order is forwarded to the external systems `PayTrack` and `DeTrack` for ordering, payment and delivery monitoring. This process is represented by the goals `Achieve[Pre-order created]`, `Achieve[Pre-order quoted]` and `Achieve[Quotation approved]`, the requirement `Achieve [Pre-order sent to PayTrack and DeTrack]`, and the expectations `Achieve[Order sent and payment tracked]` and `Achieve[Delivered followed up]`. The first three are further refined.

B. Extending the model

In the extended model, three new agents were included:

- `Ergonomic System`: Oil.Br's system responsible for the well-being of employees using the company's software;
- `EnergyMo`: Adaptation of an Oil.Br's software for monitoring the used of energy by the companies IT systems;
- `Sustainability team`: Oil.Br's employees responsible for creating and evaluating the sustainability criteria of products, services and suppliers[1].

Sustainability goals aim to minimize the three impact orders of the system, defined in Section II-A[2]. The first impact order refers to the effects directly caused by the production and use of the system. Two opportunities to reduce this impact were identified and are represented by the goals `Achieve [Energy consumption monitoring]` and `Achieve [User health preserved]`. These are explained later. Second and third impact orders are mitigated by adapting the ICLEI Procura+ methodology [8] to Oil.Br's context.

This adaptation includes an analysis of the products, services and suppliers with respect to social, economic and environmental issues. To this end, the system adopts the concept of "sustainability levels" for products, services and suppliers, calculated from sustainability criteria and their respective weights. This classification is supported by the system, but achieved in a gradual manner with the help of a sustainability team, as it is explained later. Information obtained from such classifications are taken into account in the sub-processes for registering items, requesting items and approving quotations. Note that the goals associated with these sub-processes are represented in the model by independent sub-trees whose roots are the goals `Achieve [Items registered]`, `Achieve[Items requested]` and `Achieve[Quotation approved]`, respectively. Figure 2 shows an excerpt of the model resulting from to this refinement. Each of these sub-trees is described as follows.

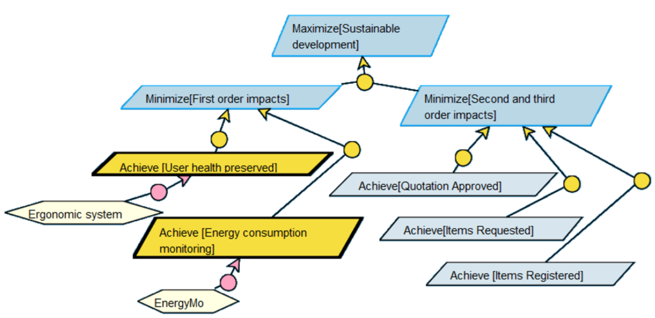

Fig. 2. Excerpt of the goal model for minimizing the three order impacts.

1) Registering items: This allows sustainability information to be registered with items. In the extended model, the system supports the registration of sustainability information for three groups of items: most requested items, direct items (which are used directly in the products sold by Oil.Br), and critical items (with high impact on sustainable development). The first group is automatically recognized by the system. The latter two must be informed when registering the item.

Figure 3 shows the goals associated with this sub-process. An employee registers a product or a service and informs whether this item is critical to sustainability or directly used in Oils.Br's products; this is represented by the goal `Achieve[New item informed]`. If the newly registered item is critical or direct, the system sends a request to the sustainability team asking for the corresponding sustainability information to be included, as represented by the goal `Achieve[Sustainability information requested if critical or direct item]`.

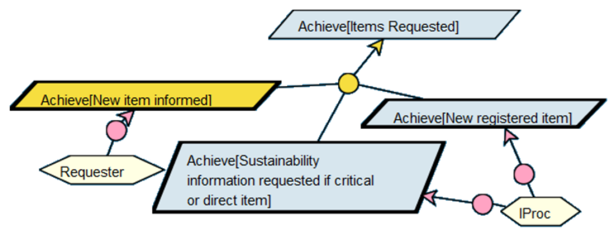

Fig. 3. Excerpt of the goal model for registering items.

2) Requesting items: As Oil.Br's procurement system is in production, items are already registered without any sustainability information. When requesting items, there are two sustainability-related opportunities: the first is to identify direct and critical items without registered sustainability information and request it to the sustainability team. The second is to consider the available sustainability levels and choose among alternative items. These opportunities are represented by the goals `Achieve[Sustainability information of critical or direct item requested, if not registered]` and `Achieve[Sustainability information of item available, if registered]`. Also, periodically, the system checks the purchase history, identifying the most requested items; this is represented by the goal `Achieve[Sustainability information of most requested items checked]`. If an often requested item does not have sustainability information associated to it, the system informs to the sustainability team. This excerpt is shown in Figure 4.

The refinement of the goal `Achieve[Sustainability information of the item registered]` consists in registering the sustainability criteria with their relative weights and values. These are defined by the sustainability team, so that the system can calculate the sustainability level of products and services. This refinement is shown in Figure 5.

Finally, the request for an item must be approved. Figure 6 shows the refinement of the goal `Achieve[Request responded]`. In order to contribute to sustainable development, one must ensure that only the necessary items are being ordered. Therefore, the external system DeTrack informs the amount of that item in stock and this information is made available in the system, as represented by the expectation `Achieve[Amount of item in stock informed]` and the requirement `Achieve[Amount of item available]`. This infor-

[1]A compliance monitoring department already exists within Oil.Br.

[2]In this work, we also considered the social and economical impacts.

mation should be taken into account by the approver when verifying that an item is actually needed.

It is important to note that the system does not force a requester to choose the most sustainable item; it only shows the sustainability levels of alternative items, leaving the decision to the requester's discretion. For this reason, it is necessary to provide training to the staff, so that everyone can be aware of the company's goals with respect to sustainable procurement, being able to judge if a give purchase is really necessary, and understand the impact of their choices.

3) Approving Quotations: Once requested, items are grouped together and sent for quotation and approval. In this sub-process, suppliers respond to a letter of invitation and the approver compares quotations from different suppliers, choosing from whom to purchase. The approver should take into account the sustainability level of the quotation, in addition to the usual criteria of price, payment condition and delivery time. The sustainability level of a quotation is calculated from the sustainability levels of the supplier and items, the means of transport to delivery the items, and the type of packaging. The latter two are important because items may have sustainable features, but the transport used for its delivery or packaging may generate a high environmental impact. Likewise, a vendor may have multiple warehouses at different locations, which can alter the sustainability level of a given request.

The price is also considered. The system compares the price of a more sustainable item with the purchase history of alternative items, warning the approver when a request generates a significant increase in costs for Oil.Br.

The goals associated with the quotation approval are shown in Figures 7 and 8. In Figure 7, a better sustainability is ensured by the goals `Achieve[Purchase history informed]` and `Achieve[Purchase option chosen]`. Figure 8 shows the refinement of the goal `Achieve[Sustainability level of quotation available]`. The information about means transport and packaging are provided by the expectation `Achieve [Means of transport and packaging informed]`. The supplier's sustainability information is represented by the goal `Achieve[Sustainability level of supplier available, when registered]`. The refinement of this goal is analogous to the calculation of the sustainability level of an item and is not shown due to space constraints.

4) User Health and Resource Monitoring: The goals presented so far contribute to mitigating second and third order impacts on sustainability. Figure 2 shows the two expectations defined for minimizing the first order impact of the system.

In the expectation `Achieve[User health preserved]`, the external Ergonomic system monitors the time of continuous system usage and the amount of keystrokes, temporarily blocking the system when these become excessive. This system also shows, periodically, a reminder for the user to rest. This practice is already adopted by Oil.Br.

In the expectation `Achieve[Energy consumption monitored]`, an existing monitoring system, EnergyMo, can be adapted to inform the IT and sustainability teams when energy usage is overcoming certain thresholds, so that improvements can be discussed and implemented.

C. Adoption Process

The effective adoption of sustainable procurement requires sustainability measures to be adopted in a gradual and continuous manner [8][9]. For this reason, in this study, a gradual adoption process composed of the following steps has been adapted from sustainable procurement guidelines: (1) map the purchase profile, (2) allocate the sustainability team, (3) develop an action plan, (4) select products and suppliers, (5) search for alternative products and suppliers, (6) provide training to staff, (7) verify and evaluate the system. The detailing of this process is out of the scope of this paper.

D. Procura+ Guidelines

The goals listed previously follow the guidelines of the ICLEI Procura+ summarized in Section II-B, as follows:

Watch continuous improvement concerns with incorporating sustainability into the decision criteria. The extended model adopts the concept of "sustainability levels" for items and suppliers, which are automatically calculated by the system based on criteria's values and respective weights. This information is gradually registered in the system by the sustainability team. IProc uses there levels to make recommendations regarding more sustainable items and quotations, ensuring that the suggested option does not increase significantly the costs for Oil.Br.

Watch the product evaluates the sustainability of an item throughout its life cycle. This is done gradually by the sustainability team, who is advised of this need when items are being registered or requested. According to the Procura+ guidelines, an effective evaluation should consider only few criteria [8]. The sustainability team must be trained in order to choose the criteria and their relative weight.

Watch the buyer is concerned with the training of purchasing staff. Training is defined in the adoption process. It creates awareness of Oil.Br's sustainability strategy and helps employees in identifying priority items, requesting more sustainable items and approving more sustainable quotations.

Watch the supplier refers to checking whether the sustainability criteria are being met and establishing a dialogue with suppliers. In the adoption process, the sustainability team gathers information about suppliers, making them aware of Oil.Br's commitment to sustainability. That encourages suppliers to compete on sustainable practices. Note that the criteria to evaluate the sustainability of suppliers should consider the three pillars of sustainability. This ensures, for example, that their products have minimal impact on the environment, follows health and safety standards, and so on. Information regarding items and suppliers practices must be checked periodically. This is already a practice within Oil.Br for suppliers that are required to comply with standards.

V. Critical Evaluation

This was the first attempt to model sustainability in Oil.Br's procurement system.

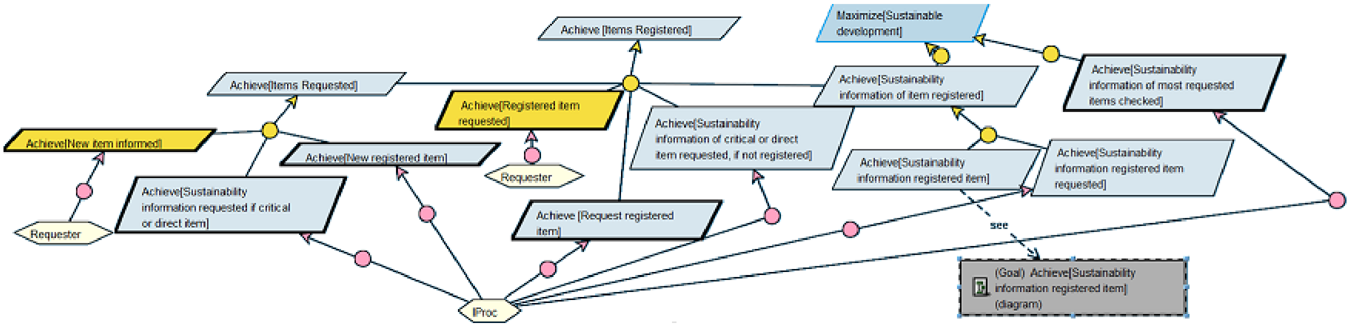

Fig. 4. Excerpt of the goal model for requesting items.

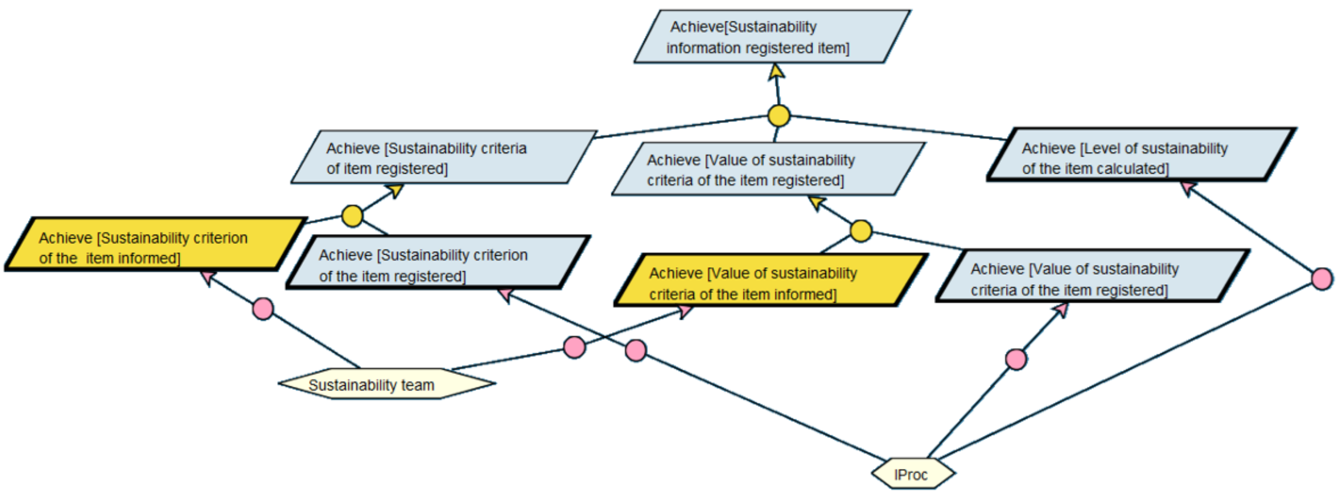

Fig. 5. Excerpt of the goal model for registering sustainability information.

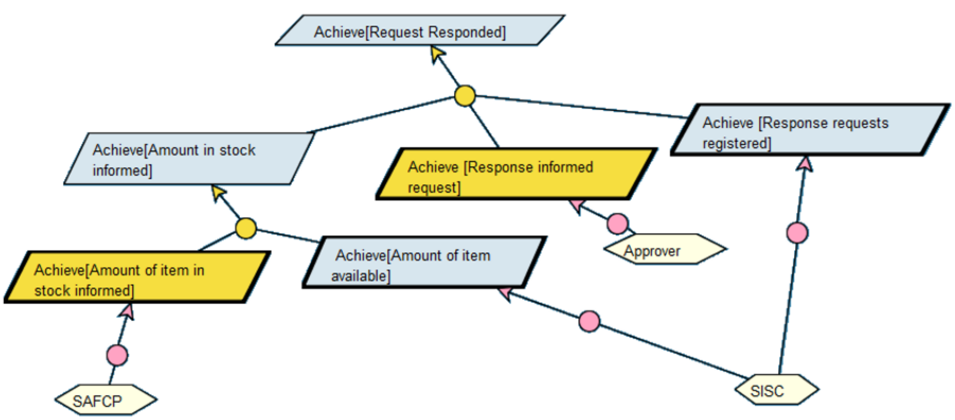

Fig. 6. Excerpt of the goal model for responding to item requests.

This involved an IT manager, a sustainability analyst, and three researchers.One researcher was experienced in KAOS and another worked for Oil.Br. Researchers conducted the interviews to build an initial model, which was then discussed and refined with the IT manager and the sustainability analyst. This section discusses the benefits and challenges identified with our experience.

A. On Incorporating Sustainability into Procurement Systems

This work aimed to respond the posed question "Is it possible to make procurement systems more sustainable? If so, how can this be made?". Our experience has shown that it was indeed possible to do so. The approach used was goal modelling. We believe the resulting model and the experience here described can serve as a starting point to other companies wishing to implement sustainable procurement systems.

The feedback from Oil.Br's stakeholders was positive, showing interest to take the work forward. During the study, the model also led to interesting discussions within Oil.Br, such as: How their processes could be adapted to implement the model? How sustainability goals impact Oil.Br's business goals? Which opportunities the purchase of more sustainable raw materials can bring into Oil.Br's final products?

Nevertheless, in order to effectively adopt the proposed model, some challenges remain. They also apply to any organizations wishing to implement such systems. They are:

Return on Investment: Although studies demonstrate that organizations with sustainable practices show financial gains [4][8], in order to promote the idea of sustainable procurement, its financial benefits must be studied. Further studies should answer questions such as: Which financial benefits such a system can bring? When these benefits will start to pay off, considering the costs to build or adapt the system? This kind of analysis is already a practice at Oil.Br.

Minimal impact on workload: Another concern is that the system should cause minimal impact on employee's workload. This is already a concern for the ICLEI's Procura+[8], in which our model is based. Nevertheless, in the case of Oil.Br, it is possible to reduce even more the impact on the workload, by delegating to the supplier the responsibility of providing the information on the sustainability criteria for products, services and itself. This is possible because Oil.Br already have in place an auditing process for suppliers.

Sustainability Indicators: In order to implement the last step of the process described in Section IV-C, one needs to define indicators for monitoring and system improvement. In the case of Oil.Br, some indicators of interest would be the number of suggested sustainable items that have been requested, the difference in price between sustainable items and their alternatives, how many items had their sustainability information registered, whether the purchase of more sustainable direct items reflect on sales etc. Such indicators could be (at least partially) collected and analysed by the system, in order to identify improvement opportunities. This type of support has not been considered in this first modelling exercise.

B. On Goal Modelling for Sustainability

With respect to goal modelling, some of its well recognized advantages were particularly useful for incorporating sustainability into software/socio-technical systems:

Problem definition: The sustainability impact of social-technical systems goes beyond the energy spent to run the software product, affecting the three pillars of sustainability. It also includes the direct and indirect impact of use of the software product, as well as its associated processes. Goal-oriented approaches, such as KAOS, are particularly useful to reason about problems associated with business structures, processes and their support systems.

Goal refinements and trade-off analysis: Usually there are concerns and resistance about the viability of implementing sustainable practices. By refining high-level goals into low-level goals and by showing the positive and negative contribution among goals, goal modelling techniques allow for a more objective analysis of the advantages and disadvantages of incorporating sustainability into a system, including a clear discussion about the impact on high-level business goals.

Assignment of responsibility: An important aspect about sustainability is that it cannot be ensured by isolated efforts. It is a concern of the whole society, requiring the cooperation of a large number of members. The same applies to sustainability within organizations. Sustainability initiatives can be jeopardized if such a concern is ignored by key organization's sectors. In this sense, goal modelling can be particularly useful in creating a shared responsibility for sustainability, by assigning goals to different agents.

Variables and functions: In order to evaluate whether the sustainability practices are being adopted and whether their envisioned benefits are being realized, indicators are crucial. KAOS allows for modelling quality variables and objective functions to measure the satisfaction of goals. This can be very helpful to define and monitor sustainability indicators.

Risk analysis: Finally, sustainability is closely related to risk mitigation. Many sustainability practices seek to avoid or minimize negative impacts on the natural environment and the society. Goal modelling facilitates the discussion between software engineers and sustainability experts in order to analyse risks, discuss alternative solutions and set priorities.

Besides the usual difficulties faced in any requirements engineering process, our main obstacle was the fact that two of the researchers were not experienced with the KAOS technique. This was overcome with training sessions and the support of the experienced researcher. Since the Oil.Br stakeholders have a wide background in systems engineering, an introduction to the technique was sufficient for the stakeholders to understand the models. With respect to goal modelling, some challenges may be faced in subsequent steps, such as the following:

On monitoring sustainability indicators: Sustainability is, by nature, a subjective concept. Can quantitative variables on goals alone be used as indicators of sustainability? How to objectively combine variables spread among goals? How to model variables and functions whose values and targets may

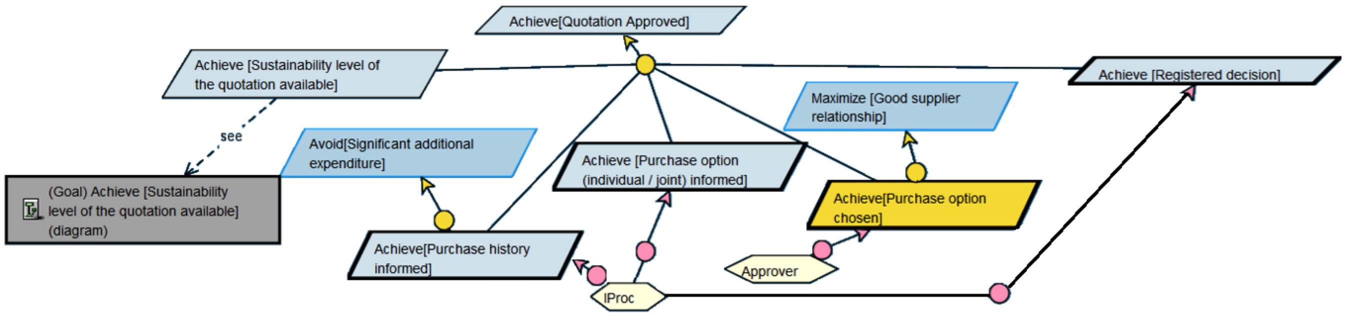

Fig. 7. Excerpt of the goal model for approving quotations.

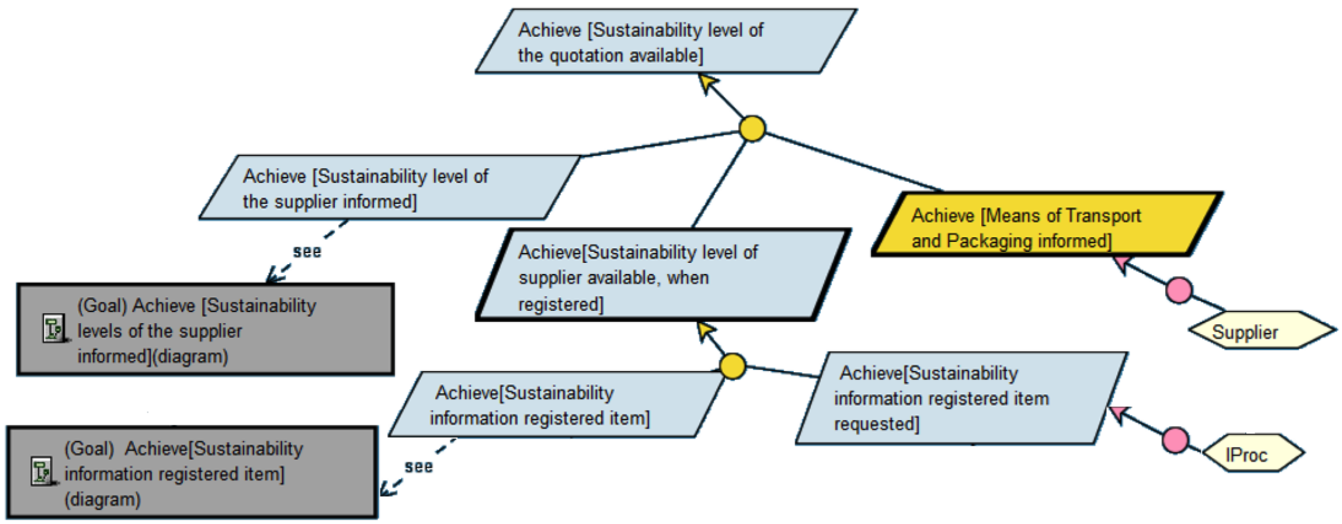

Fig. 8. Excerpt of the goal model for defining quotations sustainability levels.

vary over time? A related problem has been identified by Stefan et al. [26], concerning how alternative designs can be analysed in the face of time-varying variables.

On financial analysis: The financial benefits of sustainability may be difficult to quantify. In KAOS, variables and functions are defined at the goal level. For lower-level goals, some limited analyses can be made, such as the number of sustainable items bought or the money spent on sustainable items against alternatives. However, for high-level goals such as `Improve[Organizations public image]`, the financial benefit can be difficult to analyse, not always being a simple propagation of values from lower-level goals.

VI. Related Work

Other works have used goal modelling to reason about sustainability. Most of them, like ours, created models for specific domains. In [27], a software application to aid users in the development of a sustainable backyard food and resource system was modelled. The problem of modelling sustainability for conference organization is tackled in [15] and [28]. Stefan et al. [26] applied KAOS to model sustainability goals of a large university in central London. In [12], the authors examined different Requirements Engineering techniques to model sustainability as a first-class entity. They used goal analysis to determine priorities for sustainability goals of a software tool to support the organization of events. Generally, authors of these papers found goal-oriented requirements engineering to be a suitable approach to model sustainability.

Generic models and taxonomies for sustainability have also been proposed. Penzenstadler and Femmer [29] created a generic sustainability model that can be instantiated for products and processes. This model has been used for particular domains, as in [28]. Cabot et al. [15] state that sustainability should be a softgoal and present a taxonomy of sustainability-related goals. Nevertheless, as recognized by the authors, the taxonomy was driven by the needs of their case study and was not generic enough. Observing this limitation , the authors of [12] proposed a new one, but pointed out that their taxonomy was tentative and needed more research. In our study, we chose to construct our model directly, focusing on the three order impacts [19] and using internationally accepted guidelines in the domain of public procurement [8][9]. A future research can map our goals to a generic sustainability model or taxonomy, such as the ones mentioned previously, and observe whether they can help us to identify sustainability goals that might have been overlooked.

Finally, there are a number of other studies that look at requirements for procurement systems, as listed in Benslimane's survey [30]. Nevertheless, we are not aware of any work that deals specifically with sustainability.

VII. Conclusion and Future Work

This paper reports on our experience with modelling sustainability goals for a procurement system of a large energy company in Brazil. Procurement systems can have a considerable influence on the sustainable development of the communities around them. Our model focus on mitigating the three impact orders defined in [19] and was based on internationally accepted guidelines in the domain of public procurement [8][9]. We believe this experience can be valuable to other companies wishing to implement such systems.

We have observed that some of the advantages of KAOS are particularly useful for sustainability: it helps to reason about sustainability considering not only the software, but also their surrounding processes and systems; it allows a clear discussion about the impact of sustainability practices on business goals; it helps to create a shared responsibility for sustainability and to define indicators; it facilitates the discussion with domain experts to analyse sustainability risks.

The model led to interesting discussions with Oil.Br's stakeholders about the organization's business goals and opportunities. Yet, for adopting the proposed model, some challenges need to be addressed as future work, such as: analysing the return on investment of the system, studying forms of minimizing the impact on the users workload, and extending the model to support the collection and analysis of sustainability indicators. Furthermore, we plan to compare our model to existing generic models and taxonomies, in order to identify further goals and validate the generality of these proposals.

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