Uncovering Sustainability Requirements: An Exploratory Case Study in Canteens

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***Abstract*—Software systems are embedded into daily life and as such have significant effects on the behavior and decision making of both their users and the people affected by using these systems. Such effects can be positive or negative. Considering them in requirements engineering (RE) is an important step towards sustainable development, as RE strongly influences the development and the evolution of a software system.**

So far, RE researchers have focused on requirements about minimizing negative environmental effects. However, effects that are *enabled* by using a software system can also be positive. For example, a software system could motivate its users to take environment-friendly decisions. Corresponding requirements about such positive enabling effects have been far less addressed.

In this paper, we present an exploratory case study where we elicited requirements about positive enabling effects with respect to environmental sustainability. The project we studied is about extending an existing decision support system for meal planning in canteens by game-based elements. The extended system shall motivate meal planners who work in canteens to make environment-friendly choices.

Our contribution is an exemplar of concrete sustainability requirements as well as insight into the nature of sustainability requirements about positive effects that are enabled by the use of a software system.

***Index Terms*—enabling effects; sustainability requirements; sustainable software systems; gamification; exploratory study;**

I. Introduction

Any software system and its utilization have effects causing environmental impacts [1], [2], [3]. We categorize these effects into two groups. One group relates to the *direct effects* of *running* a software system, e.g., the energy and resources required for powering and cooling the computing equipment the system runs on or connects to. Such effects are usually considered to be negative with regard to sustainable development. The second group relates to *enabling effects*. These are effects that are enabled by *using* a software system. Enabling effects can be the result of automated processes and/or of human behavior that is influenced by using the software system. With regard to sustainable development, enabling effects can be both positive and negative [4]. For example, heating management software can reduce the energy consumption of a building significantly, which is positive. An e-commerce system providing business-to-consumer and consumer-to-consumer sales services may influence human behavior positively by encouraging people to sell used goods so that they get re-used, but it can also lead to over-consumption, which is negative. For a more detailed classification of effects of software systems on sustainability see Berkhout & Hertin [5] or Hilty & Aebischer [4].

Our dependency on software systems [6] and their ubiquity [7] within many societies has intensified the impact of enabling effects. Consequently, when striving for sustainable development, we must take into account potential enabling effects when developing a software system, in order to avoid negative effects and leverage positive ones.

The importance of considering sustainable development in software engineering has been emphasized by researchers in the field [6], [8], [9]. Due to its early influence in the development process of a software system, requirements engineering (RE) is considered to have the biggest impact on the eventual effects of a software system [10]. As such, RE provides promising opportunities to affect the transition towards sustainable development significantly [2], [3], [10], [6], [8].

Current RE contributions considering sustainable development have focused on minimizing negative environmental effects and referred to corresponding requirements as quality requirements, e.g. [3], [7], [1], [10]. Sustainability requirements related to positive effects however, have not received much attention and can not be limited to quality aspects.

Our goal is to better understand sustainability requirements related to positive effects, specifically the ones that are enabled by end-users while using a software system. This paper describes an exploratory case study in which we elicit and discuss such sustainability requirements for a decision support system (DSS) that is extended with game-based elements for motivating meal planners to make choices that reduce the CO_2 value of their meals.

The contribution of our study is twofold. Firstly, we present an exemplar of concrete sustainability requirements related to positive enabling effects. Secondly, we discuss these sustainability requirements. The study reveals that when considering positive enabling effects (i) corresponding requirements include new requirements and existing requirements that become more important, and (ii) treating these requirements as quality requirements is inadequate as we found functional requirements and constraints. The study further provides some indication that (iii) corresponding requirements can be classified into requirements about *integration*, *(meaningful) representation*, and *(fair) comparison*, and that (iv) *indirect stakeholders* who

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are no system users, but are affected by the use of the system and influence its success, are important.

This paper is outlined as follows. We first provide background on the case study and related work on RE with regard to sustainable development. In Sect. III we describe our research approach, the study design and the research questions. The results and threats to validity are presented in Sect. IV, followed by a discussion in Sect. V and conclusion and future work in Sect. VI.

II. Background and Existing Work

In this section, we provide information about the case study as well as relevant background knowledge for readers less familiar with RE in the context of sustainable development. Further, we describe some earlier RE research which is relevant in the context of our study.

A. The Case Study

This case study is part of the project *CarbonFoodPrint*[1] initiated by Eaternity[2], a company that provides software-supported solutions helping people to make their own eating habits climate-friendly. In this project Eaternity collaborates with the Swiss branch of the Compass Group [3], a world-leading food service company.

1) The Current State: The process of planning meals that is applied within the Compass Group (Switzerland) consists of two phases: First, a small culinary development team in the headquarters composes and develops meal propositions for all canteens for the forthcoming months. Based on the categories offered in a canteen (e.g. meat, veggie, low carb) the proposed meals are accordingly filtered and sent over an SAP-based system to the canteens. In the second phase, the meal planners working in the canteens adapt the meals based on specific canteen-related criteria, (e.g., their budget and customers' preferences). A decision support system (DSS) is used to support the meal planners to plan meals by providing specific functions; in particular, the possibility of selecting ingredients (e.g., tomatoes), meal components (e.g., tomato sauce or spaghetti) and whole meals (e.g., spaghetti with tomato sauce) from a large recipe database, together with corresponding information on nutrition factors and costs.

2) The Project Context: The overall goal of the *CarbonFoodPrint* project is to motivate meal planners to select ingredients whose production and transportation emitted less CO_2 than possible alternatives. The project consists of two parts. The first part focuses on the calculation of CO_2 emissions by applying life-cycle assessment (LCA) [11]. This is a specific technique to address the environmental aspects and potential environmental impacts such as use of resources and the environmental consequences of releases throughout a product's life cycle. The second part of the project focuses on the utilization and representation of these data to motivate the meal planners to select ingredients whose production and transportation have emitted less CO_2 than possible alternatives. To achieve this goal, the Compass Group (Switzerland) decided to order an extension of the existing DSS with game-based techniques for further processing the calculated LCA data and presenting them to the meal planners in a recurrent report.

3) The Context of our Case Study: The case study that we present in this paper contributes to the second part of the *CarbonFoodPrint* project. In the framework of a research collaboration with Eaternity and the Compass Group (Switzerland), the sustainability requirements for the new system were elicited and studied by the first author of this paper, together with a graduate student. As the focus on the CO_2 emission caused by the production and transportation of ingredients was given, our study is confined to sustainability requirements with respect to CO_2 which, actually, is only one aspect of sustainable development.

B. Requirements Engineering and Sustainability Requirements

Software systems are embedded in their environment which by nature is in a permanent process of change. As such, developing and evolving a sustainable software system is an ongoing process. Typically, the decisions that shape a software system are taken during RE [3].

1) Sustainability: The term *sustainability* has been used in different contexts and overused for several purposes. To avoid any misunderstanding, we briefly define the terminology used in this paper. Based on the "Brundtland definition" [12], Christen proposes to conceptualize sustainability as an "attempt to grant the right to a decent life to *all living human beings* without jeopardizing the opportunity to live decently in future" ([13], p. 2). As such he emphasizes that sustainability does not solely focus on future generations, but also on human beings living now. He also argues that sustainability is not limited to sustaining aspects, but also addresses enabling aspects. By definition, sustainability is a global (temporal and spatial) concept which makes it clear that no single technology can be sustainable in this sense. However, technology can support the transition towards sustainable development [4]. Based on this notion of sustainability we define the following terms.

- A *sustainable software system* is a software system that supports the transition towards sustainable development.
- A *sustainability requirement* is a requirement for a sustainable software system which concerns sustainability.
- A *positive enabling effect* is an effect that is enabled by using a software system and positively contributes to the transition towards sustainable development.

Different metaphorical descriptions of the roles of *environment*, *society*, and *economy* in sustainable development exist. As the economic system is part of human society, which in turn is part of the environment, we use the metaphor of nested circles, where economy is represented by the inner circle, society by the middle one and environment by the outer one. For more information see for example Hilty & Aebischer [4].

2) State of Research: The high importance of addressing the concept of sustainable development within the process of requirements elicitation has been recognized by the RE

[1] http://bit.ly/1L2Qzcc
[2] http://eaternity.com
[3] http://welcome.compass-group.ch/

community, e.g., [6] [8] [9]. However, as noted by Becker [14], this has not yet been transferred into practice successfully. Prior RE research has mainly conceptualized sustainability requirements as quality requirements (i.e., a sub-category of specific quality requirements in the taxonomy introduced by Glinz [15]).

Thereby, the focus was on goal modeling processes e.g. by regarding sustainability as a trade-off between business goals [16], by using the idea of generic goal refinement as a checklist for sustainability requirements [3], by treating them similarly to conflicting goals of budget restrictions and quality improvements [17], by suggestion how to align the objective of environmental sustainability with the other objectives [1], and by building upon different levels of impacts [18]. Further, Roher & Richardson work on patterns for sustainability requirements [19].

C. Sustainability Requirements Related to Enabling Effects

Most existing work on sustainability requirmements as described above focus on direct effects (cf. the classification presented in the introduction) and treat sustainability requirements as goals or as specific quality requirements. Sustainability requirements related to enabling effects of a software system are far less addressed both in research and – to our experience – also in industry. A possible explanation is that in most cases direct effects are directly connected to economic goals, whereas for enabling effects, such a relation is hard to establish in most cases.

Nevertheless, as outlined by Wang [20], research shows that while considerations about sustainable development are becoming more relevant in societies, positive environmental effects positively impact the value chain and the image of a company. Consequently, requirements related to enabling effects of software systems increasingly gain relevance for both companies and their stakeholders.

III. Research Methodology and Study Design

For choosing our research methodology, we considered the following facts: (i) We wanted to analyze and better understand sustainability requirements with respect to positive enabling effects, (ii) there is little knowledge available about this kind of requirements, (iii) we had the opportunity to study a real industrial project in this context. Given this situation, we chose an exploratory case study as our research methodology. Such a study enables an in-depth investigation of a phenomenon in its context [21] and is specifically suitable when little knowledge about the subject is available [22]. Further, the results of an exploratory study form the basis for both theory generation [21] and constructive solution design.

A. Research Goal and Research Questions

According to our research plan and the given project context, we formulated our research goal as follows.

Goal. Analyze *sustainability requirements* for the purpose of *developing sustainable software systems* with respect to *positive enabling effects* from the viewpoint of *the end-users* in the context of a project for extending an existing software system with game-based mechanics.

Research Questions. From this goal we derived two research questions:

RQ1: What is specific about requirements concerning positive enabling effects?

RQ2: How can game-based mechanics motivate positive enabling effects when extending existing software systems?

B. Study Design

We followed a "mixed methods" approach [23], consisting of three sequential steps: a *contextual inquiry*, *semi-structured interviews* and an *online questionnaire*. We used this approach for investigating our research questions from more than one perspective, thus getting more thorough results. As mentioned in Sect. II.A, the tasks of eliciting the requirements and conducting the study were both performed by the first author of this paper, together with a graduate student.

1) Study Setup: The process for all three steps and the questions to be asked were elaborated by the first author of this paper with support from the graduate student, then reviewed by a group of RE researchers and finally improved according to the feedback received. The interviews and the questionnaire were both piloted with people neither specifically related to the domain of RE nor to the one of sustainability. This approach was chosen to make sure the questions are clear to participants who are unfamiliar with these domains [24].

The study was carried out over a period of four months and included eight steps: (1) Preparing the contextual inquiry, (2) carrying out the contextual inquiry and evaluating the results, (3) designing the interview questions, (4) conducting pilot interviews, (5) carrying out the interviews and evaluating the results, (6) designing the questions following the guidelines for creating a questionnaire by Kitchenham & Pfleeger [24], (7) publishing the questionnaire, (8) evaluating the questionnaire results. Note that the results of the pilot interviews were not included in the data analysis.

All steps of the study were conducted in German. Consequently, the questions and interviewee quotes reported in this paper are our translations of the German originals.

2) Selection of Participants: The Compass Group (Switzerland) selected the participants for the contextual inquiry and the interviews. However, we could provide our criteria for the selection process. The following of our criteria were accepted and applied by the company: (1) all participants are responsible for the meal planning process and as such are direct end-users of the DSS; (2) the contextual inquiriy is conducted in two sessions, one in the headquarters of the company and one in a canteen; (3) at least 15 meal planners are selected for the interviews; (4) the group of participants is heterogeneous with regard to canteen size, region, and work sector ("Business & Industry" (B&I) and "Eductation" (Edu)). We did not include gender, age or nationality into our selection criteria, since we considered them as irrelevant for the purpose of the study. Eventually, 19 meal planners working in different canteens participated in the semi-structured interviews.

The URL of the online questionnaire was sent to all meal planners (about 150). 67 participants finished the online questionnaire. However, seven of them did not answer the question about current reasons for changing ingredients. *The questionnaire results presented here come from the 60 meal planners who answered all questions (this includes all participants of the interviews and the contextual inquiry).*

3) Contextual Inquiry: To understand the current situation, i.e., how meal planners currently work and apply the existing DSS, we conducted a contextual inquiry in two sessions: the first one at the headquarters of the Compass Group (Switzerland) and the second one in one of the canteens. Contextual inquiry [25] is an elicitation technique that studies stakeholders in the field, bringing the requirements engineer in contact with the stakeholders in their real work environment. Thereby, the requirements engineer takes a role similar to the one of an apprentice, asking questions while observing the work process. By allowing requirements engineers and stakeholder representatives to work together and to share insights, a contextual inquiry enables a full understanding of the work practices in the specific work environment. As a contextual inquiry is exploratory and open-ended, we did not prepare questions beforehand, with the exception of some ice-breaking questions for starting the inquiry sessions.

4) Semi-Structured Interviews: The questions for the interviews were grouped into three parts: *demographics and current work routines*, *usability*, and *motivation*. While the questions about the first two parts build on the results of the contextual inquiry, the ones about motivation regarding the game-based aspects refer to the results from our previous research on requirements for game-based approaches motivating sustainable consumption [26]. Four representative interview questions are given in Table I. IQ-1 is from part one about current work routines, IQ-2 is from part two about usability, and IQ-3 as well as I-Q4 are from part three about motivation, however, I-Q4 also affects part two. The full set of interview questions (in German) is available at [4].

The interviews lasted between 25 and 45 minutes on average. The time difference can be explained by our approach of conducting semi-structured interviews with a mix of open-ended and specific questions. We did this for enabling the elicitation of both foreseen and unexpected information [27]. This was specifically relevant since the domain knowledge of favorabale enabling effects is still immature in RE. It also helped to build a positive rapport with the interviewees [28].

All interviews were conducted over Skype by calling the interviewees on their business phones. This approach was chosen because the interviewees were distributed over the whole country. So visiting them all would have been too costly and also not possible in the timeframe given for the interviews. Half of all interviews were conducted by the first author of this paper, the other half by her graduate student. To align the interview styles and reduce observer bias, the first two interviews were conducted jointly by the first author and her student and then discussed between them in a retrospection session. As mentioned above, the interview questions as well as the interviews were piloted before conducting the actual interviews.

5) Online Questionnaire: We used the results from the interviews as a basis for designing the online questionnaire. Our goal was to elicit quantitative information about important aspects of sustainability requirements from a sample of involved people which is larger than the number of meal planners interviewed. We exploited the majority of the interview questions in the online questionnaire, omitting the ones that focus on the end-user's attitude towards the project. Table I shows four representative questions (QQ-1–QQ-4) that we further analyze in this study. Semantic differential scales [29] were applied to evaluate the participants' attitude. This type of scale is similar to the Likert scale [30] with the benefit of revealing both the direction and the intensity of each opinion. For questions about familiar topics we used an even scale (four point), for questions where we expected less or non-familiarity, we used an odd scale (three or five point, including a neutral point). This approach is generally suggested for defining the number of alternatives given in ordinal scales [31]. The link to the questionnaire was published over the intranet of the Compass Group (Switzerland) together with background information about the project, who we are, the goal of the study and criteria for participation.

Technically, we used an online questionnaire tool[5] for creating the questionnaire. The full set of questionnaire questions (in German) and the questionnaire design are available at [6].

C. Collecting the Data

Data collection started in July 2014 with the two contextual inquiry sessions and ended in October 2014 when the online questionnaire was online for two weeks.

The full data set has a size of 81, comprising the data from two contextual inquiry sessions, 19 interviews and 60 fully completed questionnaires. It turned out that the first contextual inquiry session had primarily served for making the researchers familiar with the context of the project, so we excluded it from the data set. Further, one interview was not recorded due to a technical problem which we realized only after the interview was finished. Hence, we also excluded that interview from the data set. All interviewees as well as the participant of the contextual inquiry also answered the questions in the online questionnaire. So we have a total of 79 data points from a total of 60 participants for analysis. With respect to the canteen sectors, i.e., Business & Industry (B&I) vs. Education (Edu), the data are distributed as follows: (i) contextual inquiry session: zero B&I, one Edu; (ii) interviews: fourteen B&I, four Edu; (iii) online questionnaire: fifty B&I, ten Edu.

D. Participant Demographics

Some demographic information about the participants is summarized in Table II. 83% of all participants work in

[4]http://bit.ly/1QyuR3i

[5]http://ww3.unipark.de

[6]http://bit.ly/1FiFKdO

TABLE I
INTERVIEW QUESTIONS (IQ-) AND QUESTIONNAIRE QUESTIONS (QQ-)

Identifier	Original Question Id[1]	Question (English translation)
IQ-1	2.d	According to what criteria do you compose a meal?
IQ-2	3.a	Can you imagine that the idea of reducing the CO_2 value of meals due to the choice of ingredients is realizable in your canteen?
IQ-3	4.a	Are you additionally to the CO_2 value interested in the following information? i.What the CO_2 value means e.g. how many kilometers driven by car do correspond to it? i.1 Are you further interested in other representations? If so in which?
IQ-4	6	Do you believe that the CO_2 values of different canteens can be compared with each other in such a report?
QQ-1	4.1.1	What does motivate you to change a meal? Formulated in a clearer way, how strong does one of your changes affecting a meal component or ingredient depend on the following criteria? (costs, variety, customer preference, season, compliance, environmental aspects)
QQ-2	5.3	How should the CO_2 emission value of your meals additionally be represented in order to raise your interest? (number of kilometers a mean of transportation has to make; amount of energy an ordinary private household has to use; number of days an ordinary private household has to be heated in order to emit the same amount of CO_2; number of trees that are needed to compensate the same amount of CO_2);
QQ-3	7.1.1	How good do you think is the following information? Segmentation of the CO_2 based on the process steps; meal components; origin of ingredients
QQ-4	6.1	How strong have the following factors to be considered in order you perceive the comparison of the CO_2 emission of different canteens to be fair? (size of the canteen according to the number of cooked meals; the number of employees working in the kitchen; the number of meal categories served in a canteen; the customer preferences)

"IQ" refers to the interview questions and "QQ" to the questionnaire questions. The column "Original Question Id" refers to the corresponding original question id of the interview or the questionnaire, available under [1]: http://www.ifi.uzh.ch/rerg/research/stakeholderengagement/garuso

TABLE II
OVERVIEW OF ALL PARTICIPANTS WHOSE DATA WAS EVALUATED

Attributes / Domain	Business & Industry	Education
Percentage of all participants	83%	17%
Average # of years in position	7	5
Median # of years in position	5	3
Average # of meal categories	3	4
< 150 meals/day	42%	20%
150-499 meals/day	42%	40%
500-1999 meals/day	16%	40%

B&I canteens and 17% in Edu canteens. On average, the participants have more than five years experience in their position. Regarding meal variety and number, participants working in B&I canteens have three meal categories on average (e.g., meal with meat, vegetarian, low-carb), while participants working in Edu canteens have four. Around 40% of all participants from both sectors work in canteens that produce between 150 and 499 meals per day. 42% of the B&I canteens and 20% of the Edu canteens produce less than 150 meals per day, and more than 500 meals are daily produced in 16% of the B&I canteens and in 40% of the Edu canteens.

E. Analyzing the Data

All data is exploratory, which means we did not pre-specify a hypothesis as it is done in a confirmatory analysis. The end-product of exploratory data analysis is rather suggesting patterns for further studies and providing hypothetical insight into these patterns instead of statistical figures [32]. As such we did not apply any statistical tests, but provide first insights into sustainability requirements for positive enabling effects with regard to sustainable development.

1) Contextual Inquiry: Information from the contextual inquiry sessions was first structured to identify main work processes which then were used for defining the interview questions. In the presentation of the results in the next section, the data from the contextual inquiry is not analyzed separately, but presented together with the data from the interviews.

2) Semi-Structured Interviews: To be able to better evaluate the data from the interviews we structured the data by first transcribing and then coding them according to the process described by Seaman [33]. The corresponding codes are listed in Table III. The results of this analysis were used to define the questions and structure of the online questionnaire.

3) Online Questionnaire: As it is common in exploratory studies, we visually analyzed the quantitative data from the questionnaires, choosing divergent stacked bar charts.

IV. RESULTS

In this section we present our results. As usual when presenting qualitative results, the data are complemented with quotations from the interviewees. The quotations are written in italic, the interviewee who stated the quote is indicated in brackets by "I-" followed by the number of the interview. We coded relevant information in the qualitative results to structure and quantify them; these codes are underlined and in brackets. Table III lists the sixteen codes that we used, together with the frequency of their appearance in the interviews. The questionnaire results for QQ-1–QQ-4 (cf. Table I) are visualized in Figures 1-4 in the same order as the corresponding questions.

We present the results grouped by topics. Within each topic, we first present the results from the interviews regarding this topic, and then the corresponding results from the online questionnaire.

A. Requirements Looked through the Sustainability Lens

The first aspect we investigated was whether and how the current set of requirements changes from the end-users' perspective when adding the dimension of sustainable development to the domain context (RQ1). We first focused on actually existing requirements causing the participants to change ingredients in their current work process. Second, we elicited requirements that the participants perceive as important if they had to select ingredients with respect to CO_2 emission. This subsection highlights the aggregated results related to this aspect.

1) Current Requirements Motivating Change: We specifically asked the interviewees about reasons for changing ingredients in the proposed meals they get from the culinary development team (IQ-1). The three criteria mostly mentioned are *customers' preferences*, *costs* and *variety*.

As indicated in Table III for thirteen interviewees customers' preferences (changeIngredients_customers_current) are a strong reason to change ingredients, twelve emphasized the relevance of cost restrictions (changeIngredients_costs_current) and six mentioned the variety (changeIngredients_variety_current) of their meals as an important reason. Interviewee I-8, for example, highlighted both variety and customers' preferences: *"I do it according to the following criteria, such that there is variety. Theoretically, pork is the cheapest meat we can get, but I nevertheless look that it is only served once a week. Also a little bit because of our Muslims (...)"*.

In the online questionnaire, we further explored these results by asking the participants to rate the importance of *costs*, *variety*, *customers' preferences*, together with *the seasons*, *compliance with suppliers*, and *the environment* as a reason for them to change the ingredients (QQ-1). Participants could rate the importance on a semantic differential scale of four criteria: "Plays no role at all", "Plays a minor role", "Certainly plays a role", "This criterion is one of the most important reasons for change". The results shown in Fig. 1 support what we found in the interviews: *Customers' preferences* and *costs* are the two most important reasons to change ingredients in both Edu and B&I canteens. *Variety* and *season* come next. Participants working in Edu canteens rate these two criteria as equally important, while participants working in B&I canteens rate *season* to be slightly more important than *variety*.

2) Considering Sustainability Requirements: When asked the interviewees whether they can imagine reducing the CO_2 emission of their meals by selecting specific ingredients (IQ-2), thirteen were positive about having the potential to do so (successCO_2Red_changingIngredients_new). However, the interviewees agreed that this goal is only achievable when considering certain constraints. The results described below show that (i) *costs* and *customers' preferences* are perceived as the two most relevant constraints if the context of sustainable development is added; (ii) the influence of these two constraints becomes stronger in this context and new constraints become relevant; (iii) an integration of the game-based extension into the existing DSS is important.

TABLE III
OVERVIEW OF INTERVIEW RESULTS

Codes Used to Quantify the Qualitative Results (Semantic:[effect_causedBy_inSystem])	**Frequency** Number	Percent	**Origin** IQ	Spont.
changeIngredients_customers_current	13	72	✓	
changeIngredients_costs_current	12	67	✓	
changeIngredients_variety_current	6	33	✓	
successCO_2Red_changingIngredients_new	13	72	✓	
constraintCO_2Red_costs_new	9	50		✓
constraintCO_2Red_customers_new	9	50		✓
constraintCO_2Red_space_new	2	11		✓
successCO_2Red_integratedInWorkProcess_new	13	72		✓
successCO_2Red_alternativesShown_new	6	33		✓
successCO_2Red_CO_2Rep_new	17	94	✓	
successCO_2Red_CO_2RepGraphically_new	5	28		✓
successCO_2Red_CO_2PerOrigin_new	2	11		✓
successCO_2Red_CO_2PerProcessSteps_new	3	17		✓
successCO_2Red_CO_2PerComponents_new	4	22		✓
comparisonCO_2Possible_gamification_new	13	72	✓	
comparisonCO_2Possible_numberOfMeals_new	8	44		✓

The codes are presented in the order that they appear in the paper; the upper group is referred to in Sect. IV.A, the lower one in Sect. IV.B. "Red" stands for "Reduction", "Rep" for "Represented". In column "Origin", "IQ" indicates codes that stem from explicitly asked interview questions, while "Spont" indicates codes found in information spontaneously raised by interviewees.

Cost constraints (constraintCO_2Red_costs_new) were stated by nine interviewees to challenge the successful consideration of CO_2 emission when selecting ingredients. Three of them regard cost restrictions as a major criteria for a project failure. The rest of them is not that strict, however they mentioned that local and organic products usually are more expensive than non-organic products or products from farther away. They highlighted that if their budget remains the same, customers had to pay the cost difference. Interviewee I-17 considered the relevance of a company-wide change: *"Well it [the success] depends on what kind of food it is. In my opinion, if costs raise, we have to pass these costs on to our customers in order to stay in the green zone [with the costs]. (...) Actually, the whole company should have to participate."*. I-14 stated: *"(...) We have to get the cheapest products in order to fulfill the terms of the company and meet the demands of the customers (...) the customers have to rethink because, if I buy a regional product, this has immediate influence on my costs. "*.

Customers' preferences are further regarded as a constraint that challenges the success of the project (constraintCO_2Red_customers_new) by nine interviewees. Seven of them can imagine to possibly manage this challenge by involving the customers (e.g., by explaining the effects). The other two do not think that customers will change their eating habits or pay more for climate-friendly food. I-14 stated for example: *"Well, the cooks would like to consider this [the CO_2 emission related to the ingredients]. It has been a nonsense to offer tomatoes in December. However, it is a fact that not us, but the customers do rule the market (...) In my opinion the*

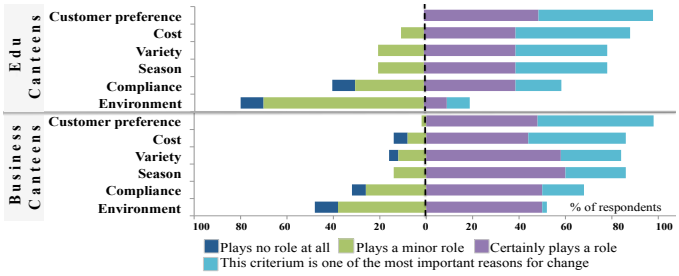

Fig. 1. Evaluation of reasons to change ingredients in the current work process

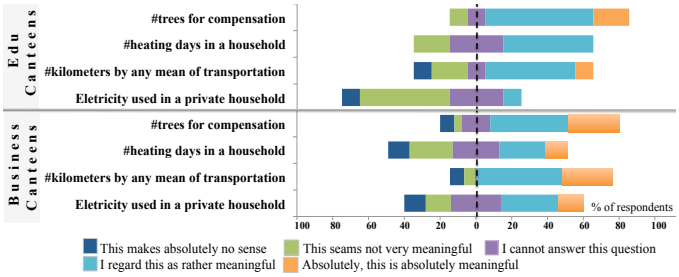

Fig. 2. Evaluation of alternatives for representing the CO_2 value

awareness of the customers is not yet there."

The size of the work space was highlighted by two interviewees (constraintCO_2Red_space_new) as a major constraint. Little space in the kitchen affects work processes and as such the choice of ingredients. I-12 put it this way: *"Our restaurants are not all equipped in the same way (...) Some [of us] really must additionally plan their meals based on the available space [to process the food] and the storage possibilities and then decide whether they buy fresh broccoli or frozen broccoli."*

The proper integration (successCO_2Red_integratedInWorkProcess_new) of the game-based extension in the existing DSS is regarded as highly important by thirteen interviewees. For example, six of them said that it is highly important to have immediate access to alternative ingredients with a lower CO_2 emission value while planning meals over the system (successCO_2Red_alternativesShown_new). I-2 emphasized: *"(...) there really must be alternatives with which the CO_2 emission value can be reduced. Showing a direct alternative in the sense of 'tomatoes from Italy instead of cherry tomatoes from overseas' should be possible."* In this context, I-7 highlighted time pressure as a reason: *"When we get the [suggested] meal plan, it [the system] has to be ready with the CO_2 emission values. Because we cannot search extensively for this information on the lists of the vegetable, meat, or fish suppliers (...) this [information] has to be integrated and then we can work."*

B. Game-based Mechanics for Positive Enabling Effects

The second aspect we investigated was about how game-based mechanics have to be applied to motivate positive enabling effects in the given context (RQ2). Our focus was on a meaningful representation of the CO_2 emission value and on relevant factors for comparing the values of different canteens with each other. In this sub-section we present the aggregated results.

We asked the interviewees if the CO_2 emission shall be represented (successCO_2Red_CO_2Rep_new) by more familiar measures (IQ-3) and provided the number of kilometers driven (i.e., how many kilometers one could drive for emitting the same amount of CO_2) as an example. Seventeen interviewees agreed on the importance of a meaningful representation. I-12 added that such a value would even be more meaningful if represented by a journey. *"It would be good if you could say, we have saved that amount of CO_2, this is enough to travel from here to Moscow or simply, you could travel that far with this amount (...) because we do not know what consumes how much [CO_2]. For example, when I drive home with my car, I know I produce CO_2, but I do not know how much. And this is the reason why we don't know what is a good value and what is a bad one."* Five interviewees highlighted the relevance of using graphics and pictures (successCO_2Red_CO_2RepGraphically_new). I-14 explained it this way, *"(...) something like '[with this amount of CO_2] you could have driven from here to there with a truck' and then showing something similar to Google maps. This way, it becomes visible right away that I could have driven to Marseilles."*

The questionnaire results underline these results. Together with the given example on the amount of kilometers we provided three more representation options to rate for (QQ-2): the *number of trees needed to compensate the amount of CO_2 emitted*, the *used heating energy*, and the *used electricity* in an average household (Fig. 2). These four options could be rated on a semantic differential scale of 5 criteria: "This makes absolutely no sense", "This seams not very meaningful", "I can't answer this question", "I regard this as rather meaningful", and "Absolutely, I think this is absolutely meaningful". The results show that the number of trees needed for compensation and the number of kilometers that can be driven are similarly perceived as highly meaningful for representing the amount of CO_2 emissions. Participants from both sectors were much less interested in a representation by the energy consumption in a household of both electricity and heating.

Segmentation of the CO_2 value was raised by four interviewees. Two of them wanted a segmentation based on the origin of ingredients (successCO_2Red_CO_2PerOrigin_new) e.g., the CO_2 value of a tomato from Greece compared to one from Italy. Three interviewees were interested in segmenting the CO_2 value according to the two process steps of production and transportation (successCO_2Red_CO_2PerProcessSteps_new), and all four found it relevant to segment the meals with regard to their components (successCO_2Red_CO_2PerComponents_new), e.g., the two components pasta and pasta sauce. I-14 made this very clear: *"When you do something like this [the project as a whole], I think it is good that we have a learning effect, something like 'Ahaaaaaa, there it is, this shrimp has messed up our whole meal statistics (...) This way rethinking happens. We are a bit practice-oriented."*

These results were exploited further in the questionnaire by asking to rate the segmentation factors *origin*, *meal components*,

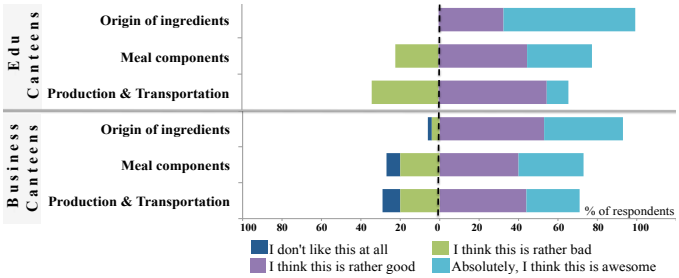

Fig. 3. Evaluation of segmentation factors

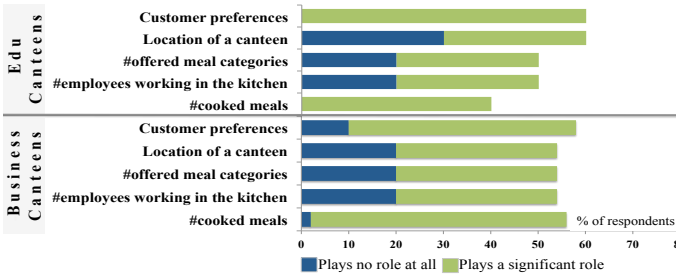

Fig. 4. Importance of different factors regarding comparison

and *process steps* (QQ-3) on a semantic differential scale of four criteria: "I don't like this at all", "I think this is rather bad", "I think this is rather good", "Absolutely, I think this is awesome". The results show that the majority of both sectors is interested in comparing ingredients based on their origin (Fig. 3).

As game-based techniques typically involve comparisons, we specifically asked whether the CO_2 value of different canteens can be compared with each other (IQ-4); thirteen interviewees said yes (comparisonCO_2Possible_gamification_new). Eight of them stated that the most important condition to consider for enabling comparisons between canteens is the number of meals produced (comparisonCO_2Possible_numberOfMeals_new). I-17 got very specific: *"You cannot compare a small canteen with a large one (...) If I compare two small canteens with each other that sell on average approximately sixty to eighty meals per day, then I think this is comparable. (...) I think here we should differentiate such that we only compare very similar canteens, also with respect to the location."*

These interview results are supported by the results from the questionnaire (Fig. 4). The participants could rate the importance of *number of meals*, *of employees working in the kitchen*, *of meal categories offered*, *location of the canteen*, *customers' preferences* for comparison (QQ-4), on a semantic differential scale of four with the two opposite criteria: "Plays no role at all" and "Plays a significant role". The majority of participants from B&I canteens selected the number of meals, followed by customers' preferences to enable fair comparison, while the majority of participants form Edu canteens selected customers' preference as the top criterion, followed by the number of meals.

C. Threats to Validity

We discuss the threats to validity using the usual four categories: internal, external, construct, and conclusion validity [34].

Internal Validity reflects the relationship between cause and effect. The internal validity of our study is limited due to its very nature: in an exploratory case study in a real world project, many potentially confounding factors cannot be controlled. A potential threat is the fact that the persons participating in the contextual inquiry as well as the interviewees were selected by the Compass Group (Switzerland). We do not consider this a major threat because we provided the company with our selection criteria and also did not find any evidence for selection bias when analyzing the interviews. Answering the online questionnaire was voluntary, which may cause the results to be biased due to highly supportive or highly non-supportive participants. Since the subject of the study was equally interesting for both supporters and opponents, we do not believe that the outcome of our study is affected by this potential threat. We mitigated potential maturation problems by scheduling the interviews during working hours and limiting their duration to 20-40 minutes.

External Validity refers to the extent of being able to generalize the results. The biggest limitation to the external validity of our study is the fact that (i) the study was conducted in a single company and (ii) the project was limited to positive enabling effects with respect to CO_2 emission. However, the setting of our study is typical for systems in the service domain: employees of a service company use a software-based system as end-users to provide services to the customers of the company, while the customers' preferences as well as cost considerations have a major influence on the system's requirements. Further, reducing CO_2 emission is a problem that, in our opinion, can be considered to be representative for the whole domain of problems considering sustainable development. Based on these two reasons, we argue that our results are generalizable at least to some extent to positive enabling effects about sustainability in general for systems in the service domain.

Construct Validity describes our ability to measure what we actually intend to measure. All participants had the same tasks. However, we believe to have reduced mono-operation bias by including different work locations and work domains (Business & Industry, Education) into our study. We have minimized mono-method bias by using methodological triangulation (contextual inquiry, interview, questionnaire). To avoid evaluation stress, we assured all participants that their data were treated confidentially and evaluated for research purposes only.

Conclusion Validity is concerned with drawing correct conclusions based on our observations. The first author was involved in designing the study and executing the elicitation techniques, which could potentially cause observer bias. For mitigating this threat, we used methodological and observer triangulation and reviewed the structure and questions of all three elicitation methods with a group of experienced RE researchers. By conducting several pilot studies we strengthened the quality of our wording. Further, we encouraged the

interviewees to ask for clarification if something was unclear. Therefore, we do not consider measure reliability as a major threat.

V. Discussion

In this section, we discuss the results of our study with respect to our two research questions and present some key findings.

A. RQ1: What is specific about requirements concerning positive enabling effects?

The results of our study show that the requirements do change when sustainability comes into play. In our study, when extending the existing DSS for meal planning with game-based mechanics for motivating environment-friendly choices to achieve a reduction of CO_2 emissions, we mainly found three kinds of changes in requirements: new constraints, existing constraints that become more important, and new functional requirements.

For example, the size of the kitchen is a new constraint that the interviewees only perceive when the system is used in the context of positive enabling effects for achieving a reduction of CO_2 emission. The smaller the kitchen, the less fresh food can be processed, which means that the meal planners have to go for more frozen or pre-processed food. This, in turn, has an effect on the CO_2 footprint of the meals.

Participants from both Edu and B&I canteens identified *customer preferences* and *cost restrictions* as the most important constraints. The interviewees emphasized their fear about increased cost constraints in the context of positive enabling effects due to higher prices for local and organic food. Further, they are afraid of loosing customers by excluding off-season products, which results in a smaller variety of food. That means that the existing constraints of *customer preferences* and *cost restrictions* become more important in a sustainability context.

72 percent of all interviewees emphasize the need to integrate the information about CO_2 emission values into the DSS. 33 percent specifically want to be able to immediately access a list of alternative ingredients with respect to their CO_2 footprint. These are new functional requirements.

Consequently, treating sustainability requirements as a sub-category of specific quality requirements (cf. Section II-B2) turns out to be inadequate. Requirements concerning positive enabling effects can be functional requirements or constraints.

The growing importance of customer issues in the context of positive enabling effects such as *customer preferences* and *cost restrictions* also provides evidence that in the context of sustainability requirements, there is a strong need for taking into account also the indirect stakeholders of a system (i.e., those who are not end-users of the system, but are affected by its use, e.g., customers).

B. RQ2: How can game-based mechanics motivate positive enabling effects when extending existing software systems?

The results show that it is important to integrate the game-based mechanics directly into the underlying system and that end-users have to perceive the representations of sustainability goals to be meaningful as well as comparisons to be fair.

As mentioned above, the interviewees emphasize the need to integrate the information about CO_2 emission values into the DSS and want to be able to immediately access a list of alternative ingredients with respect to their CO_2 footprint.

The requirement of representing the CO_2 values in a meaningful way is perceived as relevant by 94% of all interviewees. Metaphorical representations such as *number of trees needed to compensate the CO_2 emission* or *number of kilometers made by a mean of transportation until the same amount of CO_2 is emitted* are preferred over more abstract representations such as energy equivalents. Interviewees also mentioned the importance of concrete and visual representations e.g a concrete example for a trip from city A to city B, preferably indicated on a map. A proper segmentation of the displayed information is also important. In our study, most participants favored the origin of ingredients as segmentation criterion.

As discussed in our previous research [26], comparison of individual achievements is an important game mechanic for motivating sustainable actions. The results of our study underline the importance of considering the work context to enable fair comparison when comparing the CO_2 footprint of different canteens with each other. The relevance of *customer preferences* as a factor for enabling fair comparison again underlines the need for taking the needs of indirect stakeholders into account.

When analyzing the interview data with respect to the codes that originate from information provided spontaneously by the interviewees (see Table III), we found that this information (and hence, the corresponding sustainability requirements) can be grouped into three categories: (a) integration of sustainability information into the current system and work process (i.e., by properly extending the current software system instead of just adding a new, separate module), (b) meaningful representation of the addressed sustainability aspect (CO_2 emission in our study), and (c) fair comparison of the achievements of the addressed users (meal planners in different canteens in our study). Although more research is necessary to establish the generalizability of this finding, our study provides some evidence that a classification of sustainability requirements with respect to positive enabling effects into the classes *integration*, *(meaningful) representation* and *(fair) comparison* makes sense.

C. Key Findings

In summary, we draw five key findings about sustainability requirements regarding favorable enabling effects from the results of our study. In the context of positive enabling effects regarding sustainable development:

- Requirements for a software system do change when sustainable development is considered.
- We find both new requirements and existing requirements that become more important.
- Considering sustainability requirements to be a subset of quality requirements is inadequate. We also found functional requirements and constraints.

- Game-based mechanics need to be integrated directly into the underlying system.
- Meaningful representations of the sustainability aspect as well as fair comparison are important.

Further we have two findings where our study provides some evidence, but further research is necessary.

- Sustainability requirements can be classified into three classes: *integration*, *(meaningful) representation* and *(fair) comparison*.
- Indirect stakeholders, i.e., those affected by the use of the deployed system, should be involved when eliciting sustainability requirements.

VI. Conclusion and Future Work

We reported on the results of elicited sustainability requirements regarding positive enabling effects. The study includes 78 data points from 60 participants working in 60 different canteens. Our main contribution is to reveal differences of such sustainability requirements compared to requirements in traditional settings, as well as important requirements to consider in a context of sustainability requirements for favorable enabling effects. Moreover, we found evidence that indirect stakeholders are important in this context and a possible classification of sustainability requirements.

In our future work we will further exploit the findings of this study. In particular, we plan to investigate the elicitation of sustainability requirements from indirect stakeholders who are outside of organizational reach.

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