Responsible software

A research agenda to help enterprises become more sustainable

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Abstract— **[BACKGROUND] Responsible enterprises are key to reaching a sustainable economy that cares about the people and the planet. Their spectrum is wide and it encompasses, among others, non-profit non-governmental organisations, social economy enterprises and companies with a committed corporate social responsibility. Responsible enterprises face many challenges, such as complying with governmental regulations, defining sustainable business models, having a positive social and environmental impact, and fostering ethical consumption. [OBJECTIVE] Our premise is that responsible enterprises need responsible software, which is software that assists enterprises in becoming increasingly responsible. We intend to discover the challenges that responsible enterprises face during the process of becoming more sustainable and to envision how enterprise modellers and software developers can use their competences and knowledge repositories to support enterprise missions. [METHODOLOGY] We have conducted a literature review and interviewed relevant stakeholders in the area in order to elicit a number of problematic phenomena related to enterprise responsibility. We then filtered the elicited issues to focus on those that are related to and can be tackled by applying software. [RESULTS] We have elaborated a roadmap for future research endeavours on responsible software. Interestingly, a core practice to be properly supported is socio-environmental auditing. [CONCLUSION] This research agenda will surely require close collaboration between academia and industry, as well as a close collaboration among experts from different disciplines. Let this paper be a call for action.**

Index Terms— **Responsible software, responsible enterprise, enterprise modelling, information and communication technology, sustainability, socio-environmental auditing, research agenda, research roadmap.**

I. Responsible Enterprises are Agents of Positive Change

Economy shapes the world we live in. This has a bright side and a dark side. On the bright side, economy moves the machinery that produces the goods and delivers the services we need in our daily lives. From the food that satisfies our hunger or the medical technology that saves our lives, to the education we receive or the repair of our bikes. On the dark side, the environmental disasters caused by some industries or the recurring financial crises have a big impact on the planet and its people. Three types of stakeholders are acting to improve the situation and tip the balance towards the bright side: (i) responsible consumers base their acquisition, usage, and disposal of products on a desire to minimize harmful effects and maximize

the long-run beneficial impact on society [4], (ii) responsible enterprises integrate social, environmental, ethical, human rights and consumer concerns into their business operations [5], and (iii) responsible governments foster a more sustainable behaviour of the former two [6]. Each of them are facing their own challenges and, although their underlying mechanisms are highly interconnected, in this paper we focus on the needs of responsible enterprises. Specifically, we are interested in investigating and engineering *responsible software*, which is software that assists enterprises in becoming increasingly responsible. Responsible software can enable actions that increase the social and environmental responsibility of enterprises (see Fig. 1). For instance, the difficulties that large cooperatives have had so far to scale up their management practices from a representative democracy to a participatory democracy [7] could be alleviated by new developments in decision support systems, business intelligence and user engagement interaction techniques. Ideally, responsible software would also increase the competitive advantage of responsible enterprises. For instance, increasing customer loyalty by appealing for ethical consumerism.
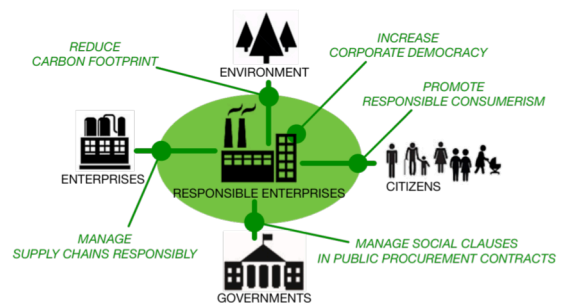

Fig. 1. Context of responsible enterprises and external stakeholders, with examples of responsible actions enabled by responsible software

Responsible software is part of a second wave of sustainable information and communication technology (ICT), which goes beyond reducing computing-centric energy use and focuses on achieving technological and corporate strategic objectives by maximizing benefits for society at large [8]. With this work, we intend to discover the open challenges of responsible enterprises and define a research roadmap for responsible software intended to help them overcome such challenges and support them in their missions. This paper also positions responsible software among existing disciplines.

The remainder of the paper is structured as follows. Section II presents the research methodology applied in this work. Section III defines a basic conceptual framework that allows understanding and structuring the challenges properly. Section IV positions responsible software within erstablished disciplines. Section V presents the research agenda as a set of challenges and provides examples. Section VI concludes the paper, discussing the need to perform interdisciplinary research and calling for a joint collaboration between industry and academia.

II. OUR APPROACH TO DISCOVERING THEIR CHALLENGES

The research methodology is depicted in Fig. 2. In the following, we summarise the process. For the sake of brevity, the details (e.g. profile of the interviewed enterprises and subjects, interview structure and questions) are included in an online appendix[1].
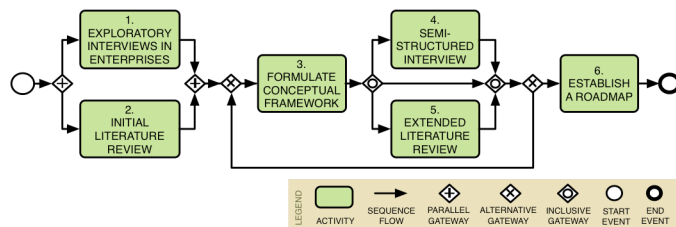

Fig. 2. Overview of the research methodology

After an initial literature review, we visited over 30 responsible enterprises and conducted informal exploratory interviews with the company stakeholders, in order to get to know the domain. The selection of responsible enterprises was the result of convenience sampling. In any case, the sample includes cooperatives, foundations, associations and enterprises of any other legal form, as long as their mission includes social and environmental values. The exploratory interviews already gave us hints on the problems such enterprises currently have and allowed us to formulate a preliminary conceptual framework.

Then we have conducted 5 semi-structured interviews on the issues that responsible enterprises face in their quest to balance their economic sustainability with a good social and environmental impact. With the intention to understand the concerns of the problem owners, we interviewed experts in social economy (in countries where social economy is regulated by law, such enterprises must have strong social and environmental values), political sciences (in order to elicit challenges related to the relationship between responsible enterprises and governments), social business consulting (because advisors are expected to be aware of the needs of their clients), responsible enterprise networking (regarding relationships and interactions among responsible enterprises) and collaborative economy (included as a result of the increasing concern that collaborative economy should champion ethical values[2]). Several groups of questions were defined in advance (see Table I), but we let the interviewees freely change from one subject of discussion to another, steering the interview occasionally not to leave important topics unaddressed. Some questions were asked to all

[1] https://www.staff.science.uu.nl/~espan002/respsw/respswapp.pdf
[2] http://sharingaccelerator.com

subjects, some specific questions were formulated only depending on the expertise of the subject, and some guiding questions were only used if we deemed necessary to foster more discussion.

TABLE I. OVERVIEW OF THE INTERVIEW STRUCTURE

Group of questions	Number of questions
Demographic information	6
On the notion of responsible enterprise	2
On the challenges of responsible enterprises	2
Specific questions on challenges of social economy enterprises	2
Specific questions on challenges of collaborative economy enterprises	5
Specific questions on challenges of responsible enterprise networks	3
Guiding questions	8
If the interviewee is part of a responsible enterprise	5

For the sake of brevity, we only include here the two questions related to challenges of responsible enterprises and one guiding question. See the online appendix[1] for the complete set.

- What major challenges do responsible enterprises have ahead?
- What challenges related to consultancy and software do responsible enterprises have?
- Think of the following aspects of responsibility (from the Common Good Matrix) and how software could help enterprises address them: human dignity, cooperation and solidarity, ecological sustainability, social justice, democratic co-determination and transparency. (Guiding question)

We recorded 288 minutes of interviews and took notes on the fly. Later, each interview was replayed and the notes were completed, identifying the challenges of responsible enterprises mentioned by the subject. Since the interviews were carried out over a four-weeks period, we also used later interviews to confirm the challenges that had been mentioned in previous ones, asking the subjects on those matters. We used the interview notes to update the conceptual framework. We defined five major categories of enterprise responsibility work practices (see Fig. 5), which we also used to structure the roadmap. Then the researchers discussed each challenge and identified areas within business informatics, computer science and information science that could potentially contribute to meeting it. We brainstormed to imagine the breakthroughs that are still needed. Evidently, the process was more iterative, incremental and opportunity-driven than described above. In parallel, we also performed a snowball literature review that included grey literature, aiming at clarifying concepts and finding supporting evidences for our arguments.

There are threats to the validity of our conclusions. For instance, the interviewed subjects were selected by convenience sampling. However, we consider that they are good surrogates for the problem owners, since they are active members of their academic and industrial communities. Evidently, in the future, whenever each challenge is tackled individually, a deeper investigation of the problematic phenomena (e.g. additional interviews with problem owners) should be done. The interviews were conducted and later reviewed only by one author. However, to decrease the researcher bias, the questions were word-

ed to avoid influencing the response, the subjects were often required clarifications or confirmations of the conclusions, and the results of this research has been shared with them. Moreover, since this research is purely exploratory, we had no interest in obtaining any specific result. Finally, the literature review was not systematic, so some primary studies may have remained unnoticed.

We present the conceptual framework and the research roadmap in subsequent sections.

III. A BASIC CONCEPTUAL FRAMEWORK

A *responsible enterprise* is an enterprise that performs accordingly to ethical values, taking care of the impact of their activities on society and on the environment, beyond its legal obligations. To formulate the definition we have taken into account how the area of business management [9, 10, 11, p. 50, 12, pp. 520-527] and the European Commission [5] define the term, analysing their commonalities. It should be no surprise to notice the relation with the triple bottom line approach to enterprise sustainability [1] (see Fig. 3.a). It is also important to highlight that, for many authors, enterprise responsibility begins where the law ends [13].

a) Three pillars of enterprise sustainability [1]

b) Four pillars of software sustainability [2]

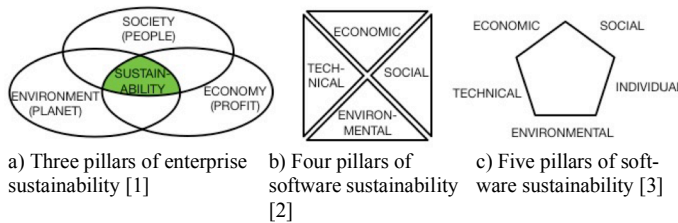c) Five pillars of software sustainability [3]

Fig. 3. Responsibility at bird's-eye view

In the context of this work, enterprises should be understood in the broad sense; i.e. an organisation or a project that is complex enough to require methods to design, enact or manage them. Still, by default, we will refer to organisations, for the sake of simplicity. Many types of organisations fall under the category of responsible enterprises. For instance, non-governmental organisations working on environmental issues, health improvement, third-world development or human rights (e.g. Amnesty International[3]); social economy enterprises, such as cooperatives, foundations and associations (e.g. Consum[4], a big Spanish cooperative supermarket chain); social enterprises and other public or private, for-profit enterprises having a committed corporate social responsibility (e.g. Patagonia[5], a sustainable clothing company); ethical banks (e.g. Triodos[6]); watchdog organisations keeping vigil on responsible enterprise behaviour (GoodElectronics[7]); educational institutions promoting ethical values and responsibility[8].

Of course, unless precise, measurable criteria are defined, assessing responsibility requires some degree of judgement and

[3] https://www.amnesty.org
[4] http://www.consum.es (in Spanish)
[5] http://www.patagonia.com/us/patagonia.go?assetid=2047
[6] https://www.triodos.com
[7] http://goodelectronics.org
[8] http://www.uu.nl/en/organisation/faculty-of-law-economics-and-governance/societal-impact/social-entrepreneurship-initiative

the best approach is reaching evidence-based, inter-subjective agreement. In any case, enterprise responsibility can be seen as a continuum (see Fig. 4) and, moreover, as a commitment; that is, an enterprise truly interested in becoming more sustainable can be deemed responsible. In fact, responsible enterprises are prone to enact continuous improvement processes to enhance their socio-environmental impact.

Fig. 4. Enterprise responsibility can be seen as a continuum

The behaviour of responsible enterprises is driven by *business ethics value systems* that are translated into commitments and norms. Often, such values, commitments and norms are explicitly specified in documents at different levels: supra-national level (e.g. European directives on non-financial reporting [14]), national level (e.g. laws governing social economy in France [15], Spain [16] or Greece [17]), inter-enterprise level (e.g. principles of sustainable banking[9], sustainable mining best practices [18], charter of principles of REAS[10] -a heterogeneous network of social and solidarity economy enterprises-), strategic management level (e.g. sustainable organisational missions[5]), tactical or operational management level (e.g. internal documents prescribing business processes and rules).

As a result of their value system, many responsible enterprises consider money as a means to a greater common good and not an end by itself. This enables responsible enterprises to balance trade-offs between the different pillars of sustainability, instead of just aiming at maximising benefit at any cost. They try to avoid creating a socio-environmental debt with their actions. Often, responsible enterprises internalise more *negative externalities* than conventional enterprises, which implies that they assume the costs of avoiding or repairing negative impacts of the economic activity in unrelated third parties. For instance, any legal conventional company is expected to properly treat industrial water before dumping it into a river; however, a responsible company will often go beyond legal obligations and will further contribute to keeping the environment clean (e.g. by purifying waste water more than strictly required and by planting trees). Also, responsible enterprises often pay above-average salaries and are willing to contribute to societal development. As a result, they incur in more costs, thus reducing the benefits.

To level the playing field, many national and regional governments tax economic activities with negative externalities (e.g. taxes on pollution) and stimulate positive externalities (e.g. subsidies to non-governmental organisations having a good impact, tax abatement for Spanish social economy enterprises, inclusion of social clauses in public procurement contracts [19]).

As a result of their commitment with sustainability, responsible enterprises run the risk of having a competitive disadvantage. Friedman advocated that the only social responsibility

[9] http://www.gabv.org/about-us/our-principles
[10] http://www.economiasolidaria.org/carta.php (in Spanish)

of a business is to increase profits within the rules of the game (i.e. legally) [20, pp. 60-61]; he was openly against broadening the concerns of corporate social responsibility (CSR) since he considered that diluting the focus on profit introduces many confounding factors in strategic decision making. Moreover, besides considering the increased costs, responsible enterprises need to take care of potential backfires of their CSR actions [21], especially in cases where customers perceive signs of *greenwashing*, a form of disinformation from organisations seeking to repair public reputations and further shape public images [22]. In any case, it is widely accepted today that there is a compelling business case for making a substantial commitment to CSR, as long as its strategy is carefully formulated and monitorised [23]. In fact, one of the purposes of responsible software is providing responsible enterprises with specialised consultancy services and software to use their good deeds and responsible behaviour to their advantage.

As a result of the literature review and the interviews, we defined five categories of work practices related to enterprise responsibility (see Fig. 5). Four of them can be seen as interrelated stages in relation to responsible enterprises (categories B to E): the promotion of responsible economy leads to the creation of responsible enterprises, which usually enact improvement processes during their lifetime to increase their responsibility, and which need to collaborate and compete with other enterprises that might be equally responsible or not. Most interviewees insisted that assessing the impact of enterprises is a core process, so measuring responsibility deserves a category on its own (category A).
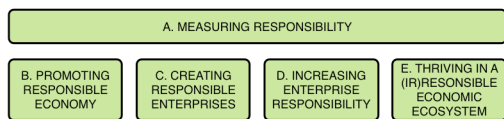

Fig. 5. Categories of enterprise responsibility work practices

A. Measuring responsibility

Socio-environmental auditing (SEA) is the process of assessing and reporting the social and environmental effects of a company's economic actions to particular interest groups within society and to society at large [24, 25]. Other terms related to SEA (either synonyms or hyponyms) are non-financial reporting, social balance, social audit, social accounting, environmental accounting, impact accounting, and (socio-environmental) impact assessment. SEA complements enterprise financial statements.
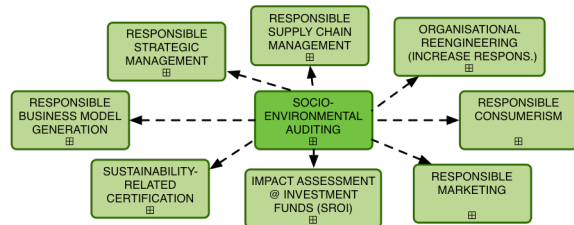

Fig. 6. Socio-environmental auditing enables other responsible processes

SEA practices are currently voluntary and can serve different purposes: public relations (e.g., marketing), comparison (e.g., responsible consumerism) or continuous improvement

(e.g., reengineering an organisation to become more sustainable). During our interviews and literature review, we discovered that most processes related to responsibility require some degree of SEA (see Fig. 6). For instance, an organisational reengineering project aimed at increasing the responsibility of the enterprise requires knowing what is the current baseline (i.e. the result of an initial socio-environmental auditing); this way, after the project, the improvement can be assessed (by performing an additional audit).

SEA practices are very diverse and there are many initiatives intending to standardise them; e.g. Global Reporting Initiative, Common Good Matrix, B Corp, ISO 26000, SA8000, SASB, LEED, Fair Trade, REAS Social Audit. At a bigger scale, municipalities (e.g. Transition Town, Common Good Municipality, Agenda 21) and nations (e.g. Happiness Index, Common Good Index, Social Progress Index) can also assess wellbeing in non-financial terms.

B. Promoting responsible economy

Many governments [6], educational organisations[8], and economic institutions (e.g. OECD [26], ILO [27]) are actively promoting responsible economy by writing and promulgating laws and standards, fostering their adoption, and educating citizens. We have chosen to keep these initiatives out of the scope of responsible software. But we do consider another mechanism that governments use: the inclusion of social clauses in public procurement contracts. A *social clause* is a requirement within a procurement contract or process which stipulates that the contract should provide added social value [28]. For instance, a public contract that will lead to new employment could ensure that some long-term unemployed citizens from the local community are hired. The European Parliament has promulgated a directive fostering social clauses [29]. Social clauses have a direct counterpart in responsible enterprise work practices; i.e. managing the actions taken to comply with such clauses and to report on the outcomes.

Enterprises also have their own mechanisms to promote a responsible economy, as part of their relation with consumers: responsible enterprises often have interest in being transparent and they can also have an impact on ethical consumerism.

C. Creating responsible enterprises

Responsible entrepreneurship can benefit from methodological and institutional support to ensure a successful kick-start. There are techniques such as the Strongly Sustainable Business Model Canvas [30] that facilitate defining a business model that embeds sustainability as a core value. Some incubators and accelerators such as Impact Hub[11] or Ashoka[12] are focused on social enterprises. Some investment funds also target responsible enterprises; e.g. the Silicon Valley Social Venture Fund[13] and the European Venture Philanthropy Association[14]. Enterprises applying for such funds need to prove their social nature, typically by measuring their responsibility (or estimating it, in the case of incipient business ideas).

D. Increasing enterprise responsibility

Responsible enterprises usually undertake a lifelong continuous improvement process intended to reduce negative externalities and increase the positive ones. Iterations of this process are also known as organisational reengineering and, to perform them with maturity, the process outcome needs to be measured. Often, reengineering projects are intended to increase the level of achievement of business ethics values. This has an implication in enterprise modelling and consultancy practices, since they need to integrate SEA practices.

E. Thriving in a (ir)responsible economic ecosystem

Responsible enterprises compete in a free-market economy, driven by their value systems, establishing rivalry with other enterprises, and engaging in cooperation with other responsible enterprises. Strategic management becomes necessary.

IV. POSITIONING RESPONSIBLE SOFTWARE

Responsible software is software that assists enterprises in becoming increasingly responsible. It supports the above mentioned enterprise responsibility work practices.

a) With respect to ICT for sustainability   b) From a broader perspective
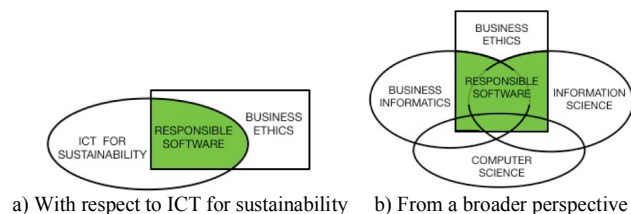
Fig. 7. Position of responsible software within established fields

Within ICT for sustainability, responsible software is positioned closer to sustainability by ICT (greening by ICT) than to sustainability in ICT [31, p. 21] (a.k.a. greening of ICT [32]). Furthermore, responsible software crosscuts this discipline with enterprise responsibility and business ethics [12] (see Fig. 7.a). In a broader perspective, responsible software drinks from business informatics, information science and computer science, as they are crosscut by business ethics (see Fig. 7.b). With regards to the levels of impact of ICT defined by the LES model [31, pp. 26-32], responsible software is related to the Enabling Impact (e.g. enabling corporate democracy) and the Structural Impact (e.g. an increase in software-based corporate transparency can fuel responsible consumerism).

In order to better understand the relationship between responsible software and sustainability, additional dimensions such as technical and social sustainability need to be considered (see Fig. 3.b and Fig. 3.c, respectively).

V. A ROADMAP OF RESPONSIBLE SOFTWARE RESEARCH

In the following, we use the same categories shown in Fig. 5 to structure the challenges. We describe each challenge and provide examples outlining potential solutions.

A. Measuring responsibility

1) Achieving interoperability of measurement frameworks.

The relationship among the measurement frameworks underpinning different SEA initiatives remains unclear. This makes it difficult for other stakeholders to interpret, understand, and compare reports from different enterprises (e.g. one using the Global Reporting Initiative and another one using the Common Good Matrix). Moreover, if a company intends to report their socio-environmental impact using two or more frameworks, a lot of redundant work is required. There is a need to identify commonalities and differences, as well as supporting the interoperability between the sustainability measurement frameworks at the structural (metamodelling), content (indicator semantics) and technological (software) levels. Once all frameworks are properly modelled and their relationships are understood, it should be possible use develop model-driven technologies implementing transformations among the frameworks, to achieve a flexible interoperability (e.g. if the frameworks evolve, the transformations that allow reusing measurements can also be evolved).

2) Improvement of measurement frameworks and sustainability maturity models

Many of the indicators in SEA measurement frameworks are qualitative or Likert scales. Also, many sustainability maturity models follow a checklist approach; that is, an enterprise obtains a given maturity level if all the processes and best practices prescribed for that level are enacted by the enterprise, without any indication of the current performance of these processes. For instance, according to the SURF Green ICT Maturity Model, an enterprise achieves a maturity level 4 (out of 5) in the "E-waste Policy" attribute when the enterprise recycles both the equipment own by the organisation and the one own privately by its members. But, does the enterprise ensure that the outsourced recycling is properly done so that the equipment does not end up in a dumping site abroad? What percentage of equipment ends up being properly recycled? In conclusion, the measurement frameworks and maturity models can be improved by adding key performance indicators that would provide a more precise picture of the enterprise responsibility.

3) Improve the technology to support measurements

The maturity of the software supporting SEA is typically low. Many indicators, to date, are qualitative or require subjective estimations. A higher degree of quantification, automation and even crowdsourcing could be achieved by developing electronic surveys, mobile apps, social network analysis algorithms, etc. For instance, if a cookie manufacturing company is interested in assessing to what extent the residents of the neighbourhood are affected by the smell the factory produces, they could gather live feedback from the citizens by means of web surveys or mobile apps.

Usability engineering is also important. For instance, (i) companies and consultants within the Economy for the Common Good initiative use a PDF handbook and an Excel spreadsheet as sole support for SEA, and (ii) REAS indeed has a fully-functional web application but its usability, customisability and interoperability could be improved. To increase the adoption of SEA technologies beyond early adopters, a better user experience is required.

Another need expressed by two subjects is designing a methodology for deploying SEA tools in heterogeneous networks of responsible enterprises, so that the collected data re-

sides in a central repository. Cloud technologies can tackle the technical problems, but proper policies need to be developed to regulate information access, transparency and security.

B. Promoting responsible economy

1) Bridging the gap between responsible enterprises and citizens

Some responsible enterprises are interested in increasing their social transparency. The current approach consists on publishing SEA reports in the company website, but more advanced interaction technologies could be used in the future. To further engage citizens in social dialogue, a feedback loop needs to be enabled, for which new media and social networks could be used. Similarly, some companies have expressed their interest in educating their consumers so as to increase their awareness of sustainability issues. And if a company want to further increase citizen co-determination, enterprise decision-support systems need to take the citizens' opinion into account.

2) Making sense of social clauses

According to subjects from companies and consultancy firms, (i) it is frequent that enterprises cannot easily prove the fulfilment of the demands stated by social clauses, and (ii) they often lack the methods and technology to assess the impact of their CSR initiatives. Responsible software should assist them in this, by relating the outcomes of the actions resulting from the contract enactment to the business ethics values associated to the social clauses. Also, governments and enterprises could use software to collect citizen requests and feedback concerning responsible actions.

Additionally, research is needed to identify meaningful social clauses that specifically apply to the software industry (e.g. labour conditions in outsourcing, energy efficiency, hardware supply chains, use of open source licenses).

3) Developing policies and standards for responsible software

There is a need to establish standard features and information structures for SEA input and reporting. Open source reference software architectures and best practices would contribute to creating development communities. Semantic web technologies and ontologies could facilitate automatic interpretation of published SEA reports. All in all, standardisation efforts, certifications and auditing protocols would eventually bring maturity to the responsible software. This will contribute to paving the way for greater adoption of responsible software.

C. Creating responsible enterprises

1) Validation of sustainable entrepreneurship approaches

In general, subjects expressed needs concerning a better support to the creation of responsible enterprises. Therefore, the academic and industrial communities should provide and validate methods and tools for responsible enterprise incubation. Moreover, a better integration with SEA methods and tools is needed.

2) Investigating social entrepreneurship within the software industry

Further investigation of responsible entrepreneurship within the software industry is also convenient. It is known that few university spin-offs take a cooperative legal form [33]. What is the situation within software-related spin-offs? What is the commitment with responsible economy that these companies have? What challenges do these companies have ahead in their quest to make a good impact in people and the planet? It is necessary to explore successful business models on responsible software development, in order to identify good practices and guidelines for future entrepreneurship. We would like to answer the question of how a company can make money by engineering responsible software, or by engineering software responsibly.

D. Increasing enterprise responsibility

1) Responsible enterprise modelling

As mentioned above, measuring responsibility is a key process that allows establishing the baseline of current responsibility. Another product of the audit is typically a set of ideas for improvement actions that the consultant and the enterprise stakeholders came up with during the audit; there was general agreement among the interviewees knowledgeable of SEA practices that applying measurement frameworks during the audit produces insights on what aspects of the enterprise can be improved. This enables a continuous improvement process that entails reengineering practices. Enterprise modelling comes handy at this stage. However, there are signs that the process of enterprise modelling and reengineering needs to be tailored to responsible enterprises. We still have not found evidences that existing enterprise modelling languages need to be extended with new modelling primitives, but specific guidelines are definitely needed. There are differences in the process of enterprise modelling and reengineering in responsible enterprises. Cooperatives provide a paradigmatic situation, given their characteristics as social economy enterprises; the workers are owners of the company, following the principle of one person, one vote. Some examples of such differences are:

- Trigger: In cooperatives, not only top management but any member may trigger the reengineering process, provided they rally enough support from other members.
- Goal: In social economy enterprises the criteria to judge reengineering success are not just profit and efficiency, but also social and environmental indicators.
- Constraints: In cooperatives, no member can be fired as a result of organisational restructuring, what limits the possible reengineering outcomes (i.e. the solution space).
- Way of working: In cooperatives, not only enterprise modelling and evolution needs to be collaborative, but also agreed according to the democratic principle (all important decisions are made in an assembly meeting).

Moreover, consultants specialised in responsible enterprises are interested in comparing enterprise model patterns in responsible and conventional enterprises. This can be later used to define a methodology for corporate restructuring (which might even including model-to-model transformations). For instance, a limited company in the process of changing its legal form into a cooperative requires deep changes in its organisational structure, processes, and software.

2) Investigating responsible software development processes

The ultimate aim of responsible software is promoting business ethics. However, there is a gap in knowledge about the flow of ethical values since they are expressed by the affected stakeholders until they end up coded in the software. This will require case-study research and traceability analysis. This line of research could eventually lead to identifying needs for extending requirements engineering methods to elicit, model and keep traceability of business ethics concerns. We also expect interesting insights when comparing proprietary and open-source responsible software development.

3) Tackling each aspect of responsibility

Each indicator in socio-environmental auditing measurement frameworks entails additional challenges related to enterprise modelling and software. For instance, the Common Good Matrix defines 17 business ethics indicators and improving their values is far from straightforward; for the sake of brevity, we only elaborate three:

- Corporate democracy and transparency. Social economy enterprises have been enacting democratic decision-making on fundamental strategic issues for centuries. Now this practice seems to be increasingly important among other forms of responsible enterprises, as stated by subjects and given the fact that it appears in every SEA measurement framework we analysed. Fig. 8 shows how, in cooperatives, decisions are made in assemblies that involve all corporate levels. For big cooperatives this is a major challenge. For instance, Consum has opted for representative democracy. Should the chain of supermarkets go for participative democracy, they will need software to support remote participation in assemblies, e-voting, etc.
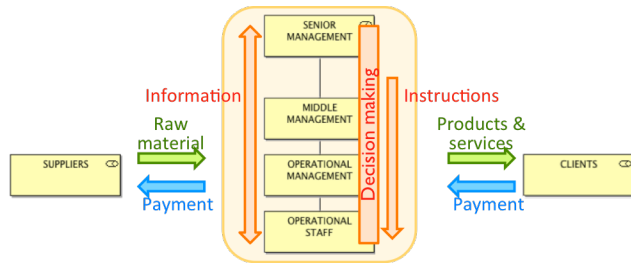

Fig. 8. Democratic decision making in cooperatives

- Social transparency and codetermination. This indicator refers to the relationship with external stakeholders, within the social environment. In today's globalised world, this requires using new media and visualisation techniques (e.g. interactive websites, social networks, etc.), to report on companies' responsible missions, their internal performance, and their external impact. Novel transparency requirements engineering methods can be applied here [34].

- Reduction of environmental impact. This refers to diminishing environmental effects towards a sustainable level. A well know topic in the ICT for sustainability community. We already mentioned above the need to improve the sustainability maturity frameworks themselves. Moreover, to facilitate adoption of ICT sustainability auditing, it is nec-

essary to tailor the frameworks, methods and tools to the enterprise, to define clear responsibilities and to embed the sustainability auditing into the ICT department processes. The requirements per industry sector need to be investigated. Fig. 9 shows (at a coarse-grained level) a process that we are currently running in Utrecht University.
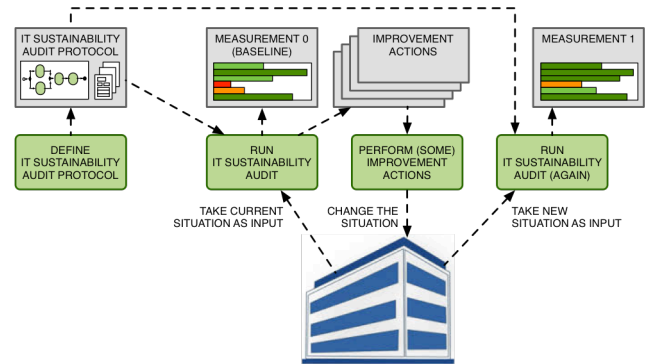

Fig. 9. ICT sustainability auditing at bird's-eye view

4) Increase the responsibility of collaborative economy

Collaborative economy promotes that people get from each other what they need. It is built on distributed power and trust within communities [35]. Also, it is closely related to the notion of *prosumer* (i.e. the same person acting as consumer and producer of goods and services). Although the premises of collaborative economy seem quite altruistic, the are also shadows [36]. A call for a responsible collaborative economy has been made. Besides regulatory changes to address these new forms of decentralised businesses, it becomes necessary to embed ethical values into the software support to collaborative economy. Studying the patterns of business and software interactions that lead to good externalities will enable the definition of repositories of good practices and success cases.

5) Leveraging voluntary efforts in responsible enterprises

Very often, responsible enterprises rely on voluntary work to achieve their mission; such is the case of many non-governmental organisations. Managing volunteers effectively (i.e. the volunteers succeed in carrying out the designated tasks) and efficiently (i.e. in a way that it is less costly than hiring staff) is challenging, especially in low-resource organisations. Several of the interviewed subjects pointed to the inefficiency of regular volunteering management techniques when the commitment of the volunteers is low. Networking software could facilitate structuring small and loosely coordinated groups of volunteers; more importantly, it would allow profiting from the efforts of low-contributing volunteers situated in the tail of the power-law distribution.

Another type of initiatives that heavily rely on voluntary efforts is social innovation projects. Social innovation implies undertaking activities and services that are motivated by the goal of meeting a social need and that are predominantly developed and diffused through organisations whose primary purposes are social [37]. Some social innovation projects are software-based. Their value is often exponentially proportional to the amount of users. But users do not come automatically; they need to be engaged. Take the case of a web-based applica-

tion that maps bike thefts in the city of Utrecht (the Netherlands), and that also spreads the word of each theft to increase the chances of recovering the bike[15]. Despite its partnerships with the municipality and police, the project can only successfully deliver value if the users indeed report bike thefts and participate in the community. Understanding the reasons for user (dis)engagement will enable creating a repository of best practices and software patterns that work effectively. This research requires an interdisciplinary approach combining a psychological approach to motivation, enterprise modelling to design proper organisational structures and business processes, and human-computer interaction to design multi-platform mechanisms for user engagement.

6) Investigating the role of open source software in increasing the responsibility of enterprises

There are various reasons to pay a special attention to open-source software. Firstly, it can provide solutions that small and medium responsible enterprises can afford. It also offers the chance to develop sector-specific and sector-independent auditing and strategic management tools to keep organisational behaviour aligned with the social mission. For instance, a network of small social enterprises can work together in defining the requirements for a tool; it is still to be assessed to what extent existing open-source software development communities would engage in such developments. An initial step could be creating an inventory of all open-source responsible software projects.

Last, but not least, the transparency of open-source software contributes to increasing the transparency of the products it is embedded into. The automobile industry and the public opinion have recently been shocked by the Volkswagen emissions scandal. The manufacturer tweaked software controllers to deceive emission tests, resulting in higher emissions of nitrogen oxides under real driving conditions. This deceit is considered to have caused deaths due to respiratory illnesses, although estimating the actual impact is difficult [38]. This discrepancy between real-world and test performance occurs in other industries as well; e.g. Samsung televisions have been proved to be less energy-efficient than stated in their technical specifications[16]. Many voices are being raised to claim that open-source software would prevent such fraudulent behaviour. Developing such embedded software is outside the scope of responsible software, but understanding the relationship between open-source developments and business ethics would shed light into how this paradigm increases enterprise responsibility, as well as its consequences in responsible business ecosystems.

E. Thriving in a (ir)responsible economic ecosystem

1) Responsible management software for thriving in vibrant ecosystems

Most interviewed subjects highlighted the importance of strategic and tactical management tools for responsible enterprises. A first step would be studying currently applied strate-

gic management methods and tools, with a special focus on small and medium enterprises and cooperatives (e.g. small Spanish cooperatives experience a lack of professionalisation in management [39] and are still to adopt basic practices and software for this purpose). This would also allow identifying problems and needs.
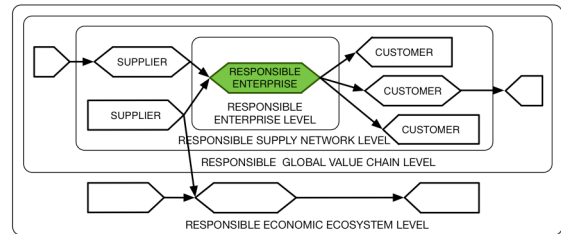

Fig. 10. Understanding responsible ecosystems is key to providing responsible enterprises the tools they need to succeed (notation adapted from [40])

For instance, in a responsible ecosystem, strategic management needs to be global. A responsible company often feels responsible for the behaviour and success of its suppliers and consumers (see Fig. 10). In today's global economy, firms often do business with companies that operate far away. Therefore, responsible strategic management systems need to be context aware and highly interoperable with those in cooperating firms. This is expected to help responsible companies control, change, or maintain their position in their business ecosystem.

2) Characterisation, modelling and analysis of responsible economic ecosystems and their software

From the economic perspective, it is interesting to analyse vibrant and successful ecosystems of responsible enterprises, beyond value chain concerns. This will enable discovering patterns, best practices, co-evolution, and survival strategies that help responsible enterprises compete with enterprises whose behaviour is not so strictly bound by ethical value systems. This will require an interdisciplinary approach, combining business ethics, business ecosystem analysis and software support for storing, visualising and analysing the information. In turn, the outcome will benefit several academic communities; for instance, social economy researchers are interested in better support for investigating the so-called corporate value contamination in a larger scale. Corporate value contamination can happen in cases of hybrid cooperation; for instance, when one or several cooperative enterprises partner with a shareholder enterprise and the profit-oriented values of the latter prevail over the socio-environmental values of the former [41].

Many responsible enterprises engaging in close cooperation and solidarity interactions with responsible partners will eventually need to open up and ensure interoperability at several levels (e.g. organisation structure, business processes). This will require proper consultancy methods and software support.

Also, the specific relationship between open-source software ecosystems and responsible economy ecosystems can be investigated. And, eventually, the research line could end up defining a software maturity model for responsible ecosystems, building on top the knowledge body of software ecosystems [42, 43].

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3) Responsible value chain modelling and analysis

Enterprise modelling at the supply chain level needs to include socio-environmental impact as part of the analysis and simulation. Evidently, responsible companies who are dependent on socially or environmentally risky supplies do not only assess the impact of the chain but also engage in negotiations with the suppliers to improve the responsibility of the overall value chain. This is the case of Fairphone, who are pioneers in sustainable mobile manufacturing; they aim at having a sustainable supply chain, even though this is very challenging in electronics domain due to the large and dynamic supply chains, the type of raw material (e.g. coltan), and the working conditions in assembler factories. They use advanced life-cycle assessment methods and tools, which are very specialised. However, not all enterprises have the same needs and we believe it is convenient to integrate SEA features into existing supply and value chain modelling and analysis methods (e.g. e3-value [44]), so as to extend the current profit-optimisation analyses with sustainability concerns.

It is also necessary to provide tools to report on the improvements of the supply chain responsibility to external stakeholders (e.g. consumers, governments). Fairphone has partnered with Sourcemap, the first crowd-sourced directory of supply chains and environmental footprints. Moreover, if impact assessment data were made public (or, at least, shared within an ecosystem of collaborating responsible companies), this would enable data mining to provide deeper analysis of the complex interactions of the globalised economy.

Lastly, the paradigm of circular economy promotes industrial practices that, on a large scale, produce no waste or pollution. This requires discovering, modelling, simulating and managing industrial symbiosis, in which even the sub-products of a factory, are the input for another company.

4) Support responsible consumerism and marketing

Consumers need to know the degree of responsibility of enterprises and the impact of their products, in order to make informed purchasing decisions. Responsible enterprises should also capitalise on their positive impact. Some mobile apps for comparing company and product impacts are starting to appear. However, their scope is typically local or they focus on big brands. Also, they have limitations on entering information or maintaining it updated, what limits their value. Several options need to be investigated to overcome the current limitations. For instance, the source of impact information can come from citizens/consumers or from the enterprises themselves (both having threats of bias), and the data repository can either be centralised or federated (both having inherent challenges).

Citizens having uncovered needs that a responsible enterprise could satisfy require mechanisms to find out about their offerings (e.g. search engines and maps for matching consumer needs and product and service offerings, and locating the shops). Recommendation and matching algorithms should apply multi-objective optimisation techniques to take into account the sustainability trade-offs and user preferences (e.g. cost, distance, ecological impact of the product, local trade concerns such as short distribution circuits, social responsibility of the enterprise, etc.).

5) Understanding the social and environmental impact of current software development practices

The focus of greening of ICT is frequently put on reducing the consumption of energy and resources for producing, using and disposing of ICT, with a special emphasis on hardware. However, we believe that the social impact of widespread global software development practices such as outsourcing and off-shoring should be investigated as well. This will require bringing together the disciplines of business ethics, labour and software ecosystems research. Modelling methods such as the Software Supply Network diagram will need to be extended [40]. Finally, we consider that the responsibility of the software industry would benefit from tailoring and carrying out socio-environmental audits of software developer and vendor firms.

VI. CONCLUSIONS: LET'S ACT!

Responsible enterprises care about their social and environmental impact. An increasing number of enterprises are interested in becoming more responsible, affected by different forces. Among the internal forces, the relevant stakeholders in the enterprise (e.g. shareholders, owners, employees) may believe it is the right thing to do. Among the external forces, the motivation can be improving the public image of the company, a response to responsible consumer pressure, the influence of watchdog organisations, or the advent of new regulations. For instance, in 2014, an amendment to the Accounting Directive was adopted by the European Parliament and the Council regarding the disclosure of non-financial and diversity information by organisations with more than 500 employees, companies on the stock market and public interest organisations [14]. European Union member states should transpose the rules on non-financial reporting into national legislation by the end of 2016. Similar situations can be expected in other countries worldwide in a near future. From the job market perspective, this scenario brings interesting job opportunities, such as ethical business consultancy, in-house business analysis in companies running CSR programmes or committed with sustainability, and ICT consultancy in the area of responsible software.

In this paper, we have investigated the domain of responsible software from a research perspective, by means of a literature review and a series of interviews with subjects from responsible enterprises and networks, academic experts and business consultants. Responsible software requires the application of enterprise modelling and software to assist responsible enterprises in becoming increasingly responsible. As a result, this research lies in the intersection between ICT for sustainability and business ethics. Then we have defined a research agenda with open challenges. Socio-environmental auditing happens to be a key practice that allows measuring and defining improvement actions.

We are engaging in collaborations with ethical business consultants and responsible enterprises. We are open to collaboration with other researchers and practitioners, from the ICT for sustainability community, or from any other related discipline. We believe responsible software constitutes an interdisciplinary line of research that is timely and promising.

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