An Assessment Technique for Sustainability: Applying the IMAGINE Approach to Software Systems

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***Abstract*—Sustainability is a concept for which exist many definitions, but most of them are either vague or too limited; no consensus has been achieved. One pragmatic solution is to provide an implicit definition by setting up a standard with criteria that have to be fulfilled, e.g., by a company in order to reach their self-set sustainability goals.**

The problem is that even with a defined goal or strategy for sustainability, practitioners lack of reference frameworks to align to and from there to derive concrete objectives and activities. Consequently, it is hard to implement such goals or strategies through the use of IT.

This paper presents the application of the IMAGINE approach [5], for analyzing and assessing sustainability, on a system supported by IT and software systems. The approach was implemented and its applicability assessed in an industrial case study in a Master student's research project.

The approach provides project managers, business analysts, and requirements engineers with the capability to devise a specific strategy for particular contexts and sustainability goals.

I. Intro: Context & Problem

Sustainability standards are used to assess companies interested in validating and certifying their products, projects, or development and management practices. They consist of norms and reference criteria related to ideas that pursue sustainability, and the assessment is usually performed by a third party.

Several standards that are currently available focus on sustainable development [1], [2], but we can also find standards for sustainability reporting [9], [10], or sustainable design [7], [3], among others. Furthermore these standards can be segmented in the industry-specific sectors, like those listed by the Industry Classification Benchmark [8], for instance food, oil and gas producers, mining, transportation, healthcare, and telecommunications.

A. Problem

None of these standards is designed for the application in all contexts, and considering all sustainability dimensions. Norms like the ISO 14000 for Environmental Management, cover the environment dimension but do not give guidance for software systems. Besides, the software systems and IT supporting such developments are often obviated from the lifecycle analysis of a sustainable development project or not clearly indicated in the analysis. Especially for software systems, sustainability standards are not yet available and the majority of research focuses on green IT, energy-efficient software, and human computer interaction [11], [12]. Consequently, practitioners in software development lack a guideline for assessing sustainability in their systems.

B. Contribution

We provide the results of a case study in applying the IMAGINE approach [5], an analysis approach from the domain of sustainable development, to a software-intensive system that exhibits a significant impact on the sustainability of city mobility. It has been adapted to include the role of technology into the analysis, and to inspect in depth the rationale, drivers and impact of the planned solution. It can be applied from the early phases of idea definition up to project finalisation, production and maintenance.

II. Background: IMAGINE and DriveNow

This section gives a short introduction to the IMAGINE approach and background on the DriveNow case study.

A. The IMAGINE Approach

The IMAGINE approach [5] originates from the environmental studies field and applies systems thinking principles [6].

It was designed to guarantee the cooperation of users, experts in all levels, performers and public representatives, through the identification and understanding of problems of sustainable development, definition of optimal indicators to measure success, and to develop on decisions about further development, to conclude with the activities for achieving the desired scenarios.

Thus the application of IMAGINE involves the use of participatory techniques, the inclusion of varied groups of stakeholders, the identification of meaningful and relevant indicators for the groups, and the use of scenarios for current and future states. This enables the tracking of the evolutionary behavior, the recognition of deviations from the goal to apply timely corrections. It has only been applied so far in environmental systems.

The IMAGINE approach is carried out in five steps:

1) Understanding the context: identify the stakeholders, their perspectives, and scope the system to be assessed.
2) Agreeing on Sustainability Indicators (SI) and bands of equilibrium: identify relevant indicators for each group of stakeholders, agree in a common set for the whole system, and establish reference boundaries within which each SI remains sustainable.
3) AMOEBA scenario making: develop the desired future situations of the system in terms of the selected SI to measure and depict it in an AMOEBA diagram.
4) Review and Metascenario making: review the status of the system conducting the whole process again and contrasting the scenarios and diagrams over time.
5) Publicity and Marketing the message: end of an Imagine iteration where the outcomes are publicized among potential consumers of the information.

For each one of the steps a variety of instruments to ease the adoption in companies is available in [14], for example: Controlling, Corporate Social Accounting, Corporate Volunteering, Cross-impact analysis, Dialog instruments, Eco-design/Design for environment, Environmental Shareholder Value, Mission Statement, Reporting, Scenario analysis, Supply Change Management, Sustainability Balanced Scorecard, and Total Quality Environmental Management.

B. The DriveNow Case Study

Our industrial case study is developed for a car sharing system deployed in 2011 in three major German cities by BMW, Mini, and Sixt in a 50%-50% venture. The project concept was designed to provide new mobility services that are individually attractive and socially sustainable.

The business model of DriveNow presents the rent of premium vehicles for a short period of time within the city using public parking areas inside an established perimeter without incurring in additional parking costs.

We chose DriveNow for our case study as it is been marketed as a positive contributor towards sustainability and environmental protection. Among their main goals are the reduction of CO2-emissions by: replacing old private cars for new shared cars, integrating new technologies and introducing electronic cars, and reducing the number of cars with only one passenger by encouraging car pooling.

The project involves automobiles and technology for efficiency, care-hire know-how, IT systems and a comprehensive customer registration and interaction network. The whole lifecycle is highly dependent on technology, from the development of the equipment and software, the infrastructure, disposition and maintenance of registration, authentication and interaction platforms between the provider, partners, users and members of the community, and the creation of startups extending the service.

The initial idea of modern mobility services was integrated with environmental focuses, engaging the project in sustainability initiatives.

C. Outline

The remainder of this paper describes the application of the IMAGINE steps for the case study of the DriveNow system. Section III describes how the system of interest is scoped, Section IV presents the process of selection of sustainability indicators (SIs) and definition of bands of equilibrium for these indicators, Section V explains the development of future scenarios and the AMOEBA diagram, Section VI discusses some open issues and limitations. Section VII concludes with open issues and suggestions for future work.

III. Understanding the Context

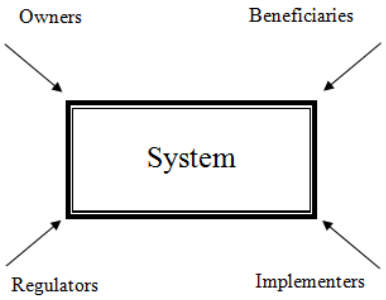

Fig. 1. System and Stakeholders, acc. to [5]

The assessment begins with the comprehension and delimitation of the system or project of interest, and the context where it is applied. This first step is crucial to obtain a well defined problem and a precondition for a successful assessment.

A. Stakeholder Perspectives

The system of interest is scoped from four main perspectives as illustrated in Fig. 1, by directly gathering information from relevant stakeholders and available documentation. The four perspectives are formed by individual representatives of stakeholders under the roles of owners (customers), implementers (developers), beneficiaries (users), and regulators (government, legislation).

Figure 2 shows the results of the stakeholder analysis for all four perspectives in DriveNow. The owners are BMW, Sixt, and Stattauto, and the regulators are the government, certifying organizations, and controlling agencies like the police. The beneficiaries are the drivers, the community, and friends, and the implementers include the whole development process as well as marketing and additional service providers.

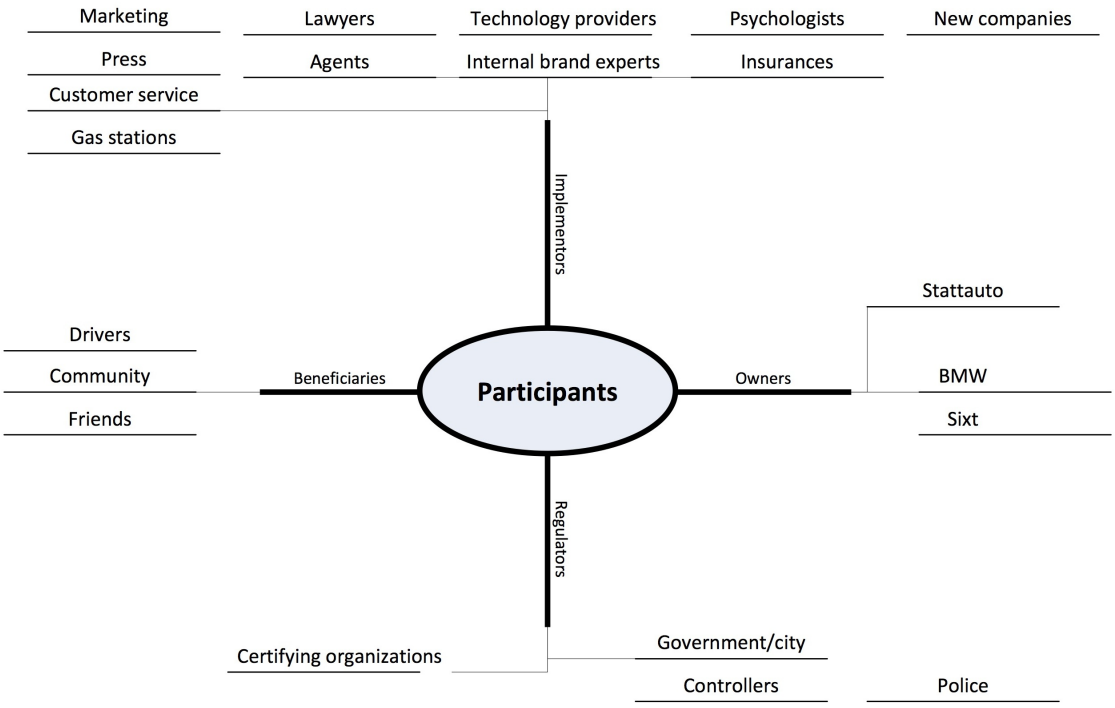

Fig. 2. Participants and Root Definitions in DriveNow

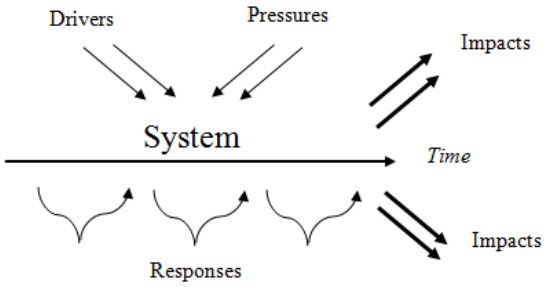

Fig. 3. DPSIR approach, acc. to [5]

B. Driver-Pressure-State-Impact-Response Approach

The information can be gathered by any participatory technique, using the Driver-Pressure-State-Impact-Response (DPSIR) approach [4] shown in Fig. 3. The DPSIR seeks to identify the Drivers to design the system, the Pressures to use unsustainable products or practices, what aspects of the current State might seem affected by the introduction of the system, which Impact and level of severity is expected, and what are the Responses of the environment and users to the system regarding sustainability. The most common technique in the early steps of the analysis are structured interviews. As major result after the consolidation of the interview data, the main objectives of the system and the assumptions made are identified and concisely stated. A graphical overview of the DPSIR analysis approach is provided in Fig. 4. For the complete set of DPSIR indicators in DriveNow, see [13, p. 25-29].

C. Root Definitions

For a succinct statement of the result we use Root Definitions. A Root Definition is a structured description of a system and a clear statement of activities which (might) take place in the context of our system. A properly structured root definition comprises three elements: *W*hat the aim of the system is, *H*ow that aim is to be achieved, and wh*Y* the activity is carried out w.r.t. a long-term aim. This is stated as "A System to do *W*, by means of *H*, in order to achieve *Y*".

The root definitions elaborated for DriveNow were:

1) The Car Sharing Project focused on private users that do not own a car, and realized by the implementers, in order to establish the brand as a mobility service provider, while removing old cars from the streets, assuming behavioral patterns, government support and managing feasibility, capacity of production, offer and demand, prices and easiness of use.
2) The Car Sharing Project focused on offering community members that do not own a car, in order to provide a support and convenience when needing a car for occasional use, while involving them into the membership and

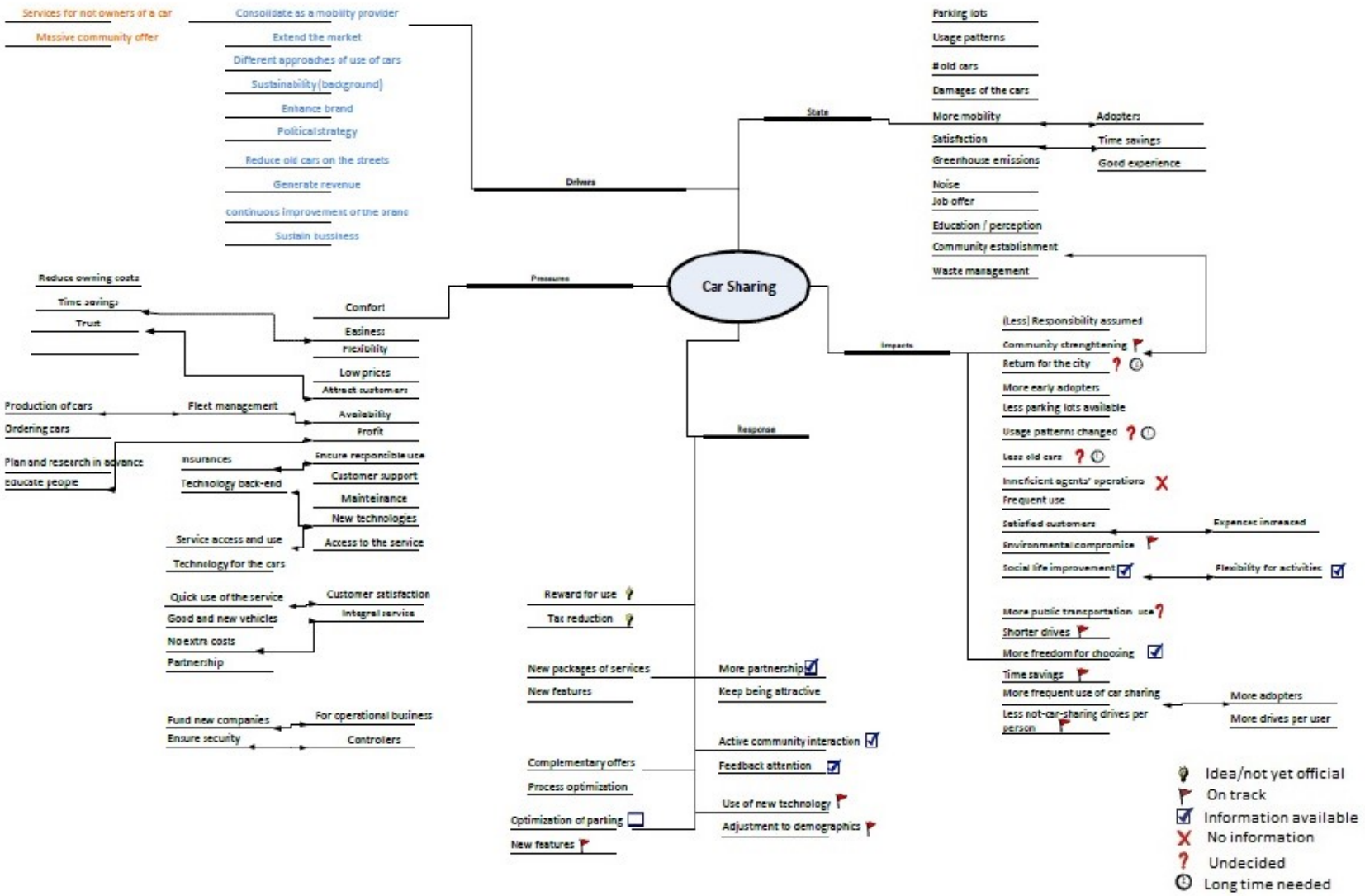

Fig. 4. DPSIR indicators in DriveNow

maintaining the initiative sustainable without profiting, assuming behavioral patterns, government support and managing prices and schedules of use.

D. Data Collection in Interviews

The interviews to collect the information in our case study were conducted with three representatives for the groups of Owners, Beneficiaries and Regulators. The implementers' point of view was partially covered by the representative of the owners. Once the system and context are clearly defined, the next step is the selection of reference measures and the establishment of sustainability criteria for each one of them.

The full documentation of the case study is accessible as Technical Report [13].

IV. Agreeing on Sustainability Indicators and Bands of Equilibrium

Group	Theme	Subtheme	Indicator
Social	Equity	Poverty	Percent of Population
			Living below Poverty Line
			Gini Index of Income Inequality
			Unemployment Rate
		Gender Equality	Ratio of Average Female Wage to Male Wag
	Health		
	Population		

Fig. 5. Sustainability Indicator Catalogue (Excerpt)

Topic	Subtopic	Indicator
Environmental	Conservation and efficiency	Energy consumed
Social	Transportation	Duration of peak periods
Economic	Business & Economics	Supply/demand balance (saturation)
Human	Mobility	Active transportation use
Technology	Green IT	Green Technology availability

Fig. 6. Identified Topics in DriveNow (Excerpt)

There is no general consensus on the concept of sustainability; the definition of sustainability varies from company to company and from person to person, i.e. a precise conception of sustainability varies depending upon who is using it and in which context [5, p. 28]. Hence flexibility on the selection of important measurements is needed, without losing standardization and the comparison capability among companies.

A. Catalogue of Sustainability Indicators

A general catalogue of sustainability indicators (SIs) is therefore employed here and only those relevant and suitable for the context are pre-selected. They are prioritized in a subsequent step by simultaneously looking at the priority assigned for each group of stakeholders.

The catalogue is part of our research results and was created based on general indicators and extensions for which we could find official measurement values. The catalogue is structured into groups, with corresponding standard themes, sub-themes, a list and a description of each indicator; Fig. 5 shows a fragment. For the full catalogue, please refer to [13].

B. Prioritization of Concerns

The final selection of SIs from the set of pre-selected ones is performed by a multi-dimensional stakeholder prioritization of concerns, here the most relevant SIs for each stakeholder are contrasted with the other stakeholders. The contrast is graphically depicted in a 2x2 matrix were each SI is assigned a point in the grid according to the relevance for each pair of stakeholders.

Next, the SIs are grouped into topics, subtopics and finally listed individually. Our extension takes as basis the three dimensions of the Triple Bottom Line, respectively the Environmental, Social, and Economic perspective as topics, and adds two more, namely the Human and Technology dimensions. The Human dimension associates the SIs pertinent to individuals, contrary to the social dimension that refers to the society collectively. The Technology dimension makes reference to the technological infrastructure supporting the different tasks over the lifecycle, as well as technology capacity limits, availability and access to technology based on demographics, extension and integration of additional services, and communication mechanisms enabled by technology. The structure is, hence, based on the five topics of our extended approach, i.e. environmental, social, economic, human and technology, each with subtopics and a list of selected SIs to be measured.

C. Bands of Equilibrium

With the priority SIs selected, we define a band of equilibrium describing the boundaries within which our SIs values must stay. This band is determined according to the selected measurement unit and method, and is given by two values, one for the minimum value our SI can have such that it is still sustainable (any value lying below is unsustainable by lack), a second value for the maximum value of our SI to still be sustainable (consequently, any value above is unsustainable by excess).

For DriveNow, a general catalogue of SI indicators was developed, and a sub-set of them was selected and structured based on the information gathered in the previous step [13, p. 37-47]. The bands of equilibrium were defined using values found in standards, regulations and publications, applicable to the DriveNow project.

At this point we have the foundations for the elicitation of current and future scenarios. The next step evaluates the weaknesses and strengths of the current status of the system, the potential for improvement of particular SIs, as well as the overall improvement. It also gives a suggestion on the prioritised corrective actions to take.

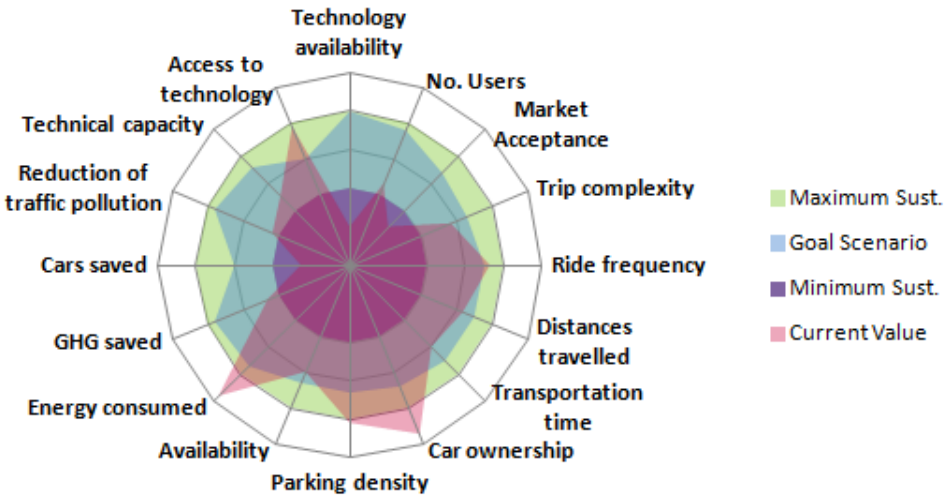

Fig. 7. Current and Goal Scenarios of DriveNow

V. AMOEBA AND SCENARIO MAKING

In this third step we start with the current situation appraisal of the system and the definition of the future scenarios we want to attain with the time. A consolidation of the previous conducted steps can be summarized in the future scenarios and AMOEBA diagram. By obtaining a current measure of the system for each SI, and defining the values we ideally expect to reach at different future points in time, we obtain the current and goal values for each scenario. For simplicity in this paper we only consider one future scenario, therefore only a goal value.

A. Data Collection for Values

The current and goal values for each SI were obtained from official concept descriptions, sustainability reports, press publications, public statistical data from the city and government, market analyses, and other documentation. The measurement data from all sources were obtained by experts in the field, in some cases with the aid of specialized equipment (e.g. sensors measuring air pollution) and in general being reliable data.

B. Future Scenarios

The scenarios are depicted considering the four values determined for each one of the priority SIs, the two values of the band of equilibrium established in (Step 2), the value of the current measurement and the value for the goal in the future, all four for one scenario. These are plotted in an AMOEBA diagram, for each defined future scenario, see Fig. 7.

The graphical representation of the future scenarios in an AMOEBA diagram enables the visual identification of SIs that are lying outside the band of equilibrium either by exceeding the maximum sustainable, or by not reaching the minimum sustainable limit, and those SIs closer or further from the goal value. By overlapping these four scenarios global insights can be gained about the system, its sustainability level, its weaknesses and strengths. An AMOEBA with too many 'teeth' will indicate several weaknesses on particular SIs in comparison to the level of the other SIs, on the contrary a more circular amoeba is an indication of equally evolved SIs as far as they lie within the band of equilibrium.

The primary corrective actions must be those that accomplish a sustainable and effective positive reaction without negative effects, such that a more sustainable current situation of the system can be achieved in a short time. A more sustainable situation is characterized by an AMOEBA diagram where no SI lies outside boundaries, and ideally all of them are close to the goal value.

C. Analysis According to Sustainability Dimensions

An additional element of the assessment is the balance of SIs belonging to each one of the five topics of our approach, see Fig. 8. The amount of SIs belonging to a certain topic are grouped together, plotted and the whole topic highlighted, building a color coding of five shades.

In the AMOEBA, we can observe the general balance of the system, depicting the priority SIs for multiple stakeholders in parallel. In our example (see Fig. 7) a shadow color is assigned to each dimension (environmental, economic, social, human, and technology), the SIs belonging are plotted close to each other, and then highlighted with a triangular surface.

D. Current Challenges in DriveNow

For readability, only a sub-set of indicators was selected for the AMOEBA diagrams presented here. Since the project was launched only one year ago, some SI values are undefined or did not change with respect to the initial scenario. However, Fig. 8 clearly depicts the challenges that DriveNow is currently facing:

- With regard to the environmental aspect, the number of cars that could be saved still has to increase.
- In the technological sector, there are some availability issues for system improvements that have yet to be solved.

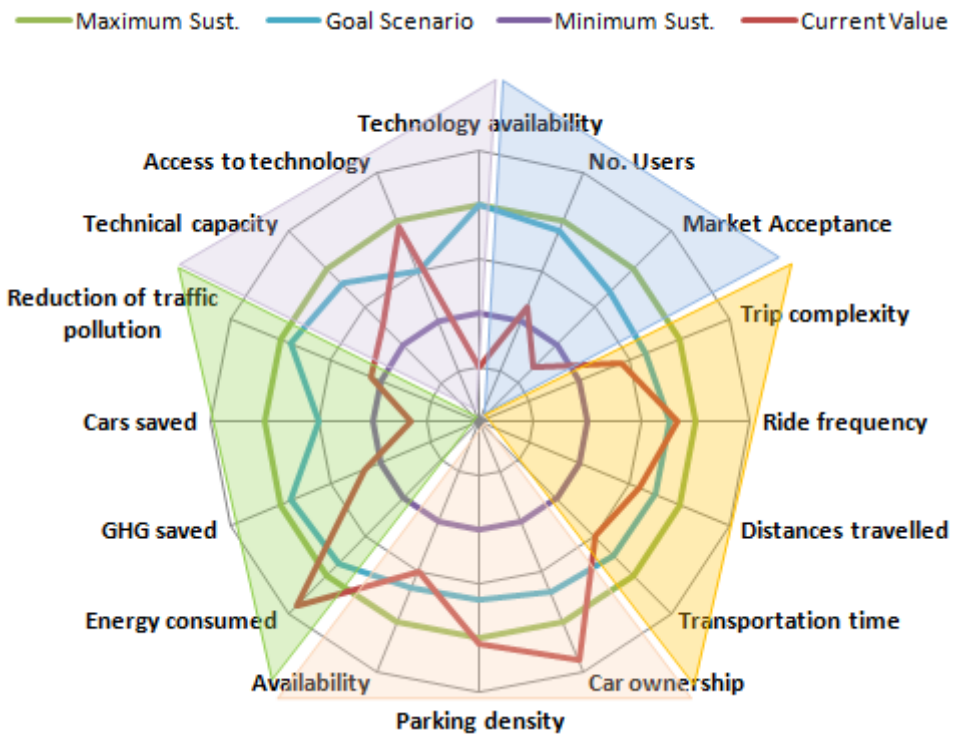

Fig. 8. Amoeba diagram for DriveNow

- For the economic perspective, the market acceptance is currently too low and needs to be improved.

As the analysis can only provide insights into misalignments with goals, the respective actions to be taken to solve the challenges are subject to individual efforts at BMW and Sixt, but we could provide them with a concise overview of the current status of the project with regard to the sustainability dimensions.

VI. Discussion

We are aware that the application of the IMAGINE approach [5] in this setting is not in an application domain originally intended by its inventor. This research had the goal to investigate the applicability and usefulness of an approach from within classical sustainability research to requirements engineering for software-intensive systems.

A. Informal Evaluation

There is no formal evaluation possible as there is no data officially available that would have all the information gathered using the IMAGINE approach. However, the feedback by our industrial partner indicated that the analysis results included not only a summary of the information they had originally elaborated when gathering scope and requirements of the project, but also held some new aspects due to its completeness and integrity.

B. Assessment of the AMOEBA Diagrams

From the AMOEBA diagram we can determine where flaws occur, distinguish the issue areas, and draw some conclusions about the corrective actions. Further investigation and feasibility analysis can be performed to ensure that sufficiently informed decisions are made.

A sustainable system in the AMOEBA diagram should have all the colors in an equal proportion. Whenever a topic is left unattended, this is an indication for the inclusion of additional SIs in that specific topic, it is mainly achieved through strategy revision and sensibilization. The topics with a high proportion of unsustainable SIs in the current scenario implicitly advise future steps to achieve the desired scenario and the main points to invest.

After some corrective actions have been applied and a reasonable time has passed, new data must be collected, and the results of the whole process must be revised and adjusted.

C. Assessment of the DriveNow Case

The DriveNow project was originally designed to encompass mainly economic and social aspects. The introduction of the environmental facet has not shown positive results yet, since it takes long time to exhibit changes. Moreover, the results have been affected by the plan of future important contributions to the environment as is the introduction of electronic cars. The assessment presented a current overview of the project, revealed relevant faults regarding environment, the achievement of goals, and promising results with respect to

the social and economic aspects. It provides a basis for review and forthcoming analyses.

VII. Conclusion

The extension of the IMAGINE approach, an encompassing analysis approach from the sustainability science domain, has been successfully applied in an industrial case study with a system that has been online for a year, supported by IT and with a focus on sustainability in its roots. The developed indicator catalogue is available for use in other assessments in related application areas.

A. Summary

The first two steps are mainly used to scope the right problem and the participation of several stakeholders from each group enriches the result. The third step provides succinct information and an overview of the current system status, as well as it provides insights and indications of strengths, weaknesses and potential for improvement. The fourth step is there to enable flexibility and make possible an evolutionary assessment over time. This information can later be used for informed and precise decision making relating to sustainability matters.

B. Benefits

Our experience with the IMAGINE approach with regard to requirements engineering practices exhibits improvements in the elicitation process. The identification of stakeholders in different areas and at different hierarchy levels, including government and certifying organizations, sustainability experts, potential and real partners, as well as market factors, endorsed the balance regarding prioritization and completeness of the elicited requirements.

The formulation of root definitions helped to state purposes clearly and to define a more sharp scope. The SIs help to state finer measurable objectives, as well as to convey long and short term goals. The AMOEBA diagrams depict information of different scenarios in a manageable and compact way, understandable for the participants, and useful for the assessment over time. The flexibility of the approach regarding the instruments that can be used in the different business areas eases and assist the adoption into companies.

C. Assessment

The take-away message is that it is worth looking over the rim of one's teacup and evaluate the use of techniques of related domains in a different setting. It is unlikely that approaches are applicable one-to-one, but it is very likely that it can be adapted in a way that contributes more than developing new techniques from scratch. In the case at hand, the study brought new insights for the system and a means to perform an encompassing analysis that will be reused in the future evolution of the project.

D. Future Work

We intend to develop a toolset to support the usage of the IMAGINE approach, which eases the current and historic information management for a system under consideration, and the review step in posterior revisions. This work can be integrated to be part of a broader sustainability quality model and established as a state of the practice standard for assessing sustainability in any context.

Acknowledgment

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