Design of IT structures in vaguely defined application environments - Experiences from actor interaction in the blue bioeconomy

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Abstract: This contribution focuses at appropriate IT structures for innovative market segments which form an application environment that is only fundamentally defined in digitization efforts. The core feature are vague application profiles for IT structures to be set up, which players in such market segments can use internally, but especially in environmental and social interaction. For the example of the emerging blue bioeconomy, experiences in setting up a cross-location, distributed IT structure are presented, which is geared towards advising and supporting actors in the blue bioeconomy by a diverse team of experts. Key findings lie in (i) the need to integrate different dimensions of vagueness in the treatment of increasingly defined information in a three-layer model of the IT structure, (ii) the development of the IT structure in an open process that takes into account the dynamics of the market sector, and (iii) the constant training of the members of the expert team on content, routines and limitations of the IT structure in consulting of actors.

Keywords: Vague Data, Digitalization, Distributed Systems, Decision Support, Co-Creation.

1 Introduction

Adequate and efficient IT structures must be adapted to an application environment with its specific actors. This paper aims at providing an example and more generic insights into foundations for needs-based use, but also for the development of such, consistently heterogeneous IT structures [ShPA21].

Ideally, the design of appropriate IT structures should be carried out together with stakeholders. This actor-inclusive approach offers decisive advantages due to various aspects (e.g. [KaKK19], [PWGK20]). Cost reasons, the provision of hardware and software adapted to requirements and the fastest possible operational capability, but above all full controllability and usability for actors, whether individually or in cooperative situations, are central target criteria.

A critical challenge in design is that the respective social processes with their ecological,

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operational and also social implications have a requirement for the design of the IT structure due to their properties. It must be able to deal with often fuzzy information and a dynamic socio-ecological context. These vague application environments do not allow a short-term solution to a known, well-defined need of a rather limited user group or narrow field of application. Rather, an IT structure must be set up that reacts adaptively to changes in the longer term and supports the design of change processes.

The currently establishing market environment of the blue bioeconomy (BB) is one such application environment. This market environment covers the production of biomass in aquatic systems on land and in the sea and its further use for products and services. Players in this market segment are linked to society in a variety of ways, e.g. in production at natural locations or technical systems in the environment, such as through approval, control and sales. One component of the digitization efforts in the BB is the support of individuals and institutions in the course of establishing companies and entrepreneurial processes. Appropriate IT structures must adequately reflect central elements of this socio-ecological context.

This article explains the efforts of actors in the BB to define and build an adapted IT structure. The actors comprise experts from various institutions who have joined forces in an advisory network (AQUATOR). This network supports entrepreneurs and companies in setting up a new business and managing their operations sustainably. From the specific observations and findings, approaches for the definition of general variables for the design, realization and application of IT structures are derived, which are initially vague and only partially defined ready to be differentiated in longer-term practice.

2 Blue bioeconomy as an application environment - Application example AQUATOR

Blue bioeconomy (BB) is a term for the production and use of marine or generally aquatic renewable biological resources (living beings and their products) to provide products, processes and services in all sectors of the economy [ExTW19]. With this goal in mind, developments are taking place worldwide. Business cases emerge in addition to the established economic sectors of fisheries and agriculture, which have also undergone a significant expansion in recent years.

This general context of the BB, with a reference to the situation in Germany, leads to an application environment that is characterized by two crucial features. A first feature relates to maturity of BB as a whole as well as that of the individual products, processes and services. These market building blocks do not yet complement each other to form a tangible economic sector. Another feature is the situation of companies. Many companies are in a start-up or early founding phase. Additionally, BB has achieved less market significance in Germany than in many other countries worldwide or in Europe. Networks for the exchange of information between the actors of the companies, for

example for the optimisation of operational management, standardisation or positioning of BB in the entire economic environment, exist only to a very limited extent.

One step towards optimising these problems would be a contact point for all BB stakeholders to advise, support and evaluate in all phases of business start-up and management. Such a contact point named AQUATOR is being set up within the framework of the Innovation Space Bioeconomy at Marine Sites (BaMS). The BaMS initiative, funded by the German Federal Government, deals with the utilization of aquatic potentials and their use in business cascades and cycles [Bioö00]. AQUATOR is a team of experts who cover various decisive areas of competence at BB, such as licensing issues, corporate governance, environmental assessment, market penetration, animal welfare and quality assurance. These experts are geographically located in the Federal States of Schleswig-Holstein and Lower Saxony and are active in research institutions, companies or affiliated with public authorities. Users of the team are spread over the entire northern German region.

With a view to setting up a specific IT structure, the needs of this diverse, distributed AQUATOR team for various tasks in consulting and supporting BB actors in all phases of a company provide the use case. Since the BB as well as the AQUATOR itself are in an establishment phase, only early steps of the definition and design of the IT structure can be presented here. By working with currently more than 30 users of the AQUATOR, who represent three reference systems, start-ups and companies as persons, the IT structure and its use has developed in the project from the beginning of 2021 to spring 2023. A couple of milestones mark the respective process as follows.

(i) Working groups at Oldenburg and Lübeck initially pursued a data-driven approach for data-collection, stirred by usage in environmental assessment according to DIN 14044 [Dine21] among others. Hard and soft data are stored and later processed in established IT applications (i.e., Umberto, MCDA-PROMETHEE). To reduce redundant retrieval of data at the advisory and support level required datatypes were compared and later grouped according to international standards such as United Nations International Standard Industrial Classification of all economic activities (ISIC) [Unit08].

(ii) Due to diversity of data and foreseeable technologies a single centralized solution to capture all information does not seem realistic. Considering the resources needed to create an entity relationship model respecting the resulting variation of data types (texts, numbers including units, process images and data) the idea of a database was disregarded. It was agreed to document and administer the subject-specific information in a distributed but coordinated manner.

(iii) The preliminary data sheet on environmental data was revised and modified based on Finkbeiner [FKOS03] to reduce complexity for direct application in contact with external users. Templates were created in Excel both for the structured recording of hard data and soft data.

(iv) In 2022, Blue.HQ was released for the usage by all BaMS projects and partners in

full. This contains a Nextcloud based blue.cloud enabling users asynchronous processing and delivery of documents, data, information and workflows. It was decided by the AQUATOR team to integrate it into the project infrastructure and processes.

(v) A general introduction and regular reoccurring 15-minute training units on the cloud system were offered within the team to enhance accessibility and participation.

(vi) To standardize workflows and management of data, especially originating from the consultancy level, a small working group was set up aiming to consolidate the AQUATOR and the resulting network of AQUATOR members, affiliated experts and institutions with their respective technical expertise.

The layers and corresponding file formats at the present stage used in the project are summarized in Table 1.

Type of information	Data and information layer	Analysis and evaluation layer	Consulting and support layer
Communication and documentation	.docx, .eml, .md	.pdf	.docx, .pdf, .eml, .pptx
Measurement values and numeric data	.xlsx, .csv	.xlsx, .csv	.xlsx, .csv
Images and videos	.mp3, .mp4, .png, .jpg		.png, .jpg
Modeling and analysis		.vpg, .umberto	

Tab. 1: The layers according to Fig. 1 at which information plays a role and corresponding file formats used in the AQUATOR.

Several experiences resulted from the process so far. Decisive for the process are the following aspects in particular:

(i) In consulting activities, users out of three reference systems and 16 start-ups were provided with the coordinated data collection forms. These were often returned incompletely or information as transmitted in other forms. This led to increased vagueness in the data due to inconclusive knowledge. Project staff then extracted the majority of information from personal conversations, e-mail texts and supplementary documents and further processed for modelling tasks. Plausibility checks on the information provided as part of the modeling process resulted in new inquiries on data.

(ii) Soft data was directly transferred to data entry sheets, based on templates, when generated in interviews and accompanying processes by project staff. A different approach to the scope and level of detail of the contributions can be observed. In interviews with appropriate guidelines, the form and sequence of data collection are structured, and the content of the answers varies through the process of interpretation by the interlocutors. Impacting the later evaluation in example are the different meanings by the respondents assigned to topics blocks and questions.

(iii) Involving the toxicology project members in the data collection process revealed overlapping information content. The toxicological assessments require information on regulations of individual branches of industry (e.g. food, animal feed, cosmetics) as well as data on substance groups. Measurement data is generated in pollutant analysis and can be included in environmental assessment issues with regard to energy and mass flows that occur.

(iv) Data protection turned out to be a critical aspect in the consultation process and general unrestricted access is not advised. This reinforced the previous decision against a centralized solution, especially considering the available project-resources.

(v) The supported companies show a wide range of applications and issues. The topics vary from aquaculture, further food production, clothing or robotics applications and services in raw material or environmental management. This diversity and the stages of companies ranging from start-ups to established small and medium-sized enterprises posed an additional challenge in support-level and data-collection. Difficulties in data-transfer even occur in similar undertakings such as aquaculture facilities. It can be found that operators may choose different technical or operational approaches at process level even within a single company. The previous points thus illustrate the increased vagueness both due to non-conclusively defined data in the BB environment under consideration and with regard to their transferability.

At the same time, two further needs for development and implementation work of the AQUATOR IT structure have emerged. (i) For targeted user-related work at the integrating support and advisory level, further improvements must be available in the direction of work-flow and materials for the initial consultation of companies and are currently developed. These materials are to standardize the teams of experts' support level activity with their corresponding companies. In this context, (ii) the creation of an improved overview of the network of experts associated with the AQUATOR team is required. This has shown how important information on their competencies and specific environment is for better involvement of this group of people in the advice and support of the user actors.

3 Vague data in a vague application environment

The greatest challenges in the experienced development of an application environment for a distributed team of experts and consultants within the fields of BB are based on the nature of the data available and to be processed as well as in their vague - since neither general nor concretely to be defined - requirements. A wide variety of data is available from the areas of operation, market, society and the environment, which are used for consulting business start-ups and management in the field of BB. These different types of data differ fundamentally both in terms of quality and in their general type and nature resulting in special challenges for an application that supports the team of experts and

consultants. These generic challenges comprise four dimensions.

Hard and soft data - To be able to get a comprehensive overview of a company's boundary and framework conditions in the BB the team of experts and consultants needs to be able to access a large amount of distributed data of different nature. When defining a possible application environment it quickly becomes clear that there are two different categories of data to deal with whose processing and linking is technically possible, but semantically rarely leads to meaningful results.

On the one hand, there is "hard" data from the areas of operation, market and the environment. Their collection and processing are usually clearly defined, tested and reproducible, so an interpretation of the data and the results leaves only little leeway. On the other hand, there is "soft" data from the field of society, whose collection and processing are usually less clearly defined, tested and reproducible.

In the case of "hard" data a simple measuring device might be sufficient to obtain clearly defined and reproducible data, which can be interpreted according to clear rules and further processed with other "hard" data. But in the case of "soft" data, the type and execution of their collection usually has a profound influence on the results of the data. The attempt to transform the collected "soft" data into a similar or compatible format of the "hard" data is usually done by categorizing or scaling answers in questionnaires. However, the specification of these categories and scales as answer options has already an interpretative, selective and drastic influence on the answers given. For example, when querying "acceptance", the specification of the answer options – both linguistically, such as "acceptable", "less acceptable" and "not at all acceptable", and numerically, such as "on a scale of 1-10" – has a decisive impact on the result of the survey and thus on the data obtained. In order to minimize such influences on the later data quality the answers should be recorded as free text. A subsequent classification of answers in free text into categories or their mapping on a scale is also subject to an interpretive and selective influence. So it should always be taken into account that these data are always interpretations.

Regardless of how the answers are recorded as free text or predefined categories and scales, it should also always be taken into account that the formulation of a question and the context within a questionnaire can have a strong influence on the respondents' answers. Finally, the reproducibility of the collected data is also not reliable, since a repetition of the same survey with the same group of people at a different time can produce very different results.

Non-finally defined data - Another challenge for the team of experts and consultants is the rapidly developing and changing corporate world in BB, which is directly reflected in an unfinished application environment. A high degree of new technologies and continuous optimizations in already known processes and procedures quickly result in outdated and thus only partially meaningful data and process mappings. So ideally an application environment for consulting on business start-ups and management must react

and be adapted just as quickly to these changed and improved conditions. Nevertheless, the application environment will always have to work with data that is not sufficiently up-to-date or accurate – and thus vague – and, above all, does not sufficiently reflect the corporate structure and environment. Therefore, it must be able to grow and expand in a timely manner according to its requirements and will never be completed in this sense.

Non-exhaustive knowledge - Directly from the previous point arises the problem of inconclusive knowledge and incomplete data directly associated with it. In most cases, these data gaps are identified and closed by calculations with preliminary and insufficiently validated and confirmed models, which, on the one hand, results in different data for one and the same question depending on the model, and on the other hand, it knowingly works with possibly erroneous data. Either way, this results in a certain uncertainty - and thus vagueness - in the data used. This uncertainty is continuously reduced by the learning process, both individually in the companies and across companies in BB.

Portability of the data - Another important point is the knowledge of the high operational diversity in the BB. This is not solely based on the different sizes of the companies or the different products and services they create and offer. Rather, different companies of the same size with similar products and services pursue very different approaches to procedures, reflected in very different process and supply and material flow chains. This directly results in a high heterogeneity of the use cases, which in turn has a direct influence on the transferability of the existing data to the circumstances of the company to be advised.

In addition to these differently chosen approaches to corporate management, there are also the different local conditions, which have an influence on the overall view of a company and thus its advice at different levels. In addition to economic (e.g. energy prices, subsidies), logistical (proximity and connections to suppliers and customers) and ecological (e.g. restrictions and requirements to be met) aspects, it is particularly the social factors (such as acceptance) whose transferability of the data is the lowest.

4 Methodology - IT Structure in the blue bioeconomy application context

Based on the application environments and data quality described above, the scientific task in a transdisciplinary approach is to develop and reflect on a design profile for a possible IT structure, which makes it possible to process or intersect a wide variety of information from the areas of environment, market or society and operation in the BB.

Thus, in accordance with legal requirements in the field of environment, information from the areas of operational environmental processes, ecological processes, environmental and ecosystems including toxicology, nutrients, organisms and their communities or physiology will or must be incorporated into the evaluation processes. In

addition to possible subsidies and regulations, buyer behaviour and acceptance of the company and its products also play a decisive role in advising and evaluating the market and society. And finally, information from the area of operations on the topics of financing and revenues, technology, personnel and the supply chain must also be taken into account.

In AQUATOR, the accumulated knowledge of a team of experts and consultants is to be used via an application in order to be able to offer advice, support and evaluation for business start-ups and management in the BB. Since the individual members of this team are distributed across different departments, both spatially and in terms of content, the data available to the individual members is to be collected and managed in a decentralized manner and on site in databases. These databases should serve as the basis for the actual application as a platform and be able to be integrated via APIs and decentralized access management as required. By using a platform with several local data sources, the effects of the "non-conclusively defined data" from above is counteracted as effectively as possible. Likewise, this approach is more useful for the individual members of this team of experts and consultants, as they can more easily adapt their own database and integrate it into other applications, which usually translates into a higher motivation to maintain the database and thus results in better, more accurate and more up-to-date data sets.

Following the classic three-tier architecture [Ecke95] the following layers result in the application environment under consideration:

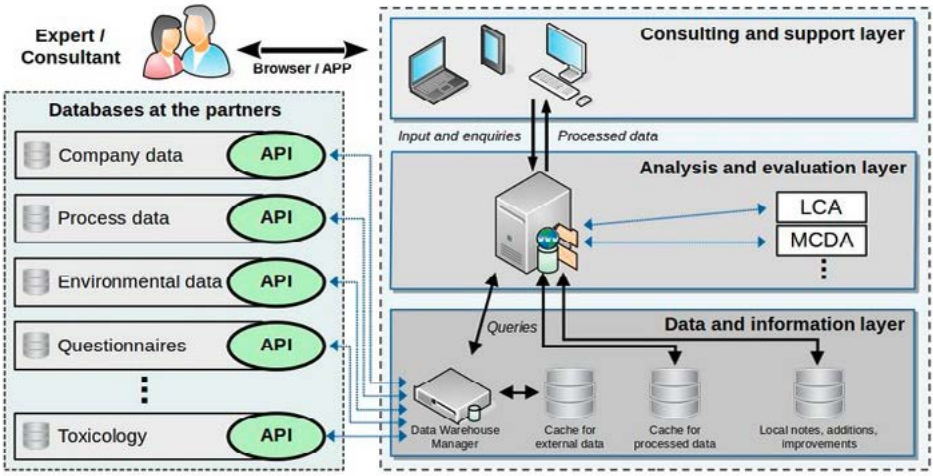

Fig. 1: Design profile of a possible IT structure for a platform for consulting by experts in the field of blue bioeconomy, based on the classic three-tier architecture.

Data and information layer (data storage and access tier) - In this layer the requests are received and passed to the external databases via API. The data received in response is passed on to the analysis and evaluation layer for further processing. In addition to a classic local cache memory, which caches the data obtained via the API, other data generated during processing in the analysis and evaluation layer is stored in a database in this layer. In addition, the comments and improvements as well as additions noted by the user in the consulting and support layer are stored here. Since the "soft" data in particular is always subject to a high interpretative influence, a correction of data on external data sources via the API is deliberately avoided in order to always be able to find an "unadulterated" data set.

Analysis and evaluation layer (business rules tier) - In this layer the inquiries from the consulting and support layer are received and processed. If necessary, requests are sent to the data and information layer and data is received from it for processing. Depending on whether this data is already available in processed form or not, further more complex processing is also carried out here, primarily from the areas of life cycle assessment (LCA) and multi-criteria planning and decision support (MCDA). This is where it is defined which data is to be requested and processed in order to provide the team of experts and consultants with the necessary information during consulting, support and evaluation.

As described above, the results of data processing are influenced and falsified by both "non-finally defined data" and "non-exhaustive knowledge" resulting in an unfinished application environment. Improving the data quality can only be achieved by continuously adapting, improving and expanding the data processing in this layer.

Consulting and support layer (presentation tier) - The actual interaction with the user takes place via the consulting and support layer. All relevant data of a company to be advised is recorded and passed on to the analysis and evaluation layer. Likewise, the results of the analysis and evaluation layer are presented to the user for evaluation.

At this layer, all four of the above effects of vague data show up. At this point, not only a simple presentation of the results should take place, but rather the user should be helped to recognize these effects and thus avoid possible errors in the evaluation. Therefore, it is important to provide the user with the methods used in data collection and processing in addition to the results. Particularly in the case of the more "soft" data, access to the raw data – usually as formulated questions and answers in a questionnaire or interview – must be made available and thus enable a new interpretation of these. Ideally, these new interpretations should be stored in the data and information layer in a well documented manner so it can be taken into account in future consultations.

The incorporation and appropriate representation of these vagueness in the interface of the application is largely responsible for a comprehensive recording of the circumstances by the user and thus responsible for the success in consulting, support and evaluation in a company start-up and management.

5 Insights and reflection

The discussions during the planning of an adequate IT structure for a successful support of a team of experts in consulting, support and evaluation in the start-up and management in the BB, it was quickly recognized that the greatest challenges due to the use of vague data lie in an equally vague application environment. The development and implementation of such a IT structure would be a diligent work and its generated results would usually be unambiguous if (i) only data were used, which are usually clearly defined, tested and reproducible, and (ii) the application environment is not or little changeable. This explicitly does not apply to the use case under consideration. Rather, diverse vagueness is characteristic of the BB market segment and its players. The interaction with these actors is therefore even more demanding at the advisory and support level in the decision-making process than, for example, with actors from other fields of social cooperation and development such as the bioenergy environment [PWGK20] or climate-adapted water management [KaKK19].

The use of vague data in a weakly differentiated application environment has the consequence that the data is reinterpreted in order to process it more easily and unambiguously, which can lead to greater falsification and misinterpretation of the results. The support of experts in data acquisition, classification and processing in the BB environment with non-conclusively defined data and existing knowledge remains essential and thus automatically leads to a pre-interpretation.

In order for such a pre-interpretation to be recognized, every user must have a sound knowledge of the subject matter and should be given access to the uninterpreted raw data at any time and the general system of a pre-interpretation should be presented in a comprehensible manner. This in-depth understanding is the basis for the successful fulfillment of the role of a knowledge broker, as it is expected as a function by the users of a complex advisory service offered in the BB of AQUATOR (cf. [KaKK19]). However, the use case has shown that in many cases direct access to the raw data must be restricted due to trade secrets or data protection reasons and can at best be made available to a selected group of experts for the respective consulting task. This also leads to the fact that a centralized storage of all raw data and information is not feasible, especially with the available resources.

Comparing the present situation to works on information systems the participation of users plays a key role in the development process [DíMc09],[LeCC22] as well user's training. Both are taking place in the ongoing project while the IS and IT structure is yet in the implementation phase [DíMc09]. Simplicity, transparency, ease of control and robustness are demanded of this group of people. IT-related innovations are clearly taking a back seat as a necessity. Existing standard solutions in the hardware and software area are sufficient to meet previous requirements for an IT structure in the vague BB application environment.

This is combined with an understanding of the IT structure as a kind of service to reduce

redundant queries in the vague application context and to improve networking between experts and provide them with relevant data. Regarding the use case, it can be recommended to use the data and information level for the structured provision of meta-information and, where practical, in alignment with existing recommendations such as the FAIR principles [WDAA16]. The comparison of systematically collected information can thus be carried out in the expert network in coordination with the persons to be advised. The link to databases (e.g. Ecoinvent) is then carried out in the analysis and information level for the specific consulting case through the work of the experts.

The use case shows that the heterogeneity of the BB-specific information exceeds the technical knowledge of each individual member of the addressed group of people. For the use of the IT structure at the consulting and support level, which is crucial for the interaction with user actors, the greatest possible transparency about the location of individual pieces of information and their intersection routines in the analysis is essential. For this reason, the steps of internal training on properties and use s at all three levels of the IT structure are of great importance. This is the only way for participants to recognize the options, functions and limitations of the databases and analysis tools integrated into the IT structure. This knowledge creates competence in interacting with actors and leads to a trusting relationship. At the same time, competence and trust lay the foundations for the next steps in the development of an IT structure in which BB increasingly does justice to the vagueness and dynamics of this application environment. This also implies that the development and meaningful use of such challenging application contexts are always to be understood as a process in which the environment and actors are permanently subject to a dynamic that requires continuous adjustments to IT structures. Fixed IT structures are inapplicable in vague application environments.

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