EuroGEOSS Showcases: Applications Powered by Europe

Deliverable 2.1

Initial model for e-shape co-design

The e-shape project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement 82085

ABSTRACT

This deliverable describes the model of a co-design process adapted to e-shape. Several forms of co-design methods already exist and have been experimented in different fields and contexts. However, in e-shape context, specific challenges need to be addressed, involving both a collaborative challenge (coordination of highly skilled experts in many different fields) and a cognitive challenge (development of innovative services that are both user-driven and generic). To address these issues, an e-shape-specific co-design process needs to be developed. To better understand this process, an analytical framework is introduced and enriched through the analysis of the SoDa service operated in collaboration between ARMINES / Transvalor and the research center Observation, Impacts, Energy (O.I.E.) of MINES ParisTech. In this analytical framework, developing services from Earth Observation is described as building a relationship between data, information and usages. This framework helps us to identify the kinds of actions to be undertaken in order to build EO-based services, that are designing and redesigning over time (1) information which is use-generative (that is having the power of generating multiple usages), (2) data-information relationships and (3) information-usages relationships. By using this framework to represent each pilot's situation, co-design needs of e-shape pilots can be identified. Co-design actions will then be carried out based on this diagnosis. The e-shape co-design model proposed in this deliverable is expected to be updated and completed during the project, especially taking into account the results of future co-design actions.

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1 Introduction

The co-design of showcases and pilots in e-shape implies a dual challenge:

- A collaborative challenge: how to coordinate highly skilled and specialized experts in multiple institutions and fields of expertise (e.g. users, practitioners, developers, scientists, data managers, instruments designers).
- A cognitive challenge: how to bring these experts to propose breakthrough innovative services, with a rigorous exploration of the unknown, without being cognitively "fixed" (Jansson et Smith 1991). More specifically, one of the main challenges is to combine a user-driven approach (that involves many different fields with their own specifics) and a genericity-driven approach (that is building products able to address multiple usages).

This deliverable describes the model of a co-design process adapted to e-shape. This document is organized as follows: a first part makes a state of the art of co-design (existing situations and methods, and critical issues). In a second part, the co-design situation in the context of e-shape is analyzed based on an analytical framework and the history of the SoDa service operated in collaboration between ARMINES / Transvalor and the research center Observation, Impacts, Energy (O.I.E.) of MINES ParisTech. In a subsequent section, perspectives for co-design methods adapted to e-shape are presented.

This "e-shape co-design" model is expected to be updated during the project in an iterative way.

2 State of the art and critical issues in co-design

In its contemporary form, co-design seems to be widely used as a way to better engage different stakeholders in the design process. However, different interpretations of co-design notion exist depending on the disciplines and application fields. To better understand this notion, in this first part, we propose a state of the art of co-design and analyze its critical issues, based on the analytical framework provided by most recent advances in design theory.

2.1 A brief genealogy of the notion of co-design

2.1.1 1970s-1990s: Co-design of embedded systems

The term "co-design" appeared first in the 70s to designate the design of "embedded computer systems", i.e. software that operate in complex systems. According to (De Micheli and Gupta 1997), *"hardware/software co-design means meeting system-level objectives by exploiting the synergism of hardware and software through their concurrent design "* (p. 349).

As underlined by (Dubois 2015) in his in-depth analysis of co-design history, there is a "myth" in this early representation of co-design, just as there is a myth in co-design today. Dubois cites De Micheli and Gupta: *"co-design can lead to products of superior quality (i.e., performance/cost, flexibility) with a shorter design and development time as compared to traditional integrated circuit design methodologies"* (p. 362). And this type of co-design was mainly oriented towards technical software techniques (CAD, integrated simulation software, etc.). Despite limited success and adoption, this first wave of co-design works underlines several issues related to co-design situations:

- Higher integration between heterogenous types of expertise throughout the development process so that design work cannot be divided in a linear or modular way.
- Integrated learning: the authors underline the necessity of "co-simulation" (Wolf 1994). "*Co-simulation usually refers to some sort of mixed hardware-software simulation-for example, one part of the system may be modeled as instructions executing on a CPU while another part may be*

modeled as logic gates." (p. 980). More generally this underlines the necessity to *organize learning* at the crossroad of different types of expertise.

- Co-design situations, at least at this time, could be driven by a shared list of requirements: "*Whereas performance is the most important design criterion for information processing systems, reliability, availability, and safety are extremely important for control systems*" (De Micheli and Gupta 1997).

2.1.2 1990s-2000s: co-design as a relationship between buyers and suppliers

In the end of the 1990s, another stream of work analyzes the relationship between buyers and suppliers. Integrators and suppliers are not only contracting and bargaining on price and logistics conditions but are actually more and more "co-designing". In automotive industry, it is said that Original Equipment Manufacturers (OEMs) and first tier suppliers "co-design" to actually designate situations where OEMs delegate the design of components, modules or systems to their suppliers.

These co-design situations lead to shed light on new critical features:

- Scholars underline the relationship issues: how to contract? How to make sure that the supplier has the required design competences, and also the required co-design competences, meaning the capacity to collaborate in design phases? (Araz and Ozkarahan 2007).
- The co-design goal is usually relatively well-identified by the list of requirements that define the object/service to be developed.
- Interestingly enough, this form of co-design could appear as a form of "dis-integration" of the design of a complex system (by opposition of the co-design of embedded systems). It underlines the fact that co-design is not necessarily an increased integration but, more than that, is **the capacity to organize coordination and division of design work that is adapted to the most complex systems**.

2.1.3 Since 2000s: co-design as user involvement

In the end of the 2000s, co-design is also used to account for designing with users. Scholars in innovation management and design describe planned meeting in which professional designers organize user involvement in the design of new products and services (Le Masson and Magnusson 2005; Magnusson 2003; Sanders 2002; Sanders and Stappers 2008). As explained in (Dubois 2015), the processes rely on tools and techniques such as mental maps, drawings, prototyping, storyboarding, product and use lifecycle. Good practices are described into details in (Sanders and Dandavate 1999; Brandt et al. 2004). And in a review, (Mattelmäki et al. 2011) underlines that the term 'co-design' is quite ambiguous but encompasses the following dimensions of the user-involvement based co-design methods:

- Co-design is *"utilized in design context in which designers are involved and the topic of the activity is related to design exploration, envisioning and solution development"*.
- Co-design has "*an empowering mindset and it gives voice and tools to those who were not traditionally part of design process".*
- Co-design is *"about engagement of potential users but also about stakeholder collaboration"*.
- Co-design includes *"process and tools of collaborative engagement, events for learning and exploration".*

In these cases, we see some new features of co-design situations:

- The innovation issue might be relatively open and exploratory.

- The participants have very heterogenous knowledge and competences (lay user vs professional designers or scientists can participate in co-design workshops).
- The collective logic is extremely loose, compared to the buyer/supplier co-design mentioned above (very limited contractual aspects).

2.1.4 Lessons learned from the genealogy of "co-design" notion

This short genealogy brings critical notions for co-design approaches:

- It is important to **distinguish co-design situations and co-design methods**. There are many different co-design methods and their domains of relevance cannot always cover all co-design situations and co-design needs. As a consequence, there might be co-design situations that require new co-design methods.
- Co-design situations are generally characterized by:
    a. **A need for design** – more or less innovative.
    b. **A need to coordinate very heterogenous actors** – with varied competences, with varied design experiences, …
    c. **The design relationship between these actors has to be re-invented**: in some situations, they never worked together (e.g. user involvement); in other situations, they previously worked together but not in a design regime (e.g. buyer-supplier relationship); and in even other situations they were used to design together but they have to change the way to organize their design collaboration (embedded system co-design).

To deal with these situations, different co-design methods can be implemented. The following section further describes the performance of existing methods.

2.2 Key results on co-design methods (Dubois 2015): limits of 'reactive' co-design, i.e. without knowledge acquisition/creation.

There are few studies on the exact performance and impact of design methods, particularly co-design methods. To bridge the gap between high expectations and occasionally disappointing results, Dubois (2015) systematically studied 22 cases of user-involving co-design situations in five countries - Belgium, Finland, Canada, the Netherlands, France. All cases were systematically conducted according to an explicit, exemplary co-design method. The method consists in involving multiple stakeholders (including users, but also scientists, companies, publics authorities, associations, etc.) in a workshop to work on a common innovation issues (like 'smart city', 'a new university building', etc.).

The results can be summarized as follows:

- *Phenomenon 1:* There are limited results in term of innovation. Note that this phenomenon is not necessarily an issue since, as mentioned above, co-design situations are not necessarily aiming at innovative design.
- *Phenomenon 2:* Participants are usually very satisfied after the first workshop – then they are quickly weary (after a second or third workshop).
- *Phenomenon 3:* There are noticeable results in term of "social transformation": co-design improved both the participants' desire and the ability to work together. The study shows that social relationships often go from poor to positive during workshops.

These results obtained on user-involving co-design methods correspond to empirical research done on supplier-buyer co-design (Zirpoli and Caputo 2002). However, whereas previous studies in innovation management stressed the importance of a strong social structure to be able to innovate, Dubois' results show that **design activity can actually support the *creation* of new social networks**.

Using design theory (Hatchuel and Weil 2009), Dubois (2015) then proposed an explanation of these three phenomena. Participants in the workshop actually share knowledge and explore a shared "desirable unknown" - that is a concept which is unknown and of interest for the participants. Sharing knowledge contributes to the creation of new social relationship; and the "desirable unknown" finally constitutes a "common purpose" for the new community. Hence design theory proposes an explanation for the phenomenon 3. It also contributes to explain phenomena 1 and 2:

- The knowledge involved in the co-design workshop is actually limited to the knowledge that is immediately available when speaking with other participants. Hence co-design process does not enable to learn (participants have no internet access – or they do not have or do not take time to access to external knowledge, or they do not have ways and means to create new knowledge through research and experimentation). Without new knowledge, design theory predicts that the design process will only bring about solutions with a low level of innovation. Hence design theory explains phenomenon 1.
- Participants' satisfaction is mainly related to the fact that they use the knowledge of others and/or others used their knowledge to design a desirable unknown. After several sessions, the participants have finally used all their shared knowledge. Without new knowledge to share, the participants become weary.

Last, Dubois (2015) also tested this hypothesis with an experimental setting. The experiment largely confirmed the hypothesis. His results demonstrate that co-design methods are of 'reactive' nature, i.e. they are based on a 'reaction' (by analogy with chemical reactions) between each participant's knowledge.

These results confirm 1) **the capacity of 'reactive' co-design method to create new forms of coordination**; 2) that 'reactive' design methods can be adapted for co-design situations with limited ambitions in term of innovation; and 3) **the necessity to develop new co-design methods to overcome the limits of the 'reactive' model to yield actual innovations**.

2.3 Design theory helps identifying critical issues of co-design: collaborative challenge and cognitive challenge

Hence there is quite a gap between available 'reactive' co-design methods and innovation ambitions. To begin to bridge this gap, one can analyze the issues of innovative co-design, and hence co-design needs, by relying on results obtained in the field of design theory and methods for innovation.

In the recent years, a large stream of research has contributed to clarify the issues and methods related to innovative design (for a synthesis, see Le Masson et al. 2017).

To summarize there are:

- Cognitive issues:
    a. Innovative design requires knowledge expansion, usually in many heterogenous types of knowledge. It means intensive knowledge acquisition and creation in areas that are varied, multi-disciplinary, occasionally 'far' from the competences brought by the (initial) participants.
    b. Innovative design requires to overcome so-called cognitive fixation, i.e. to go beyond design paths that are cognitively easy to formulate and to explore counter-intuitive design paths. Design theory predicts that innovative design requires more rigor to be more creative.

- Collaborative issues:
    a. Innovative design requires to coordinate high level experts in very different disciplines. Noteworthy, innovative design considers that a 'user' is actually a high-level expert on usages. More generally in innovative design expertise is not limited to technical or scientific expertise but actually correspond to any kind of knowledge, including (as already said) usages as well as culture, standards and norms, patents, business rules and models, competition and state of the art, etc.
    b. Innovative design works on "desirable unknown". This means that "desires" and "values" are part of the game – there can be participants with heterogenous or even conflicting values in an innovative design process. And the 'values' can be enriched during the design process.
    c. Over time, the design process might require involving new players. Hence innovative design cannot rely on a fixed, closed group of participants and should be able to integrate new stakeholders, depending on the evolutions of the design process.

In the last decade, methods have been developed to address at least some of these issues. A process called "KCP" (referring to the three phases of the process: Knowledge – Concept – Project) is one of the most efficient method, largely used in the industry (see KCP chapter in Le Masson et al., 2017). Akthough we will not describe in detail the method here, its critical features include:

- KCP begins with a so-called K-phase (knowledge phase), that focuses on sharing knowledge to prepare the ground for the future exploration of innovative concepts. Participants are expected to share any knowledge (e.g. technical, economic, commercial, scientific, legal, use-oriented) that might indicate issues in the current solutions, suggesting new potential for development. This phase results in making a "state of the art" (existing solutions) and a "state of the non-art" (anomalies, limits of participants' expertise), shared by all participants. This K-phase allows to take into account the diversity of expertise, mentioned previously as one of the collaborative issues of innovative design.
- The C-phase (concept phase) is driven to explore original concepts, called "projector concepts", formed in such a way that cognitive fixations are overcome.
- The P-phase (project phase) focuses on aggregating, recombining and developing the original suggestions from the C-phase to organize a coordinated design process. It does not consist in selecting a couple of feasible ideas but actually consists in building a design strategy that covers very short-term (quick and smart solutions) to very long-term explorations.

Up to now hundreds of KCP have been carried out in the industry (Le Masson et al. 2017), showing at a large scale that this method can support innovative design process in a given company, where it can successfully address cognitive and collaborative issues. Hence, KCP covers several of the challenges above:

- Cognitive challenge: KCP is adapted to knowledge expansion and it is built to overcome fixations. In this perspective it goes beyond 'reactive' methods.
- Collaborative challenge: KCP enables several experts to design together.

Dubois (2015) has suggested that KCP method can be used after a 'reactive' design phase, at a moment where participants share a common 'desirable unknown' and are ready to find new knowledge. However, it has also been shown that **KCP process should be further developed to meet the challenges of innovative design processes in more open environment,** where multiple stakeholders interact in an innovative design way, **without a common authority, without a common interest, and even without a common "desirable unknown".**

After this brief state of the art, we may conclude that:

- ‘Reactive’ co-design methods are adapted to co-design situations where innovative design is not needed.
- Co-design methods such a KCP can meet the requirements of co-design situations where there is a clear shared authority, with a shared ‘desirable unknown’ and the actors are actually coordinated by one single, leading company.
- In case of more complex co-design situations, co-design methods have to be developed.

Regarding e-shape context, as highlighted in the introduction, **specific challenges need to be addressed, involving both collaborative aspects** (coordination of highly skilled experts in many different fields) **and cognitive aspects** (development of innovative services that are both user-driven and generic). Therefore, **e-shape co-design will build on existing methods but will require methods that go beyond ‘reactive’ co-design** (because they need knowledge expansion); as well as **adaptations of KCP methods,** because of the relative complexity of the ‘ecosystem’ of actors.

To initiate the development of these specific methods, the co-design situation in the context of e-shape needs to be more precisely characterized and is thus described in the next section.

3 CO-DESIGN ADAPTED TO E-SHAPE CONTEXT: WHAT IS THE CO-DESIGN SITUATION?

The context of Earth Observation involves developing very specific forms of co-design methods. Indeed, compared to the situations described in the previous paragraph, particular elements seem to hinder the development of new usages from EO data:

1. A very **high level of technical expertise** is needed to develop services from Earth Observation data, combining both knowledge on data processing and knowledge on the domain of the final usage.
2. **Data and usages appear to be particularly distant.** Indeed, from the final users’ point of view (often different from the data owners), it might not be obvious that EO data can be helpful for their activities because of the complexity of this type of data. Furthermore, from the point of view of the experts in charge of processing EO data, potential usages might be difficult to identify. Most of the time, there is at least one foreseen application - satellite missions have an initial scope with an initial focus and an identified user community - however these data often prove to be helpful for additional applications, initially unforeseen.

As a result of this distance between data and usages, **a specific process is needed to build data-usages relationships**. This process is described in the following paragraphs, shedding light on the specificities of the co-design situation in e-shape. It will be shown that co-design actions might not only concern the final product delivered to the end-user but might be useful for other elements involved in the data-usages relationships.

3.1 Analytical framework

Developing services from EO data can be described as **building a relationship between data and usages.** Several branches of literature have already delved into the question of transforming data into usages, especially:

- Information theory (Shannon et Weaver 1963) suggesting the distinction between data and information.
- Information and knowledge management literature (Blackler 1995; Tuomi 1999; Zins 2007): describing the transformation of data into knowledge and distinguishing between three elements – data, information, knowledge.

- Statistics and decision theory (Wald 1950; Raïffa et Schlaifer 1961; Savage 1972) – shedding light on the value of information.

Based on this literature, several elements can be highlighted (they are also summarized in the framework below):

- **Data is different from information**. Data can be considered as contextualized: it is related to the measuring device (e.g. the tension at the output of a certain sensor in the satellite). Therefore, data has to be reworked to correspond to what statisticians and data scientists call the value of a variable: data is transformed to correspond to **information, that is expressed in a more decontextualized language** – meaning that it is understandable out of the instrumental context (e.g. temperature in GPS coordinates x, y, z at a universal time t).
- **Value (or usage) refers to the use of information in a particular context**. Indeed, in decision theory (Wald 1950; Raïffa et Schlaifer 1961; Savage 1972), information has value because it increases the "expected utility" in a decision situation (defined as the expected value of an action to an agent). Value actually corresponds exactly to this increase in expected utility. Hence it can be considered that **there is value once information is indeed used in a certain context (that is a certain usage)**. Similar considerations can be found in knowledge management literature where knowledge is related to a certain context of use (Zins 2007).
- Processes are therefore needed to transform data into information, and information into value. As highlighted in knowledge management literature, the reverse process also has to be considered, that is transforming value into information and information into data. These **transformation functions are called "f" (relationship between data and information) and "g" (relationship between information and value) on the framework**.

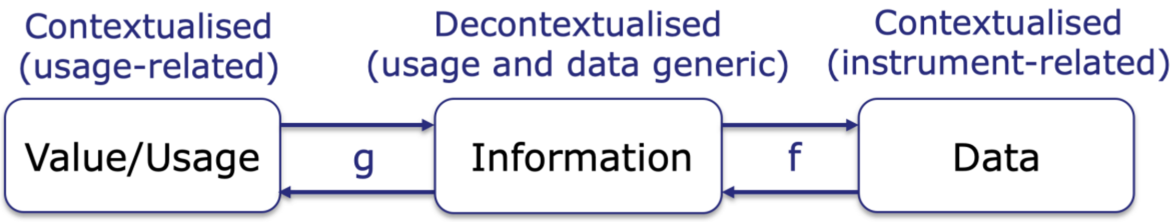

Figure 1: Data-information-usage framework.

In the context of developing EO-based services, the different elements of this chain do not all exist and thus have to be designed and built. For example, a common starting point can be having access to new data and the objective is then to build usages out of this data (in this case, the whole chain towards usages has to be designed). Or another common starting point is to have a specific demand on the usage side and then the objective is to build the chain towards relevant information and data.

This data-information-usage framework already informs us about the kinds of design actions needed to build data-usages relationships: the design process does not only concern the final usage but **all the elements of the data-usage relationship: information, data-information relationship and information-usage relationship**.

This framework is not specific to EO context and has been introduced in a static perspective (it does not make apparent how data-information-usage relationship is built over time). Therefore, the following questions still need to be explored:

- **What are the elements that seem to be more particularly critical to build a relationship between data and usages in the EO context?**
- **What are the dynamics of the design process in a long-term perspective?**

One historical case of the development of EO-based services has been analyzed to bring forward some insights on these questions, allowing us to better characterize the co-design situation in e-shape.

3.2 Historical analysis of the development of Solar Radiation Services

Based on the data-information-usage framework, we have analyzed the history of the current research center of MINES ParisTech located in Sophia-Antipolis, O.I.E. (Observation, Impacts, Energy), from the 1980s up to now. This center has been working on solar radiation estimation from satellite data, and the development of services and products for solar energy practitioners.

3.2.1 In the 80s: focus on designing models to obtain solar radiation estimates from satellite data

The center's research work on solar radiation started in the 80s, as it was involved in a project supported by the European Commission's Solar Energy R&D Programme. The project aimed at assessing solar radiation more precisely and reliably, especially by integrating new data coming from satellites (whereas at the time solar radiation was mainly derived from networks of in-situ solar instruments, that were installed in a limited number of locations). The project developed models in order to link solar radiation estimates and Earth observation data including new satellite data.

Our analysis is mainly based on the final report of the European Commission describing the objectives of the project and the results of these three different approaches (Grüter et al. 1986). The situation of this project can be described using the data-information-usage framework as follows:

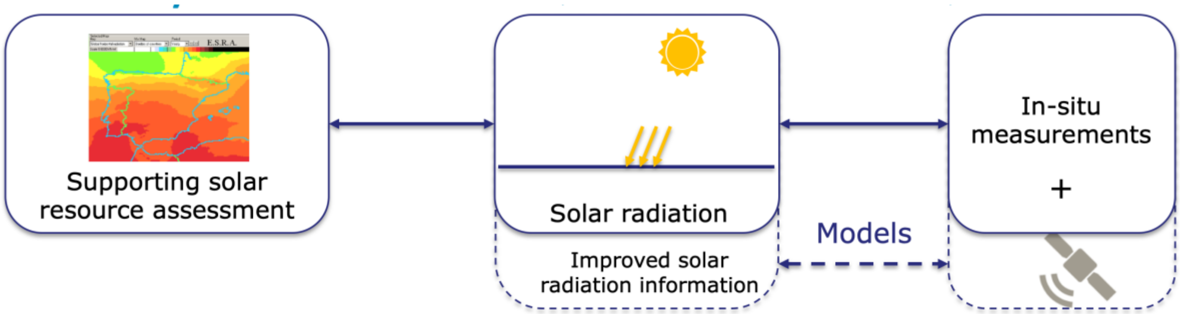

Figure 2: European project in the 80s: designing the model to use new satellite data for an improved solar radiation information.

The objective was to derive a certain type of information (here solar radiation at ground level) by using a new kind of data (satellite data, in addition to existing in-situ instruments). At the time, some usages of these solar radiation estimates were already considered by the European Commission – for example the European Solar Radiation Atlas (ESRA) to support solar resource assessment. In this project, the research efforts mainly focused on the exploration of the different ways of designing models linking satellite data and solar radiation (that is on the element "f" of the framework – relationship between data and information).

The project investigated three separate approaches to build this relationship (Figure 3):

- A physical approach (relying on physical modelling of the atmosphere).
- A statistical approach (relying on a statistical relationship between solar radiation measurements and satellite data).

- A combined physical-statistical approach (introducing a variable with a physical meaning related to cloudiness, which is then statistically related to solar radiation with fewer regression parameters than in the fully statistical approach).

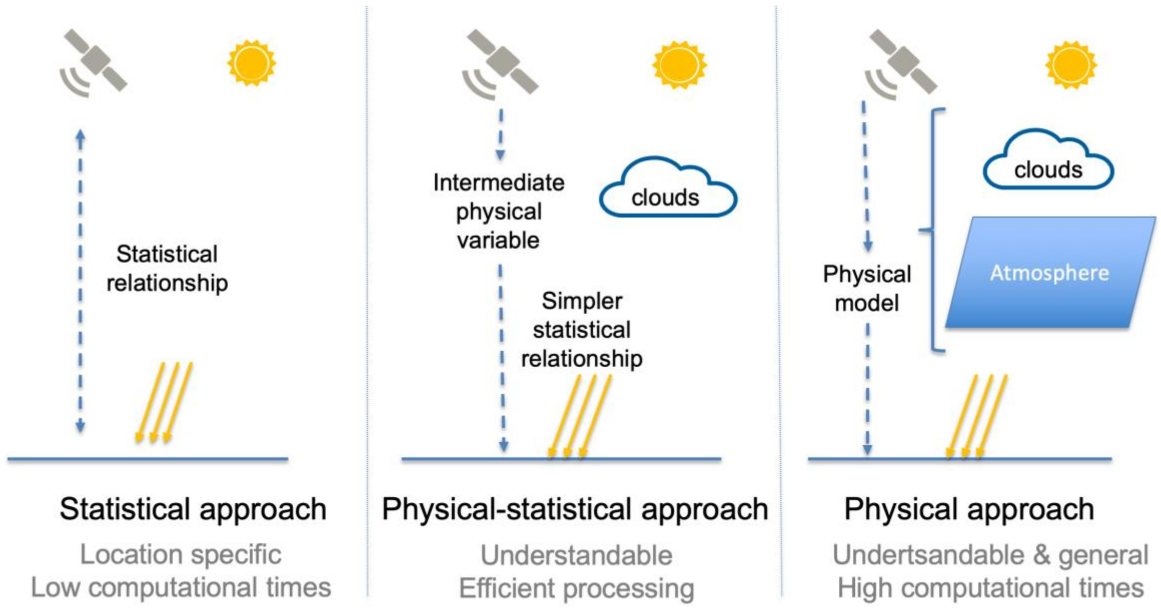

Figure 3: Comparison of the three approaches in the report of the project (1986).

This example brings forward two important elements relevant for our approach in e-shape:

- Even if the type of information and type of data are well known (for a given application), important research efforts are needed regarding the model linking data and information. More specifically, **not only is the model in itself important but also its underlying structure or approach.**
- The **specific role of the community can also be underlined**. In this example, the European Commission played an important role in organizing the comparison between the three approaches. It can be noticed that not only were three different models compared, but the underlying approach or structure of these models was discussed. Thus, the output of this project was not only to select the best performing model, but also to provide the community with a description of the structure of the models. To summarize, it appears **that the project owner and funder played a crucial role in making emerge best practices for model designing, and not only in selecting a best performing model.**

3.2.2 Evolution of data-usage relationship in a long-term perspective: variety of design activities

After this project, the O.I.E center has continued its research work on solar radiation. This paragraph examines how the data-usage relationship has evolved overtime and how the ecosystem has structured around this process.

3.2.2.1 Solar Data (SoDa) project: evolution of all the elements of the data-usage relationship

After having initiated the research works on the model linking solar radiation at ground level and EO data, major advances were performed by O.I.E. center under the SoDa project sponsored by the European Commission from 2000 to 2003. This project aimed at answering the needs of research and industry for information on solar radiation by expanding from existing usages (mainly concerning users skilled in handling meteorological data) to new usages for a broader range of user communities.

To do so, the project gathered a consortium including researchers with expertise in solar radiation and information technologies, and potential users. At this time, the consortium involved in the project was facing the same problem of distance between EO data and final usages mentioned previously (Rigollier et al. 2000). As already highlighted in 3.1., it can be noticed that **although the project aimed at resulting in effective usages, O.I.E did not focus on building the final usages. Considering the high level of expertise specific to each field of application, the final user was the one developing its own service, based on SoDa services. O.I.E therefore focused on building, improving the reliability and robustness of all the elements of the chain linking EO data and usages, in an iterative way**, i.e.:

(1) Enriching the pool of available information: better space and time availability of solar radiation estimates, different parameters related to solar radiation (cloudiness, sunshine duration, atmospheric optical thickness etc…), and also other useful non-radiation parameters such as terrain elevation and orography.

(2) Working on creating the link between information and usages ("g" on the framework), by providing “one-stop-shop” easy access based on web-service technologies and specific interfaces; and also relying on interaction with users to continuously enrich information.

(3) Working on the creation and evolution of the link between EO data and information (“f” on the framework): development of a new version of Heliosat method to be able to process long-term (more than 15 years) archives of satellite data taken with different sensors, and also the other algorithms required for the assessment of the different parameters included in the information pool.

3.2.2.2 From SoDa project up to now: continuous evolution of all the elements of the data-usage relationship and specific structuration of the ecosystem

The same dynamic of expansion can be noticed after SoDa project, involving all elements of the data-usage relationship.

(1) The O.I.E. center has kept on enriching the pool of available information (for example moving from only monthly solar resource maps to more complex tools indicating variation in time of solar radiation at a specific location,…), and has focused on making it useable in many different contexts through the development of routines and other supporting tools.

(2) Supporting (1), the O.I.E. center has continuously modified their model in order to capture the scientific advances on atmosphere and clouds description thanks to the development of new instruments and computation means, sometimes rebuilding the method and moving towards more physical approaches i.e. with the development of Heliosat 4 method (2008) to take advantage of the new instrument aboard the second generation of Meteosat instruments.

(3) After the SoDa project ended, the O.I.E. center has put significant efforts on operationalizing the link between information and usages, by 15capitalizing on the project results and creating “SoDa Service” in 2003. Different kinds of communities have progressively been addressed (building engineering, farming, solar energy companies, etc…). A specific business model had to be set up for these services, resorting into a freemium approach: free basic solar radiation information at a certain resolution and per paid sophisticated services. Furthermore, this process resulted in the involvement of new actors in the ecosystem: in order to make the services operational 24/24 hours and 7/7 days, the algorithms and processing chain were transferred in 2009 to a commercial organization - Transvalor / ARMINES - in charge of operating, maintaining and commercializing the services.

More recently, becoming part of the Global Earth Observation (GEO) community, has pushed the O.I.E. center to implement common standards impacting all the elements of the data-usage relationship. Implementing such standards has largely contributed to make the Heliosat methods a reference, especially at the European level, as it is now one of the official providers of solar radiation data for the European Commission (within Copernicus Atmosphere Monitoring Service).

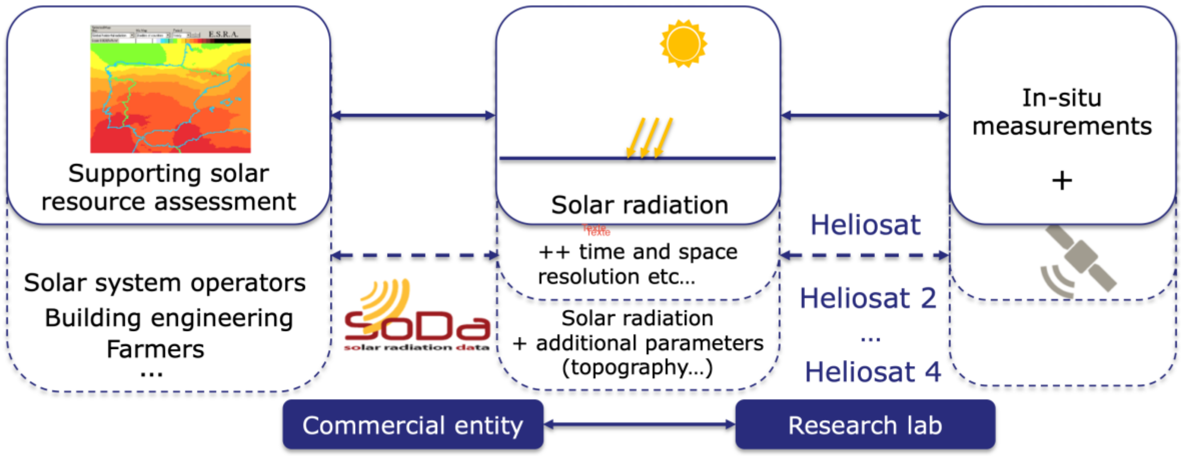

Figure 4: Evolution of all the elements of the framework illustrated on the history of O.I.E. center.

3.3 Insights on the data-information-usage framework based on this historical analysis

In the context of developing EO-based services, the different elements of this chain still have to be designed: the starting point can be either data (then the chain towards usages has to be built), or a specific demand on the usage side (then the chain towards relevant data has to be built).

Based on the analytical framework introduced in paragraph 3.1., the kinds of design actions needed to build data-usages relationship have been highlighted: the design process does not only concern the final usage but **all the elements of the data-usage relationship: information, data-information relationship and information-usage relationship**.

The historical analysis of SoDa Service helps define **some additional properties of this framework,** especially on (1) the crucial elements to be designed in the EO context and (2) the dynamics of the design process in a long-term perspective.

3.3.1 What are the crucial elements to be designed?

This long-term analysis more specifically highlights the role of "information". As exposed earlier, Earth Observation data can seem distant from final usages. Therefore, it appears that information has a significant role to cope with this distance. It could be described as the necessary bridge or **pivot between data and usages**.

In our example, solar radiation information is a form that is both understandable and manageable by users (unlike raw satellite data), and also by experts involved in data processing, allowing them to handle user needs in a language compatible with models.

To say it differently, the pool of available information of SoDa services plays the role of a bridge which is both data-generic (allowing several sources of data to be used to build information) and context-generic (information is useable in many independent contexts). To go a step further, in order to play its pivotal role, what needs to be more specifically designed is **"use-generative" information**, meaning that it is not only compatible with multiple usages, it also has a power of arousing multiple usages.

The **function transforming data into this "use-generative" information** also has to be designed, as illustrated by the efforts made on building Heliosat methods and making them evolve. Interestingly, finding one best-performing model was not the only focus: one of the key elements was also to **focus**

on the underlying structure of this model, especially allowing its continuous evolution to take into account changes occurring either on the data side or on the information side.

Finally, designing **the relationship linking "use-generative" information and usages** ("g" on the framework) is also needed. This relationship has to be designed in the two directions "information towards usages" and "usages towards information". The relationship "g" can therefore be qualified as a **"recontextualizing" function** when going from decontextualized information towards a usage corresponding to a contextualized information; or a **"decontextualizing" function** when going from a contextualized information (given by a certain usage) to build a decontextualized information:

- In the "recontextualizing" perspective, the long-term issue is to build a "g" that is not only designed for a specific usage, but a **"g" that has the capacity to address multiple usages**. In the case of the O.I.E. center, this function "g" has progressively been built with the creation of SoDa web services and Transvalor taking care of the operational maintenance and commercialization of the service.
- In the "decontextualizing" perspective, the issue is to be able **to build a decontextualized information from specific usages**, that has then the power to be "use-generative" that is able to address multiple usages.

To illustrate this on SoDa example, the help desk has played an important role in building "g" in both perspectives. Indeed, it has been used both in a recontextualizing perspective (for example users needing help to adapt the decontextualized information to their specific contexts), but also in the decontextualizing perspective: based on exchanges with users, the objective has also been to identify the new kind of decontextualized information that could be designed (for example solar radiation for a given wave length…).

3.3.2 What are the dynamics of the design process in a long-term perspective?

In the literature dealing with value creation from data (in management and innovation management fields), two types of dynamics are often mentioned: either new data "self-evidently" leading to designing value (this can be assimilated to a form of "techno-push" dynamic, that we label **"data-push"**), or usages calling for data (this can be assimilated to a form of "market-pull" approach, that we label **"usage-pull"**). Two illustrative examples are presented hereafter (Trabucchi et Buganza 2019).

- Regarding "data-push": an application called "Strava" allows its users to track their sport activities and get useful information on them such as average speed, performance stats and so on. Data collected by Strava have directly value for the application's users, and aggregated data from all runners and bikers' activities have also value for public departments of Transportation. Indeed, these datasets allowed the latter to better plan the construction of future bike lanes by identifying where they were the most needed.
- Regarding "usage-pull": Sage Bionetworks is a not-for-profit organization that partners with researchers, patients and healthcare stakeholders to drive data-driven projects contributing to health improvement. In one of its projects, the organization aimed at finding new ways of managing symptoms of Parkinson's disease (targeted usage) and had to design a way to collect data on symptoms and their evolution. To do so, Sage Bionetworks launched "mPower" app, that could be used by people affected or not by the disease. Through this app and additional surveys, the organization was able to analyze different tasks based on the sensors embedded in the smartphone (camera, touchscreen and microphone), and therefore to analyze and monitor the symptoms over time.

These two perspectives are too simplified as suggested by the analytical framework data-information-usage and the case of the O.I.E. center. Indeed, **the dynamic is rather characterized**

with an intertwined expansion of all the elements of the framework, with many different possible configurations. For example, given a first data-information-usage relationship (as it was in the 80s before using satellite date), an improved "f" can be designed (Heliosat method), leading to improve existing usages (solar energy atlases), or new usages. Or given certain information or data, new usages can be allowed thanks to the design of an improved "g" (operationalization and commercialization transferred to Transvalor), or new information leading to new usages without modifying "g" (once SoDa web services were in place), etc.

To facilitate further expansion of the data-usage relationship and make it more robust, it is interesting to note that the ecosystem has structured in a specific way. In the case of the O.I.E. center, the data-usage chain has been shared between the center, mostly focusing on the data-information part ("f"), with still some involvements in the information-usage part ("g"), and Transvalor, mostly focusing on the information-usage part ("g") with still some involvements in the data-information part ("f"); each partner sharing its advances with one another to progress iteratively.

3.3.3 Conclusions on co-design situation in e-shape context

To summarize, based on an analytical framework and the historical analysis of the O.I.E. center, we are now able to better characterize the co-design situation in EO context: different types of design activities are undertaken when building services from EO data (possibly involving heterogeneous actors) and co-design might be seen as a support for all these activities.

We have especially identified the following design activities needed to build the relationship between data and usages, and to continuously expand it over time, that are **designing and redesigning (1) information which is "use-generative", (2) data-information relationships that are able to adapt to future advances and (3) information-usages relationships that are able to cope with multiple usages**.

More specifically, in e-shape context, each pilot builds upon existing services, involving at least one final user (that is a specific usage) and aims at expanding these services. Therefore, **our analytical framework can be used to represent (1) the initial state of each pilot** as an existing data-information-usage thread, and (**2) the pilot's targeted state** as broader and more robust data-information-usages relationships thanks to the intertwined expansion of all the elements of the data-information-usage relationship.

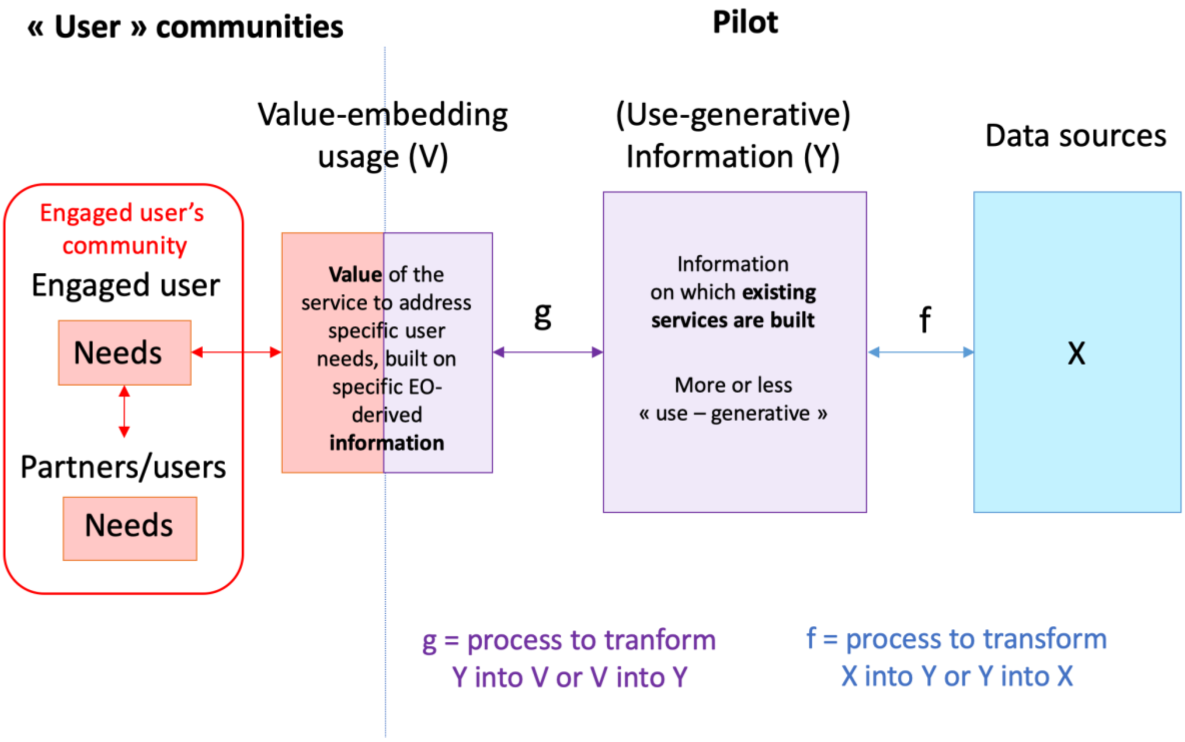

Figure 5: Representation of one e-shape pilot's initial state based on the data-information-usage framework.

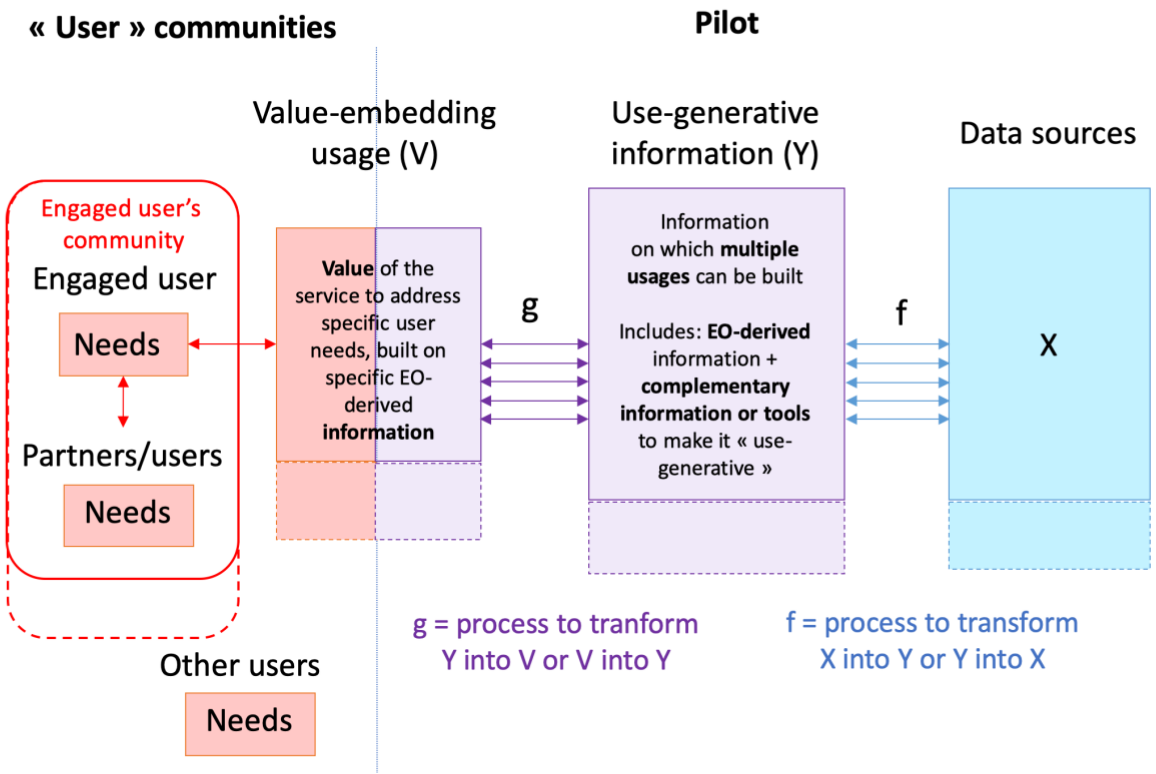

Figure 6: Representation of one e-shape pilot's targeted state based on the data-information-usage framework.

Co-design adapted to e-shape can therefore be seen as a way to **support the different design activities involved in the development of e-shape pilots, taking into account the long-term perspective**. It especially implies making sure that the following conditions are met:

- There is **no hole in the initial "data-information-usage" relationship** (that is clearly identified usages, information and data sources and processes linking them).
- **Future data-information-usages relationships are planned to be designed in a sound way as described in this section**: specific structures and organizations for "f" and "g" able to cope with, e.g. multiple usages and future expansions, information that is use-generative, relevant data sources, reliable users engaged in the project.

4 PERSPECTIVES FOR E-SHAPE SPECIFIC CO-DESIGN METHODS

As explained in the first section of this report, it is important to distinguish between co-design situations and co-design methods. In the previous section, we have focused on better understanding the co-design situation specific to e-shape context. The present section describes **how co-design methods are expected to be developed, based on this characterization of e-shape contex**t.

4.1 Diagnosis of co-design needs based on the analytical framework

4.1.1 Description of the process

As explained earlier, different types of design activities are undertaken when building services from EO data. Because of the variety of these design activities, **a first step is needed in the co-design process to make a diagnosis of co-design needs.** The latter can be defined as **elements that are (1) crucial to ensure the sustainable development of services as defined in previous section, (2) but currently not addressed or difficult to handle by the pilot.**

To identify these co-design needs, the following process has been set up:

1. **The data-information-usage framework is used as a tool to represent the situation of each e-shape pilot**. A first version is drawn, only based on existing documents already filled by the pilots. Initial and targeted states tend to be mixed up in these documents, thus they are not distinguished yet at this phase of the process. Based on the framework, the conditions needed for a sustainable development of services are examined and blocking or unclear elements are identified.
2. Through Confluence[1], this framework is then shared with each pilot. Specific questions are raised based on the identified blocking or unclear elements.
3. These questions are expected to be answered by the pilot on Confluence as far as possible.
4. A telco discussion is then organized with the pilot leader to clarify the elements remaining unclear and further assess his/her knowledge on the mentioned user communities, through a "story-telling" exercise where the pilot leader is asked to take the user's point of view and imagine the sequence of actions conducted by the user to implement the service provided by its pilot.
5. Thanks to these clarifications, the pilot framework is updated and divided into two distinct frameworks: one for **the initial state and one for the targeted state** (as shown in Figures 5 & 6)
6. **Co-design needs** are then identified based on these frameworks.

[1] Confluence is the online knowledge management platform of e-shape, open to e-shape participants.

4.1.2 Example of Pilot 2 – Showcase 3

To take an illustrative example, the analysis of Pilot 2 – Showcase 3 (Energy) is presented below. This example has been selected as a first co-design initial assessment example because it belongs to the same family of solar radiation products as for current SoDa services.

Blue boxes correspond to data, purple boxes correspond to information (Y), red-purple boxes correspond to usages embedding value (V), red boxes correspond to identified needs from the users' community, and grey boxes correspond to the related actors. The content of the boxes is not commented in detail in this document: the focus is rather to illustrate the overall process of the diagnosis of co-design needs.

Figure 7 illustrates the framework, developed from the documents describing the pilot. Red circles point out the unclear or blocking aspects. In this example:

(1) to what extent is InSunWeTrust (i.e. the engaged user of this pilot) a robust actor?

(2) what are the links with communities such as aggregators for energy trading?

(3) and to what extent information on variability has value for the identified users?

This framework has been presented to the pilot members and has been considered as very useful to represent the pilot's situation in a synthetic way.

The subsequent telco session has also been experimented with the pilot team and proved to be efficient to clarify initial state (Figure 8) and targeted state (Figure 9) of the pilot; and to identify co-design needs (Figure 10).

In the case of this pilot, it appeared that five aspects could be supported by co-design:

1. The pilot seems to be divided into two sub-pilots. Co-design could help to clarify the articulation of these two segments.
2. One crucial aspect of the pilot's success is the ability to demonstrate the value of time-based solar energy monitoring. Co-design could help to define the good ways of "showing" this value, involving InSunWeTrust (ISWT on the framework).
3. The development and operationalization of the pilot are jointly shared by the O.I.E. center and Transvalor (commercial entity). Specific efforts are needed to build clear relationships between these two actors to ensure the sustainability of the service and future services in a long-term perspective. Co-design can be used to support these efforts.
4. Similarly, it seems crucial to build information that is "use-generative". In order to foster new usages, co-design could help to find ways of "showing" information in order to generate multiple usages.
5. Finally, from a technical perspective, a detailed Digital Surface Model (DSM) is needed to operate the service. The DSM is currently provided by a French public institute. To further extend the service, co-design could be used to investigate alternatives to this source of data.

It is interesting to note that in this case, **the design of the final usage (supported by ISWT) is not the priority of co-design actions** (although ISWT will probably be involved in some of the actions, namely on the aspect n°2). Indeed, ISWT seems to be a skilled partner, able to cope with the expansion of usages, which is well structured: the pilot's issues mainly occur on other elements of the chain.

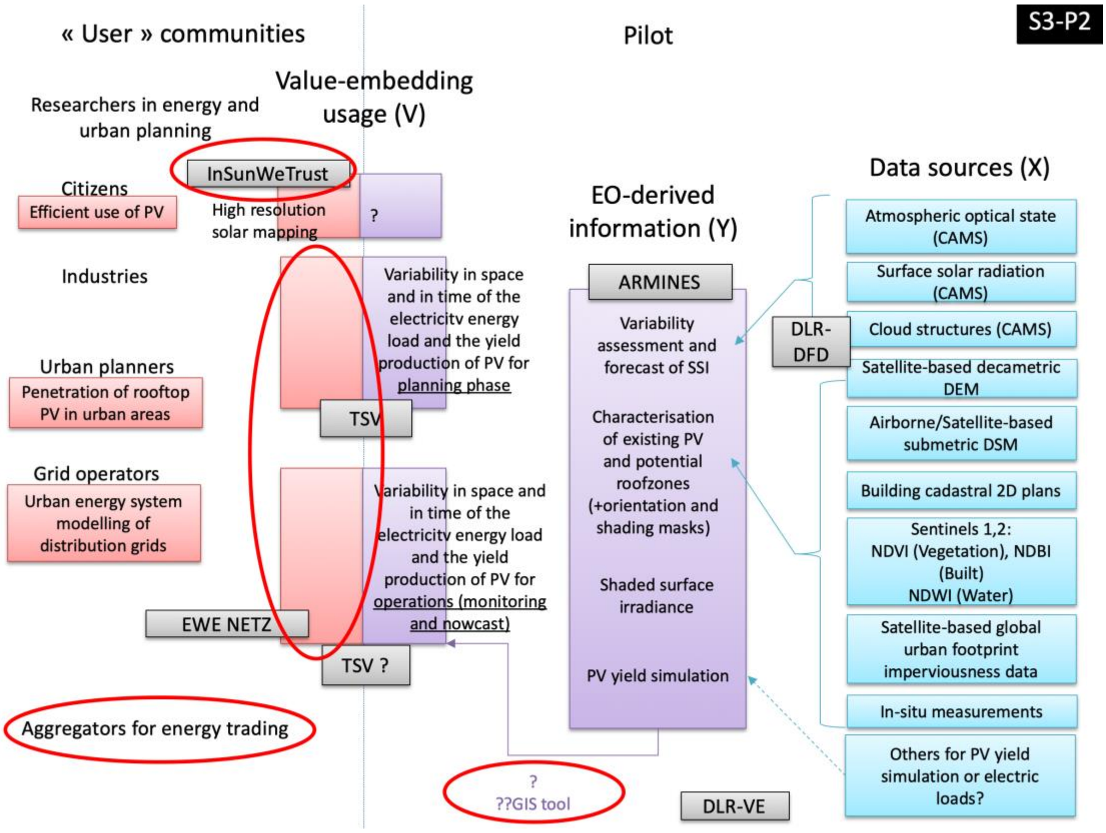

Figure 7: Framework representing the pilot 2 – showcase 3 (before telco session).

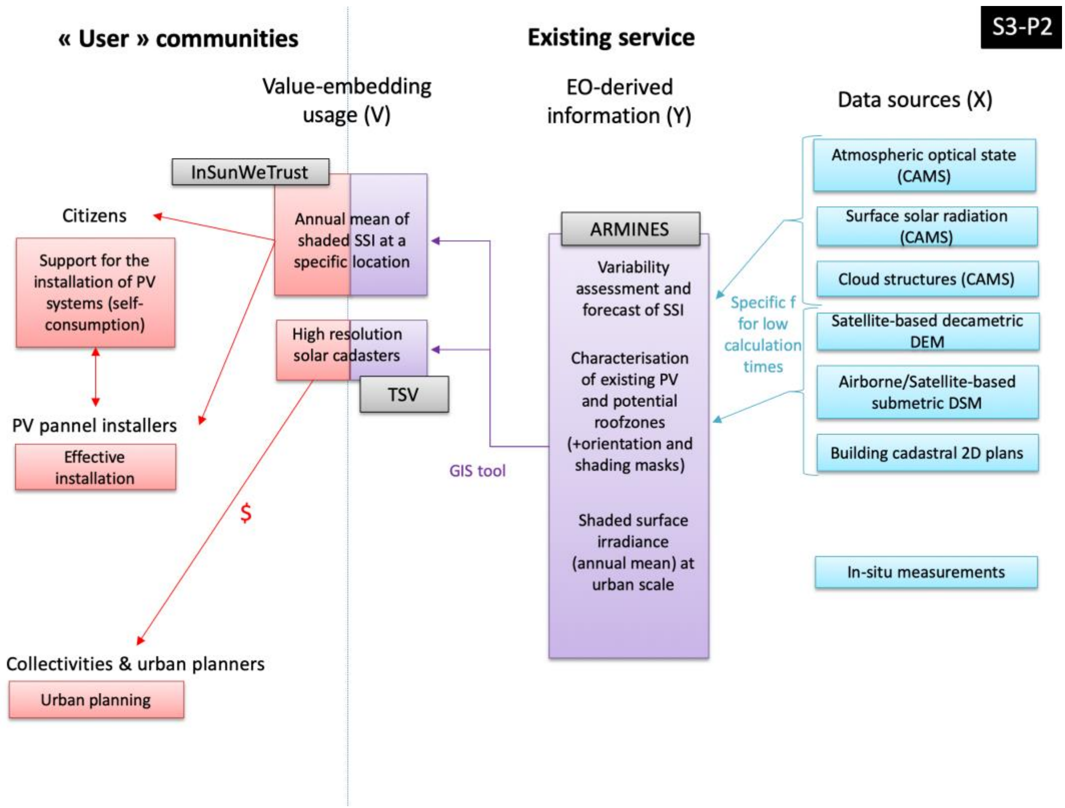

Figure 8: Framework of the initial state of the pilot 2 – showcase 3 (after telco session).

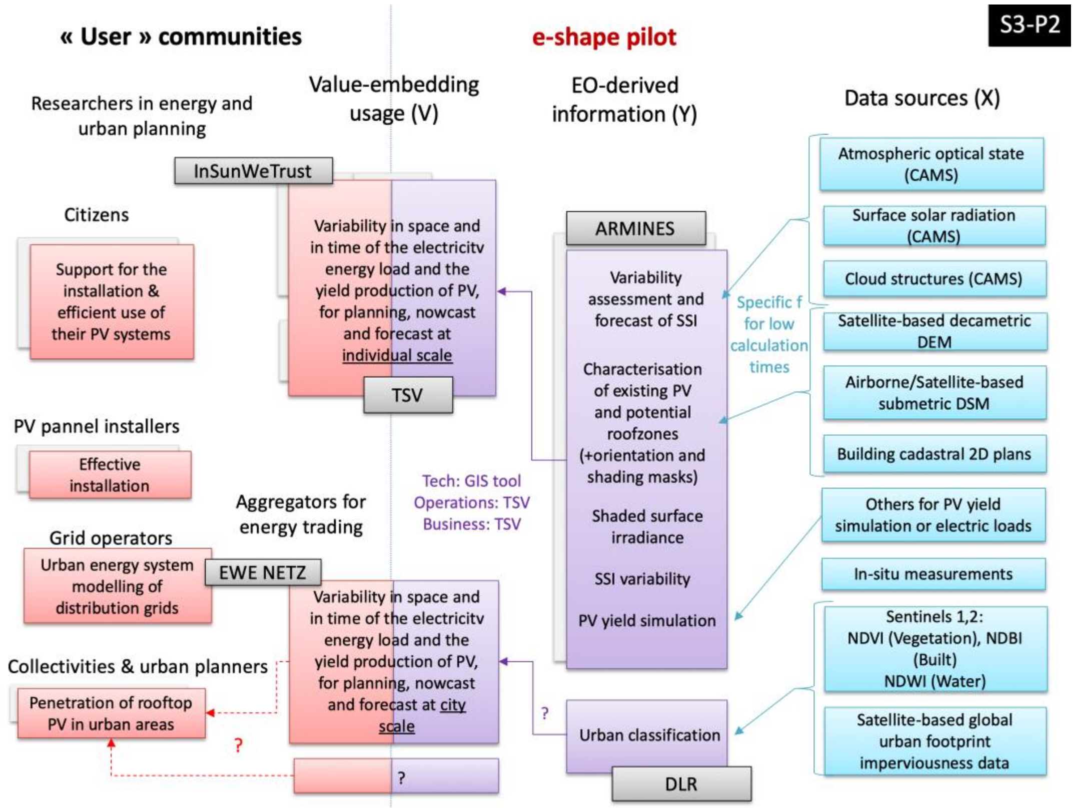

Figure 9: Framework of the targeted state of the pilot2 – showcase 3 (after telco session).

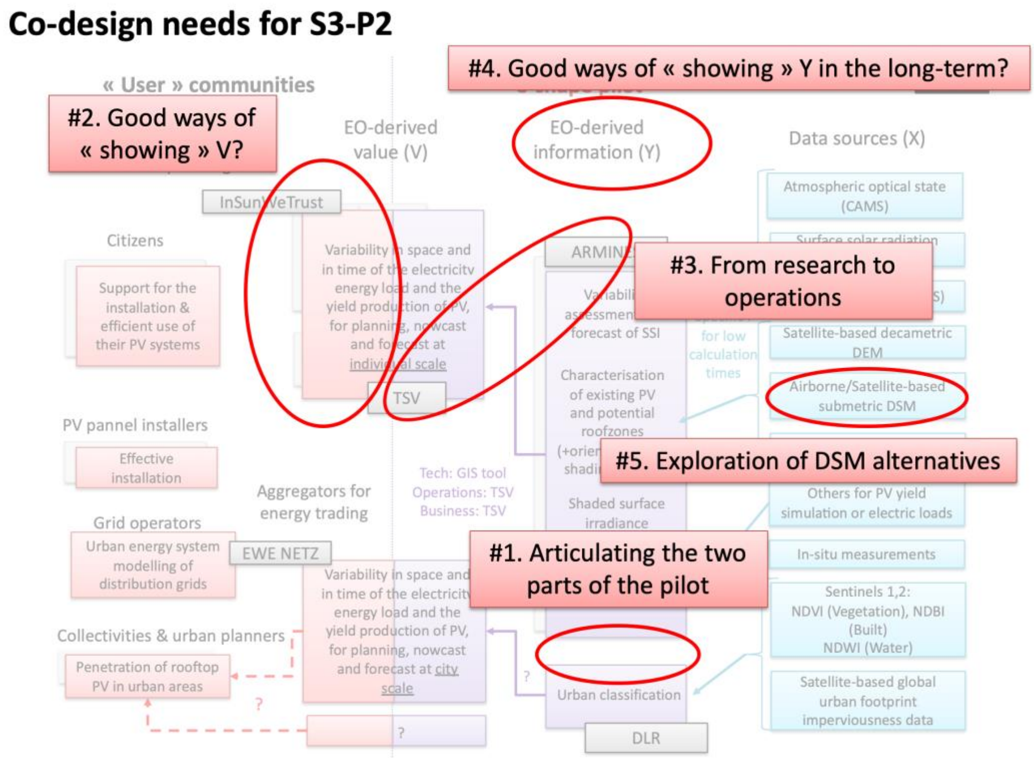

Figure 10: Identification of co-design needs of the pilot 2 – showcase 3.

4.2 Next steps for the development and deployment of e-shape co-design

The next steps for the development of an e-shape specific co-design process are detailed hereafter:

- **Finalizing the diagnosis of co-design needs** for the 27 pilots.
- Carrying out **specific co-design actions based on this diagnosis of co-design needs**, investigating forms of co-design methods adapted to the addressed situation.
- **Standardizing** this process.

For the diagnosis of the 27 pilots' co-design needs, a specific process has been set up in cooperation with the other Work Packages, as described in 4.1.1., and will be completed in the following months.

The forms of co-design actions still need to be further investigated. They will leverage and expand existing co-design methods. As explained in the first section, existing co-design methods for user-involving co-design situations are particularly efficient regarding the social aspect but limited in terms of innovation of the outputs.

In the context of e-shape, this existing type of "reactive" co-design might be useful in situations where there is a need of smoothing the relationships between some stakeholders or creating new coordination. However, in situations with more ambitions in terms of innovation and exploration, other forms of co-design methods are needed. Existing methods in design theory (KCP) could be useful as a starting point but will also need to be adapted. Finally, the co-design methods already used in other EuroGEO projects (such as ECOPOTENTIAL) could bring interesting insights by analyzing both the co-design situation and the implemented method in itself.

The co-design actions will be implemented in a certain order of priority (especially in situations where some elements are completely blocking the pilot's development process). Moreover, based on the preliminary analysis of the pilots, it appears that some similar issues are shared by different pilots. The objective is therefore to propose a **comprehensive framework to help understand the types of needed co-design actions related to these different configurations**. Standardized tools (such as webinars, documentation, etc…) are planned to be developed to **allow each pilot to carry out co-design actions on its own – at least for the most common issues.**

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