THE DOUGHNUT AS A SUPPORT OF THE "SUSTAINABLE VALUE ENGINEERING"

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ABSTRACT

Societies are faced to ecological crises and widening disparities. This has to be integrated in the management of complex projects as they are increasingly complex and impactful. Value Analysis can serve assessing the value of a project i.e. knowing how the project will be perceived by the Stakeholders. It is a collaborative approach that helps make decisions in the early stages of a complex project.

This paper aims at demonstrating that a new "Sustainable Value Analysis" (SVA) provides a decision-making support toward sustainability. SVA uses a new definition of Value and a set of indicators based on the Doughnut.

Methods for the introduction of sustainability in the upstream design phases have limitations, which are highlighted in the literature review. Yet, the potentials of value approaches can be shown. Based on this analysis, an illustrative case is proposed to demonstrate how to integrate the ecological and social dimensions in a classical Value Engineering approach to determine SVA. The article concludes that the SVA allows identifying and characterizing the sustainable dimensions of Value, through a collective approach based on Stakeholders.

Keywords: Complexity, Collaborative design, Design engineering, Stakeholder, Doughnut

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1 INTRODUCTION: THE STAKES OF SUSTAINABILITY IN EARLY PHASES OF COMPLEX SYSTEMS

Our study focuses on the integration of Sustainability in the early stages of the design of complex systems. According to us, sustainability is not just about protecting the environment: it is about taking into account the place of human beings in their environment. We will focus in our article on the social and environmental dimensions while considering the economic and technical dimension as largely supported by classic approaches such as Value Analysis (VA)/Value Engineering (VE) or System Engineering (SE) (de Graaf et al., 2019; Lalevée et al., 2021b). The interest in these phases comes from the fact that they have a strong impact on the entire life cycle of the system while having a limited commitment of resources. As highlighted by (Kolltveit and Grønhaug, 2004), it is recognized that the quality of the execution of the early project phases is critical to project performance. This makes this phase an interesting phase to make decision. In our approach, we define complex systems as systems designed during complex projects. Thus, they have the following characteristics (Hass and Lindbergh, 2010; Yang et al., 2019): 1) different technologies coexist in the same system. This operates over a long period of time, which exceeds the technological cycle time of the technologies involved: it is necessary to be able to replace elements and ensure the functioning of the system, 2) Stakeholders with very different interests must be taken into account and 3) the system must meet many very different needs. What characterizes complex systems is therefore the uncertainty linked to the different socio-technical levels described above. The complexity creates difficulties in early decisions for the design of complex systems. In fact, two "dimensions" of the project are implemented to make a decision in order to achieve a complex project, with a dynamic point of view as shown by (Lyneis, Cooper and Els, 2001). On one hand, the management of the resources implemented but also of the various Stakeholders who must be involved in the project for it to succeed. On the other hand, there is the design dimension: what choices can be made with the information that is available at this design level of the system? What indicators can support these design choices and what is their level of reliability? These two dimensions must be managed simultaneously and indicators and support must come to underpin the decision-making, which is mainly made by decision-makers. However, in complex system, the design project must meet multiple needs and it involves various Stakeholders with needs and interests that cannot be reduced to the technical dimension. The challenges in these upstream design phases are therefore to build a shared vision of the project and its Value that will be perceived by all the Stakeholders.

The aim of this paper is to demonstrate that the Doughnut could be a support to determine a Sustainable Value of the project, through exchanges of a group of work in the case of Value Analysis studies.

Firstly, a literature review had been achieved to compare some methods and tools used to design a sustainable complex system as soon its early phases within a collaborative framework. Secondly, we based ourselves on the indicators used to determine the Value of a project within the framework of a company dedicated to project management. We noticed that there was a lack of a framework for social and ecological indicators. Our proposal is to use the "Sustainable Value Analysis" to construct a "measure" the Value for each Stakeholder. We confronted this proposal through a workshop with students (Master) and practitioners. We concluded that the Doughnut could serve as a support for exchange or even convergence to determine the social and ecological indicators for the design of sustainable systems. We will then illustrate this proposal with an illustrative case based on the workshop conducted with students and practitioners.

Based on these observations, the authors will conclude that the "Sustainable Value Analysis", proposed in this paper could lead to facilitate the integration of Sustainable dimensions as soon as early phases of complex system design with a collaborative approach.

2 WHAT METHOD USING TO INTRODUCE SUSTAINABILITY IN EARLY PHASES OF COMPLEX SYSTEMS DESIGN?

2.1 The limits of the LCA

From a general point of view, sustainability in design can be integrated at various levels, as described by (Ceschin and Gaziulusoy, 2016)). We can go through the product level (green design, ecodesign)

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on which we act on the behaviour of the end users of a product or system (systemic design). These evolutions make it possible to approach the evolutions of tools and methods to come. In this context of the need for changes to integrate sustainability, work on Life Cycle Assessment (LCA) approaches is carried out. Although being the most used to integrate ecological dimensions in design being "the best evaluation tool" (Millet et al., 2004), the LCA has limits like data availability (Allais, 2015) or the fact that it is already used as a non-dynamic method (Laratte and Guillaume, 2014). It is already a environmental-focused approach dedicated for experts (Millet et al., 2004). Thus, it is considerate as a non-sufficient tool to make design decisions in the upstream phase of a design project (example developed in (Lalevée et al., 2021a)), as described by (Millet et al., 2004), while the early phases of design are able and "it is important to both reduce costs and improve a product's sustainability performance" according to (Schöggl, Baumgartner and Hofer, 2016).
Considering the social dimensions, although a major challenge, poses many problems. (Visentin et al., 2020) underline the lack of frameworks, methodologies and tools to integrate social dimensions into the design of products and systems. However, to be able to integrate such dimensions, (Visentin et al., 2020) show that the context in which the design project takes place is a key factor. The actors of a project must be integrated into the design of the indicators so that they can, through a group of work for instance, take a decision. This is supported by (Messmann et al., 2020), which draw up a literature review of social impact indicators for the supply chain. By studying 91 review articles, they show that depending on the optimization goals pursued, the indicators to measure the same impact might differ. They recommend creating quantitative indicators, in order to explain the impacts, which are based on a working group. This working group works with the most used media as references, such as the Global Reporting Initiative (GRI) or the International Guidance Standard on Social Responsibility (ISO/CD 26000, 2010). We can notice that this comes to corroborate the fact that the Stakeholders of a design project, as in Value Analysis, are a key element. They are the ones who, through the framing of needs, provide elements of context as shown by (Lalevée et al., 2020). Based on these observations, we can wonder how to identify and choose relevant sustainability indicators in a given context. In summary, social aspects need to be better integrated into existing methods such as LCA.

2.2 The limits of the classical Value Analysis – identification by practices

As described by (Mandelbaum and Reed, 2006), the terminologies of "Value Analysis", "Value Management" or "Value Engineering" are sometimes used interchangeably. In this article we will assume that "Value Management" is the overall framework in which we place ourselves. Indeed, we are seeking to frame a design or redesign process. In some papers, a distinction is made as to the tools used: on the one hand, Value Analysis (VA) is commonly used to redesign a system in order to make it evolve, on the other hand, Value Engineering (VE) is interested in new systems", as suggested by [2]. In this paper we will use the term "Value Engineering" or "Value Analysis" indistinctly.
Based on feedback from a company that does project management, we were able to see that the evaluation criteria used in the context of a Value Analysis (VA) were mainly oriented towards dimensions functional / technical or financial. We will report on our observations and show that social and ecological dimensions are missing to be able to take into account all the dimensions of Sustainability. Our research is based on data from 10 system design or redesign case studies which were studies conducted by ECP company, working on project management assistance in complex and technical systems design. They were chosen for the availability of data internally to the company. 5 systems related to projects in the rail sector and 5 related to projects in the nuclear field. ECP, a subsidiary of the Assystem group specializing in project management, conducts Value Analysis for its customers who now wish to introduce sustainability issues into their projects. Thus, an inventory work was done in order to know what it was about these dimensions in the projects. It had also been noticed that even if these criteria are identified, it is quite difficult to integrate them in value analysis methodology to include them in decision-making process. For this reason, we focused on understanding how to assess sustainability aspects in early design phase to be able to take it into account in value management

2.3 Literature review to identify sustainability assessment methods to integrate sustainability in Value Management in early design phases

To make decisions that are sustainable, the Stakeholders of a project must be able to understand each other and converge, based on elements. These elements could be the Value obtained within a VA

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approach. Le limits encountered are the integration of all dimensions of the sustainability issues. A support to make a decision is therefore necessary and seems most often to be expressed through indicators. The lack of methodologies that allow the integration of sustainability issues with a group of work were described earlier with the example of the LCA.
We are able to ask us if it should not simply focus on the integration of the basic needs of the Humanity and the planetary boundaries, as described by (Raworth 2012, 2017). It is used to show that what is important for the human species is its survival in good conditions (basic needs within planetary constraints). In this sense, many systems respond to needs that are artificially created or respond to notions of comfort and not to a vital need. Thus, the "real needs" are those that allow us to respond to our survival in good conditions: protect the environment and ensure the dignity of all human beings. The framework described above could therefore help stakeholders to think about the priority of these needs. Indeed, we could hypothesize that the Stakeholders will first have to meet these needs. For this, we propose to use the Doughnut of (Raworth, 2012) as a framework to design complex systems. Our choice is explained not only by the integration of theses “real needs" in respect of life on our planet but also by its ability to be understood by all, including Stakeholders, in order to support the construction of indicators and decision making in a context of uncertainty.
We can conclude that there are various problems with the integration of the Sustainability in the early phases of design of complex systems. Indeed, from a general point of view, the most used method is LCA. However, it is incomplete and focused mainly on environmental impacts. It is based on data to perform calculations, which makes it unusable in a context as uncertain as the upstream design phases. Beyond these "technical" aspects, we have seen that VA is, in principle, based on collective work. Therefore, the group of work must be able to manipulate (so, to understand) the various indicators. However, LCA is a method dedicated to environmental experts that have to manipulate many data. We hypothesize that the Doughnut of (Raworth, 2012, 2017), makes it possible to identify and characterize indicators making it possible to evaluate technical solutions by introducing socio-ecological dimensions. The assumption we make is that the Doughnut can be understood and handled by everyone.

2.4 The Doughnut to define a frame to design for all within planetary boundaries

To conclude, we have seen that VA could be used in early phases of complex design not only to include the Stakeholders and their needs into decision-making but also to introduce Sustainability dimensions with the ambition of having a sustainable approach to Value in complex projects.
Regarding Sustainability, we have seen that there is no ideal method for integrating these issues into the upstream design phases of complex systems. We assume that Raworth's Doughnut is a framework that allows us to focus on the basic needs of the humanity while respecting planetary boundaries. The Stakeholders are crucial to integrate sustainability issues: they will determine the indicators to be used in accordance with their context.
We are going, in the third section, to describe why and how this approach were developed. The test of the proposal will be described. An illustrative case in the fourth section will help us to make recommendations for practitioners. The methodology used is as follows:

- A theoretical analysis of the two frameworks, VA and the Doughnut, that permits to understand what are the contributions and limits of them to address sustainability issues in the context of a group of work design in early phases;
- A proposal for a combination of VA and the Doughnut to better support decision making in early phase and throughout the design process. To test it, we have made some workshops that will be described and a theoretical description and then an illustration of the proposal (based on the workshops) will show how to use the Doughnut as a support to design a complex system.

3 TOWARD A "SUSTAINABLE VALUE ANALYSIS" BASED ON THE DOUGHNUT

Our proposal is to use the Doughnut described by (Raworth, 2012) as a framework to determine social and ecological indicators to measure the Value of a complex system in the framework of Value Analysis (as defined by (Mandelbaum, Reed and Leader, 2006) and used in France, based on (NF X50-152:2007-09, 2007; NF EN 1325:2014-04, 2014). We will first see what is the potential of the Doughnut to address the Sustainability in early phases of complex system design.

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Our proposal aims to provide a decision-making support in the conceptual phases of the design of complex projects. It will allow all the Stakeholders to be included in the process of establishing decision-making support, based on their real needs not only linked to technical and economic dimensions but also with social and ecological dimensions.

3.1 Theoretical description of the proposal: a new definition of the value

The proposal is a mixed approach of VA used to valuate –as a classical approach- technical and economic dimensions, coupled with a socio-ecological frame –the Doughnut- to evaluate all the dimensions of a complex project. The "Sustainable Value Analysis" is defined by an extension of the concept of Value.

Compared to a classic VA approach where Value corresponds to the satisfaction of needs in relation to the associated costs, the idea of having a Sustainable Value Analysis is to have an approach allowing the satisfaction of social needs, represented by the social dimension of the Doughnut; and the cost extended to the ecological dimension, represented by the planetary boundaries in the Doughnut (Raworth 2012, 2017).

Thus, the "Sustainable Value Analysis" is a methodology that combines a classical Value Analysis and the Doughnut as a framework for the Stakeholders to determine social and ecological indicators.

3.2 Using the Doughnut as a support for indicators to design sustainable systems

The proposal is a mixed approach of VA used to valuate –as a classical approach- technical and economic dimensions and the Doughnut as a support to frame the indicators to introduce social and ecological dimensions. Thus, we propose to give the framework of the Doughnut as described by (O'Neill et al., 2018) in order to serve as a support for discussions and decision-making as to the different dimensions that enter into the project. Indeed, we assume that this framework is suitable for all Stakeholders because it was created using indicators based on data from the population of nearly 150 countries. Ideally, the Stakeholders must be able to know individually and collectively what each of them can expect from the others and how this influences the project and its impacts, whether positive or negative. In this way, the various Stakeholders establish a rating of the established solution proposals.

Concretely, it is proposed to give the Doughnut to the group after having determined the needs of each of the Stakeholders and having carried out the Functional Analysis. These two stages make it possible to identify the first solutions and to compare them on technical and functional or even economic criteria. Each of the Doughnut indicators is then discussed by the group of work to determine the importance of each:

- Is there an interest for one of the Stakeholders present in this working group?
- What is this interest and why?

With these questions and the needs framing done earlier, the working group can discuss whether or not each of the Doughnut criteria and indicators should be retained in the project they are interested in. We will illustrate our proposal in the following sections.

4 ILLUSTRATION OF THE "SUSTAINABLE VALUE ENGINEERING"

We propose to develop an illustration based on an experimental study.

We proposed to a group of work the grid with the Doughnut criteria and indicators and asked the stakeholders to make an evaluation by asking the question "how do the solutions impact or contribute to these different indicators"? They were asked to evaluate 5 scenarios and one baseline. We proposed that they work in the following way: 1) Position the solutions in relation to the proposed indicators: in what way does each solution have an impact or a contribution? 2) Evaluate, with a scale of 1 - which corresponds to a very strong negative impact on planetary limits and a very limited contribution in terms of social thresholds - to 5 - which corresponds to a nil or even positive impact on planetary limits and a very important contribution in terms of social thresholds. As a result, we have a table (or graph) that allows us to compare the results.

4.1 Experimental study

To validate the hypothesis of using the Doughnut as a support, we proceed in two distinct steps. We have offered a "Doughnut workshop" to 19 master's students (in "engineering and management of the

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environment and sustainable development" of the UTT) as well as to 9 practitioners of the management of complex technical projects. This workshop included an introductory part on the issues of sustainability in technical projects, a general presentation of the functioning of the Doughnut (Raworth, 2012, 2017) then a grip through an example of Doughnut indicators.
In groups of 3 to 5 people, students and industrials should determine from a functional analysis and technical data (origin of materials, weight, pollution, etc.) which bike (simple example to learn) was the most sustainable. The objective of the workshop was to determine if, in a given time of manipulation of the concept, people more or less initiated to the stakes of sustainability were able to have reflection, to exchange or even to converge in relation to these indicators.
Our test led us to determine that indeed, the handling of the Doughnut was relatively easy since over a handling time of approximately 1h30, it is possible to have the first results. We will discuss this after illustrating the case and highlighting the mechanisms that led to obtaining indicators and converging on a sustainable solution via the Doughnut.

4.2 Presentation of the illustration case

The case presented here was used many times now to demonstrate or illustrate how it is possible to use the VE. (Lalevée et al., 2020) mentioned the following case: there is two cities A and B far from about twenty kilometres from one another. The objective of the project is to find some solutions to link up A to B. Existing small roads between A, B are overloaded, and a highway exists near to B from North to South without any exit to lay out B. Furthermore, some residential subdivisions were built on the outskirts of both cities; a river is situated at a few hundred meters of A and B South's limits, and there is a mountain to the North. These topological constraints do not let us think about an "easy" solution. A consulting company is solicited by the Government to determine what is the project (management and Stakeholders) which would design the best solution. As a reminder, the solutions are as follows: the reference is the current system linking cities A and B, by individual transport on small roads or by bus, A is the bus scenario, B is the bus/train scenario, C is the full train scenario, D is scenario bike/train and E is scenario bike/bus. In order to be able to compare these different scenarios in a visual way, the group of Stakeholders decided to try to make a summary graph.
For more details on the course of a classic VA, the authors invite you to read the articles (Lalevée et al., 2020, 2021a).

4.3 Determining the Sustainable Value Analysis

The observations of this section are inspired by the workshops made with students and practitioners.
The needs of the Stakeholders are: 1) functional, i.e. which allow the system to respond to what it was created for This can be "transporting people from city A to city B" for example. We are not going to dwell on this functional dimension which was discussed by (Lalevée et al., 2021a). The second dimension is the 2) non-functional dimension, ie the stakes and ambitions related to the Stakeholders. They can be for example to "preserve local jobs" or "preserve a healthy city for future generations".
Based on these needs, the Stakeholders determined that some indicators from the Doughnut were not useful. The main reasons for not using the indicators were that the stakeholders did not see the benefit for them and the project. In this example, only the following indicators were used to describe the needs, based on (O'Neill et al., 2018):

- "Employment" to represent "preserve local jobs". Indeed, the Stakeholders agreed that the employment rate is representative of the preservation of local jobs.
- "Life satisfaction" and "social support" to represent "preserve a healthy city for future generations". Indeed, Stakeholders agreed that life satisfaction combined with social support indicators are representative of the need to "preserve a healthy city for future generations".

The next step is to determine the notation of each solution. Since we are in the conceptual phases of the project, it is difficult to have precise data. Thus, an expertise based on the group of work made it possible to have these results (see Table 1):

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Table 1. Notation of each solution based on a classical VA and with the Doughnut indicators

Solutions	Classical Value Analysis (/5)			Sustainable Value Analysis (/5)		
	Technical dimension	Economical dimension	Technico-Economic	Social dimension	Ecological dimension	Socio-Ecological
	contribution of the function	cost of the solution		contribution for the Stakeholders	cost for the Stakeholders	
REF	2	1	2	2,6	1	2,6
A	2,5	5	0,5	4	1,1	3,6
B	3	2	1,5	5	1,75	2,8
C	4	2	2	5	1,7	2,9
D	5	2	2,5	5	1,3	3,8
E	1	1	1	5	1,75	2,85

They decided to have a decision-making that compares the technical and economic value, which is to say to balance the technical and financial indicators; and a socio-ecological value, ie social and ecological indicators. To do this, they relate the results of each of the indicators mentioned above. This representation makes it possible to highlight the response to needs (technical vs social) as well as the potential impacts on resources (financial vs ecological). It is a choice of representation that must be discussed and will be in the section dedicated to this.

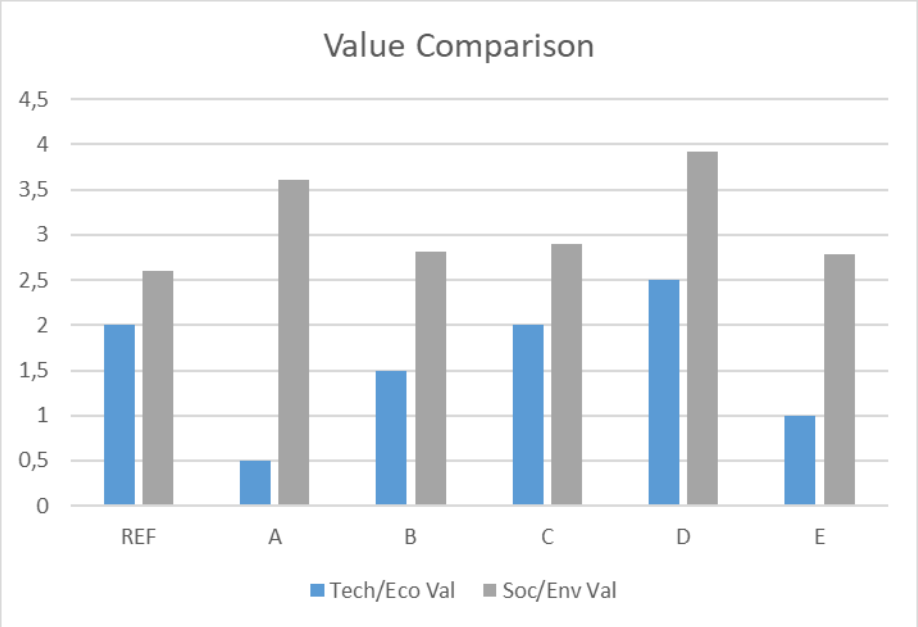

Figure 1. Value comparison of the 5 scenarios and the reference

5 DISCUSSIONS BASED ON THE ILLUSTRATIVE CASE

5.1 The Doughnut as a support: is it useful?

To design complex projects, we know that the upstream phases are crucial and that the Stakeholders of a project are the main levers for their success. We must therefore integrate their needs. We have seen that the integration of Sustainability is a major issue today and that LCA is a method that is limited in introducing these issues despite it being the most used method today. We hypothesized that the

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Doughnut, as defined by (Raworth, 2012, 2017) could be a support for exchange and convergence for the Stakeholders of a project within the framework of a sustainable design.
Value Analysis practitioners, in the context of the design of complex technical systems, today have difficulty integrating sustainability issues. The Doughnut is intended to be a framework for these Value Analysis practitioners. Indeed, the Doughnut makes it possible to establish a “zone” of comfort for all while respecting planetary limits (Raworth, 2012, 2017). In this sense, we assumed that it made it possible to integrate the issues of all the Stakeholders in terms of social and environmental dimensions. From a practical point of view, it was necessary to determine how to use it. Our proposal is to support the Value Analysis methodology with this Doughnut: it is given in a “raw” way to the working group. After carrying out a needs analysis, it is then decided according to everyone's needs, to review each of the Doughnut criteria. This can take time as pointed out during the workshops. This is a limitation to this approach in an industrial setting. If the choice of indicators seems quite simple to make thanks to the framing of needs, a measurement system must be determined. In the upstream phases, what was undertaken is a rating by expertise between 1, the lowest rating, and 5, the best rating. During the tests, what seemed to be the most difficult was to have only this type of very subjective evaluation. The question raised is how to improve the scoring system?
We can conclude that the Doughnut seems to be an interesting framework since it makes it possible to frame social and ecological indicators to be integrated into Value Analysis. However, the tests show limits such as the time it takes to determine the indicators or the scoring system.
Regarding the handling of the Doughnut, we saw that it could be a laborious job. However, and given the universality of the approach, the Doughnut seems to be an easy tool to understand and handle by everyone: students and practitioners in project management had very different profiles, some having no perspective on the issues of sustainability. They all managed to discuss these issues based on the Doughnut, to manipulate indicators from this Doughnut until they converged and compared solutions via this Doughnut. Our tests show that with a little time (1h30 of manipulation), it is possible to compare some technical solutions based on the Doughnut.
The limits that have been noted regarding time are entirely justified in the context of a service or the management of a project. The operationalization of the methodology still needs to be tested. For this, we recommend that VA practitioners define indicators that are useful in their particular context. Indeed, we have that the indicators must meet specific needs. We propose to practitioners, and this could give rise to research work, to determine the "best" indicators and the associated evaluation criteria that would make it possible to operationalize the AVS. It would seem relevant to have an approach by domain since, as we have seen with feedback from AV practices, each has its specificities.

5.2 How to represent the Sustainable Value of a project?

One of the questions raised during the workshops with the practitioners, but also the students, is the final representation of the Value. A classic VA uses curves that highlight the best solution in a given context. This curve is then used to support decision-making, which is often the funder. We have, within the framework of the Sustainable Value Analysis, proposed a graphic representation highlighting the technical-economic value, which is in fact that commonly used in AV and a socio-ecological value. The advantage of this representation is to highlight two systems in play. On one hand, we have the system that we want to design and on the other hand, Earth system. This representation allows at least raising the question of socio-ecological issues in technical projects. To go further in terms of representation, it will be necessary to study the impact that the aggregation of indicators can have on decision-making. At this stage, we cannot give definitive advice on the "right level" of representation to adopt.

5.3 Recommendation for practitioners

We have been able to show that the use of the Doughnut concept seems to be relevant in order to frame the design indicators of complex technical systems, within the framework of Value Analysis. We recommend that practitioners 1) not use this Doughnut is not a finality. Indeed, it is a support for exchanges and convergences for the working group. You have to be able to adapt it to a particular context.

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A second piece of advice that can be given to practitioners is 2) to train in the issues of Sustainability: the use of the SVA cannot be done without knowledge not only of the issues of Sustainability but also of the functioning of the Doughnut and of the work that has been or are currently being conducted.
To conclude, we can say that the Doughnut is a support that is interesting and seems to be mobilized within the framework of an AV in order to have a sustainable approach. However, there is still work to be done in order to have a methodology that is operational in times that are acceptable for practitioners: framing indicators with a measurement system adapted to a context would potentially make it possible to overcome these limits.

6 CONCLUSION

This article allowed us to better understand the limits of VA/VE in the context of design for sustainability and more particularly for collaborative decision-making integrating Stakeholders and the diversity of dimensions of Value.
We have demonstrated that the VA/VE, combined with the Doughnut (Raworth, 2012, 2017) as a support allows 1) to better integrate the Stakeholders in the decision-making process of the by using a collaborative process of construction of the specifications resulting from the VA. It also allows undertaking to disseminate knowledge around Sustainability to all stakeholders and allows creating a new dimension of Value. The combination of the two approaches also makes it possible 2) to integrate a greater diversity of criteria making it possible to define the Value of a system: the model based on the "needs / costs" ratio is extended beyond the current financial and technical values used in the evaluation of complex systems projects.

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