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Subjective evaluation of aggregate supply scenarios in the Ile-de-France region with a view to a circular economy: the ANR AGREGA research project

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Abstract: With growing numbers of construction sites, aggregate supply in the Ile-de-France region (Paris and the surrounding area) will be a major issue in the coming years. This means that dialogue is needed between stakeholders to build and evaluate scenarios together for the future in this area of aggregate supply and waste reclamation. This work had the goal of describing, analysing and discussing the first evaluation of potential scenarios from the thematic and methodological standpoint, asking questions about issues of sustainable circularity in the aggregate sector in Ile-de-France. In the state of the art, tools for objective evaluation are being widely developed in the sector, whereas tools for subjective evaluation remain largely unexplored, hence this work. As results, we have given structure to what challenges will be raised for a circular economy for supplying aggregates in Ile-de-France. However, the challenges are not even for all of the issues, scenarios and impacts.

Keywords: aggregate; construction waste; sectors; circular economy; deliberative process; scenarios; stakeholders; issues; Ile-de-France.

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Philippe Lanceleur holds a Brevet de Technicien Supérieur in Computer Science (Paris) in 1987 and a European Master in Ecological Economics and Sustainable Development Policy, obtained at the University of Versailles-Saint-Quentin-les-Yvelines (France) in 2002. As a PhD student in Economy, at Paris-Saclay University he participated to the AGREGA project. He mainly collaborates to build and maintain the ePLANETe technical platform, in order to create multiuser environment that provides multi-stakeholder, multi-criteria tools.

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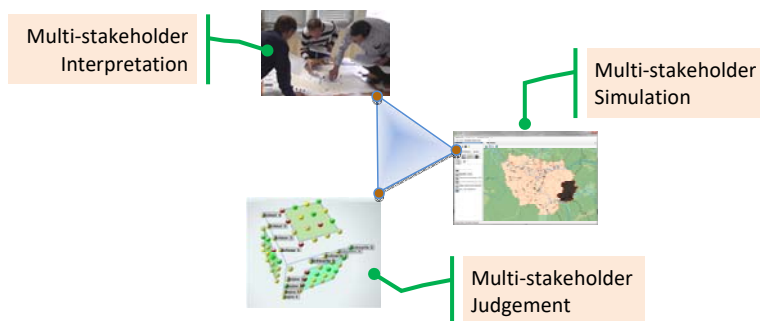
1 Introduction

With the construction of the Grand Paris Express project (SGP, 2018), the construction of 70,000 housing units per year, the organisation of the Olympic Games in 2024, the Europacity project, etc., supply of aggregate in the Ile-de-France region (Paris and the surrounding area) will be a major issue in the coming years (PanoramaIdF, 2017). So, facing this expected growth in demand, the profession has forecast possible production

issues, as different constraints become more intense (PIPAME, 2016): de facto constraints (urbanisation and the like), environmental constraints (recommendations from the French authorities, in this case the regional department for energy and the environment, DRIEE, to reduce alluvial production) and societal constraints (resistance by residents to new facilities because the activity is a source of inconvenience). Waste recycling still remains an option because, among others, the process benefits from better resident acceptability (possibility of facilities in urban areas, backfilling quarries), and it is supported by a European Directive (OJEUW, 2008) that sets a minimum material reclamation objective for 2020 at 70% by weight of waste from construction and demolition activity. However, the use of recycling remains limited (ratio capped in concrete production, cost of materials handling still estimated to be high, etc.). What is more, because of competition, the sector perceives resistance from companies establishing inert waste storage facilities. So after the Ile-de-France region (IdF, for short) recommended suspending the extension/creation of new inert waste storage facilities in Seine-Et-Marne for 3 years, to boost recycling (PREDEC, 2015), this measure was cancelled (Le Parisien, 2016).

The entire situation justifies the need for all those involved in Ile-de-France to talk and together build future scenarios for aggregate supply and waste reclamation, a dialogue whose results would contribute to the implementation of future regional schemes for quarries and regional plans for management of construction waste. To implement this, the idea, inspired by Chamaret et al. (2009), consists in leveraging scientific methods that publicly recognise the plurality of the values and, in the same way, to publicly indicate the issue of the research (or lack of research) for all the diverse stakeholders coexisting. These scientific methods would allow stakeholders in Ile-de-France to mould more, sometimes diverse opinions, on the different scenarios that they build together. Consequently, this multi-stakeholder discussion should not be about eliminating the contradictions but instead to admit them and discover original ways to articulate them and allow action.

Figure 1 The three AGREGA tools developed to analyse scenarios (see online version for colours)



Financed by the French Research National Agency (ANR) as part of its theme ‘Towards a Circular Economy – Associated Methodology and Services’, the AGREGA¹ project wants to provide a cornerstone in supplying scientific means of dialogue, by developing three tools that are functionally independent but complementary: a set of scenario interpretations (role playing games), a model for simulating scenarios and a tool for evaluating scenarios (see Figure 1). The simulation tool evaluates ‘aggregate and

construction waste' systems *objectively* (by estimating variables) whereas the judgement tool evaluates these systems *subjectively* (giving a social meaning), and the role-playing games fall in between.

In this article, the authors ask about the circularity issues in aggregate supply in the Ile-de-France region, a question answered using the multi-stakeholder judgement tool in Figure 1. More precisely, the article's objective is to report, analyse and discuss the theme and methodology of how the evaluation process is achieved for the first time with the different stakeholders in Ile-de-France that it has been possible to meet. The challenge is to build an evaluation that integrates the question of circularity in the aggregate sector.

The rest of the article is organised to reflect on the intellectual pathway followed to do the work. Section 2 describes the circular nature of the aggregate sector. Section 3 then presents the methods and tools used for this subjective evaluation of scenarios and Section 4 presents and analyses their results. Section 5 discusses the work, both in terms of theme and methodology, and Section 6 concludes the article.

2 The circularity of the aggregate sector

2.1 Definition of the circular economy (CE)

How to define circular economy (CE) is hotly debated, mainly due to the abundance of concepts featuring it. Some scholars for example even claim that the CE stands on 'shaky ground' (De Man and Friege, 2016). Geisendorf and Pietrulla (2018) *inter alia* suggested a revised definition of the CE by better redistributing the concepts currently existing among, on one hand, boundary conditions or enablers, and on the other hand, a CE's core characteristics.

While we await a clear conclusion, let us summarise CE as an economic model whose objective is to produce goods and services sustainably, limiting consumption and waste of resources (raw materials, water, energy) and waste production. This breaks the linear economy model (extract, produce, consume, discard) to move to a 'circular' economy model.

The concept of CE officially entered into law in France in the law on Energy Transition for Green Growth of 17 August 2015 (JORF, 2015). This law recognised the transition to a CE as a national objective and as one of the pillars of sustainable development.

The transition towards a CE requires progress in several domains:

- sustainable supply: take into account the environmental and social impacts of the resources used, particularly those associated with their extraction and exploitation
- eco-design: taking into account environmental impacts on the entire life cycle of a product and integrate them from the design stage
- industrial and territorial ecology: synergise and mutualise between several economic stakeholders the flow of materials, energy, water, infrastructures, goods or even services to optimise the use of resources in a region
- the economy of functionality: prefer use to possession, sell a service rather than a good

- responsible consumption: take into account the environmental and social impacts of all steps in the product life cycle in the choice of purchasing, whether the buyer is public or private
- lengthening the duration of use of products by means of repair, second-hand sale or purchasing, or donations, as part of reemployment and reuse
- improvement of prevention, management and recycling of waste, including reinjecting and reusing materials from waste in the economic cycle.

The law of CE also contains structuring objectives concerning waste prevention and management:

- waste prevention: to reduce by 10% the quantities of household and similar waste, and to stabilise the quantities of waste from economic activities produced in 2020 relative to 2010
- recycling: to reach in 2025 65% of recycling for non-hazardous non-inert waste
- to reduce landfill by half in 2025 relative to 2010.

The CE has been a substantial area of work for the European Commission for a long time (OJEUW, 2008). Like in France, the CE is perceived at the European level as a means of improving the environment, while strengthening and sustaining the industry, particularly by securing the supply of raw materials through greater use of materials from waste recycling. The move to a CE is at the core of the initiative on the effective use of resources established from the Europe 2020 strategy for intelligent, sustainable and inclusive growth.

By means of cyclic economic processes, the CE reduces consumption of natural resources (including energy) and net waste emissions. The CE therefore relies on the creation of ‘positive loops’ for each use or reuse of the material or product, whether this is within an economic or ecological process. It affirms the rule of 4Rs, as adopted in a French context²:

- 1 reduce
- 2 reemploy
- 3 reuse
- 4 recycle.

We also note the approach of the CE with respect to environmentally sustainable development objectives:

- first, to reduce environmental pressures to respect the biosphere’s ‘capacity’
- secondly, investments in eco-innovations for ‘virtuous cycles’ that contribute to the biosphere’s major cycles.

2.2 The circular economy and the aggregate sector

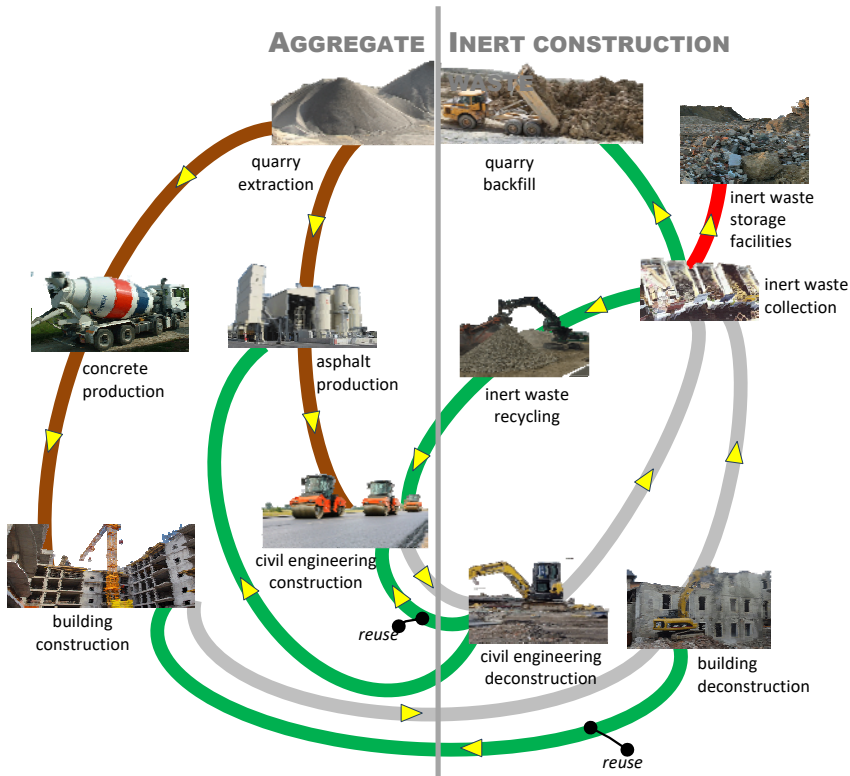
So, how are these forms of circularity expressed in the scope of the aggregate sector?

The CE is in reality a major issue for the aggregate sector (PIPAME, 2016) and more generally the construction sector (e.g. the sector for civil engineering and building construction). Consequently, in the construction sector we also see the preceding rule of 4Rs:

- *Reduce*:
 - a use of natural resources
 - b send waste to landfill, and instead use recycling or reclamation.
- *Reemploy* excavated soils from deconstruction, for backfill on the same site, or elsewhere.
- *Reuse* inert waste from asphalt from deconstruction:
 - a for road construction
 - b for backfill of quarries at end of life.
- *Recycle* waste to be integrated into road construction.

Figure 2 tells us how to express forms of circularity in the aggregate sector, in terms of materials. This figure is inspired by (PanoramaldF, 2017) but there the ‘waste’ section focuses on inert construction and demolition waste (CDW).

Figure 2 A view of circularity in the aggregate sector, focused on the secondary circuit (on the right), on inert construction waste (see online version for colours)



In the rest of this article, the term ‘waste’ will implicitly refer to inert construction waste, unless otherwise indicated.

2.3 Literature review of the aggregate sector and circularity

Work on the aggregate sector and its circularity (CDW management) covers a part of the whole value-chain depicted in Figure 2. For example, Augiseau and Barles (2017) estimate the consumption of concrete components (aggregates, sand, cement, etc.) as well as the quantity of materials that could potentially be recycled tomorrow, through urban mining so partly substitute for primary resources in highly urbanised countries. Other work identifies the impact of concrete design mixes in terms of the environment (Göswein et al., 2018) or performance (Fraj and Idir, 2017) according to, inter alia, the aggregate types – including recycled aggregates - used for that design. Rodriguez-Chavez (2010) and more recently Ioannidou et al. (2015) chose to focus on quarries in the construction industry. The former simulates aggregate resource extraction including as scenarios the recycling of demolished concrete, and the latter developed indicators (physical, societal, economic and more) – including recycling of demolished concrete – which are potentially determinants of the access acceptance to quarries. Finally, Fevre-Gautier et al. (2012) at a local scale and Mignon and Bréquel (2017) at a national scale focused their work only on the CDW circuits. They particularly studied barriers, legislation, practice, etc. regarding CDW management in France or in other countries like Belgium.

Although useful, all these tools (generally in the form of simulation models or maps) can mainly be used for objective evaluation (i.e., for modelling and estimation of variables) of the issues and management options in the aggregate and CDW sectors. On the other hand, tool development for subjective evaluation (i.e., to give societal meaning of these objective results, according to each stakeholder) remains largely unexplored for the sectors. We think the analytical process should be reversed: since making stakeholders collectively debate is the expected end, such a subjective evaluation (societal judgment) of issues and options by multiple stakeholders should be the entry point of the study, and this should then be evaluated in a structured and methodological way. From that entry point, different sources of knowledge like models could then be mobilised, for example, to focus the dialogue about options and to make unavoidable judgments more considered (Epstein, 2007). Another possible source of knowledge is role-playing games (recall Figure 1 for the global scheme for AGREGA).

Regarding the CE, we should mention the table top board role-playing game named risk and race (RR) designed by Vito (2018). Supported by the European Institute of Innovation and Technology (EIT)/Raw Materials (EIT_RM, n.d.), and developed for educational purposes. RR is an engaging and hands-on way to learn about the opportunities and challenges of the CE. Nonetheless, like with the above modelling tools, this game makes no explicit mention about the structure of the collective debate that drives its use.

Starting from this state-of-the-art, our work first focuses on the subjective evaluation itself. We then return to the situation of the knowledge sources (particularly modelling and role-playing game tools) in the discussion section (Section 5.2).

3 Methods and tools

Because of the circular structure of the aggregate supply, we suggest grasping it on several levels:

- categories of stakeholders that represent the various production phases, expressed in Figure 2
- performance issues, i.e. the conditions (expressed by the stakeholders) in which the aggregate supply and waste reclamation system for Ile-de-France falls into a CE
- scenarios of aggregate supply and waste reclamation
- indicators, to be identified and mobilised in the evaluation process.

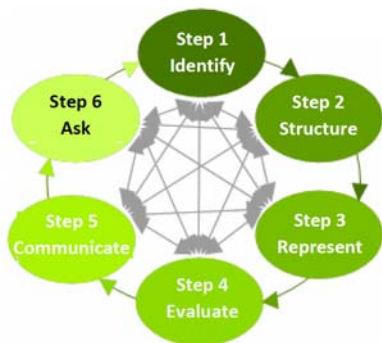
So we propose a multi-stakeholder and multi-criterion approach to evaluation. This approach engages the different stakeholders in constructing place for policy and environmental debate in a deliberative perspective, i.e. with the exchange of opinions in a constructive dialogue (O'Connor, 2002; Dryzek and List, 2003; Blondiaux, 2008; Douguet et al., 2009). The approach also allows the comparison of different aggregate supply and waste reclamation scenarios.

3.1 Methodology

To structure the mobilisation of the knowledge necessary for multi-stakeholder and multi-criterion evaluation of aggregate supply and waste reclamation scenarios, the meta-method of integrated environmental evaluation INTEGRAAL (Maxim and O'Connor, 2009) was adopted (as the added value of this paper is not in comparing methodologies used for multi-criteria analysis, we chose INTEGRAAL because it is an adequate methodology for this study). The INTEGRAAL meta-method (details below) allows deliberative processes for each of these stages. We conceived this deliberation as the establishment of dialogue between actors in order to collect diverse perspectives and to exchange in a structured way. The dialogues between actors can occur in restricted committees or a collective way, according to the stages in which they are inserted.

INTEGRAAL is a meta-method which, through six main steps (that are not necessarily linear), aims to engage experts and stakeholders in an integrated evaluation process (see Figure 3).

Figure 3 The meta-method, INTEGRAAL (see online version for colours)



The INTEGRAAL meta-method applies to the AGREGA problem as follows:

- Step 1 Identification of terrains, objectives and scenarios (to regional and local scales) for aggregate extraction and/or recycling, which may simultaneously meet the criteria for technical feasibility, of economic profitability, of environmental quality and societal acceptability.
- Step 2 Structuration of the problem of ‘social choice’, in terms of stakeholders, categories of performance issues (e.g. sustainability of environmental services, economic viability, institutional feasibility) and options for action (scenarios). This step stands both on a deeper field study (including interviews) and of the literature.
- Step 3 Mobilisation of tools to represent the situation. As part of AGREGA, it is in this step that the role-playing game tools and prospective simulation will be added (see Figure 1), to determine systems of changing indicators that will characterise the forms of circularity, the zones and territories, on regional and local scales.
- Step 4 Mobilisation of stakeholders of step 2 for a multi-criterion evaluation of aggregate supply and waste reclamation scenarios from a varying range of indicators obtained previously.
- Step 5 Communication of results of the study to participants but also to the wider public. Then the process moves from research to decisions.
- Step 6 Feedback on experience on how the evaluation approach occurred.

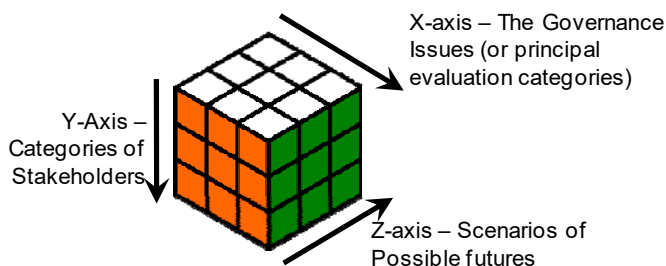
As part of the AGREGA project, the ePLANETe portal is mobilised as a structural element of the implementation for the INTEGRAAL meta-method. The development of ePLANETe as a ‘Knowledge Portal’ is part of a movement to create an interpretative website for the discovery and deliberation of problems for sustainable development. We could consider, more technically, modelling of eco-socio-economic systems, as an innovative and experimental integral participatory approach.

3.2 Tool for subjective evaluation

To allow comparison of different aggregate supply and waste reclamation scenarios, we selected the ‘deliberation matrix’ tool, an online tool for multi-stakeholder and multi-criterion evaluation from ePLANETe. Designed on the idea of the Rubik’s Cube(TM), the deliberation matrix constitutes a method and an electronic tool that allows the comparison of forms of associated injustices to be structured with different socio-environmental conflicts. It implements three axes of multi-criterion and multi-stakeholder evaluation (Figure 4):

- 1 an axis of categories of stakeholders, those who will make an assessment
- 2 an axis of performance issues
- 3 an axis of supply and reclamation scenarios.

Figure 4 Summary of axes involved in the subjective evaluation (see online version for colours)



This matrix is filled in two steps.

The first step is the definition of elements located in the various axes, with the following questions:

- Scenarios axis: which are the situations to be compared?
- Issues axis: what are the criteria for comparison?
- Stakeholders axis: who are the stakeholders?

Figure 5 Example of a segment of the deliberation matrix (see online version for colours)

[illegible]

The second step of completion is the conclusion itself. The stakeholders' conclusion corresponds to the intersection of the three axes. For each of the different scenarios studied, the conclusion is made by creating a 'matrix segment' presented at the intersections, risks and opportunities, as expressed by a category of stakeholders, by resituating relative to the performance issues (see an example of the segment in Figure 5). The matrix is therefore composed of different segment representing the conclusions issued by the different categories of stakeholders.

To draw a conclusion, an individual or a group of individuals is asked to state their opinion on the interest of the set of scenarios for all of the issues. None of the scenarios, issues or categories of stakeholders is weighted. The idea is to have a common knowledge base concerning the conclusion that different categories of stakeholders may have concerning the scenarios.

The conclusion is composed of a basket of indicators composed of one to five indicators that come either from preselected indicators, or from indicators proposed directly by the stakeholders themselves. For each of the indicators selected, a conclusion will be drawn. It is composed of a value conclusion, which is conducted from the choice of a colour:

- green for 'good'
- red for 'bad'
- yellow for 'so-so'
- white for 'do not know'
- blue for 'no opinion'.

For each of the indicators, it is possible to provide a commentary to justify the choice of colour and to attribute a subjective weight to assign the importance of the argument in the global decision. The weight of each indicator in the argument may be relativised by using a subjective weight (defined by the stakeholder). There is a 'comments' area for specifying their choice of conclusion.

To draw a conclusion concerning a *STAKEHOLDER 1/SCENARIO 1/ISSUE 1* trio, from one to five indicators are selected, attributing a value and a subjective weight and if possible, a comment (see Table 1).

Table 1 Draw a conclusion in the deliberation matrix (see online version for colours)

<i>Scenario 1/Issue 1</i>				
<i>Name of the indicator</i>	<i>Value</i>	<i>Subjective weight</i>	<i>Comment</i>	<i>Summary conclusion</i>
CO ₂ emissions		15%	Related to road transport	
Water quality		15%	COD < 125 mg/l	
Quality of biodiversity		15%	Diversity of species	
Quantity of water consumed		20%	Drop 10%	
Landscape quality		35%		

The indicators used to express its conclusion may be quantitative or qualitative indicators. The indicator is taken in the broad sense, i.e., any piece of knowledge that the stakeholder considers to be of interest to express their conclusion. Here it is not the

quantification or qualification of the indicator that is important, but the meaning that the stakeholder attributes to the conclusion.

The colours in the matrix are attributed as follows:

- when the values selected in the indicators are not the same, as in the example in Table 1, summary conclusion proportionally fills with the dominant colour (here, 80% green)
- where there are two indicators, one green and the other red, the red value is shown (the less favourable value is selected in the summary conclusion, which favours dialogue between the stakeholders)
- when there are three indicators each with different values, it is the yellow that is shown as summary conclusion (uncertainty).

In the example in Figure 6, three indicators were selected to show the representative diversity of indicators to draw a conclusion (O'Connor and Spangenberg, 2008). This is ability to respond, sustainability of activities and supply/interruption. More precisely, this is selecting a small number of indicators that express the diversity of points of view on the intersection of the axes of the deliberation matrix in question.

Figure 6 Basket of indicators for intersection (see online version for colours)



So the point is not to seek exhaustively, but to select indicators that will serve as arguments in the conclusion expressed through this basket of indicators. Each of the arguments may have a different subjective relative weight (all the arguments have the same relative weight 100% in this case).

Table 2 Analysis of conclusions, for a given stakeholder, in the deliberation matrix (see online version for colours)

	<i>Scenario 1</i>	<i>Scenario 2</i>	<i>Scenario 3</i>	<i>Scenario 4</i>	<i>Scenario 5</i>
Issue 1					
Issue 2					
Issue 3					
etc.					

For one category of *STAKEHOLDER*, the results of the evaluation for all of the scenarios and issues (or matrix segment) will be presented, *at the first level of interpretation*, in the form shown by Table 2. Other categories of stakeholder will also have their matrix segment.

On the *second level* of interpretation, for all *STAKEHOLDER/SCENARIO/ISSUE* intersections, we can identify indicators and arguments selected to draw the conclusions (see Table 1 on how to draw a conclusion).

Results can be analysed as follows. For *SCENARIO 1*, conclusions are drawn on a first level of interpretation, as shown in Table 3.

Table 3 Analysis of conclusions, for a scenario 1, in the deliberation matrix (see online version for colours)

	Stakeholder 1	Stakeholder 2	Stakeholder 3	Stakeholder 4	Stakeholder 5
Issue 1					
Issue 2					
Issue 3					
etc.					

A *third level of interpretation* exists. It is at the level of indicators. Here the uses of a given indicator are given as part of the deliberation matrix. Then we know who mobilised this indicator, talking about which issue(s) and which scenario(s).

4 Results when applied to aggregate sector and circularity

The first step for completing the deliberation matrix is to define the elements of the various axes (step 2 of INTEGRAAL):

- scenarios for aggregate supply and waste reclamation
- performance issues
- stakeholders identified during the AGREGA project.

The deliberation matrix was constructed in two deliberative stages. The first step was to construct the values of the three axes of the deliberation matrix. During the period April to June 2014, 26 interviews were conducted with producers of aggregates, the French government and its representatives, the Ile-de-France region, local public actors, consultants from public authorities, users (public works), etc., actors in the supply chain, environmental use associations, scientists, user representatives (fishermen). Initially, from the elements provided during the interviews, this established, using a discourse analysis, a first list of performance issues. This also made it possible to finalise the list of actors to be interviewed. This first proposal of performance issues was deliberated within the AGREGA project's user committee in March 2015. This user committee is made up of representatives of the stakeholder categories named above.

These interviews also provided first elements for the establishment of the scenarios and were discussed at this committee as well as at another user committee in April 2016, to establish the bases for the construction of the narratives of the five scenarios. These

five scenarios consist of a narrative and an estimate of the needs in terms of aggregates and their use, waste produced and their use in a circular economy perspective. These narratives and estimates were produced from the different interactions that the authors had with the stakeholders, either as part of the interviews or as part of the user committee.

During the second phase, from June–October 2017, the goal was to fill in the deliberation matrix. We contacted the different stakeholder categories and formed groups to fill in slices of the matrix. The deliberation took place in groups that bring together representatives from the same category. Interactions between the participants made it possible to enrich the filling of the deliberation matrix slices by introducing new information, by making explicit controversies (Dryzek and List, 2003), and improved the proposals for performance issues and the description of the scenarios. A final workshop has to be organised to give feedback to participants.

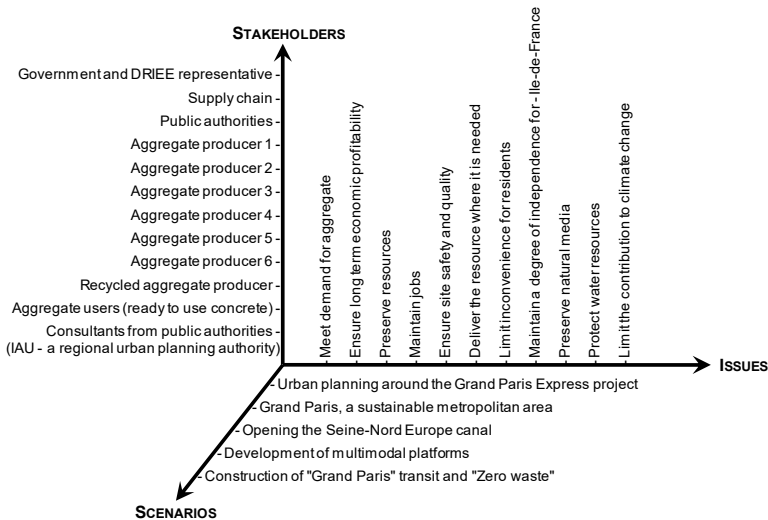
To identify the people who could help us achieve this goal, stakeholders were inventoried by the members of the AGREGA project. During the interviews, the stakeholders we met were also asked to refer others they thought would be relevant to enrich this first corpus.

We ended with 26 interviews, from which we could understand and structured a system for ‘Aggregate Supply in Ile-de-France: its stakeholders, issues and possible scenarios.’ We also gathered needs declared by the stakeholders on the prospective tools (See Figure 1) developed in AGREGA and invited the stakeholders to actively invest in the implementation of these tools.

4.1 Results for the elements on the three axes

Using the schematic organisation of the three axes in Figure 4, Figure 7 summarises those elements for the interviews.

Figure 7 Summary of elements on the stakeholders/issues/scenarios axes



4.1.1 Stakeholders identified

Ten categories of stakeholders were identified to represent the diverse primary and secondary (recycling) group in the aggregate sector:

- aggregate producers (professional associations, integrated groups, small and medium-sized businesses)
- national bodies and their representatives (MEDDE, DREAL, DRIEE, the prefectures)
- Ile-de-France region
- local public stakeholders (general counsels, Société du Grand Paris, SCOT, PNR, etc.)
- consultants from public authorities (IAU, ADEME, Agence de l'Eau, etc.)
- users (union representatives from the Fédération Nationale des Travaux Publics, Syndicat Français des Industries Cimentières, Syndicat National des Entreprises de Démolition)
- stakeholders from the supply chain (e.g., HAROPAPORT, SNCF, VNF, RFF)
- scientists
- community associations (e.g., environmental associations)
- user representatives (fishermen).

The last two stakeholder categories did the initial interview (to set up the three axes) but did not participate in the concluding session. In the category of aggregate producer, six different stakeholders were interviewed. So in all, the stakeholders axis has 12 stakeholders (see Figure 7).

4.1.2 Performance issues identified

We identified 11 performance issues. These issues represent the conditions in which the 'Aggregate supply and waste reclamation in Ile-de-France' can be viewed as part of a CE (Chamaret, 2015). These performance issues show challenges for the economy, not only through accounting for materials circularity, but also how the activity affects biosphere cycles (water, carbon, biodiversity).

The list of issues is summarised on the issues axis in Figure 7 and is detailed below.

4.1.2.1 Meet demand for aggregate

Ile-de-France consumes about 30 million tonnes of aggregate per year. Its needs are essentially for concrete for building and future transport infrastructure (As road structures are in a good state). The Grand Paris project causes a substantial unknown for future needs. Aggregate producers only have a few levers on demand. They can only meet demand. One of the difficulties in managing aggregate supply is related to the lack of information on needs, which makes the work of planning difficult for all stakeholders.

4.1.2.2 Ensure long-term economic profitability

The production of aggregate requires substantial onsite investments, so long-term management is required (it may take more than ten years to open a site). This element causes relative inertia in companies, who cannot change strategy quickly.

4.1.2.3 Preserve resources

Aggregate is an exhaustible resource, though reserves are still substantial in France. Nevertheless, increased scarcity of alluvial resources, a high quality material, mean that it is now reserved for more noble uses like concrete manufacturing, whereas previously it had been also used for roads. This observation obliges the profession to find alternatives to this material, and also new uses.

4.1.2.4 Maintain jobs

Quarries provide jobs. The 1,550 companies employ 14,660 people. Indirect jobs are estimated at 50,000 (UNPG, 2011). These are mainly onsite jobs, so they are important in the current economic context.

4.1.2.5 Ensure site safety and quality

Quality and safety issues are substantial in construction. However, they do compete with the issue of resource preservation. Research and development work has been conducted in various fields (constructors, concrete and cement producers, quarrymen) to ensure the same quality of work with less material. This question is being asked particularly for materials from recycling, whose use today is very regulated. This issue could also be looked into for understanding the development of new techniques related to recycling.

4.1.2.6 Deliver the resource where it is needed

For aggregate, the question of transport and logistics is major: for heavy but cheap resources, transport costs make up a substantial portion of final cost. Aggregate transporters double their price for every 30 km. So there is a massification issue for the resource for better economic profitability.

4.1.2.7 Limit inconvenience and disturbances for residents

Aggregate extraction does not profit residents, yet they have to suffer the disturbance it causes: noise, dust, traffic, changing landscape, etc. Ever increasing opposition to quarries opening is an expression of NIMBY (not in my back yard) syndrome that we often find for industrial activity. Elected officials, often unaware of materials questions, often follow the opinion of their constituents and oppose projects (in particular by producing urban planning regulation).

4.1.2.8 Maintain the current degree of independence for Ile-de-France

Ile-de-France extracts about 11 million tonnes of aggregate per year, to which we must add the production of alternative materials from concrete recycling, asphalt and clinkers from incineration of household waste (5.5 million tonnes). With its average annual consumption of 30 million tonnes, the region has an average need deficit of 45%. Therefore we must import materials from nearby regions but also places further away like Belgium. The decisions to export or not to Ile-de-France are firm decisions, following political reorientations. Therefore, it is important that the region displays a desire to maintain a level of dependence of maximum 45%, even if the feasibility of this objective is questionable for some stakeholders.

4.1.2.9 Preserve natural media

There are differences of opinion on the question of whether quarries are beneficial to natural media or not. However, the impacts of the activity on natural media exist. Increased societal interest for the preservation of the environment makes it harder and harder to access the resource with ever increasing exclusion zones.

4.1.2.10 Protect water resources

Using aggregate may cause impacts on water resources: water consumption for washing and transformation, risk of proximity to water catchment areas, etc. Using alluvial resources poses a particular problem. Water management plans (Called SDAGE in French) enforce tighter and tighter constraints. It happens that the quarrymen do not obtain enough water to allow them to wash the resource.

4.1.2.11 Limit the contribution to climate change and pollution

Like all industrial activity, quarries consume energy and emit greenhouse gases when they extract, transform and transport resources. Depending on the materials and modes of transport, the impact is of varying degrees. However, the difficulties in accessing the resource lead to sites becoming progressively further from production and therefore of greater and greater distances having to be covered. This point means that for some stakeholders, this question is one of the most important for activity.

4.1.3 Scenarios identified

Aggregate is a low value-added product. Its price depends mainly on transport and handling costs. Imagining supply scenarios from a CE perspective requires identification of key variables and how they change over space and time, depending on the various contexts.

As a result, five aggregate supply and waste reclamation scenarios (Horizon 2018-2030) have been defined, with broad participation, to envisage different situations in which the opportunities and risks of developing a CE around aggregate supply are mixed.

4.1.3.1 Urban planning around the Grand Paris Express

This scenario proposes:

- a Retaining the major developments that are part of constructing Grand Paris for a more cohesive region.
- b Anticipating environmental changes.
- c Consolidating the attractiveness of this space. In this vast project, components relate to:
 - 1 improved habitat
 - 2 rail infrastructure that needs to be modernised and developed.

A network transport project, the Grand Paris Express, whose route has been specified and should achieve this.

4.1.3.2 Grand Paris, a sustainable metropolitan area

This scenario repeats much of scenario 1, but also integrates new aggregate needs relating to organising the 2024 Summer Olympic Games in Paris, Europa City, redevelopment of the Plateau of Saclay.

4.1.3.3 Opening the Seine-Nord Europe canal

This scenario carries out in two steps. The first step is the construction of the Seine Nord Europe canal, which will connect the river Oise to the Dunkerque-Escaut canal, from Compiègne to Aubencheul-au-Bac, near Cambrai. The large canal construction site (107 km) will lead to redevelopment for 7 years (from 2018 to 2024) requiring substantial transport of materials such as backfill and rubble, rip-rap and alluvium, of about 57 million cubic metres. In a second step, from 2024, river transport will become more important, rising from 28% today to 30% in 2030.

4.1.3.4 Development of multimodal platforms in the transport of aggregate and waste

The development of massified, alternative and complementary modes of transporting merchandise other than roads is a national political priority in France. These alternative modes would actively contribute to the reduction of greenhouse gas emissions (this may coincide with the French regulation on the polluting emissions of motors [Engins Mobiles Non Routiers (EMNR)] coming into effect in 2019). To tackle this situation, various choices have been made. One is to develop multimodal platforms in a 30 km network around Paris Petite Couronne (inner Paris), along supply axes (rail, river, road).

4.1.3.5 Construction of 'Grand Paris' and 'zero waste'

In this scenario, the objective is to achieve 'zero waste' to inert waste storage facilities to maximise recycling and reclamation. In the regional plan for prevention and waste management from construction sites (PREDEC, 2015), six major issues have been identified, looking out to 2020 and 2026:

- 1 generalise and systematise recycling
- 2 strengthen offering and develop the demand for recycled aggregate
- 3 develop reemployment, reuse and recycling of inert excavated earth
- 4 supervise practices during soil raising
- 5 favouring backfill by inert waste as part of redevelopment of quarries
- 6 ensuring territorial re-equilibration of storage capacities for inert waste.

4.2 Analysis of the evaluation of scenario 5 (zero waste)

Once the elements on the axes are identified, the second step is the phase of drawing a conclusion. Those results are presented here.

However, given the high number of conclusions drawn (5 scenarios * 11 issues * 12 stakeholders), this article will only show and analyse, for illustration, a single segment of the matrix (see Figure 8): the one where each stakeholder expresses their opinion on the ability of scenario 5 (zero waste) to meet the 11 issues. This scenario explores increasing demand for recycled aggregate and limitations on waste deposit in inert waste storage facilities. Three main questions are highlighted in the analysis of this scenario.

Figure 8 The segment of the matrix where each stakeholder makes a conclusion on scenario 5 (zero waste) and according to the 11 issues (see online version for colours)

Sub: "Zéro déchet"	Aggregate P...	Aggregate P...	Aggregate P...	Aggregate P...	Aggregate P...	Aggregate P...	Supply Chain	Aggregate U...	Aggregate P...	Public Aut...	Advisers...	State and ...
Aggregate D... <input checked="" type="checkbox"/>												
Profitabil... <input checked="" type="checkbox"/>												
Resources ... <input checked="" type="checkbox"/>												
Employment <input checked="" type="checkbox"/>												
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IDF Indepe... <input checked="" type="checkbox"/>												
Preservati... <input checked="" type="checkbox"/>												
Water prot... <input checked="" type="checkbox"/>												
Climate ch... <input checked="" type="checkbox"/>												

The first question is on the issue of 'meeting demand for aggregate' (Figure 8). Table 4 traces indicators used to express the diversity of stakeholder judgements for this issue.

For aggregate producers, on one hand, recycled aggregate is still an ideal component for road construction (choosing green). On the other hand, they wonder about the quality of recycled aggregate to meet all the qualities for concrete production (choosing red). Recycled aggregate producers are reserved about this issue because, the regional plan in Ile-de-France especially covers non-hazardous waste and not inert waste, and that plan does not really have any impact on building regulations.

Table 4 Indicators list for aggregate demand issues

<i>Indicator name</i>	<i>Value</i>	<i>Stakeholders</i>
Accompanying elected politicians	Good (1x)	Consultants from public authorities (1x)
Collaborative approach	Good (1x)	Consultants from public authorities (1x)
Demolition field	Good (1x)	Aggregate producers (1x)
Deposit for recycling	Good (1x)	Aggregate producers (1x)
Market	Bad (1x)	Consultants from public authorities (1x)
Product quality	So-So (1x)	Aggregate users – concrete manufacturing (1x)
Recycling	Good (1x)	Aggregate producers (1x)
Recycling – brand image	Bad (1x)	Aggregate producers (1x)
Recycling – concrete quality	Good (1x)	Aggregate users – BPE (1x)
Industry strategies	Good (1x)	Consultants from public authorities (1x)
Stability of recycling market	Good (1x)	Aggregate users – BPE (2x)
R&D in recycling	So-So (1x)	Public authorities (1x), Aggregate producers (1x)
Insurance practices	50% bad (2x)	Aggregate producers (1x), Aggregate producers (1x)
Recycling – compatibility	So-So (1x)	Aggregate producers – recycling (2x)

Consultants from public authorities are, on the one hand, convinced that reclaiming/recycling the waste is a good idea to meet demand even if we close all the inert waste storage facilities. On the other hand, they face the necessity that recycled aggregate stakeholders must collaborate to develop new opportunities locally and that there is a need for R&D in this sector. This collaboration could take the form of developing a common recycling platform (as presented in scenario 4).

This proposal is also related to the second question about the independence of the Ile-de-France region concerning aggregate supply. The desire is to maintain a level of dependence of maximum 45%. The main blockage for the use of recycled aggregates to develop the circular economy, according to public authorities, is linked to existing standards. Users of ready-to-use concrete feel that for the ‘zero waste’ scenario if we limit the use of recycled aggregate to a maximum goal of 20% (currently at 10–15%), increasing the recycled portion in concrete is a promising option to meet their need for aggregate (choosing green).

The third question is about profitability (see Table 5). This question is often evoked in parallel with challenges of ‘preserving resources’ and ‘maintaining jobs.’ On the one hand, this scenario is considered by aggregate producers as an opportunity for developing new products, as long as over the long term, the volume is permanently compatible with the ability for absorption in Ile-de-France (choosing green but only a half). On the other hand, they wonder about the economic and environmental performance of the use of recycled aggregate in concrete: the price of the recycled aggregate, risks associated with recycled aggregate, needing more transportation, needing more cooperation and coordination to develop competitive platforms for recycling.

Table 5 Indicator list for profitability issues

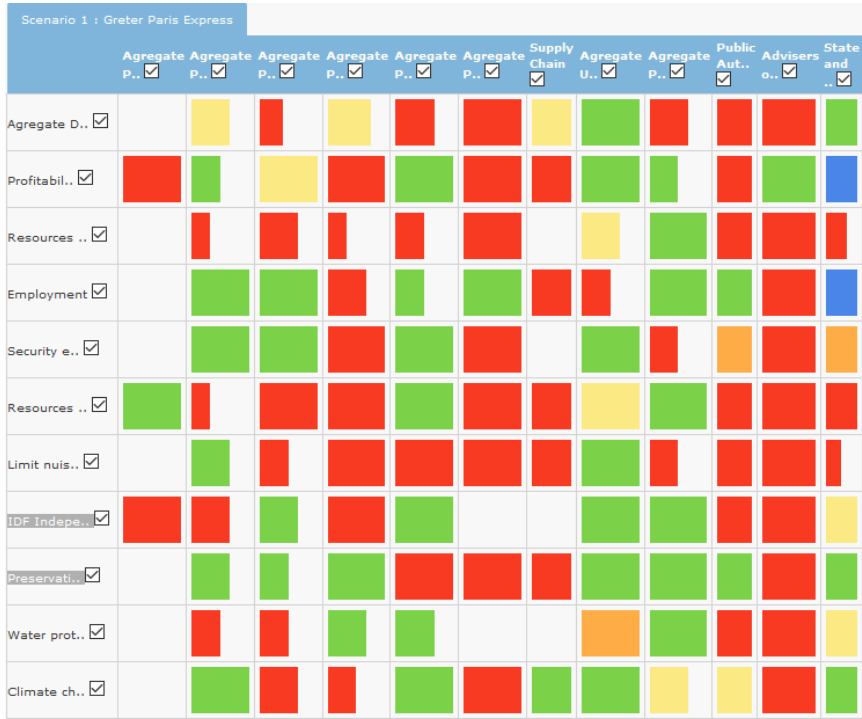
<i>Indicator name</i>	<i>Value</i>	<i>Stakeholders</i>
Supply	Good (1x)	Aggregate producers (1x)
Competition	So-So (1x)	Aggregate producers (1x)
Cooperation - competition	Bad (1x)	Aggregate producers (1x)
Coordination of actors	Good (1x)	Aggregate producers (1x)
Diversification of sources of supply	So-So (1x)	Public authorities (1x)
Public subsidies	Bad (1x)	Aggregate producers (1x)
Optimisation of supply chain	So-So (1x)	Aggregate producers – recycling (1x)
Durability of demand over time	So-So (1x)	Aggregate producers (1x)
Recycling of excavated material	Bad (1x)	Aggregate producers (1x)
Cost of backfill	So-So (1x)	Aggregate producers – recycling (1x)
Risk	Bad (1x)	Aggregate producers (1x)
Technical aspects	Good (1x)	Aggregate producers – recycling (1x)
Selective sorting platform	Good (1x)	Aggregate producers – recycling (1x)
Proximity	Good (1x)	Aggregate users – BPE (1x), Aggregate producers – recycled (1x)

4.3 Short analysis of the four other scenarios

Though scenario 5 seems to be the scenario that fits logically in a circular economy perspective, by its proposal to limit the storage of inert waste, each of the other four scenarios offers a specific vision of the insertion towards a circular economy. It is not only a question of considering the forms of material circularity, but also a question of taking into account the insertion into the cycles of the biosphere. The question of the preservation of natural environments and water quality are considered in each of the scenarios. But it is rather the issue of CO₂ emissions that remains as a major challenge, notably in the transportation sector.

More specifically, but not in detail, here are the main elements of analysis of the four scenarios. One of the main concerns of scenario 1 is the capacity of the aggregate production sector to supply an additional 5 million metric tons, in accordance with the conditions, notably the independence of the Ile-de-France region for the supply of aggregates (see Figure 9). This concern is major since it is linked to the negotiations of the new regional career plan on the opening of new careers. The state and its representatives are also questioning the reorganisation needs of the sector to meet the increase in demand. At the heart of these discussions, the determination of housing construction objectives is a decisive figure for knowing what the real increase in demand will be compared to the current situation. Different approximations are made. Some are produced from the estimate by the aggregate sector, others are made from the commitments of the French government. The results vary from 45,000 to 70,000 housing units/year currently built.

Figure 9 Analysis of scenario 1 – Grand Paris project (see online version for colours)



Construction of the Grand Paris project will also generate the production of waste associated with deconstruction and excavated land. The flow is expected to reach around 30 million metric tons, of which around 23% goes to landfills for inert waste, 22% to recycled aggregates, 32% to backfill in situ and 33% to backfill in Ile-de-France. The quality of this waste is a major issue, considering its possible uses.

Scenario 2 reinforces the idea of increasing aggregate demand from one to two million metric tons per year (see Figure 10). In addition to the capacity to respond to demand, the challenge is to readjust the offer, according to the priorities, in particular, related to the Olympic Games. This scenario pushes stakeholders to make explicit whether or not Grand Paris project can be developed as a sustainable metropolis. Different challenges are highlighted: the development of an ambitious strategy around the circular economy, the maintenance of the independence rate of the Ile-de-France in the supply of aggregates, the economic model and the return on investment of technical challenges especially in the insertion of recycled aggregates in concrete in construction.

Scenario 3 proposes the creation of a new aggregate supply opportunity from northern France and elsewhere in Europe (see Figure 11). The two main issues raised were the relevance of work of this nature that would be open after 2025 for the construction of Grand Paris project and the development of supply and export of waste by river. The competition generated by this opportunity is not considered as critical at the moment. The economic profitability of this waterway is not yet known for the transport of aggregates and other opportunities for supply by river are to be strengthened within the Seine Valley.

Scenario 4 envisages the development of platforms for mass transport and to favour alternative transportation modes. The platforms would give access to other production sites in France whose basements are different from the Paris subsoils. It would be possible to carry other materials. In principle, these platforms would be favourable for the markets. In addition, they would not necessarily compete with local carriers if we imagine these platforms as recomposition sites. The major challenge is the coordination of aggregate stakeholders to develop these platforms, particularly with regard to recycling. One proposal has already been made, the Stonehenge project, but the momentum around this project is still weak because of the integrated rather than cooperative strategy of industries in the sector.

Figure 12 Analysis of scenario 4 – development of multimodal platform (see online version for colours)

Sc4: multimodal Platforms												
	Aggregate P.. <input checked="" type="checkbox"/>	Aggregate P.. <input checked="" type="checkbox"/>	Aggregate P.. <input checked="" type="checkbox"/>	Aggregate P.. <input checked="" type="checkbox"/>	Aggregate P.. <input checked="" type="checkbox"/>	Aggregate P.. <input checked="" type="checkbox"/>	Supply Chain <input checked="" type="checkbox"/>	Aggregate U.. <input checked="" type="checkbox"/>	Aggregate P.. <input checked="" type="checkbox"/>	Public Aut.. <input checked="" type="checkbox"/>	Advisers o.. <input checked="" type="checkbox"/>	State and .. <input checked="" type="checkbox"/>
Aggregate D.. <input checked="" type="checkbox"/>												
Profitabil.. <input checked="" type="checkbox"/>												
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4.4 First cross analysis of results

Our analysis of the evaluation of aggregate supply scenarios for the perspective of a CE leads to questions on how to tackle increased aggregate demand, as it would rise, according to these scenarios, from 26 million metric tons (Mt) to 30 or 31 Mt per year. This consumption level corresponds to the production before the 2008 financial crisis. Therefore, it is not an exceptional level of demand, but the situation has changed, in particular in terms of political commitment: construction of the Grand Paris Express, construction of 70,000 housing units per year, organisation of the 2024 Olympic Games, Europacity, redevelopment of Paris Saclay and desire for waste reclamation (PREDEC, 2015). Therefore, we must identify how it is possible to provide 4 or 5 Mt per year of natural or recycled aggregate. This first cross analysis takes up the 11 performance issues as challenges for how to insert the aggregate supply considered in each of the five scenarios into the CE view. It provides the key elements related to each performance issue.

4.4.1 Meet demand for aggregate

This issue brings us to questions of the forms of aggregate demand (natural or recycled) and also of the quality of recycled products, of the capacity of the construction sector to integrate recycled aggregate into their products (15% in concrete, for example). Scenario 1 (urban planning around the Grand Paris Express) envisages exploring a form of circularity in terms of materials. We need to have the main current supply coefficients to tackle increased demand. The demand would be 30 million tonnes. 16.5 Mt would come from Ile-de-France (6.2 Mt of alluvial aggregate, 3.8 Mt of solid rock and 6.5 Mt of recycled aggregate); the rest, 13.5 Mt, would be imported (4.4 Mt of alluvial aggregate, 8.9 Mt of solid rock and 0.2 Mt of marine aggregate). This scenario also shows that 30 Mt of waste would be produced per year (21.6 Mt of inert waste, 7.8 Mt of non-hazardous waste and 0.6 Mt of hazardous waste). After sorting this waste will be intended for in situ backfill (8 Mt), for the production of recycled aggregate (6.5 Mt), the backfill of various sites (former quarries, etc. 8.5 Mt) and for inert waste storage facilities (7 Mt). Scenario 2 (Grand Paris project, a sustainable metropolitan area) fits with this logic with a demand of 31 Mt/year of aggregate. The construction of the Seine-Nord-Europe canal envisages massification of supply. However, much about the capacity for that supply is still uncertain (implementation of suitable barges, implantation location of multimodal platforms, reality of double freight, etc.). Scenario 5 asks about material deposits for recycling, quality of recycled aggregate, etc.

4.4.2 Ensure long-term economic profitability

Increased demand for aggregate will not necessarily be translated by new investments, and its profitability can be envisaged long term. This could impact the aggregate offering at a given moment. The economic profitability must be broader – towards taking into account quarry backfilling. This waste reclamation can be more profitable than new extraction products, causing less recycling.

Opening the canal would allow massification of the aggregate supply coming from other regions or countries. However, the profitability of this type of supply will depend on the amount of the toll.

4.4.3 Preserve resources

Aggregate resources are abundant, however, some are more limited (alluvial for example). Preservation of the resource in Ile-de-France passes through mixes of materials and through the importation from other regions or sources (marine aggregate). Recycled aggregate, changing demand and innovations may also participate in the preservation of natural resources.

4.4.4 Maintain jobs

The question of jobs is envisaged more from the point of view of recycling. Increased demand for aggregate will maintain jobs more than create new ones. The development of the recycled aggregate sector could be an opportunity for job creation, for new training.

4.4.5 Ensure site safety and quality

This is mainly a question of regulations, of resources being suitably qualified for their jobs, of responsibility and a ten-year guarantee and of the price of recycled aggregate. Recycled aggregate can be used in concrete production up to 15-20% without affecting construction quality.

4.4.6 Deliver the resource where it is needed

This issue lies on the fundamental question of how to organise the delivery system to minimise its impact while reaching the location where it will be used. Various dimensions exist for organisation: flow organisation towards sites in Grand Paris, organisation of the massification of waterways and rail transport and organisation of flow for housing construction (since the radius for concrete delivery is 30 km). Scenario 3 (opening the Seine-Nord-Europe canal) would allow massification of the aggregate supply coming from other regions or countries (Belgium, England, Sweden, etc.). This scenario asks about competition or complementarity with all ports along the Seine (HAROPA), the development of multimodal platforms for distributing aggregate locally.

4.4.7 Limit inconvenience for residents

Inconvenience to residents occurs at different levels, such as the quarry, multimodal platforms and transformation platforms for recycled aggregate. But we could also include the effects of the massification of road transport. Concerning production locations, 115,000 people are concentrated in the area 300 metres around legal locations for production sites. A waste recycling platform will directly impact urban centres.

4.4.8 Maintain a degree of independence for Ile-de-France

This degree of independence is a political choice, which raises a question for diverse stakeholders: how can it be maintained at around 45% if demand increases, and if production capacities fall? This question is related to environmental preservation in the broad sense, to opening new quarries at the risk of facing the NIMBY phenomenon, and to the desire of other regions to supply Ile-de-France. Recycling could be an

alternative. However, the development of the European cross-border rail network could change the longer-term situation.

4.4.9 Preserve natural media

Two important themes are on the preservation of natural media. The first relates to exploitation of quarries, the second to redevelopment of quarries. In this case, we talk about the quality of backfill, of redevelopment plans. There is no overall vision; instead, local solutions.

The construction of the Seine-Nord-Europe canal may spread the pressure over natural media in several regions

4.4.10 Protect water resources

The aggregate production sector consumes little water (use for washing aggregate, roads, etc.). Quarry work may be one of the factors that can make water tables and wet zones more vulnerable. The theme of vulnerable of water resources may impact aggregate use (ranging from minor and major water basins to terrace operations) and approaches to renewal of authorisations for operations or new authorisations.

4.4.11 Limit the contribution to climate change

Though the major work envisaged in Scenario 2 (Grand Paris, a sustainable metropolitan area) is closer to aggregate production locations, leading to less impact from the transport sector, CO₂ emissions will nevertheless rise. The development of the production of recycled aggregate requires the consumption of energy and may cause higher cement consumption. Like natural aggregate, the spatialisation of recycled aggregate production relative to the demand will impact CO₂ emissions. The development of multimodal platforms will also vary these emissions according to their position relative to the demand. Currently, road transport represents 59% of traffic, waterways 28%, and rail 13%. If rail and river transport, strengthened by the construction of the Seine-Nord-Europe canal, were developed, that would be more ecologically sound long-distance transportation. Changes in road transport also occur due to the switch to standard EURO 6 for lorries and the use of 44-tonne lorries.

5 Discussions

5.1 Thematic discussions

The various performance issues have allowed us to structure the challenges of a CE for supplying aggregate in the Ile-de-France region. However, we observe that the challenges are not even for all of the issues, scenarios and impacts. Certainly, recycling is involved in most of the issues to varying degrees depending on the issue and not always with the same effects: often positive (employment, etc.) but also sometimes negative (e.g., disturbance, increased CO₂ if increased incorporation in concrete production – because of the cement, etc.). Moreover, recycling is not the only contributor to the challenge: backfill is also concerned, in particular to meet the issues of long-term economic profitability (because long-term recycling profitability alone is not guaranteed) or even to

absorb the effects of increased aggregate demand (for some of the scenarios evaluated). In all, this is not only about imagining forms of recycling or waste reclamation, but also of the insertion of production, transport, use, recycling and reclamation activities into the biosphere cycles. Developing CE strategies requires strengthening of the coordination between the stakeholders to mobilise governance forms including land use planning projects. However, we have not solved all of the issues at this time, because according to our work, there will always be scenarios that involve sending waste to inert waste storage facilities.

5.2 Limits of the current results

In spite of our efforts, some stakeholders that play important roles in the CE decided to not answer our interview or meeting invitations (see Figure 4). Part of the explanation is that they do not feel directly concerned by the question of aggregates as such. The construction of performance issues and challenges related to each scenario towards a CE would have been improved by their participation. These included construction stakeholders, inert waste storage facility managers, railroad stakeholders and associations representing environmental matters and local residents. All interpretation of results from this work will take account of this situation.

In the AGREGA project, we experimented different forms of deliberation, not only during the construction of the axes of the deliberative matrix or during its filling. We sought to develop original forms of deliberation by mobilising different types of knowledge, different conceptual approaches and tools.

Moreover, whereas the specificity of this approach to evaluation is the engagement of a diverse set of formal (from results of simulation or observation) or informal knowledge, the knowledge from this formal portion could not be taken into account in the judgement process, since the modelling portion is still under development. More generally, the knowledge from the two other tools planned as part of AGREGA, the simulation model and the role-playing games (reminder Figure 1) have not really been taken into account. Consequently, we have not for example considered space and time during this deliberation process, i.e., the element bearing the knowledge on how geographic distribution of offers, demands and constraints of the sector changes over time (prospective), and along the sector's supply chain. This mechanism for spatial and dynamic representation of indicators would however merit being strengthened (Andriamasinoro, 2013) to enrich the debate.

The perspectives for connecting these three tools (towards integrated analysis) are detailed in the sections that follow.

5.2.1 Connecting the matrix with the modelling tool

It is not easy to develop this modelling, to objectively represent the 'aggregate and construction waste' system. Indeed, as we drew our conclusions, we observed at least two points that make the model harder to construct. First, there are controversies about two important figures. The first figure relates to how many housing units are built per year: stakeholders claims vary from 45,000 to 70,000 units per year. The second figure is the limit of aggregate production, in Ile-de-France and imported from other regions: what is

the threshold where we will have to consider structural changes in the production of natural aggregates? Secondly, the modelling requires access to a set of data to represent the system. But this data is not all easily accessible (for example, the flow of materials to produce secondary aggregate). To move forward on these points, it would be interesting to use related scientific work such as (Augiseau and Barles, 2017), which also tackles the problem of ‘aggregate and construction waste’ in Ile-de-France.

Once the modelling method has been developed, the next step will be to establish a bridge

- between the objective knowledge from that scientific modelling work, which will provide estimations about key variables (economic, risk, environmental, etc.)
- and these necessary for the decision process in legislation or management strategies.

Establishing this path is not easy because it requires mobilisation of two knowledge systems:

- positive use of knowledge to represent the situation or simulate possible changes
- and normative use to give it social meaning, where knowledge serves as arguments to express the conclusion provided.

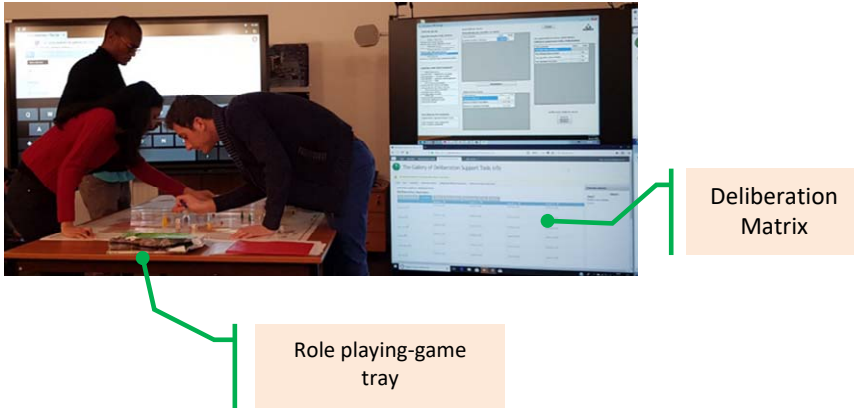
One possible mode of operation for this path would be management of emerging areas (David, 2010). Indeed, from these simulation models new objective knowledge will probably emerge on aggregate supply or waste management. However, and to repeat (David, 2010), although the simulation is indispensable, the most interesting emerging area will not then be the phenomena in the simulation but those of new ideas that this simulation would raise in stakeholders, and what will feed their reflections and analyses as they draw conclusions on the scenarios. This is even more true when as (Feitosa et al., 2011) reminds us correctly, any result from an exercise modelling complex systems does not represent precise provisions or deterministic responses and that the results of such an exercise ought mainly to serve to feed public debate (In our case, the conclusion of AGREGA scenarios).

5.2.2 Connecting the matrix with the role-playing games tool

The other element of the AGREGA project that has to be connected with the matrix is the sets of roles. This is a different but complementary way that the deliberation matrix will be used to make a subjective evaluation of the scenarios in the ‘aggregate/construction waste’ system in Ile-de-France. Currently, the set is developed either for pedagogical reasons (De Yrigoyen, 2017) or in for more operational purposes (Le Port, 2017) but in any case, this is independent work.

The bridge between matrix and sets of roles is being built. The first experimentation currently consists, in a pedagogical sense, of alternating each turn – where one turn corresponds to one scenario – with an evaluation process for the scenario that is being interpreted. Figure 13 shows a photo of a session of this type, taken in February 2018. The current results are limited to the identification of indicators (known or emerging from discussions) that can be implemented for the two tools simultaneously and to the improvement of the logistic block between the two tools.

Figure 13 Photo of a session (February 2018) aiming to connect sets of roles (interpretation of scenarios) and completing the deliberation matrix (evaluation of the scenarios) (see online version for colours)



5.3 *Open discussions on the methodology*

As introduced above, the specificity of this approach to evaluation is the engagement of diverse knowledge forms. These may be formal, from the results of simulation or observation, or informal. So the stakeholders

- a reproduce the different knowledge produced in AGREGA, relative to their relevance, relative to performance issues and scenarios
- b increase their knowledge of the domain.

The approach also allows stakeholders to express their doubts, uncertainties and controversial points. The stakeholders play two roles:

- a they hold knowledge for the representation of the problem (during construction of performance issues, scenarios, advance identification of indicators)
- b but also they have stakes in the matter, when they state their conclusions on the different scenarios, relative to the various criteria that form the performance challenges.

Moreover, the work done in the AGREGA project has shown the value of this evaluation approach: to help to remain prudent relative to decided opinions (as a reminder, the tools developed in AGREGA aim to forge opinions). We show this prudence explicitly by always stating the criteria for the conclusion. For example, it would have been logical beforehand to think that the recycled aggregate producers would be immediately in favour of the ‘zero waste’ scenario. This scenario would increase their market segment relative to inert waste storage facilities, in a context where recycling is also favoured and supported by a European Directive (OJEUW, 2008). However, when explaining the criteria, the evaluation showed that these categories of stakeholders accepting this scenario is in fact much more complex than this supposed opinion favourability: logistical constraints to recover the flow, preservation of water resources, absorption capacity for the area, etc.

This way of reasoning prudently on the opinions can moreover be generalised outside beyond the context of the AGREGA project and of aggregate and waste. For example, in the economic and political world, one supposition would be to say that the USA is the greatest world power, an opinion accepted by a great number of thinkers. However, if we refer to a criterion of 'perception of corruption' (the lowest), the greatest world power in 2015 would be Denmark (Transparency, 2015). And if we consider the criterion 'unemployment rate', the greatest world power in 2017 would be Qatar (TradingEconomics, 2018). So, by systematically showing the issues and criteria first, it would be more prudent to state that the USA is the greatest world economic power and according to the criterion GDP, whose method of calculation was defined by some stakeholders.

In reality, and to repeat (Chamaret et al., 2009), the methods of technical evaluation (e.g. cost-benefit analysis, risk evaluations, safety standards validated scientifically, etc.) offer a robust solution for the comparison of alternatives, depending on the conventions of political economists. Nevertheless, increasing scientific uncertainty and issues becoming more and more complex no longer allow us to be satisfied with one expert opinion or model concluding that a decision is good or bad for region or that a situation or opinion is true or false. This state of affairs may open people up to permanent dialogue, which is encouraged by the deliberative method.

6 Conclusions

Aggregate supply in the Ile-de-France region has become a major issue for the decades to come. Faced with expected increase in demand, a production shortage has been announced because of more intense factual, environmental or societal constraints. Recycling and waste reclamation still remain an option. But recycling remains limited. What is more, because of competition, the sector perceives resistance from companies establishing inert waste storage facilities. The entire situation justifies the need for all those involved in Ile-de-France to talk and together build the future scenarios for aggregate supply and waste reclamation, to evaluate of options for action based on scientific methods that publicly recognise the many values and the need for diverse stakeholders to coexist.

Conducted under an ANR research project named AGREGA, this work had the goal of describing, analysing and discussing the first evaluation of the potential scenarios from the thematic and methodological standpoint, asking questions about the issues of circularity in the aggregate sector in Ile-de-France. The evaluation process by multiple stakeholders and on multiple criteria concerns aggregate supply scenarios and waste reclamation. To structure the mobilisation of knowledge necessary for evaluation, the meta-method of integrated environmental evaluation INTEGRAAL was selected, an approach that, through 6 main steps (which are not necessarily linear), aims to engage experts and stakeholders in an integrated evaluation process. What is more, to allow comparison of different aggregate supply and waste reclamation scenarios, we selected the 'Deliberation Matrix' tool multi-stakeholder and multi-criterion evaluation.

Our results defined ten categories of stakeholders, five scenarios and 11 performance issues. The various performance issues have allowed us to structure the challenges of a CE for supplying aggregate in the Ile-de-France region. However, we observe that the challenges are not even for all of the issues, scenarios and impacts. Certainly, recycling is

involved in most of the issues to varying degrees depending on the issue and not always with the same effects: often positive (employment, etc.) but also sometimes negative (e.g., disturbance, increased CO₂ if increased incorporation in concrete production – because of the cement, etc.). Moreover, recycling is not the only contributor to the challenge: backfill is also concerned, in particular to meet the issues of long-term economic profitability (because long-term recycling profitability alone is not guaranteed) or even to absorb the effects of increased aggregate demand (for some of the scenarios evaluated). In all, this is not only about imagining forms of recycling or waste reclamation, but also about the insertion of production, transport, use, recycling and reclamation activities into the biosphere cycles. Developing CE strategies requires strengthening of the coordination between the stakeholders to mobilise governance forms including land use planning projects. However, we have not solved all of the issues at this time, because according to our work, there will always be scenarios that involve sending waste to inert waste storage facilities.

From the perspective of this work, we propose progress towards integrated analysis of aggregate supply and waste reclamation in Ile-de-France, given this times in the angle of three complementary tools provided by AGREGA (see Figure 1): a deliberation matrix (subjective evaluation), a simulation model (objective evaluation) and a role play tool (combining both). This integrated analysis, once a functional pathway is established between these three tools, will allow better examination of the opportunities, risk control associated with these opportunities and their feasibility, with a view to proposing a coherent set of decision-making tools from even richer knowledge.

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Notes

- 1 BRGM, ARMINES, UNICEM, Université de Saclay, ANDREIL-GAME, IAU and VNF are partners in the AGREGA project (Anticipation and regional management of aggregate resources, from the French 'Anticipation et gestion régionale des ressources en granulats'). The project is under the reference ANR-13-ECOT-0008.
- 2 A French context adopts the 4Rs principle whereas in an English context, there is no distinction between reemploy and reuse. In the French context, 'reemploy' means there is no change in the use (e.g., giving an old shirt to the Red Cross for others to wear, so no change in use) while 'reuse' means there is a change in use (e.g., a glass previously used to drink water, now being used as a flowerpot, so a different use for the same object). Throughout this paper, we use the French context.