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Integrative decision-making strategy for fluvial neighborhoods in transition

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Abstract. The changing relationships between cities and their waters over the centuries lead today – after a clear sidelining of rivers in the city – to question their potential for building new interactions. Current densification objectives of the existing built fabric resonating with the protection measures against floods bring out a broad field of exploration regarding the evolution of the urban riverbanks. Within this context, the research presented here focuses on the Rhône, an emblematic territory of the regeneration of urban riverbanks. Besides the technical means of risk management in flood-prone areas, landscape, urban, and architectural issues question the project approach to adopt for the development of new fluvial neighborhoods. Furthermore, many challenges raise for the management and steering of these sites in transition. Their regeneration in sustainable fluvial neighborhoods being closely linked with the accentuation of their characteristics, the ambition of the ongoing research consists in developing an integrative decision-making strategy specific to the issues related to the transformation of the urban sites along the Rhône. In that order, three steps are applied: 1. a prospective phase on four representative study areas, 2. the development of specific city-river balance components, and 3. the experimentation of an unprecedented multi-criteria comparative evaluation approach. These tools are not only strongly interconnected but are also parts of the integrative decision-making strategy, which is the main expected output of the research.

1. Introduction

The complex history of city-river relations shows an evolution of their relationships oscillating between phases of adaptation and control [1]. Until the industrial revolution, river areas take on various functions related to supply, transport, energy, and defense, while imposing cohabitation with recurrent floods. From the 18th century, industries gradually take over the banks, benefiting from the water resource as much as from the urban proximity and the connection to the railroad. In the 20th century, parking lots and highways intended for individual transport also occupy the banks, accentuating the city-river distance: the rupture becomes functional and physical [2]. The post-industrial era of the second half of the 20th century leaves vast sectors known as brownfields [3]. Today, we observe a (re)appropriation of the river banks that takes place through leisure and walking purposes, based on an increased interest of the society for the environment and quality of life. Hence, during urban history, city-river relations evolve from embeddedness to exclusion [4], highlighting unbalanced relationships between urban areas and rivers flowing through them: either the dynamics of rivers are controlled through technical risk management, or urbanization denies the presence of rivers through functional, infrastructural or morphological considerations. Currently, ecological, environmental, patrimonial, identity, and recreational issues are fueling debates on the “reconquest” of urban banks.

This renewal potential has been developing over the past ten years along the Rhône, as part of the sustainability challenges that go with some regeneration projects on urban river sites. Over 810 km, the Rhône crosses 2 countries (Switzerland and France), 3 metropolises (Geneva, Lyon, Marseille), and 377 municipalities, for a population of around 3 million people. The rhodanian urban region is the result of a long series of adjustments, operations, and appropriations over time: “in their diversity, urban sites



[along the Rhône] testify to the tension between the attraction exercised by the river and the caution imposed by its proximity” [5]. In the light of the climatic emergency, this territory is living a decisive time in its evolution, while the question of the axes of intervention on the river sites intensifies. In this perspective, the principle of densification towards the interior of urban territories coincides with the pressure to occupy land on the river banks [6] and goes hand in hand with the imperatives of urban sustainability and the notions linked to the concept of the polycentric compact city – density, diversity, and mobility [7]. Thus, the Rhône is not only a vector of urbanity [8] but also has great potential in the deployment of green and blue corridors thanks to its structuring force in terms of landscape, ecology, biodiversity, and public spaces [9]. More generally, the “Rhône hydrosystem”, i.e. the river and its associated spaces, would provide human beings a series of ecosystem services classified into three categories: production, regulation, and cultural services [10].

Questioning the limit of the city by the water [11] necessarily implies to consider urbanization beyond the stretched face of the public riverbank, that is to say, the neighborhood in its total urban scale [12]. In the context of brownfield regeneration and in line with the *UN Sustainable Development Goals number 11 “Sustainable cities and communities”*, sustainable neighborhoods – urban, dense, and mixed-use centers – offer a study area that is vast and representative of the urban space as well as sufficiently delimited to allow concrete action [13].

At the convergence between the evolution of city-river relations, the rhodanian territory in development, and the neighborhood as scale of intervention, the doctoral research presented here explores how to favor a sustainable regeneration of fluvial neighborhoods – activators of balanced interaction between urban areas and the Rhône – through an integrative decision-making strategy. To achieve this research objective, three steps are applied: prospective visions, components of the city-river balance, and a multi-criteria evaluation approach. The article provides a first overview of this ongoing research conducted at the Ecole Polytechnique Fédérale de Lausanne (EPFL). It deepens the theoretical context and the main research objective. Then, it presents the research methodology as well as a set of preliminary results taking the prospective visions developed for the site of Sion (Switzerland) as an example.

2. Theoretical context and research objective

The research project is embedded in the theoretical context described here below. The attentive consideration of these aspects contributes to defining the research objective and, ultimately, the research methodology.

2.1. Rhodanian strengths and weaknesses

If the evolution of city-river relations are “trends”, assessable in terms of intensity (values, functions, and degree of use of rivers) rather than strictly by successive phases [14], then the rhodanian territory represents a rich case study. The river, vector of multiple uses, pushes the rhodanian urban region into different dynamics of the city-Rhône relationship, because “the positive and negative aspects of river sites, in terms of attraction and vulnerability, are opposed without canceling out” [15]. These rhodanian trends reveal themselves as strengths and weaknesses linked directly or indirectly to the river. Helping refine the knowledge of the territory, they are divided into several themes – Urbanization and flood risk, Energy and transport, Ecosystem and landscape, Tourism and leisure, Heritage and culture of the river.

2.2. Managing transitions towards sustainability

Defined as fundamental transformations of large socio-technical systems towards more sustainable production and consumption patterns, sustainability transitions study has a multidimensional character and refers to the long term. It includes three fundamental concepts: reflexive governance, multilevel perspective of socio-technical transitions, and management of transitions [16]. This research aims to contribute to the specific theme of managing transitions towards sustainability by developing an action model adapted to the regeneration of fluvial brownfields. To this end, it endeavors to develop a framework to favor the integration of the various challenges at stake, which is an “arena transition” formed of federated stakeholders around a “partnership for sustainability” despite the divergences of interests [17]. In this sense, the notions of “co-creation for sustainability” [18] and “participatory action-research” [19] are presented as important tools in the construction of a process integrating a multiplicity of actors and objectives. Through research, academic institutions offer thus opportunities to enrich sustainability transitions management, for example, by the construction of decision support tools.

2.3. City-Rhone balance potential

In Switzerland as in France, the various risk management measures, the introduction of economic and environmental considerations, as well as the rediscovery of a certain rhodanian culture inaugurate an evolution in the relationships between many cities of the Rhône and their river [14]. Both the “Plan Rhône” and the “Plan d’aménagement de la 3ème correction du Rhône” provide guidelines to guarantee the sustainable development of the rhodanian watershed territory. However, these framework conditions alone are not sufficient to respond to the urban problem of the evolution of fluvial sites: stakeholders are confronted with new questions to move from the territorial to the neighborhood scale.

Consequently, the research intends to seek and develop a new relationship, to guarantee a future where all urban functions - environmental, socio-cultural, economic, and institutional - can be integrated and where the water and city will be able to dialogue fairly. Given the specificities of the river and its urban territory, exploring a concept of balanced city-Rhône interactions at the neighborhood level could help redefine urban relationships with water. Unlike “reconciliation” or “reconquest” notions seeking for a previous state [20], the notion of city-Rhône balance, polymorphous, open and progressive, is part of the sustainability transitions dynamics: it aims at the strategic integration within sustainable neighborhoods of the rhodanian strengths and weaknesses specific to each site and of the shared components of city-river relations.

2.4. Research objective

Taking into consideration this theoretical context, the main expected output of this research is the formulation of an “Integrative decision-making strategy for rhodanian neighborhoods in transition” and will consist of three fundamental steps:

1. A process promoting the generation of prospective visions (study areas, studios, workshops). Through a research-by-design methodology, this step aims to explore the many landscape, urban, and architectural issues questioning the project approach to be adopted for the development of new fluvial districts.
2. An approach to define specific components of the city-river balance (examples, references, interactions). This step of the work wishes to bring out the specific priority transition vectors towards the city-Rhône balance.
3. A multi-criteria comparative evaluation approach (procedure, criteria and indicators, application). This step aims to develop a suitable evaluation and visualization tool. It is not only an integral part of decision-making support but also participates in the construction of new institutional approaches in sustainability.

3. Research methodology

The research methodology seeks to respond efficiently to the main research objective, which is an integrative decision-making strategy. Pursuing related but distinct objectives, various methodological approaches are proposed based on three complementary and interdisciplinary steps: 1. Creation of the prospective visions process, 2. Definition of the components of the city-river balance, 3. Development of a multi-criteria comparative evaluation approach.

3.1. Creation of the prospective visions process

Using a research-by-design approach, this part of the research includes three stages that concern the development of prospective visions on rhodanian urban fluvial sites: the study areas selection, the organization of a synergy between the architectural studios and the research, and the setting up of professional workshops to deepen prospective visions.

3.1.1. Study areas. Following the Rhône, 4 different study areas are selected. The relationship of rhodanian cities with the river is not uniform [5], therefore the parameters taken into account in the analysis of the current state of each study area are as follows:

- Parameters linked to the location (position in relation to the river, demographic data, etc.);
- Parameters linked to the physical environment (site size, density, typologies of buildings, etc.);
- Parameters linked to use (type and rate of activity, number of users, cultural elements, etc.);
- Parameters linked to the city-river interaction (type and nature of the link with the river, public spaces and green spaces, ecosystems, risks, etc.).

3.1.2. Project studios. Thanks to an iterative approach – from urban project to constructive detail – the architectural studio deals with multiple scales. In groups, architecture students analyze, explore, and experiment sustainable architecture strategies allowing to reorient urban development inward, near public transports, and generate sustainable modes of construction. The research is combined with the

architectural studio: for each of the 4 chosen study areas, between 8 and 15 projects are developed by the students (in groups of 2 to 4), for around 50 projects in total. At the end of each studio year, the projects presenting the best qualities in terms of interactions between the study area and the river are selected to form the "raw material" for the creation of prospective visions.

3.1.3. Professional workshops. Prospective visions look broadly at the interactions between urban space and fluvial space, intending to see rhodanian balances emerge, beyond the physical contact with water. Thus, based on the selected student project studios, 3 prospective visions per study area – a total of 12 – are developed and consolidated during two specific professional workshops. These workshops, which bring together the research project team (professor, post-doctoral student, doctoral student, and assistants), the experts invited during the studios' reviews (practicing architects), and guest practitioners (external architect-urban planners), take place on relatively short sessions, trying to reconstitute a town-planning study-test procedure. The prospective visions produced during the workshops are then developed, evaluated, and compared using the multi-criteria evaluation approach.

3.2. Components of the city-river balance

The definition of the components of a sustainable city-river balance is formed through three main axes: theoretical research based on the deepening of bibliographic references, study and analysis of examples, and interactions with stakeholders in the form of questionnaires, interviews, and panels.

3.2.1. References. A review of the literature allows studying the evolution of the specific characteristics of the city-river and city-Rhône relationships. Questions of sustainability at the neighborhood level are tackled in parallel, in order to connect these two themes. This step already provides insights on the development of multidisciplinary interest in urban river sites [21] and on the rich potential of the rhodanian territory [5]. Some references offer a sensitive understanding and representation of the river landscape [22], while other contribution mainly questions the rivers in their roles as spaces for economic activity [23]. Thus, the various contributions from literature constitute a solid anchor in questioning the city-river balance at the neighborhood scale.

3.2.2. Examples. The establishment of structured information about existing and planned fluvial neighborhoods – along the Rhône and elsewhere in Europe – enable to compare the concepts extracted from the literature with the reality of the contemporary built territory. For example, the Berges du Rhône in Lyon, Lyon Confluence, the Ecoquartier fluvial de l'Ile-Saint-Denis, and Wasserstadt Solothurn contribute to a greater understanding of the issues involved in the renewal of city-river relationships and the principles of sustainability referring to them. For each project, quantitative and qualitative parameters are analyzed: historical perspectives, graphic documents, publications, site visits, interviews with people involved, etc. This stage seeks to identify the specificities and possible common features of these urban regeneration projects.

3.2.3. Interactions with stakeholders. A series of targeted interactions with stakeholders active in various urban fluvial territories is carried out through questionnaires, interviews, and panels. The stakeholders are experts – practitioners and theorists – coming from various professional backgrounds (architects, urbanists, hydrologists, local authorities, etc.) to guarantee the multidisciplinary approach specific to the concept of sustainability. The interactions refer to the stakeholders' field experience to determine the elements that can define a potential rhodanian fluvial character. The aim is to build an interdisciplinary dynamic promoting the exchange of knowledge and contributing to: bringing out the specificities and common points of each rhodanian study area, defining the components of the city-river balance, and confronting the multi-criteria evaluation approach.

3.3. Multi-criteria comparative evaluation approach

This phase of the research concerns the development of an evaluation approach specifically adapted to the multi-criteria comparison of different prospective visions.

3.3.1. Procedure. The principles already used in some research work carried out on other types of urban areas – in particular SIPRIUS [24] and NEBIUS [25] – will be transposed and adapted to the multi-criteria comparison of the city-river balance of the prospective visions. The approach is therefore structured according to a framework of environmental, socio-cultural, and economic sustainability indicators augmented by indicators referring specifically to the evaluation of the city-river relation.

3.3.2. Criteria and indicators. The first step determines a list of criteria to be evaluated in order to move towards a multidimensional representation of the issues characterizing sustainable fluvial neighborhoods in transition as well as the components of sustainable city-river balance. In this perspective, different evaluation criteria will be integrated into two categories: the criteria relating to the context (referring to aspects which clearly exceed the physical limits of the neighborhood) and the criteria relating to the project (referring to aspects whose challenges lie within the specific perimeter of the neighborhood).

The second step consists in defining indicators in order to determine a measurable value to indicate the degree of satisfaction regarding each criterion. This notion of value can be both quantitative and qualitative, provided that it gives an explicit indication of the prospective vision evaluated. Thus, equivalent importance is given to quantitative and qualitative evaluation, the latter having the advantage of a certain flexibility, particularly in the context of a prospective approach. The definition and selection of indicators are carried out while respecting a certain number of methodological requirements, which can be classified according to six fundamental principles: exhaustiveness, relevance, sensitivity, objectivity, accessibility, readability [26].

3.3.3. Application and optimization. To test and optimize the multi-criteria evaluation approach, it is applied to the prospective visions as well as to the current state of the 4 study areas. The test application includes “evaluation workshops” conducted during the interactions with stakeholders, which allow the group of experts to assess and compare the prospective visions. This process also contributes to the iterative optimization of the multi-criteria evaluation approach previously developed and to improve the possibilities for its transposition into practice. This part also includes the development of the graphic representation of the evaluation results. Taking into account the requirements linked to the concept of decision-making support and the need to disseminate research results to various audiences, methods of representing the results of the comparative evaluation of prospective visions will be tested and refined separately by criterion and indicator, as well as by grouping several indicators or criteria in a synoptic manner.

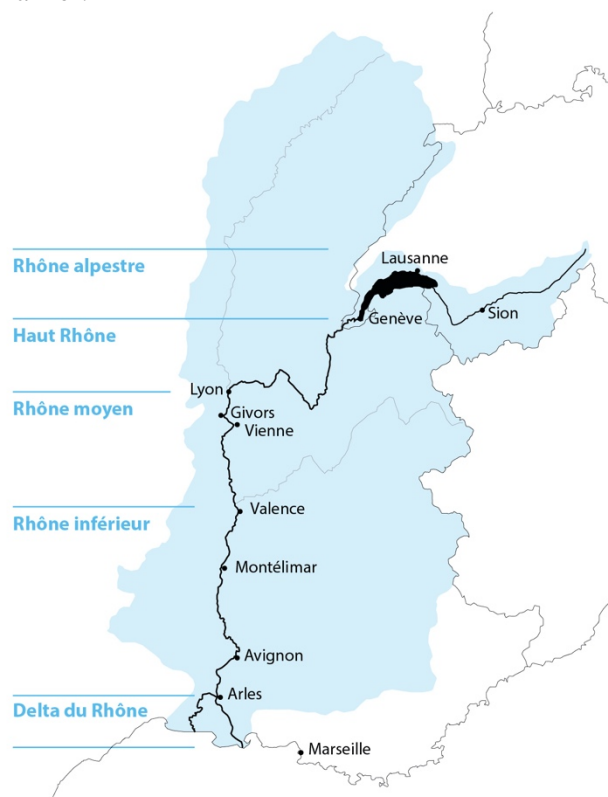


Figure 1 Schematic representation of the rhodanian watershed in Switzerland and France, with the five hydraulic entities of the Rhône.

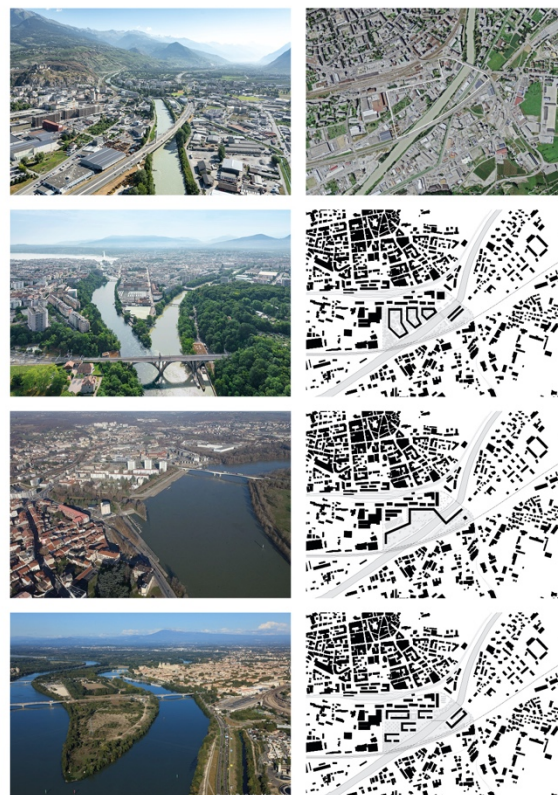


Figure 2 Aerial views of the 4 study areas along the Rhône: Sion, Geneva, Givors and Avignon.

Figure 3 Sion's study area (current state S0) and the 3 selected prospective visions (S1, S2, S3).

4. Preliminary results

The 4 study areas along the river, one per hydraulic entity (excluding Delta), are as follows: Sion located along the Rhône Alpin, Geneva located along the Haut Rhône, Givors located along the Rhône Moyen, and Avignon located along the Rhône Inférieur (Figure 1). Each study area shows a strong link to the river, landscape, and logistics axis – as well as the presence of a significant mobility infrastructure in direct proximity – as road or rail bridges (Figure 2). The study areas are regenerated into mixed-use neighborhoods, including a flagship program, which is adapted according to the specificities and needs of each study area. Sion carries the theme of education with a new campus, Geneva deals with the creative economy through cultural activities, Givors lends itself to the establishment of a port infrastructure, and Avignon hosts a museum.

In Sion, out of the 8 projects developed during the studio *Rhodanie Urbaine 2018-19*, 3 were selected and deepened into prospective visions. Each prospective vision weaves different relationships with the Rhône and the urban context: large city blocks for (S1), a long continuous shape (S2), and urban ensembles opening onto the river (S3) (Figure 3).

In order to assess these prospective visions, the multi-criteria evaluation approach defines 6 fundamental criteria: Density and diversity, Carbon neutrality, Environmental quality, Lifestyles, Feasibility, Relations to water; and includes 36 indicators (Table 1). For each indicator, a datasheet contains all the necessary information for its evaluation.

For example, Table 2 illustrates the datasheet of indicator 6c “Aquatic atmosphere”, an original and innovative indicator under development. Like the other indicators, it uses reference values (V_L , V_A , V_T , V_B), in this case aiming to assess the social activity linked to the river encouraged by the prospective vision. Indeed, as open public spaces along urban rivers can strengthen social resilience [27], we assume that public programs and common fluvial built spaces - in their capacity to generate specific social interactions - need to be addressed at the neighborhood scale. Table 3 presents the detailed assessment for each prospective vision as well as for the current state of Sion’s study area.

A histogram shows the values achieved by each prospective vision and allows to compare them (Figure 4). The profiles of the current state (S0) and of the 3 prospective visions (S1, S2, S3) show uneven performance. S0 reaches the average value (V_A), mainly because of the patrimonial quality of a vegetable garden on site. Linked to its low spatial types diversity and its water relation limited only to the view, S1 is the poorest enhancer of social activities, barely reaching the limit value (V_L). S2 shows a great diversity of social interaction potentials as well as rich water relations and various degrees of privacy, it could then easily reach the best practice value (V_B). Finally, because of medium results in all dimensions, except for the degree of privacy, S3 hardly grasps the target value (V_T).

Preliminary results show that the proposed methodology has the potential to be operational and could contribute to defining rhodanian sustainable neighborhoods. Moreover, comparison of different prospective visions turns out to be a precious tool - particularly in an iterative process - generating insights and new directions for the pursuit of the research work.

Table 1. Summary List of Criteria and Indicators for the River-city balance

Criterion Code	Criterion Title	Indicator Code	Indicator Title
1	Density and diversity	1a	Land use coefficient
		1b	Degree of functional mix
		1c	Urban form
2	Carbon neutrality	2a	Average annual emission CO ₂
		2b	Non-renewable primary energy for construction, renovation and demolition of buildings
		2c	Hydraulic potential for renewable energy production
3	Environmental quality	3a	Biodiversity
		3b	Permeable soil
		3c	Flood risk
4	Lifestyles	4a	Conviviality
		4b	Family friendliness
		4c	River culture
5	Feasibility	5a	Profit
		5b	Profitability
		5c	Governance
6	Relations to water	6a	Accessibility to the river
		6b	Fluvial public spaces
		6c	Aquatic atmosphere

Table 2. Datasheet of the indicator 6c

Indicator	6c Aquatic atmosphere
Definition	Collective sensitivity to the aquatic environment
Evaluation mode	Analysis of the number and quality of social activities linked to the river
Measurement unit	Qualitative scale (from 0 to 5)
V _L (Limit Value)	Level 2 (in 5) The project shows a relatively weak offer of fluvial social activities
V _A (Average Value)	Level 3 (in 5) The project shows a moderate offer of fluvial social activities
V _T (Target Value)	Level 4 (in 5) The project shows an important offer of fluvial social activities
V _B (Best Practice Value)	Level 5 (in 5) The project shows a systematic offer of fluvial social activities
Data source	Prospective visions

Table 3. Toolbox of the indicator 6c (Aquatic atmosphere)

Dimensions	Tools	S0	S1	S2	S3	
Social activities (Different spatial types)	0 = 0 1 = 1 2 = 1.5 3 or more = 2		1	1	2	1.5
Social activities (Degree of privacy)	private = 0 collective = 0.5 public = 1		1	1	1.5	1.5
Water relations	none = 0 visual relation = 0.5 close relation = 0.5		0	0.5	1	0.5
Patrimonial element	no = 0 yes = 1		1	0	0	0
Score	from 0 to 5	3	2.5	4.5	3.5	

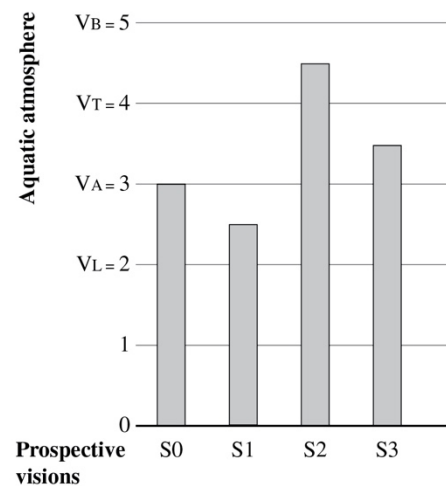


Figure 4 Test-application: evaluation of indicator 6c.

5. Conclusion

Today as in the past, city-river relationships are changing and multidimensional. In order to contribute to the development of new sustainable fluvial neighborhoods, this doctoral research proposes to apply 3 related but distinct steps: the creation of a prospective vision process, the definition of the components of the city-river balance, and the development of a multi-criteria evaluation approach. When combined together, these steps form the main expected output of the research: an integrative decision-making strategy for rhodanian neighborhoods in transition. This decision-making strategy could be applied to other rhodanian territories but also serve as a basis for the implementation of similar integrative strategies in other fluvial contexts. In the perspective of sustainability transitions – systemic, evolving, and over the long term – this decision-making strategy does not offer ready-made solutions but is expected to help as an action model, to clarify the needs and expectations of different stakeholders, to understand the specific characteristics of concerned sites and to develop adapted prospective approach. The ongoing research is moving in that direction with the deepening of its tools, in particular by developing the next prospective visions on Geneva's study area (studio Rhodanie Urbaine 2019-2020) and the organization of the first panel with stakeholders, scheduled next summer.

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