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Developing an economic model for the redevelopment of a portfolio of brownfields

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Abstract: The redevelopment of brownfields is an issue of increasing concern for urban and water managers. Brownfields, which once supported economic activities, are now abandoned or underutilized sites, frequently becoming a source of nuisance for nearby communities and pollution of water resources. Nonetheless, their redevelopment offers valuable opportunities, especially if multiple or large areas are available. In this presentation, we introduce a preliminary economic model based on mathematical programming, which is designed to maximize the benefits of redeveloping a portfolio of brownfields. This approach incorporates: (1) the benefits of brownfields redevelopment (financial, social and environmental) for a set of redevelopment alternatives; (2) sites characteristics; and (3) regulatory requirements and regional policy orientations. The outcome of the model assigns the redevelopment project to each brownfield parcel, and displays the aggregated social benefit, allowing accounting for potential synergies between different redevelopment combinations. To illustrate this, we run the model to optimize the redevelopment of a simplified case study inspired on an industrial zone in Lyon, France. We therefore describe how the tool can contribute in analysing trade-offs of policy-making scenarios. Hence, we attempt to address gaps on literature by two integrative contributions: (1) the approach allows combining the choice of the most appropriate redevelopment at the site scale and the priority order of redevelopment for a portfolio of brownfields at a regional scale; and (2) the model proposes an alternative to incorporate the criteria of sustainable assessment in a cost-effectiveness analysis.

Keywords*:* Brownfields Redevelopment; JEL: C610 Mathematical Programming; Optimization Techniques; Q580 Environmental Planning; R520 Land Use.

1 INTRODUCTION

By definition, the term 'brownfield' embrace sites that are currently underused, vacant, derelict or contaminated and need some kind of intervention in order to host a new economic activity. Hence, we consider brownfield sites as a resource. The presence of brownfields often implies costs of management and social nuisances, especially in the case of brownfields located in urban areas. This, addition to the potentials of new projects, turns brownfields redevelopment into a valuable opportunity for urban reconfiguration. The purpose of the model is then to represent the choice of redevelopment alternatives in order to maximize the resulting benefits, taking into account rehabilitation costs, in using the frameworks of good practices of brownfields management.

For the scope of this conference proceeding, we aim to show the potential of managing brownfields redevelopment at a portfolio scale, testing if it leads to better economic outcomes in comparison to a case-by-case management. From a methodological perspective, we use mathematical programming to develop a model and contrast the economic optimization of the redevelopment of a portfolio of brownfields with and without coordination. In application, the model can be used as a decision-making tool for urban planning.

2 MATERIAL AND METHODS

2.1 Modelling a portfolio of brownfields

In this subsection, we discuss why it may be important to manage brownfields at a portfolio scale, proposing to test if the management of a portfolio of brownfields generates a different solution than a site-by-site approach. First, we assume the decision of investment is rational in terms of utilitarian economic theory, choosing in order to maximise benefits. We argue that in a site-by-site approach, as decisions are made considering one site at the time, there is little room for coordination. In our model, the decisions of this approach are expressed as shown in equation (1), where there are j sites, i alternative projects of redevelopment, X represents the hectares of brownfield redevelopment projects for each site, and B represents de benefit by hectare according to the sites and projects. We hereafter refer to this as the reference solution (RS). On the other hand, we argue that a coordinated planning of redevelopment (i.e. portfolio scale), acknowledges investors about the potentials and life cycle of other projects, therefore enabling them to take advantage of potential synergies. Accounting for such synergies may or may not change the output configuration (choice of redevelopment projects), but we expect that it would modify the aggregated value of redevelopment. We refer to this second approach as coordinated solution (CS), this is represented in equation (2). Furthermore, we test if the maximization of benefits including social and environmental values drive the model to propose a different solution, and if so, what would be the distributional consequences. We refer to this last proposition as social-welfare solution (SWS), represented in equation (3), where subsidies (S) are included to represent social and environmental gains in a rational decision of investment. Later on, this could help to discuss the suitability and pertinence of including the monetary valuation of social and environmental changes within the economic analysis.

$$\sum_j MAX\ U \sum_i X_{i,j} * \left(B_{i,j}\right) \qquad (1)\ \text{RS}$$

$$MAX\ U \sum_i \sum_j \left[X_{i,j} * \left(B_{i,j}\right)\right] \qquad (2)\ \text{CS}$$

$$MAX\ U \sum_i \sum_j \left[X_{i,j} * \left(B_{i,j} + S_{i,j}\right)\right] \qquad (3)\ \text{SWS}$$

2.2 Conceptual model

As aforementioned, the model is conceived to account for a set of brownfield sites, its technical and environmental characteristics, as well as the context of its surroundings. On this preliminary version, each site is described with size, shape, location, distance to transport facilities and residential areas, soil conditions, urban regulations, and expected rehabilitation cost. On the other hand, the model database also describes a set of alternatives of redevelopment, its technical requirements and benefits (private, social and environmental). The use of constraint equations allows accounting for goals and regulations of the case study as well as the technical requirements of the projects. Hence, the model identifies a matrix of viable redevelopment activities for each site, and then chooses between the redevelopment projects to achieve the maximal total benefit. Figure 1 illustrates how the model is structured and how it incorporates the context of the case study.

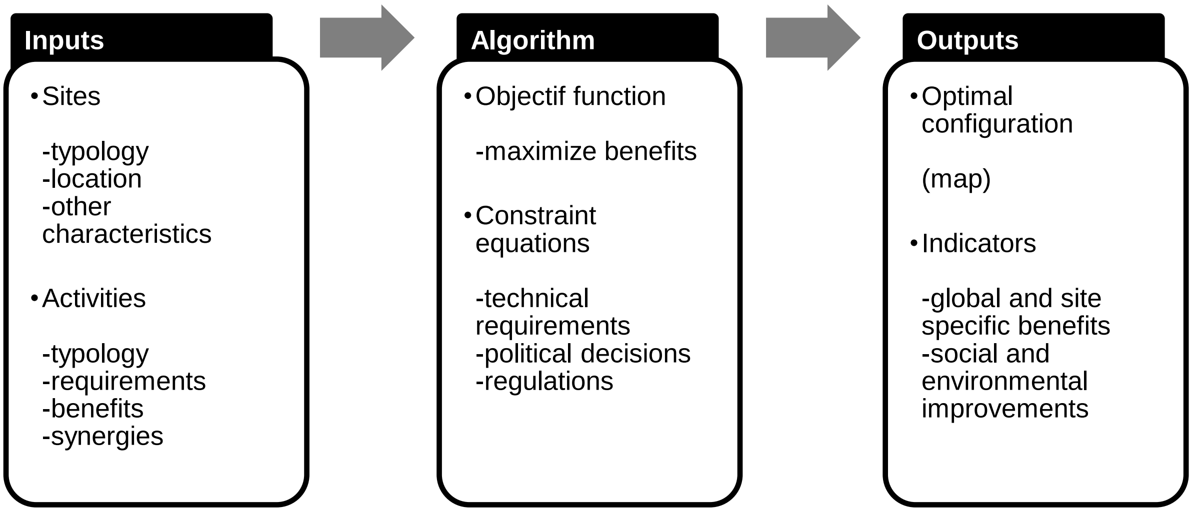


Figure 1. Conceptual model

2.3 The case study

We present an application to a simplified case study inspired in the "Vallée de la Chimie" (VdC), an industrial zone in Lyon, France. VdC is one of the biggest poles of employment in the metropolis of Lyon, embodying a very productive territory that extends itself more than 15 kilometers along the Rhone River, regrouping up to 12 municipalities. Most of the industries have been set for decades and have experienced a natural evolution from their early starts in the past century. Consequently, VdC contains a certain amount of empty or underused spaces. Figure 2 displays a map of the full territory of VdC and aerial view zoom.

Figure 2. La Vallée de la Chimie

The VdC includes by itself several spaces containing biodiversity along the Rhone River, and it is adjacent to residential areas. Therefore, the urban planning for the redevelopment of VdC is imperatively tied to political, social and environmental requirements. For instance, decision-makers of Lyon metropolis expect VdC to continue supporting the economic activities of the region within three main axes: industry, chemistry, and environment. In addition, projects are likely to be encouraged if they help to fulfil some of the major urban goals (waste and material management, energy production, conservation of biodiversity, transport improvement). Moreover, the constant expansion of the metropolis generates urban sprawl, which adds value to this opportunity for urban redevelopment. As for regulation, the main reference is the recently updated zoning Plan to Prevent from Technological Risks (PPRT by its French acronym) originating from some currently established activities that are potentially hazardous (chemical procedures, oil refinery). The new PPRT has two main consequences: First, it sets perimeters that restrict the allowed human presence for future projects (i.e. redevelopment alternatives); and second, it urges owners of concerned sites to adapt to the new regulation. The later can be accomplished by demanding the expropriation of the site or by reinforcing security measures depending on the zone category and the current activity on the site. For these reasons, we consider that the complex territory that surrounds the brownfield sites of VdC fulfils all the characteristics to test the model.

3 Illustrative application of the model

To illustrate our model, we portray a set of 5 sites inspired on the real brownfields of VdC, which we pair with 5 types of redevelopment alternatives. Table 1 summarizes the information included in the database, and Figure 3 displays the layouts of running the model. This virtual case describes the fourth site as particularly costly to rehabilitate (grey) due to a high contamination expected. As for the redevelopment alternatives, the first two projects are described as environment-orientated projects (green), the third and forth as energy production projects (yellow), and the fifth as a petrochemical industry (red).

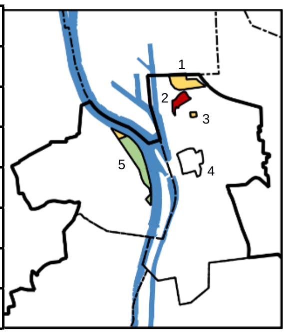
Sites – Projects characteristics:	
• Private & social benefits	• Distance to transport facilities
• Rehabilitation costs	• Distance to residential areas
• Size	• Soil conditions
• Employment	• Synergies

Table 1. Database parameters

We run the model using an objective function as shown in equation (3). For illustrative purposes, we test the model two times with and without the inclusion of synergy potentials. As result, the solution of the program displays a table with the optimal allocation of hectares for each site and redevelopment alternative (Figure 3). The optimal solution of the first test assigns: project 4 for the first, third, and a small part of the fifth site; the petrochemical industry for the second site; none for the fourth site; and project 1 for the majority of the fifth site. For the second test of the model, a blue rectangle represents the inclusion of a synergy between projects 2 and 3. In contrast to the first test, this time the solution includes the implementation of projects 2 and 3, where the latter is allocated in the fourth site despite the high rehabilitation costs.

Test 1.

(has.)	S1	S2	S3	S4	S5
Projects P1	-	-	-	-	29
P2	-	-	-	-	-
P3	-	-	-	-	-
P4	18	-	2	-	2
P5	-	8	-	-	-
Total (%)	100	100	100	0	100



Test 2.

(has.)	S1	S2	S3	S4	S5
Projects P1	-	-	-	-	31
P2	8	-	-	-	-
P3	-	-	-	8	-
P4	10	-	2	-	-
P5	-	8	-	-	-
Total (%)	100	100	100	34	100

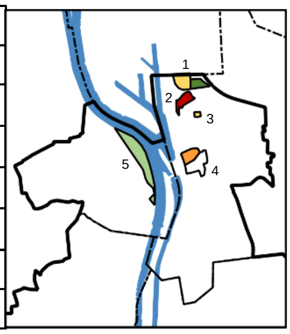


Figure 3. Layouts of the model solutions

4 Upcoming work and challenges: Estimation of benefits and addressing uncertainties

The financial costs and expected benefits of new projects can be more or less simple to determine. At the very least, we assume these financial costs are included on private investors profit calculation. As for the benefits, we use reports of similar projects in France as proxies to account for private benefits, and avoided costs and value transfer approaches to estimate the social and environmental gains.

On the other hand, the need of rehabilitation implies costs that embody a more uncertain territory. Straightforward, the depollution threshold(s) and the choice of remediation techniques are highly dependent on the future use of the sites, so the final environmental conditions ensure the suitability between site characteristics and future activities. Whereas site environmental data is uncertain and future activities are yet to be chosen, it was decided not to internalize the choice of remediation techniques within the framework of the model. To address this issue, we propose to classify sites in regard to the available information concerning past activities and presence of contamination, then attribute a probability function of rehabilitation costs for each site accounting for the mean cost of remediation techniques within French references.

We conclude that the model has potential to guide decision-makers by shedding an initial light on how the brownfields should be redeveloped from an economic perspective. However, we acknowledge the importance of considering the limitations and uncertainties related to the estimation of benefits and rehabilitation costs.