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A CAAD Based Method for Designing Industrial Plants in Sensitive Landscapes

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The protection and management of the visual landscape require new conceptual and operative tools to better link (integrate) the creative and the evaluation phases of the design process. These tools should aid the designer to take into account and evaluate the visual impact of a new project from the early steps of the process: that is the same as saying that we have to upset the logic of EIA (Environmental Impact Assessment), a procedure that usually is applied when the project is finished or is coming to an end. This paper illustrates the first results of a research that aims to produce a system to aid the designer of buildings or infrastructures — industry plants, transport systems, etc. — that could generate a strong impact on the surrounding landscape. To this end we applied some methods and techniques which was worked out in scientific fields that have developed a lot in the late years: MCDA (Multi-Criteria Decision Aid) and CAAD (Computer Aided Architectural Design). The paper describes a software prototype to aid design of industrial installations for the early design phases.

Introduction

The environmental crisis has had a direct impact on the methods and tools used in planning. Not only in architecture, but across the entire range of industrial planning and other activities that affect our physical surroundings. Over the past years man's intervention has contributed to degrading the landscape, by which we mean the perceived environment. Thus, the need to reclaim and protect the environment is fundamental. One of the main causes of environmental decay is that many industrial plants were built without their natural surroundings being taken into account. It is therefore necessary that not only the architectural projects' qualities are improved upon, but that the relation between buildings and their natural context is taken into consideration.

In recent years a great deal of research has been conducted on the visual impact of man made structures on the landscape (Smardon, Palmer and Fellema 1986, Taylor, Zube and Sell 1987, Giangrande 1994). Furthermore, studies have demonstrated the importance of methods and instruments using Computer Graphics for the Evaluation of Visual Impact. (Maver, Purdie and Stearn 1985, Sansoni 1994, Turnbull and Gourlay 1987).

The following case study will illustrate methods based on CAAD (Computer Aided Architectural Design) and MCDA (Multi Criteria Decision Aid) which help planners design constructions in sensitive landscapes without damaging the view of the landscape and at the same time improve the architectural quality of the construction. A medium-size industrial plant was chosen as a test case: an incinerator of solid urban wastes. The number of incinerators of this kind are expected to increase in the next few years.

The methodology

The methodology is based on the assumption that, particularly in industrial planning, the space for alternative solutions is hardly ever explored; thus a strategy is used to rapidly explore the space for new design alternatives, from which the best one is selected. Thanks to the use of interactive technology, the project-evaluation cycle can be repeated until a satisfactory solution is found. Usually, an industrial plant is made up of a series of technological elements, each one having a special use of its own. Designing a plant of this kind means that each of these different elements must be assembled in the most economic and efficient manner. Another important factor is the aesthetic quality of the building in relation to its surroundings.

An industrial plant is strongly constrained by technology, therefore it is possible to consider a plant as an assembling of a set of functionally independent elements. The incinerator itself is also made up of a number of assembled parts. The experiment on the incinerator involved breaking the plant down into technological sub-systems: the unloading of wastes, the storage of wastes, the combustion of wastes and treating combustion fumes. For each of these stages, corresponding technological elements carry out the above mentioned functions together with nine different *morphological-functional groups* (e.g. group wastes-storage, group wastes-combustion, group cinders-stoking, etc.). Every group is made up of one or more elements and constitutes an autonomous unit.

The first part of the method enables the designer to explore a wide range of alternative solutions using a certain strategy for the assembly of components. Geometrical and technological (materials, surface treatment) constraints of every morphological-functional group are established in the initial stage, so that the designer knows what space he can operate in.

There are different planning solutions for every group. A solution can vary according to its morphology and/or orientation. These alternative solutions can be considered the abacus of components at the designers' disposal. The final project is the sum of different, integrated solutions chosen for every group of components. Once a number of projects has been drawn up, each one is evaluated in terms of how it relates to the surrounding landscape.

In this experiment, the plant has been situated in an area to the North of Rome, of discrete aesthetic value. Lastly, once the best project is selected, the final modifications are made to maximise the quality of the results. The design process is not linear but cyclic, if the result is not satisfactory is possible to tune up the project coming back in the modelling phase.

It is important to note that in this case the quality applies to the outside, aesthetic-perceptive aspects and not the technological aspects which have been tested in an earlier phase. The project is evaluated by simulating the view of the plant from a series of critical standpoints ("key" points), taking into consideration historical-cultural values, natural values and the number of people present in the area.

Photographs are taken from key points in the landscape and are subsequently used as a background for electronic photomontage simulations (Nakamae, Harada and Ishizaki 1986, Sansoni 1989).

In this case the designer has a very different approach from traditional ones. Indeed the project is conceived by directly assembling three-dimensional components; furthermore, results are verified by reconstructing the plant form perspectives taken from the key viewpoints. The formal quality of a project is considered in relation to its surrounding landscape and never in an abstract vacuum.

In figure 5 is shown a photo taken from one key point; in the figure 6 and 7 are shown two alternatives design solutions.

The evaluation method

To evaluate the alternatives we use the AHP method (Saaty 1980). AHP (Analytic Hierarchy Process) is a multicriteria decision-aiding method (MCDA) developed by T.L. Saaty in the 1970s which aims at quantifying priorities (weights) for a given set of actions or alternatives on a ratio scale. The MCDA method, which uses qualitative criteria, allows to compare different solutions of the project and to evaluate the visual impact generated by each solution, due to the physical and perceptive alteration of the features of the landscape. The quality of design solutions is estimated comparing pictures of the landscape (without the project) against the same pictures with the project included in the landscape. We use for the evaluation, for each project, the pictures taken from the "key" points.

The aim of the evaluation is to select the better design solution considering altogether the surrounding landscape (perceived environment) and the project. The visual quality depends, according to recent studies, either from the capability that the elements in the scene have to stimulate an affective response apart from the cognitive process (Ulrich 1983), or inferring to assert the aesthetic position of the observer (Ceccato 1987). The projects are then evaluated using criteria in according with different observer position's: aesthetic, affective and architectural.

When we consider the aesthetic criterion, according to Ceccato's theories, we consider meaningful, from the aesthetic point of view, a peculiar rhythmic subdivision in fragments of mind's attention; the aesthetic value is explained with the agreement (positive value) or the disagreement (negative value) between such subdivision and the subdivision due the peculiar perceptible character of the observed object.

When we evaluate with the affective criterion we consider the presence of elements that infer an affective pre-cognitive response like focality, depth, ground surface texture, deflected vistas, presence of vegetation and water. The architectural criterion is referred to the quality resulting from the analysis of the internal relations of the parts against what we consider the whole.

With these premises we can have two different design's strategy: a "mimetic" or "opposite" position. When we adopt the opposite position we play on the contrast between landscape and plant, creating volumes clearly well-defined and recognisable; or we can point out the technological characteristic of the project with the choice of certain materials and colours. If we use a mimetic position the behaviour is the contrary: e.g. the elements of the plant are hidden in simple volumes and the materials and colours are selected matching with these of the surrounding landscape.

To carry out entirely the methodology we developed three software tools to generate quickly alternatives design's solutions and to evaluate the results: *Impianto*, *Inceneritore* and *AHP*.

Software Tools

Impianto

The *Impianto* (Plant) program is a user friendly interface to aid the generation of different designs' alternatives. This software was built with the hypertextual environment *Hypercard* by means of the language *Hypertalk*. The interface is formed by a series of cards linked through buttons and fields those are directly manageable by mouse. The design-solutions, that are in the morphological-functional groups' abacus, are not all compatible; this is why was built an incompatibility-graph between the different solutions, conforming to the *AIDA* method (Luckman 1984). An incompatibility-data-graph was included in *Plant*.

Then by *Impianto* we can check the compatibility between the design-solutions and we can automatically calculate their relative positions once that we chosen a complete plant project. Besides, *Impianto* supplies the user also with a guide to understand better the plant problems; the guide is made by textual information easily callable. Information regards the shape and general constraints of the groups.

Impianto is arranged in four sections: *Dati Geografici-Tempo Locale-Osservatore* (Geographical Data-Local Time-Observer point of view), *Immagine Fotografica del Contesto* (Landscape Photograph),

Morfologia e posizione dei Gruppi Funzionali (Morphology and positions of Groups), Materiali e Colori (Materials and Colours).

Geographical Data-Local Time-Observer points of view:

In this section we put the observer location's and direction of view, the local geographical coordinates and the local time (regarding the photograph). Such data are required to carry out properly the simulations: with the geographical location and the local time we can define the sun position at the moment of the shot. The photo will be then used for the photo-montage.

Landscape Photograph:

The information included in this section concern the general lighting conditions and the data on the lens and on the film of the used camera (figure 3). The lighting of the scene depends on sun location's and on meteorological conditions; the quality and the intensity of the light scattered in the environment changes according to the presence or not of clouds in the sky. An other point of view to consider is the presence of the haze. Generally, excluding particularly limpid days, there is always a certain amount of haze that involves the loss of the detail of the scene; colours became less saturated and the objects, when are far from the observer, become blurred with colour of the background. To simulate such effect it is necessary to select on the photo (previously digitised by scanner or Kodak photo-CD technique) that will be used for the montage, the prevailing colour of the background. The colour is described by the RGB (Red, Green and Blue) tern.

By means of three bar with a mobile cursor we can empirically gauge the direct light intensity, the amount of the ambient light and the quantity of haze.

Other information presents in this section concerns the data useful to describe the synthetic camera (lens, film and size of the picture on the screen); such data enable to make a perspective with a field of view equivalent to which of a real camera with certain lens and to have the picture on the screen and the used film with equality of ratio.

Morphology and positions of Groups:

Inside this section we generate design alternatives. As above-mentioned, the incinerator is divided in 9 morphological-functional groups; every group corresponds to a certain part of the plant. For every group there are different design alternatives. A finished plan of the incinerator is defined assembling and correctly arranging a design alternative for each group (figure 4). For every design alternative is shown an isometric view and a plan in which are showed sizes constrains and the local coordinate system of the geometric model.

Besides, there are in the card general information on the sizes of the component parts of the groups, information on possible constrains of position and directions for use colours and materials on the surfaces.

To choose a design-solution, between a group of alternatives, it is sufficient to select it by a button placed on the card. From the general control card it is possible to check automatically if there are some design solutions not compatible.

At last once all the parts of the plant have been selected it is necessary to place them correctly under a common coordinate system; by means of a button is started the calculation that supply automatically every group's position with regard to a common coordinate system.

Materials and Colours:

In this part of the program colours and materials, of selected solutions, are established. The features of the material are fixed, conforming to RenderMan (Upstill 1989) interface guideline. The RenderMan interface, a powerful and flexible 3-D scene description tool, is used for rendering the geometric models of the project. The RenderMan interface by the Shading Language allows to define shaders; a shader is a procedure written in the RenderMan Shading Language that allows to describe in sophisticated way materials and surfaces using, also combined, procedural and texture mapping techniques. Every selected solution is made up of certain numbers of parts: we can allot to each part different colours or shaders.

The output of Impianto is a file including the designer's choices made in the four sections. This file contains the necessary information useful to execute the geometric modelling program Inceneritore.

Inceneritore

This is an application written in C language using the Pixar's RenderMan Interface Bytestream Protocol Library to generate the full scene description in a RIB file, through the output data of Impianto.

A RIB (RenderMan Interface Bytestream) file comprises the complete geometry model data of the project, colours and materials of every part and data on scene lightening. The program is completely transparent to the user, once executed a RIB file (scene description) is produced in autonomous way.

This program consists of two parametric graphic libraries. The first basic allows to build the geometrical primitives; the second, made throughout the first, allows to generate the geometrical models of the component's Abacus. The program uses all the data produced by Impianto to directly generate the geometric model with all the attributes about colours and materials; moreover data on camera, lighting and haze. The RIB file can be read and visualised by any software (like Showplace and MacRenderMan) compatible with the RenderMan interface.

The final pictures are produced using the photo, taken by the sensitive points of view, as a background. Further image processing it is later executed by means of right software (like Adobe Photoshop); so it is possible to add vegetation and to touch up the picture.

AHP

The AHP program is a software tool founded on AHP method to estimate the Visual Impact on the landscape and to choice the better design solution (considering the architectural design and landscape context). Also this software was build using the Hypercard development environment. AHP guides the user in the evaluation process with a step by step procedure (figure 1). The quantitative outputs of the evaluations are showed with the help of graphs for better communicate the results (figure 2).

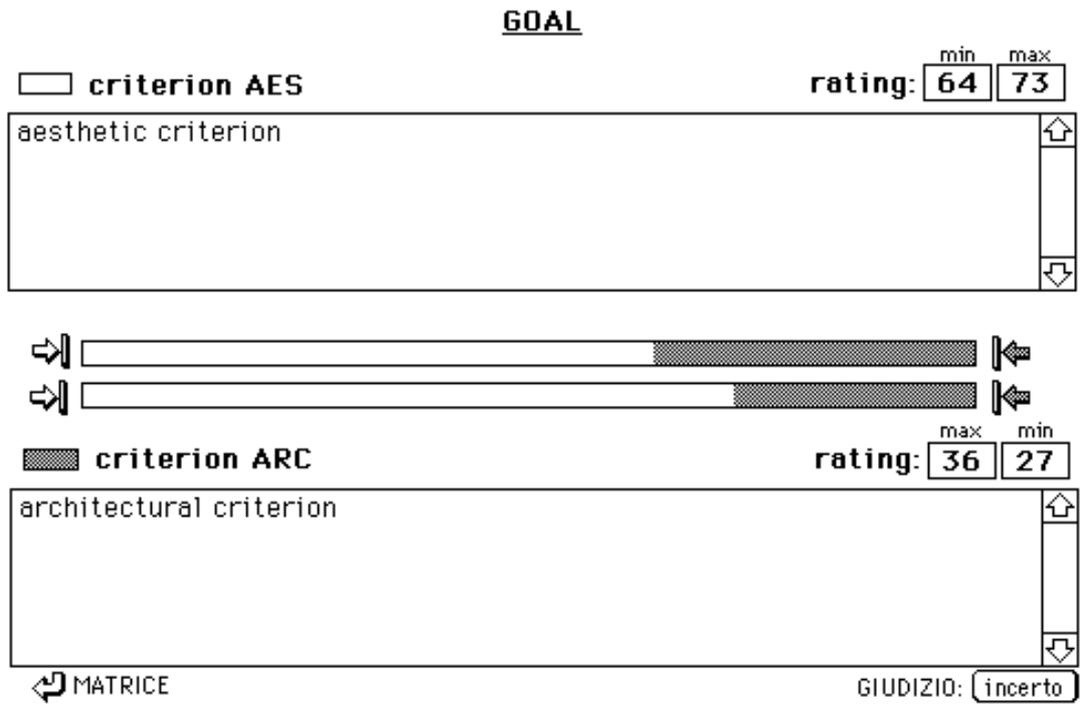


Figure 1. The AHP program. The paired comparison of two evaluation criteria.

PRIORITA' DEGLI ELEMENTI TERMINALI

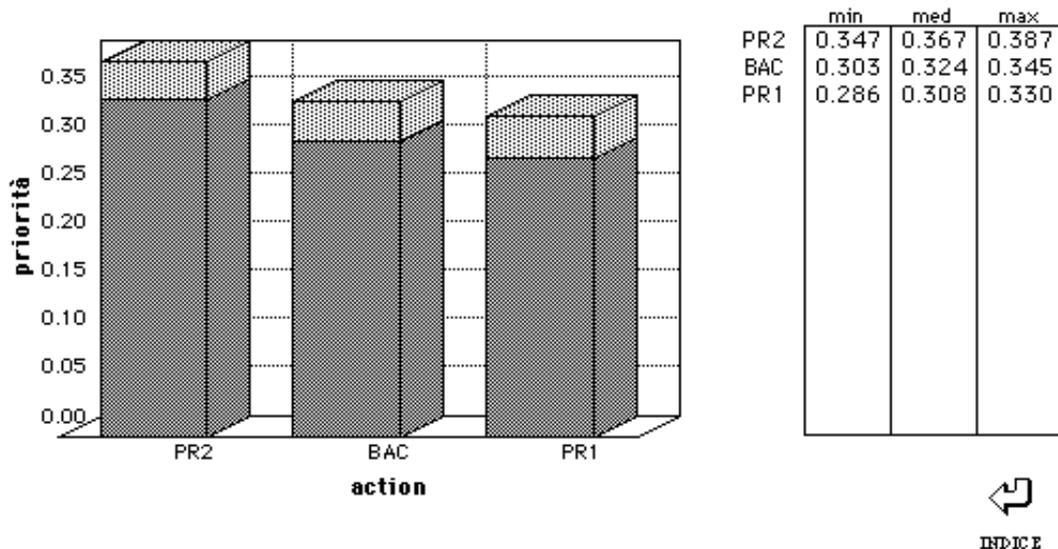


Figure 2. The AHP program. The final priority of two design alternatives (PR1, PR2) and the background (BAC).

IMMAGINE FOTOGRAFICA DEL CONTESTO

INTENSITA' DELLA LUCE DIRETTA (SOLE)

(notte) (sole estivo al meridiano con cielo sereno)

MIN
MAX

INTENSITA' DELLA LUCE DIFFUSA

(notte) (presenza di forte luce diffusa dal cielo, dal suolo, ecc.)

MIN
MAX

FOSCHIA

(assente) (nebbia fitta)

MIN
MAX

COLORE DEL BACKGROUND (valori R,G,B): R G B

OBIETTIVO DELLA FOTOCAMERA (mm):

altezza
larghezza

DIMENSIONI DEL NEGATIVO (mm): x

LARGHEZZA DELL'IMMAGINE SUL MONITOR (pixels):


INDICE GENERALE


WRITE

Figure 3. The Impianto program. The card to control the lighting, the haze and the camera parameters.

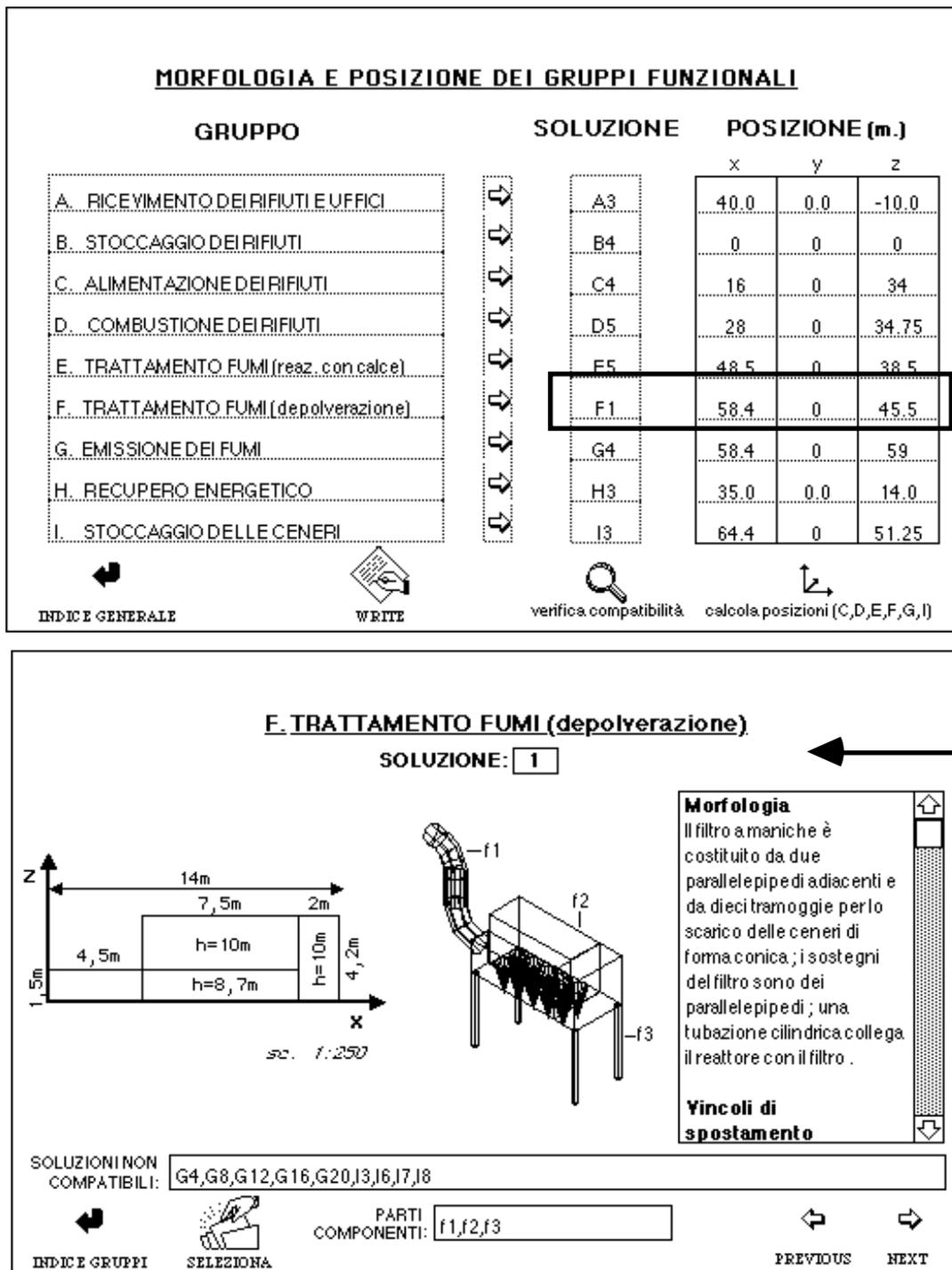


Figure 4. The Impianto program. Two cards from the section useful to select and to position the groups.

Conclusions and future developments

In this work a methodology to aid designing industrial plants in "sensitive" landscape was proposed. The method makes use of different software tools during the several steps of the design and evaluation process.

The designer works assembling quickly design-alternatives that are directly evaluated against the real landscape pictures. We are involved in several new research contexts.

We are working to better integrate various software tools and developing more powerful user interfaces improving the interactivity. With this aim we are working either with Ipertextual tools or by a typical CAD development system like AUTOCAD.

An other research's direction considers to use logic programming (Coyne et al. 1990) techniques to describe the compatibility links and the positions among the parts. With this approach the designer can choose some elements, that he or she considers effective in that peculiar landscape, and get as answer by the program all the compatible solutions left. The designer then goes on narrowing the space of the alternatives, choosing in successive phases new elements so much that he arrives to an adequate design solution.



Figure 5. Photograph of the project site taken from one key point.

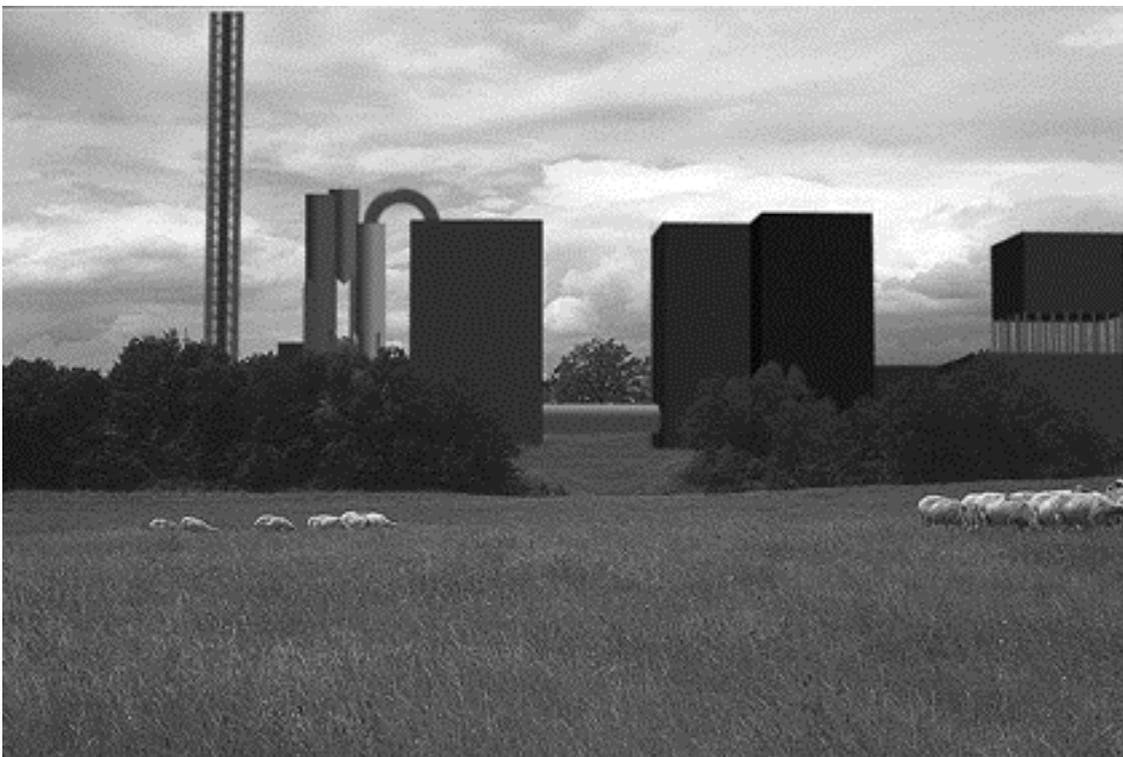


Figure 6. First design solution of the incinerator.

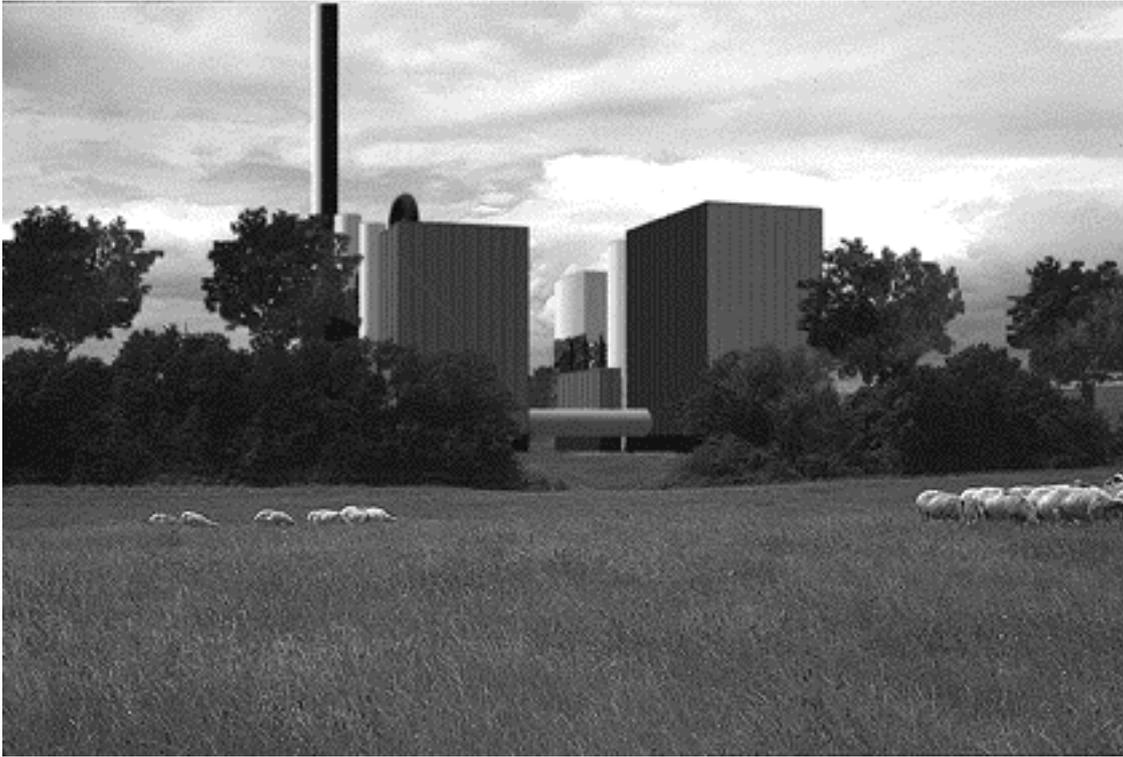


Figure 7. Second design solution of the incinerator.

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