Emerging Visualization Technologies To Support Public Participation In Urban Mass Transit Planning Context

by

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Abstract

With the post-modern turn in planning theory, the public's input is now required in a wider variety of areas. Nevertheless, the discourse about planning has remained too technically oriented, depriving the general public from a real understanding of the issues at stake. The development of multi-media, web-based tools could provide the public with common concepts and a common vocabulary to discuss and elaborate a shared vision on planning-related issues.

This thesis develops such a tool to educate the public about urban transportation auditory impacts. By combining movies, sounds and simulations, we offer multiple representations of sound in an interactive and interpretative way which could augment the social knowledge about those issues. Furthermore, the same framework could easily be expanded to encompass other technical elements.

This tool prefigures one of the multiple ways by which information technologies will impact the planning practice. This thesis will also suggest some of the possible evolutions in the planner's role within this new technology-enhanced environment.

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A camel is a horse designed during a public meeting.

anonymous

Part I

Introduction and Background of the project of this thesis

Chapter 1

Introduction

1.1 Public participation in the transportation planning process

The participation of the public has been an essential element of any planning process for years ([Steger, 1972]). But as Tett or Forester would point it out, such a process was intrinsically distorted and involved the citizen at a late stage, when the problem has been framed and the available options already narrowed [Forester, 1989, Tett and Wolfe, 1991]. To remedy to those shortcomings, the United States "Intermodal Surface Transportation Efficiency Act" ISTEA requires public input at the early stages of any project and for a large range of elements:

> *The planning process [should] consider such factors as land-use and the over-all social, economic, energy and environmental effects of transportation decisions.* [FTAStaff, 1990, p. 11].

Nevertheless, the fields of input (such as civil engineering, transportation planning,...) often use "technical jargon" which clouds the Public's comprehension of the issues and can potentially distort perceptions of the information. Indeed, the transportation field is mainly dominated by technically-oriented professionals for whom a proposition such as "L_{eq} is the average, over a period T, of the natural logarithm of the amplitude of the acoustic wave length, which is also its energy" makes sense. Nevertheless, as they try to explain these concepts to a non professional audience, they often get lost explaining the basis of natural logarithms or they oversimplify the concepts.

By depriving the stakeholders of a common representation (whether images, words or symbols) of the issues, such a process prevents any real discussion, any formation of "intellectual capital" which would empower the public and shift the decision making from the dominant economic power to the citizen[1].

[1] Orwells, in *1984*, demonstrates how the destruction of the absence of words describing certain concepts would undermine our ability to explore those concepts.

Furthermore, by defining the agenda independently of the public ("we need some new capacity here, let's discuss with the public the implementation of a light rail system along this corridor"), such a process already frames the answers and defines the range of possible conceivable futures. The public participation in the decision making process remains illusionary.

1.2 Hypothesis of this thesis

Grounded on the assumptions that the current urban transit participation process is not satisfactory and that the information is distorted, this thesis makes the hypothesis that a reasoned use of multimedia technologies could remedy the distortion of information and enhance an inclusionary process (as proposed by Forester [Forester, 1989]).

The development of the new Information Technologies make technical aspects, and as well as intangible notions, more easily graspable through the use of multimedia representations. The creation of an tool could thus have the capacity to explicit the multiple dimensions of each urban transportation mode and to make them easily available either during collective use or through individual consultation via the World Wide Web. This tool would aim at educating the public, at giving it a common vocabulary and at developing the current discussions around urban public transportation.

Obviously, the use of such a medium is not risk-free. Forester warns that any communication tools carry some systemic distortion of information. An in-depth reflection on the meanings conveyed by the medium will thus be necessary.

1.3 "Roadmap" of this thesis

In a first part, we will describe the theoretical planning background of the thesis, and in particular, the requirements of contemporary "post-modern" planning practice. Then, we explain the impacts of noise related issues in the social fabric of a communities, and therefore, the strategic position of a good sound understanding within the public.

In a second part, we will describe how the multimedia could positively participate to the education of the public about noise.

Then, in a third part, we will explain how the noise representations could be greatly enhanced by some noise contours simulations. The models and the technical aspects of this endeavors will be explicited.

Finally, in a last part, we introduce the prototype we have developed. We, in particular, explain how the apparition of such multi-media tools could impact the whole planning practice and we suggest some directions in which the planner's role could evolve.

Chapter 2

Planning background

2.1 Theoretical situation

To fully explain the current position of planners with respect to the public participation process in transit planning, a little detour to the fundamentals of post-modernism is necessary. This shift in planning paradigm has been completed by Habbermas' reflections on communicative rationality and the limits of communications.

2.1.1 The cultural shift of post-modernism and the limits of the rational planning

Started in the 1960's and 1970's in literature criticism, post-modernism rapidly become a dominant paradigm in both the arts and the social sciences. It has four foundations (although true post modernists would challenge that very notion): "deconstructivism", "anti-foundationalism", "non dualism" and "encouragement of plurality and difference" [Milroy, 1991]. In that perspective, the individual is considered as "taken in" and "shaped through" his/her relationships to others, through communicative practices. Since the individual's consciousness is dialogically constructed, everyone has communicative abilities and can use them in the public realm [Healey, 1996]. Furthermore, the notion of unity in the social body disappears as it is now viewed as a web of relationships that can't be rationally apprehended. Diversity, pluralism, inclusionary become key-words and concepts to intervene in the social fabric.

In that context, the traditional role of the "planner as an expert" becomes irrelevant because the city could not be considered as an global homogeneous object. Even the pluralist approach of the 70's which tries to unite different points of views appears useless as it denies the essential variety of post-modern societies. "To the rational plan producer should succeed a planner able to shape communication networks" ([Tett and Wolfe, 1991]).

2.1.2 Habbermas, Forester and the communicative turn in planning

The post modernism critique established that the essence of planning should be communication. Simultaneously, Forester built on Habermas's Communicative Rationality to demonstrate how any form of communication is intrinsically distorted [Forester, 1989]. His proposition is that information is power, not only by its sole content, but also and mostly because its medium influences the very acceptance of the issues.

> *"Communication is a form of action by itself more than simply a way of communicating truth"* [Innes, 1996].

It shapes the terms of the debate, it limits the available options, it focuses attention on specific issues forgetting other concerns, it casts who decides and who reacts... Information defines the way people think and consider a problem. Furthermore, Forester argues that the information is systematically distorted in a way that reflects the dominant form of power. The traditional planner is just an (unconscious ?) agent who, through his/her work, perpetuates the power structure of their environment.

Indeed, in the traditional planning approach, the planner-expert creates information to respond to a problem that decision makers, not the public, have created and thus defined. In that information production process, the public is usually excluded, both as a result of the "elitist" values of the planners and because of the barriers posed by specialized scientific knowledge and technical jargon [Day, 1997]. Furthermore, formal knowledge often has little impact on the final decision [Innes, 1996].

Nevertheless, even if it does not have any significant meaning conveyed, the very act of communicating shapes the public perception, depriving it of any real democratic control on his fate. Tett and Wolfe have shown how a systematic distortion of the planning discourse implicitly excludes the public of the "public" planning process [Tett and Wolfe, 1991][1]. Forester lists the various surreptitious ways by which the power, by means of the planner, distorts the information (obfuscation, limitation of the options, false assurance, distraction from key issues, pretension to legitimacy, misrepresentation of facts...). The ideal of the neutral planner could not resist this analysis.

A radical shift in the planning paradigm is thus necessary. The new role of the planner should be focused on enhancing the communication process with and among the public and counteracting the inherent twists of information. Four criteria should re-structure the public discourse : comprehensibleness, sincereness, legitimacy and accuracy [Forester, 1989]. The planning process becomes an interactive and interpretative process that changes all its players, including

[1] Their study of 5 Canadian master plans is based on the Foucault's theories of power and control. Although they focus on the written discourse, their conclusions could be extended to any kind of communication medium in the planning process/

the planner. An inclusionary process, it encompasses a multitude of claims and aims at developing the reflexive and creative capacities of its participants. The planner should

> *"help others articulate their world's generative themes."*
> ([Murgerauer, 1993])

In that perspective, the "expert knowledge" could become collective intellectual knowledge only if a dialogue get instituted to talk about its meaning, its accuracy and its implications. Planning is now about attention and arguments, and only marginally about plans [Forester, 1989].

2.2 The potential of information technologies for planning-related communication

2.2.1 The new opportunities offered by the multimedia

Forester explains that the planners already have all the techniques to fight the misinformation and to create a fair inclusionary public process. My hypothesis, in this thesis, is that the multimedia could offer new tools that could enhance the communication even further.

The traditional planning process often involves access to three kinds of information : physical information (documents, maps, images...), electronic information (computer based displays) and cognitive information (through the human recollections and stories telling). Apart from their specific distortion, each of those media present challenges that are involved with communicating their message to the public. For example, physical information needs to be organized, quantitative data may be difficult for laypersons to interpret, computers are typically designed to support interactions with only one user at a time...). Furthermore, the integration of physical, electronic and cognitive information remains problematic, and the information access is usually sequential although the conversation may not be.

On the contrary, by integrating drawings, texts, graphs, sounds, narrative descriptions, CAD, charts and videos, the multimedia technologies allow to present a variety of perspectives on the same subject. Its visual orientation makes its message attractive and the quantitative data more easily graspable.

The second asset of multimedia representation is its capacity to be annotated real time, fostering even more the communication process by displaying immediately the reactions or ideas of the public. Furthermore, technologies as hypertext allows non linear discourse which is closer of the mind's way of functioning.

Finally, the Collaborative Planning Systems tools are now Web based. Not only does it allow a better diffusion of the knowledge, but it allows access to a wide range of data and images that could easily be incorporated in the presentation. Through this access to the WWW, the multimedia tools could link the public to more specialized sites, if specific needs arise. It also allows a more accurate and frequent up-date of the information displayed.

All those elements could increase any individual knowledge and, thus, stimulate an inclusionary dialogue by creating a common knowledge of the issues (see [Shiffer, 1995a, Shiffer, 1995b]).

Nevertheless, the multimedia should remain a tool for and not a substitute of the planner [Flemming, 1994].

Furthermore, it is not exempt of the distortions of information pointed out by Forester. Since multimedia acts partially on the visual and irrational perceptions of the public, manipulations are all the more easier to convey. The planner's role is thus all the more important to help the public to appropriate the knowledge received.

Moreover, as Coyne describes it in the case of a design studio ([Coyne, 1996]), multimedia does not carry the same kind of messages as traditional media. Citing McLuhan, he states that "the medium is the media". He opposes precision and approximation, superficiality and profundity, representation of a project and experience of the audience.

2.2.2 Previous works on the same subjects

The idea of using multimedia as an educative tool is not new. The use of multimedia tools has already been widely employed in education and entertainment [Cawkell, 1996]. Architects routinely uses virtual reality to simulate the impact of their projects. Indeed, [Rahman, 1992] describes an experiment related to this thesis' project. He used multi media techniques to put an architectural project in context and then asks people to judge its impact using a set of subjective criteria.

Although the merits of multimedia tools in planning have already been described ([Shiffer, 1992, Howe and Brail, 1994]), few projects have actually been conducted in the field of visualizing transit characteristics. Indeed, most of the efforts have been directed toward GIS, expert decision support systems, and spatial representation of data[2]. Nevertheless, the official reference guide on public involvement in transportation decision-making ([Pub, 1996]) praises the qualities of "computer presentation and simulations".

The transportation field offers few additional resources in support of enhanced public participation with such a tool. Indeed, much of the energy seems to have been devoted to ITS (and its applications in terms of "on board" information) and to expert systems[3]. Furthermore, smaller scale projects tend to be

[2]An extensive reviews of recent years (1992-1997) issues of *APA Journal, towns planning, URISA journal*, have not produced any articles about multi media, except, in a couple of times in the context of GIS.

[3]I unsuccessfully reviewed the recent issues of *Transportation Research Records (1995-1998), Transportation (1995-1998).*

more focused on network optimization and air transportation issues[4].

Finally, the main reference for this thesis remain the transit visualization project at the MIT's CRL. At a first approach, it does not appear to be completely suited for public participation processes. Indeed, its scope might seem too important for neophytes. Furthermore, although it constitutes an extensive database, the data might appear a little raw for non-specialists and the comparisons between modes are not easy. Nevertheless, it constitutes a foundation on which this project is grounded.

2.3 Position of the thesis in this background

As already mentioned before, this tool would aim at informing people about the consequences of their choices of transportation mode. In that perspective, this tools would rather be used in the early stages when the alternatives are to be made between general transportation modes (light rail, trolley, regular buses, rapid transit, commuter trains, no public transportation (ie cars only)[5].

Each mode could be described along dimensions that are relevant to the public. Those dimensions are already well documented, although each author emphasizes different aspects of them [Merlin, 1984, Cohen and Reno, 1992, Lovelock et al., 1987]. We can organize a list as follow :

1. Technical description of the mode
   (a) Power supply, vehicle control (guidance), train composition (modularity).
   (b) Length, width, boarding level, handicapped access.
   (c) Capacity per vehicle, seated capacity, peak hour capacity
   (d) Average Speed, maximum speed, acceleration.
   (e) R/W (grade separated, at grade, no dedicated R/W), reliability.
   (f) Typical type of stations, station access, station spacing, amenities provided in station.
2. Urban impact
   (a) Space consumption (in straight line, in curve, at intersection...), in movement and at rest (parking spaces...) per person and/or per person.miles.
   (b) Urban footprint of possible R/W. Cut effect and local accessibility issues
   (c) Station design and insertion in the built environment.
3. Investments and Operating Costs (the costs are highly dependent of the context, but typical values for a mostly flat and friendly environment might be relevant).
   (a) Per miles (passenger perspective)
   (b) Per tax payers
   (c) Property value around the infrastructure (???)

[4]The Princeton transportation library lists most of them : http://dragon.princeton.edu/ dhb/main.html

[5]The Automated Guideway Transit is purposefully omitted from the list as Its future and its real value appears unclear.

4. Energy consumption
5. Safety (perceived, real...) for the ridders and for the neighborhood (in term of accident). Very tricky aspect that we may want to let aside.
6. Level Of Service
   (a) Headway, frequence, waiting time.
   (b) Travel time, including walking time.
   (c) Comfort (physical (seat availability, crowding, privacy (car), riding comfort) and aesthetic (vehicles and station)).
   (d) Reliability (variability of travel and of waiting time, congestion.)
   (e) Alternative use of time.
7. Nuisances
   (a) Pollution (general, local...)
   (b) Noise (in straight line, incurve (rail modes), at start)
   (c) Vibration
8. ...

This thesis is necessarily limited in time and subsequently in scope. Thus, for reasons that we will explain in the chapter 3, we decided to focus on the issue of noise.

This object of this thesis is *not* to come with new figures for it. The challenges of this thesis are to understand what are the real concerns of the people, to analyze what they do not understand and to offer multi-media representations of those notions.

One of the issues is the organization of the information, under the double constraint of being user-friendly and maximizing the opportunities for comparisons between modes. The project could either be:

-Didactic. The user progresses through the database along an "hyper text" path. This perspective is particularly suited for an individual usage.

-Encyclopedic or comprehensive[6]. The project is rather a database of multimedia representations of the impacts of urban transportation modes. The planner uses it as a support to his own explanations. The matrix of the *transit impact project* lies in that categorie.

For time constraints reasons, we will rather focus on a limited number of in-depth representations of urban noise, taking real life examples to support our purpose.

[6] For lack of a better word.

Chapter 3

Noise and Society

In the previous chapter, we described the general background and the various dimensions through which the social impacts of any urban transportation modes could (should ?) be assessed. Obviously, all those dimensions do not have the same importance for a community; and their ranking would be highly subjective. Furthermore, no formal study has been conducted to address this issue. All the same, among the "adverse" effects of any new public transportation mode, no second sight is needed to acknowledge that atmospheric pollution and noise are among the major concerns for any impacted community. The length of this thesis limits the amount of material which could be covered and researched. Thus, we have focused its subject on the representation of transportation noise in an urban context.

Indeed, noise occupies a particular situation in our urban life. First, hearing is a very specific sense, which makes noise unescapable and rapidly annoying. Second, noise could create numerous negative outcomes, not only on health but also on the general social fabric. This chapter will explore those issues.

3.1 The specific position of hearing in human life

Man has five senses; Among them, hearing occupies a very specific position[1].

First, the human hearing system is highly susceptible to unwanted acoustic stimulation. This might be a physiological remainder of animal life when a fine hearing constituted a key element in the survival of the species. Nevertheless, we have inherited this ability; Sound is now unescapable and ubiquitous (as opposed to sight which could more easily be canceled by closing the eyes). An other inheritance from animal ancestors is the ability to put an immediate significance on sounds. Although the exact meaning of a cry could not be easily

[1] [Jones and Chapman, 1984a]

assessed, a cry will be perceived as a signal of danger whichever the cultural setting. Indeed, we have also inherited the three animal stages of "visceral" reaction to acoustic stimulation [Pelmear, 1985] :

1. Orienteering. Movement of the head and the eyes toward the direction of the sound stimulation (low and moderate sound level).
2. Startle. Flexion of the arm, opening of the mouth, blinking of the eyes (loud sounds). The subject is stressed, in a medical sense, but does not necessarily feel frightened.
3. Defensive. Preparation of the body for action (sound perceived as threatening which ever its actual level).

Secondly, hearing constitutes the communicative sense above all : Speech remains the primary mode of interactions among human beings (as opposed to writing which is mostly unidirectional). Furthermore, as human rationality has been developed around the scripture and the sight, hearing has become (has always been ?) the aesthetic sense per se. Addressing man's irrationality, it can convey a large range of feelings and emotions. People are more often moved by music than by painting. Furthermore, the use of music to put people in some kind of trance has been known for centuries (from the conditioning of soldiers before the battle to magic rituals in the "primitive"[2] tribes).

Surprisingly, whereas there is a large vocabulary to describe the visual world, auditive elements lack direct denominations and are mostly accessed through metaphors; It could almost be said that sounds "exist" to be irrationally felt and not to be accessed through the rationality of a constructed discourse. Symmetrically, the sounds become metaphors for the world. On the other hand, music did not acquire the sacred status of writing, and consequently, it easily constituted a shared body of culture among a population.

As sound is intrinsically intertwined with culture, its perception is highly determined by the social setting. The appreciation (and subsequent judgement) of any auditive stimulations depends of the societal context : the appreciation of music requires an education, and, inversely, the sounds which are regarded as undesirable in some cultural settings could be easily accepted in other civilizations.

Those elements show the pre-eminent and unescapable place of hearing in the human life and its social organization.

Finally, it is important to insist again on the very limited auditive vocabulary. As a consequence, the physical description of sound is abstract (or visual). Furthermore, the scale of human ear is so large ($20Hz$ to $20.000Hz$) that only a

[2] For lack of a better word

logarithmic scale could efficiently be employed. Those two reasons make sound a difficult matter to interpret and discuss.

3.2 Sound and Noise

3.2.1 Noise and its causes

Noise could be defined as any unwanted solicitation of the human acoustic system. A sound could turn into a noise for two reasons :

- either it is intrinsically undesirable, whichever the level at which it is played (the shriek of a chalk on a black board). Under this kind of circumstances, the problem could only be alleviated by eliminating the source of the noise and not by merely reducing its level.
- or it is not the sound by itself, but rather its interference with (or intrusion in) the listener's life which makes it undesirable, in which case moderation measures could be considered.

The "annoyance" produced by noise will be explored in the next section. In an urban context, there are basically three main sources of noise in dwellings : the noise from the street (transportation, factories...), the noise from the building (neighbors, amenities such as plumbing, lifts...) and the noise originating from the apartment itself (electrical appliances, heating, ventilation...). During the day, it could be shown that the "indoor" noise is louder than the "outdoor" noise when the windows are closed [Fidell, 1984]. This justifies our main focus on loud single noise events rather than on the general phonic background.

3.2.2 Two misconceptions about current noise levels

At that point, it seems important to clarify two misconceptions. First, noise has always existed and we can not refer to some kind of golden age of quietness and peace [Fidell, 1984]. Indeed, 20 years ago, in 1977, a survey in Great Britain showed the following results (see table 3.1 in page 23, the results are cited in [Langdon, 1985a, p. 167])

	% age of people hearing the noise	%age of people being **annoyed** by the noise
Road traffic	55 %	5%
Air traffic	35%	3.5 %
Neighbors	25%	**8%**

Table 3.1: Noise annoyance from all sources (1977, Great Britain)

In 1977, the major source of annoyance was the noise from the neighbors. Nowadays, the source of annoyance seems to have shifted from the neighborhood to traffic, but noise has always been a problem. However, the situation should not be considered as a inevitability and quietness should be considered a right as valuable as clean air or fresh water.

Secondly, the noise is not the inevitable outcome of the industrial revolution. On the one hand, the loudness of horse carriages was without common measures with the noise of contemporary cars. On the other hand, noise reduction techniques have evolved which allows considerable improvement in noise emission.

3.2.3 The measures of noise

This thesis is not the place for a complete presentation of sound and acoustic issues[3]. Basically, a single sound is the propagation of a change in the air pressure $p(x, y, t)$. A complex sound could be characterize along two key dimensions : its spectral composition and its intensity. Mathematically, at one given point, a sound could be described as the addition of all the individual waves of amplitude p, frequency $1/l$ and phase Φ :

$$S(t) = \int_{l \in \mathcal{R}} p_l(t) \sin\left(2\pi.l.t + \Phi_l(t)\right) dl$$

Those components vary with time t . A complete description $[p_l(t), \Phi(t)_l]_{l \in \Re}$ of sound at any given point is inefficient for survey matters. Several synthetic measurements have been devised :

$L_p(t)$ is the instantaneous level of the sound pressure on a logarithmic scale. It corresponds to the usual decibels. $L_p(t) = 20 \log_{10}\left(\frac{S(t)}{S_{ref}}\right)$.

L_{eq} is the average level, over a day, of the instantaneous levels described before. It is the constant level which would produced the same energy, over 24 hours, as the real fluctuating sounds. This measures focuses more on the "cumulative" effects of noise.

L_{dn} is the same as L_{eq} excepts that the "nightly" noises (between 10 pm and 6 am) receives a penalty to account for the greater sensibility to noise during the night.

L_{10} is the level which is exceeded during the 10% loudest times. This measures reflects the importance of noise peaks.

L^A corresponds to the sounds actually heard by the human ear. Indeed, the human ear perceives the medium frequencies better than the low or the high frequencies. Consequently, in the A - levels, a filter is applied which tries to account for those physiological specificities. This filter could be applied to any of the previous levels (L^A_{dn}, L^A_{10}, etc...).

[3] See for instance [Harris, 1979] for a complete and detailed description of the subject.

Each of these measures answer specific expectations or theories about on the relationship between noise and annoyance. This project has to deal with noise measures in two specific areas :

Annoyance In that field, the most commonly used and analyzed measures are time averaged measures : L_{eq} and L_{10} and their derivatives.

Noise emission In that area, the focus is on instantaneous noise production by the vehicle, thus the adequate measure would be $L(t)$.

The relationship between those two measures exists but is not very operational; As we will explain it later, we will have to mix those two kinds of measurements in our project.

3.3 Noise and Annoyance

Noise annoys. But what really annoys ? Is it the noise per se ? the the accumulation of noise exposure ? Or is noise merely a catalyzer of other environmental problems ? This section tries to summarize the large body of literature dealing with the triptych Noise-Exposure-Annoyance.

3.3.1 Inherent difficulties of the problem

Annoyance is a psychological situation very easy to acknowledge but very difficult to measure or to scale. It could be characterized as an adverse subjective response to a stimulation but it manifests itself in a variety of effects, direct and indirect [Langdon, 1985a]. Thus, it is very difficult to assess and compare annoyance, there are no "scientific measurement under a controlled experiment" but rather social surveys, with all the bias such studies may intrinsically contain.

Basically, there are three main sources of problems with those research :

Methodological reasons In particular, the framing of the questions and the way the annoyance is scaled make comparisons with other surveys difficult.

Scale of the sample The scale and the structure of the samples are critical for reliable statistical results. Usually, surveys and studies are conducted on small samples with large inherent statistical bias.

Measure of noise As we will explain in a previous subsection (3.2.3), there is not one measure of noise, but several corresponding to different appreciations of the reality. The necessary aggregation of noise data into a synthetic number makes the surveys difficult to compare. Indeed, many surveys even create their own index of noise levels so that it answers more accurately to their needs. But the inability to access to the initial data makes comparative studies impossible.

Those disclaimers being expressed, we will now focus on the annoyance. We can make the distinction between individual annoyance, which is the average annoyance[4] of a *small*, homogeneous group of people under similar noise conditions. Conversely, community annoyance is the average annoyance of a larger group of people in their natural environment[Molino, 1979].

3.3.2 Individual annoyance

Understanding the relationship between annoyance and noise is, in fact, composed of two distinct questions : first, what are the components of noise ? and secondly, how could we predict the annoyance produced knowing the "level" of each component ? The later question could not be easily answered because the studies are inconclusive. As we will explain now, annoyance does not depend exclusively on exposure to sound or on its physical components. Other psychological and environmental factors must be taken into account. Those elements are, by nature, impossible to quantify, subsequently undermining the efforts to predict individual responses to noise.

Component of Loudness

Molino defines loudness as *"the subjective intensity of a sound"* and lists extensively its affecting factors [Molino, 1979] (see table 3.2, page 26).

Primary acoustic factors	Sound Level
	Frequency
	Duration
Secondary acoustic factors	Spectral complexity
	Fluctuation in sound level
	Fluctuation in frequency
	Rise-time of the noise
	Localization of the noise source
Non acoustic factors	Physiology
	Adaptation and past experience
	Listener's activity
	Predictability of the beginning and the end of the noise
	Is the noise necessary ?
	Individual differences and personality

Table 3.2: Factors which affect individual annoyance

Molino's list is mostly focused on physical, easily quantifiable elements. He does not really consider that noise annoyance could be the crystallization of a more diffuse and more general feeling of annoyance against an aggressive (or simply unsuitable) environment.

[4]If it has a meaning

Indeed, more recent studies are more cautious when it comes to link Molino's list to actual annoyance. Langdon puts forward the number of noise events, their duration and levels and their composition. But he also insists on the larger importance of the environment. The noise annoyance could not be completely explained by exposure, but depends of the overall living conditions, of the social value of the noise and of the personality of the listener [Langdon, 1985a].

Similarly, Jones *et al.* downplay the importance of exposure to noise and rather put forward environment and psychological factors [Jones and Davis, 1984]. They make the distinction between four categories of causes :

Sensitivity to environmental factors in general Being annoyed by noise might be the expression of a broader general annoyance with one's environment. The noise, in a way, crystallizes all the frustrations.

Specific attitudes and beliefs Three main elements could be listed under this category :

1. (Unconscious) fears associated with the source of the noise (plane crashes, health attacks by pollution...)
2. Social value attached to the sources of the noise and the perceived necessity of the sound.
3. Possibility of interfering with the source of the noise and degree of control over it. [5]

Demographic variables Its impact is not very clear, although it seems that annoyance grows with age, especially among men.

Personality In the general knowledge, personality would constitute the most natural source of annoyance. Unfortunately, there are very little support from empirical facts. Neither the neuroticism, the anxiety nor the extraversion appear to be determinant in the level of annoyance induced by noise.

Finally, for Cohen and Spacapan, the cognitive meaning of sound constitutes the major cause of stress and thus annoyance. Although they consider the previously described dimensions as important, they also insist on the privacy and the intrusive aspect of sounds. There are two aspects to this questions. First, as someone can hear his neighbors, the neighbors can hear him and thus, his privacy is severely limited; Secondly, the noise, by itself, constitutes an intrusion in one's privacy. In that perspective, the predictability and the control over the noise could constitute efficient psychological counter-measures [Cohen and Spacapan, 1984].

[5] If the previous points are well beyond our control, the planners could have a decisive influence on this one. Indeed, by empowering the communities and by involving them in the decision-process, the planners could give some control back to the people. Although this control is limited, it might significantly change the acceptance of a project and thus the annoyance which results of its impact.

To conclude, it seems that acoustic components alone can not explain the annoyance levels. Larger environmental and psychological factors must be taken into account. For this reason, it is not possible to predict the individual reaction to given acoustic conditions per se. It also illustrates the impossibility to treat noise exposure alone. The issue of noise must be considered as part of a larger picture. Furthermore, it also shows the limits of a purely "normative" approach to noise control.

3.3.3 Community response to noise

(The community response concerns "aggregate" annoyance to noise and not any kind of community mobilization against its cause.)

The community noise has three characteristics [Fidell, 1984] : it is chronic rather than acute, it is beyond the immediate control of the community and it affects the activities particular of the residential livings. It is difficult to assess with precision for two main reasons :

- the indoor noise might be very different from the outdoor noise (see before);
- the persons are, by nature, mobile. Thus it is difficult to assess with precision the level and the type of exposures they received.

Nevertheless, the community response constitutes an important issue the noisiest part of the cities being usually the poorest. Fidell cites the results of the study which show that, on average, when the salary doubles, the mean outdoor noise (L_{eq}) decreases by 15 dB[6]...

Theoretical explanations of noise annoyance

As for the individual annoyance, exposure to noise can not solely explain the annoyance level in a community. As Levine[7] showed it, annoyance is not directly related to exposure, it is correlated with it, (as opposed to caused by it) . This result could be related to Fidell's findings on the social distributions of noise.

Moreover, the annoyance is a dynamic process, and the community adapts to new conditions of noise. Fidell proposes a decreasing exponential law for annoyance:

$$P(t) = P(\infty) + \Delta P \left(e^{-\frac{t}{T}} \right)$$

where P is the proportion of highly annoyed people and T the time constant which varies between 2 and 8 months (see figure 3.1, page 29).

Furthermore, there is no firmly grounded theory to justify which could be the "good" noise level ($L_{eq}, L_{dn}, L_{10} \ldots$) through which explore the correlation between noise and annoyance.

[6] 15 dB corresponds to a noise 5 times louder (or softer)...
[7] Cited in [Fidell, 1984, p 256].

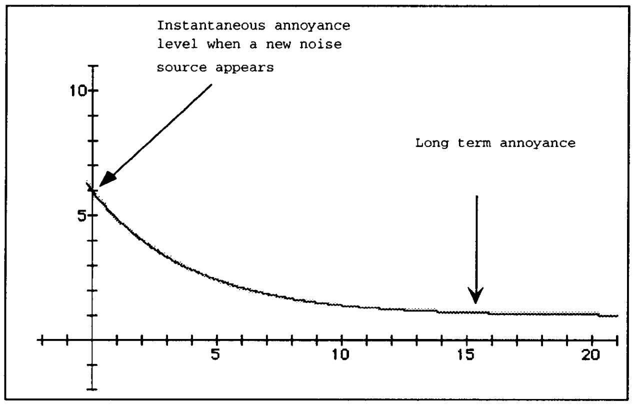


Figure 3.1: Annoyance decreases with time when a new project is introduced [Fidell, 1984]

Schultz's Law

Nevertheless, empirically, Schultz has proposed a good correlation between L_{dn} and the "highly annoyed" fraction of the population (see figure 3.2, page 30). Taking into account what has been said before, this diagram is a static representation of some kind of long term equilibrium.

Schultz's results are important because they extracted most of the previous studies and because they offer a coherent view of the correlations between high annoyance and sound exposure. Nevertheless, they could not be directly operational in the context of this thesis for several reasons :

- As we explained before, tolerance varies with the perception of the source of noise. For instance, Langdon reports that if 65 dB appears as the limit of acceptability for highway noise, this limit could be raised up to 72 dB, or even 75 dB in the case of trains [Langdon, 1985b]. The acoustic differences of those two sounds could not be the only explanation for those changes. Indeed, noise produced by trucks has an acoustic structure close to the one of trains, but trucks' noise tends to be much less accepted.

- Schultz works with aggregate data (L_{eq}) whereas in the case of our project, we will work with instantaneous sound levels which reflect the "peak" nature of transportation operations noise. Moreover, the time averaged L_{eq} or L_{dn} tend to minimize the impact of acoustically loud but timely small noise such as the passage of a train. For those reasons, Schultz measures might be more suited for traffic noise which is more regular[8].

[8] Although trucks and Harley Davidsons might create highly annoying peaks which are not accounted for in L_{eq}.

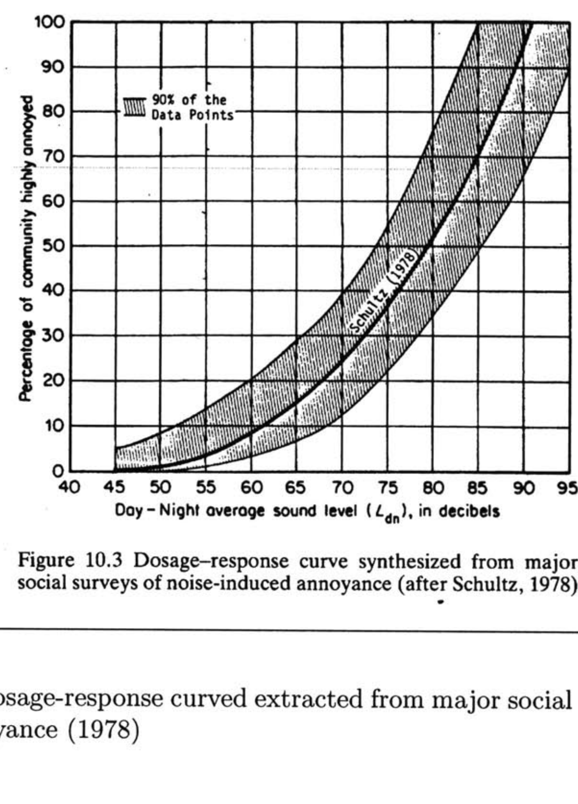


Figure 10.3 Dosage–response curve synthesized from major social surveys of noise-induced annoyance (after Schultz, 1978)

Figure 3.2: Dosage-response curved extracted from major social surveys of noise induced annoyance (1978)

Furthermore, as Dubbink explains it ([Dubbink, 1991]), we do not have a good way to represent efficiently averaged noise levels such as L_{eq} or L_{10} even though they might be more pertinent for our purposes. This might be seen as a major flaw of the utilization of multimedia technologies in noise planning. On the other hand, it seems difficult to conceive a good medium for these kind of time-averaged information[9] , and we, planners, might have to consider balancing the efficiency of such aggregate measurements with their understandability by the general public.

3.4 Noise and Health

According to the World Health Organization, health is

> *a state of complete physical, mental and social well-being* [Pelmear, 1985].

In this section, we will only explore the first two components of health and we will devote the next section to the social outcomes of noise.

As we explained before, meaningful studies of the effects of noise on health are difficult to conduct and to interpret. Basically, three main reasons complicate those studies : Noise creates induced behavior and can not be analyzed individually; each study has developed its own specific methodology, in particular, little is known about the mechanism (cumulative or instantaneous) of noise impact; Finally, the psychological context and the ability to adapt to noisy situation are not taken into account.

3.4.1 Noise and medical symptoms

The literature on noise-induced pathologies deal mostly with industrial noise, which has a specific cultural and psychological context. Anyway, there is no clear and direct link between noise and physical illness. Nevertheless, by repeatingly stressing the individual (the startle effect described before), loud environment may contribute to higher blood-pressure, heart problems and increased arousal [Burns, 1979].

Studies have also shown an increase in drug use in noisy neighborhood without being able to correlate it to higher hospital admission. It seems that this drug use might rather be an psychologically-induced behavior rather than a real need for medical support [Clark, 1984].

Moreover, it is important to distinguish between, on the one hand, the high noise levels (usually industrial) for which a causal relation could be made explicit, and, on the other hand, the low noise level environments where the relationship is less clear. Indeed, in the later context, we might rather face the

[9] As already mentioned before, the difficulty comes from the high variability of noise during a day. Playing a continuous noise of L_{eq} dB will never account for the complexity of real life noise sources, no more, by the way, than to say simply that it is equivalent to n trucks...

following linkage :

Noise ⟶ Psychological effects of Annoyance ⟶ Medical symptoms

Finally, the effects of noise and sleep have been the subject of numerous (and often contradictory) studies. The capacity of individuals to adapt to new sound conditions is high; consequently, the long term disruptions appear only with unusual or high frequency noises. This sensibility changes with age and gender. Furthermore, studies have shown strong correlations between concern about the noise (i.e. unwanted aircraft noises) and the disruptive effects on sleep [Pelmear, 1985]. However, although not a disease by itself, a bad quality of sleep could affect the general welfare of the individual and impede its professional and social development.

3.4.2 Noise and psychiatric symptoms

As for the medical symptoms, it is difficult to isolate noise from a wider pathological situation. Rather than being a primary cause, noise is understood as a precipitating elements of serious psychiatric conditions. At that point, it might be useful to refine a previous definition of annoyance (From [Clark, 1984]) :

Annoyance : "capacity of noise to bother, disturb or interrupt the enjoyment of leisure activities, the efficient performance of tasks and sleep".

The impacts of noise could thus be represented on a continuous scale as below (figure 3.3).

Increasing effects ⟶		
Feeling of begin annoyed	Interference with current activities	Pathological symptoms

Figure 3.3: Various effects of noise on the individuals

This representation is useful because the intertwined links between noise, health and the psychological state of the listeners. Indeed, noise seems to be a *precursor* rather than a *cause* of psychiatric disorder. It has an undermining pervasive and insidious effects on persons which affects the enjoyment of leisure and sleep, and through them, could affect, psychosomatically, the health of the individual.

3.5 Social Psychology of Noise

We have explored the impact of noise on health. Even if noise has limited pathological health impact, numerous studies have shown the negative social consequences of exposure to loud noises. Cohen and Spacapan[10] have summarized the current findings.

3.5.1 The effects of noise on social behavior

Studies tried to understand the relationships between noise exposure and sensitivity to others. The results are as expected; The helping behavioral response decreases with exposure to high sound levels. This loss of social openness endures even after the noise is stopped. Furthermore, the same effect is noticed under controlled conditions (laboratory) and in real life.

Further studies showed that, under loud noise, the subject are less frequently aroused by daily environmental details as if they could not focus on their outside world.

Similarly, the noise seems to *increase* (but *not to create* per se) the aggressivity of the subjects. It also impacts the attraction and the inter-personal judgement with lasting effects. The studies suggest that loud noise decreases the amount of information being processed, leading to oversimplications and distortions in the relationships.

Furthermore, noise has been shown to increase tension and disagreement within a group and to develop uncertainty. In particular, a survey in San Francisco showed that people in light traffic streets have, on the average, 3 times as much friends and 2 times as many acquaintances as the dwellers on heavy traffic street. Following the elements exposed before, the busy street inhabitants could develop less focus to other and, because of the inhospitality of their surroundings, have less opportunities for interactions.

3.5.2 Noise and communication

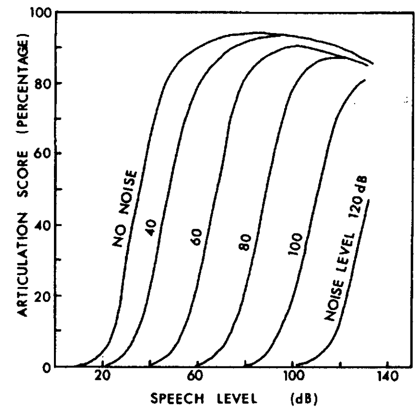
In the classical schematization of the communication process (transmitter, channel, receiver), noise impacts exclusively the media. Studies have been conducted to show the influence of noise on the communication process. Results are as expected. Basically, by speaking louder, the communication could be maintained in almost any circumstance (see figure 3.4, page 34). Furthermore, the same studies shows that random noise, such as transportation noise, are less disruptive than intelligible random noise such as random syllables.

In that respect, noise would physically disrupt the communication, thus creating the psychological reactions of this inability to communicate.

3.6 Consequences for this project

In this chapter, we have explained how noise is essential, ubiquitous and inescapable in human life. We have emphasized its major role in the commu-

[10] [Cohen and Spacapan, 1984]



Articulation score as a function of intensity for CVC syllables with no noise and with added random noise. [After Fletcher (1953).]

Figure 3.4: Speech understanding as a function of general noise and speech level (from [Ainsworth, 1985]).

nication process, and, consequently, its role as a social builder. We have also explained how noise could be disruptive in the social behavior. Although its direct medical impacts are not clear at this point, it is a major contributor to the general psychological state of annoyance, with all the repercussion this state could have on the personal, emotional and social life of the individuals.

Furthermore, we have explained how noise often crystallizes a more general and more diffused feeling of un-comfort with one's general living conditions. Because of the strategic position, addressing the issue of noise could help improve the general conditions of a community. In particular, we have explained how the feeling of control over a noise source and the social value attached on the noise source could greatly later the perception of annoyance in a community. For those reasons, if planners involve the public on noise related issues, they could have a decisive impact on the general welfare of the communities.

Following Forester's analysis, this thesis will aim at empowering the community by giving it a common knowledge about noise so that they can assess and decide fairly among the alternative they are presented. The next part will describe the tool we have built on this background.

Part II

Using Multimedia to educate the public : toward a web-based prototype

Chapter 4

The first prototype : refinement and validation of the concepts

In the previous chapters, we explained why dealing with noise is both strategic and difficult in any public participation project. This problem has been explored in great depth in the case of aircraft noise impact (see for instance [Shiffer, 1995a], [Dubbink, 1991]...). In that context, multimedia has been used to represent and simulate aircraft noise. The tools developed in such a way seem to have been well accepted by the public [Dubbink, 1991].

Nevertheless, as we explained it before, we don't have any evidence that such tools have been developed in the case of urban transportation noise. In that context, this thesis tries to develop and apply a framework for such tools. The general aim we tries to reach is to offer a large variety of uninterpreted[1] noise representation so that the public could have enough elements to make its own judgement. To achieve this goal, we want to use the multimedia tools now easily available.

4.1 Basic principles

4.1.1 Taking advantage of the "multi" of multi media

The most obvious representation aids of noise are video and sounds recording of the different urban transportation modes that we are going to consider. Nevertheless, this is too general to be operational. We will consider video and sounds recorded under the same conditions, in the same urban context. Else,

[1]By uninterpreted, we don't mean raw facts, but rather comparable situations for which we don't give our own opinion.

the comparisons would be biased, or might be considered as biased by the public. Furthermore, we need to have a highly quality stereo sound, such as digital 44.100 kHz sound. On the other hand, the quality of the picture is not as critical since we are not focused primarily on the spatial impact of urban modes. However, we have to make sure that the movies shot are equally "attractive" so that the comparative judgement of noise will not be scrambled by (subconscious) aesthetic considerations.

Since reflections on facades plays a critical role in urban noise propagation, it appears important that the user could visualize the position of the vehicle with respect to the general context. The movie could provide this general understanding, but it is constrained by the focal of the camera's lens. A GPS-like representation of the vehicle's position on a map or an orthophoto could certainly remediate to this shortcoming..

So far, we have only offered visual representations of the "context" of the sound production and some acoustic representations of the sound level. It seems important to offer some cross representations, and to use the pre-eminent place of sight to educate about noise. For that purpose, we decided to make a "dynamic" visual representations of the noise produced by the moving vehicle. The most efficient tool is the representation of noise contours either in the form of lines or of area of equal noise level. This representation will be superimposed to the GPS localization of the vehicle and the shape of the noise contours will change as the vehicle moves and its sound waves are reflected differently by the buildings (see chapter 5).

Finally, the spread of Hi-Fi players popularized the use of colored bars to represent the output sound levels in the loudspeakers. The same representations could be used here efficiently since there is not educational work to do with that tool.

4.1.2 Using the computing capacities of multimedia to allow smoother comparisons

The multimedia also, and maybe essentially, offers the unique capacity to link all those media in a smooth and predetermined way. We are going to exploit the scribing capacities of the multi-media tools in three ways :

1. The first and most obvious use of scribing is the coordination of the various representations. As the pictures and the sounds are coordinated in a movie, we want our five representational aids to be coordinated so that the user could get a complete appreciation of the situation.

2. The second use of those multimedia capabilities is the possibility to navigate within the representation of one mode. This is an essential feature to allow the user to make a reasoned judgement about the situation he faces.

This navigation could be either temporal or geographical. The latter could be achieved through multiple shots of the same scene, all synchronized so that the user could easily navigate from one point to the other while the vehicle "moves" on the street.[2]

The temporal navigation could be attained by the ability to reposition the vehicle in any position in the street. The movies, sound contours and other representational aids should then resume from the new position.

3. Finally, as the user should be able to view the same situation from various point of view, he/she should also be able to experience the "exact" same scene but with different transportation modes. The reason is that most people have a poor "sound" education and a poor "acoustic" memory . It is thus important to be able to replace one vehicle by another without having to replay the whole sequence.

   Indeed, in many "dynamic" noise representations, the switch from one mode A to another mode B requires a complete "rewind" of the sequence. The user has to unwind the representations from their beginning, and waiting for the right situation to appear, they tend to forget the initial situation. The comparisons are thus severely biased.

   Consequently, in our project, the user should be able to go back and fro among modes and to make immediate comparisons among modes seen, heard and experienced *in the same context.* This point could be attained by coordinating all the representations.

4.1.3 Choice of urban transportation modes and urban settings

As for any educational undertaking, the question of content is essential to the success of the project. When it comes to offer comparisons, one would want to be as comprehensive as possible both in term of urban setting and in term of modes presented. Ultimately, the user should be able to compare any mode (bus, metro, rapid transit, light rail, tramway, heavy rail, commuter rail, highways...) in the built context of its choice (dense core city, historic core city, light core city, suburban area, edge cities, post edge cities...). The CRL offers such a library of urban modes but shot in different settings and thus unable to serve unbiased comparisons.

Indeed, it seemed more important to offer a set of examples shot under the same urban conditions. The streets of the Boston metropolitan area provides a limited sets of possibilities. We selected three groups of comparisons :

[2]In fact, because of the limited material the CRL owns, we can not shot the exact same scene from multiple point of view. In fact, we will rather benefit of the uniformity of buses and tramway cars to pretend we are shooting the same scene each time... Adaptation...

- The steps of MIT at 77 Mass Av in Cambridge. In that setting, we can compare the noise produced by buses and trucks with respect to the general traffic (medium traffic conditions), including the special case created by the presence of a traffic light. The films were shot with one point of view only. This case was used to build the prototype, has not been completely developed and will not be used in the final product.

- The streets in Quincy around the red line station. These streets face the tracks of the red line and of the commuter line for Kingstown/Plymouth. It allows us to compare the noise produced by light rail, commuter rail and light traffic in a light urban context. Moreover, a noise reduction wall has been erected in this area, which allows us to assess the efficiency (and visual impact) of such a device. Finally, the local urban form allows to compare the noise directly on the street as well as a couple of blocks away from the sound sources.

- Commonwealth Avenue behind Boston University . This place accommodates the green line and a couple of bus lines on a very large avenue (3 general traffic lanes by directions plus 2 tracks in the middle and large sidewalks) with low buildings. The comparisons are done in a medium to light traffic context.

Those comparisons constitute a coherent set of urban transportation modes from which the public can make its opinion. Obviously, it is not comprehensive, but it shows some examples of what could be done for further research. Furthermore, those examples were not as fully exploited as they could have by lack of time and means.

4.2 Description of the prototype

With the constraints described before, we have validated our concept by building a first prototype using the point of view of 77 Mass Av. The general framework of this object is a SuperCard 3.5 project[3]. We will describe it in details in the following subsections.

4.2.1 Interface

The picture 4.1 page 40 shows the interface. Basically it is composed of five different elements :

Situation map This map is in fact an ortho photo of the area (here, Mass Av atop of 77). The current position of the vehicle is symbolized by a

[3]To be fully Web-exportable, this project should have been completely scribed in Java. The Java extensions needed to play QuickTime movies (Java Media Framework) had not been released for MacOS at the time of this first prototype. Consequently, we could not fully implement this project in Java, and we had to use SuperCard and its Web extension : Supercard's Roaster.

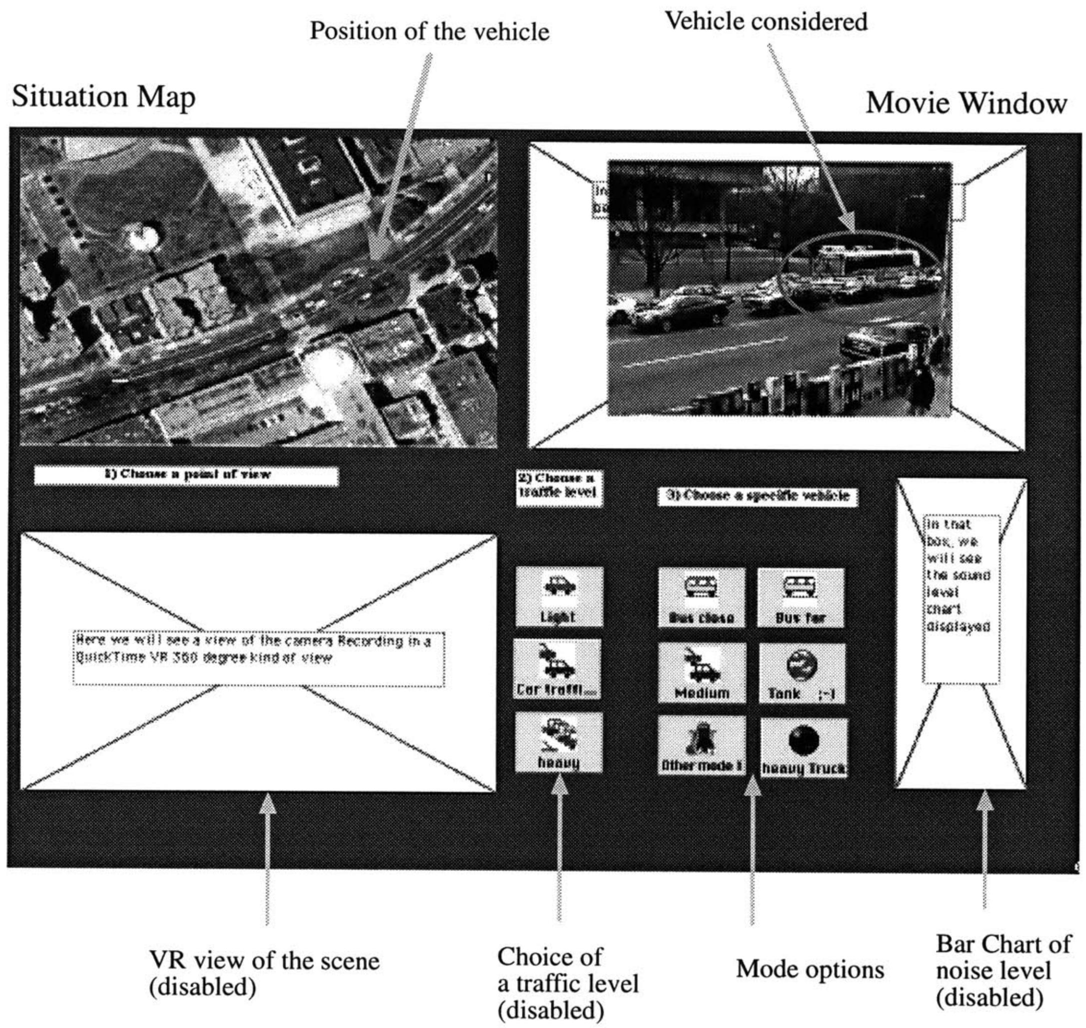


Figure 4.1: Interface of the prototype

red square which moves along Mass Av at the same speed as the movie playing on the right. The user can click anywhere in the window to move the vehicle to a new location. The movie "jumps" directly to this new position and continues playing from it.

In a later version of the project, the noise level produced by the vehicle will be displayed on the situation map. Furthermore, in the case of this prototype, we only considered one point of view (the steps of Mass Av). In the completed projects, several points of view should be integrated. In that perspective, the recording stations will be spotted on the situation map as "hot" spots which will allow the user to "instantly" move from one angle of view to the other one.

Movie window The movie window shows a Quicktime movie of the vehicle coming. The quality of the image is not essential and the colors were enhanced a little[4]. On the contrary, the sound is a high quality 44.000 Hz 16 bits digital sound (equivalent to a CD quality). In this prototype, the quicktime handle bar is still present, but in a later version of the project, those will be removed and the movie will be completely controlled from the situation map on the left.

Traffic and transportation mode selection This set of buttons is at the heart of the project. The three buttons on the left allow the user to select the traffic level, from light to heavy. The 6 buttons on the right select the transportation mode on which to focus (none, buses, light rail, metro, heavy truck etc...).

In the case of Mass Av, those options were not all activated. Indeed, among the recordings we made, only four of them were satisfying. Thus we presented a prototype with buses, traffic and trucks only. Anyhow, those buttons have the key functionality of changing "instantly" the transportation vehicle, as if under a spell. The point of view and the location of the vehicle remains unchanged and the movie continues playing, but displaying now the "new" vehicle.

VR view This functionality was not activated in this first prototype. In the final project, this window should present the view of the spot where the recording has taken place, using quickTime VR. The 360 degrees presentations it provides will allow the user to get a sense of the spatial configuration around the recording device.

Noise meter viewer The noise meter viewer was not ready for the first prototype. In the final project, a bar decibel meter will be presented here, measuring the total noise at the recording point.

[4]We used the "Hue" filter in Adobe Premiere to make the colors more bright and lively.

4.2.2 Methodology and material

The prototype has been constructed using IncWell's SuperCard 3.5 for Mac. The scribing has been done under SuperCard's SuperScribe.

The movies have been shot using a video camera Sony HandyCam Video 8 XR with mono, low quality sound. The movies have then been digitalized using Adobe's Premiere 4.0 under MacOS. A Hue filter has been applied to enhance the colors.

Simultaneously, the sound has been recorded, as a separate SoundPro 16 sound file, using a portable Mac PowerBook G3. The sound has first been pre amplified using a Sony Mini-Disc Recorder. The output quality has been selected as 44.000 Hz, 16-bit sounds.

The sound files have then replaced the original low-quality soundtracks of the movies using Premiere 4.0 as a film editor.

4.2.3 Scribing

General Heuristic

The major issue in the scribing part of the prototype is to keep track of the position of the vehicle, both in the situation map and in the various movies. This point is essential to allow the user to switch from one movie to the other while keeping the vehicle's position unchanged. There are two difficulties to achieve this point : first, each movie has a relative length, because each vehicle drives at a different speed and because the movie were recorded with vehicles at different starting points. Second, some vehicles had to make a stop either to the 77 Mass Ave cuckoo lights or, in the case of the buses, at the bus stops. Those stops vary in length but should be coordinated with the rest of the movies and with the situation map.

The prototype answers the first issue and opens doors to answer the second part of the problem. SuperCard has the capability of getting the current playing time of any playing film in the format HH:MM:SS:FF where FF is the number of frames (we played the movies at 15 frames per second). Thus, we can easily, and in real time, know the relative playing time with respect to the total duration of the movie.

$$r = \overbrace{\frac{\text{Current playing time}}{\text{Total Playing Time}}}^{\text{In the movie}} = \overbrace{\frac{\text{Current location}}{\text{Total length to cover}}}^{\text{In the situation map}} \tag{4.1}$$

Using this ratio, we can easily compute the relative position of the vehicle if it was driven at a constant speed along the street.

This ratio is actualized in real time and is stored. When the user wants to switch the vehicle, the movie is started at the relative time corresponding to the ratio explained before.

Conversely, when the user click on the situation map, the horizontal position of the mouse is recorded and using the ratios from equation (4.1) we can reposition the movie and the vehicle at their new location.

This technique has the tremendous advantage of being (relatively) easy to implement and to scribe using SuperCard's built-in language : SuperTalk. On the other hand, it has three flaws for which we are going to propose patches :

1. Some movies are shot with vehicle starting in the middle of the street (Student center as opposed to Vassar Street). In this case, the red dot should not go all the way up to Vassar Street, but should come along its route at a slower pace.

   This effect could easily be achieved by specifying the originating and end coordinates of the vehicle as data accompanying the movie. It will be incorporated in the final product.

2. Some vehicle could have to stop on their way, thus the "ratio" r should remain constant as the movie continues playing.

   The local configuration of Mass Ave allows us to achieve this effect relatively easily. Indeed, the bus stops and the cuckooing lights are close enough to be considered as one single point. As we load the data for each movie, we can easily include a time interval for which the vehicle is supposed to be at a stop (either for light or operation reasons). When the movie time is within those boundaries, it just give r the value corresponding to a stop vehicle, with respect to the total length of the film and of the route of the vehicle.

3. The vehicle speed might not be constant over its whole route. Indeed, whenever there is a stop, the vehicle slows down. This effect can not be reproduced using the simple methodology described before. Nevertheless, this point might not be essential for our purpose[5].

   Indeed, the exact position of the vehicle on the situation map is not crucial. Although users might get surprised if they see a vehicle moving on the map but not in the movie, I do not expect them to be picky on the exact position of the red dot.

Actual scribing

The code of this SuperCard project is available on-line at the CRL web site. It is easily understandable and thus, does not require further comments.

[5]Nevertheless, this effect could be achieved by multiplying the "check-points" along which the vehicle should go at certain given time. It is easily feasible but the value added is not obvious.

4.2.4 Lessons from this first prototype

As any prototype, this one was set up to test and validate a concept. Although the noise levels have not been adjusted among the films, this prototype illustrates the interest and capabilities of such comparisons.

Indeed, this first prototype showed that switching from one movie to the other could be easily achieved although the results might not be perfect (see previous section). Nevertheless, this prototype has put in light various flaws or difficulties (described before) and has given us the general framework for the definitive project.

Among the major limitations of the prototype is the size of the movies. Indeed, we have to trade off between three variables : the image quality, the sound quality and the size of the files. For the prototype, the movies' size are 60 MB on average, for a 1 minute movie, with high quality (16-bits 44.000 Hz Stereo) sound, a millions colors 320×240 image. The prototype runs with 5 movies, which makes it, roughly, a 250 MB project. This size is not exportable through the Web, although it was a requirement for the project[6].

Another limitation of this prototype is the absence of annotating mechanism. Indeed, following Forester's ideas, it is essential to give the public some ways to build their common knowledge. This is not the case in this prototype, unless it is used in a public meeting, during which the public could express freely its opinion.

Some would argue that such a mechanism is not essential in this project because we do not represent the actual streets where the transportation projects are discussed but rather some general example to educate the public. The argument is interesting, and I would expect that, if ever this project goes on line, the planners would provide their own feedback system. Nevertheless, I think that real-time comments are more valid than after the event comment, especially in the case of noise, for which memory is not very well educated.

[6] The issue of the size o the movies has become a recurring theme for this project. As we will explain it in the last chapters, the exportability of the tool will determine its use (ie private before a meeting, or public during the meeting) and could considerably change the effect produced by it. This explains the focus we have put on this issue. Obviously, this limit is temporary and should be overcome with the forecoming progress of the Web flow.

Part III

Creating visual simulations of transportation noise contours in various urban environments

Introduction

In the previous part, we described a prototype which offers some auditive comparisons between various transportation modes. The auditive approach is certainly important, if not essential, but, as we explained it before, it has serious limitations. Indeed, it uses a sense, the hearing, which is very poorly educated in most people. On the contrary, the vision is highly developed in our society. In that perspective, it seems important to supplement the hearing comparisons with some visual representations of noise levels.

Basically, several techniques could have been used ([Tufte, 1983]). Among all those, we chose to focus on a specific one the noise contours. The noise contours link all points of equal noise level as measured by their $L(t)$. This visual tool is well-known and referred to well-accepted mental models. Indeed, the spread of maps in the mass media have accustomed the public to the "feeling" of those representations.

The aim of this part is to make simulations of noise levels as the vehicle moves, in particular with the reflections on the nearby buildings and the tunnel effects that can be found in urban environment. For this purpose, a background picture will show the orthophoto of the street environment. The major buildings are highlighted to make the general situation more easily graspable. The vehicle, symbolized as a red square moves along the street.[7] Colored contours moves with the vehicle. They represent the iso-decibels contours. As the vehicle interacts with various buildings along the street, those contours are deformed to reflect the change in noise pattern due to the reflections (see picture 4.2 page 47).

[7] In the final product, the movement of the vehicle is synchronized with the playing of the movie, as described before in this report.

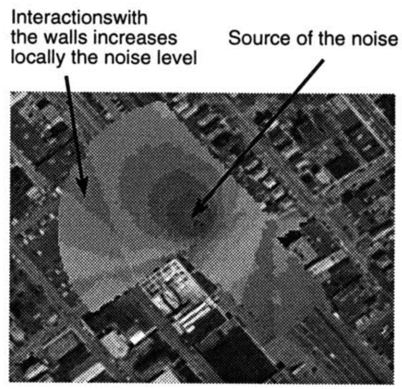


Figure 4.2: The noise contours change as they interact with walls.

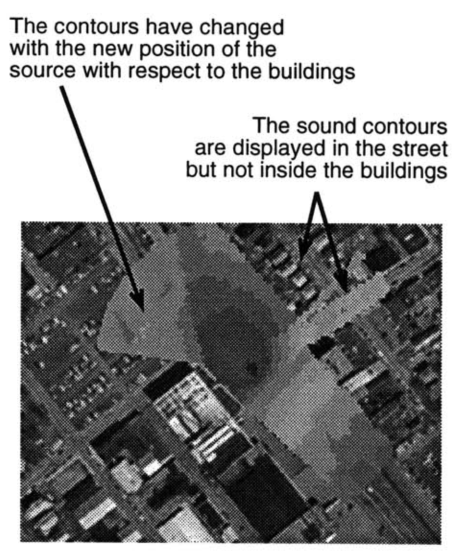


Figure 4.3: The shape of the noise contours changes dynamically with the position of the source.

Chapter 5

Noise propagation model

5.1 modelling the vehicles

This chapter presents the mathematical model we used will be described, along with its limitations. In a "classical" vehicle, there are three sources of noise: the engine, the exhaust (if applicable) and the interaction wheel/tracks or tire/pavement. Each of those sources has a specific wave length distribution and directionality.

The wavelength distribution is very important because different wave lengths have different attenuation coefficients and thus travels and are reflected differently [Piercy and Embleton, 1979, p 3-10, table 3.2]. Nevertheless, for sake of simplicity, we have not taken them until the definitive versions of this simulation tool. [1]

The directionality can not be simplified so easily. Indeed, if the interactions wheel-medium are almost homogeneous, the engine noise points forward and the direction of the exhaust noise depends of the exhaust pipe location. In that respect, we have modelled the vehicles as follow (see table 5.1 in page 49)[2].

5.1.1 Directionality of the noise

To represent the directionality of the noise, we had basically two techniques :

1. In the first technique, the universe is divided in four parts. In the side, the vehicle "emits" at a level $L_{average}$; Forwards, it emits at a level $L_{average} - \delta$ and backwards, it emits at $L_{average} + \delta$ (see figure 5.1, below).

[1] Indeed, the first idea was to discard this effect completely and to assume that noise transportation noise travels independently its nature (traffic, rails etc...). Unfortunately, during field research, we realized that rail noise could be heard from a far greater distance than traffic noise. We thus used those results to introduce and scale our noise simulations as explained in section 5.2.2.

[2] Those figures come from measurement in the field and the available literature. Because of the large variability among the various materials within one transportation mode, those measures might appear arbitrary and might not correspond to one's experience.

Vehicle type	Motor Noise	Exhaust Noise	Wheel/tire noise
Car	83dB	83 dB	not taken into account
Trucks	Forward 85 dB	Homogeneous 95 dB	Not significant
Buses	Forward 75 dB	Backward 95 dB	Not significant
Commuter Rail	Homogeneous 0 dB	Homogeneous 100 dB	Homogeneous 80 db
Subway	Homogeneous but not significant	Not applicable 95 dB	homogeneous 95 dB
Harley Davidson	Isotropic 90 dB	Not Significant	

Table 5.1: modelling the different urban modes included in the prototype

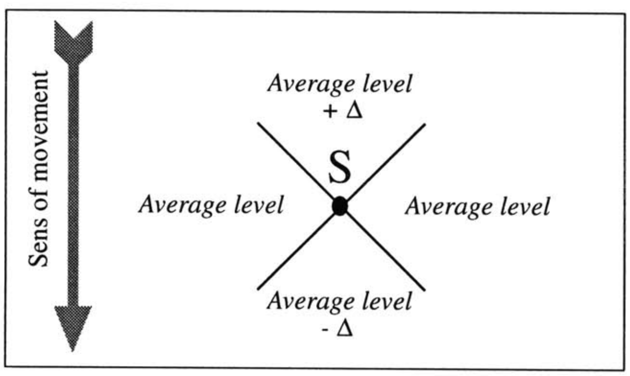


Figure 5.1: Noise level emission 1

This model is interesting, but the lack of continuity when crossing one of the boundaries makes it unrealistic.

2. In a second model, we consider that the noise level emitted varies continuously with the angle between $L_{average} - \delta$ and $L_{average} + \delta$. We used the following formula [3] :

$$L_{source}(\theta) = \frac{(1 - p \times \cos(\theta))}{1 + p} \times \delta + \left(L_{average} - \frac{\delta}{1 + p}\right) \quad (5.1)$$

With this simplistic model, we have a continuum for L which takes the following values :

	Value of θ	Value of $L_{source}(\theta)$
Front	0	$L_{Average} + \frac{1-2.p}{1+p}.\delta$
Side	$\pi/2$	$L_{Average}$
Back	π	$L_{Average} + \frac{1}{1+p}.\delta$

Table 5.2: Values of the directed source according to the direction of observation.

The values of δ and of p constitute two parameters that we can adjust appropriately; They could be determined experimentally and along with the average noise level $L_{average}$. In fact, measurements do not prove to be very conclusive, mostly because of the lack of adequate material. Consequently, we ended up choosing $p = 1$. The comparison between a directionned source and an isotropic source can be shown in the figure 5.2 below.

5.2 Noise propagation and reflection modelling

5.2.1 Noise propagation theory

The propagation of noise in an urban environment is not very well understood or modelled. Since this project aims at educate people, it does not need to provide a perfect representation of the reality. We rather tried to enhance the understanding and subsequent discussion about noise propagation.

The propagation of noise is ruled by the laws of fluid mechanics. In our model, we assumed that the fluid is almost perfect. This hypothesis allows us to almost get rid of the attenuations due to molecular absorptions and in particular, of the influence of air humidity and of temperature on noise propagation. In that perspective, we will only deal with the "classical" attenuation due to geometric spreading and the interactions with hard surfaces, such as building facades.[4]

[3] As before, θ is polar angle determining the position of the listening point. θ is counted from the direction of movement.

[4] As explained before, we will reintroduce an attenuation coefficient α afterwards, based on experimental field measurements.

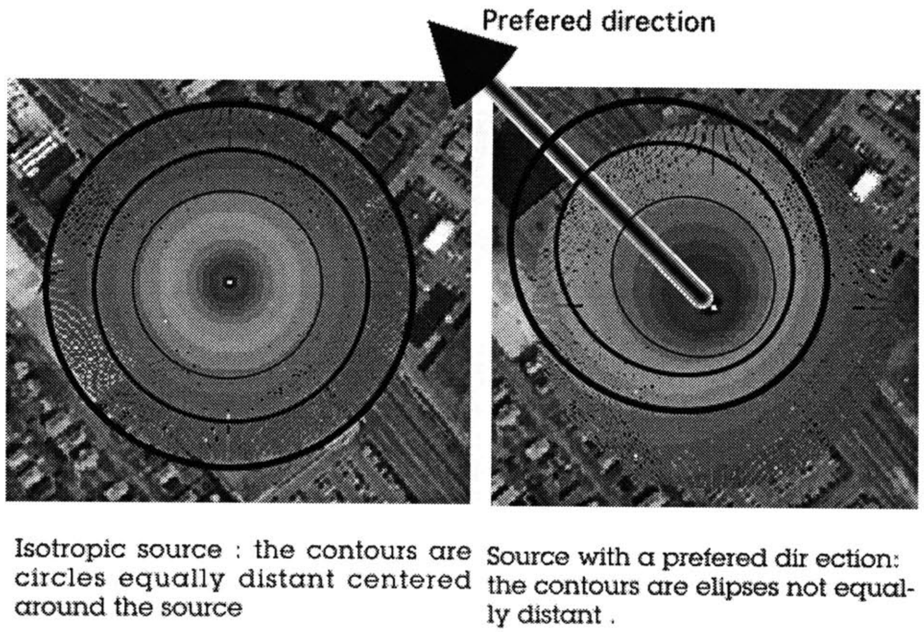


Figure 5.2: Difference between an isotropic source and a directed source

Furthermore, the sources are assumed to be grossly schematized by a monopole, emitting in one wave length only. This restriction allows us to add the pressures more easily.

5.2.2 Noise measurement

As we explained before, we have several ways to account for the noise levels.[5] We are faced with the following dilemma : on the one hand, the sound emitted by vehicle are usually measured as "instant" pressure $L(t)$, sometimes filtered with an A filter to account for the specificity of human ear ($L^A(t)$). On the other hand, the collective appreciation of annoyance refers to L_{eq} or L_{10}. By attributing colors such as green, yellow or red to instant noise levels, we implicitly give them social values which, so far, have only been studied for averaged levels (L_{10}, L_{eq}). This dilemma could be solved if we use a set of colors which are not symbolically "loaded", for example, shades of blues, of beiges, or of sepias ...

[5] see page 24

Using the logarithmic scale

We use the classic measure of the pressure level using a logarithmic scale

$$L_p = 10\log_{10}\left(\frac{p^2}{p_{ref}^2}\right) = 20\log_{10}\left(\frac{p}{p_{ref}}\right)$$

where p is the pressure, or the amplitude of the wave length.

We can not "add" logarithmic noise levels directly $L_{total} \neq L_1 + L_2$. Indeed, we can only add pressures directly $p_{total} = p_1 + p_2$. [6] Thus , using the logarithmic measurement, the addition formula becomes :

$$L_{p,tot} = 20.\log_{10}\left(\sum_i 10^{\frac{L_{p,i}}{20}}\right) \tag{5.2}$$

We will us this formula in the reflection model described later.

Finally, we assume that the noise is mostly attenuated through geometric spreading. Indeed, we assume that as the sound spread uniformly in every direction, the energy on a sphere of radius r remains constant, leading to the following relation :

$$\underbrace{p^2 \times 4\pi.r_2^2}_{\text{Energy on the sphere of radius } r_2} = \underbrace{p_0^2 \times 4\pi.r_s^2}_{\text{Energy at the source (sphere of radius } r_s)}$$

. This relationship leads directly to

$$\delta L = 20\log_{10}\left(\frac{r_2}{r_s}\right) \tag{5.3}$$

In previous sections, we have introduced the attenuation coefficient α which is necessary to account for the different propagation of car sounds and traffic sounds. This coefficient reflects the loss due to the viscosity of the air. According to Piercy *et al.* [Piercy and Embleton, 1979], the attenuation coefficient α could be reintroduced in the equation 5.3 by reformulating it as follow :

$$L(r_2) = L_{source} - 20\log_{10}\left(\frac{r_2}{r_s}\right) - \alpha.\frac{(r_2 - r_s)}{100} \tag{5.4}$$

α Is a function of the outside temperature, the humidity and the frequency of the sounds. It could take its value between 11 and 0.03. Consequently, we decided to give it the value 4 for traffic and 1 for trains.[7]

[6] We assume that the addition is possible directly, i.e. that all waves are always on phase...

[7] This effect could only be taken into account for distances larger that the average 2 blocks width of our study band. Furthermore, at 100 meters, the interactions with the facades becomes so difficult to modelled that the correction brought by this coefficient are not essential. Nevertheless, in the case of the noise measurement in Quincy, this attenuation is necessary given the topography.

Distance and directionality

So far, we assumed that the vehicle behaves as perfect sources, except for its directionality (see previously, page 51). If we now integrate both the directionality and the geometric spreading due to the distance, we will have the following noise levels[8]:

$$L(r,\theta) = \frac{1 - p.\cos(\theta)}{1+p} \times \delta + \left(L_{av.} - \frac{\delta}{1+p}\right) - 20\log_{10}\left(\frac{r_2}{r_s}\right) - \alpha.\frac{r_2 - r_s}{100} \quad (5.5)$$

This equation allows us to compute a general equation of the contours in the absence of any interactions with the walls (for sake of simplicity, we won't take into account the attenuation term $\alpha.(r_2 - r_s)/100.$).

The contours C_n are the points $P(r,\theta)$ for which L is constant :

$$\begin{aligned}
P \in C_i &\iff L(r,\theta) = L_i = L(r_i, \pi/2) && (5.6)\\
&\iff L_{av} - \frac{p.\cos(\theta)}{1+p}\delta - 20\log\left(\frac{r}{r_s}\right) = L_{av.} - 20\log\left(\frac{r_i}{r_s}\right) && (5.7)\\
&\iff \left[\frac{-p\cos\theta}{1+p}\delta\right] = 20\log_{10}\left(\frac{r}{r_i}\right) && (5.8)\\
&\iff r = r_i.10^{-\frac{p\times\delta}{20.(1+p)}\times\cos\theta} && (5.9)
\end{aligned}$$

This equation 5.9 is in fact the equation of an elongated ellipse as grossly shown in the picture below (5.3) :

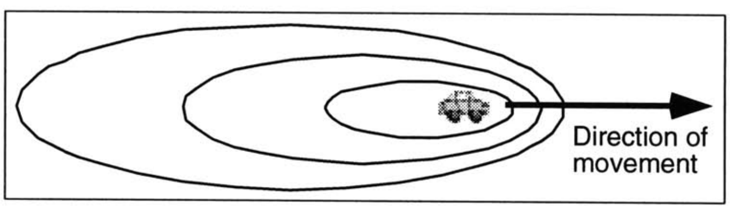


Figure 5.3: Simulated noise contours in the absence of interaction with the built environment

5.2.3 modelling noise reflection on building

The modelling occurs in a 2 dimensions universe. The reflections on the ground (see figure 5.4) and the effects of building heights on noise propagation are not taken into account. Indeed, the whole project -including most of the videos- has designed at eyes-levels to represent the vision that a passer-by would have gotten of the situation.

[8] (r,θ) are measured in the standard polar referential centered on the source S and with the direction of movement as the main axis.

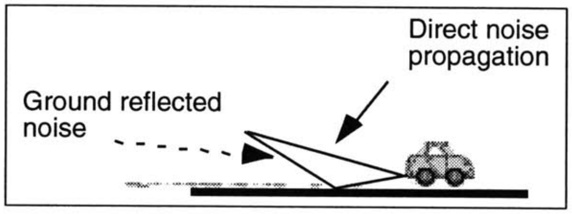


Figure 5.4: The reflection on the ground will be neglected in the rest of the project

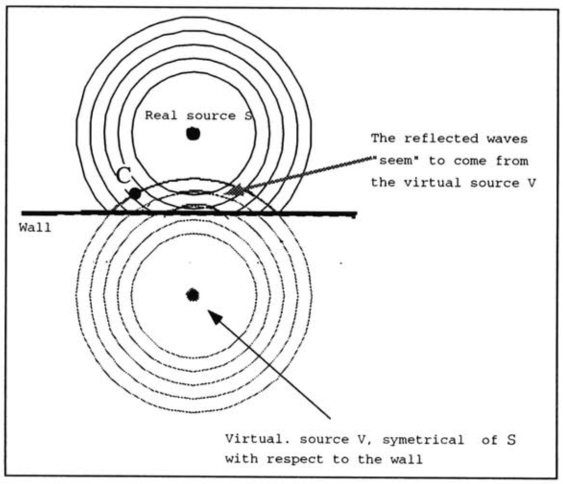


Figure 5.5: Reflection on a wall, the concept of a virtual source

Under those assumptions, we can model the sound propagation as the well-known light propagation. The sound interactions with the buildings will be constructed as the reflections of light on perfect mirrors[9]

Furthermore, the reflection on a surface is supposed to be perfect and the out-going waves are supposed to be on phase with the in-coming wave[10], thus there is only additions of pressure and we do not deal with destructive additions.

With those two restrictions, if S is the primary vehicle, all happen as if there was a virtual source V symmetric with respect of the Wall W (see picture 5.5, page 54 below).

[9] in fact, this assumption is well suited for perfectly plane and hard facades such as the glass-mirror facades of the 80's skyscrapers. In case of stone buildings, facades absorbs some of the energy of the in-coming waves and the reflection is not perfect. Furthermore, the ornaments on the facades contribute to the scattering on the sound waves. Finally, the presence of trees and other absorbing obstacles in front of the buildings further limits the accuracy of the simplistic assumptions we made in this model.

[10] $R = 1$

At any point where there is reflection and interference between the waves (point C for instance), we considered that the pressure level is just the sum of the waves. Its level on a logarithmic scale is thus given by the equations 5.2 and 5.4.

5.3 Limitations of the model

This model is very crude, and the subsequent representations it generates could be questioned. There are several very questionable limitations :

1. The model we use considers only one wave length, and, in particular, we will apply one attenuation coefficient, one propagation speed etc... This is far from describing accurately the reality; In the case of cars, the sounds have frequencies varying from 500 to 4000 Hz. But, the level of complexity involved is beyond the basic computing means that we have here.

2. The model does not take into account the facades absorptions and diffractions. None of the three sites we selected has contemporary glass architecture which could reflect perfectly the incoming sound. Thus the model can not reflected the reality of the sound interactions with the facades and will, in fact, over estimate the level of the reflected sound.

3. The model does not consider multiple reflections on the facades. Indeed, the limited amount of calculation power available does not allow an in-depth computation of resonances effects. In fact, because of the hypothesis of the model, more developed calculus would be inconsistent with the rest of the data. If multiple reflections were to be taken into account, we could not neglect the noise absorption on the surface of the facades.

4. The model does not consider the multiple obstacles between the source and the listening point. Indeed, parked cars creates screens which interacts with the noise, trees absorbs part of the sound intensity... The absence of those elements in our model will lead to a greater over-estimation of noise levels in our situation.

5. Finally, this model is very difficult to calibrate. First, the measurement of the directivity coefficients (δ and p) will be tricky. We could measure them with the vehicle stopped, but we have no evidence that it reflects well the real phenomenons which occur when the vehicle drives[11].

   The other option would be to measure the noise produced while the vehicle is passing in front of the observer. If we can decide which noise (ie front, side, back) is recorded, we could average our measurements to get a good sense of the noise levels produced by each vehicle. This could only be

[11] It is not so much an issue about noise propagation (the sound moves at 340 m/s under normal conditions), but rather the vibrations and the motion of the air around the vehicle might create conditions for noise generation which are different from the "at stop" situation.

done if we record each vehicle *alone*, else the interactions coming from the traffic will make the isolation of a particular noise difficult. It would require some high-quality materials which are not available, today, from the CRL.

Unfortunately, the various limitations of the models do not compensate and all of them tends to over estimate the actual noise level. We could have introduced "scaling" coefficients, but we do not have the adequate equipment to have reliable sound data in the real world[12]. Without good empirical data, those coefficients would tend to distort the model even more in unpredictable ways. Consequently, we preferred to stay with a model which is biased, but in a known direction.

[12]Ideally, those kind of data acquisition should be done using the same vehicle, moving *alone* in an empty urban environment (maybe at 2 am on ThanksGiving Day). Then, using high precision sound measurer, we could measure the noise impact at various point and scale the model adequately. Although those measures are not very difficult per se, they require a lot of time and a lot of precision.

Chapter 6

Implementation in Java

SuperCard, the application used to create the first prototype, does not have the required functionalities to implement a dynamic noise propagation model. In particular, it does not allow its user to draw directly on the screen, but only to manipulate already created objects. Furthermore, SuperCard is not designed to accomplish the heavy calculus required by the complicated layout of the facades in a typical street.

A more advanced language, supported by the Web, was thus required. Naturally, Java came to mind and the simulation of noise contours has been scribed using the Java 1.1.7 . The chapter describes the implementations in Java of the model described before.

6.1 Definition of the problem

6.1.1 General definitions

We will use two coordinates systems :

- The regular Cartesian system (x, y) with its origin in the upper left corner of the screen.
- A polar system (r, θ) centered on the source and with its main axis along the vehicle direction.

As we have explained it before, the vehicle is modelled as a punctual source of noise, $S(x_s, y_s)$. The level of emissions and the directivity will characterize the vehicle. As explained before, the noise level L_{Source} depends of the angle of emission with respect to the driving direction (see page 49). Thus, L_{Source} is a function of θ : $L_{Source}(\theta)$.

The quasi-isotropic model of the vehicle leads us first to parametrize the universe "impacted" by a disk of radius R centered on the source S. We will compute the noise level for every point D of the disk. Although most of the

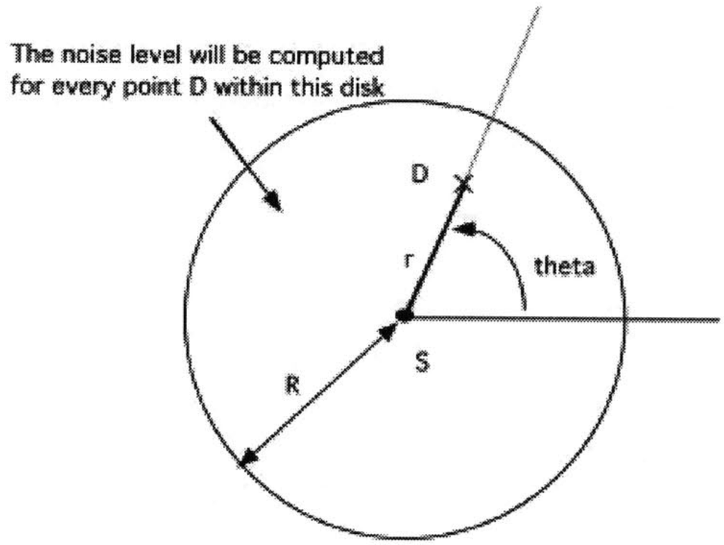


Figure 6.1: Definition of the polar coordinates and of the impacted area

calculus will be done using the "usual" cartesian coordinates, we will use a polar parametrization of the position of the point D (see figure 6.1, page 58).

Furthermore, because of the limited resolution of the computer screens, it is enough to access the points $D(r, \theta)$ for integer values only of the parameters and we can still convey a smooth picture :

$$\begin{aligned} 0 < \; & r & < R, \; r \in \mathbf{N} \\ 0 \leq \; & \theta & < 360, \theta \in \mathbf{N} \end{aligned}$$

Naturally, we convert those polar coordinates into the usual cartesian coordinates with the following equations :

$$x_d = x_s + r_d . \cos(\theta_d) \tag{6.1}$$

$$y_d = y_s + r_d . \sin(\theta_d) \tag{6.2}$$

The walls are represented by the segments : $[W_{i,1}(a_{i,1}, b_{i,1}), W_{i,2}(a_{i,2}, b_{i,2})]$. The definition is redundant for continuous facades where the end of one facade correspond to the beginning of the next one ($W_{i-1,2} = W_{i,1}$). Nevertheless, this definition is general enough to cover any possible wall configuration.

6.1.2 Mathematical justifications

Simple reflections on a wall

We begin with the case of one wall. The figure 6.2 below defines the notations.

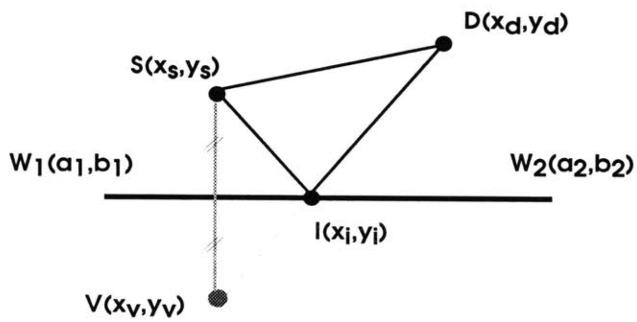


Figure 6.2: Regular reflection of a wave against a wall

To compute the reflected noise, we used the optical analogy of light interference and we adopted the well-known "virtual source" methodology. Given the point of observation $D(r_d, \theta_d)$ or $D(x_d, y_d)$ and the source $S(x_s, y_s)$, we note $V(x_v, y_v)$, the image of S through a symmetry of axis (W_1, W_2). V is the "virtual" source of noise. If the line (VD) cuts the segment $[W_1, W_2]$, the noise, reflected by the wall, reaches the point D.

Whenever a line is used, we parametrized it as follow :

$$P(x,y) \in (W_1, W_2) \Longleftrightarrow \exists t_1 \in \mathcal{R} \begin{cases} x &= a_1 + t_1 \\ y &= b_1 + t_1 \times \frac{b_1 - b_2}{a_1 - a_2} \end{cases} \tag{6.3}$$

With this convention,

$$I \in [W_1, W_2] \Longleftrightarrow t_1 \in [0, a_2 - a_1] \tag{6.4}$$

Using the notations of the previous picture, we have the following relations:

$$x_v = x_s + 2 \times \left(\frac{b_1 - b_2}{a_1 - a_2} \times \frac{b_1 - y_s + (x_s - a_1) \times \left(\frac{b_1 - b_2}{a_1 - a_2}\right)}{1 + \left(\frac{b_1 - b_2}{a_1 - a_2}\right)^2} \right) \tag{6.5}$$

$$y_v = y_s + \left(\frac{b_1 - b_2}{a_1 - a_2} \times \frac{b_1 - y_s + (x_s - a_1) \times \left(\frac{b_1 - b_2}{a_1 - a_2}\right)}{1 + \left(\frac{b_1 - b_2}{a_1 - a_2}\right)^2} \right) \tag{6.6}$$

$$t_1 = \left(\frac{y_d - b_1 + (a_1 - x_d) \times \left(\frac{y_v - y_d}{x_v - x_d}\right)}{\left[\frac{b_2 - b_1}{a_2 - a_1} - \frac{y_v - y_d}{x_v - x_d}\right]} \right) \tag{6.7}$$

From the previous equation, we can decide wether there is a reflected beam reaching D via the wall W. In that case, we have to compute the distance $d(D,I)$ and $d(I,S)$. By construction, we have [1]:

$$d_{reflected} = d(D,I) + d(I,S) = d(V,D) = \sqrt{(x_d - x_v)^2 + (y_d - y_v)^2} \quad (6.10)$$

If this equation is verified, the source S and the wall W_i contribute to the noise at the point D for the following levels :

1. *Direct contribution*

$$L^{direct}(r,\theta) = L_{Source}(\theta) - 10.\log\left(\frac{d}{d_0}\right) \quad (6.11)$$

2. *Noise reflected by the wall i*

$$L_i^{reflected}(r,\theta) = L_{Source}(\Phi) - 10.\log\left(\frac{\sqrt{(x_d - x_v)^2 + (y_d - y_v)^2}}{d_o}\right) \quad (6.12)$$

As described in the figure 6.3, the "direct" noise and the "reflected" one are emitted along different angles θ and Φ. Since the emission level depends of the angle, we have to take this effect into account in the model.

With the hypothesis we considered about the propagation the additions of sound, the same formulas 6.11 and 6.12 could apply independently of the number of walls considered.

Finally, to obtain the noise level equivalent to all those sources, we just have to apply the addition formula 5.2 :

$$L_{p,tot} = 20.\log\left(\sum_i 10^{\frac{L_{p,i}}{20}}\right)$$

Artifacts due to multiple walls

The method used to determine the reflected sound could create artifacts in the following case (see figure 6.4, page 61). The point D_2 is not reached by a *reflected* beam. But, according to our heuristic, the program would add this *indirect* contribution to its noise level. Indeed, the point I_2 is within the wall W as needed.

[1] From the previous equations, we can easily derive the coordinates of the point J :

$$x_j = a_1 + \left(\frac{y_d - b_1 + (a_1 - x_d) \times \left(\frac{y_v - y_d}{x_v - x_d}\right)}{\left[\frac{b_2 - b_1}{a_2 - a_1} - \frac{y_v - y_d}{x_v - x_d}\right]}\right) \quad (6.8)$$

$$y_j = b_1 + \frac{b_2 - b_1}{a_2 - a_1} \times \left(\frac{y_d - b_1 + (a_1 - x_d) \times \frac{y_v - y_d}{x_v - x_d}}{\left[\frac{b_2 - b_1}{a_2 - a_1} - \frac{y_v - y_d}{x_v - x_d}\right]}\right) \quad (6.9)$$

Nevertheless, those coordinates are not useful at this point. They will be used later.

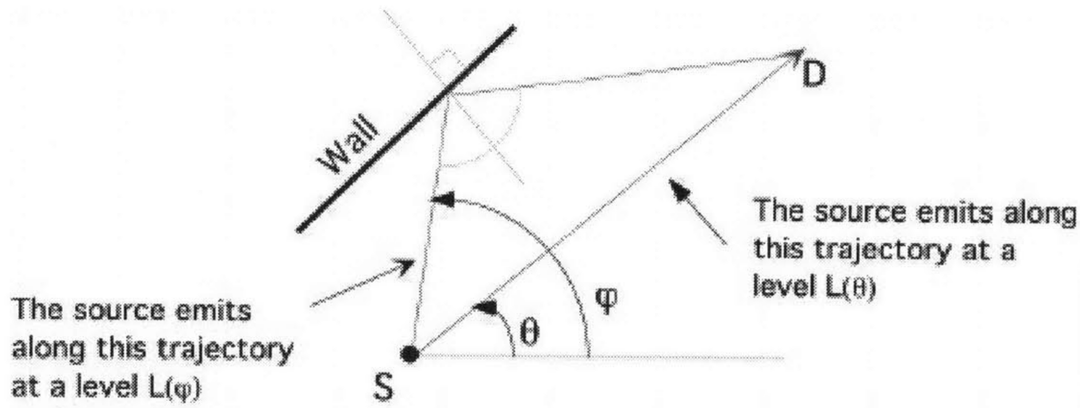


Figure 6.3: The noise level varies for the “reflected” noise and the “direct” noise

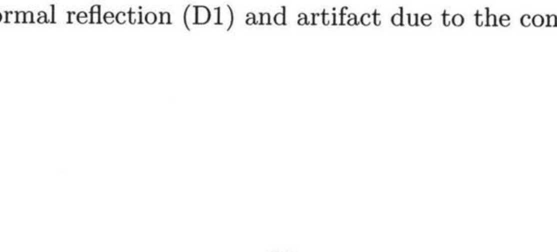


Figure 6.4: Normal reflection (D1) and artifact due to the construction (D2)

To avoid this artifact, we have to make sure that the point I is within the segment $[V, D]$ (case of I_1 as opposed of I_2).

Noise in the buildings

Since the issue is limited to the investigation of outdoor urban noise, the walls are supposed to reflect perfectly the noise and thus shields the rooms of the buildings[2].

The contours should not be drawn or calculated behind them. The parametrization used so far has to be corrected. To achieve this effect, we have to characterize a point $P(x_p, y_p)$ which would be shielded. The figure 6.5 below shows the situation and the notation :

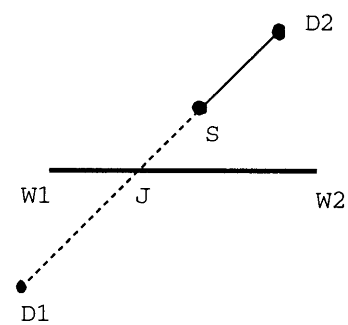


Figure 6.5: To avoid to draw "in the building", S and D should be on the same side of the Wall (SD_2 as opposed to SD_1)

The condition could be summarized by the double condition :

$$S(x_s, y_s) \in [D(x_d, y_d), J(x_j, y_j)] \quad (6.13)$$

$$J(x_j, y_j) \in [W_i(x_i, y_i), W_{i+1}(x_{i+1}, y_{i+1})] \quad (6.14)$$

As before, we use parameters to describe the lines (W_iW_{i+1}) and (SD)

$$D(x_d, y_d) \in [W_i, W_{i+1}] \Longleftrightarrow \exists t_1 \in [0,1] \left\{ \begin{array}{lll} x_d & = & a_i + t_1.(a_{i+1} - a_i) \\ y_d & = & b_1 + t_1.(b_1 - b_2) \end{array} \right. \quad (6.15)$$

$$D(x_d, y_d) \in [S(x_s, y_s), J(x_j, y_j)] \Longleftrightarrow \exists t_2 \in [0,1] \left\{ \begin{array}{lll} x_d & = & x_s + t_2.(x_s - x_j) \\ y_d & = & y_1 + t_2.(y_s - y_j) \end{array} \right. \quad (6.16)$$

[2]The case of the noise reduction barrier will explained later.

The coordinates of the point J could easily be calculated[3]. Using the previous results, the expressions of t_1 and t_2 could be found and through them, the decision wether to draw a contour in point D.

6.2 Implementation

In this section, we will describe the actual implementation in Java 1.1.7 of the equations computed before.

6.2.1 Description of the applet

As the applet runs, a window is opened where an orthophoto of the street is displayed. On top of this photo, the contours of the facades are drawn. On a final layer, the noise emitted by the vehicle is represented by areas of different colors, from red for the most intense noise, to dark green for the quieter places. This representation of noise level is shown only in a disk of radius 100 pixels centered on the vehicle, symbolized by a black spot.

This image is refreshed as the vehicle moves along the street and the noise contours are reshaped by the new configuration of the wall (see figures 6.6 below).

As we will explain it later, this applet runs too slowly to be efficiently coordinated with the movies of the prototype. Consequently, we greatly improved its heuristic, basically by reducing its "precision". The method has been to draw larger dotes 2×2 pixels and thus reducing by a factor 4 the time necessary to redraw the picture. Furthermore, being constrained by the resolution on the screen (the pixel is an indivisible unit), we can vary the number of dots to draw according to the distance to the source.[4]This second point allows to divide the painting time by another factor of 2.

[3]We have shown that in a previous section:

$$x_j = a_1 + \left(\frac{y_d - b_1 + (a_1 - x_d) \times \left(\frac{y_s - y_d}{x_s - x_d}\right)}{\left[\frac{b_2 - b_1}{a_2 - a_1} - \frac{y_s - y_d}{x_s - x_d}\right]} \right) \tag{6.17}$$

$$y_j = b_1 + \frac{b_2 - b_1}{a_2 - a_1} \times \left(\frac{y_d - b_1 + (a_1 - x_d) \times \frac{y_s - y_d}{x_s - x_d}}{\left[\frac{b_2 - b_1}{a_2 - a_1} - \frac{y_s - y_d}{x_s - x_d}\right]} \right) \tag{6.18}$$

[4]In a rapid approximation, we can estimate that a circle of radius r could be drawn using

$$n = \frac{360}{\arctan\left(\frac{1}{r}\right)} \tag{6.19}$$

elements. This procedure improves both the speed and the texture of the image.

Figure 6.6: The noises contours atop an orthophoto

6.2.2 Structure of the applet

General description

The core of this applet is based on the possibility to rewrite the Java procedure paint() which refresh the Java window and on the access to the run() method which actually runs the applet.

The run() method "moves" the position of the source by incrementing its cartesian coordinates (x_s, y_s). Then it calls the paint() procedure to refresh the screen.

The paint() method computes the noise level for each point $D(x_d, y_d)$ and then draws a rectangle of the color corresponding to the level. The points D are accessed through two parameters (r, θ), the polar coordinates with the origin centered in S.[5]

The noise level is computed through a method noise(x_d, y_d) which return the total noise level produced by the possible reflections of all walls. The actual computation of that level is basically a loop which test for each wall if there could be a reflection and, if needed, what would be the noise level produced

[5]We have immediately the correspondence :

$$x_d = x_s + r \times \cos(\theta) \quad (6.20)$$

$$y_d = y_s + r \times \sin(\theta) \quad (6.21)$$

(procedures noise(x_d, y_d) and impacted2(x_d, y_d)). All the levels are then added using the formulas previously described.

In order to limit the number of iteration, the procedure paint() tests wether the point D need to be paint or if it is behind a wall (procedure shouldPaint3).

Finally, to avoid a flickering effect, paint() actually draws on a background buffer graphic ga which is passed on the window graphic g when every point has been redrawn.

The rest of the applet initializes the data. The colors are chosen "manually" trough their RGB components (fillColors()) and stored in an array.

We modelled the facades by a continuous, broken line. Its summits $W_i(a_i, b_i)$ are stored in an array $Wall[i][j]$.

Detailed description

The applet just defines a class nWall3 and uses the libraries Swing, awt, applet and lang.Math. It implements the procedures described in the table 6.1 below[6].

6.2.3 Limitation of the applet

Apart from the limitations induced by the model of noise propagation, the speed of this implementation constitutes its major drawback. Indeed, the determination of noise level in the point D takes $O(N_{walls})$ operations. Then, to access all points in the disk we need $360 \times radius$ operation. For the applet as it is, it takes in the order of 10^6 iterations to refresh the screen... On a Mac G3 300 Mhz, it takes, on average, 5 seconds.

Some of those operations are redundant, in the painting procedure, are redundant (see before). Consequently, the flow of images remain too slow to be played synchronously with a movie.

The low speed of this applet has a second major disadvantage : the applet can not be played on Netscape 4.51, but only on Explorer 4.5. This constitutes a major drawback for an educational tool aimed at a large public.[7]

[6] The complete code of the applet is available on the CRL web site.

[7] The size of the movie files also constitute a problem, as explained before (see page 44).

Basic functions	
boolean and(boolean x, boolean y) boolean or(boolean x, boolean y)	Usual boolean operations
static double Log(double x) static public double tenPower(double x)	"natural" logarithm
Initialization of the data	
public void fillColors()	Initialization of the colors used in the applet.
void fillWalls ()	Initialization of the summits of the walls. Although those data are not stored in a file independent of the applet, they were generated automatically through a simple Supercard script.
Noise level	
int noise(int d, double theta)	Through a loop, compute the noise reflected (if any) by each wall and add them.
boolean impacted2(int i,int d, double xd, double yd) double giveValue(double a1, double a2, double b1, double b2, double x, double y) boolean sameSign(double a1, double a2, double b1, double b2, double xd, double yd)	Tests if the source, reflected by the wall W_i, could reach, indirectly the point D. Needed to eliminate the artifact described before idem
Threads	
void init() public void update(Graphics g) public void start() public void stop() public void run()	Load the ortho photo "normal" update procedure Initialize the variables (and the current thread) to the beginning of the show. Kill the current threads when the applet is stopped. Runs the show through a loop which changes the position of the Source and subsequently refresh the screen.
Painting procedures	
boolean shouldPaint3(int d, double theta)	Checks wether the point D is hidden behind a wall or should be paint.
public void paint(Graphics g)	Recompute the value of each point of disk and draw it.

Table 6.1: List of the procedures used in the code nWall3

Chapter 7

Advanced Java applet for noise contours simulation

7.1 New features

The first version of the applet could only represent the noise levels created by one vehicle in a deserted street. The reality is more complex and the public will seldom experience a unique vehicle, but rather the aggregation of multiple sources of transportation noises (general traffic, music from car stereos, sirens...). Indeed, the movies which will be presented along with those moving contours, are shot in real conditions and show both a specific urban transportation mode and the general traffic. For those reasons, it seemed important to augment the initial noise representations with the impact of the general traffic.

This effect has been achieved at two levels :

Dynamic representation As before, the noise contours will be dynamically drawn within a disk moving with the major noise source. Those dynamic contours will take into account the impact of the surrounding traffic.

Static representation The noise produced by a continuous flow of cars will be calculated and represented using the same color code. Those new contours will be superimposed to the background orthophoto. This new background will provide an idea of the "ambient" noise in which the specific transportation mode evolves. Naturally, on the edge of the "dynamic" disk, the ambient noise level and the dynamic noise contours should be the same (or almost). (see figure 7.1, page 68.)

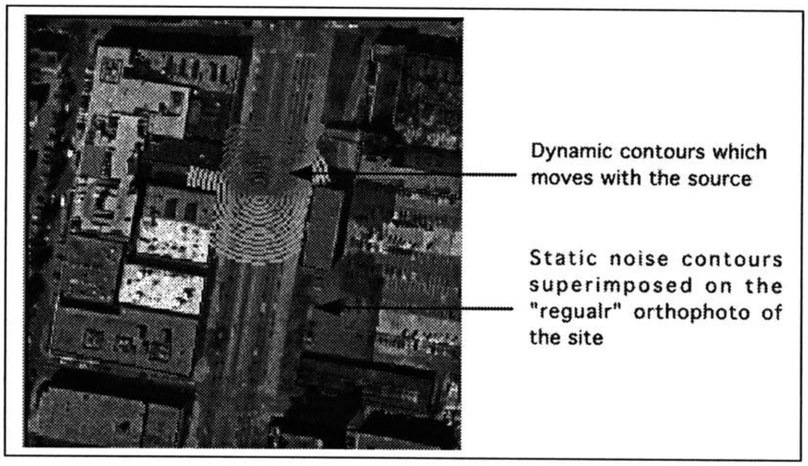


Figure 7.1: Urban transportation noise contours taking into account the ambient noise

7.2 Heuristic to simulate the traffic's noise contours (static contours)

7.2.1 Modeling

In an optimal situation, we should be able to draw a background real time, corresponding to the situation shown in the movie. Unfortunately, the limited computational capacity of the computer forces us to consider the ambient noise as static and to represent it as a fixed background image. We have modelled the traffic as lanes of discrete sources emitting at 80 dB. The interdistance between vehicles allows to simulate various levels of traffic :

Traffic level	Car inter-distance
Low	20 meters
Medium	10 meters
High (congestion)	5 meters

When two lanes of traffic are close, they are materialized as one unique lane, the sources then are doubled (83 dB instead of 80 dB). On the contrary, in the case of BU, each direction is separated by the tracks in the middle, and we represented the traffic by one row of sources per direction.

With this modeling, each source can be easily accessed through its "number" along the axis (the source i, S_i, is just i inter-distances away from the first source.). This description is very convenient for the heuristic described in the next subsection.

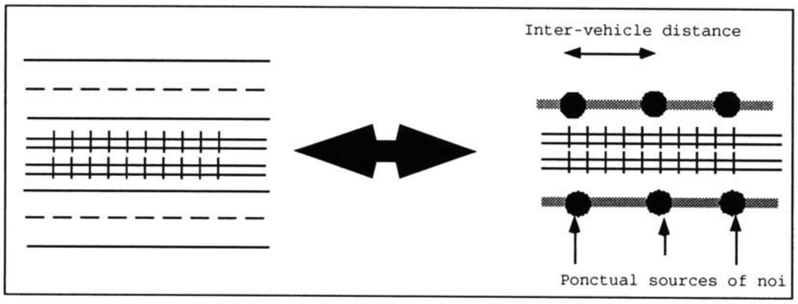


Figure 7.2: The 2 × 2 lanes of traffic in Commonwealth Avenue are modelled by two rows of equally distant sources

As before, the walls are described by the coordinates of their extremities.

7.2.2 Heuristic

The general heuristic has 5 steps :

1. Choice of the point of observation $P(x_p, y_p)$.
2. Choice of the sources which are within a distance l of P and could thus create some noise in P[1]. In fact, we just determine the first and last source indices to use : (for the notations, please refer to figure 7.3).

   We have to determine P_{min} and P_{max} corresponding to the intersection of the circle of radius l and of the line (D) of sources S_i. Then, we will just have to consider the nearest sources and we will have solved the point. The complete calculus is given as a footnote.[2]

[1]The choice of the distance $l = 50$ m is largely arbitrary. A more accurate model would vary the length l with the intensity of the source and the contextual background noise. Indeed, in very light traffic, a noisy truck could be heard hundreds of meters away, whereas in heavy traffic, its noise could be lost in the general sound environment within 10 meters. This improvement could see valuable but it would create distortions.

Indeed, in heavy traffic, the same mode would "require" a smaller representational radius l, thus creating the idea that the noise is less important. Consequently, we decided to keep the same radius l for every mode.

[2]Any point along the line $(D) = (S_0S_1)$ could be fully characterized by its linear abscise t :

$$Q \in (D) \Leftrightarrow \exists t \in \Re \begin{cases} Q = x_{S_0} + t \times (x_{S_1} - x_{S_0}) \\ y_Q = y_{S_0} + t \times (y_{S_1} - y_{S_0}) \end{cases} \quad (7.1)$$

We just thus have to determine t_{min} and t_{max} using the property that both P_{min} and P_{max} are *exactly* at a distance l of P. Analytically, this property is translated as

$$\begin{aligned} d(P, P_{min}) = l \quad &\Leftrightarrow \quad \left(x_P - x_{P_{min}}\right)^2 + \left(y_P - y_{P_{min}}\right)^2 = l^2 \quad (7.2) \\ &\Leftrightarrow \quad \left(x_P - x_{S_0} + t_{min} \times (x_{S_1} - x_{S_0})\right)^2 + \end{aligned}$$

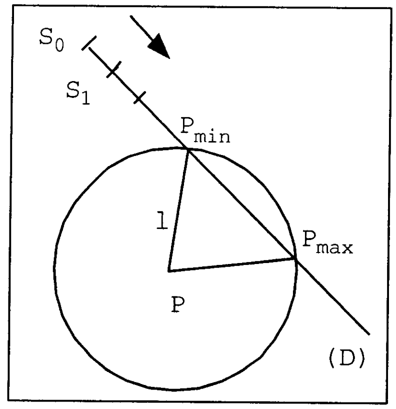


Figure 7.3: Choice of the sources S

3. Determine the walls which are in distance l of the point P. To improve the speed of the program, it will be important, in a later step, to limit the number of walls which could interact with the selected sources and the observation point. To achieve this goal we have to determine the smallest distance between the segment $[W_i, W_{i+1}]$ and the point P, (The figure 7.4 defines the notations).

   If the orthogonal projection Q of the point P on the line (D) fells within the segment $[W_i, W_{i+1}]$, Q is our closest point, else it is either W_i or W_{i+1} depending of the respective position of Q, W_i and W_{i+1}. If the distance between P and this closest point is smaller than l, the wall is susceptible to interact with some sources. It is thus selected and its indice i is stored.[3]

$$\left(y_P - y_{S_0} + t_{min} \times (y_{S_1} - y_{S_0})\right)^2 = l^2 \tag{7.3}$$

In this equation, the only unknown is t_{min}. This equation can be considered as a 2^{nd} order equation in t with, subsequently, two solutions which will correspond to t_{min} and t_{max}. Using the standards formulas, we could find :

$$\begin{aligned} \Delta &= \left((x_{S_1} - x_{S_0}).(x_P - x_{S_0}) + (y_{S_1} - y_{S_0}).(y_P - y_{S_0})\right)^2 + \\ &\quad \left((y_{S_1} - y_{S_0})^2 + (x_{S_1} - x_{S_0})^2\right) . \left[(x_{S_1} - x_{S_0})^2 + (y_P - y_{S_0})^2 - l^2\right] \quad (7.4) \\ t_{\substack{max\\min}} &= \frac{-\left((x_{S_1} - x_{S_0}).(x_P - x_{S_0}) + (y_{S_1} - y_{S_0}).(y_P - y_{S_0})\right) \pm \sqrt{\Delta}}{\left((y_{S_1} - y_{S_0})^2 + (x_{S_1} - x_{S_0})^2\right)} \quad (7.5) \end{aligned}$$

Naturally, if Δ is negative, there is no solution which means that the point P is too far away from the line of sources to be impacted. We can obtain S^{max}_{min} by dividing $t_{\substack{max\\min}}$ by the source intervale.

[3]Here are the details of the calculus : Let's first characterize any point R of the line D :

$$R \in (D) \Leftrightarrow \exists t \in \Re \begin{cases} {}_R = x_{W_i} + t \times (x_{W_{i+1}} - x_{W_1}) \\ y_R = y_{W_i} + t \times (y_{W_{i+1}} - y_{W_i}) \end{cases} \tag{7.6}$$

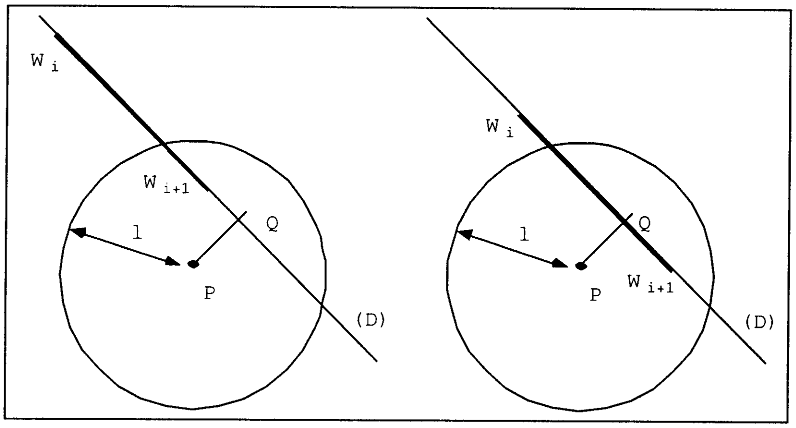


Figure 7.4: To select the walls, we determine the smallest distance between P and $[W_i, W_{i+1}]$: W_{i+1} for the left diagram, Q for the right diagram.

4. To each Source S_i selected using a loop :
   (a) To each wall W_j selected using a loop :
      i. If the wall W_j creates an obstacle between the source S_i and the observation P, create a *flag* : the source is obstructed and its direct contribution should not be taken into account.[4].
      ii. If using the reverberation on wall W_j, the source S_i could con-

tribute to the noise level in point P, add this contribution.[5]

(b) If the flag has not being raised, add the "direct" contribution of the Source S_i.

5. Paint the point P of the appropriate color. The value of the noise in the point P could be 0 after the preceding steps. It simply means that the point is shielded from all sources : the point is within a building.

This heuristic works relatively well : it requires , on the average,

$$N = n_{walls} \times 10 \times 10 \approx 10.000$$

loop iterations to paint one dot on the screen. The complete filling of the screen takes a couple of minutes on the average for a medium level traffic (the sources are thus spaced by 10 meters).

In particular, we have :

$$Q \in [W_i, W_{i+1}] \quad \Leftrightarrow \quad t \in [0,1] \tag{7.7}$$

$$Q \text{ is "after" } W_{i+1} \quad \Leftrightarrow \quad t > 1 \tag{7.8}$$

$$Q \text{ is "before" } W_i \quad \Leftrightarrow \quad t < 0 \tag{7.9}$$

The line $(D') = (PQ)$ is characterized as the line, perpendicular to (D) and going through P; Its equation is as follow :

$$B \in (PQ) \Leftrightarrow \exists t_2 \in \Re \begin{cases} B = x_P - t_2 \times (y_{W_{i+1}} - y_{W_i}) \\ y_B = y_P + t_2 \times (x_{W_{i+1}} - x_{W_1}) \end{cases} \tag{7.10}$$

By using the property that $Q \in (D')$ and $Q \in (D)$, we can find the value of t :

$$t = \frac{(y_P - y_{W_i})(y_{W_{i+1}} - y_{W_i}) + (x_P - x_{W_i})(x_{W_{i+1}} - x_{W_i})}{(y_{W_{i+1}} - y_{W_i})^2 + (x_{W_{i+1}} - x_{W_i})^2} \tag{7.11}$$

From this value of t, using the equations 7.7 to 7.9, we can determine the point K of the segment $[W_i, W_{i+1}]$ the closest to P. Then we can compute easily the distance $d(K,P)$ using :

$$d(K,P) = \sqrt{(x_P - x_K)^2 + (y_P - y_K)^2} \tag{7.12}$$

If this is larger than l, the wall is not selected.

[4] The calculus corresponding to those points have been described previously in section 6.1.2, page 62

[5] As before, the calculus corresponding to this point have been explained before. It must be noted that the program does not check if there is an obstacle in the course of this indirect sound (see figure 7.5).

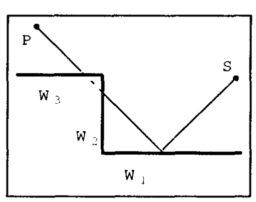


Figure 7.5: In a free space, noise reflected on wall W_1 could reach P. The actual presence of walls W_2 and W_3 stop it. The program can not take this effect in account.

7.2.3 Implementation in Java

The implementation in Java© follows closely the heuristic described previously.

Data structure for the key variables

static Color colors[[ ] an array which stores the Java©definitions of the colors used to paint the screen.

final static int length = 80 Size of the disk of influence of the noise sources.

static double emission Level of noise produced by each source.

static int sourceplus, sourceminus Index of the first and last source to utilize given an observation point P.

static final double correctionFactor = 1.3 Scaling factor between the image size and a scale in which 1 pixel = 1 m.

static double Wall[[] = new double[nWalls+1][5]] Stores the position of the extremities of the walls. Only 4 out of the 5 columns are used.

static int nSources =60

static int intervale = 20 Intervehicle distance.

static double Source[[] = new double[nSources+1][3]] Store the position of the sources. The rational is that it is quicker to store the position of all the sources *once* and to retrieve them when needed, rather than recomputing them every time.

static int wtu[[] = new int [nWalls+2][nSources+1]] Store the indices of walls to use

Procedures

The creation of static representations of traffic noise has been created as the applet *Traffic.java*. Its main procedures are briefly described below. The numbers in parenthesis correspond to the steps of the heuristic.

7.3 Heuristics to simulate the vehicle's noise in a traffic environment

7.3.1 Major differences between traffic.java and transp.java

The heuristic of this final part (transp.java) of the applet is very similar to the one used to produce the noise produced by the general traffic (traffic.java). There are some added features : first, a "main" source is added. It corresponds to the urban transportation mode studied (bus, tramway, etc...) Its

Initialization Procedures	
public void fillColors()	As before, defines the colors
public void fillWalls ()	initialize the position of the walls
public void initiateSource()	initialize the position of the sources (here equally distant).
public void initiateWtu ()	Initialize the array to store the indices of the walls to utilize
Choice Procedures	
public void selectWalls(double)	Selectes the walls to use, this procedure will be rewritten in the final version of the application.
public void selectSource(double, double)	selects the sources within $2 \times l$ of the observation point P
Noise level procedures	
public boolean shouldPaint3(double, double)	Given the position of the observation point P, determine the noise level by analyzing, for each source (first loop) and for each wall (second loop), the eventuality of an impact.
public int noise(double, double)	used before
public boolean impacted3(int, double, double, double, double)	used in the previous procedure to determine if a wall could reflect, successfully, a beam to the observation point P.
Painting procedures	
public void paint(Graphics g)	Organize all the previous elements to repaint the window.

Table 7.1: List of the major procedures used in the advanced noise simulation

sound characteristics are similar to those developed in the prototype described in chapter 5. As before, this source moves along the street.

The second major change from the previous applet is the zone of drawing which is limited to a disk centered on the major source, and is moving with it.

7.3.2 Heuristic

1. Move to the new position of the major source V(x_{source}, y_{source}).

2. Select the sources which could have an impact on *any* point within the disk. This is done by using all the same geometrical procedure but with a radius $2 \times l$ instead of l. Indeed, it would assure that the noise for points in the edge of the disk is computed using sources *outside* the disk but which nevertheless have an influence on the points of the disk (see figure 7.6).

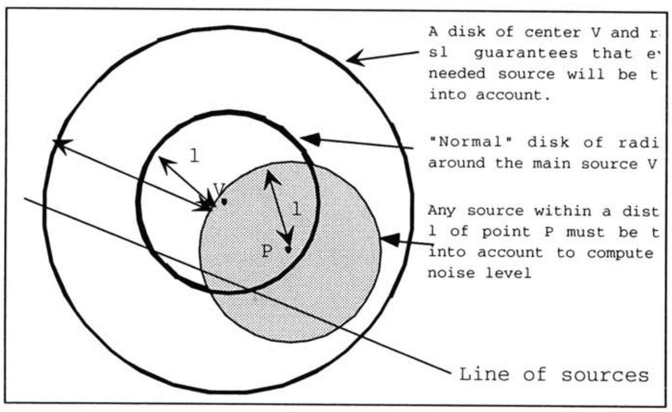


Figure 7.6: The radius must be $2 \times l$ to make sure the noise levels are correctly computed for any point of the disk

3. Similarly, determine the walls which might interact with the sources by selecting all the walls within a radius $2 \times l$.

4. For all points $P(x_p, y_p)$ within a disk of radius l centered in the main source, compute the noise level as explained in the heuristic for traffic.java (see page 69).

5. Go back to step 1 unless the vehicle has reached the end of the street.

The implementation in Java is so similar with the implementation of traffic.java that we do not feel it necessary to describe it again.

7.4 Limitations

This advanced noise simulation applet improves notably the realism and the quality of the noise simulations previously presented. Nevertheless, it has a couple of limitations worth noting.

First, the applet considers a continuous and regular flow of cars. This modeling is closer to a free-flow highway than to a dense urban street. Indeed, the traffic lights creates local accumulations of cars and irregular flows. Furthermore, when starting after a red light, cars tends to be noisier than during free driving. Thus, the modeling we chose is convenient for our heuristic but does not represent the real world satisfactorily.

Figure 7.7: Comparison between randomly distributed sources of random noise level ($83db \pm 3db$) (left picture) and regularly distributed source of similar noise level (83db) (right picture). In both case, the sources are represented by blue dots. There are as many sources in each case, although they emit at different levels.

There are several possible remedies to this problem. We tried to put sources randomly producing noise level randomly within two boundaries. The picture 7.7 shows an example of background noise with such a repartition. The random repartition could even be further improved by creating "clusters" of cars near crossing.

This kind of representations could be very beneficial to our educational project if they could be dynamic. Indeed, the very irregular shapes created by the random dispositions of sources suggest some kind of snapshot of the traffic at a given time. If they remain static, it would seem very awkward with the dynamic nature of our moving simulations centered around our study vehicle.

Unfortunately, the computing capacities available today do not permit a "portable" applet which could run both the background image and the dynamic simulations around the major source[6]. One of the multiple solutions to this problem would be giving up the "real time" goal of the program and rather get snapshots of the various evolutions of the screen, turn them into a movie which could be played hand to hand with the video of the scene. Nevertheless, the size of such movies would prevent any exportation through the Web[7].

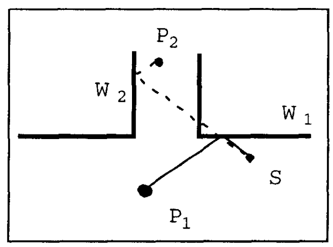


Figure 7.8: Artefacts in the current heuristic. The noise level for the point P_2 should *not* be increased by the source S.

Some of the geometrical limitations mentioned briefly in the case of the first Java^{tm} prototype could turn into real problems when a multitude of sources interact. The two major issues at stake are geometrical :

1. The absence of multiple reflections of noise limits the credibility of the model, as well as the absence of an absorption factor related to wall reflection.

2. The model can not recognize the shielding of some walls by others. The figure 7.8 introduces the notation and the typical problematic situation. Although the program recognizes that there could not be any *direct* contribution from S to point P_2, it accepts a reflected contribution against the wall W_2. In the case of one source only, it does not matter because the program is constructed in such a way that it paints a dot only if there is at least one direct contribution[8]. In the case of a row of sources, there are enough sources But in the case of multiple sources, all points could be

[6]In fact, a truly realistic application should be able to run a changing background independently from the major source, so that it could depict completely the reality.

[7]This problem will certainly be solved within a couple of years, when the flow of data through the Web will be limiteless... Nevertheless, as of today, it is still a problem.

[8]Which is, by itself, another limitation of the "one source" heuristic. Indeed, in that case, it does not admit the possibility of noise emanating "*only* from reflected noise. In fact, the model we designed can only deal with buildings considered as plain closed boxes. The reality is obviously more complex, and we would have to consider the presence of stand alone

paint. Consequently, the noise simulation in the side street might not be as "accurate" as in the main boulevard.

walls, and other non connex built elements. Those points would be useful if we were dealing with noise sources coming from different streets, for instance, in the case of a general map of transportation noise for a whole neighborhood. Here, it would complicate needlessly the model.

Part IV

The final product

Introduction

In this final part, we will describe the final project synthesizing the previous works on noise representations and simulations. Since it consists in a large Java© application, we will simply refer to it as "the application". Basically it is simply an improved version of the first prototype described in chapter II. We will describe in details its architecture, its interface and its heuristic in a first chapter. Then we will comment on its assets and its limitations. As we will explain, the concept by itself is interesting because it could enhance the communication and the understanding of the issues related to noise. Nevertheless, in its current form, the application has some limitations which should be corrected to be fully efficient.

A more in-depth reflection is also initiated on the message conveyed through this application. By message, we think more in term of mental structure. Although this project aimed at educating people through multi-media representations of noise, it also conveys a cultural framework which might, in fact, reinforce the current mental schemes rather than opening new perspectives. In the last sections, we suggest some directions for further works. It appears indeed that the concept could be easily and very effectively extended. Furthermore, we will also raise questions about the consequences of such wide-audience educational tool on the planning practice.

Chapter 8

Implementation in two different urban contexts

In this chapter, we will describe the final application. As explained before, it includes, under the same architecture, the features developed in the first prototype (variety of points of view, variety of modes, synchronization between the movie and the movements on the orthophoto, possibility of "instantly" shifting from one transportation mode to the other...) and the noise contours simulations described in chapters 5 - 7. In a first section we will describe this new application in term of interface. Then we will briefly explain its implementation in Java© in term of architecture and of general organization of the various elements previously described in this thesis. Finally, we will enumerate the limitations and strengths of the application compared to the previous prototypes described.

8.1 Description of the framework

The final product of this project is a Java application organized around one interface window. This application runs independently and could be launch on any platform running Java, as long as the Apple's QuickTime plug-in is installed[1]. For reasons that we will explain latter on, it was not possible to transform this application into an applet which could be run through a Web browser.

8.1.1 Interface

The figure 8.1 shows the organization of the user interface. Basically, it has three components :

[1] Available for free from www.apple.com.

- A simulation window which displays, as before, the noise produced by the selected vehicle on the top of an orthophoto. The orthophoto has been colorized to simulate the ambient traffic noise. A scale on left gives the relationship between the colors and the noise levels.

  As in the previous prototype, the user can click on the window to bring the vehicle to any point of his interest. Nevertheless, under the current version, all the points are not accessible. Indeed, the simulations are linked to the movies and in the latter, the vehicles start and end at different points. Those differences are taken into account in the simulation.

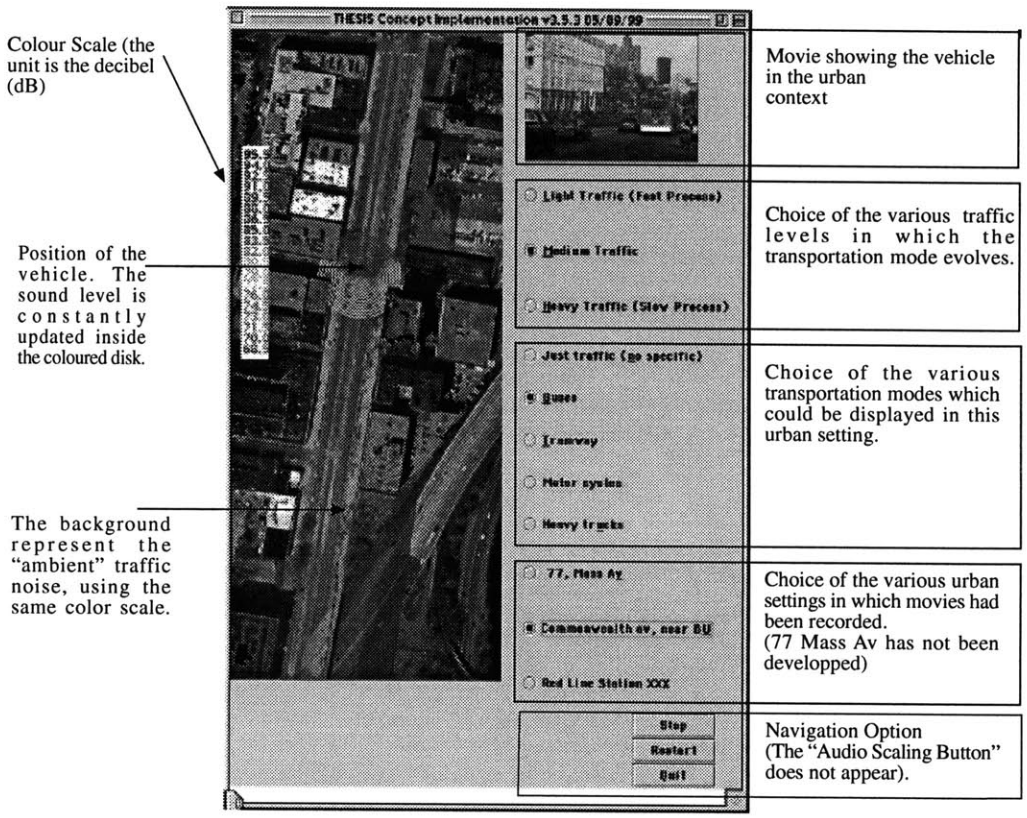


Figure 8.1: User Interface of the final application

- A movie window which shows a movie of the transportation mode in the given urban context. As in the first prototype, the movie is synchronized with the noise simulations. All the movies have been recorded and are played using the same devices. Consequently, the sounds are absolutely comparable.

- Three sets of navigation buttons which allows the user to change the traffic level[2], the vehicle to study and the urban stetting. Finally, a classic set of buttons stops the representations, starts them and quits the application.

The application is very memory consuming and still lacks some flexibility. For instance, the program needs some delays before displaying changes due to mouse clicks. This technical limitation, which could not be solved despite numerous attempts, might puzzle the user, the program seeming not to "obey".

The interface could seem rather crude. Two levels could have been expanded:

* There are no welcoming and explanatory screens. This application was supposed to be an applet running in the larger context of a Web project. In that perspective, all the explanations would have been displayed on introductory web pages. Now since this project turns to be rather a proof of concept rather than a commercial product, the explanation and introduction could be given by written on paper.

* The presentation is excessively sober, especially with when compared to the current trends in web site "fashion". In fact, this application is aimed at being an educational tool. The presence of the moving simulations and of movies are already largely appealing and any superfluous fancy elements might, in our opinion, distract even more the public from the major point of the demonstration.

  Furthermore, this program is memory consuming, especially in term of graphic resources. Any additional "fancy" graphic element would have cluttered up the memory and would have slowed the whole process.

8.1.2 Improvements compared with the first prototype

As we have explained before, this application includes a variety of new features which allow the user to make more comparisons among modes. Those improvements are not some aesthetic possibilities, but they are at the very heart of our project. Indeed, as explained in the first chapters, we aim at educating the public by helping him to build its own, personal appreciation of the impact of various kind of transportation modes. Furthermore, the concepts aims at completing the technical information with some non-scientific elements so that the public could grasp and understand fully the implications of any decision regarding those matters.

In that context, we have been pursuing a strategy of education by comparison. At any stage, we tried to augment the public's knowledge by offering comparisons of new modes with situations they might already know. In that perspective, the improvements that we have made are not purely aesthetic. We can now briefly describe them:

[2]Under the current version, only the simulations change with the traffic levels. By lack of time, we did not have the time to shot all the appropriate movie.

- The major improvement is the adjunction of the noise contours simulation synchronized with the movie. It augments significantly the understanding of the noise propagation process. Furthermore, the presence of the "ambient" noise in the background allows the user to relativize the auditive effects of a public transportation modes with respect to the rest of the urban sound environment[3].

- The synchronization of the vehicle and the movie is greatly improved by starting the vehicle and stoping the vehicle synchronously with the images of the movie.

- The comparisons are made easier and wider by offering modes which were not present in the first prototype, for instance, the motorcycle or the "big" truck. The limited resources available prevented us extend this list much further but it would constitute an fruitful direction of works.

We can not conclude this section without mentioning several features which have not, finally, been implemented. The QuickTime VR view of the recording area have not been pursued. Although technically easily completed, such a presentation would have used too much of those scarce graphical resources. Yet, such a visualization would have been useful to help the public understand the spatial situation of the recording device. If this concept happens to be used again, it could be implemented in a separate window, thus limiting the use of graphic memory.

The other absentee is the Hi-Fi like representation of noise output (noise meter). The implementation in Java revealed to be impossible today [4]. There is not easy way to access continuously the level of the sound output[5]. Nevertheless, we remain convinced that such a representation would greatly enhanced the understanding of the public.

8.2 Architecture and Heuristic

8.2.1 Architecture

Several concepts structured the architecture of this project. First, we just have one application, which includes several classes. This choice is concomitant with the use of global variables for most of data. The alternative was to create several

[3]As we explained it in chapter 3, the actual annoyance produced by any noise is strongly linked to the social values attached to the source of the noise. Those social values might have nothing to do with the actual well-being of the population impacted, but are rather often manufactured through multiple of channels (cf the on-going question about the reasons which drive people to live in the suburbs). In that perspective, offering a visual comparison between the ambient noise and the public transportation noise might constitute a small step toward a less structurally biased perception of those issues.

[4]May 19, 1999.

[5]We might rather say that there is certainly a way to access it through the Java QuickTime Library, but the cryptic documentation which goes with it did not reveal it.

independent programs which would run the various parts of the application with a central program to coordinate all the process. The later would have been more efficient in term of speed and of use of the memory. Nevertheless, the transfer of data between the various parts of the application would have been less stable and the response to user inputs would have not have been handled real time.

The application is divided in four parts largely interwoven:

1. The simulation of the noise contours constitutes a class by itself (Class Transp) although most of its variables are handled globally. It includes the right positioning of the vehicle and the drawing of the noise contours. It does not include the synchronization of the painting with the movies

2. The handling of the movies and the switching of them are grouped in the procedure static TimeRecord startMovie. It constitutes the interface between the Java QuickTime Library and the application. Its sole function is to stop the current movie, to dispose of the graphic resources used, to initiate a QuickTime session to play the new movie, to initiate the global variables to their new values (according to the new movie), and to start the movie at its relative new point so that the *current* position of the vehicle in the screen is maintained.

3. The handling of the interface, the location of the buttons and the consequences of any user input are handle by a bunch of procedures : static class RadioDemo2 extends JPanel (for the general layout), static class TrafficListener implements ActionListener, static class ModeListener implements ActionListener... to handle the user inputs. In particular, this part deals with ordering the changes of movies, of sources and the user's new positioning of the vehicle etc...

4. The initialization of the whole process and the continuous redrawing of the noise simulations are both handled in the public static void main(String args[]) procedure. It deals with determining the relation between the timeframe of the movie and the position of the source with respect to the urban context (via the procedure public static double calculateRatio).

Finally, all the resources (movies, background pictures) are stored "close" to application. Indeed, attempts have been made to store the resources on the CRL server "yerkes", but even using a T1 lane, the stream of data is too slow to play, in real time, the movies and to switch easily from one representation to the other.

8.2.2 Heuristic

We can organize the heuristic in five different and largely autonomous sequences:

a Fundamentally, this application is structured around the movie and its Java QuickTime Player. Indeed, the player can play autonomously while sending, continuously, the current playing time (caught via "TimeRecord"). This playing time is analyzed by the main procedure which then communicates the corresponding position of the source to the painting procedures. If they are busy, they ignore the data (boolean NotReady in procedure paint.). Else they redraw the left part of the window.

b The vertical position of any "click" in the simulation window is translated into a new playing time. This information is then send to the QuickTime movie player which adjust the current playing time. The first part (a) of the heuristic then deals with the redrawing of the simulation window. In particular, the current drawing is not instantly stopped[6] on a mouse click. It explains the delay which could occur between the click, the "reaction" of the movie and the actual change in the simulation window.

c The push of a "traffic" button only changes the values of the variables relative to the number and position of the traffic sources (as defined in a previous chapter). The name of the background picture changes also. But the main heuristic (a) is not directly affected and it continues to send new redrawing "orders" to the painting procedures.[7]

d The "modes" buttons changes both the movie played and the variables concerning the emission levels and directionality of the vehicle. It keeps constant the relative elapsed time between the old and the new movie. Here again it interferes only indirectly with the drawing procedures.

e Finally, the "location" button reinitiate the whole process, in particular, it reinitiate all the global data, all the drawing data (position of the walls etc...), it also restarts the movies at their beginning. This whole process is necessary because of the new environment proposed is totally different, even in term of the modes presented.

The actual implementation of the application will not be described in detail. The source code, largely annotated, is available at the CRL web site.

8.3 Results and technical limitations

Although this application has been conceived using some Java libraries not yet officially released[8], it works without major bugs. There are three major limitations :

[6]Despite numerous attempts, we were not able to stop it elegantly (ie without side effects such as crashing).

[7]The current version of this application does not include movies for every possible situations. In particular, when the traffic volume changes but the mode is not changed, the movie is not changed. If we had shot movies for every possible combination of traffic levels and transportation modes, the video would change when a "traffic" button is checked and the heuristic of the point (c) would look like the point (d).

[8]We just got a β version of the Apple's Java QuickTime Library

- The size of the movie is constrained. Indeed, the memory is rapidly saturated and the application refuses to open movies larger than 30 MB. This point constrains the size of the image (see later for an deeper analysis of the consequences).
- There are delays between the user input and the program's reaction.
- This application relies too heavily on the graphical memory of the computer which might create problems for older generation's ones.

Chapter 9

Observations and conclusions

In this chapter, we will analyze the model according to the objectives that we assigned ourselves at the beginning of this project. This analysis will encompass the technical aspects of the application as well as more general issues concerning the concept itself. As any medium, this concept has some inherent bias which must be explicited or we would fall in the traps Forester denounced. This will be the object of the first sections. Then we will make some comments on the outcomes of the technical limitations of the applications. We will in particular emphasizes the issue of portability of the prototype. Finally, we will also open the discussion on the possible impacts on this tool on people and on the planning practice. Indeed, the current technical limitations will be eased by the technological boom of information technologies. In a context freed of such limitations, this tool will just be one among a new generation of multimedia tools developed to informed the public directly, without the "classical" mediation of a planner. In that context, the planner is not destined to disappear, but his role will certainly change. We will suggest several directions of "planning practice renewal" which could be of interest.

9.1 The concept and the message

In this section, we will analyze the message and the values conveyed by our concept. We will first discuss the value added of this project as compared to other form of communication about noise. Then we will move to the biases of a multi media representation about noise. We will also consider the meaning conveyed by the use of a mathematical model. Finally, we will synthesize those findings by pondering the quality of the message conveyed.

9.1.1 Value added compared to other noise-related media

As we explained it before, the communication of urban transportation noise exists mainly (if not only) under the format of written reports on paper. Although much effort (and money) has been poured in airline noise, the urban noise has remained underfinanced so far. Compared to a paper report, this concept has several strong benefits. The major asset is its dynamic nature. Indeed, written report could only provide a very well documented "snap-shot" of a situation, denying the comprehensiveness and the liveliness created by dynamic representations. Not only does it enhance the spatial understanding of the transportation mode, but it also includes the relationship between the noise perceived and the position of the vehicle.

The dynamic nature of the application enhances the level of interest and of understanding of the users. It allows the user to repeat a sequence as many times as needed for a full understanding of the issues at stake. Furthermore, it allows him/her to focus on specific aspects and to make easy comparisons among them, until fully satisfied with his/her findings. This is essential, in our opinion, to really achieve the *"interactive and interpretative"* process required by the postmodern planning theory.

Some other multi-media tools exist which present comparisons among transportation modes (for instance the CRL's transit data bank). This kind of encyclopedic sites are interesting for the general information of the public, but they do not offer comparable examples. Indeed, the possibility to compare, in the same urban context, various modes is at the core of the educational paradigm of this project and constitutes one of its major strengths. Furthermore, the data displayed are often a little too "raw" and they are not presented using multiple kinds of knowledge, as this tool intends to do for sound related issues. In that perspective, the encyclopedic accumulation of technical data might not be fully understood by the user.

Finally, it seems important to point out the existence of other noise simulation tools. Compared to those more accurate models, our simulations might seem a little crude, but it runs real time on a common notebook. The portability (within the limitations that we have indicated before) is essential. Furthermore, those models are stand alone application and are, usually, not part of larger representation projects. As we explained before, the multiplicity of the representations is important to help the public create its own appreciation of the situation.

It is not far fetched to conclude that this concept occupy a specific and interesting position at the cross-road of noise simulation, transportation data-banks and written reports. By combining those three kinds of representations in an unique urban settings, this tool offers unique opportunity to educate, enhance the understanding and create a social knowledge in the general public.

9.1.2 Biases in the visual and auditive representations

Although this concept appear very interesting, it has several visual bias that are worth noticing. Some could be corrected in a later version realized with more means (quality of the movies and sound), other are more intrinsic to the project (choice of the colors, distraction of the public...)

Quality of the visual representation

The quality of the pictorial representations is important at two levels:

- In absolute terms, the image should be of good, if not high quality. Indeed, the first impression of the movie could determine the general acceptance of its content. Although the relation is not reciprocal, it is an element to take into account.
- The preceding argument is even more important for the movies. A poorly shot movie among good ones would obviously undermine the acceptance of this mode compared to the other. But, more fundamentally, it would also undermine the credibility of the whole process letting the public that they are manipulated by the applications.

The quality of the movie goes further the sole quality of the images. The way the movies are shot, the obstructions, the size of the image contribute to the overall appreciation of the situation.

In the case of our application, we had very limited time slots to shot the movies, consequently, their quality is relatively poor. This could reduce the positive appreciation of a layperson on this project...

Biases in the simulations

The simulations include two types of biases with different results :

Issues related to the colors The choice of colors varying from dark green to deep purple is very loaded. Indeed, it conveys the message that the noisiest elements of the representation are unacceptable and should be stopped, or at least curbed. This choice of colors did not arise from a deliberate attempt to influence the user's perception, but from a very practical observation about the difficulty to read some other colors (blue, maroon...) on the top of a black and white orthophoto. This issue of colors is all the more important that the "heavy" traffic situation generates a mostly red map, element which might make a user think that a " heavy" traffic situation is unbearable.

The second part of the color issue is the difference of saturation between the background and the foreground. Because of the way the background was created, it is much darker than the noise disk simulated around the vehicle. It might convey the meaning that the vehicle, being more saturated than the background, is noisier. This bias could be limited if we work on the background so that the colors appear as dense as the foreground.

The radar and the noise : The final version of the application does not use a double buffering system and consequently draws the noise contours continuously rather than drawing them in a hidden canvas and showing all of them at once. The result is a radar-like situation. In term of message conveyed, it tends at amplifying the vehicle as the major source of noise. Indeed, it creates a dynamic process on the top of a static background, thus suggesting that the transportation vehicle is the only "living" element of the environment and thus the source of any noise. Furthermore, the radar shape of the graphics suggest the idea of propagation of the noise over space. Once again, begin the only element of the picture to produce such an effect, it reinforces the idea of a unique source of noise and annoyance.

Those two biased, coupled with the overestimation of noise level, would certainly distort the "unbiased", comparisons-only message of this project.

Distraction of the public

The last issue to consider is the tendency of the public to get distracted by the dynamic elements of any multimedia representations. We are facing one of the major dilemmas of any educational tools : where is the boundary between catching the attention of the public and distracting it from the real message to convey. The ease to switch from one mode to the other, the dynamic representations might induce the public to play with the tool rather than to try to compare among the various options.

Even in the case of a use by a planner in a public participation meeting, the public might be more interested by the novelty of contours simulations than by the rest of the noise representation. This would constitute a major shortfall of the project. In that perspective, the role of the planner appears essential to demystify the noise simulation so that it becomes a "common" element of the presentation.

The same comment could be made concerning the movies. The dynamic nature of those components has the ability to capture the attention of the public and to create a feeling of expectation. This reaction must be defused to assure a good educational process.

9.1.3 The use of a mathematical model

We could even the reflection on the model one step further. One of the major criticism Forester made against traditional planning is its tendency to rely mostly on technical analysis and mathematical models.

The simulations could fell in the same trap. Indeed, they rely on mathematical models which, for the lay person, might look like a black box; In a way, this simulation might reassert the power of a "technician" planner which only could understand and tune up the black box. This effect could be corrected by multiplying the points of view so that the public can assert by itself the noise level corresponding to certain numerical data.

Furthermore, the simulations provide numbers, not social values. It should not be an aid to decision and not a decision maker by itself. But by providing colors, we pre-make this value attributing process.

9.2 The concept and the usability : Testing the application

In this section, we will describe the results of a couple of brief tests of the application on some DUSP graduate students.

We got two reactions from this test :

* The moving contours are interesting, not so much as an absolute scale, but rather not have a first cut of the relative noise of the vehicle with respect to the background. The issue of reflections on the facades is not noticed unless the subject is explained.

* The applications tends to be distracting because of the number and variety of moving objects along the windows. People tends to be interested by the movie because they try to recognize the place and expect some specific event to happen; at the same time, the moving contours create some distraction, with the outcome of preventing any real focus on any of the representation.

Both points are important and would certainly lead to some reorganization of the application, time permitted.

9.3 Which message do we convey ?

In this section, we will try to make an overall evaluation of the message conveyed by this application.

The first comment is that this message could be easily manipulated. Indeed, the user who tests all the possible options offered by the current version of this tool would come out with a very positive appreciation of the tramway as compared to any other urban transportation mode. The major explanation deals with the choice of modes presented. Indeed, the transportation material available in Boston is globally old and even outdated. If we had presented high-tech, eco-friendly, noise-free european buses the over-all impression would have been totally different. Practically, it means that it is very easy to distort the information with such a concept. The only solution would be to multiply the modes's representation available. Indeed, if the public could compare buses in variety of urban settings but also in a variety of shapes, this major bias would disappear.

A second reason could explain the bias toward the tram. This application presents only one dimension among all the consequences of the implementation of urban transit modes. No mention is provided about the cost, about the number of passengers carried through, about the urban space consumption and structuration... It should be emphasized that, by itself, this application will always lean toward the least noisy modes (public light rail in general) although they might not be the panacea in all circumstances.

Even if the two preceding restrictions were lifted, the public would clearly support public transportation "against" cars and motorcycles. Indeed, the whole application would lead people to realize that a car could be more noisy than a bus, while it is only carrying a couple of passengers. It would not balance this opinion with issues related to mobility or travel time. In the first chapters, we quoted Forester's criteria for a "good" information :

comprehensible, sincere, legitimate and accurate

By intellectual honesty, we can not affirm that we meet those requirements. On the other hand, we are in the typical situation where an information is so heavily biased (toward the automobile), that simply using neutral information would not suffice to counterbalance the situation.

9.4 Technical aspects

In this section, we will analyze the technical limitations and strengths of the application in the perspective of the educational goals that we assigned ourselves at the beginning of this project. We will only consider the current state of the information technologies, and thus we will discuss those points in the current context. In the next chapter, we will consider the impact of this kind of applications free of any technical limitations.

9.4.1 The portability of the application

One of the objective of this project was to create a tool to educate the public about noise related issues. In order to reach an audience as large as possible, the World Wide Web appeared to be a good medium for this tool. The use of program running on web-pages seemed indeed particularly appropriate. The use of Java© as the programming language was an attempt in that direction. Nevertheless, we encountered three major obstacles which prevented us to achieve this goal of portability. First, this application uses a lot of movies. Although the current application is only a demonstration of the concept, and thus does not have all the variety of movies it should, its 6 movies already uses more than 120 MB of disk space. Such a size excludes any realistic download from the web, except in the case of professionals who would reutilize the application several times.

Furthermore, the current movies are presented in a very small format (160×120). This size does not allow a good apprehension of the general context in which the vehicle evolves. This issue of the quality of the movies should not be dismissed too quickly. Indeed, we are primarily dealing with sound representation, but the noise simulation emphasizes on the importance of the context to understand noise levels. The use of the orthophoto should thus be supported by a good movie to help the public understand the spatial organization of the street.

To bypass the issue of movie size, we have considered downloading only the movies when they are needed (when the user changes of mode). But we are still confronted with the current sluggishness nature of the Web.

Even if we could solve this issue of downloading, we would be facing difficulties with the speed of the user's computer. The application needs a fast processor to run adequately. The issue is not so much with the playing of the movies, the threads which deal with it have a high level of priority. On a slow computer, the program will not be able to draw at the same speed as the movie plays, if it draws at all. This program has been written using a Mac G3 300 Mhz. We could assume that a Pentium II 450 Mhz should be able to match up.

The public we aim is less likely to have such a high-tech equipment. Consequently, the wide ability of the application becomes less crucial.

Finally, the application is more stable as a stand alone than as an applet. Indeed, using it as an applet with Netscape© Navigator 4.51 creates interesting, unwanted results. On the contrary, as a stand-alone, this application could use fully the portability of Java to works under any operating system[1].

Consequently, we have evolved to a concept of an applet embedded into a web-page to a stand alone application, less easily usable. This change is not minor. It is, in fact, a major shift from a tool used by individuals through the web to a tool for planners to be used in the context of larger public participation meetings. In that new perspective, any annotation mechanism becomes superfluous since the social knowledge is created "live" by the interventions from the public. The memory of those common knowledge would then be recorded by the planner.

It also means that the public will have less possibilities to interact with the tools and to understand in depth the mechanisms involved. We could regret that the public will, in general, get a rather superficial grasp at the subject.

9.4.2 The difficulties to adapt the application to any new urban context

The second major limitation of the application concerns the difficulties to adapt the program to any new urban context. By itself, the problem is not out of reach. It only deals with adding pictures, movies and acquiring data concerning the

[1] As long as Java and QuickTime are correctly installed.

position of the walls. It could easily be done in Java, though we had neither the time, nor the necessary knowledge to accomplish the task efficiently.

The absence of such a mechanism is certainly a weakness of the application. Indeed, as we already explained it, we tried to educate people by offering comparisons between situations they are familiar with and new situations. In that perspective, it seems important for the "starting point" to be as close to known situation as possible. If the initial urban setting is too different from the user's environment, two negative reactions may arise : either the user does not "enter" into the representations and can not create a knowledge applicable to its specific case; or the user will spend time to explore the new environment and will "lose" the sound aspect of the presentation. Ideally, we would like to be able to customize the application at will to include the modes, the movies and the urban setting of interests for the planner.

9.4.3 The limitations of the model

As we have already explained it before, the mathematical model we used for the noise simulations tend to over-estimate the noise level (see section 5.3). Nevertheless, it is probable that the public will either take its predictions at face value, or dismiss them altogether because of their known bias. Both case are of equal annoyance, and would go against a balanced appreciation of the public transportation modes presented. To limit this negative impact, we could have used several stratagems : the most obvious would have been to refine the mathematical model, but the "computing" cost would have increased subsequently, and it is already a limiting factor. Another stratagem would have been the introduction of a "correcting" factor or of an "attenuation" factor, to match the expected results. Finally, we could also have omitted the scale, insisting that it does present a general picture rather than exact values.

In the absence of a scale, the user would have used the colors and would have linked them to the noise he heard from the movie, thus making its own personal appreciation. It could, indeed, be the most effective situation. The number associated with noise levels (83 dB etc...) are already very loaded symbolically. The technicians used them heavily in their presentations, and the media tends to interpret them with via unsure comparisons :

> "80 dB correspond to the noise on a sidewalk along an highway"
> "100dB : passing subway train"[2]

This kind of assertion freezes the discourse on noise, frame the terms of the debate (and structure the social acceptance of a highway as compared public transportation modes). By not giving the public a scale[3], we let it make its own judgement and we avoid the certain criticism on the validity of the model.

[2]From a Flier by McCormick, Taylor and Associates on the *levels of noise* distributed during the 1999 APA conference.

[3]Although, we could mention that a bus peaks at 90 dB when it starts, etc...

9.4.4 The creation of a database of comparable examples

Several dimensions of this concept could be improved and refined. Among them, none is more crucial that the creation of a vast data base of examples to incorporate in the framework previously developed. By offering a wider range of representations, we could limit the risk of manipulations by the planners while broadening the knowledge of the public. Nevertheless, this expansion is not without difficulties; Indeed, the creation of such a database is expensive in term of money and human resources. To be really coherent, such a project should include examples in as many urban settings as possible. It should encompass all possible urban transportation modes, and with that respect, the data base should imperatively include European and Asian examples.

Under limited resources, the criteria of choice might be problematic and would represent the priorities of the funder. It must be emphasized that this choice might constitute the core of an involuntarily manipulation of the tool by only presenting projects, or comparisons which seem reasonable to the Administration; By so doing, it would frame the options available and thus would deprive the public from a real decision making process.

Among the criteria of choices, it seems important to emphasizes both the comprehensiveness and the comparability of the examples. Indeed, under limited resources, the "quickest" solution would be to film each mode only once in the urban setting which is the most suitable but which, consequently, would be different for each of them. Some requirements concerning the built environment might give the impression that the examples are comparable. We think it would not be efficient. Indeed, the difference in recording environment would appear suspect to a suspicious public.

At that point, we face the two key methodological problems:

- In the previous paragraphs, we have made the deliberate choice of an education by quantity. Some pedagogues would have argued that we should rather limit our presentations to a couple of well-chosen and meaningful examples, from which the public could really learn. The shortfall of numerous examples being the risk of drowning the public under movies and sounds. This point is crucial in the future development of this concept. Indeed, if hundreds of movies are added, navigational tools will become indispensable. They should help the public select the context and the modes that could be of interest. In that perspective, the choice of the relevant dimensions to index this library becomes critical.

  Furthermore, if we stick to a comprehensive data bank, a annotation mechanism must be devised to help the public keeping track of the modes and contexts it has explored. A check-list tool could be satisfactory if the questions are adequately framed to be neutral.

- The previous question leads to one of the major issue of this project. If this project aims at educating by comparisons but using the intellect, then a large data bank is not necessarily. Indeed, the commentaries accompanying the representations would educate and improve the public's understanding. On the other hand, if the project tries to provide a "non-rational" apprehension of urban transit modes, then a variety of movies is essential. 20 years ago, this debate would have been answered easily; Common knowledge, direct descendant of the Enlightment spirit, would have denied, then, any space to the second kind of apprehension of the reality. But the background that we described in the first chapters forces us to consider non "purely rational" educating means. Indeed, cognitive and intuitive knowledge are now fully part of the contemporary planning practice.

  In that perspective, it seems important to provide both kinds of representations. It appears the only way to offer to "non-technical" people an access to the issues at stake and, by so doing, to assure a really inclusionary process. inclusion

9.4.5 Developments of the tool

Apart from the data-bank aspect of the needed developments, we could also consider other of technical improvements which, far from being purely aesthetic, could improve the understanding of the sound related issues. A multiplication of the points of views should be implemented. This idea was proposed along with the first prototype, but, by lack of resources, was not pursued in the final product. By providing multiple perspective, both visual and auditory, of the same scene, it would greatly augment the number of comparisons available.

An other major technical improvement would be the adjunction of an annotation mechanism. This mechanism would have two aims : first, it would help people to build their own memory of the sound, and thus would enable them to discuss their findings[4]. The second dimension is outward oriented. An annotation mechanism would allow an asynchronous communications in the case of a web based tool. Even if the first experiments of public participation mediated by the Web might not be very conclusive, we can forecast major developments in that area. In that perspective, our tool will have to include some kind of annotation capacity.[5]

[4]This point is not as frivolous as it might seem. As we pointed it out before (see section 3.1, page 21), by lack of vocabulary, by lack of training we have a much poorer acoustic memory than a visual memory. Any form of help would thus be welcome to allowed any elaborate discourse on noise related reactions.

[5]Behind this position, lays the assumption that the web will become as easily available as the phone to all classes of the society. If it was not the case, the whole problematic about this tool would change. Indeed, by providing such an empowering tool such as this one to the wealthiest half of the population, we would reinforce the "natural" strength of the upper-society at the expense of the very ones that this project was supposed to serve... In such a case, the "philosophy" of this tool might have to be twisted again by envisioning its use

Finally, as we explained before, it appears essential to consider this tool as only a small piece of a larger project which would present, similarly, the characteristics and the other impacts of urban transportation modes. Such endeavors have already been entreprised, for instance, at the MIT's CRL. Such an effort should be expanded using the latest available technologies to offer comparable representations of the essential -in its philosophical meaning- dimensions of all transportation modes.

9.5 The planning practice with an educated public

In this last section, we will engage the discussion about the consequences of this tool for the planning practice. We will assume that all the technical and social limitations that we have previously listed could be overcome. In that perspective, this discussion broadens to the role of "educational" web-based multimedia tools in the planning practice. We could, indeed, easily envision, in the very near future, the development of comparisons based tools to educate the public on zoning[6], or EPA regulations, or any kind of technical data. In such a context, the role of the planner will change dramatically.

9.5.1 The public meeting with an educated public

If the planners decide to play the game, the temporal organization of a public meeting will change enormously in this new context. Indeed, the planners will have provided, in advance, the main elements of the plan, such as the *current* options, the technical constraints and some useful web-links to begin a search about the representations o the alternatives. Maybe a list of the most appropriate modes could also be supplied. Obviously, he/she would have emphasized that this list is, by no mean, exhaustive.

Given those first elements the public should be able, individually, to search the web, run the comparisons among modes and come up to the meeting with a good list of questions, of suggestions about other alternatives etc... It is probable that an online discussion will already have started via some chat rooms moderated by the planner. It would also be conceivable that if any one wants to propose any new alternatives, he/she would have to post that, in advance, on the web. Indeed, it would allow the other participants to review the given modes and build up their own opinion. It appears also to be the only feasible way to structure (somewhat) the forecoming public meeting[7]

only in the context of a public participation meeting. It would, then, also aim primarily at stimulating questions in the public rather than educating per se.

[6]In some kind of twists of GIS

[7]Some would also argue that it would give time to the planners to prepare their rebuttals.

The public meeting would, we assume, not change notably in format. On the other hand, its content might considerably evolve. The major obstacle will be the decision making process. The tools of this kind have the ability to broaden up notably the universe of the possibles. With so many conceivable alternatives and the instant access to unbiased and easily graspable technical data, the discussion could wander endlessly, let alone the creation of a consensus in the public...

We could take this rather bleak vision on its counterfoot. It is undeniable that some NIMBY reactions would be strengthen by arguments originating from those tools.

9.5.2 New roles for planners

With multiplications of web based educational tool, the role of the planner planner will certainly evolved. We can assume that two dimensions will become pre-eminent:

The planner as a manager of communication networks Freed from the limitations induced by the inaccessibility of technical data, the sphere of the the public discourse will certainly explode. In that perspective, the planner will be facing two challenges :

1. How to assure a fair representativity of all parties ? The issue is not so much of the access to a communication network, but rather to assure that the message will be heard and taken into account. It would be illusionary to imagine that the equalitarian free speech "anomalies" of the web will last long. Without being Cassandra, it is not very far fetched to assume that the dominating social forces will also propagate through the communicating channels of the web. In that perspective, the role of the planner as an arbitree and a moderator of the communication will become all the more important.
2. How to remain result oriented ? Although postmodern theory reaffirms the importance of the communication act as a result by itself, the planner also has some very practical decisions to be made. With the multiplication of the alternatives available, skills will have to be developed to assure that the meetings,or the discussions remain focused and opened to any comments, ideas and opinions. The planner will have to achieve a comprehensive discourse on the transportation modes, to engage the public into a discussion, to help a social knowledge to emerge while at the same time arrive at a conclusion at the need of the meeting. The idea would not be to persuade, but to convince the public of the validity and the adequation of his positions with the aspirations that they will have expressed through their reactions and propositions. In a way, his work might even be eased by the variety of alternatives offered by this tool. Indeed, by being

offered a larger vocabulary to express its comment, the public will be able to describe more accurately its concerns thus easing the task of the planner.

The planner as a referee More fundamentally, the planner might have a new and more essential role to play in the maze of a web-structured world. Indeed, the exponential growth of information available on-line has not delivered a mechanism to assess the quality and the validity of the information available. As technicians make plans after the vision of the public, the planner should be the one who nourishes this vision with consistent and reliable information. The planner would not only be a facilitator, or a mediator, but a referee about information, of propositions evolved from personal research on the web.

In that perspective, the 21^{st} century planner will have to master a larger variety of skills than ever considered by the post modern planning theory, and might become some high-tech version of the 15^{th} century's artist /scientist /planner. At the same time, we have to make the observation that the problem facing the planner will not change fundamentally. The availability of tools does not solve the questions about the design of the projects...

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