Environmental Impact on Highway Geometric Design in Western Europe Based on a Geographical Information System

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Attempts were made to reveal the interrelationships between environmental impacts and other important planning goals as well as between the design flow in modern highway geometric design guidelines, with special emphasis placed on environmental protection issues. The governments of most western European countries have enacted laws requiring Environmental Compatibility Examinations for traffic projects and also require engineers to conduct environmental compatibility studies (ECSs) that assess environmental impacts when planning highways. These studies must always be done before starting the design and construction phases of a highway construction project and must examine all existing natural, ecological, and cultural resources that are important to the integrity of an observed region. The ECS consists of two parts: (a) a space-related sensitivity investigation and (b) a comparison of alternatives. Geographical information systems (GISs) are recommended for use in conducting those studies. A case study involving a sensitivity investigation with thematic maps based on digitized geographical information is described. The thematic maps were developed to portray important environmental resources. By using a computer-supported GIS examination procedure, the thematic maps were superimposed, weighted, and evaluated to develop a new map. The new map, which incorporates those environmental resources, is used to identify the low-conflict corridor (the corridor that minimizes environmental effects) in the investigated region. Incorporation of the new design component, an ECS, into a computerized GIS format is a significant step forward in helping to present such work to the public for clearer understanding and general approval. It is recommended that future editions of the Green Book include material on ECSs.

"It is no question, that modern highway engineering has to respond to the mobility requirements of the citizen as well as to the highly developed economy. Providing traffic service to users is imperative and is certainly part of the quality of life, we are used to, today" (*1*). Alternately, the increasing impairment of the human living space concerns all people.

Therefore, the preservation and conservation of natural resources are important tasks for the future. The goals of protecting nature and the landscape as well as the soil and water and avoiding the creation of disturbances to the ecological balance have become priorities. However, *environmental protection* in western Europe is often used as an argument to abandon further completion of the highway network. In this connection it is recognized that (*1,2*)

1. The European governments have serious intentions toward nature and the environment. By abandoning the future completion of traffic routes, however, problems cannot be solved, economic growth and employment cannot be ensured, and traffic safety cannot be improved.
2. Environmental protection is no longer an empty formula for the highway engineer. At all planning, design, or construction phases, the relevant consequences of a project on the environment must be investigated, evaluated, and balanced against other public and private interests.
3. It must be understood, however, that by examining the environmental compatibility of a highway project, all planning stages and the resulting necessary adjustments become more difficult, more extensive, more time-consuming, and more expensive.
4. Thus, environmental protection is expensive. In most cases in western Europe it can be estimated that between 5 and 20 percent of overall project costs must be spent on environmental protection.

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BASIC PROCEDURE IN ROAD PLANNING AND DESIGN WITH SPECIAL EMPHASIS ON ENVIRONMENTAL PROTECTION ISSUES

The elaboration of a roadway design includes several design levels. With each level the designs become more concrete and the maps more detailed. At the same time, however, the remaining planning levels are always concentrated on fewer alternatives, since useless alternatives are excluded by such a selection procedure. In principle planning, design, construction, and operation must be regarded, meaning that the project must be harmless to the environment, safe, economical, and if necessary, efficient for traffic, and afterward the continued operation must be ensured (*3*).

Parallel to the technical elaboration, legal procedures take their course, by which harmonization of development planning, acquisition of land and soil, achievement of rights (water and trespassing rights, etc.), the extent of compensation, and the allocation of structural performances must be cleared and settled in accordance with public and civil laws and the design progress (Figure 1) (*4*).

The numerous relationships among driving behavior, road design, traffic flow, and environment require an iterative procedure for the establishment of the design. This means that first assumptions must be made, and during subsequent design stages it must be determined whether these assumptions are correct or incorrect (in the latter case, the design process must be repeated with better assumptions). Furthermore, a conclusive solution is almost impossible; this means that for present problems, different alternatives (which cover all of

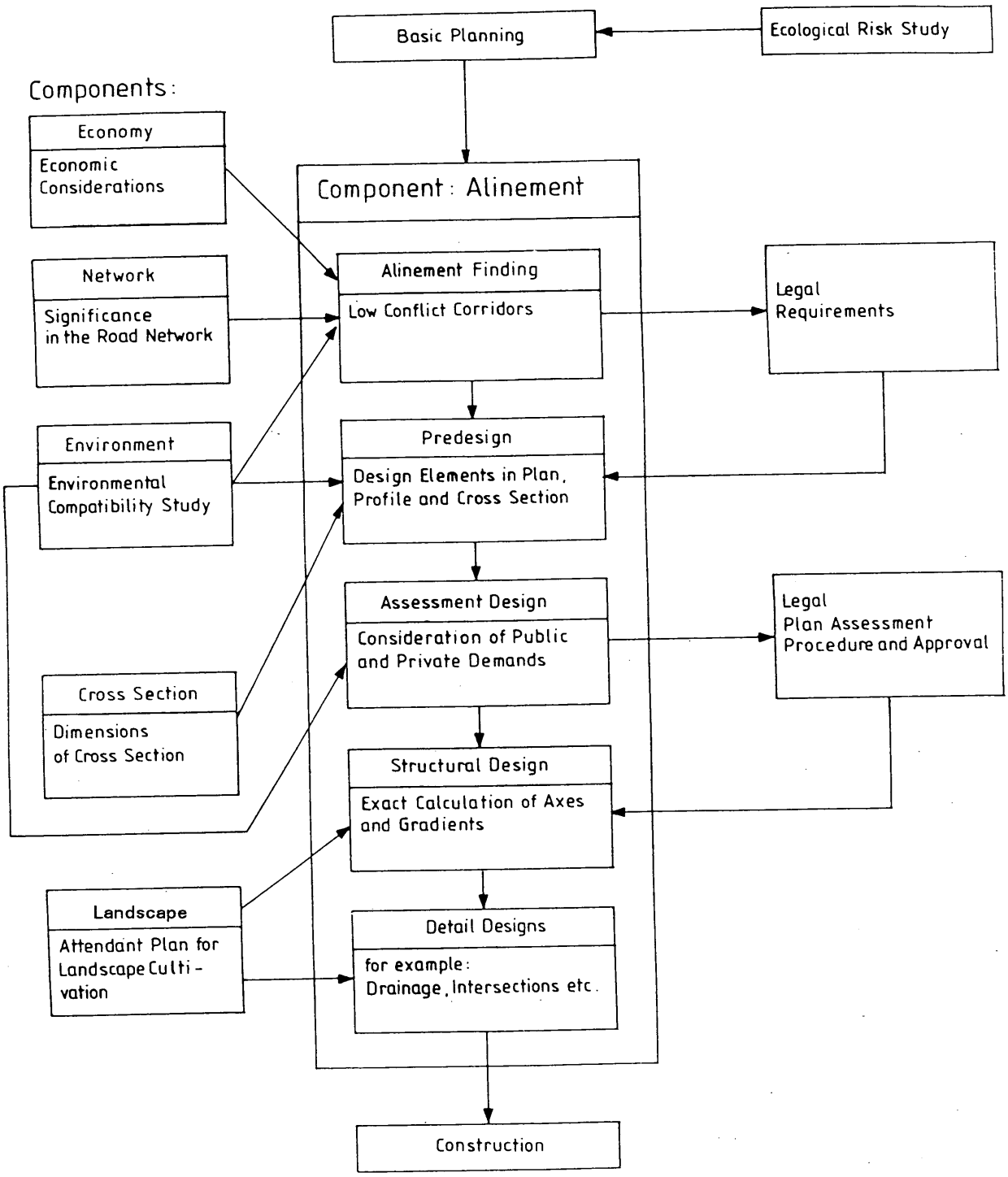

FIGURE 1 Design levels in the range of validity of modern highway geometric design guidelines with special emphasis on environmental protection issues.

the possibilities as much as possible) must be investigated so that designers can select the most appropriate one.

In planning federal and state routes the responsible authorities are in general required to participate at all planning levels. The basis for this in Europe, and especially in the Federal Republic of Germany, is the "Law for the Realization of the Guidelines of the Board of June 27, 1985 for the Environmental Compatibility Examination (ECE) for Specific Public and Private Projects (85/337/EWG)" (5) of February 12, 1990.

According to this law, uniform principles for effective environmental precautions must be applied; this means that the effects on the environment must be described and evaluated, and the result of the ECE must be considered in all official decisions related to the approval of a traffic project.

Thus, for the construction or alteration of a federal or state route, which must undergo a legal plan assessment (development plan), the law requires that an ECE be performed (*5*). The ECE procedure is regulated by law; it is a continual and integrated part of the levels of planning for alinement determination and plan assessment.

The ECE is based on an environmental compatibility study (ECS). The *Instructural Guide for the Environmental Compatibility Study in Highway Planning (ECS)* is used (*6*). The ECS must normally be conducted in two elaboration steps (Figure 2).

1. A space-related sensitivity investigation, which includes goal-oriented space analysis and goal evaluation, establishment of relatively low conflict corridors for the alinement, and allocation of specific conflict areas.
2. Comparison of alternatives, which includes a comparative evaluation of alternatives, including the rehabilitation or restoration alternative and the zero (do nothing) alternative.

During the first level of planning, during which alternative routes are determined, graphical elaboration is sufficient (Figure 1).

In further evaluations, the following route determination criteria should be considered:

- Traffic-related goals of regional planning;
- Environment-related evaluation criteria, including actual use and biotype function, present soil and water function, landscape quality, dwelling function, recreational function, cultural and other resources worthy of protection, and climate and air;
- Soil conditions;
- Vicinities of settled areas;
- Section length, sizes of radii of curves, and gradient;
- Necessary engineering structures;
- Need for demolition of buildings; and
- Construction time and costs.

The result of the alinement finding is the selection of a priority alternative, which is based on the comparison of alternatives (Figure 2).

The next planning phase is predesign (Figure 1), in which the selected routes for one or a few different alternatives are examined and the design elements for cross section and alinement are determined. Axes and gradients are calculated at least for the main points and the constraint points. More exact information about impairment of the environment and residents, construction and operation costs, and road user costs is available at this phase. In many cases legal procedures can still take place at the predesign phase. However, today, a more profound at least partial, elaboration is often necessary.

After the predesign is approved, the structural design, which represents further development of the predesign, is made. All axes, gradients, drainage, and the exact need for property can be determined by performing calculations. The structural design serves as the basis for the acquisition of land, the invitation of tenders, and the allocation of structural performance (Figure 1).

For single parts, for example, drainage and intersections-interchanges, or for the whole construction process, further detailed designs may still become necessary.

At the level of these detailed designs, interferences with nature and the landscape must be presented separately according to the required compensation and replacement procedures discussed in the attendant plan for landscape cultivation (*7*).

In Figure 1 the range of validities suggested for geometric design guidelines for modern highways is presented for the different design levels, with special emphasis placed on environmental protection issues to clarify the interfaces with the other design components and legal requirements.

In conclusion, it can be noted that the environmental compatibility examination presents an integrated procedure in road planning and design. With increasing planning accuracy, increasing verification of environmental issues takes place. The following environment-specific investigations must be performed in detail at the individual design levels according to Figure 1 (*8*).

Basic planning	Ecological risk evaluation
Alinement design	Environmental compatibility study
Detailed design elaboration	Attendant plan for landscape cultivation

Because of the close involvement between the design flow and the ECS in an integrated road design, it will become necessary to regard environmental protection issues to a greater extent in the future.

ENVIRONMENTAL COMPATIBILITY EXAMINATION IN WESTERN EUROPE: EXAMPLE GERMANY

As discussed previously, the governments of most western European countries have enacted ECE laws (*5*) and also require engineers to perform ECSs (*6*) when planning highways, railroads, waterways, and airports. These studies must always be done before starting the design phases of a project.

Thus, for major new construction, reconstruction, rehabilitation, and restoration projects, an environmentally justified compatibility study must be developed for any future highway route or location in western Europe, which will be addressed in the following discussion. The studies must include all existing natural, ecological, and cultural resources that are important to the integrity of an observed region. [These statements agree fully with the U.S. point of view (*9*)].

The space-related sensitivity investigation of the ECS is based on a presentation that covers the entire area for all relevant functions of the environment, with special regard to the following:

- Protected and protection-worthy settled and unsettled areas and resources,
- Areas with special environmental sensitivities or with specific significance for the environment, and
- Existing and planned land use.

In addition to the space-related sensitivity investigation, the highway engineer must identify alternative alinements that should be evaluated in multidisciplinary cooperation with regard to relatively low conflict corridors. By comparing the alternatives, the results must be presented on the basis of numerous elaboration steps (*5*); the most important ones are as follows:

- Evaluating the advantages and disadvantages of the alternatives,

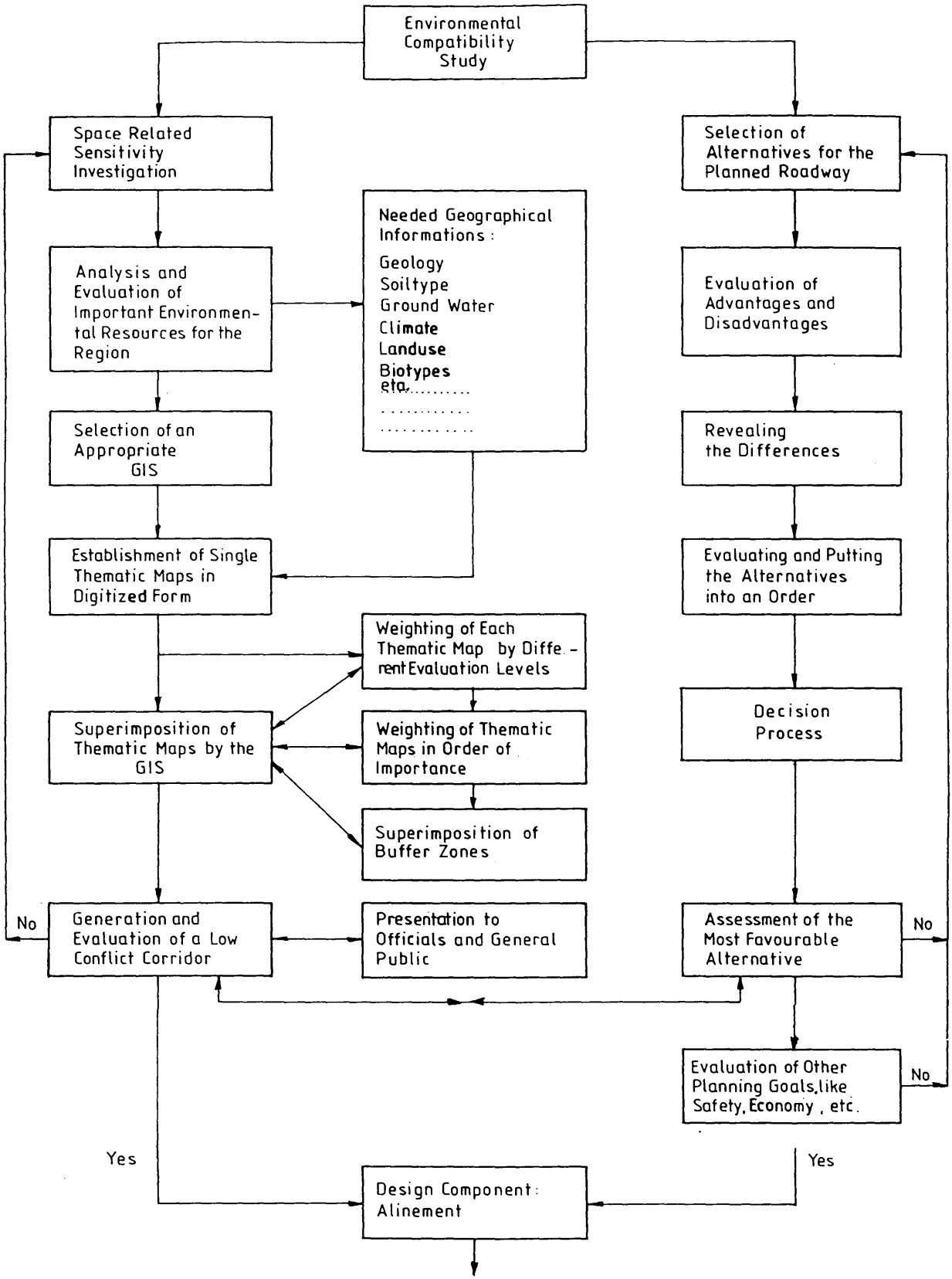

FIGURE 2 Flowchart for the design component: environmental compatibility study.

- Revealing the differences, and
- Evaluating the alternatives and putting them into order from the position of environmental compatibility to reach a sensible decision.

For a better understanding of the individual steps that are involved in an ECS, the flow chart in Figure 2 was developed. On the left side, the impact of the space-related sensitivity investigation is presented, whereas the right side reveals the selection of alternatives for the planned roadway. As can be seen, other important planning goals, such as safety, aesthetics, and costs, are also evaluated in connection with the assessment of the most favorable alternative.

Geographic information systems (GISs) are recommended in the *Instructural Guide for the Environmental Compatibility Study in Highway Planning* (ECS) (*6*) for conducting the sensitivity investigation. The following simplified case study reveals the application of a GIS for generating a low-conflict corridor for one alternative alinement.

CASE STUDY FOR THE DEVELOPMENT OF A LOW-CONFLICT CORRIDOR

In the varied and intensively used cultural landscape of western Europe, the sensitivity investigation will identify few areas free of conflicts that would allow for the design of new highways. Rather, a pattern will emerge in which conflicts from competing important environmental goals vary from area to area, with some areas having more impacts (conflicts) than others.

To develop a low-conflict corridor, it is necessary to search one's way through all of the conflicting environmental concerns to find those areas where environmental concerns are limited. A low-conflict corridor is an area with a relatively low level of need for environmental protection, minor environmental meaning, and a low level of environmental sensitivity where a highway between goals A and B can be designed (*5,6*); that is, it is the corridor in which a highway would have the least environmental impact.

In the center of the case study area stands the town of Staufen im Breisgau, which is in southwestern Germany, near the French and Swiss borders. The town is in a scenic and commercially rich region. The historical town center, with its medieval half-timbered houses and attractive old vineyards in the surrounding area, attracts thousands of tourists each year. The Black Forest, with its rich biotypes, is in the vicinity.

Increasing numbers of tourists and the growing economy during the past two decades have caused an enormous increase in through traffic in Staufen, with an increase in both accident frequency and severity. An important state route (SR 123) leads directly through the residential, shopping, and commercial areas of the town. Therefore, the federal, state, and municipal agencies have decided to provide a bypass around Staufen to alleviate the critical traffic conditions and safety problems.

In-depth environmental studies are required for attractive and environmentally sensitive regions like the Staufen area. To understand the important environmental impacts of the planned bypass, data bases in the form of thematic maps were developed by experts. In this connection it was found that the protection of the following environmental elements is of specific importance for the Staufen region and would need to be examined by an ECS before the acutal design and construction phases of the bypass could begin. The environmental elements to be investigated in the space-related sensitivity investigation of the ECS for the Staufen region are

1. Groundwater potential,
2. Climate,
3. Biotype distribution,
4. Land use, and
5. Recreational value.

The following environmental issues were not regarded in detail in the case study:

1. Landscape (politicians decided to avoid negative impacts on the Black Forest region east of Staufen because of its areas of natural beauty, wildlife, and recreational significance that had to be conserved; therefore, the plain adjacent to the Rhine River was the sole planning alternative);
2. Geology and soil type (in the planning area, similar strata and soil types are present; thus, the impacts of geology and soil type could be excluded from further analysis);
3. Noise (from the beginning it was decided to provide as much distance as possible between the planned bypass and residential and recreational areas and to protect the areas that would be affected by using noise protection barriers; therefore, the impact of noise was not shown on a thematic map); and
4. Others (no more relevant issues were found by the multidisciplinary team of experts studying the natural resources of the Staufen region).

To protect the first five environmental resources discussed above, thematic maps were used to decide whether specific areas are suitable for the bypass (see Figures 3 to 7). The thematic maps were developed by AKG Software Consulting, Ballrechten-Dottingen, Germany.

Regarding the time and costs required to establish the thematic maps, it should be mentioned that in Germany the time period between the stages of basic planning and approval of the plan assessment (Figure 1) is usually at least 5 years because of the complex and complicated legal procedures. In the present case study, about 1 year was needed for the basic elaboration of the thematic maps without considering the additional time that was lost for detailed analyses during the planning processes; these detailed analyses were necessary because of public and private protests. The costs up to this point can be estimated to be about 50 percent of the planning costs to this point. No indications of the portion of the overall project costs can be given, because the project has not been completed.

The data bases represented by the thematic maps in Figures 3 to 7 contain current conditions as well as future conditions concerning new residential, commercial, and recreational developments, as far as they were known during the elaboration phases.

Because geographical information based on thematic maps was available for the present study, a GIS (*10–13*) appeared to be the most suitable procedure for analyzing the complex relationships. A Canadian program known as SPANS (*14–16*) was used in the study to search for a low-conflict corridor on the basis of the five thematic maps shown in Figures 3 to 7. The benefit of SPANS is that data of different formats and from different origins can be read, analyzed, and displayed together. Normally, the thematic maps originated by a GIS are differentiated by discriminating col-

ors. This was not possible here, so discriminating hatchings were used to present the results; these may sometimes be of lesser quality than color graphical presentations.

Thematic Maps: Groundwater Potential

The thematic map of the groundwater potential is shown in Figure 3. Discriminating hatchings are used to differentiate three main groundwater levels: low, medium, and high. If the level is low, the risk of fast and uncontrolled flow of pollutants is low. On the contrary, if expressways with high traffic loads (like the bypass in the Staufen region) are planned in areas with high groundwater levels or permeable soils, they might pose a great source of danger for the environment. Traffic accidents involving tanker trucks or other high-risk transports can happen any time and could threaten the groundwater resources because of pollution.

Therefore, the groundwater level must be regarded as an important issue for the sensitivity investigation. Areas with high groundwater levels and short distances to local drainage systems should be avoided, if possible, when planning a new highway (in this case, a four-lane divided bypass).

In connection with groundwater levels, the presence of permeable or impermeable soils is also of great importance. For example, in the case of an accident, impermeable polluted soils can be dug out to prevent groundwater pollution. Because in the Staufen region the soils are comparable and mainly impermeable, it was not necessary to include in this study the thematic map for soils.

In conclusion, high-volume roads should not be planned in areas with high groundwater levels or permeable soils (Figure 3).

Thematic Map: Climate

Thematic maps of climate may include temperature, weather, and humidity conditions as well as wind speeds and directions. Because the region to be investigated is relatively limited, significant changes related to the first three issues are not to be expected. However because of the climatic condition caused by the nearby Black Forest Mountains going over the Staufen area into the River Rhine Valley, wind speed and direction play important roles. Therefore, the thematic map of wind conditions was established and is presented in Figure 4.

For example, alterations in the morphological contours of the landscape created by building highways and railroads—elevated or depressed, including the corresponding structures—can affect local wind systems significantly. In addition, cutting down parts of forests for traffic routes could lead to wind speeds up to four times greater than those before the forests were cut. Local experts have shown that the newly planned bypass will not cause these types of major impacts in the Staufen region. Wind speed and direction, however, are always important issues in connection with every major road being planned.

The local wind speeds are arranged on the thematic map of Figure 4 and are again differentiated by three levels (high, medium, low). The main wind direction is shown by arrows. In many cases the emission concentration depends strongly on weather conditions. In particular unfavorable circumstances exist for wind calm and inversion situations. Therefore, for the same amount of emission there can exist emission concentrations that differ by a factor of 5. (The Greek capital Athens is a typical example of a location that often has extreme emission loads.)

Considering the planned bypass project, it is important that the wind force is sufficient to blow away and disperse the exhaust emissions, which mainly consist of health-damaging substances (carbon monoxide, hydrocarbons, and nitrogen monoxide from gasoline engines as well as soot particles from diesel engines). Alternatively, the main wind direction should not flow from the highway corridor to residential or recreational areas.

In conclusion, in planning the locations of high-volume roads, sufficient wind speed and the main wind direction are of great importance (Figure 4).

Thematic Map: Biotype Distribution

Biotypes are the natural areas where protected species live. These areas are very important for the ecological balance of a region.

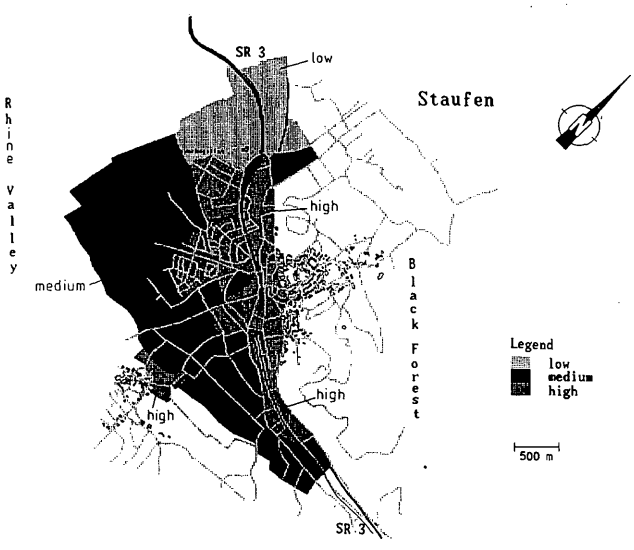

FIGURE 3 Groundwater potential.

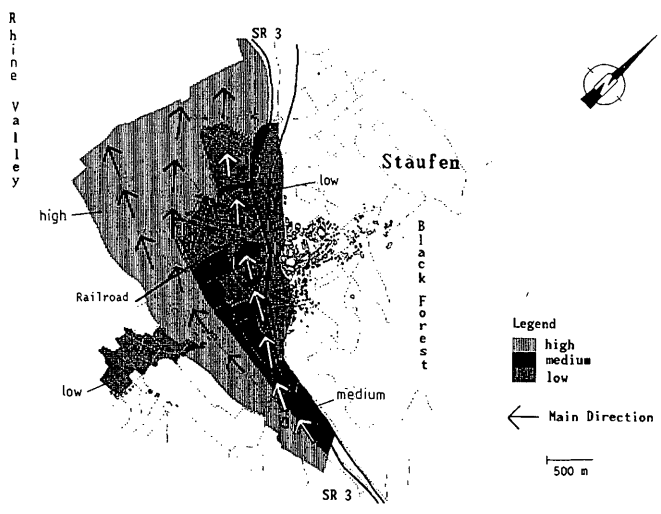

FIGURE 4 Climate (wind speed).

Biotypes include the fauna (biotypes of animals) and flora (biotypes of plants) of the observed area.

The thematic map of the biotype distribution is shown in Figure 5. The necessary data were developed and provided by a local biological expert. Again, the map is differentiated into three levels by using discriminating hatchings. *High* means conservation areas with natural beauty and wildlife: in the present case, mostly river, brook, and pond areas, parks and gardens, as well as the Black Forest region at the northeast side of Staufen. For this case study *low* means relatively invaluable agricultural and commercial land.

In conclusion, the distances between the planned bypass and important biotype areas should be as great as possible (Figure 5).

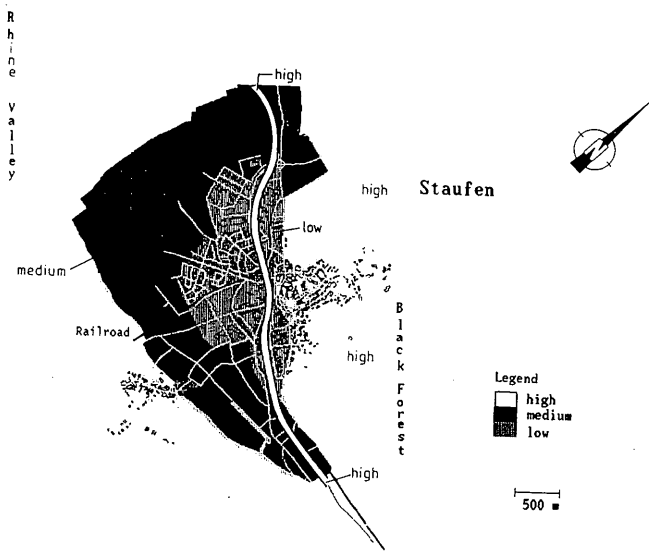

FIGURE 5 Biotype distribution.

Thematic Map: Land Use

The land use of the Staufen region is shown in the thematic map in Figure 6. As can be seen, the land use is subdivided into residential and shopping areas, commercial, and agricultural areas and green land. Politicians and local groups requested that residential and shopping areas be protected by all means.

In conclusion, for the planned bypass, agricultural and green lands as well as commercial lands can be used.

Thematic Map: Recreational Value

According to the thematic map in Figure 7, the recreational value of the area concerned can be evaluated. The map in Figure 7 was based on a poll conducted in the Staufen region in 1990. Thus, the results presented in the thematic map in Figure 7 express the opinions of Staufen citizens, visitors, and tourists.

In conclusion, only areas with mainly low levels of recreational value should be used for the planned bypass project.

Other Thematic Maps

For other planning projects, additional thematic maps are certainly of importance (*5,6*). The environmental impacts are so complex that every project usually requires a modified selection of thematic maps for conducting environmental compatibility studies in highway planning. This, however, does not change the fundamental procedure of the ECS in searching for a relatively low conflict corridor by using GISs for superimposing project-specific thematic maps, as discussed below.

Superimposition of Thematic Maps and Buffer Zones

On the basis of the five thematic maps that were developed, the space-related sensitivity investigation of the ECS will be per-

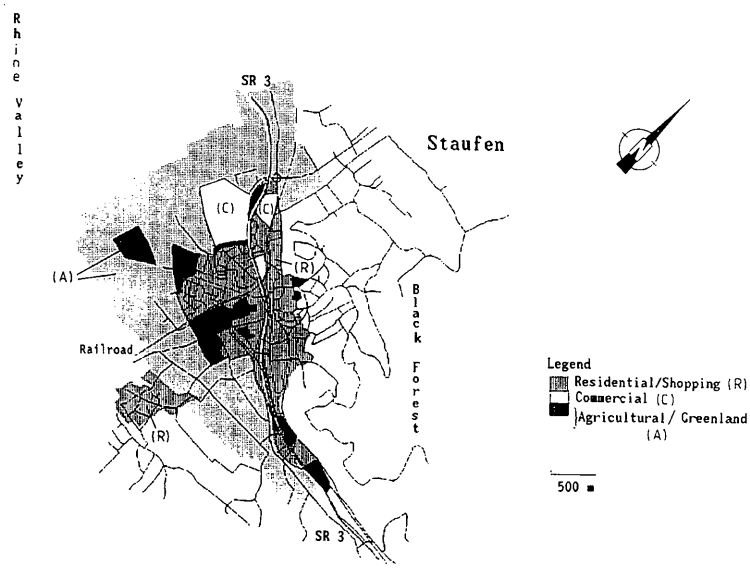

FIGURE 6 Land use.

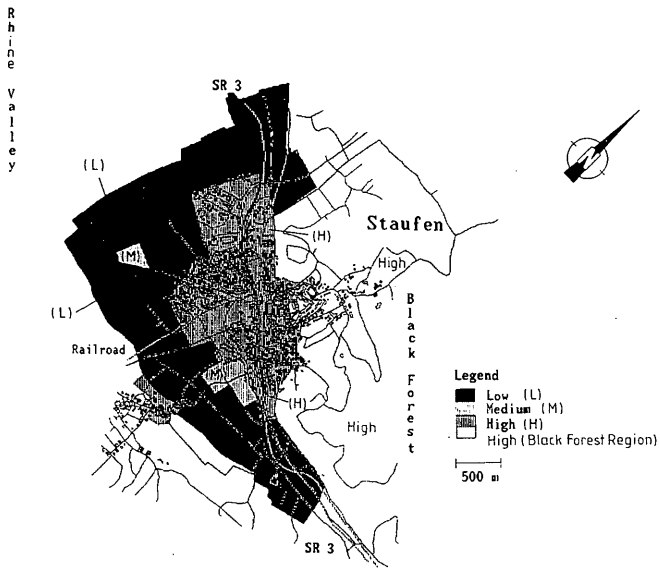

FIGURE 7 Recreational value.

formed for the planned bypass of Staufen. The analysis is done by the superimposition of the thematic maps (Figures 3 to 7) by using a computer-supported GIS examination procedure. The Canadian program SPANS (*14–16*) was used in the study. The thematic maps are available in the computer in digitized form and are therefore usable directly for the calculation processes provided in SPANS. The different layers (thematic maps) of such a map superimposition should contain all important data of the observed region to differentiate protection-worthy and less valuable areas (normally distinguished by the levels low, medium, and high). These evaluation levels, based on digitized map information, can be described on the personal computer screen or a printout by using discriminating colors or hatchings (Figures 3 to 7).

One great advantage of this method of analysis is that computer-supported GISs have the ability of calculating a weighted examination of the different superimposed digitized thematic maps. *Weighted examination* means calculation of the data from the thematic maps to create a new map that includes all relevant results of the superimposition process.

In actual practice, the weighting process is a two-step process, according to Figure 2. First, each thematic map is analyzed by the study team and subdivided into areas of similar environmental impacts. An evaluation level (for example, low, medium, or high) is then assigned to each area. The GIS allows the user to assign a weight to each evaluation level of a thematic map. In the present case study, the first step of Figure 2 "weighting of each thematic map" was performed by weighting the advantageous evaluation level by the factor 3, the medium level by the factor 2, and the disadvantageous evaluation level by the factor 1.

This information is entered into the GIS. The study team could also have selected numerous other factors by this procedure.

Next, the GIS can be applied to superimpose the thematic maps on each other in order of importance. This order is decided by the study team and reflects the importance of local conditions. SPANS allows this to be done sequentially. For this case study, the second step of Figure 2, weighting of thematic maps in order of importance, was performed in the following way. The most important environmentally justified issue was the groundwater potential; this was followed by the thematic maps for wind speed and direction, biotype distribution, land use, and recreational value.

According to two decision criteria, order of evaluation levels within each single thematic map and sequence of the thematic maps between each other, the computer-supported calculation procedure of SPANS generates an overall map of the results. On the basis of the results shown in the composite map, areas of different levels of environmental impact can be identified (Figure 8). By identifying the areas with environmental sensitivity, the suitability for a low-conflict corridor or corridors can be established for one or more alternatives for the planned bypass. (That means, according to Figure 8, a relatively high level of suitability should be present in the corridor.)

In addition, distance buffers around the corresponding alternatives can be superimposed on the new area-specific map. The distance buffers are provided in steps of 50 m. Thus, distance requirements can be examined by assessments such as the following:

- The new highway should pass no closer than 250 m to residential or recreational areas, or
- The distance between the bypass and a protection-worthy biotype should be at least 100 m.

Of course, the input of any other local distance requirement is possible. Those distance arrangements can be solved clearly and quickly by a GIS.

By assigning weights to the different evaluation levels of thematic maps in a reasonable order, by superimposing the thematic maps in a desired sequence, and by introducing distance buffers, a relatively low conflict corridor with lateral buffer zones could be established for the planned bypass in the Staufen region, according to Figure 8.

The overall width of the buffer zones for the established corridor covers 500 m, 250 m at each side of the axis of the planned bypass. By comparing the results of Figure 8 with the evaluation levels in Figures 3 to 7, it can be concluded that the corridor, developed by the computer-supported GIS examination procedure, excludes at least high-conflict areas.

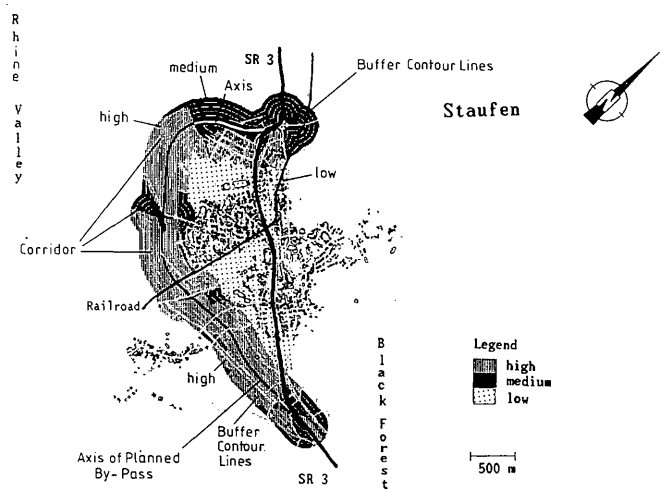

FIGURE 8 Suitability for the low-conflict corridor.

Results like those in Figure 8 will help federal, state, and municipal officials make unbiased and factually correct decisions regarding the protection worthiness of the environmental issues that are being discussed.

In addition, according to Figure 2 (right side), the ECS requires a comparison of alternatives. For the bypass around Staufen, three alternatives were investigated. The relatively low-conflict corridor shown in Figure 8 proved to be the most favorable one for the planned four-lane divided bypass according to the three sensitivity investigations conducted for the different alternatives. The evaluation must also include other important goals, aesthetics, economy, function, safety, and traffic quality. These important goals must always be kept in mind in parallel with the development of the new design component ECS (compare Figures 1 and 2).

Because the corridor lies in the plain of the Rhine River Valley, longitudinal slopes are low and considerations of vertical alinement are of minor importance. Thus, the low-conflict corridor first identified serves the placement of the horizontal alinement.

Finally, two questions should be answered. These questions mostly appear when discussing or presenting the results of an ECS:

1. Do there exist cost and time comparisons between existing methods of developing an ECS and those using a GIS? The only answer can be as follows: if an appropriate GIS is available, the cost and time factors will be reduced considerably because of the automatic weighting and evaluation processes performed on the basis of quantitative criteria (expressed, for example, by thematic maps). Only a few aspects of an ECS could be dealt with manually, if at all, and only qualitative results could be expected. A cost and time estimation would lead to speculation because of the numerous different relationships and interrelationships that would influence a specific project.
2. Would the GIS data base approach change the location of a planned highway over the location that might have been selected by engineers who may have been provided similar information but without the graphical analysis tools? The only answer can be probably not. However a question remains: How would the engineer be provided those complex pieces of information without the graphical analysis tools of a GIS?

CONCLUSION AND OUTLOOK

The design flow in modern highway geometric design guidelines with special emphasis on environmental protection issues was discussed in relation to the corresponding interfaces to other design components and legal demands.

Because most western European governments have enacted ECE laws, a new design component called ECS must be regarded in future highway geometric design guidelines.

ECS consists of two parts: (a) space-related sensitivity investigation and (b) comparison of alternatives.

ECE and the ECS already present an integrated procedure in road planning and design. With increasing planning accuracy, an increasing level of verification of environmental issues takes place.

An essential part of the ECS, the sensitivity investigation, must include all relevant functions of the environment with regard to areas worthy of protection, areas with specific sensitivities, and existing and planned land uses. GISs are recommended for use in conducting those studies. The goal of every ECS is to identify the highway corridor and the highway alternative that together have the least environmental impact on the region. A second part is concerned with the selection of alternatives for the planned roadway.

A case study involving a sensitivity investigation with thematic maps based on digitized geographical information was presented. The thematic maps were developed to portray important environmental resources, such as groundwater potential, climate, biotype distribution, and land use. By using a computer-supported GIS examination procedure, the thematic maps were superimposed, weighted, and evaluated to develop a new map. The new map, which now represents those environmental resources on a single map, is used to identify the low-conflict corridor (the corridor that minimizes environmental concerns) in the investigated region.

One important consequence of the present study is that in highway geometric design an ECS must be conducted before starting any predesign, design, or even construction phase of a project. Examination of the other important planning goals takes place after the assessment of the most favorable alternative by the ECS. The case study revealed in this way how protection-worthy areas can be left intact, and future highways can be placed in those areas for which it is less important to maintain the integrity of the region being examined. Finally, such a procedure saves money and time in the complex highway geometric design process, because only those alternatives for which mainly low-conflict areas are available and their corresponding alinements must be considered. Normally, there are only a few such areas. Thus, the optimum solution is a product of the ECS, which is conducted at the beginning of the planning process.

Incorporation of the previous concepts about the new ECS design component into a computerized GIS format is a significant step forward in accomplishing such work and in helping to present it to the public for clearer understanding, and it will probably contribute toward general public acceptance and approval.

It is recommended that future editions of the Green Book include material on the new ECS design component.

ACKNOWLEDGMENT

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