INTEGRATING CASE BASED REASONING AND GEOGRAPHIC INFORMATION SYSTEMS IN A PLANNING SUPPORT SYSTEM: ÇESME PENINSULA STUDY

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ABSTRACT

INTEGRATING CASE BASED REASONING AND GEOGRAPHIC INFORMATION SYSTEMS IN A PLANNING SUPPORT SYSTEM: ÇESME PENINSULA STUDY

Urban and regional planning is experiencing fundamental changes on the use of computer-based models in planning practice and education. However, with this increased use, "Geographic Information Systems" (GIS) or "Computer Aided Design" (CAD) alone cannot serve all of the needs of planning. Computational approaches should be modified to deal better with the imperatives of contemporary planning by using artificial intelligence techniques in city planning process.

The main aim of this study is to develop an integrated "Planning Support System" (PSS) tool for supporting the planning process. In this research, "Case Based Reasoning" (CBR) –an artificial intelligence technique- and "Geographic Information Systems" (GIS) –geographic analysis, data management and visualization technique- are used as a major PSS tools to build a "Case Based System" (CBS) for knowledge representation on an operational study. Other targets of the research are to discuss the benefits of CBR method in city planning domain and to demonstrate the feasibility and usefulness of this technique in a PSS. "Çeşme Peninsula" case study which applied under the desired methodology is presented as an experimental and operational stage of the thesis.

This dissertation tried to find out whether an integrated model which employing CBR&GIS could support human decision making in a city planning task. While the CBS model met many of predefined goals of the thesis, both advantages and limitations have been realized from findings when applied to the complex domain such as city planning.

ÖZET

VAKA TEMELLİ MANTIK YÜRÜTME VE COĞRAFİ BİLGİ SİSTEMLERİNİN PLANLAMA DESTEK SİSTEMİ BÜTÜNÜNDE ENTEGRASYONU: ÇEŞME YARIMADASI ÇALIŞMASI

Şehir ve bölge planlama, bilgisayar destekli modellerin planlama pratiğinde ve eğitiminde kullanımında önemli değişiklikler yaşamaktadır. Fakat kullanımlarındaki artış oranına rağmen, "Coğrafi Bilgi Sistemleri" ve "Bilgisayar Destekli Tasarım" kendi başlarına planlamanın ihtiyaçlarını tam olarak karşılayamamaktadır. Bilgisayara dayalı yaklaşımlar, yapay zeka tekniklerinin şehir planlama sürecinde kullanımıyla, çağdaş planlamanın gerekliliklerini karşılayacak biçimde düzenlenmelidir.

Bu çalışmanın temel amacı, şehir planlama sürecini destekleyecek entegre bir "Planlama Destek Sistemleri" modeli geliştirmektir. Bu kapsamda, bir yapay zeka tekniği olan "Vaka Temelli Mantık Yürütme" tekniği ve coğrafi analizler, veri yönetimi ve ilgili gösterimler için kullanılan "Coğrafi Bilgi Sistemleri", "Vakaya Dayalı Sistem" modeli kurma aşamasında, temel planlama destek sistemi araçları olarak seçilmiştir. Araştırmanın diğer hedefleri ise vaka temelli mantık yürütme tekniğinin şehir planlama alanına getireceği faydaları tartışmak ve planlama destek sistemleri içinde uygulanabilir ve kullanılabilir olduğunu göstermektir. "Çeşme Yarımadası" alan çalışmasında ise, yukarıda tariflenen yöntemler ışığında, tezin operasyonel ve deneysel safhası uygulanmaktadır.

Bu tez çalışmasında vaka temelli mantık yürütme ve coğrafi bilgi sistemlerinin entegre olarak kullanıldığı bir model yaklaşımının plancıya, şehir planlama sürecinde, karar verme aşamasında yardımcı olup olamadığı denenmiştir. Vakaya dayalı sistem modeli tezin önceden belirlenmiş çoğu hedefini karşılarken, şehir planlama gibi karmaşık bir alana uygulanmasıyla elde edilen bulgular, modelin hem avantajları hem de kısıtlı yönleri olduğunu göstermiştir.

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ABBREVIATIONS

AI: Artificial Intelligence

CAD: Computer Aided Design

CBR: Case Based Reasoning

CBS: Case Based System

DSS: Decision Support Systems

GIS: Geographic Information Systems

GUI: Graphical User Interface

GPS: Global Positioning System

ICTs: Information and Communication Technologies

KBS: Knowledge Based Systems

PSM: Problem Solving Method

PSS: Planning Support Systems

RBR: Rule Based Reasoning

RS: Remote Sensing

SDSS: Spatial Decision Support Systems

VR: Virtual Reality

CHAPTER 1

INTRODUCTION

1.1. Aim of the Study

This study is investigating the usefulness of "integrating planning support system (PSS) tools for supporting the planning process". Hence, this approach consist applying case based reasoning technique (CBR) and geographic information systems (GIS) to provide a planning support for solving spatial problems. Therefore, urban planning discipline could improve its effectiveness by using recent advances in artificial intelligence (AI) techniques and information and communication technologies (ICTs).

In this research, "Case Based Reasoning" technique will be used to build a "Case Based System" (CBS: CBR&GIS) as a major PSS tool. By the development of a system that integrates CBR as an AI reasoner and GIS as a spatial analyst, could be very helpful to planners for reaching a knowledge acquisition on a special purpose in planning process. In such an integrated system, CBR will provide a retrieval method (at least) by using previous experiences in proposing a solution to a new problem or providing relevant experiences to the planners.

Goals of the study are:

- To demonstrate the feasibility and usefulness of CBR technique in PSS tools,
- To combine knowledge inference capability of CBR with analytical, management and visualization capability of GIS within an operational pilot study,
- To examine whether CBR technique and CBS model could benefit the city planning process.

1.2. Main Focus

City planning process is experiencing fundamental changes by emerging impacts of using computer-based models in planning practice and education around the world. However, besides this increased use, it is realized that GIS or CAD alone cannot serve all of the needs of planning.

"The world has changed: Can planning change?" (Castells, 1991). The question of how our computational approaches can be modified to deal better with the imperatives of contemporary planning practice should be considered in this concept. Because the real world is constantly changing, planning must be concerned with this continual change (Chadwick, 1971). In this manner if there will be a re-orientation in planning process, city planners must demonstrate both theoretically and practically what is possible now and what may be possible in the future to cope with continuous change.

Main hypothesis of this dissertation is: "Information of previous cases could be used to solve new ones by a reasoning and spatial model approach in city planning process". Thus there are several research questions taken into consideration:

1. What are the features of current computer based planning models?
2. How can we use/integrate CBR technique as a PSS tool in city planning process?
3. What we desire to see in our model? And how?

1.3. Methodology: Intersection of City Planning, Artificial Intelligence and Information Technology

Methodological aspects of the study are structured into five parts:

- A review of the structural concepts of PSS&CBR and citing arguments from these findings,
- Examining the PSS tools, CBR techniques, RBR techniques and related software packages of spatial analysis, modeling, visualization and planning issues and their conceptual ideas. Explanation the need for CBR as promising approach of PSS and also for city planning domain,
- Developing a CBS model (CBR&GIS): Explaining the features, components and steps of this proposed approach and application and evaluation of the model.
- Evaluations and concluding comments about this proposed approach and its findings.

Background of the research and conceptual basis is presented in Figure 1.1 below:

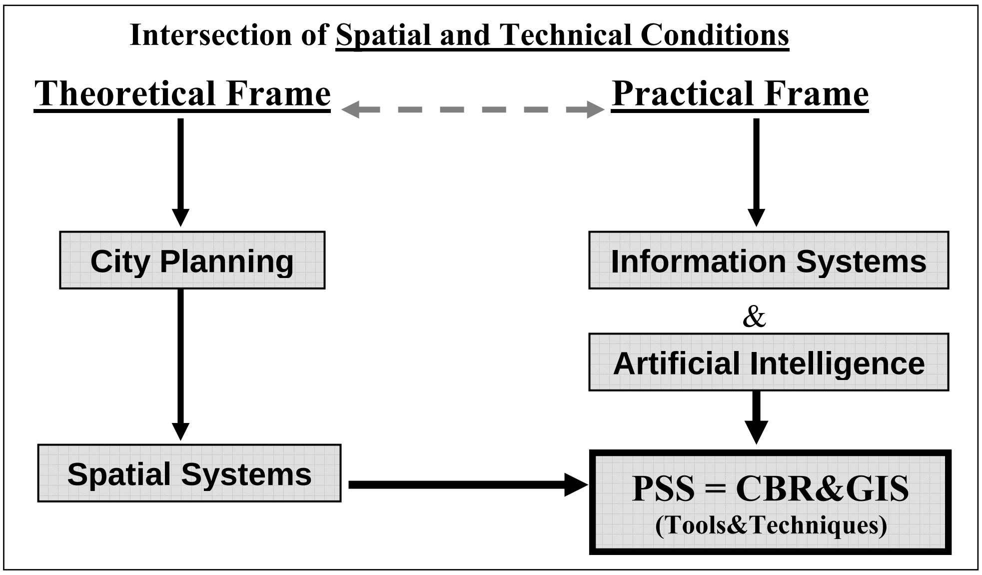


Figure 1.1. Background of the research: Integrating PSS in planning process

This conceptual framework above tries to outline how we can use PSS, - technologies that are driving planning (Batty, 2003) - in city planning process. Under the "PSS framework", this study will present "planning support" by allowing more intelligent modeling systems "CBR technique" and "GIS" in city planning domain.

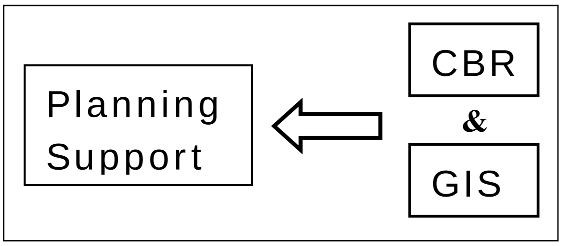


Figure1.2. Main aim of the research

In preparing the conceptual background, aim is not to make an analytical approach on terminology or to find final solutions, concepts and critical debates about PSS and CBR have been tried to understand properly from reviews. Detailed reviews of PSS, AI and ICTs and making comparative analysis are out of the scope of the study. Additionally this dissertation is not totally based on descriptive context. An operational case study is provided for comprehending the aims of research. However, to make a physical plan or to reach exact solutions to real problems are not intended.

There is lack of empirical PSS studies in Turkish city planning domain. One major contribution of this dissertation will be to fulfill a knowledge gap and awareness generally with PSS but especially with CBR&GIS integration locally. This dissertation is trying to differ from other studies by integrating CBR and GIS for providing a geo-spatial planning support in Turkish city planning practice through a practical example (see Chapter 4: Çeşme Peninsula Study). The proposed experimental system will try to process tabular data and link the inference to spatial data.

The real aim of the study is to improve the effectiveness of spatial decision support by applying these techniques to planning practice. A working scheme for the study is presented to check whether research aims, main questions and assumptions are reasonable.

Table 1.1. Thesis working scheme-Analytical framework

Content	Reasoning & Notes	Method or Technique
Main Focus and Statement: • Advances in ICTs&AI have transformed technique, space and even daily life. Thus, perceiving the new form of space and to plan the future cities, we must redefine our methods and set new planning tools and techniques. • Urban and regional planning is experiencing fundamental changes that are having an impact on the use of computer-based models in planning practice and education. However, with this increased use, there is still a knowledge gap in ICT/AI and city planning relationship.	• To be verified by citing arguments from literature. • Lack of empirical cases.	• Examining the advances in ICTs & AI. • Understanding the content of computer based planning. • Understanding the attitude of planners.
Thesis Aim : • To integrate the PSS tools for supporting the planning process. • CBR & GIS are used to develop a model. • To provide a planning support by knowledge retrieval and inference	• To be supported and proved by theoretical and practical basis.	• Figure 1.1 • CBR • GIS • Case Study
Assumptions, Scope: • GIS or CAD alone cannot serve all of the needs of planning. • Computational approaches can be modified to deal better with the imperatives of contemporary planning practice, hence more intelligent models needed. • Information of previous cases can be used to support the solution of new ones.	• A hybrid system is needed to reach knowledge inference &planning support.	• Examining the existing and developing structure and models of computer based planning.

Methodology and Conceptual Basis
How can we use CBR&GIS as an integrated model in city planning process?
• Literature review on the PSS&CBR studies.
  o What are the recent cases in the world?
  o What are the recent cases in Turkey?
• Developing the desired model on a pilot project
  o Usage and calibration of CBR software tool
  o Integration of CBS (CBR&GIS) model
• To query whether these models benefit the planning process.
	• PSS should be an integral part of the planning process.
	• What we desire to see in our model?
	• How?
		• Figure 1.3
		• Literature review.
		• Examination of tools and techniques of PSS&CBR
		• Case study
		• Evaluation of findings

1.4. Structure of the Thesis

Within the broad field of spatial and information technology and artificial intelligence concepts, there are focused components which must be clarified. Therefore, the rest of the thesis is organized as follows (see Figure 1.3). Chapter 2 and 3 presents a literature review of related work on PSS and CBR. PSS: a general framework for all computer based approaches in spatial and planning issues is presented in Chapter 2. A brief introduction to CBR technique, model development and establishing hybrid spatial systems such as CBR+GIS concepts are introduced in Chapter 3. In Chapter 4, “Çeşme Peninsula” case study illustrates the use of CBR&GIS in city planning through a practical example. By this pilot project, an evaluation framework for implementation success and failure is tested and findings are discussed. In the final 5th Chapter, the concluding remarks of CBS model approach and evaluation of case study research findings are underlined. Moreover, the benefits, contributions and deficiencies/limitations of using CBS model in urban planning discipline are discussed. Chapter 5 also presents the recommendations for further studies.

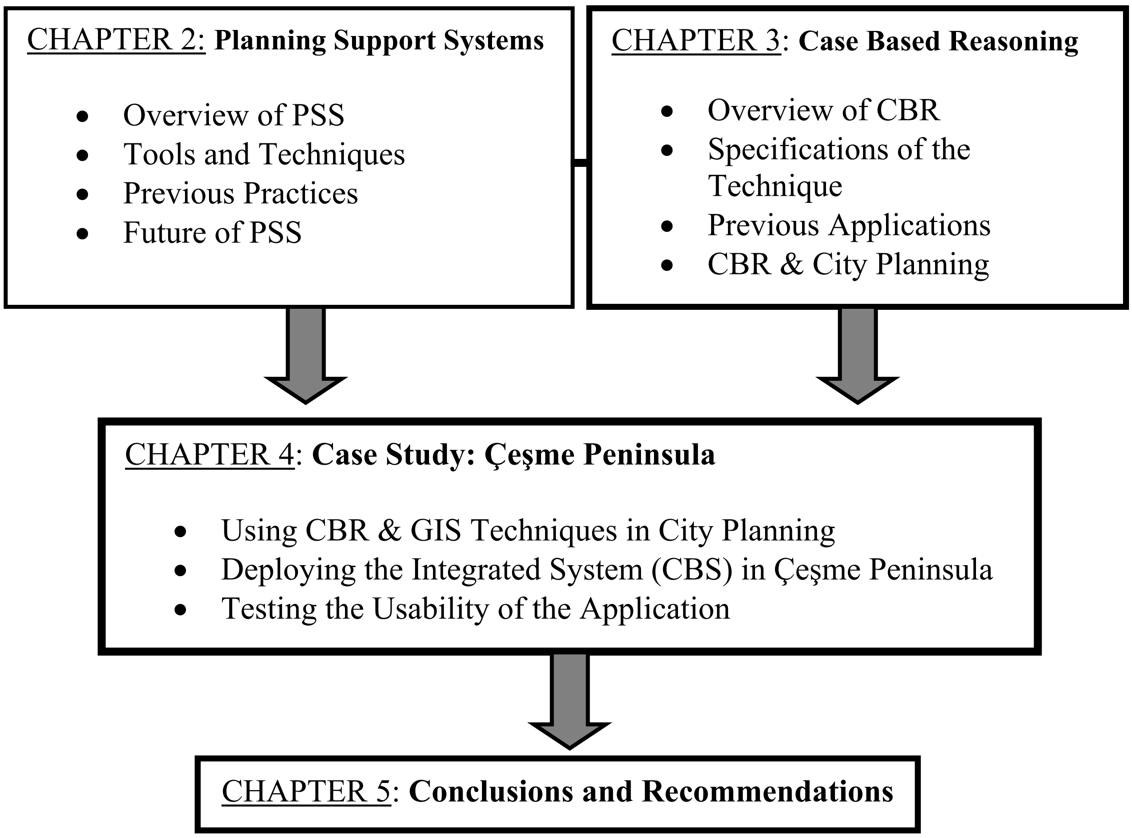


Figure1.3. Outline of the Thesis

CHAPTER 2

PLANNING SUPPORT SYSTEMS

In this chapter of the study, literature review has been realized to examine the existing structure and models of Planning Support Systems (PSS). Studies that consider the concrete and practical issues on PSS have been searched. Therefore, main structure of the PSS has been clarified by citing arguments from literature.

Some of these recent studies are about hardware and software trends. These studies tried to explore emerging trends in the broad field of spatial technology. While hardware developments open up potentials, it is the software which eventually gives the planner access to the technology.

Most of recent studies on PSS have tried to demonstrate the achievement of the PSS development goal: combining information (stored in the GIS or in database manager) with models (provided by several reasoning techniques) and visualization (provided in map, tabular, graphic forms and other spatial multimedia) to support planning practice. Several definitions have been proposed about the PSS (also about tools and techniques) in the literature including, in chronological order:

1. The PSS term first used as *"constellation of digital techniques (such as GIS) which were emerging to support the planning process"* (Harris, 1989; Batty, 2003, p.v),
2. Klosterman (1997, p.51) views PSS as *"an information framework that integrates the full range of current and future information technologies useful for planning''*,
3. Geertman and Stillwell who propose that PSS *"involve a wide diversity of geo-technology tools that have been developed to support public or private planning processes at any defined spatial scale and within any specific planning context"* (Geertman & Stillwell, 2003, p.5), and most recently,
4. Brail who defines them as *"planning decision support systems that have as their purpose either projection to some point in the future or estimation of impacts from some form of development"* (Brail, 2005).

Planning Support Systems (PSS) are tools that have been developed and are being used to support public or private sector planning activities at any spatial scale. In fact, up till now there is no widespread accepted definition of PSS. As a working definition, we could define PSS as geo-technology related instruments consisting of theories, information, methods and tools for supporting the professional planning tasks (Geertman, 2002).

According to Geertman&Stillwell classification, PSS studies could be presented by two main groups: a) systems dedicated to planners' analytic, forecasting or design tasks and b) systems designed to improve their presentation and/or communication (Geertman and Stillwell, 2003). The classification table presented below (see Table 2.1) considers fourteen (available/recorded) PSS analysis, forecasting, reasoning and visualization tools that are described in the collections prepared by Brail and Klosterman (2001) - "PLANNING SUPPORT SYSTEMS: Integrating Geographic Systems, Models, and Visualization Tools" and Geertman and Stillwell (2003)- "PLANNING SUPPORT SYSTEMS in PRACTICE". There are also substantial amount of academic interest still growing about PSS.

The models could be categorized by two dimensions: 1. Technique, the modeling approach that was used to develop the PSS and 2. Task, the analytic task which the PSS helps address. The five sample modeling techniques listed in Table 2.1 by the order in which they were first applied to planning: large-scale urban models, rule-based models, state-change models, case based models and cellular automata models (Klosterman & Pettit, 2005).

Table 2.1. Categorization of recent PSS applications
(Source: Klosterman & Pettit, 2005)

PSS	**TASKS**				
TECHNIQUES	***Land-Use/ Land-Cover Change***	***Comprehensive Projection***	***Impact Assessment***	***3D Visualization***	***Knowledge Representation***
Large Scale Urban Analysis	*METROPILUS*	*METROPILUS*	-	-	-
	SPARTACUS	*SPARTACUS*			
	TRANUS	*TRANUS*			
	UrbanSim	*UrbanSim*			
Rule Based Systems	*CUF*	*What If*	*Community VIZ*	*Community VIZ*	-
	What If			*INDEX*	
				Place^3 S	
Case Based Systems	*GIS b CBS*	-	-	-	*GIS b CBS*
State Change Analysis	*CUF II*	-	-	-	-
	CURBA				
Cellular Automata	*SLEUTH*	-	-	-	-
	DUEM				

2.1. An Overview of Planning Support Systems

2.1.1. What is Planning Support?

Increases in capacity, speed and continually lower cost of computer equipment (hardware), development of specialized application software packages, new opportunities in data availability and unlimited communication&sharing via internet generate a new excitement in the world of computer based planning. "*This realization has renewed planners' interest in computer modeling and stimulated the development of PSS which combine GIS and non-GIS data, computer based models and advanced visualization techniques into integrated systems to support core planning functions such as analysis, plan preparation and evaluation*" (Klosterman, 1999b, p.393). These subset of geo-information technologies, dedicated to support planning process to explore, represent, analyze, visualize, predict, prescribe, design, implement, monitor and discuss issues associated with the need to plan (Batty, 1995). According to PSS literature (Geertman & Stillwell, 2003; Brail & Klosterman, 2001; Klosterman & Pettit, 2005; Vonk & Geertman, 2007), PSS is capable of improving the handling of knowledge and information in coping with complexity of planning tasks and also planning process.

2.1.2. What is System?

System: An assemblage of objects arranged in regular subordination, or after some distinct method, usually logical or scientific; a complete whole of objects related by some common law, principle, or end; a complete exhibition of essential principles or facts, arranged in a rational dependence or connection; a regular union of principles or parts forming one entire thing (Babylon's free dictionary, 2007).

"*Many technologies are already being used -with varying degrees of effectiveness- to support planning processes and provide these outcomes. These technologies are evolving and new technologies are emerging. When one or more technology is adapted to a planning issue it may be referred to by its authors as a PSS. In many cases, however, it is fair to ask 'Where is the System?*" (Bishop, 1998, p.89).

Many planning approach may indeed have an assemblage of things, and they may be complex, but they can not form a unitary whole. To create an ideal planning-specific system without an existing software base would be much harder. Software modules already exist in the form of commercial GIS packages, all manner of static and dynamic models, and emerging visualization systems (Bishop, 1998). Although GIS is capable of data acquisition, manipulation, and display, current GIS softwares should be reinforced by specialized modules and reasoning techniques to be a part of PSS.

2.1.3. Why Integration?

Most geo-information tools do not readily fit the changing needs of the planning profession. PSS are generally regarded as systems in which technologies dedicated to the planning profession are brought together. PSS specifically support the whole of or some part of a unique planning task (Geertman & Stillwell, 2004).

It is reasonable to conclude that, there are increasing opportunities for making the technologies work together more systematically and effectively. Some of the necessary developments for extensive integration of the components are arising from advances in new hardware and software trends. Advances in hardware and software trends give new capabilities for extensive integration in PSS. Meanwhile, in addition to the potential benefits of these new technologies, there are still existing deficiencies/limitations in planning support. The emerging technologies and models try to overcome these shortcomings.

A model in science is a physical, mathematical, or logical representation of a system of entities, phenomena, or processes. Basically a model is a simplified abstract view of the complex reality. Scientific modeling is the process of generating abstract, conceptual, graphical and or mathematical models (Wikipedia, 2009). It is important to emphasize that a model is not the real world but merely a human construct to help us better understand real world systems. For example, the "vector data model" represents geography as collections of points, lines, and polygons in GIS.

The conceptual ideal spatial model for a complex, spatially diverse environment (such as a city) may include:

1. The data storage, analysis and mapping capabilities of GIS,
2. The availability of purpose-built decision support models or procedures (several AI/reasoning techniques) and
3. Realistic, real-time, interactive visualization of the impact of decisions (partly within GIS and partly by developing customized GUI).

All these components should work together with seamless integration for efficiency. Together these create a continuum of support linking the real world to final decisions. From the world we draw data, from data we develop information, conceptual and computer-based models, and these aid our understanding & evaluation processes which support our decisions. All stages are supported to some degree by developments in visualization (Bishop, 1998).

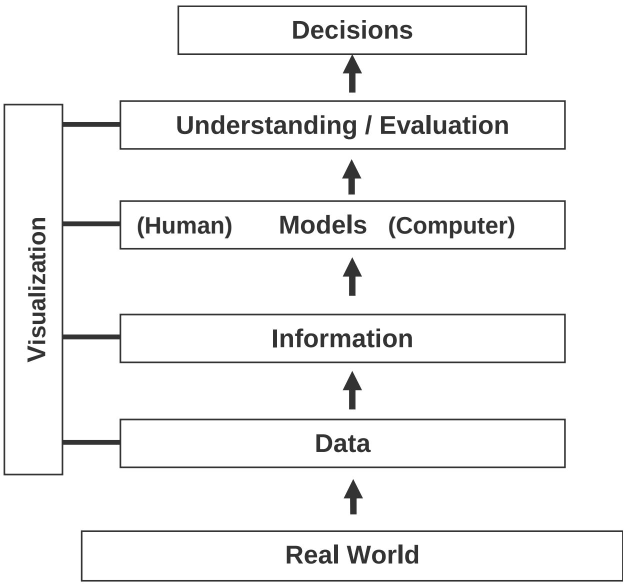


Figure 2.1. Spatial model: Abstraction of real world to decisions
(Source: Bishop, 1998)

2.2. Development of Planning Support Systems

In the 21st century, PSS have arrived in concept and in application. Urban planners, policy makers and citizens have the means to visualize alternative futures for cities and regions. PSS began in response to planners' fascination with GIS as a reminder that geographically referenced information and spatial analysis techniques alone cannot adequately support all of the planning (Harris, 1989). PSS models include planners' familiar tools (such as GIS, land allocation models) for conducting analysis, projecting future conditions, modeling spatial interaction and newly emerging artificial intelligence techniques such as artificial neural networks, fuzzy-logic, genetic algorithms, case based reasoning, cellular automata, expert systems, data mining, multi-agent systems, analytic hierarchy process and other reasoning procedures.

Although the term PSS itself is fairly recent, the ideas go back to the 1950s. According to Klosterman (1999a), PSS have matured into a conception of integrated systems of information and software, which brings together the three components of traditional decision support systems: information, models/simulation, and visualization. "*The development of a decision support system is a multifaceted enterprise that is built on four foundations: mathematical theories, theories focusing on the structure and behavior of urban entities, theories of the planning process and the theories of spatial representation*" (Brail & Klosterman, 2001, p.11).

We may read the progression of technology-planning relationship with many intertwined ways. The special emphasize here is that recognizing ICTs and PSS as planning tools in a larger historical perspective and following the paths as parallel to changing debates in planning, technological systems, as well as planner's attitude toward technological systems (Velibeyoğlu, 2004). As demonstrated in the Table 2.2, Klosterman (1997) suggests that, there has already been a parallel progression over the past decades in terms of the planning profession's view of its own role and purpose and in terms of the evolving concerns of information technology.

Table 2.2. Evolving views of planning and information technology
(Source: Klosterman, 1997; Brail & Klosterman, 2001)

Decade	Views of Planning	Concerns of Information Technologies (IT)
1960s	Planning as Applied Science/System Optimization: Information technology is viewed as providing the information needed for a value-neutral and politically-neutral process of "rational planning".	Data: "Observations which have been cleaned, coded, and stored in machine-readable form" Electronic data processing (EDP)
1970s	Planning as Politics/Politics: Information technology is seen as inherently political, reinforcing existing structures of influence, hiding fundamental political choices, and transforming the policy-making process.	Information: "Data which has been organized, analyzed, and summarized into a meaningful form" Management information systems (MIS)
1980s	Planning as Communications/ Discourse: Information technology and the content of planners' technical analyses are seen as often less important than the ways in which planners transmit this information to others.	Knowledge: "Understanding based on information, experience, and study" Decision support systems (DSS)
1990s	Planning as Reasoning Together/Collective Design: Information technology is seen as providing the information infrastructure that facilitates social interaction, interpersonal communication, and debate that attempts to achieve collective goals and deal with common concerns.	Intelligence: "Ability to deal with novel situations and new problems, to apply knowledge acquired from experience, and to use the power of reasoning effectively as a guide to behavior" Planning support systems (PSS)

Klosterman uses this historical timeline in the evolution of planning to specify the needs that planners have when using computer programs; each era in planning history represents a different definition of the main use of planning, and therefore, produces a different set of tasks and tools that are necessary to complete the planning process successfully.

There are reasons why PSS issues are rising timely. First, the rapid evolution of hardware has made it possible to design, construct and test complex computer programs that simulate complex systems such as cities and regions. Interactive environments are powerful and nearly common today and over the early decades of the 21^{st} century, the visualization tools and models presented will become commonplace as fully integrated systems requisite to the urban planning process. Second, there has been a noticeable development in computer software such as 3D visualization/virtual reality software as well as continuing evolution in the analytical capacity of GIS. Third, there is the incredible growth in the availability of data and information resources globally. The rapid growth of an information generating industry has fed on hardware and software developments. There has also been incredible development in satellite imaging, with resolutions as fine as one meter now available (Brail & Klosterman, 2001).

Finally improvement of internet infrastructure rises up the potential for web-based applications and also technical/social group interactions. Professionals, academicians and practitioners use the internet to broadcast and share information and specific resources for collaboration and participation. For instance, web based PSS offers community to visualize the results of alternative planning scenarios over the web and exploring the effects on their quality of life and on their environment as a participative approach.

Briefly, four themes –hardware, software, data and the internet– act as the catalyst to the rapid evolution of PSS (Brail & Klosterman, 2001). It is expected that their use will become widespread in the next decade. Also system needs expert personnel to operate.

Although general structure of PSS is defined above, PSS could be divided into three major sections: information processing/management, modeling/simulation and visualization techniques.

2.3. Geographic Information Processing and Related Technologies

We live in the information age. Much of this information is fragmented and technical, requiring the clustering of specialists to process it. The contemporary interest in ICTs and GIS, continuous the involvement of the planner as a data analyzer and synthesizer of diverse information from socioeconomic, environmental and technical disciplines (Hartshorn et al., 1992).

By the advances in ICTs, the use of these techniques is raising rapidly. The city itself is becoming digital of which urban planning is just part of it. In this integrated cycle, information system is the kernel of all tools and the information society must be based on effective digital communication (Laurini, 2001). Digital planning systems will dominate the planning process, so planners must learn how to use these emerging systems effectively. We can classify the geographic information processing section to two major categories: GIS and GIS related technologies.

2.3.1 GIS

There are several definitions of GIS, but essentially a GIS is a computer-based tool for mapping and analyzing things that exist and events that happen on earth. GIS is regarded as a set of tools for the input, storage and retrieval, manipulation and analysis, and output of both spatial and attribute data and it is unique in its capacity for integration and spatial analysis of various datasets such as land use, population, transportation, infrastructure, network, topography, hydrology, climate, vegetation, etc. in addition, output component of a GIS provides a way to see the generated information in the form of 2D thematic maps, 3D visualizations, tables, diagrams, graphics, etc.

The history of GIS depends on the history of using computers to handle and analyze mapped data. Availability of powerful, low-cost and easy to use GIS tools (both hardware&software) and more extensive spatially referenced data are making GIS an essential tool for planning tasks. It also reflects the dramatically increased quantity and quality of spatially referenced information that is becoming available with the maturation of municipal and regional GIS databases, the incredible growth of the internet and the emergence of new tools and techniques (Klosterman, 1999a).

GIS was a backroom operation reserved for mostly technical staff and used largely for static presentation of data. This role started to change in the 1990s with the introduction of desktop GIS and friendly interfaces of the softwares. Desktop GIS is the traditional software application (designed to run on PC) that is thought of when software is labeled as GIS. Many popular GIS software, such as ArcGIS (ESRI), MapInfo (Pitney Bows), AutoCAD Map (Autodesk), Idrisi (Clark Labs), GeoMedia (Intergraph), Microstation (Bentley Systems), NetCAD (Ulusal Cad ve GIS Çözümleri A.Ş) and TransCAD (Caliper Corporation) have the capability to perform most of the basic operations.

The advent of the internet focused even more public interest on the GIS technology. As a result, new GIS/PSS tools which reshape technology based planning share three common features: accessibility, analysis and action (Allen & Goers, 2002).

- Analysis: The new tools produce much more than colorful maps because GIS technology can now create complex models. Community data can be turned into insightful evaluations of alternative plans and development impacts (e.g. CommunityViz Software, 2005; INDEX Software, 2005).
- Accessibility: GIS technology is increasingly accessible, both to professional planners and practitioners and to citizens. In some cases, tools are showing up at public meetings for real-time use during deliberations (e.g. PlaceMatters, 2005). Additionally, planning and geography departments added GIS lectures to their educational curriculum.
- Action: Perhaps most exciting about these progressing GIS tools (perhaps GIS based PSS tools) is their interactivity and relevance to real world decision support. Users can create scenarios "on-the-fly," get immediate feedback on the implications of their choices, and reach consensus on outcomes much more quickly then before (Allen & Goers, 2002).

The hearth of any PSS will undoubtedly be a GIS. It is necessary to focus on the use of GIS in planning, but only GIS is not equal to PSS. The set of functionalities available in propriety GIS for modeling, planning or decision making is still quite limited. Most functions need to be added through specifically designed add-ins such as statistical, optimization, simulation and decision support software (Malczewski, 2004). A PSS needs to incorporate a wide body of knowledge and use a broad range of data sources and techniques. GIS is an essential tool for analysis and display of information, but needs to be complemented by theories and models from a broader perspective (Brail & Klosterman, 2001).

PSS=Variety of Theoretical Bases + Technological Tools (e.g. GIS+Modeling Techniques)

As a result, a PSS cannot consist of a GIS alone. Instead, planners will have to strengthen existing GIS tools to meet their needs. PSS must include the full range of planners' traditional tools for urban and regional economic and demographic forecasting, environmental modeling, transportation planning and predicting future development and land-use patterns (Brail & Klosterman, 2001). It must also include theories, decision support aids and newly emerging artificial intelligence techniques.

2.3.2. GIS Related Technologies

GIS is an integrated technology. It allows for integrating a variety of geographical technologies and also with reasoning, modeling and decision making techniques. According to Malczewski (2004), these technologies/techniques could be classified by the role of the item in enhancing GIS capabilities. But in some reviews of PSS and GIS literature, all these "related techniques" (and also GIS) are accepted within PSS framework.

Table 2.3. GIS related technologies
(Source: Adapted from Malczewski, 2004)

Technology	**Role of the Technology in Enhancing GIS**
Database Management Systems (DBMS)	Storing attributes for display in GIS; Data querying, sorting, joining, appending, updating, restructuring, relating tables and fields.
Computer Aided Design (CAD)	Delivering effective use of computer technology in geometric modeling, 3D modeling and animation; Enabling appropriate rendering.
Land Information System (LIS)	Extending GIS capabilities to land surveys and land records for legal, administrative and an aid records for legal, administrative and an aid for planning and development.
Automated Mapping/Facilities Mapping (AM/FM)	Enhancing GIS functions by automated mapping and map maintenance for public utilities such as waterworks, drainage, gas and electricity.
Global Positioning System (GPS)	Enhancing location accuracy of objects and verifying accuracy of attributes in GIS; Enabling navigation and tracking.
Remote Sensing and Photogrammetry (RS-RSP)	Integrating image processing and analysis; Source of raster data;
Spatial Decision Support Systems (SDSS)	Extending GIS functions for spatial decision making
Planning Support Systems (PSS)	Extending GIS functions by modeling and visualization to support planning
Multimedia Systems (MS)	Enhancing visualization of geographic information by use of sound, videos, images, hypertext and hot links
Internet-based Systems (IS)	Enhancing communication, participation,data sharing, joint task operation and online GIS service delivery
Groupware Systems (GW)	Enabling multiple users in different locations to commit tasks related to planning and decision making

In my opinion two of them must gain importance as broad fields: Remote sensing (as source of raster data sets) and web based systems (as enhancing participation and collaboration). Remote sensing is defined as the acquisition of information about an object without being in physical contact with it. The advent of satellites is allowing the acquisition of global and synoptic detailed information about the earth and environment (Elachi & Zyl, 2005).

Remote sensing is a very broadly based field. Professionals with backgrounds in such diverse areas use the information processed from remotely sensing data. In addition, many remote sensing experts are involved in basic research developing new sensor systems, other instruments, and defining new analytical techniques. Experts are also actively engaged in the area of digital image processing, which is changing rapidly with major improvements in the power of computer systems, networks and visualization techniques.

The option of one meter resolution in satellite imagery and aerial photography will make the information useful for geographic and urban analysis. Also these opportunities allow the user for generation of digital terrain models (DTM) and for accurate georeferencing, street mapping, identifying and locating features and infrastructure by using global positioning systems (GPS).

Typical samples for GIS related and web based systems are Geoportal and Google Earth. Geoportals are web gateways that organize content and services such as directories, search tools, community information, support resources, data and applications. The goals of geoportals are to establish a web based portal for one-stop access to maps, data and other geographic services; to institute a collaborative process to develop data content standards ensuring consistency among data sets and allowing government and private sector to share data and integrate multiple sources of information (Maguire & Longley, 2004). Older information services were implemented on mainframes without any link to the exterior. By the advances in ICTs, all isolated GIS will disappear (Laurini, 2001). Groupware, OpenGIS, WebGIS, GOS (GeoSpatial One Stop), INSPIRE (Infrastructure for Spatial Information in the European Community), Google Earth and many other web based geo-spatial applications/consortiums have made a major contributions to the interoperability and collaborative efforts in city planning and geographical studies (Geospatial One Stop, 2005; Google Maps, 2009; INSPIRE, 2008). Also, an increasing amount of information can be downloaded from the internet.

Figure 2.2. INSPIRE Geoportal
(Source: INSPIRE, 2008)

The INSPIRE geoportal map viewer is an application that lets you view one or multiple Internet map services in your web browser. The initiative intends to trigger the creation of a European spatial information infrastructure that delivers to the users integrated spatial information services. These services should allow the users to identify and access spatial or geographical information from a wide range of sources, from the local level to the global level, in an inter-operable way for a variety of uses. The target users of INSPIRE include policy-makers, planners and managers at European, national and local level and the citizens and their organizations. Possible services are the visualization of information layers, overlay of information from different sources, spatial and temporal analysis (INSPIRE, 2008).

Google Earth provides you an interactive, 3D exploration of the planet through aerial and satellite imagery of the world. Google Earth lets you fly anywhere on earth to view satellite imagery, maps, terrain, 3D buildings and even explore galaxies in the sky. You can explore rich geographical content, save your toured places and share with others (Google Earth, 2009). In addition, users can create KML[1] files within Google Earth or export their project from their GIS software into KML file. The KML file specifies a set of features (placemarks, images, polygons, 3D models, textual descriptions, etc.) for

[1] Keyhole Markup Language (KML): KML is an XML-based language schema for expressing geographic annotation and visualization on existing or future web-based, two-dimensional maps and three-dimensional earth browsers like Google Earth

display in Google Earth, maps and mobile, or any other 3D earth browser (geobrowser) implementing the KML encoding. Each place always has a longitude and latitude. Other data can make the view more specific, such as tilt, heading, altitude, which together define a "camera view" (Google Earth, 2009).

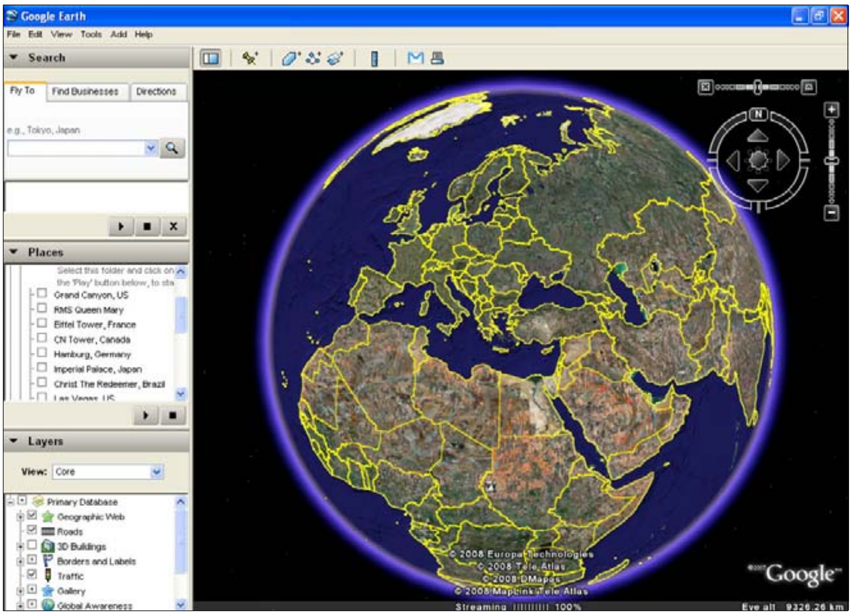


Figure 2.3. Google Earth

2.4. Simulation, Modeling and Scenario Construction

Modeling systems simulate the urban futures and permit the evaluation of alternatives, testing of alternatives and to make judgments based on these alternatives and the construction of scenarios. To conduct this alternative analysis we use models that can project demographic, economic, and land-use changes in cities and regions into the future and which can estimate the effects of these changes.

Many of these models/simulations allocate aggregate area wide projections of population and jobs to sub areas (household and job location). Depending on the model's purpose, these areas may be as extensive as a multi-county region or as small as a rural enclave located among forests and farms (Brail & Klosterman, 2001). There are varying conceptual approaches, methodologies, and overall designs on modeling and simulation issues. It will be quite possible to construct a PSS that projects the future across various scenarios and at different geographic scales. Models deal with alternative land development patterns and work at both the broad metropolitan level and for small communities.

Notable PSS examples of simulation, modeling and scenario construction are presented as “What-if”, “CommunityViz , “INDEX” and “Tranus”.

What-if is a scenario-based, policy-oriented PSS (developed by Klosterman) that uses available GIS data (requires existing land use files from Arcview or ArcGIS software to operate) to support community based processes of collaborative planning and collective decision making. It incorporates procedures for conducting land suitability analysis, projecting future land use demands and allocating the projected demands to the most suitable locations. The system allows users to create alternative development scenarios and determine the likely impacts of alternative public policy choices on future land use patterns and associated population and employment trends. It is easy to use, can be customized to the community’s data, user’s database and policy issues, and provides outputs in easy-to- understand maps and reports (What if?- GIS based PSS, 2006).

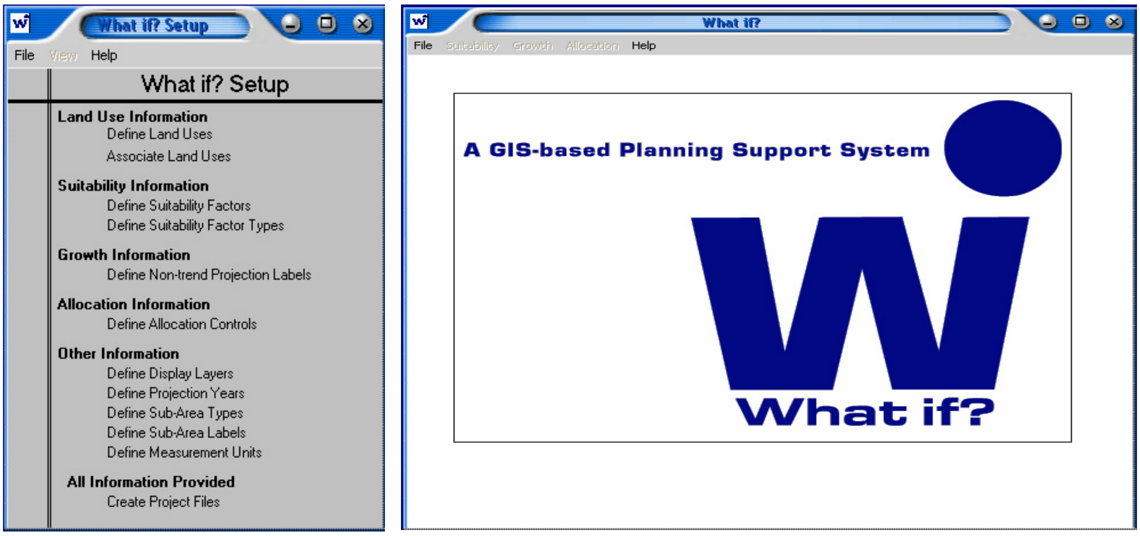


Figure 2.4. What-if PSS-main window

What-if does not attempt to predict future exactly, instead it shows What would happen if:

- Development policies are enacted,
- Growth assumptions prove to be true.

Main components of What-if are suitability scenarios, growth scenarios and allocation scenarios. The model abandons the unrealistic goal of producing a single “exact” prediction of the future for the preparation of a range of alternative scenario-based forecasts which reveal a range of potential futures (which means flexible), so alternative policy choices allowing users to choose between these alternatives and to determine their impacts on the area being studied (What if?- GIS based PSS, 2006).

In this example below, What-if is used on a pilot study. This study was presented before in İYTE, Department of City Planning in 1999 fall & 2000 spring semester as a graduate student project. The aim of the project was to propose an alternative approach for development and planning of rural settlement "Emiralem town" and GIS was used as a tool to make socio-economic and geographic analysis and also to prepare threshold and synthesis maps of those settlement. What-if sample application snapshots and outcomes are presented in Figure 2.5, 2.6, 2.7.

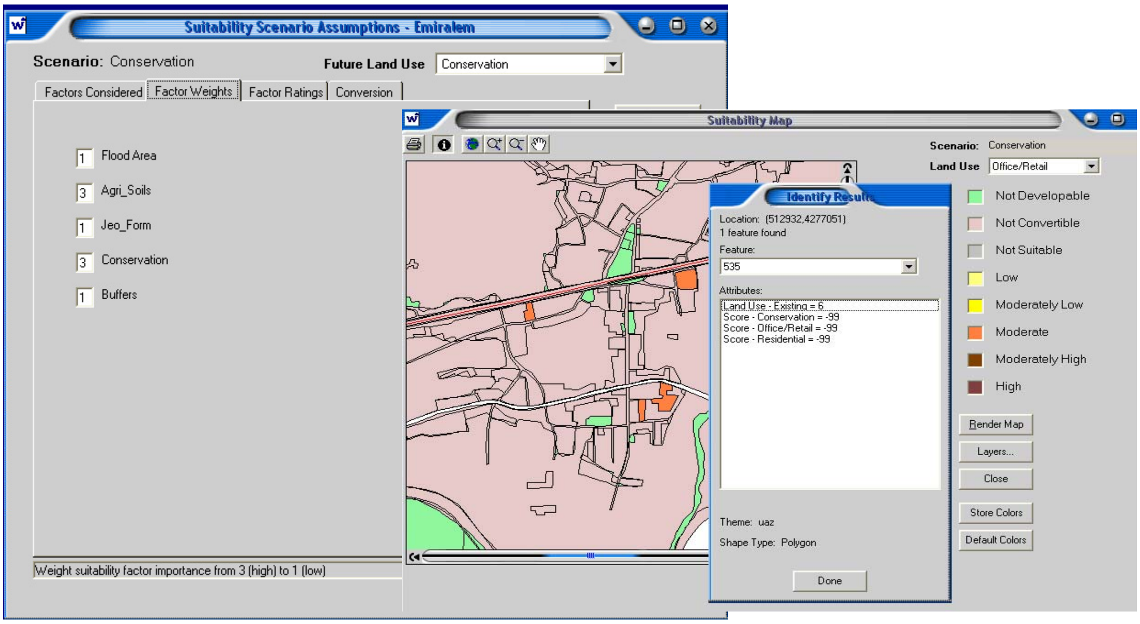


Figure 2.5. What-if PSS-suitability scenario

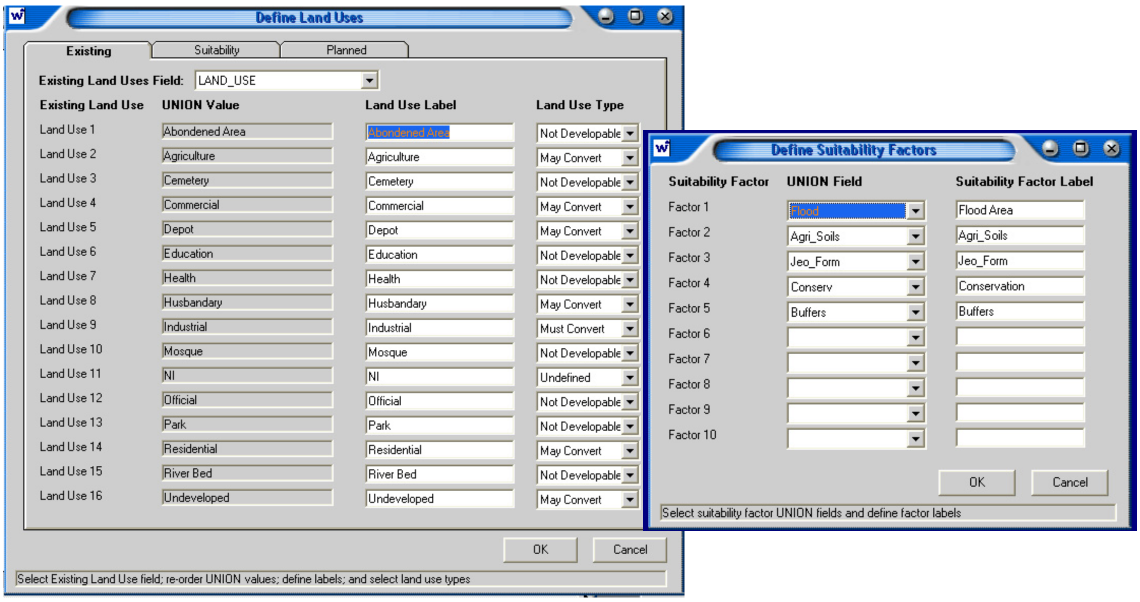


Figure 2.6. What-if PSS-defining land uses and suitability factors

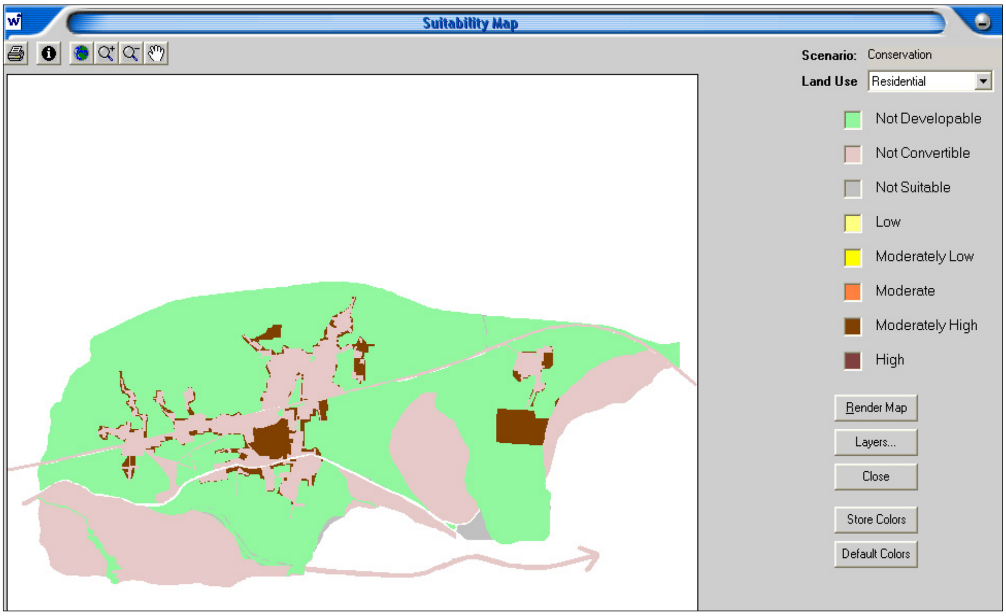


Figure 2.7. What-if PSS-suitability map

It is decided that these GIS layers of the former project could be used in the operational stages of What-if process. After specifying the required information such as land use, suitability factors, projections and allocation factors, we reached a suitability map as a result (see Figure 2.7).

CommunityViz is an ArcGIS based decision support system for community planning and design applications. This is achieved by enabling ArcGIS to modify data on the fly, linking it to real-time photo-realistic 3D visualizations and adding the fourth dimension (time) through the use of agent-based predictive modeling. In doing so, all types of data become mutually accountable to each other and the impacts of the alternative planning scenarios and designs can be evaluated on the fly. CommunityViz software is a set of planning and decision support tools that integrate 2D mapping, 3D visualization and policy simulation technologies that can be applied to the planning and design issues of communities. By using the software, users can propose policies and suggest design alternatives. Also, community members can visualize immediately how these changes might affect their environment physically, economically and socially (Kwartler & Bernard, 2001).

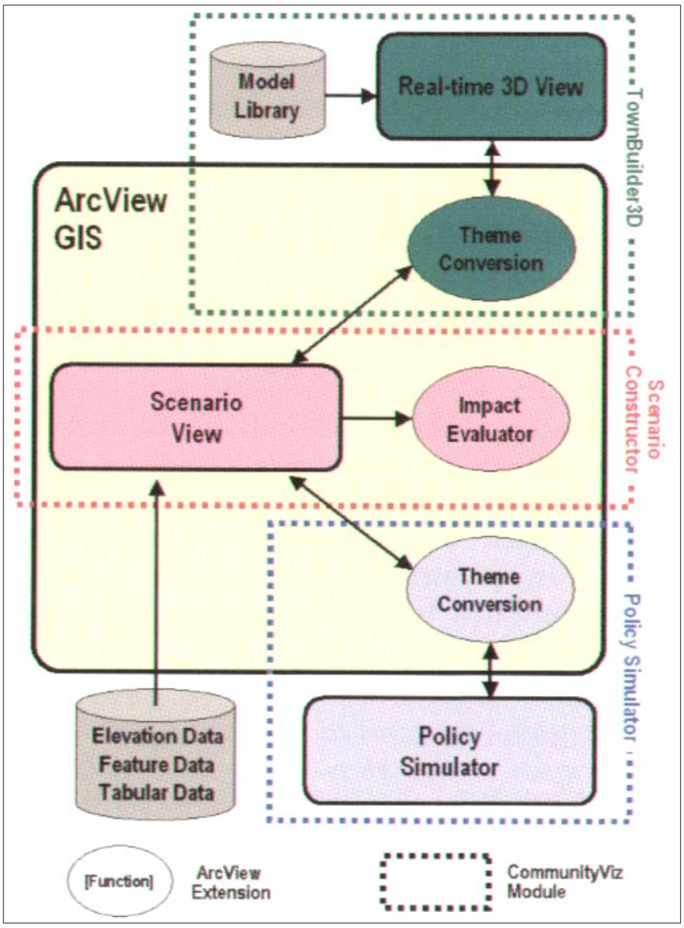


Figure 2.8. The structure of CommunityVIZ: Scenario constructor, TownBuilder3D and policy simulator
(Source: Kwartler & Bernard, 2001)

Figure 2.9. CommunityVIZ sample project
(Source: CommunityViz Software, 2005)

INDEX is a GIS based PSS that estimates the potential impacts of community land-use and design decisions. It is centered on a set of indicators that are used to assess current community conditions, evaluate alternative actions and monitor changes over time. INDEX was developed in response to central themes in contemporary planning-collaborative decision making by public officials and citizens, the new urbanism movement and sustainable development initiatives. One important feature of INDEX is its capacity to estimate the transportation impacts of land-use decisions, including the exploration of how travel behavior is influenced by design decisions (Allen, 2001).

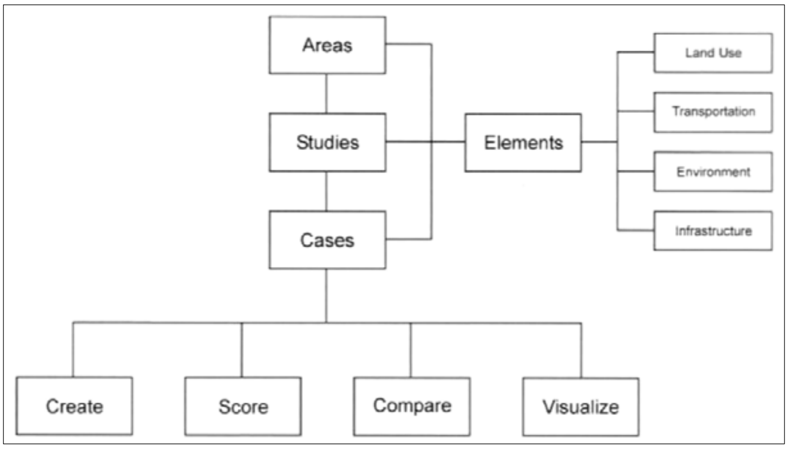


Figure 2.10. INDEX framework
(Source: Allen, 2001)

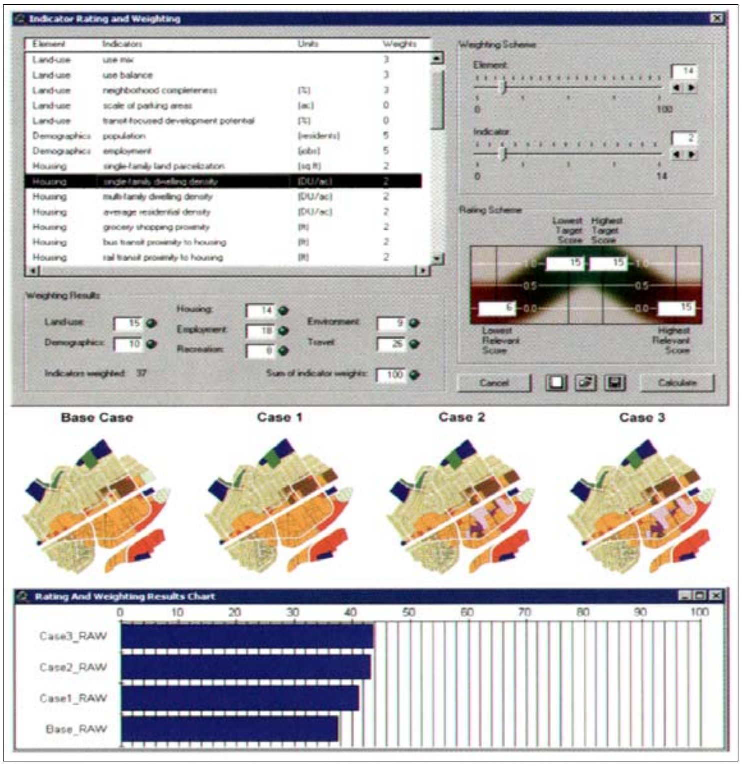


Figure 2.11. INDEX-Indicator rating and weighting
(Source: Allen, 2001)

Tranus is one of the integrated land-use and transport models currently operational (Modelistica-TRANUS, 2008). Tranus has its roots in spatial interaction and discrete choice theories and creates dynamic simulations with feedback loops between the land-use and transport modules. One important component of Tranus is its ability to deal with both the supply and demand for land. Tranus model can be applied at urban, regional or national levels. As a practical experience, De La Barra (2001) applied the Tranus model to Swindon, England and simulated the transport scenarios and alternative land use. Simulation results include job and population distributions, changes in floor space, land consumption and transport-energy consumption across the study area (De La Barra, 2001)

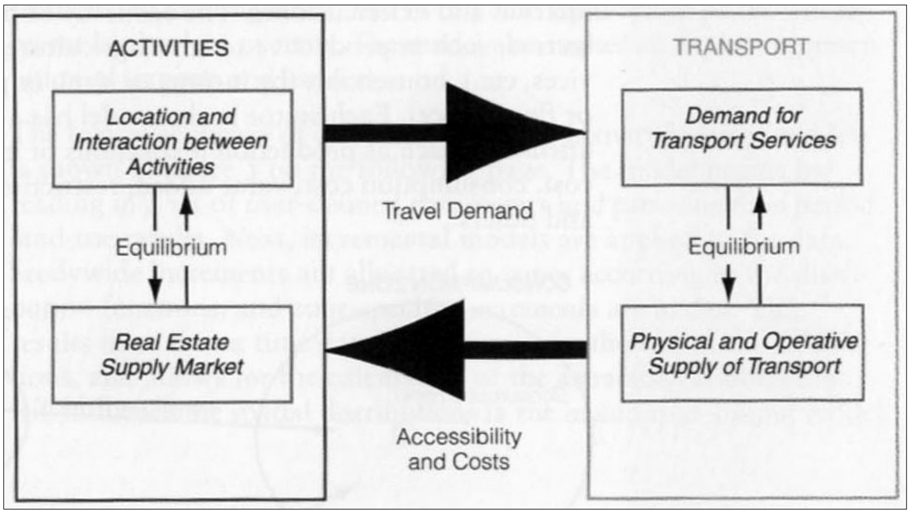


Figure 2.12. Tranus Model-main components
(Source: De La Barra, 2001)

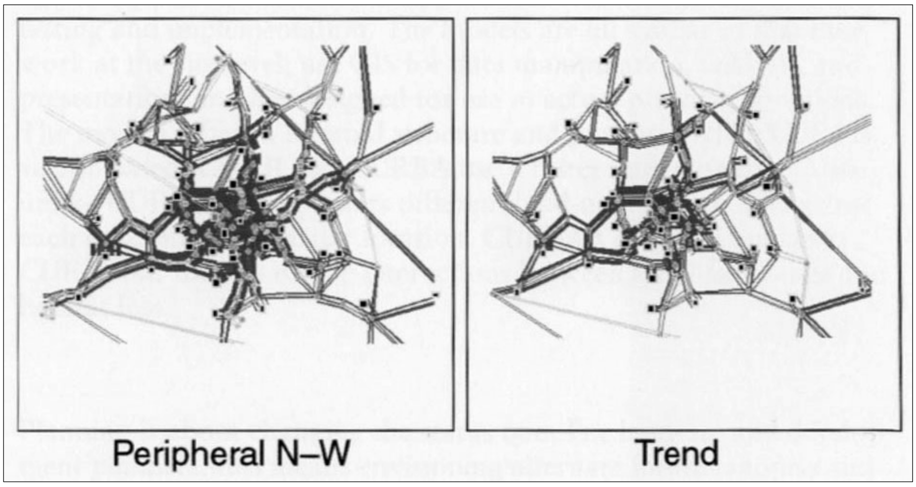


Figure 2.13. Tranus-assigned nonmotorized trips 1996-2016
(Source: De La Barra, 2001)

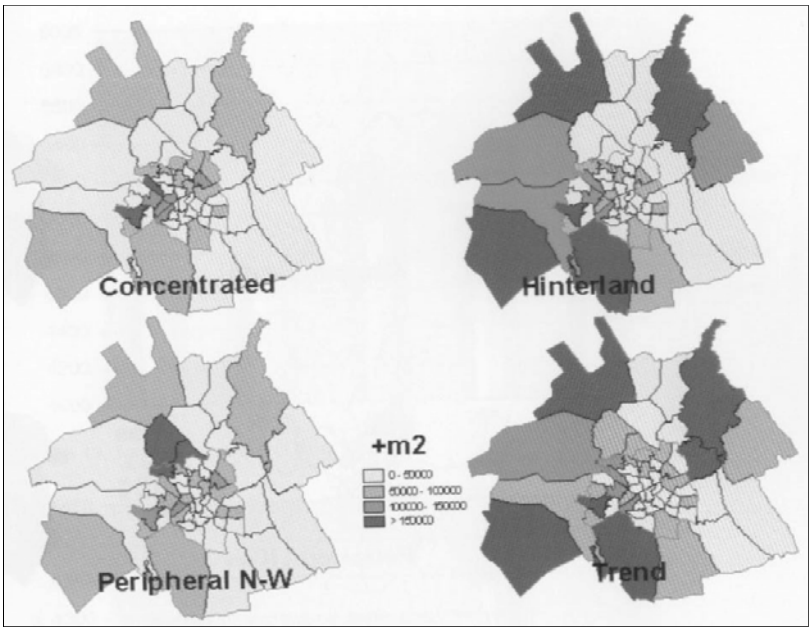


Figure 2.14. Tranus-floor space growth 1991-2016
(Source: De La Barra, 2001)

Shi and Yeh (1999) developed a system that integrates a case based reasoning technique and GIS to build case based system in Hong Kong, China. They tried to show how CBR can be used to handle planning applications in development control. In addition to provide decision support to planners, the system can also be used as an automation system.

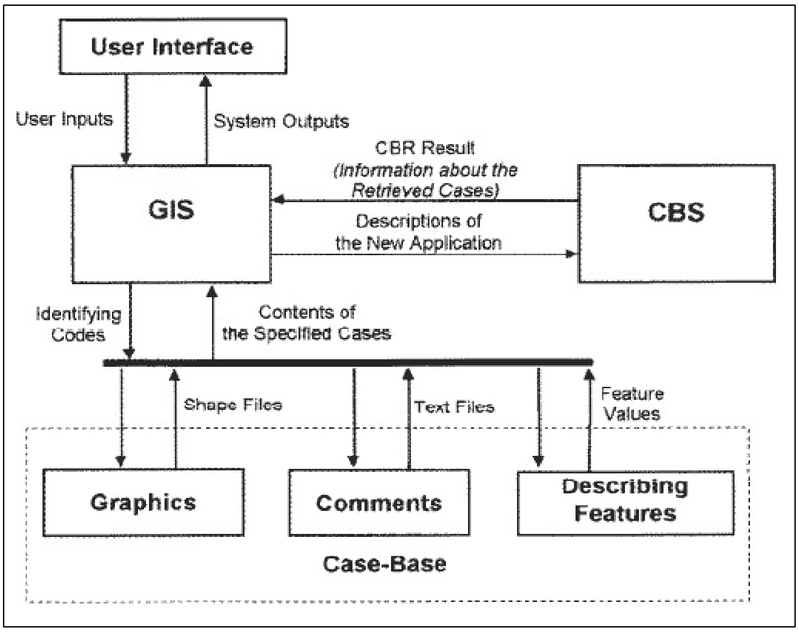


Figure 2.15. Integrated CBR and GIS system
(Source: Shi & Yeh, 1999)

The system simulates the way of handling planning applications in which the planner has to recall and make reference to similar planning application case. Instead of doing it manually and have to rely on the experience of the planner who dealt with the case, the CBS will help the planner to re-use previous similar cases in making decisions on the new applications (Shi & Yeh, 1999). A separate subchapter is devoted to this study for comprehending the notable modeling approach in Chapter 3.

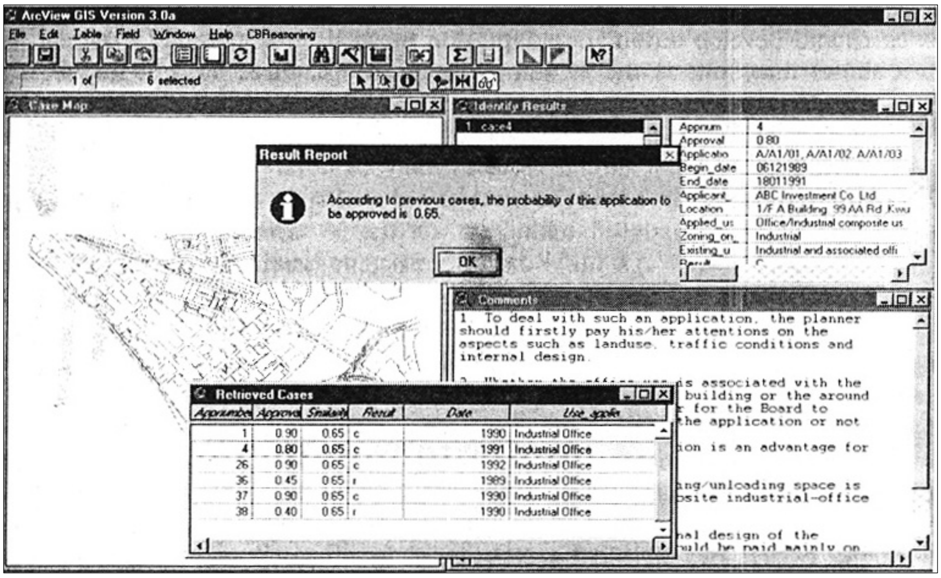


Figure 2.16. CBR&GIS application result: Retrieved cases
(Source: Shi & Yeh, 1999)

2.5. Visualization

Living in a complex world requires the exploration of multiple perspectives and a variety of visual information resources. Visual tools can provide perspective views for understanding our environment. Visualization studies cover GIS, CAD, 2D/3D modeling, web-based applications, animations, virtual reality (VR) and other hardware/software tools which are utilized in various projects (Brail & Klosterman, 2001). VR is a technology which allows a user to interact with a computer-simulated environment, even real or imagined one.

For instance, 3D visualization of IYTE campus area is presented in Figures 2.17 and 2.18 as an exploratory version for visualization. This project was developed in 2006 by graduate level planning studio and students were intended to evaluate existing built environment and the planned (proposed) environment with using PSS tools. After finishing the 2D GIS maps of the campus area, 3D visualization outputs were prepared by "SideBuilder3D" extension of the CommunityViz software.

Figure 2.17. Panoramic view from IYTE Campus area

Figure 2.18. 3D Visualization model: IYTE Campus area

2D/3D visualizations are used for displaying the world and there is a rapidly increasing momentum toward a broad scale use for a variety of purposes. Some of the planners' interest is constructing 3D visualization (sometimes virtualization) of cities.

Examples from Izmir and Istanbul are presented through 3D city guides. İzmir 3D City Guide[2] is developed for displaying brief information about the city. This web based application offers displaying satellite images, previous maps, 3D buildings and searching major places and address information to users. İzmir 3D City Guide is still on progressive development by enhancements; addition of more data sets and extra features.

[2] İzmir 3D city guide is customized version of "Citysurf Software" and developed by Turkish company Piri Reis Data Processing Tech. Eng. Software Education Trade Ltd./Ankara. Visit http://www.citysurf.com.tr and http://www.izmir.bel.tr for more information.

Figure 2.19. 3D Visualization of Konak Square by İzmir 3D City Guide

Beyoğlu Municipality (İstanbul) web based applications are presented in Figure 2.20. In this 3D city guide below, extrusions of special buildings and areas of Beyoğlu were developed upon Google Earth basis.

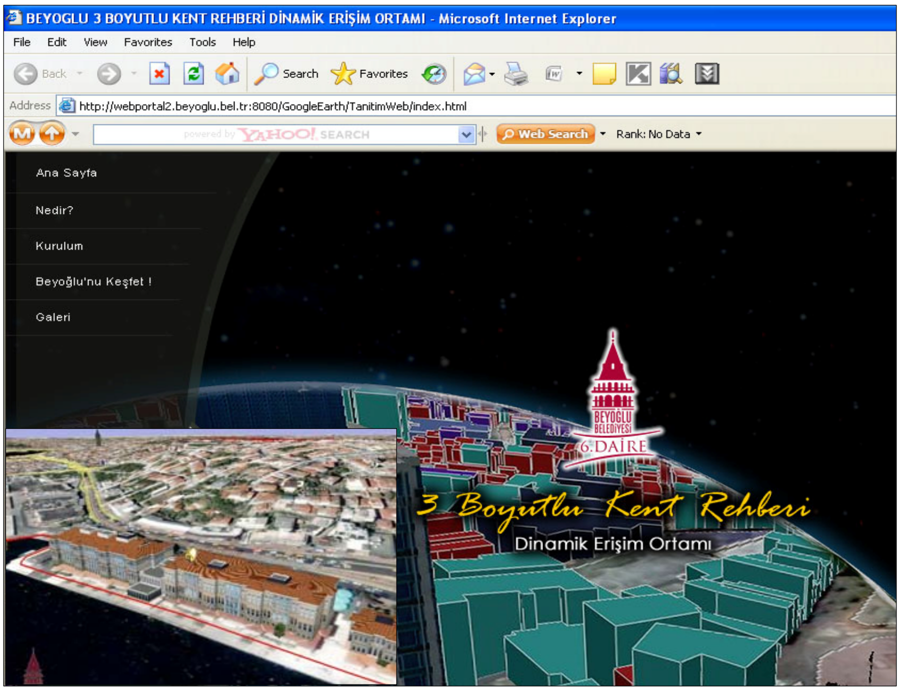


Figure 2.20. 3D City Guide of Beyoğlu
(Source: Beyoğlu 3 Boyutlu Kent Rehberi, 2008)

Visualization of different city examples (some of them are virtual cities) could be found on the web. One notable sample is "Virtual London" project. Centre for Advanced Spatial Analysis-University College London (CASA-UCL) is developing the project by using standard GIS and CAD techniques but a variety of new photorealistic imaging techniques and photogrammetric methods of data capture are being used to render detailed scenes. CASA has started this work to create a 3D model of London in 2005, but later aim of the project is extended (named as Virtual London: Online Participation).

Although the project is designed for professional use by architects and planning, it is also targeted at the wider public through various processes of public participation across the web. The target of building this communication within the built environment is creating innovative manner using multi-user environments in which participants will be able to roam around a "virtual gallery" as "avatars" (digital representations of themselves) and explore the issues relating to London in game-like space. Currently project staff is exploring how the model can be ported to external users using 'free software; such as Google Earth and ArcExplorer (UCL/Virtual London: Online Participation, 2009). Variety of sources such as images, videos and critics about the visualization and virtual space could be found at "digital urban blog": Digital Urban: Virtual London, 2009.

Figure 2.21. Virtual London model
(Source: Batty et al., 2001)

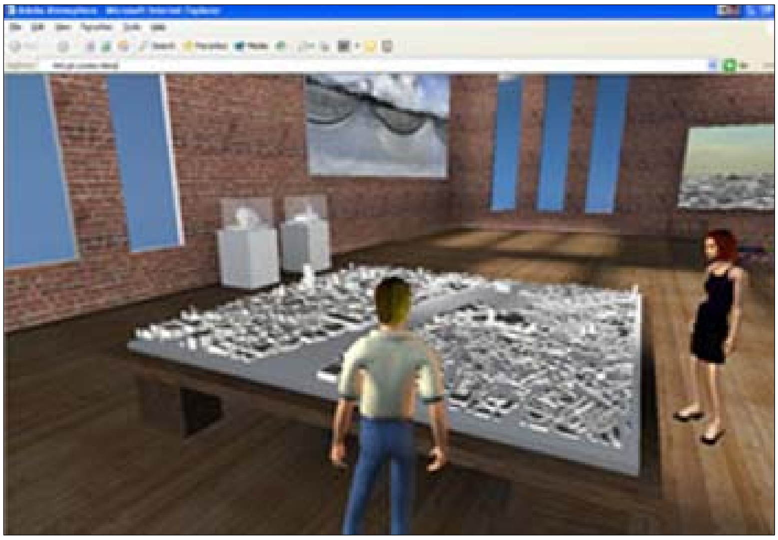


Figure 2.22. Virtual London-space
(Source: UCL/Virtual London: Online Participation, 2009)

Another concept is spatial multimedia in planning. Spatial multimedia is defined as the integration of video/image, sound and text in a distributed environment. For instance, spatial annotation refers to the ability of computer users to place comments on maps and graphics. These comments may be in the form of audio, video/image, text or sketches.

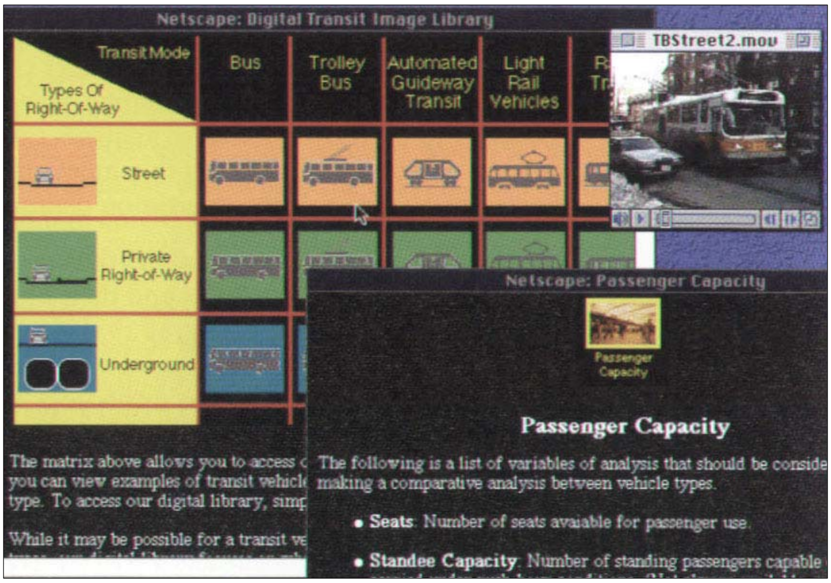


Figure 2.23. Urban transit vehicles and operating environments
using digital motion video with sound
(Source: Shiffer, 2001)

2.6. Evaluation of PSS

Urban planning has adopted a variety of modeling and data manipulation techniques and technologies over the last 30 years by using computer aided products. More recently, software developers which try to support planning have begun to look towards integration of various operations and have begun referring to their products as PSS (Bishop, 1998).

According to Kammier (1999), the use of computers in urban planning has followed a long road to establish operational and meaningful PSS. PSS is now a widely accepted term which encompasses a broader ranges of concepts such as space, geography and environment, than the earlier term decision support system. Thus the ideal PSS is as easy to define as it will be difficult to implement technically and institutionally (Klosterman, 1999a).

As a departure point from Britton Harris's landmark special issue on urban models – ‘Urban development models: new tools for planning’ (Harris, 1965) – *“the dream of using computer-based tools to support planning has proven to be much more difficult to achieve than he or we imagined. However, many valuable lessons have been learned and the use of computers to support planning has clearly come a long way since the 1960s. We continue to be optimistic that the further development of truly collaborative PSS tools that can be adapted to a wide range of planning problems will lead to their widespread adoption by planners, community groups, and decision makers”* (Klosterman & Pettit, 2005, p.482).

Although most of the recent studies (Brail & Klosterman, 2001; Geertman & Stillwell, 2004) suggest that the future of PSS as research tools is bright indeed, the future role of PSS in “professional planning practice” is less clear. Inventories show that currently a large diversity of PSS exists, but that the implementation in spatial planning practice is dragging far behind the supply of tools. Brail (2005) suggests that three factors are required for computer-based tools to be widely used in practice: “a shared commitment to a well-defined methodology, extensive government support, and the ability of available/feasible tools to provide needed outputs for a substantial user community”. None of these conditions exists for PSS anywhere in the world today. Until this vicious cycle is broken, PSS will never reach their potential for improving planning practice.

While many studies focus on how to develop PSS, few studies focus on the use of it in practice. One notable example is from Turkey which tried to examine "what is actually happening in organizational settings of city planning practice deriving from the use of information technology and systems". The general theoretical framework of the thesis has elaborated the nature of implementation, computer-assisted urban planning, and various evaluation frameworks to measure the individual (planning practitioner), organizational (planning department of selected local governments; Ankara, İzmir, Bursa), and societal (various stakeholders outside the department) consequences of information technologies and systems (Velibeyoğlu, 2004). Author's research strategy was based on a variety of qualitative approaches, questionnaire-based surveys and semi-structured/unstructured interviews.

In their empirical research to find reasons for limited PSS use and lessons to enhance PSS use in practice, Vonk & Geertman draw upon various sources of knowledge and expertise (PSS users, developers, and experts), thereby using a range of methods (interviews, literature study, web-surveys). In applying these methods, they used a framework describing three key elements that determine the use of PSS in planning practice (see Figure 2.24). The figure shows that tools with a certain *instrument quality* are created by developers, after which they *diffuse towards practice*, in which they need to be *accepted by intended users* to become used in practice (Vonk & Geertman, 2007).

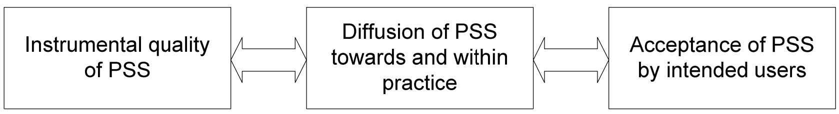


Figure 2.24. Three main factors affecting use of PSS in practice
(Source: Vonk & Geertman, 2007)

According to Vonk & Geertman some of the bottlenecks focus on perceptions of the instrumental quality of the PSS. The main bottlenecks concerning instrumental quality were that the quality of the PSS needs significant improvement in terms of usefulness and user friendliness. In particular, the more advanced PSS poorly match planning tasks. Also, while supply focuses on advanced systems, practice demands simpler systems. Furthermore, while many PSS aim to support decision makers, they poorly meet their demands. Some other bottlenecks focus on diffusion of PSS towards and within planning practice. The main bottlenecks concerning diffusion were that diffusion of PSS towards and within planning organizations is characterized by a large degree of friction. In some situations, managers consider the implementation of PSS as a risk and instead they follow their own top-down strategies without PSS. Furthermore diffusion is hampered by the lack of cooperation between PSS developers and planners concerning PSS (Vonk & Geertman, 2007).

Vonk & Geertman state that other bottlenecks concerning user acceptance were lack of awareness of the existence and potential of PSS in planning practice, lack of experience with using PSS and a general lack of appreciation for PSS by the actors in the planning community. Also lack of user friendliness and usefulness were reported as blocking user acceptance. Furthermore, organizational support for implementation is often limited and potential users are insufficiently organized. In addition, difficulties in acquiring data and data quality problems lower user acceptance of PSS.

A factor that underlies all these factors is the miscommunication between developers, experts and users on PSS. Figure 2.25 shows the main categories of bottlenecks blocking widespread use of PSS in practice and their effect on the handling of knowledge and information in planning. They do not have a well-developed shared communication network to exchange knowledge and experiences. This causes PSS development and the usage of PSS tools to remain largely within the field of developers and academics instead of planning practice. PSS technology is still quite new and many crucial insights on successful development and application are still missing (Vonk & Geertman, 2007).

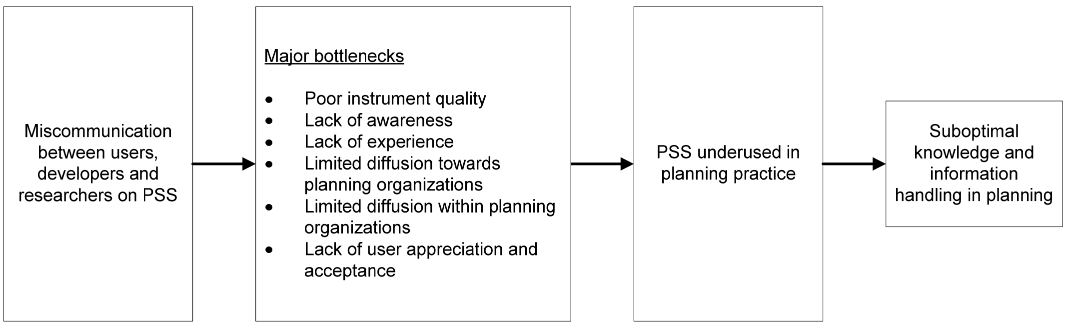


Figure 2.25. Main bottlenecks blocking usage of PSS in spatial planning
(Source: Vonk & Geertman, 2007)

Enhancing the application of PSS in planning practice could improve the handling of knowledge and information in planning. Although an application of PSS to support a decision making problem may increase the efficiency of the data and information processing operation, it is not the real aim of the system. More important, a

PSS aims to improve the effectiveness of decision making by incorporating judgments and computer based programs within the decision making problem. PSS can be considered as an example of collaborative SDSS. Well-designed PSS should provide an interactive, integrative, and participatory support for structuring planning tasks (Malczewski, 2004). Figure 2.26 provides an overview about the lessons learned from empirical studies.

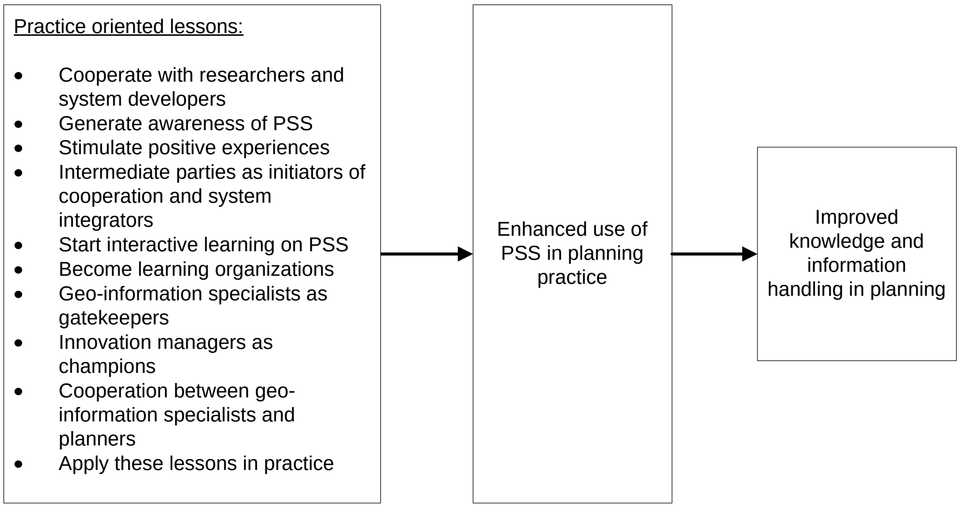


Figure 2.26. Lessons to enhance usage of PSS to improve knowledge and information handling in planning
(Source: Vonk & Geertman, 2007)

Although the lessons are influenced by the perspectives of Dutch organizations in Vonk&Geertman's research, many of these lessons can be generalized. In fact, specific situations must always be carefully evaluated (Vonk & Geertman, 2007). Briefly improving the instrument quality, improving the tools' awareness, improving the experience, improving the collaboration between planning organizations, improving the user appreciation and acceptance could facilitate the performance and efficiency of PSS in planning practice. Also researchers contribute more effort especially on urban issues to reduce knowledge gap and lack of empirical studies.

2.7. Future of PSS

PSS tools will become more flexible, giving users more creative freedom and the internet (web based applications) will become the major part of PSS that facilitates collaboration and participation. In this environment, several key technological developments have occurred in the area of decision support and various PSS tools to support collaboration and group processes have been developed, implemented, evaluated, and refined. GIS and PSS has been applied as a collaborative decision support system, allowing interested parties to interact with public or private planning agencies on projected plans as a participatory approach. For instance, Yiğitcanlar (2002) proposed a new model called "GIS based Participatory Decision Making Approach" which aimed enhancing participation, collaboration and strategic choice by its components on a planning case study in İzmir.

There are some evidence to show that PSS is no longer a tool used only by professional planners and experts, these geo-information tools are also increasingly being employed by community groups and non-governmental organizations as part of their planning efforts for enhancing participation and collaboration. PlaceMatters initiative from USA states that their mission is to support the creation and maintenance of sustainable and vibrant communities and regions through the application of innovative decision making tools and methods. This website (PlaceMatters, 2005) is a resource for communities (professional planners, public agencies, and concerned citizens) to identify tools and processes for better community design and decision making.

Technology is becoming more available, less expensive, easier to use and more relevant to real world problems. The Internet and web-based applications are creating an environment with almost ubiquitous access to a world of information. Conditions of data availability and quality are also improving. New era of technology based planning is emerging not only in theory and application also in education.

CHAPTER 3

CASE BASED REASONING

This chapter presents an overview of case based reasoning (CBR) technique. The process of CBR technique is described and integration of CBR and spatial systems is outlined from reviews. In addition to conceptual CBR issues, studies that consider the practical applications have been searched. Therefore, literature survey about the usage of the CBR technique has been clarified and also narrowed through spatial analysis and city planning perspective. Special emphasize is given to recent studies which tried to establish a spatial decision support systems (SDSS) by using CBR technique and spatial/geographic information systems. The benefits and limitations of using integrated/hybrid systems are discussed.

3.1. An Overview of Case Based Reasoning

3.1.1. What is CBR?

There are several definitions about CBR in the literature:

- To use previous similar cases to solve, evaluate or interpret a current new problem (Kolodner, 1993).
- CBR is an artificial intelligence (AI) technology that encodes problem-solving expertise as a database of cases, where each case encodes a solution to a previously-encountered problem (Stottler Henke AI Software Solutions, 2006).
- CBR is a model of reasoning which consists in solving new problems by adapting solutions that were used to solve old problems (Riesbeck & Schank, 1989).
- CBR means to solve a new problem by remembering a previous similar situation and by reusing information and knowledge of that situation (Aamodt & Plaza, 1994).

3.1.2. Basic Specifications of CBR Technique

CBR is a family of AI techniques that simulates the human behavior in solving a new problem. Thus in CBR, reasoning is based on remembering. When confronted with a new problem, it is natural for a human problem-solver to look into his/her memory to find previous similar instances for help. An important reason why a person can become an expert is that he/she can remember and properly use suitable cases in solving new ones (Shi & Yeh, 2001).

CBR differs from other methods like rule/model based approaches that it allows the knowledge to be represented as an inferred case instead of generalized/abstracted rules. While most of AI technique try to make prediction, CBR tries to retrieve most relevant/useful case(s) and utilize existing knowledge (if fits the situation). CBR systems can point to the similar cases on which the prediction is based as justification. In addition, it clearly presents and explains the internal working of the model to user when compared with the 'black box' nature of other AI methods. For instance artificial neural network (ANN) method has a limitation what constitute the optimal structure of the network (hidden layers and bias neurons). Briefly, CBR only uses local information at first step rather than deriving generalized rules or models.

In CBR approach, new problems are handled by remembering old similar ones and moving forward from there. Referencing to old cases is advantageous in dealing with situations that recur. However, CBR technique is based on two tenets about the structure of problem solving process. The first one is similar problems have similar solutions and the second one is future problems are likely to be similar to current problems (Leake, 1996). When the two assumptions hold, CBR becomes an effective reasoning strategy.

"Remembering a case" to use in "later problem solving" is a necessary learning process. According to Kolodner, features of the CBR approach:

- Learn from experiences,
- Learning to be integrated/based on reasoning,
- Learn from mistakes and do not repeat them,
- Allows a reasoner to solve problems with a minimum of effort,
- Provides a way of dealing with an uncertain world,
- In most cases, what was true yesterday is likely true today.

By its cyclical nature, CBR is capable of 'learning' from previous experiences (or iterations). Thus it can adapt to both 'good' and 'bad' answers. Hammond (1988) gives the principles of CBR as:

1. If it works, use it again,
2. If it works, don't worry about it,
3. If it didn't work, remember not to do it again,
4. If it doesn't work, fix it.

Regardless of whether a case-based reasoner solves a routine or novel problem and of whether the problem solving outcome is success or failure, the system learns from its experience. The user/system learns from experience to gain prior success or and avoid prior failures (Leake, 1996). At the highest level of generality, a CBR cycle may be described by the following four processes (Kolodner, 1993):

- ***RE*TRIEVE** the most similar case or cases,
- ***RE*USE** the information and knowledge in that case to solve the problem,
- ***RE*VISE** the proposed solution,
- ***RE*TAIN** the parts of this experience likely to be useful for future problem solving.

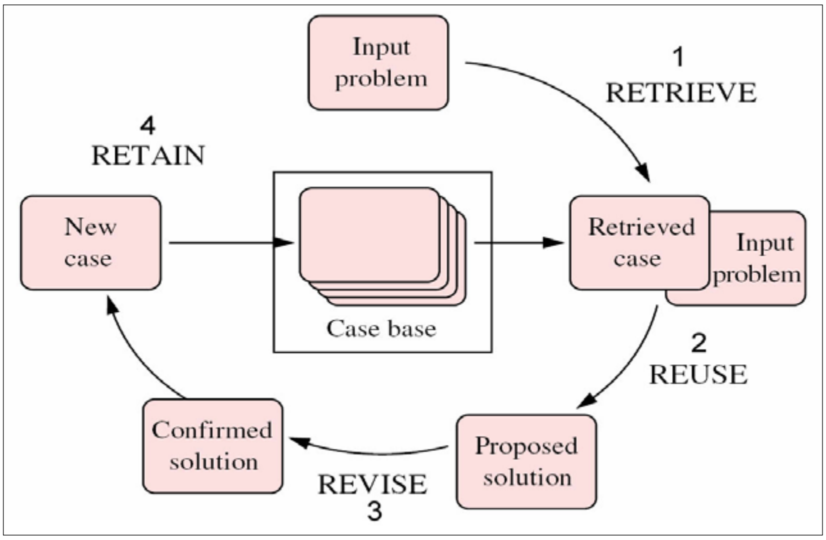


Figure 3.1. Generic cycle of CBR (4 REs)
(Source: Kolodner, 1993)

Each CBR process involves several more specific steps (see Figure 3.2). The top level task is problem solving and learning from experience. Other four major CBR tasks: retrieve, reuse, revise and retain are partitioned to sub-tasks. An initial description of a problem defines a new case (Holt & Benwell, 1996).

The **retrieve** task starts with a new case description and ends when a best matching previous case has been found. The goal of the matching task is to return a set of cases sufficiently similar to the new case (similarity computing techniques are used).

The **reuse** of the retrieved case focuses on two aspects: the difference among the past and the current case and what part of a retrieved case can be transferred to the new case. The retrieved case is combined with the new case through reuse into a solved case. The possible two subtasks of reuse cycle are copy. In copy task differences are abstracted away and solution class of retrieval transferred to the new case. In adapt task there are two main ways to adapt past cases: reuse the past case solution (transformational use) and reuse the past method that constructed the solution (derivational reuse).

The **revise** phase consists of evaluating the case solution generated by the reuse phase. During the revise process, this solution is tested for success, for example by being applied to real world or evaluated by an expert (or domain specific knowledge) and repaired if failed.

During **retain**, useful/successful experience is saved for future reuse and the case base is updated by a new learned case. It is the process of incorporating what is useful to retain from the case-solving episode into the existing knowledge (Holt & Benwell, 1996).

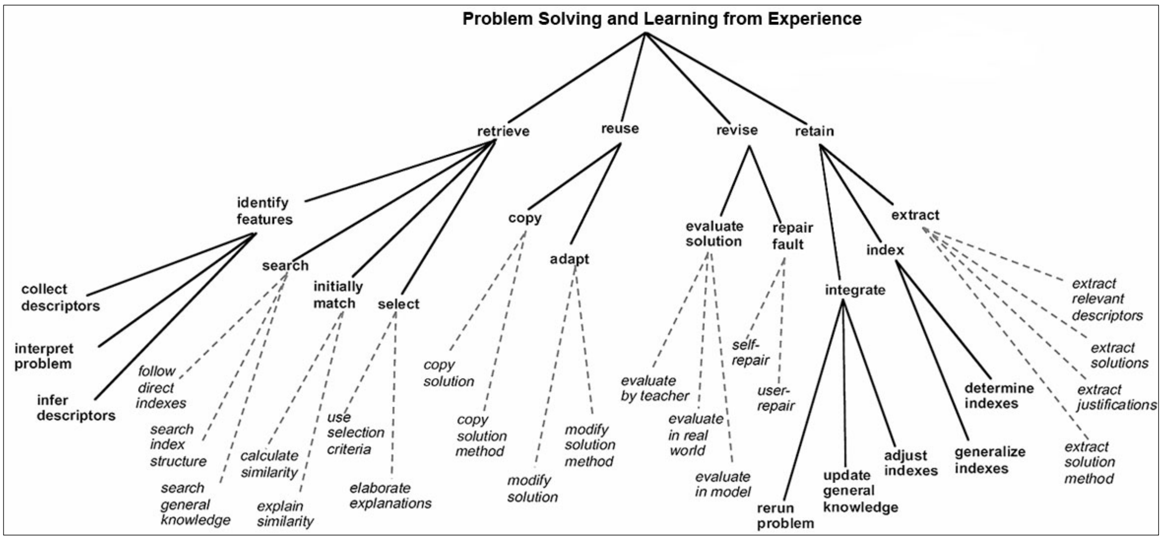


Figure 3.2. Task-method decomposition of CBR
(Source: Aamodt & Plaza, 1994)

The challenge for using CBR technique for particular application environments is to produce (or utilize) suitable methods. When establishing a CBR system, user should answer the major CBR queries (Kolodner, 1993):

1. How to represent knowledge in cases?
2. How to index cases for accessibility?
3. How to implement retrieval process for efficiency?
4. How to adopt old solutions to fit new situations?

Case Representation: The hearth of a CBR system is its case base. *"In CBR terminology, a case usually denotes a problem situation. A previously experienced situation, which has been captured and learned in a way that it can be reused in the solving of future problems, is referred to as a past case, previous case, stored case, or retained case. Correspondingly, a new case is the description of a new problem to be solved"* (Aamodt & Plaza, 1994, p. 3). The representation problem in CBR is primarily the problem of deciding what to store in a case, finding an appropriate structure for describing case contents, and deciding how the case memory should be organized and indexed for effective retrieval and reuse (Aamodt & Plaza, 1994). Nevertheless, a case must contain a past solution and the useful features about the domain specific knowledge.

Case Indexing: An indexing technique plays an important role in a CBR. The primary role of indexing is feature matching and retrieval of cases. In this respect, cases should be indexed. Cases may be indexed by a prefixed or open vocabulary, and within a flat or hierarchical index structure. An index is composed of two terms: An index name and an index value (Aamodt & Plaza, 1994). The major part of indexing is adjusting the case base among searchable qualitative and quantitative values or value ranges. A feature weight is also assigned as an importance ranking to the features. Thus, acceptable ranges of the relevant parameters help the feature matching and retrieval process. Uncertain, subjective and irrelevant inputs are not accepted and should be eliminated in this process. There are software editor facilities to graphically build parts of the case/index structure, and to generate user dialogues.

Case Retrieval: The ultimate aim of a CBR application is firstly "the retrieval process". This is the process of extracting "similar" cases and finding the most similar case (or cases) that are supposed to suggest the right solution. *"The retrieve task starts with a partial problem description, and ends when a best matching previous case has been found. Its subtasks are referred to as identify features, initially match, search, and select, executed in that order. The identification task basically comes up with a set of relevant problem descriptors, the goal of the matching task is to return a set of cases that are sufficiently similar to the new case - given a similarity threshold of some kind, and the selection task works on this set of cases and chooses the best match"* (Aamodt & Plaza, 1994, p. 14).

Similarity Assessment: CBR uses matching and ranking to derive similarity. Matching is achieved through index and weights, while ranking is the total of the match score. CBR also searches and matches the entire database not just by comparing two values. Most CBR systems use the nearest neighbor[1] matching technique for retrieval (Kolodner, 1993). Nearest neighbor algorithm is represented as follows:

$$S\,(I,S) = \frac{\sum_{i=1}^{n} W_i \times sim\left(f_i^{input}, f_i^{stored}\right)}{\sum_{i=1}^{n} W_i} \tag{3.1}$$

Function for 3 features:

$$S = \frac{W_1 \times sim\left(f_1^{input}, f_1^{stored}\right) + W_2 \times sim\left(f_2^{input}, f_2^{stored}\right) + W_3 \times sim\left(f_3^{input}, f_3^{stored}\right)}{W_1 + W_2 + W_3} \tag{3.2}$$

Result is between 0-1 interval or percentage:

$$S = [\,0,1\,] \text{ or } S\,(\%) = [\,0,1\,] \times 100 \tag{3.3}$$

where:

S: Similarity Score
W_i: Feature Weights
n: Feature Number
f_{input}: feature value of input case
$f_{history}$: feature value of stored case base

If $S = 1$ two cases are equal   If $S = 0$ two cases are totally different

We can calculate the similarity of two feature vectors (includes five attributes) with assigned weights as (Funk, 1995):

Sample Similarity Matrix:

$$S = \overset{W_i}{\begin{bmatrix} 0{,}8 \\ 0{,}9 \\ 1 \\ 0{,}85 \\ 0{,}75 \end{bmatrix}} \text{ X } sim_i \left(\overset{f_{input}}{\begin{bmatrix} 50 \\ 2500 \\ 500 \\ turism \\ fault\ lines \end{bmatrix}} \overset{f_{stored}}{\begin{bmatrix} 27 \\ 4000 \\ 513 \\ agriculture \\ no\ fault\ lines \end{bmatrix}} \right) \tag{3.4}$$

[1] The k-nearest neighbor algorithm (k-NN) is a method for classifying objects based on closest training examples in the feature space. The k-nearest neighbor algorithm is amongst the simplest of all machine learning algorithms. An object is classified by a majority vote of its neighbors, with the object being assigned to the class most common amongst its k nearest neighbors.

Similarity function determines the measure of similarity between the new problem and each stored case. Most similarity measures use a numeric value to indicate the level of similarity. This numeric value is the result of matching and ranking techniques to provide a similarity/match score. There are numerous statistical analysis techniques exist, such as inverse distance weighting, using linear, exponential or logarithmic functions, fuzzy-logic and artificial neural networks (ANN) to determine similarity (Holt & MacDonell & Benwell, 1998). Another issue in similarity assessment is how to determine the right features to compare. Input problem descriptions should be sufficient to determine the similarity of old and new situations (Leake, 1996).

Case Adaptation: After retrieving the similar cases, they may not exactly answer the problem; it is necessary to adapt retrieved case(s) to the problem. Once matching cases are retrieved from the case base, they should be adapted to the requirements of the current case. Adaptation is generally regarded as the difficult part of CBR process. Difficulties with the case adaptation have led many CBR systems to simply replacing the "retrieve-adapt" cycle with "retrieve and propose" cycle (Kolodner, 1993). Adaptation phase is equivalent of reuse and revise steps in CBR process.

Case Retainment: Retain phase is also called "learning" process in CBR systems (see also Chapter 3.1.4.1). In ideal CBR the case base is updated no matter how the problem was solved. If the problem was solved by other methods, including asking the user, an entirely new case will have to be constructed for saving. But an explanation or another form of justification of why a solution is a solution to the problem may also be marked for inclusion in a new case. Failures (i.e. information from the Revise task), may also be extracted and retained, either as separate failure cases or within total-problem cases (Aamodt & Plaza, 1994).

3.1.3. Previous Applications of CBR

CBR has developed into a mature and important field of AI and used by various researchers from various countries. Research in cognitive science and on the nature of human memory at Yale University and the works of Roger Schank on dynamic memory (Schank, 1982) form the roots of CBR. One of the earliest CBR systems to be developed was CYRUS (Kolodner, 1983) which was based on the memory organization packet concept put forward by Schank (1982). CYRUS was developed with a focus on how memory is used to answer questions of understanding (Bhogaraju, 1996). Frontier examples of CBR applications are given in Table 3.1.

Table 3.1. Frontiers of CBR systems
(Source: Bhogaraju, 1996)

Name	**Developers/Authors**	**Domain**
CYRUS	Kolodner, J., 1983	Representation in memory and understanding.
MEDIATOR	Simpson, R. L., 1985	Dispute mediation.
JUDGE	Bain, W. M., 1986	Subjective assessment
CHEF	Hammond, K. J., 1989	Recipe planning.
CASEY	Koton, P. ,1989	Heart failure diagnostics.
CLAVIER	Mark,1989; Hennessey et al.,1992	Autoclave loading designs.

There are several studies have addressed specific considerations on using CBR for design issues. These design applications tried to bring new considerations to the use of CBR in design. Each implementation serves as an example for those who intend to use case-based design as a computer support system for designers. Table 3.2 lists a selection of implementations:

Table 3.2. Applications of CBR to design
(Source: Adapted from Maher & Silva-Garza, 1997)

SYSTEM NAME	**DESIGN DOMAIN**	**REFERENCE**
Archie, Archie-II	Architecture	E. Domeshek and J. Kolodner, "The Designer's Muse," in Issues and Applications of Case-Based Reasoning in Design, M.L. Maher and P. Pu, eds., Lawrence Erlbaum Associates, Hillsdale, N.J., 1997, pp. 11–38.
Cadre, Faming	Architecture	B. Faltings, "Case Reuse by Model-Based Interpretation," in Issues and Applications of Case-Based Reasoning in Design, pp. 39–60.
Cadsyn, Casecad	Structural Systems	M.L. Maher, B. Balachandran, and D.M. Zhang, Case-Based Reasoning in Design, Lawrence Erlbaum, 1995.
Fabel	Architecture	A. Voss, "Case Design Specialists in Fabel," in Issues and Applications of Case-Based Reasoning in Design, pp. 301–338.
Gencad	Structural Systems	A. Gómez de Silva Garza and M.L. Maher, "The Adaptation of Structural System Designs Using Genetic Algorithms," Proc. Int'l Conf. Information Technology in Civil and Structural Engineering Design, Elsevier Science, New York, 1996, pp. 189–196.
Janus	Architecture	G. Fisher, R. McCall, and A. Morch, "Design Environments for Constructive and Argumentative Design," Proc. Human Factors in Computing Systems Conf., ACM Press, New York, 1989, pp. 269–275.
Seed	Architecture	U. Flemming et al., "Case-Based Design in a Software Environment That Supports the Early Phases," in Issues and Applications of Case-Based Reasoning in Design, pp. 61–86.

Several recent approaches in Table 3.2 used the case based design concept for design assistance or design automation. Although practitioners have addressed these issues in developing and implementing case-based design systems, they also indicated that this aspect of case-based design has not matured enough to lead to general principles of how to represent a design case (Maher & Silva-Garza, 1997).

Additionally, the following studies were selected noteworthy samples from the related literature. Many domains used CBR for different purposes, such as software development-computer engineering (Recio-Garcia et al, 2005; Chan & Chen & Geng, 2000), electronics, robotics, mechanics (Lee D. & Lee K., 1999), urban planning (Shi & Yeh, 2001), environmental planning (Kaster & Medeiros & Rocha, 2005), architectural design (Domeshek & Kolodner, 1993), architecture (Doğan, 2005), civil engineering (Dikmen & Birgönül & Gür, 2007), real estate (Pacharavanich et al., 2000), industrial engineering (Chang & Cheng & Su, 2004), farm planning (Bhogaraju, 1996), soil/landscape analysis (Holt & Benwell, 1999), medicine (Abidi & Manickam, 2002), tourism (Niknafs & Shiri & Javidi, 2003) and consumer services.

Shi & Yeh (2001) developed a system that integrates a CBR shell (ESTEEM) and GIS package (ArcView) to build Case Based System (CBS) in Hong Kong, China. They tried to show how CBR can be used to handle planning applications in development control. Authors state that CBR can simulate the present working style of a planner in dealing with development applications which is based on his/her knowledge of past application records. They used the previous planning application cases to support the suggestions to the decision makers rather than generalizing rules and then performing a logic inference to get the conclusion. A special subchapter (see Chapter 3.2.2) devoted to this study as a successful and inspirational reference for this dissertation.

Kaster & Medeiros & Rocha (2005) explore a solution which couples CBR to a spatial decision support system to help planners to profit from others' experiences in Brazil. Proposed model, named WOODSS (WOrkflOw-based spatial Decision Support System) is based on GIS and scientific workflows. The research describes how CBR has been used as part of WOODSS' retrieval and storage mechanism, to identify similar models to reuse in new decision processes. As a future work, authors state that retrieval scheme must be extended to handle geographic data, using GIS functions in the similarity evaluation. In addition, the implementation can be extended to single user to multi-user environment for participatory planning.

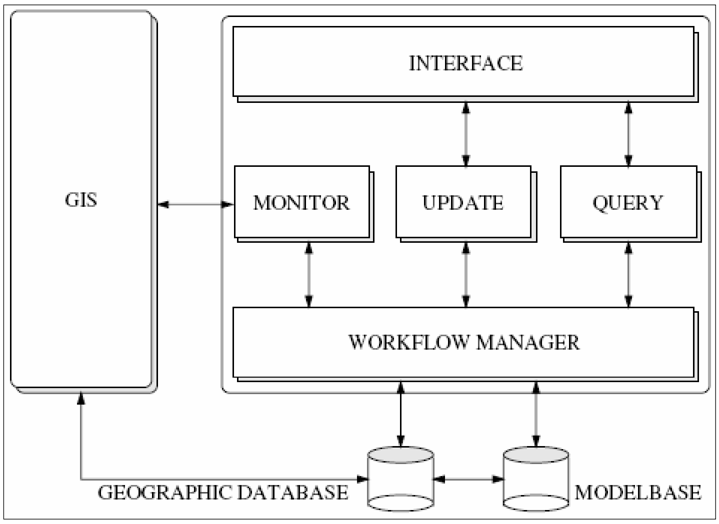


Figure 3.3. Architecture of WOODSS model
(Source: Kaster & Medeiros & Rocha, 2005)

Holt & Benwell (1999) proposed an approach, which consist of combining CBR with GIS to form a hybrid system to solve spatial problems. Authors applied the hybrid system: "ZONATION" to the problem of soil classification which is solved by the searching the case base for other spatial cases similar to the problem case. Then the results from this new approach with a traditional method of soil classification compared. They used the CASPIAN software for retrieval mechanism. According to Holt & Benwell, CBR is beneficial in modeling spatial and environmental issues.

Pacharavanich et al. (2000) examined the usefulness of the CBR system for the valuation of townhouses in Bangkok/Thailand. This system should be useful as an aid for experienced valuers and a guide to assist inexperienced valuers to learn proper judgment and methodology. A CBR software shell was used a tool. A larger sample of valuers needs to be investigated when the system is developed further. The research shows that the system has potential to become a viable tool for the valuation of residential property.

Recio-Garcia et al. (2005) from Complutense University of Madrid have developed jCOLIBRI[2] framework which aims to formalize CBR and to provide a design and implementation assistance with software engineering tools. They try to demonstrate the usefulness of the jCOLIBRI framework in view of encouraging other CBR researchers to use it. jCOLIBRI is an object-oriented framework in Java for building CBR applications and provides graphical tools and codes to facilitate the CBR systems design. The main advantage of using jCOLIBRI is that it provides an easier

[2] jCOLIBRI: Java Cases and Ontology Libraries Integration for Building Reasoning Infrastructures

development of CBR systems. To reach this goal they propose a design process that is based on reusing existing CBR knowledge (terminology, designs, tasks, methods, and implementations), the integration of new components, and the extension of existing components and their collaborations. They have also focused on some design, implementation and use details regarding jCOLIBRI 1.0&2.0 platforms such as: travel recommender, cooking advisor, spam filter, etc. The research is still broadening by experiences acquired during the development and with contributions around the world (JCOLIBRI, 2008).

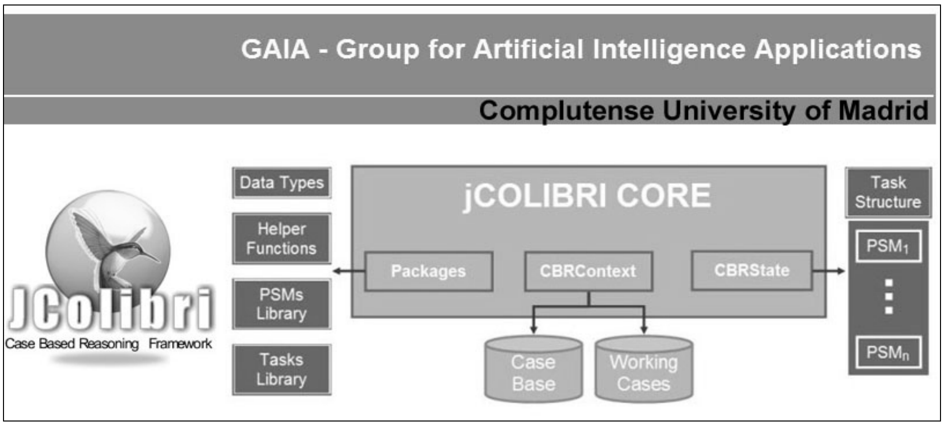


Figure 3.4. jCOLIBRI 1.0 architecture
(Source: Recio-Garcia et al, 2005)

Abidi & Manickam (2002) propose a novel medical knowledge acquisition approach that leverages routinely generated electronic medical records (EMRs) as an alternate source for CBR-compliant cases in Canada&Malaysia. They present a methodology to autonomously transform EMR to specialized CBR-compliant cases (OCC: operable clinical cases) for CBR driven medical diagnostic systems. From an information-content perspective, routinely collected EMRs contain both the situation (observed symptoms and findings) and the solution (diagnosis/prognosis/treatment-plans prescribed by a medical expert) information. According to authors, transformation of generic EMR to specialized OCC is an interesting yet challenging research problem in a real-life setting; nevertheless, initial results, though based on certain realistic premises are quite encouraging.

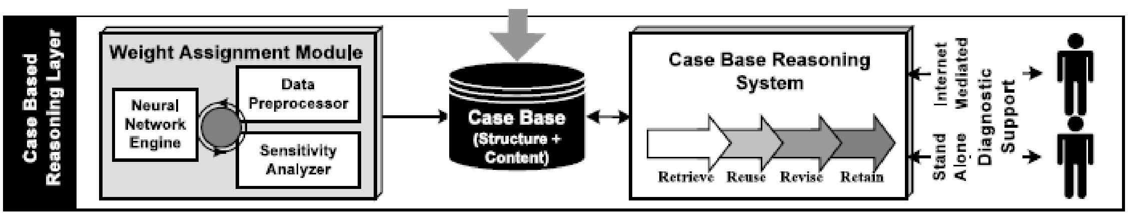


Figure 3.5. CBR task specific layer
(Source: Abidi & Manickam, 2002)

	EMR CONTENT
PROBLEM	▪ Personal Identification ▪ Demographics ▪ Admission Information ▪ Nursing Documentation (assessments, care plans, medication charts, vital signs, etc.) ▪ Symptoms & Signs ▪ Patient History
SOLUTION	▪ Admitting Diagnosis/Prognosis ▪ Clinician Requests, Orders, Prescriptions and Procedures ▪ Progress Notes on Treatment
OUT-COME	▪ Physical Examination Assessment ▪ Rehabilitation Progress Notes ▪ Diagnostic and Therapeutic Reports ▪ Discharge Summary

	CASE CONTENT
PROBLEM	▪ Age ▪ Gender ▪ Symptoms (list) ▪ *{Specific, Type of symptom}* ▪ Vital Signs (list) ▪ *{Temperature, Respiration, Pulse, Blood pressure}* ▪ Lab Report (list) ▪ *{Type, Value}*
SOLUTION	▪ Diagnosis/Prognosis (list) ▪ *{Category, Stage}* ▪ Prescription (list) ▪ *{Type, Dose}* ▪ Procedure (list) ▪ *{Type, Duration}*
OUT-COME	▪ Assessment (list) ▪ Rehabilitation (list) ▪ Progress Status

Figure 3.6. Electronic medical record (EMR) and case content
(Source: Abidi & Manickam, 2002)

Lee, D. & Lee, K. (1999) from South Korea presented a ship design assistant in their research. Major design factors and parameters of the existing ship data were stored in case base as design cases and was connected with database for information exchange. To extract a good and suitable design case for a new ship design from case base, learning algorithm was adapted. They developed the interactive intelligent conceptual design system: BASCON-IV. As a result of this work, a reliable design support system is available which greatly help ship designers perform the conceptual design using existing mother ship data.

Bhogaraju (1996) developed a CBR system that evaluates crop rotations for their soil erosion and risk of insect pest problems in USA. The purpose of this system is to provide decision support for an automated whole-farm planner. The system was prototyped by using ESTEEM software. The proposed automated planning system: CROPS, requires an adequate methodology to assess the impacts of cropping plans on pests and pesticide risks. This research provided a framework to develop a robust CBR system that will allow CROPS to generate pest risks for a given crop rotation. Author inferred that effectively domain-specific algorithms are required to be able to implement a CBR system to its fullest potential.

Archie is the product of collaboration between architects, computer scientists, design researchers and environmental social scientists at the AI lab of Georgia Tech's College of Computing. Archie helps architects in the high-level task of conceptual design as opposed to low-level tasks such as drawing and drafting, numerical calculations, and constraint propagation. It is a case-based design aid that provides access to past experience so that human designers can adapt the cases for use in a present situation. Firstly, the system implemented for office building design and contains several types of information like area, lighting, furniture, budget, etc. It supports architects during the conceptual design phase through three means: (1) raising design issues, (2) proposing responses to design issues, and (3) identifying pitfalls and opportunities. This is accomplished by not only collecting successful cases, but also by having some cases that didn't work out as was hoped for (Domeshek & Kolodner, 1993; Heylighen & Neuckermans, 2001).

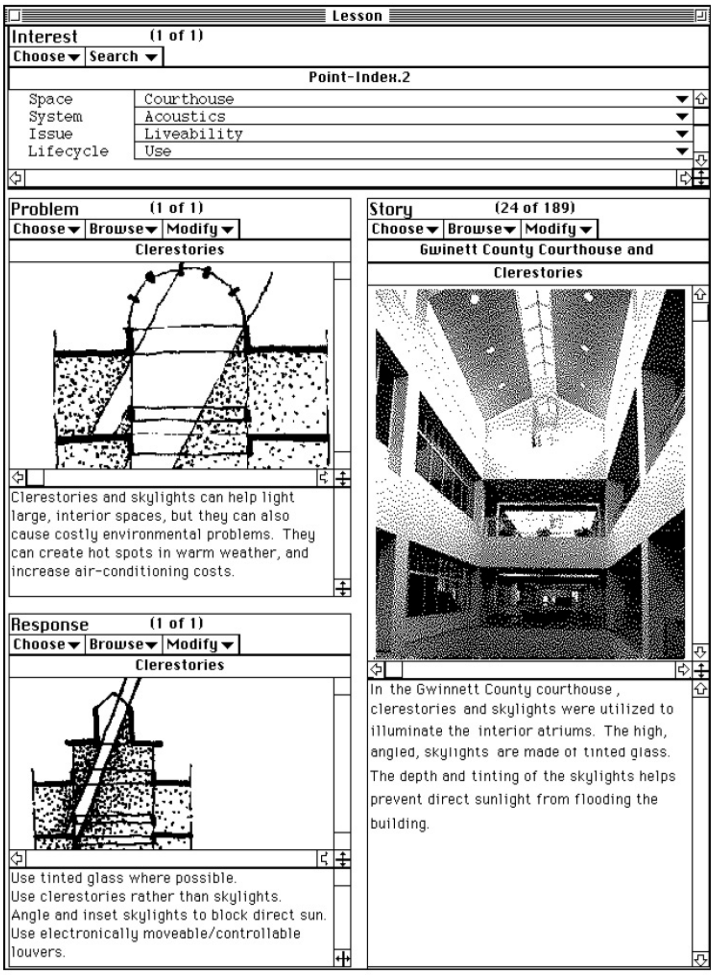


Figure 3.7. Archie screen capture
(Source: Zimring & Bafna & Do, 1996)

Archie II is the newer version of former Archie. In Archie II, cases were not just described, but the case materials have been drawn from post-occupancy evaluation studies, which were collected from the builder. Evaluations of the current buildings serve to highlight the good and the bad features of the design (Domeshek & Kolodner, 1993). Archie-II supports architects during the early conceptual stage of building design by providing them design cases from the past. The system focuses on case representation and retrieval, leaving manipulation completely to the user (Heylighen & Neuckermans, 2001). However, developers of the Archie state that the studied versions of Archie could be regarded as partially successful in supporting architectural design and also some of the most important contributions of the Archie experiment are the lessons they learned from its limitations.

There are also significant studies about CBR application in Turkey. Doğan (2005) investigates the possibility of predicting the cost of construction early in the design phase by using machine learning techniques. To achieve this objective, CBR prediction and artificial neural network (ANN) models were developed in a spreadsheet-based format. The study demonstrated the practicality of using spreadsheets in developing CBR and ANN models for use in construction management as well as the potential benefits of enhancing CBR and ANN models by using different weight generation methods. Conclusions mainly cover methodological contributions that include the development of ANN and CBR Excel models and their testing results of cost data.

Table 3.3. Main parameters used in the cost prediction model
(Source: Doğan, 2005)

Input Attribute No	Attribute	Range
1	The total area of the building	330 m^2 – 3,484 m^2
2	The ratio of the typical floor area to the total area of the building	0.07 – 0.26
3	The ratio of the footprint area to the total area of the building	0.07 – 0.30
4	The number of floors	4 – 8
5	The type of overhang design	No overhang or one-way
6	The foundation system	Pier, wall, slab
7	The type of floor structure	Cast-in-situ concrete, precast concrete
8	The location of the core	At the sides, in the middle
Output	The cost of the structural system per square meter	\$30/m^2 – \$160/m^2

Dikmen & Birgönül & Gür, (2007) aimed to present a DSS tool to estimate bid mark-up values for international construction projects in a more systematic way. Using the 95 cases (collected by a questionnaire), a CBR model has been developed to estimate risk, opportunity and competition ratings. ESTEEM software is used to develop CBR model. The study differs from others by searching the problem from three aspects: risk, opportunity and competition. They state that, in order to improve accuracy of the model, higher number of scenarios should be incorporated into the case base.

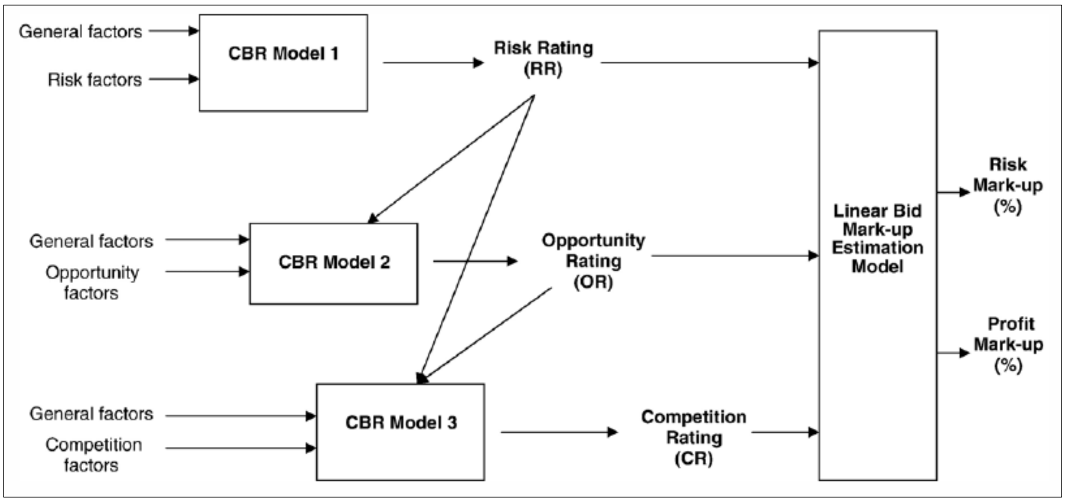


Figure 3.8. Generic structure of the bidding model for a construction project
(Source: Dikmen & Birgönül & Gür, 2007)

Moreover, CBR is an active area of research and has also been adopted by many companies such as AT&T, British Airways, Cisco, Compaq, Daimler-Benz, Dell, GE, Intel, Lockheed, Nokia, Siemens, Visa and Google (Case Based Reasoning Homepage: AI-CBR, 2007; Cognitive Computing Lab, 2009).

3.1.4. CBR & Problem Solving

Cases record the past, giving us and computer a way to make assumptions about the present. The CBR process (4RE cycle) seems feasible for problem solving situations. It might be easier to capture experts' knowledge in the form of rules, so building expert systems might be easier in CBR. CBR technique is a promising way to build and apply more powerful PSS. In contrast to rule-based or model-based reasoning, CBR uses concrete knowledge directly and its inference is basically the processes of retrieval and adaptation (Shi & Yeh, 2001).

There are no universal CBR methods suitable for every domain of application. The challenge in CBR as elsewhere is to come up with methods that are suited for problem solving and learning in particular subject domains and for particular application environments. A set of coherent solutions to these problems constitutes a CBR method (Aamodt & Plaza, 1994).

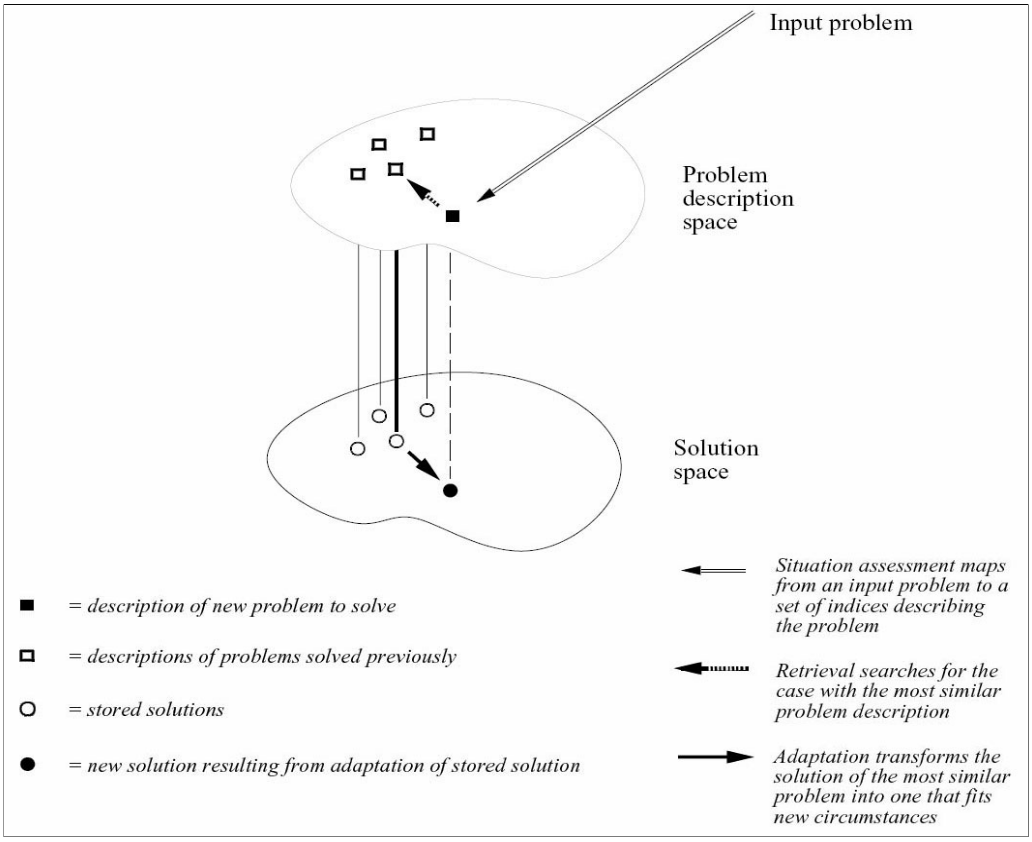


Figure 3.9. Case based problem solving
(Source: Leake, 1996)

In the problem solving process of CBR, the basic idea is, given the description of a new problem, retrieving from a case base a similar problem and the solution of this case is adapted to this new problem. A case-based system has two main components, a case base and a problem solver. The case base contains the description of the solved and unsolved problems. The problem solver has two modules, the retriever and the reasoner. Given the description of the problem, the set of features that define it, the retriever has the function of searching and retrieving a similar case from the case base.

Watson suggests that if we know the result of 10 X 10, then we can multiply the 10 X 11 by (10 X 10) +10 in CBR context. The following example provides a simple illustration of how CBR system can be used as a problem solver. This example is concerned about printing problems. The user begins by typing in a description of the problem. For instance:

"printer outputs white streaks"

Then the search results are displayed. In this sample 5 of 96 cases selected:

Case	*Score*	*Description*
1	100	ink cartridge low on toner causes white streaks
2	73	ink cartridge low on toner causes faded print area
3	55	using bad transparency stock
4	45	printing on the wrong side of the paper
5	44	damaged ink cartridge is causing black streaks

The similar cases are displayed with a number indicating the percentage of the number of attributes in the retrieved case that match the search criteria and ranked in ascending order. The user can click on the case (e.g. case 1) and a picture with instructions of how to re-install the toner is displayed (Holt & Benwell, 1996).

3.1.4.1. Learning from Successes and Failures

Learning in CBR systems is driven by both successes and failures. After a solution has been generated, the final step is to apply the solution, to repair it if necessary, and to learn from the experience.

Success-driven learning: When the CBR process is successful; the resulting solution is stored for future reuse, avoiding the need to rederive it from scratch. Stored cases provide the information that a particular solution did or did not work in a specific real situation. In this way, case acquisition refines initial domain knowledge and allows the system to favor solutions that are more likely to be successful, based on its experience (Leake, 1996).

Failure-driven learning: CBR is committed to the value of learning from failures as well as successes. First, failures reveal that learning is needed. Second, failures help focus decisions about what to learn: the needed learning must help avoid future failures (Leake, 1996). CBR systems learn both from task failures, in which their solutions are unsuccessful, and expectation failures (Schank, 1982), in which observed outcomes differ-for better or for worse-from predictions. For example, when a planner generates a plan that is expected to work and doesn't, there are two failures. The task failure prompts the system to try to learn a successful plan; the expectation failure prompts the system to learn how to anticipate similar problems in the future, in order to avoid them (Hammond, 1989).

In CBR systems, failures can trigger multiple types of learning. When a failed solution is repaired, the new solution is stored; this is simply learning from a new successful solution. In addition, information about the failure itself can be stored as database for future analysis when new information becomes available (Riesbeck & Schank, 1989) or to provide a warning about possible future failures that should be avoided. Within a planning context, if our purpose is to learn from previous cases bad practices are certainly very important.

3.1.4.2. Advantages and Limitations

In the literature, previous researchers of CBR technique cited the advantages of applying the system. Watson (1995) and Kolodner (1993) summarized the general advantages of CBR from the view of both sides of a system builder and system user. In this summary, I would also like to give samples from reviews for city planning domain.
CBR tends to store knowledge in the form of concrete instances rather than abstract and general rules or models, the system builder can largely avoid meeting the knowledge elicitation bottleneck (Watson, 1995). Firstly, extracting knowledge "becomes a simple task of acquiring past cases". Secondly, different solutions to different cases of a similar problem -which are quite common in planning- can be explicitly and conveniently represented. And finally, when the new problem is solved and the effects of the solution in the real world are known, the user can conveniently save this new case in the case-base and increase the knowledge of the system. Case-based systems are maintained and expanded easily by the addition of cases.

According to Shi & Yeh (2001), from the perspective of the users, the enlightening style of CBR may be more welcome to planners. There are five main reasons for this:

1) The reasoning process is more visible to the users,

2) *The user can take part in the inference process,*

3) *The way CBR provides help is not compelling,*

4) *The cases can provide knowledge about exceptions,*

5) *A real case is more inspiring than abstract knowledge.*

Especially the third reason is more advantageous to planners: CBR will not just tell the planner what he/she should do. Instead, it presents cases related to previously handled similar problem and suggests what has been done under similar situation, what the consequences of the applied solutions are and what tips the precedents can provide for dealing with the current problem (Shi & Yeh, 2001).

The ability to retain cases and form new generalizations is one of the main strengths of CBR systems. This method of incremental learning results in increased efficiency in familiar situations and allows a CBR to cope with problematic situations (Kolodner, 1993).

In summary, a CBR provides planners to recognize, understand and generate creative solution to a new problem while it provides raw but comprehensive and original information, and tools to facilitate the decision-making process.

The use of CBR is not without limitations. One of the obvious limitations is the lack of cases for new problems and changes in the planning/spatial environment which makes previous cases to be irrelevant. In general, a CBR system will be able to generate a better recommendation if it has a large case base. CBR is unsuitable when there is little or no case data available. Therefore, a large collection of cases might be necessary for developing an effective CBR system. A CBR system might be tempted to use old cases blindly, relying on previous experience without validating it in a new situation and it might allow cases to bias it too much in solving a new problem (Kolodner, 1993). Such situations require robust indexing and similarity assessment.

In the process of learning, a CBR might try to retain all the cases it encounters and increase its case-base quickly. This might reduce the efficiency of the reminding schemes if the cases are not significantly different from one another. By employing control measures like setting a threshold number of instances required for forming a generalization the problem of false generalizations can be overcome. Validation and verification of CBR systems is a difficult process. Further, most CBR systems add solved cases to their case-base. Such learning mechanisms can impact a CBR's performance, and thus, validation results. However, some of the conventional methods of validation and verification used in KBS development can be extended to CBR systems (Bhogaraju, 1996).

Another disadvantage of case-based reasoning is that users might rely on previous experience without validating it in the new situation (Kolodner, 1993). For instance, in medical/clinical CBR applications, there is no guarantee that every patient could be cured by similar former record of treatment. Users might allow cases to bias new problem solutions. In addition, when novice users are reasoning, they might not recall all appropriate sets of cases for solving problems.

However, successful use of the technique depends on how to acquire, represent, index, retrieve and adapt existing cases for particular domains. According to the background literature of CBR, attention is also devoted to the combination/integration of CBR with other methods to establish more efficient systems. There is also a need to explore the integration of CBR with rule-based reasoning. Different reasoning engines can be complementary to each other (Kolodner, 1993; Shi & Yeh, 2001). Rule based system can be used when there is no case in the CBR which is similar to the new application or when new regulations are introduced which make old cases in the case-library to be irrelevant. The integration of theses two reasoning engines may lead to a more powerful system.

3.2. Using CBR Technique for Geographic and Spatial Analysis

The study of CBR is driven by two motivations. The first one is the desire to model human behavior (from cognitive science). The second one is the pragmatic desire to develop technology/technique to make AI systems more effective (Leake, 1996). In this respect, the use of PSS, such as CBR, can reduce the time to process the applications and help in making consistent decisions for similar applications. When dealing with such problems, experts usually draw upon previous experiences or the memory of how similar cases had been solved in the past. This is the type of problem solving cycle which is most suitable for CBR. Also it can overcome the problems with black box inference process of some AI techniques and rule-based reasoning.

According to Holt & Benwell (1996), lack of analytical and modeling functionality is a major deficiency of current spatial information systems. Therefore, there is a perceived need to integrate spatial information systems with additional analytical approaches to overcome this deficiency. CBR is proposing a methodology for building and applying more practical PSS for planning. The results derived directly from real cases in CBR process are more convincing and acceptable to planners. Urban planning often requires the experiences and expertise of planners and assistance of planning models and analytical methods in its complicated decision-making process. However the capability of people in handling large amount of information and the availability of experienced planners are often limited (Shi & Yeh, 2001). By the usage of CBR technique, the traditional working style of a planner (which are based on his/her knowledge of past records) in dealing with applications could be simulated. The following section tries to highlight CBR issues/methods relate to GIS and city planning process.

This is an example of "search to find a similar spatial pattern and associated non-spatial attributes" from the study of Holt & Benwell (1996). They state that users may need to know about a spatial phenomenon before they make a decision. Knowing what has been done before can aid the decision-maker. All process is simplified for easy comprehension.

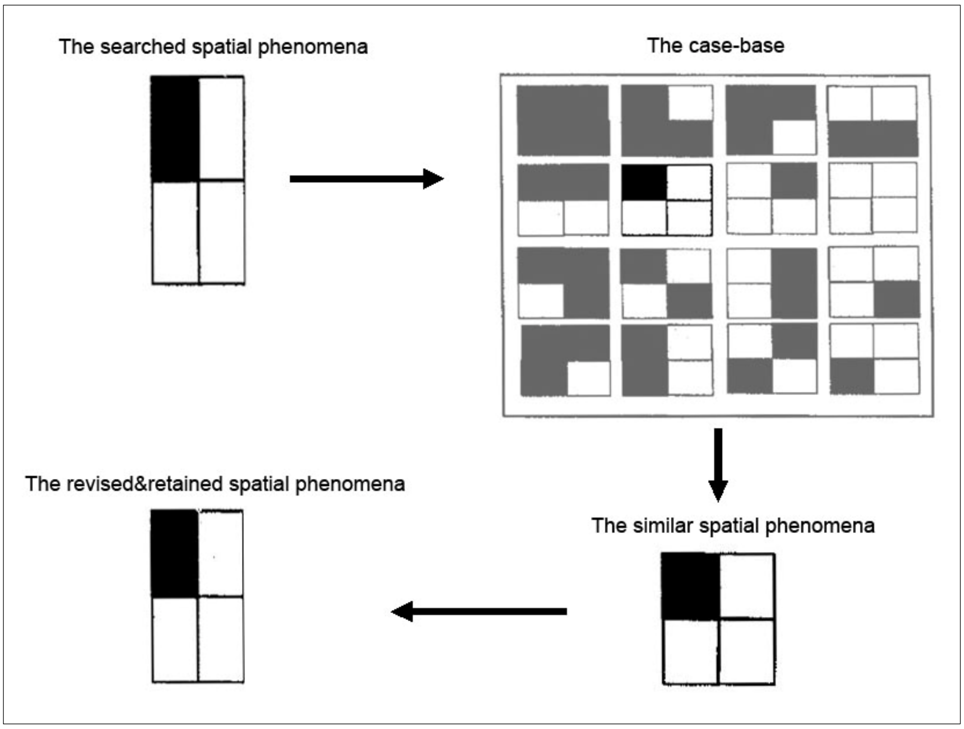


Figure 3.10. Using CBR for spatial phenomena
(Source: Holt & Benwell, 1996)

3.2.1. System Building by Integrating CBR&GIS

City planning domain has been experiencing various problems. If GIS are to be used to solve these problems, then systems with a diverse range of analytical functions are needed. Hence there have been attempts and approaches to integrate additional analytical approaches with GIS.

Within the similar studies in literature (Benwell&Holt, 1999; Shi&Yeh, 2001; Kaster&Medeiros&Rocha, 2005) CBR has been used as a part of spatial reasoning system to assist spatial/nonspatial retrieval mechanism. Most of these approaches consist of CBR and GIS to form a hybrid system to solve spatial/urban problems. In a planning case (in terms of CBR), spatial and non-spatial information are very important in representing the features of a case. In this manner, CBR could improve the ability of SDSS.

GIS has inevitably become a widely used powerful tool in planning. GIS can store, display and generate spatial information related to a case. Therefore a system that integrates CBR and GIS can very helpful to planning process and planners (see Figure 3.11). "*In such an integrated system CBR will provide the method for decision support in proposing a solution to a new problem or providing relevant experiences, tips or lessons to the planners"* (Shi & Yeh, 1999, p. 349). In the handling of spatial data, GIS can be an analysis, data generator, a database management system and a visualization tool (as a fundamental part of PSS).

3.2.2. Building a Sample CBS for City Planning

In this subsection (CBS for city planning), major specifications of establishing a CBR application in city planning are presented mostly by samples and reviews from the study of Shi & Yeh (1999): "The Integration of Case-Based Systems and GIS in Development Control". Based on the discussion developing an integrated model, Shi & Yeh (1999) developed a system that integrates a CBR shell (ESTEEM) and a GIS package (ArcView) to support planning process (development control) in Hong Kong. They tried to show how CBR can be used to handle planning applications in planning department. While developing this system, they went through the entire process of system building (in their study: development control): a) how to define a case; b) how to define the index of such cases; c) how to build retrieval and adaptation methods; and d) how to apply such a system to practical planning. In some studies (not in general), quantitative evaluation step were utilized for testing the whole system for verification/validation purposes.

The building of CBS includes the case library, defining an index for the cases and retrieval and adaptation methods primarily. From the functional perspective, the system has three basic parts: GIS module, CBR module and a case library. Accordingly, the system provides two kinds of retrieval methods: nonspatial and spatial.

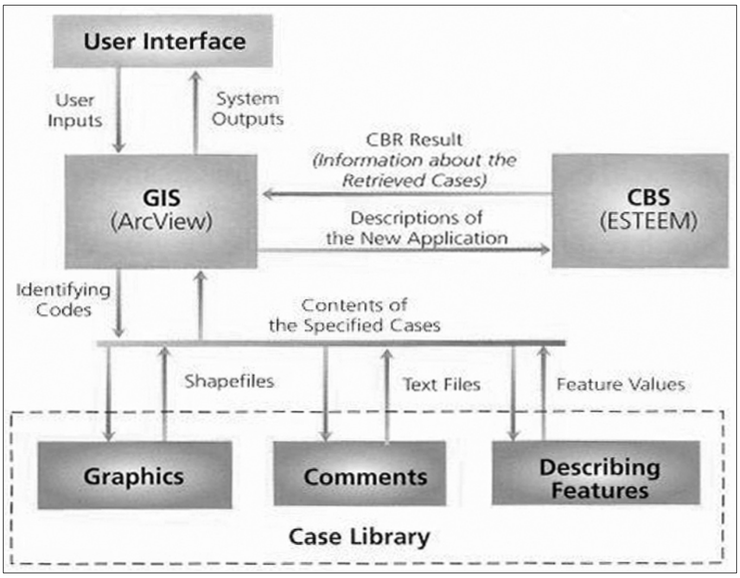


Figure 3.11. The framework of the integrated CBR and GIS system
(Source: Shi & Yeh, 1999)

The case library is the core of CBR. Two questions must be answered before building a case library: 1) What is a case in this domain? 2) What should be used to describe a case or what are the contents of a case? (Shi & Yeh, 1999) For instance, in this system, a planning application case has three parts: graphics (vector data), tabular features and comments.

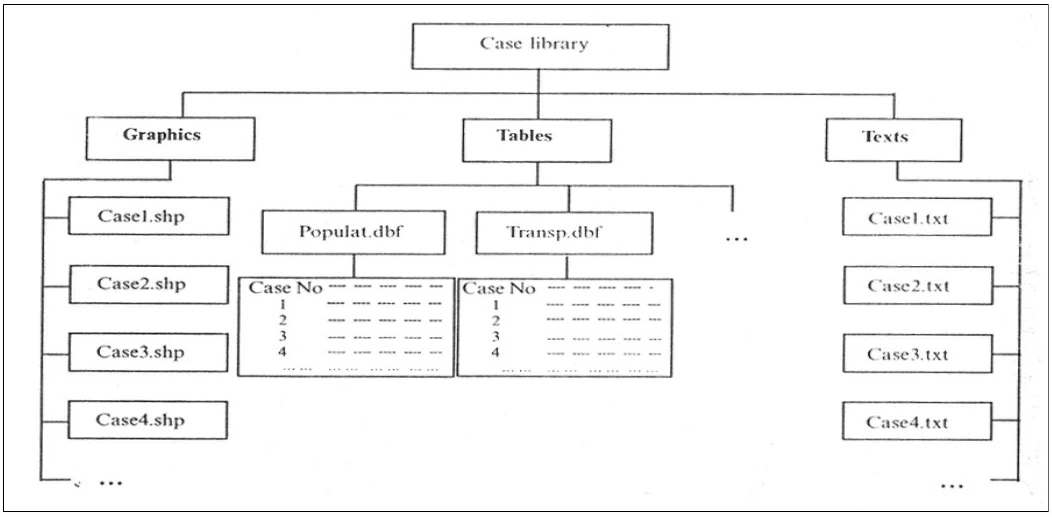


Figure 3.12. The structure of the case library of the system
(Source: Shi & Yeh, 1999)

The index of the case is the symbolized and simplified or partial description of the case. With the index, cases can be more efficiently and appropriately retrieved (Kolodner, 1993). Two types of indexes were used in this kind of CBS systems, spatial index and conventional database index. Spatial index could be built with GIS software, so user can directly retrieve cases through the index maps. Database index could be built with CBR tool (sophisticated software) like jCOLIBRI, ESTEEM, CBR Express, CASPIAN, REMIND or customized Microsoft Excel spreadsheets.

Table 3.4. The dimensions of the index for building CBS
(Source: Shi & Yeh, 1999)

Dimension	Data Type	Value Range
Time of the End	Number*	1980 ~ 2000
Planned Use	One of a List (an element from a defined list)	- I (industrial) - C (commercial) - Ra (residential group A) - Rb (residential group B) - Rc (residential group C) - G/IC (government/institution/community) - CDA (comprehensive development areas) - V (village type development) - OS (open space) - GB (green belt) - OST (open storage) - SSSI (site of special scientific interest) - UU (unspecified use)
Existing Use	Text	(Simple words describing the existing land use, such as industrial, office, oil depot, residential, natural protection, vacant, warehouse, agriculture, and so on. If the information is not available, N/I will be assigned to this dimension.)
Applied Use	Text	(Simple words describing the proposed development, such as industrial, warehouse, office, low-density residential, recreational,

A theoretically ideal CBR tool should support each of the main processes of CBR (4 REs). In addition, the tool must be flexible to integrate with other systems such as GIS and must provide a user interface both for the developers and operational users. (Watson, 1996)

The cases should contain case specific details as much as possible, because they are very important for distinguishing one case from another and will directly affect the final decision. For retrieval, the system should know how to match each feature of a new application with those of a previous case and how to evaluate the similarity between two cases. The similarity assessment methods for evaluating each feature and the entire case should be defined and the value of each parameter of the algorithm must be set. (Shi & Yeh, 1999)

The nearest neighbor algorithm (NN or KNN) is used by the system (for retrieval) to find the similarity between a new problem and a previous one. The KNN algorithm is:

$$s = \frac{\sum_{i=1}^{n} w_i \times sim(f_i^I, f_i^R)}{\sum_{i=1}^{n} w_i} \qquad (3.5)$$

where s (Similarity Score) is the sum of weighted similarities of each feature and only those cases whose s is larger than a predefined threshold (for example, 60 percent) will be retrieved as the similar cases; w; is the importance of feature i, sim is the similarity assessing function for comparing feature f_i, and f_i^I and f_i^R are the values for feature f_i in the input new case and the retrieved old case respectively (Kolodner, 1993).

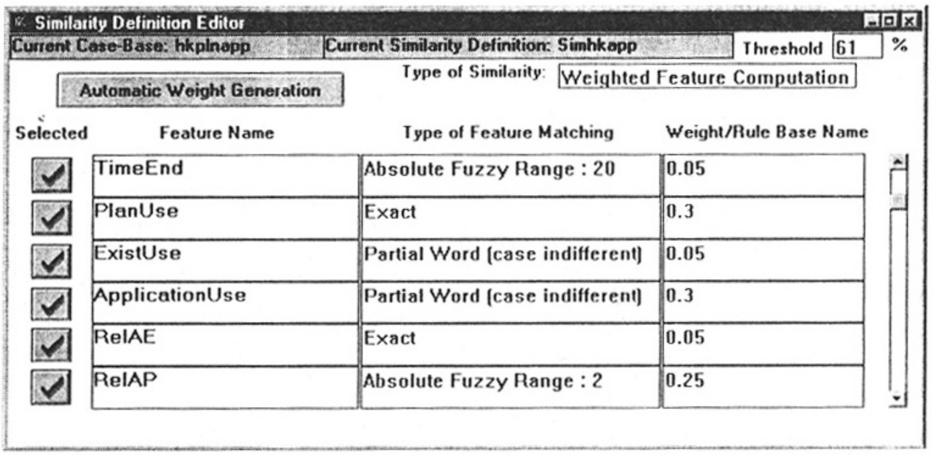


Figure 3.13. A similarity-assessment template for retrieving cases with similar land uses
(Source: Shi & Yeh, 1999; ESTEEM Software-Stottler Henke AI Software Solutions, 2006)

When retrieving cases, the system calculates the similarities of the old cases in the library. For instance, in the study of Shi & Yeh (1999), only those cases whose similarity values are higher than (or equal) a threshold (in general, this is not compulsory) set by the user will be retrieved (see Figure 3.13). In that template, the similarity assessment methods for evaluating each case are defined and the value of each parameter is set.

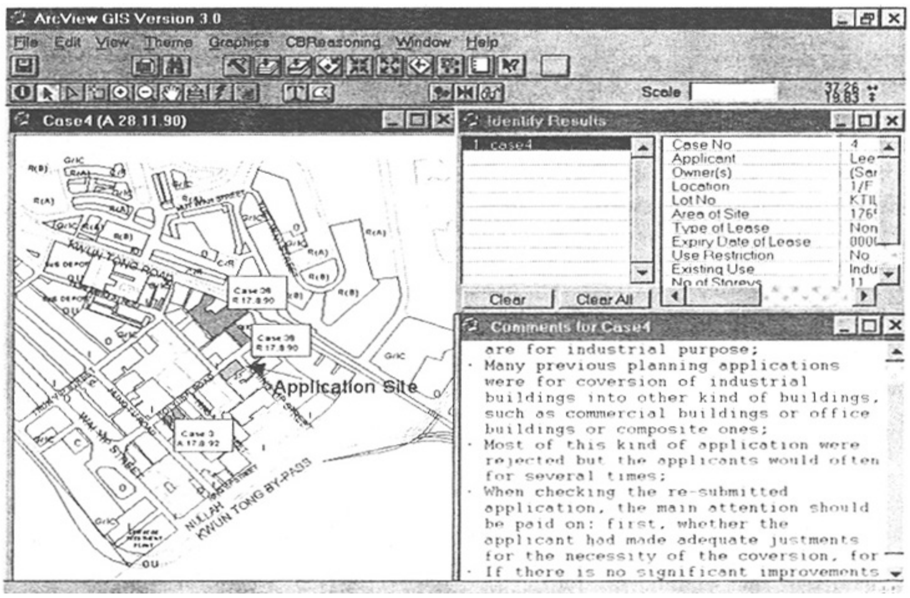


Figure 3.14. Representation of a planning application case
(Source: Shi & Yeh, 1999)

Although CBR cycle is defined by 4Re process; retrieve, reuse, revise and retain, certain studies used adaptation and learning instead of reuse, revise and retain. In most situations, it is very rare to see a new case is exactly the same as a previous case. Users have to adapt this knowledge according to the context of the new problem. Moreover, to develop an automatic adaptation process is a challenging attempt.

The reuse of the retrieved case solution in the context of the new case focuses on two aspects: a) the differences among the past and the current case and b) what part of a retrieved case can be transferred to the new case. When a case solution generated by the reuse phase is not correct, an opportunity for learning from failure arises. This phase is called case revision and consists of two tasks: a) evaluate the case solution generated by reuse. If it is successful, learn from the success (case retainment), b) otherwise repair the case solution using domain-specific knowledge (repair fault) (Aamodt & Plaza, 1994).

According to Shi & Yeh, retrieved similar previous cases could be modified to some extent to fit (adapt) new situation. For example, under the new condition, a new opinion may need to be added, a previous opinion may not be needed any more or need to be modified (Shi & Yeh, 1999). They state that the algorithms of adaptation can be presented with if-then rules:

IF new case location < > previous case location,

AND new number of parking lots > previous number of parking lots

THEN the car parking problem is not serious

There is no special learning scheme in their system, the planner can add or delete cases according to necessity and the knowledge of the system. This is the process of incorporating what is useful to retain from the new problem solving episode into the existing knowledge. The learning from success or failure of the proposed solution is triggered by the outcome of the evaluation and possible repair (Aamodt & Plaza, 1994). A new planning application can be stored as a new case. After the case is stored in the case library, planner can still modify it later with new knowledge and delete the obsolete cases. Thus the planners can easily make the system learn from practical work. Flow diagram of the whole system is presented in Figure 3.15.

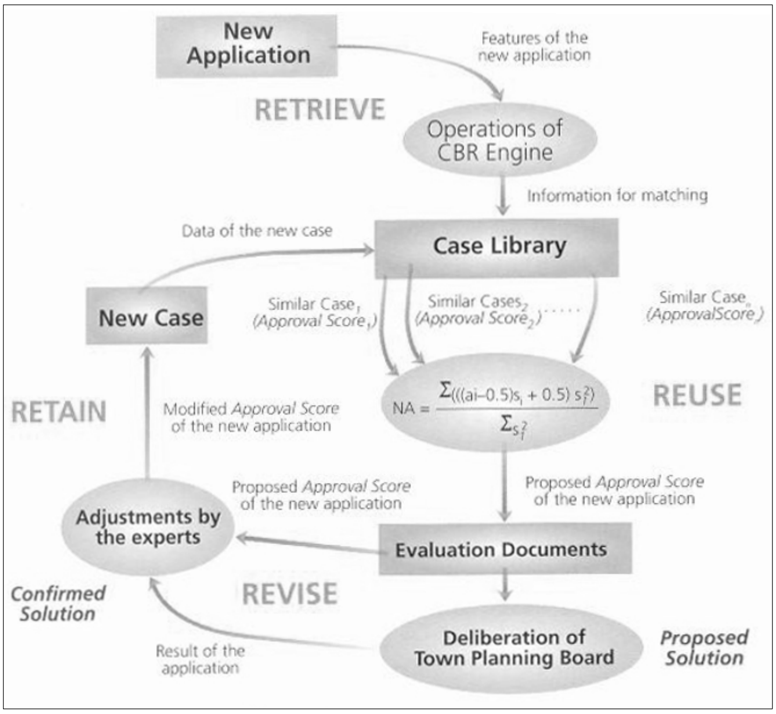


Figure 3.15. Flow diagram of the CBS
(Source: Shi & Yeh, 1999)

The aim of developing CBS is to help planners to prepare reasonable, comprehensive and consistent recommendations on planning applications. The system simulates the way of handling planning applications in which the planner has to recall and make reference to similar planning application case. Instead of doing it manually and have to rely on the experience of the planner who dealt with the case, the CBS will help the planner to re-use previous similar cases in making decisions on the new applications (Shi & Yeh, 1999). By the advances in its structure, the proposed approach will be an effective and feasible PSS in decision making process for planners. In addition to provide decision support to planners, the system can also be used as an automation system. According to authors, the capability of matching and adapting cases, which is based on "spatial similarities" and relationship, is another important topic that needs further research.

3.3. Future of CBR based Spatial Approaches

The concept of decision support and knowledge-based systems has evolved in the 1990s from a 'static' system focusing on the combination of objective and subjective knowledge into an 'intelligent' system (see Chapter 2/Table 2.2). Unlike the conventional DSS, the intelligent system is characterized by the ability to handle "novel situations and new problems" to apply knowledge acquired from experience and to use the power of reasoning effectively as a guide to behavior (Klosterman, 2001).

During the 1990s there has been a movement away from the traditional knowledge-based approaches toward the development of CBR systems along many AI techniques (Clayton & Waters, 1999; Holt & Benwell, 1999). The advantage of the CBR approach over the traditional rule-based reasoning is that it can record and represent knowledge that is hard to express with explicit rules or is too case-specific (Shi & Yeh, 1999).

A number of people who studied CBR technique state that (Shi&Yeh, 2001; Benwell&Holt, 1999; Kaster&Medeiros&Rocha, 2005; Domeshek&Kolodner, 1993) using the spatial similarity concept for exploratory spatial analysis and design proposal needs further research, because the concept have not been totally clarified and identified. For instance, retrieval of GIS maps, CAD drawings and raster images should be investigated in order to progress the technique. For example, a pollution source has the spatial relationship of distance and direction to a residential building. How to use GIS to automatically recognize this relationship and automatically retrieve cases with similar pattern needs further research (Shi & Yeh, 1999).

According to Holt & MacDonell & Benwell (1998), variety of queries and context (non-numeric, graphical, spatial, etc) could be used for similarity measuring and retrieval.

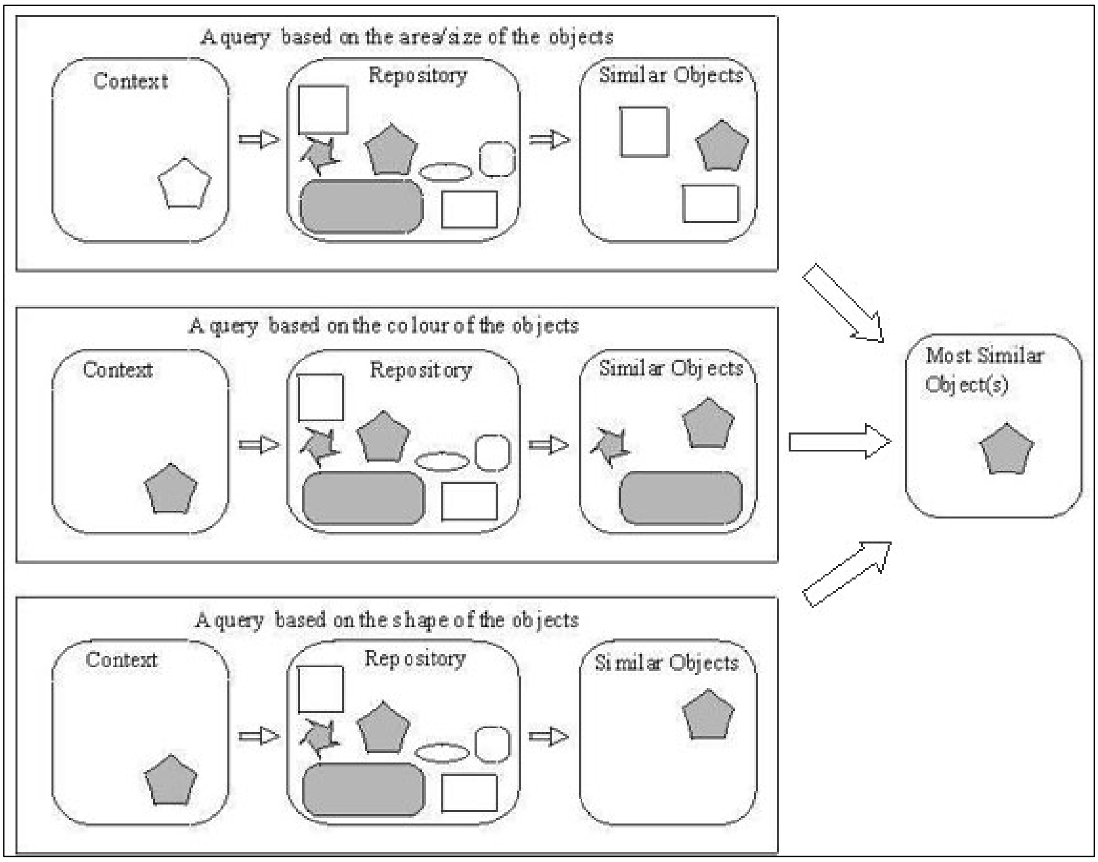


Figure 3.16. A non-numeric attempt to measure similarity
(Source: Holt&MacDonell&Benwell, 1998)

Although experimental and limited CBR systems could partially and conceptually support the spatial decision making process, it is possible to develop promising and satisfactory approaches. Moreover, improving the quality and usage of CBR tools deserves another research area.

In Chapter 2&3, the brief survey on literature have been done and theoretical and practical lessons learned from recent studies (both PSS and CBR). In the next chapter, an empirical case study research reveals the application of desired model. In Çeşme Peninsula Study, an experimental and partly hypothetical planning process is simulated. Firstly cases are generated within GIS environment. The proposed system will try to retrieve tabular data and link the inference to spatial and exterior data. Hence, after retrieving the similar cases from the case library, to enable an extended connection to further data (about the similar cases) is considered to provide knowledge acquisition. In Chapter 4, "Çeşme Peninsula case study" illustrates the application details of the PSS model "CBS" (CBR&GIS) in city planning through a practical example.

CHAPTER 4

CASE STUDY: ÇEŞME PENINSULA PILOT PROJECT

In this chapter, a pilot study is presented for comprehending the methodology of the thesis. In order to achieve the goals of the study and to verify the hypothesis, proposed model is tested on a pilot project by integrating Case Based Reasoning (CBR) technique and GIS (which was named Case Based System-CBS formerly) as a PSS tool. Although the hearth of many PSS is GIS, PSS cannot consist of a GIS alone. It must also include other techniques to aid spatial decision support. To develop a CBS model - classification and configuration of its requisites systematically to use on an operational pilot project - is aimed. Briefly, this chapter provides details of the model implementation process on a pilot study area in Çeşme Peninsula.

This pilot study will also try to identify the proper role and advantages of using CBR and other required computer based tools in the desired planning process. Thus, it is expected that the case study will help to query feasibility, advantages and limitations of CBR technique for city planning issues. The significant features, mechanism and steps of the CBR process on planning action will be clarified in the further steps of the chapter. Running the CBS model in a case study is applied by practical usage of this approach within a partly hypothetical city planning project. It is considered that creating and using a partial PSS model could be proved in the end of the study.

The major aim of developing this pilot project is to utilize the former city planning experiences (land use pattern, geographic analyses, conservation regulations and plans) of "Çeşme Peninsula" and to estimate and interpret the possible incremental/minor applications of urban/spatial cases in the future by retrieving this experiences. In Çeşme Peninsula Study, an experimental and partly hypothetical planning process is simulated. Firstly cases are generated semi-automatically within a GIS environment by cellular representation. The proposed CBS model will retrieve the cases through tabular data and link the inference to spatial and exterior data. For instance, after the similar case(s) found, we can reach their GIS data, reports, photos, etc. Hence, after selecting the similar cases from the case library, to enable an extended connection to further data (about the similar cases) is considered to provide knowledge acquisition.

4.1. Using CBR Technique in City Planning

According to previous studies in the literature, it is clear that urban and regional planning is experiencing fundamental changes on the use of computer-based models in planning practice and education. However, with this increased use, "Geographic Information Systems (GIS)" or "Computer Aided Design (CAD)" alone cannot serve all of the needs of planning.

In order to predict the probable future, urban professionals need to understand how the new technologies act in the planning process and urban space. For practitioners in urban planning, the main goal is to understand ICTs' potential in solving the current urban problems (Maldonado, 2004). Computational approaches should be modified to deal with the imperatives of contemporary planning by using planning support tools and artificial intelligence techniques in city planning process.

As mentioned in the Chapter 3, CBR is an artificial intelligence technique. There are several definitions about "CBR technique" in the literature:

- Using past cases to make a decision,
- Using suitable answers of recent problems for solving new ones,
- To use previous similar cases to solve, evaluate or interpret a new problem,
- Modeling by past events.

Undoubtedly, CBR systems are domain dependent. In addition, real planning problems and their solutions are specific and local. But they can be used in a specific CBR model which adjusted to local situations.

For the success of the CBR method, user/expert must be informed about the concerned scientific field. This method starts by the definition/query of the new case as an input, and releases the most similar case(s) as an output. The process of CBR method is an open source application and it is distinguished from other techniques (like rule-based/black box methods) by using concrete knowledge base or experimental facts for knowledge inference. Therefore it is decided that the practical/local usage of the CBR technique could benefit the city planning process. In the next section, application of the model to the city planning discipline is tested on a pilot project to comprehend predefined goals of the thesis.

4.2. System Development in Çeşme Peninsula

Previous city planning experiences could be used to make new plan decisions/recommendations. Consequently, a digital archive and a working reasoning model are needed to verify this hypothesis on a real case.

In this study, it is tried to provide a spatial decision support model. When developing minor/incremental implementations (assumed as a new case) within a structurally planned region like Çeşme Peninsula (see Figure 4.1&4.2), we can find most similar recent cases and use their knowledge in decision making. There are no universal CBR methods suitable for every domain of application. In this respect, the following subsections provide model implementation process in Çeşme Peninsula.

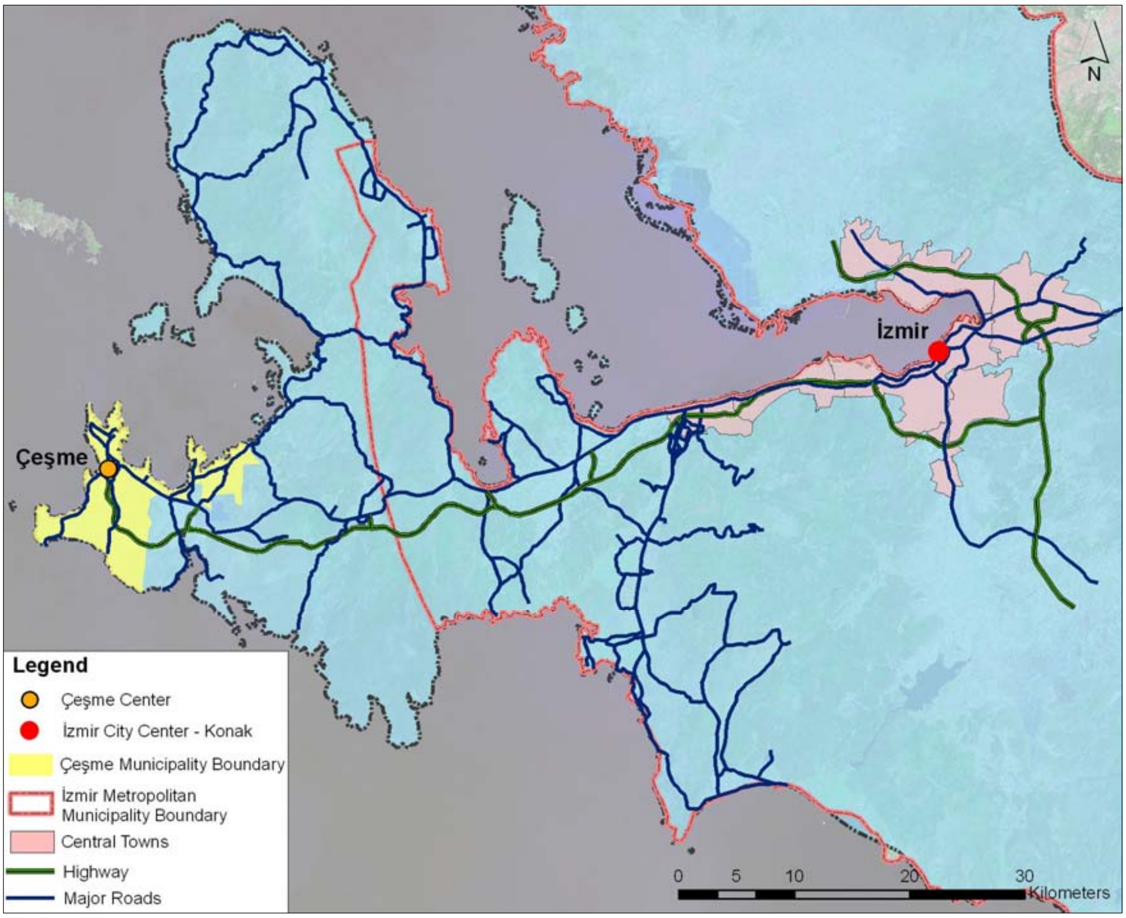


Figure 4.1. Location of Çeşme Peninsula in İzmir Metropolitan Area

Figure 4.2. Project area–Çeşme Municipality boundary
(Source: Google Earth, 2009)

4.2.1. Selection of the Study Area

Çeşme Peninsula is a special place for both having natural-cultural heritage and development potentials. Çeşme is under pressure of continuous tourism investment and urban development demands. There are variety of modifications on archeological and natural sites and variety of plan revisions since **1980s** in the planning history of the region. Brief information about archeological and natural sites and planning history of Çeşme region are listed below:

- **Archeological and Natural Site Regulations**

First conservation decision made for preserving the historical and natural beauties of Karaburun-Çeşme Peninsula is Resolution No: 3890 of İzmir Conservation Committee 1 in 23.07.**1992**.

Abbreviations are used to symbolize conservation types in legend illustrations:

A: Archeological Conservation

D: Natural Conservation

K: Urban Conservation

Numbers are used for hierarchical order. For instance D1 are superior to D2 about conservation criteria.

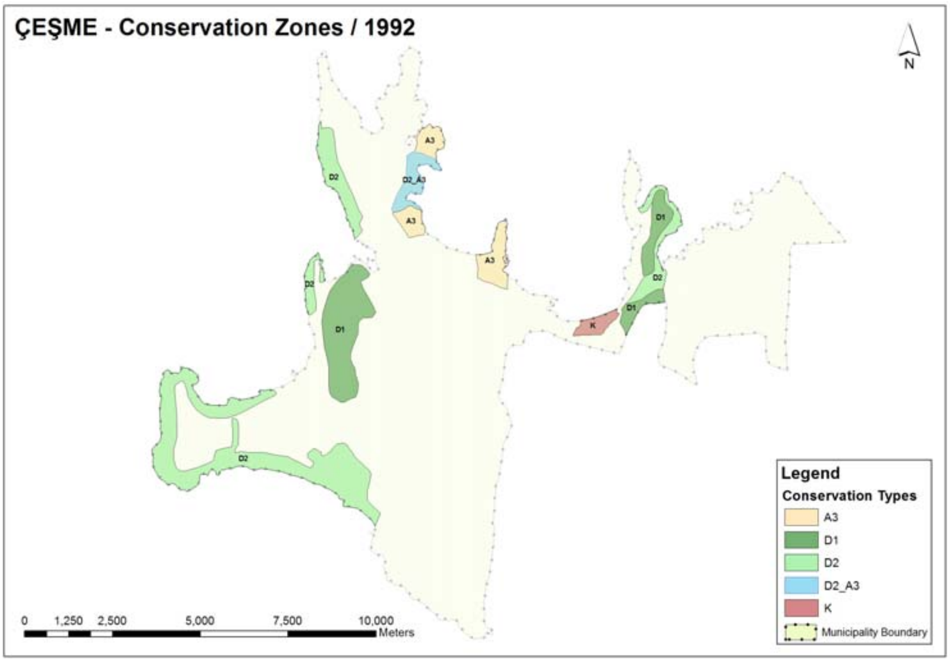


Figure 4.3. Conservation Zones – 1992
(Source: İYTE, 2002)

Later on, some changes have been made for adjusting conservation and development balance and to control informal physical development. İzmir Conservation Committee 1 stated new archeological and natural site locations and classifications Resolution No: 5928 in 06.10.**1995**.

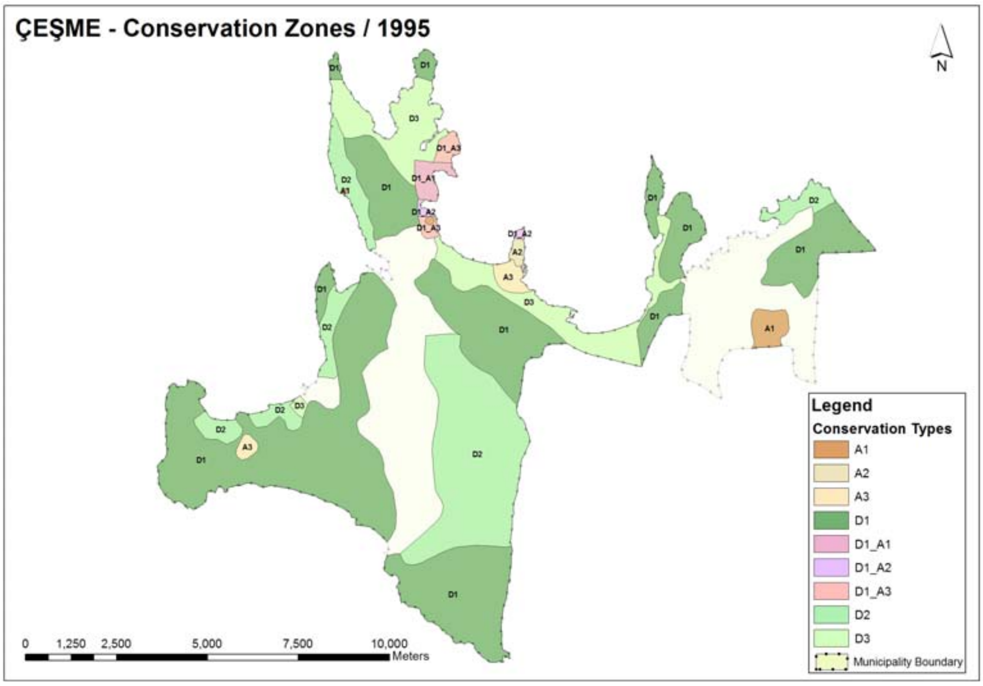


Figure 4.4. Conservation Zones – 1995
(Source: İYTE, 2002)

Conservation committee modified the archeological and natural site zones and classifications in **1996**, **1998** and finally **2006** for: a) preventing the dilemma of conservation and development by establishing a new balance between public interest and individuals' (private) interest and rights, b) sites have been classified according to their importance, characteristics and the conditions for conservation and use in that district, c) geographic analysis such as; ownership pattern, existing plan decisions, soil classification, geological condition, underground and fresh water resources, infrastructure investments and damp buffer zone used in evaluations (İYTE, 2002).

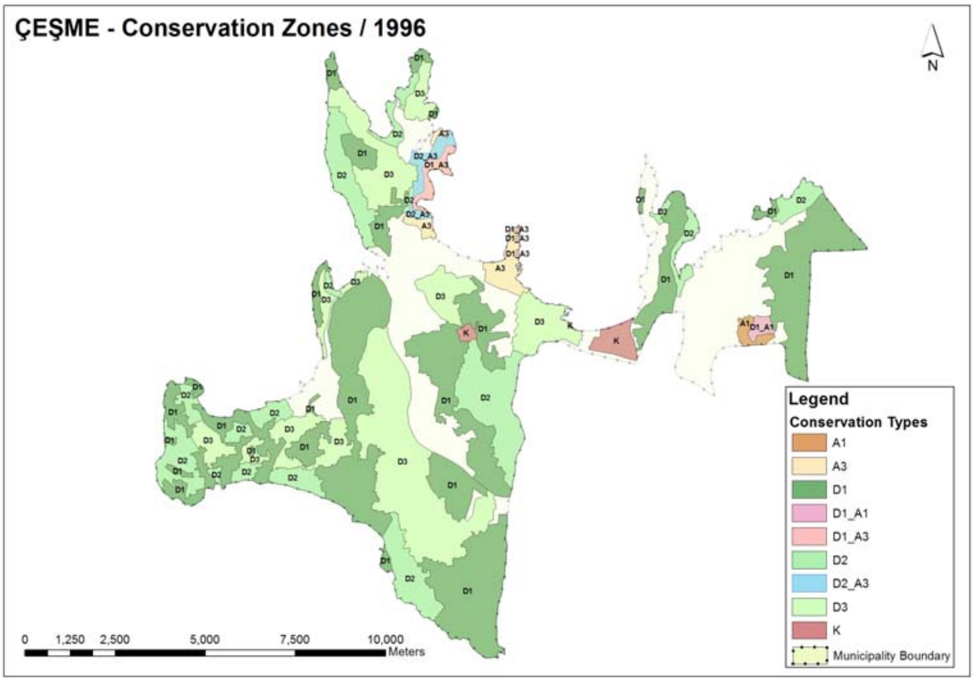


Figure 4.5. Conservation Zones – 1996
(Source: İYTE, 2002)

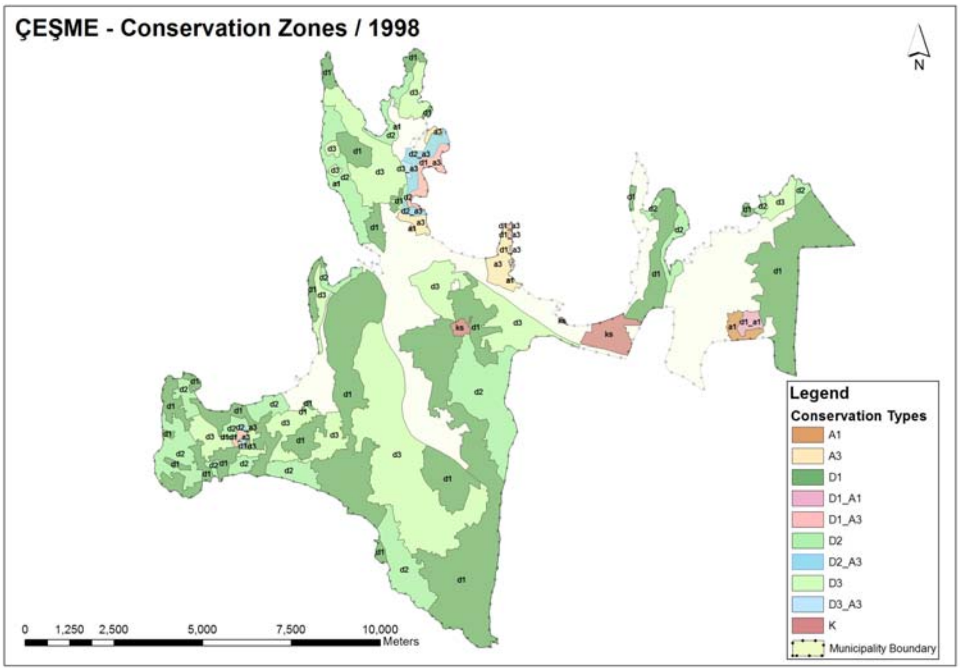


Figure 4.6. Conservation Zones – 1998
(Source: İYTE, 2002)

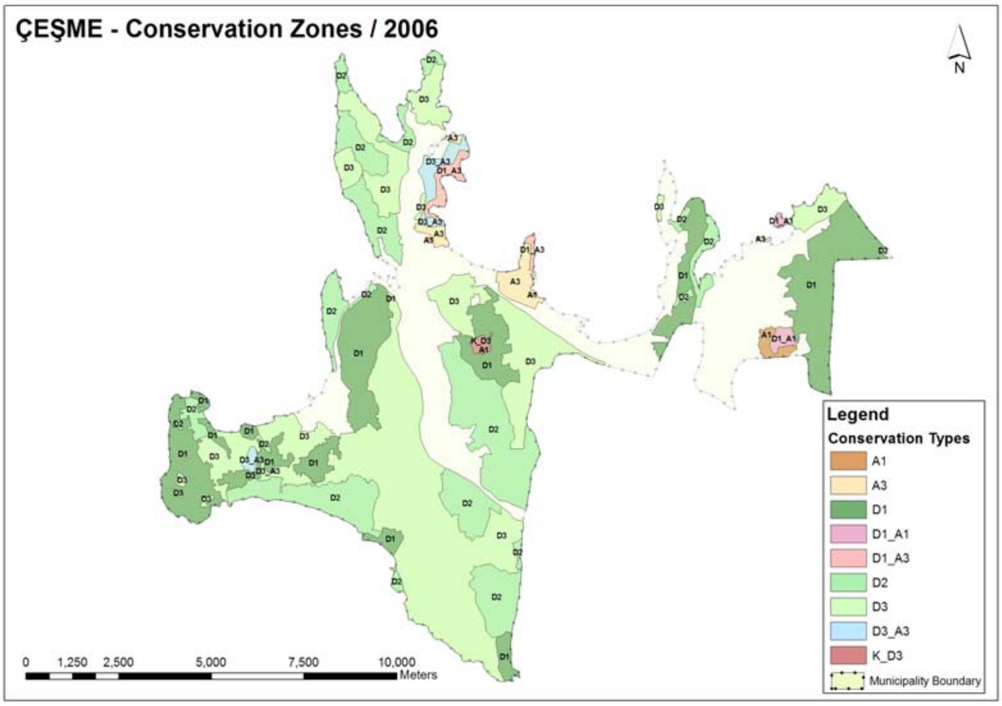


Figure 4.7. Conservation Zones – 2006
(Source: Ege Planlama, 2006)

- **Previous Planning Practices**

First structure plan (Çevre Düzeni Planı) of the Çeşme Peninsula (1/25000 scale) was prepared by the Ministry of Public Works and approved in 13.11.**1984**. The scope of the plan boundary was Çeşme, Alaçatı, Ildırı, Çiftlikköy and Dalyanköy settlements.

The next structure plan (1/25000 scale) of the region was prepared and approved by the ministry of public works and settlements in **1991**. This plan was intended for within Çeşme Municipality boundary. Çeşme Municipality made additional revisions on this plan in **1992**, but this revision was not approved by the Ministry. This revision plan was approved and implemented later by the municipality as a master plan of Çeşme.

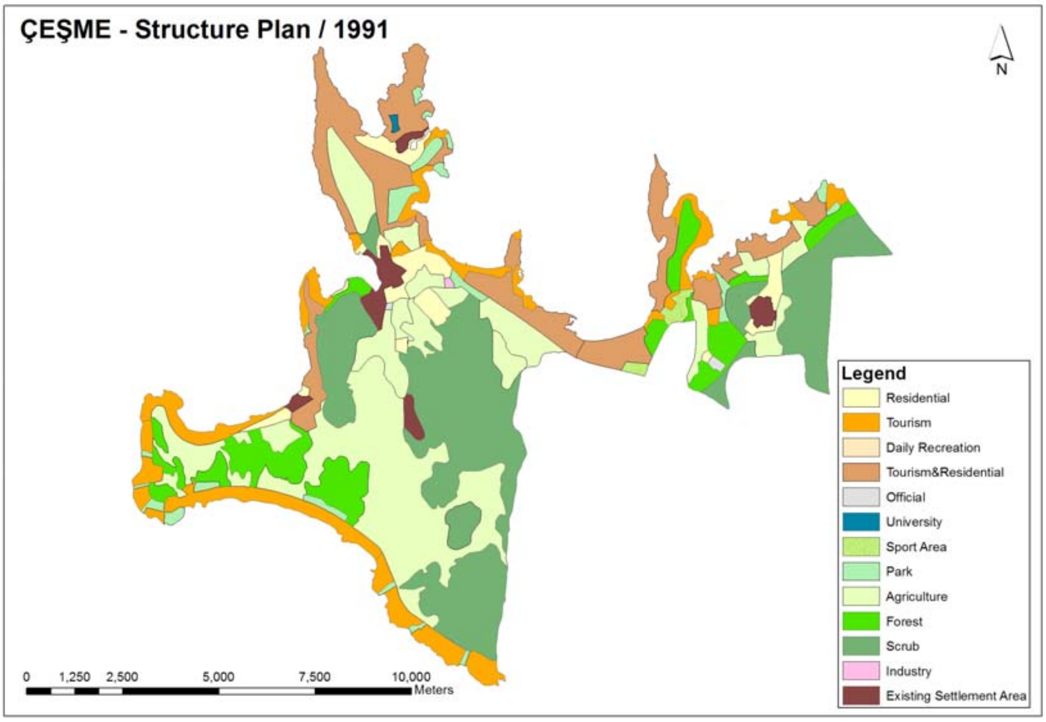


Figure 4.8. Structure Plan – 1991
(Source: İYTE, 2002)

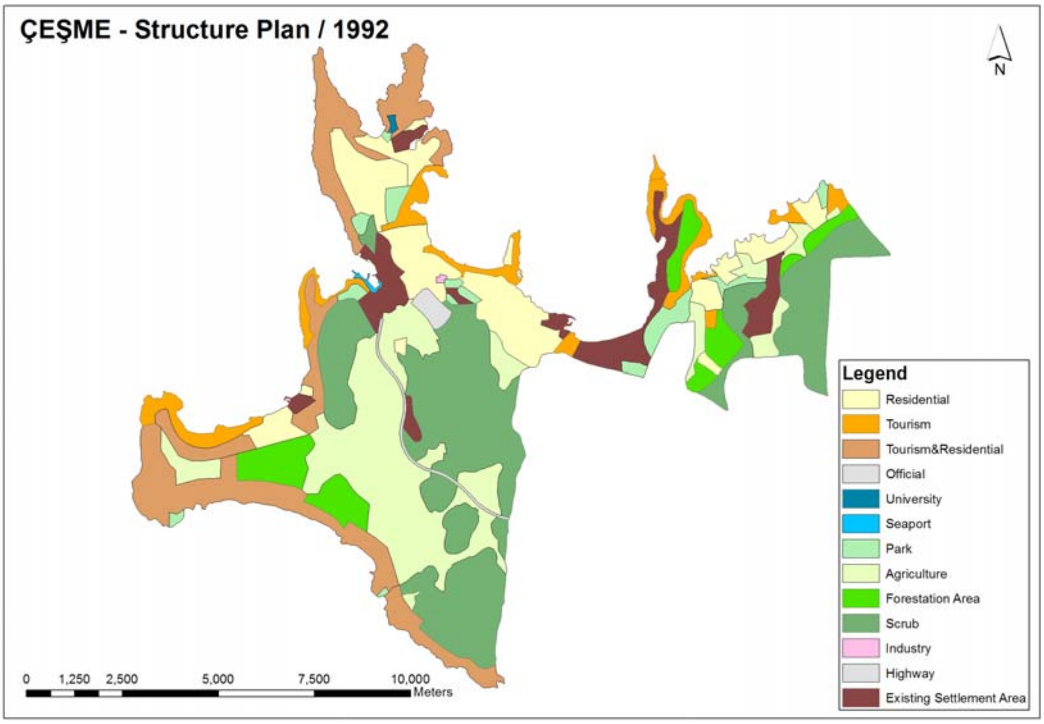


Figure 4.9. Structure Plan – 1992
(Source: İYTE, 2002)

The latest structure plan (and current) for Çeşme was prepared by İYTE City and Regional Planning Department during 1996-2002 period and approved by the Ministry of Public Works and Settlements in **2002** (İYTE, 2002).

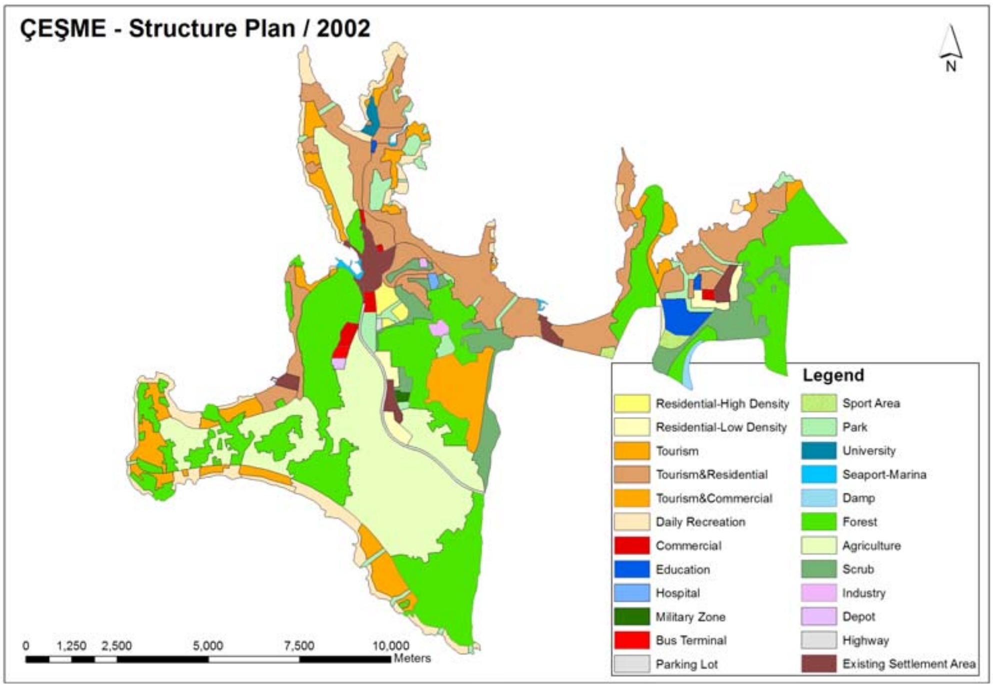


Figure 4.10. Structure Plan – 2002
(Source: İYTE, 2002)

Çeşme City (Çeşme Tourism City Project) is a part of "Tourism Strategy of Turkey-2023" project/strategy of Ministry of Culture and Tourism. Ministry of Culture and Tourism prepared a structure plan (1/25000 scale) in **2006** within "Çeşme-Alaçatı-Paşalimanı Cultural and Tourism Preservation and Development Region" which was depended on Tourism Encouragement Act No: 2634. This structure plan consists 10330 hectares of tourism development sub-regions and has been generating alterations and conflicts on existing structure plans of Çeşme and Alaçatı Municipalities.

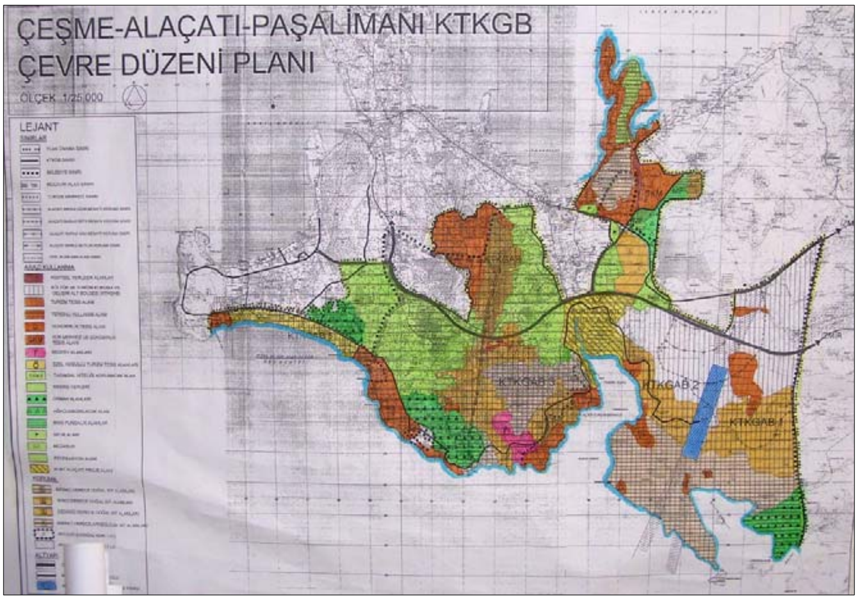


Figure 4.11. Tourism Development and Structure Plan – 2006
(Ministry of Culture and Tourism, 2007)

Ministry of Environment and Forestry provided the regional/environmental plan of Manisa-Kütahya-İzmir provinces (1/100000 scale) in **2006**. This regional plan consists of policies, strategies, spatial development and land use regulation issues of that multi-provincial region. Consequently, Çeşme Peninsula is located within the geographic scope of this regional plan (İzmir part) and hierarchically affected by the conservation and land use regulations of the plan. Figure 4.12 is derived from Structure Plan of Manisa-Kütahya-İzmir (Ege Planlama, 2006).

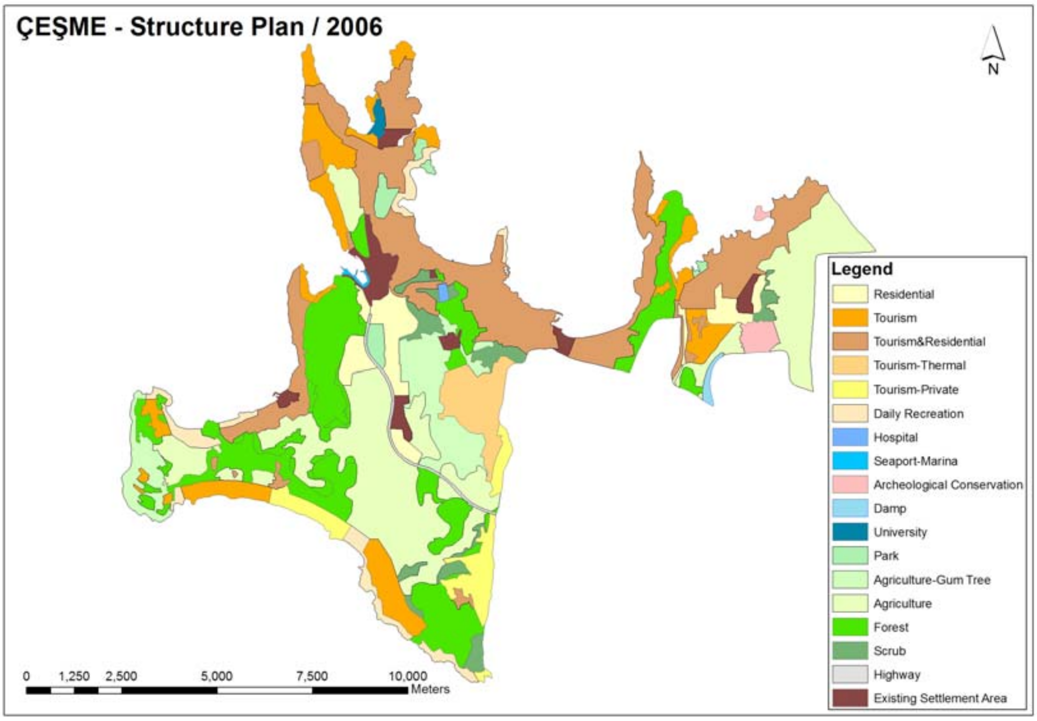


Figure 4.12. Structure Plan – 2007
(Source: Ege Planlama, 2006)

Previous-existing "planning applications and conservation decisions" which explained about the Çeşme region above are problematic and cause uncertainty in legislation-authorization and implementation. Due to the existing administrative, managerial and planning factors, it is decided that the geographic/spatial extent of the project area should cover Çeşme Municipality boundary (see Figure 4.2).

Another advantage of selecting Çeşme Peninsula region as a case study is, gathering required data like geographic analysis, natural and historical conservation zones/regulations and structure plans are available/usable. According to all these factors, it is considered that Çeşme could be a proper pilot project area for the case study.

4.3. Building the CBS Model in Çeşme

If planners try to consider all aspects of the problems/issues, city planning domain can show infinite variety. Thus, any attempt to study all the facts relating to a system is unrealistic. This situation can be overcome by simplification and with sampling methods. Planners can proceed by abstraction from the real world to symbolic representation by which to analyze, understand and deduce (Chadwick, 1971).

In this manner, it is decided that the practical usage of CBR includes a) building the case library, b) defining an index for the cases, and c) building retrieval and adaptation methods (Kolodner, 1993). In the second step, a system that integrates a CBR tool and a GIS package form the CBS. In this integrated formation, the GIS part provides the functions of handling spatial data and CBR part makes inference. In this respect, jCOLIBRI (see Chapter 4.3.2) software (CBR tool) and ArcGIS (GIS tool) software were chosen for developing the approach. In such an integrated model, CBS could provide a method for "planning support" in proposing a solution to a new problem or providing relevant experiences, tips or lessons to the planners.

ArcGIS software is used for preparing and handling geospatial data and jCOLIBRI software is used to utilize the GIS database as a case library, indexing of these cases and retrieval processes (see Figure 4.13). Firstly, spatial data and non-spatial attributes are generated by using ArcGIS as a tabular input for the CBR software jCOLIBRI. Then user must calibrate this database to develop a case library structure for jCOLIBRI.

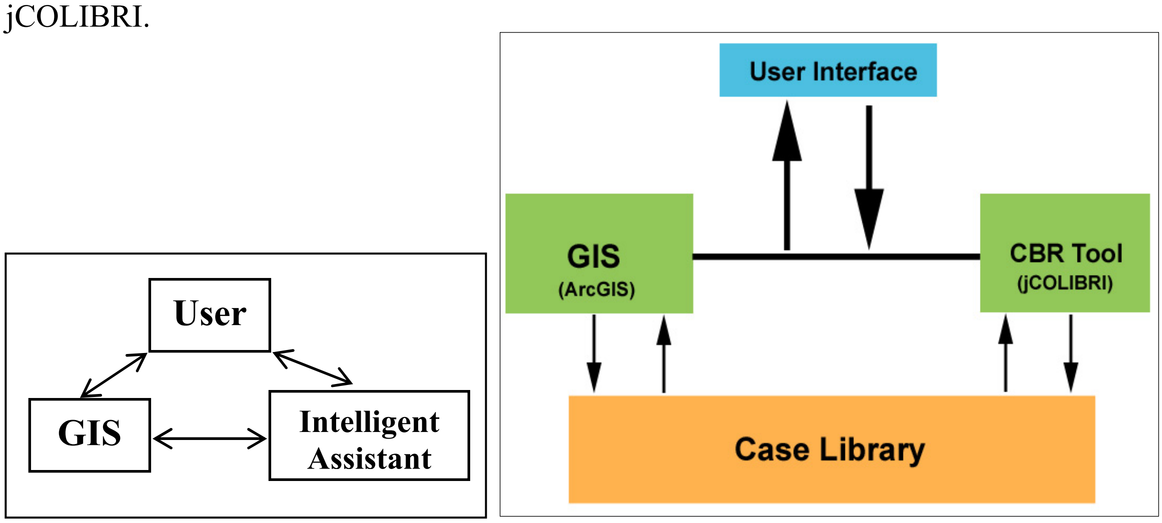


Figure 4.13. Prototype of the CBS architecture
(Source: Adapted from Lanter, 1992; Shi & Yeh, 1999)

In the process of preparation steps before running the model, data is converted from raw or existing form into one that can be used by GIS:

- Up-to-date maps and related database are presented for using in CBS development cycle,
- Spatial and tabular data were acquired, reformatted, georeferenced (if required), compiled and checked to reduce errors,
- All dataset were updated for using in ArcGIS software,
- Main features of the jCOLIBRI software were tested to use for CBR framework.

After finalizing the prerequisite works defined above, extended explanations, steps and examples for developing the CBS are presented in the next sections.

4.3.1. Developing the Case Library

Cases are the fundamental units of CBR. They are the essence of CBR and their structure in effect determines how CBR operates. A case is a contextualized piece of knowledge, representing an experience that teaches a lesson fundamental to achieving the goals of a reasoner (Kolodner, 1993).

Main steps for building a case library:

1. Defining what a case is (contents/general information),
2. Deciding which features should be used to describe the case,
3. Input the feature values for each case.

Case representation is the hearth of the CBR system, so case library should correctly represent the experience and knowledge (about the domain) we obtained before. There must be a good number of projects in the ideal case library. To acquire a data is not enough for developing a case library; this data should be identified, classified, indexed and reformatted if required.[1]

[1] Database and case base are used for different purposes. Database systems are designed to do exact matching between queries with stored information, while the goal of CBR is to retrieve most similar cases and knowledge inference.

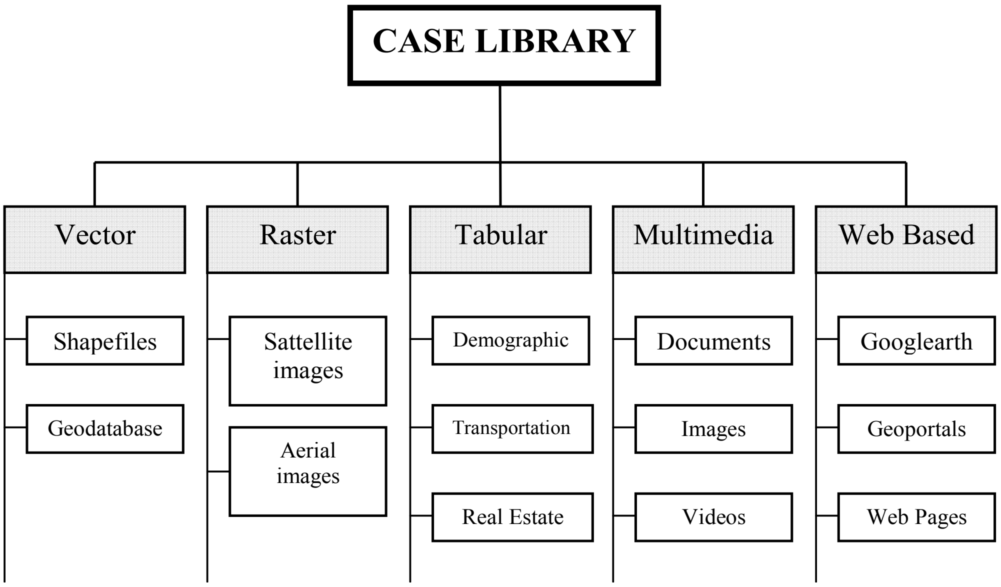


Figure 4.14. The structure of the desired case library
(Source: Adapted from Shi & Yeh, 1999)

This library topology could be extended both vertically and horizontally. In addition, by the support of relational database management systems[2] (RDBMS), GIS software facilitate to establish linkages between inner and outer components, so RDBMS could benefit the CBR process. Afterwards, we can store geodata within GIS environment and link it to other sources to build effective case library topology (see Figure 4.14).

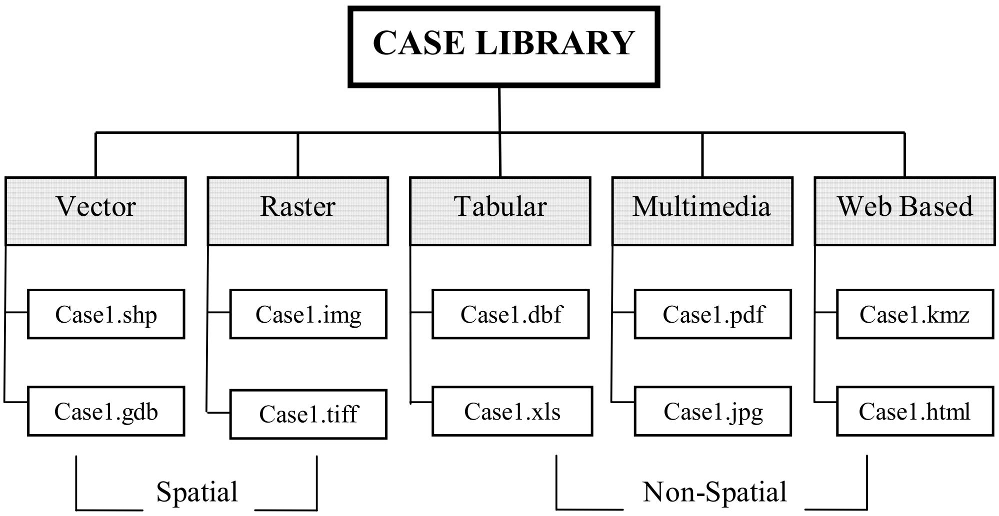


Figure 4.15. A case instance for developing case library

[2] Relational Database Management System (RDBMS): A database or database management system that stores information in tables (rows and columns of data) and conducts searches by using data in specified columns of one table to find additional data in another table. Advantages of using relational model include: easy access for users, flexibility for unforeseen inquiries, easy modification and addition of new relationships, data, records and physical storage of data can change without affecting the relationships between records (Malczewski, 2004).

A separate subsection (Chapter 4.4.4) is devoted to clarify CBR cycles within jCOLIBRI software framework and pilot study.

4.3.2. CBR Software Tool: jCOLIBRI

To operate the CBR tasks, an interactive software tool is needed. There are available CBR tools for applying the technique to the domain specific problems/issues. A theoretically ideal CBR tool should support the **4Re** process which means: **retrieve** the most similar case(s), **reuse** its/their knowledge to solve the problem, **revise** the proposed solution and **retain** the experience. In addition, the tool must be flexible/developable to integrate with other systems. Hence, CBR tools should not be stand alone tools; they must be able to import records from existing databases and communicate with other applications (Watson, 1996).

According to the selection principles given above, jCOLIBRI was chosen to use as a CBR software tool. This software tries to help application designers to develop and quickly prototype CBR systems interactively. jCOLIBRI is a Lesser General Public License[3] (LGPL) software which means; it is free, available for researchers and some source codes are open, however you can modify or redistribute it under the terms of the LGPL rules. jCOLIBRI is not developed for commercial purposes. Also when compared to previously used (some of them discontinued) CBR software tools (ESTEEM, CBR Express, CASPIAN, REMIND and others), it is free, mature, platform independent and still under progressive development both by its developers and contributions.

[3] Lesser General Public License (LGPL): The GNU Lesser General Public License is a free software license published by the Free Software Foundation. It was designed as a compromise between the strong-copyleft GNU General Public License or GPL and permissive licenses. The LGPL places copyleft restrictions on the program itself but does not apply these restrictions to other software that merely links with the program. There are certain other restrictions on this software. The LGPL is primarily used for software libraries; although it is also used by some stand-alone applications. You can use/modify these packages under the terms of the LGPL rules.

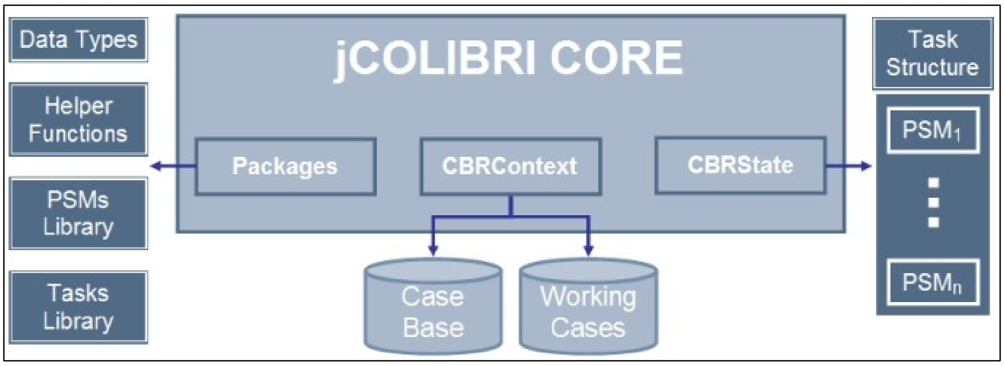


Figure 4.16. jCOLIBRI 1 core
(jCOLIBRI, 2008)

jCOLIBRI is an object-oriented framework in Java[4] programming language that aims to formalize CBR and to provide a design and implementation assistance with software engineering tools. Recio-Garcia, Sánchez, Díaz-Agudo and González-Calero from the Department of Software Engineering and Artificial Intelligence at Complutense University of Madrid/Spain intend to design a tool to help application designers to develop and quickly prototype CBR systems. Furthermore they want to provide a software tool useful for students who have little experience with the development of different types of CBR systems.

jCOLIBRI formalizes the CBR knowledge using a domain-independent CBR ontology (CBROnto) which is mapped into the classes of the framework, a knowledge level description of the CBR tasks and a library of reusable Problem Solving Methods (PSMs) (Recio-Garcia et al., 2005).

jCOLIBRI 1 is mainly aimed at CBR system designers. A CBR application can be built by instantiating the framework, or through the GUI-based configuration tools, which allow users to build the application without writing codes. Nevertheless, if we want to build a very complex CBR system or we need problem solving methods that are not available in the framework, then we can program new methods and incorporate them into the framework, contributing them for other CBR system designers to use. According to Recio-Garcia, although this initial platform was quite successful, it

[4] Java is a programming language originally developed by James Gosling at Sun Microsystems and released in 1995 as a core component of Sun Microsystems' Java platform. The language derives much of its syntax from C and C++ but has a simpler object model and fewer low-level facilities. Java applications are typically compiled to byte code that can run on any java virtual machine (JVM) regardless of computer architecture.

presented some limitations. The most important limitation was the coupling between the components oriented to developers and the composition tools for designer users. These difficulties led to develop a new architecture. jCOLIBRI 2 is the result of the experience acquired during the development of the first version. Although this improved architecture presents significant changes, it conserves many elements from the previous architecture which have proven to be good design ideas. The new design of jCOLIBRI 2 attempts to remodel the architecture into a clear white-box system oriented to programmers, and a white-box with builder layer that is oriented to designers (Recio-Garcia, 2008)[5].

In this study, jCOLIBRI software is used for the CBR part of the CBS model implementation process. To understand the utilization of CBR framework, more specific applications of jCOLIBRI will be clarified in the forthcoming sections.

[5] For more information about jCOLIBRI, see APPENDIX A

4.4. Implementing the CBS Model in Çeşme

4.4.1. How the Model Operates

The goal is to help city planners to provide planning support in solving similar problems by learning from past solutions in the city planning domain.

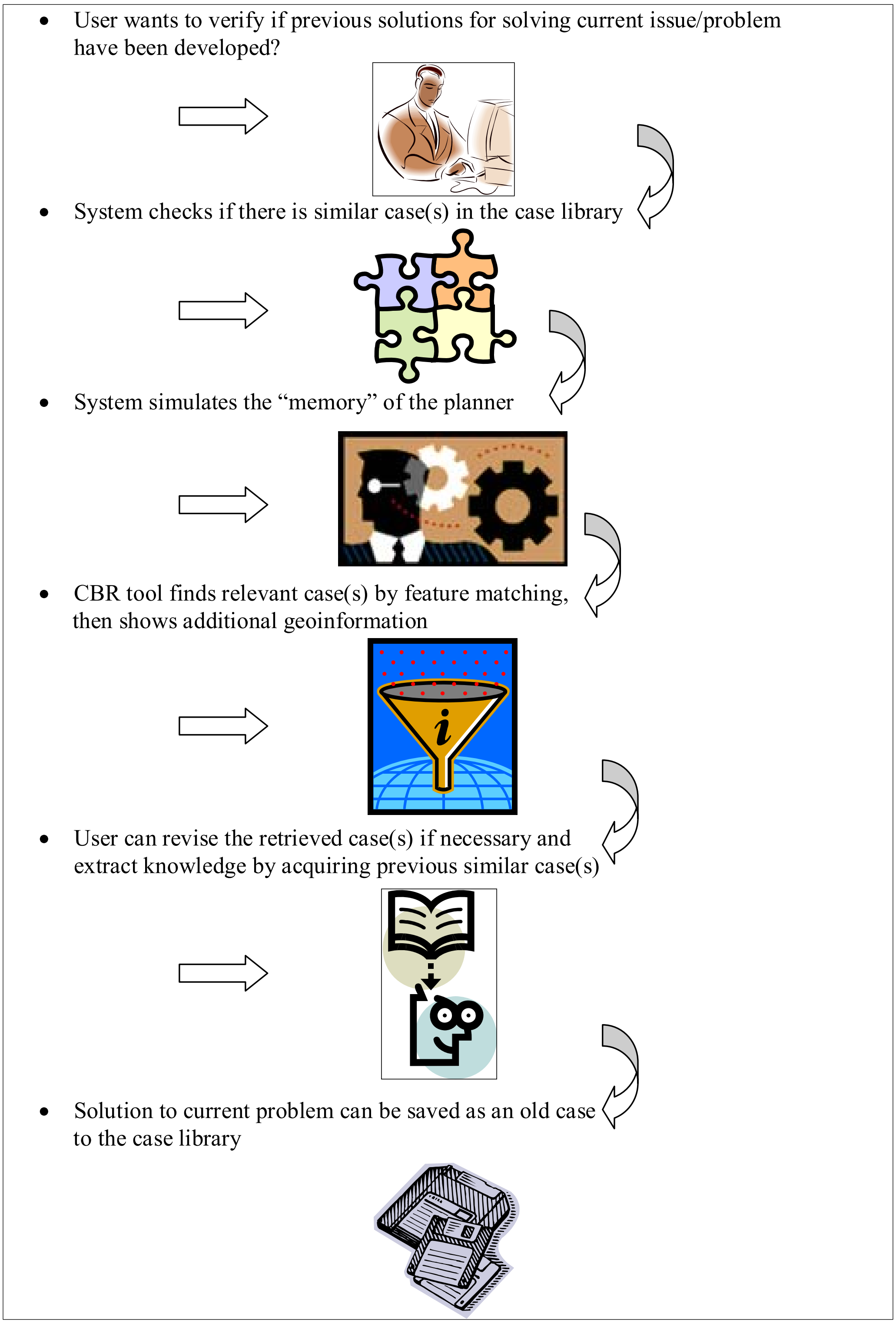


Figure 4.17. Example of use

4.4.2. Obtaining Data

Firstly GIS data of land use pattern, geographic analyses, and conservation regulations of Çeşme were used to build main case library.

The most common approach for structuring the geography of the real world in the GIS raster or vector system is to use a layered structure. The layered approach can be conceptualized as vertical layering of the characteristics of earth surface. From the perspective of building the case base, it is important to note that the layered approach - modeling the geography of a real world into a series of attribute layers- was used as a map overlay technique (Malczewski, 2004). Therefore, to build up a spatial representation of a study area, multiple layers are used.

Data Layers: Three data frames are used: land use and roads, geographic analyses and conservation zones. These analyses were generated for creating the structure plan of Çeşme by İzmir Institute of Technology, Department of City and Regional Planning in 2002. Classifications of these layers are as follows:
Coordinate System: Projected Coordinate System-metric
Projection: Universal Transverse Mercator (WGS_1984_UTM_Zone_35N)

LAND USE: Existing land use pattern and major roads:

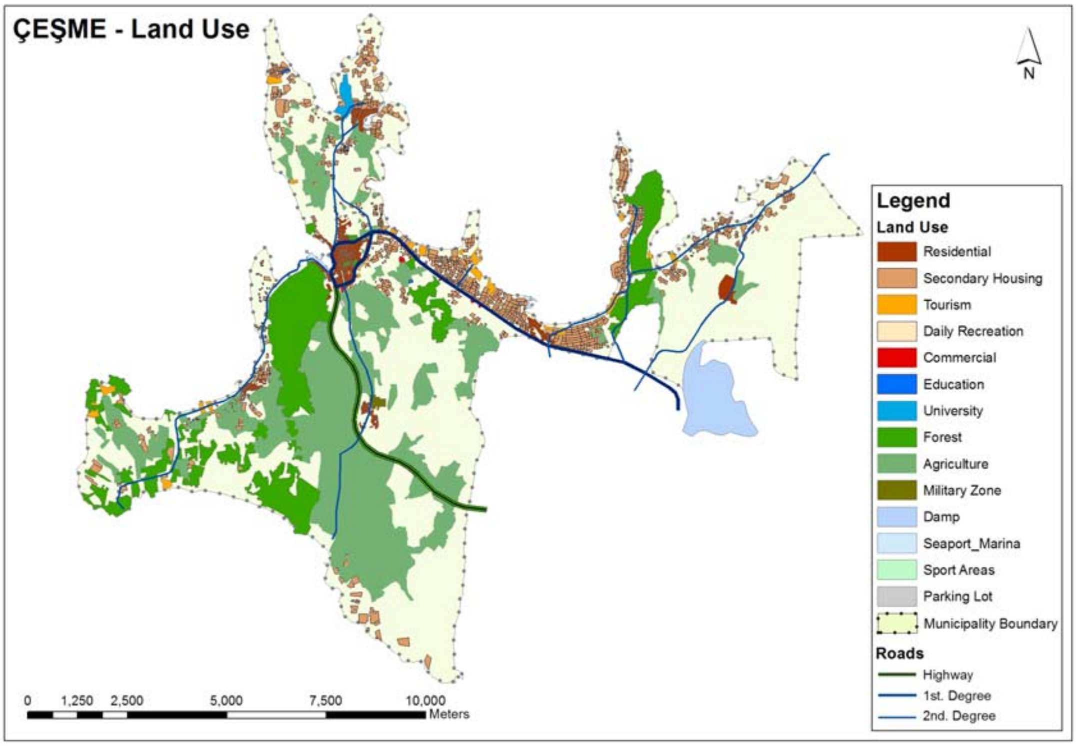


Figure 4.18. Land Use – 2002
(Source: İYTE, 2002)

ANALYSES: Ownership, Geological Formation, Slope and Seashore Buffer Zone.

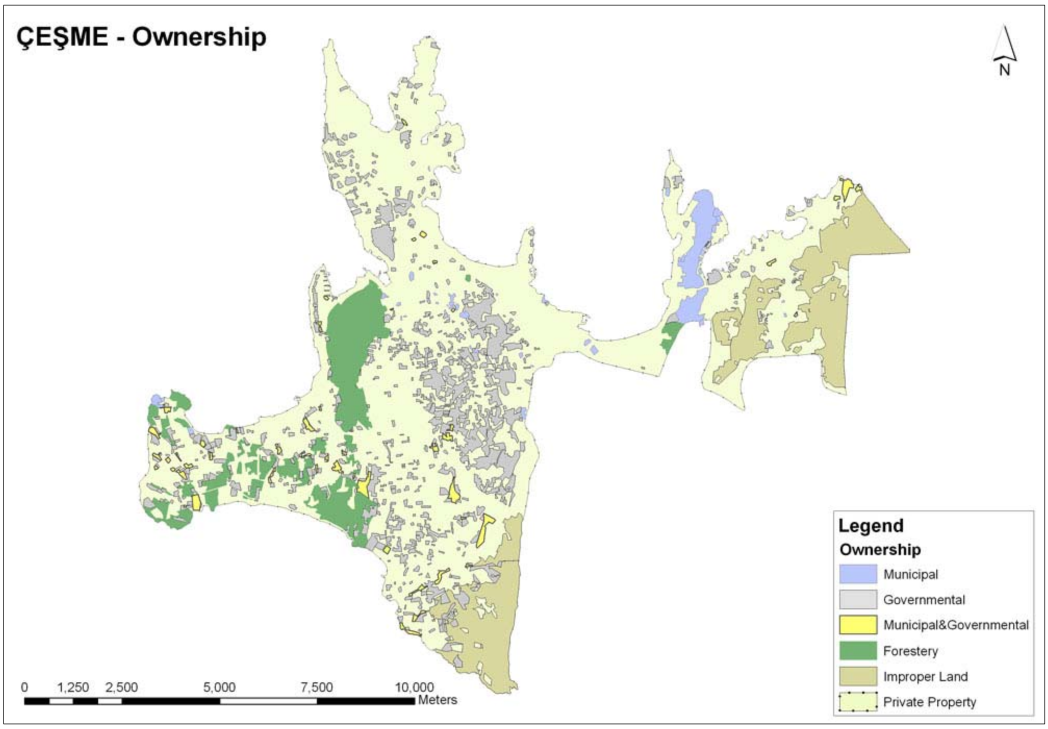


Figure 4.19. Land Ownership
(Source: İYTE, 2002)

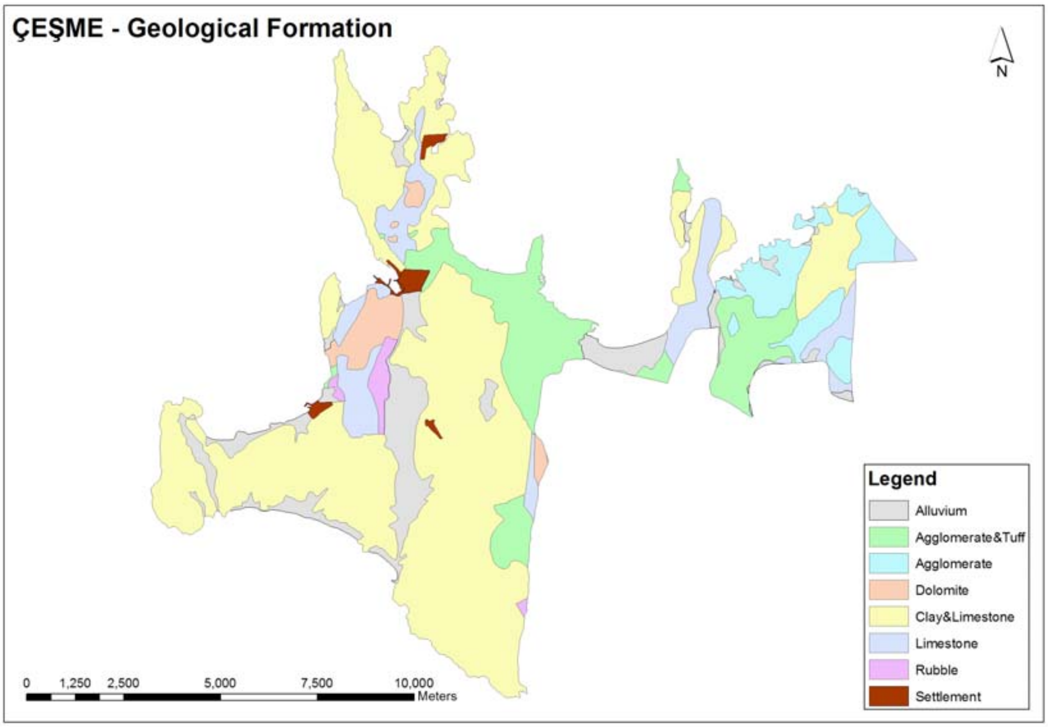


Figure 4.20. Geological Formation
(Source: İYTE, 2002)

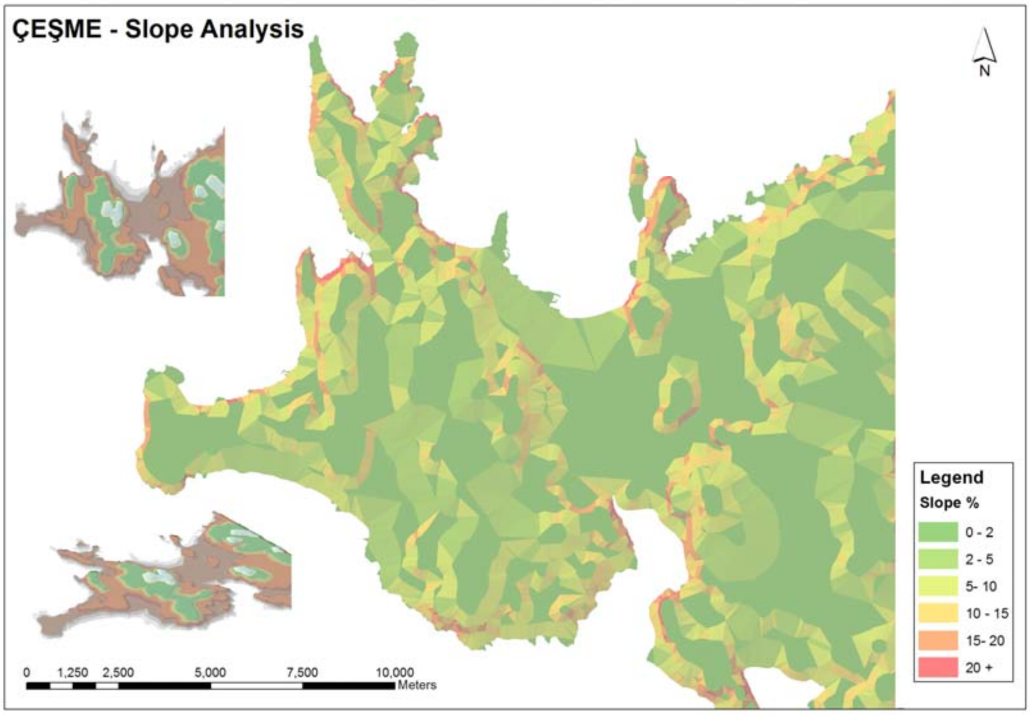


Figure 4.21. Slope Analysis
(Source: Falling Rain, 2005)

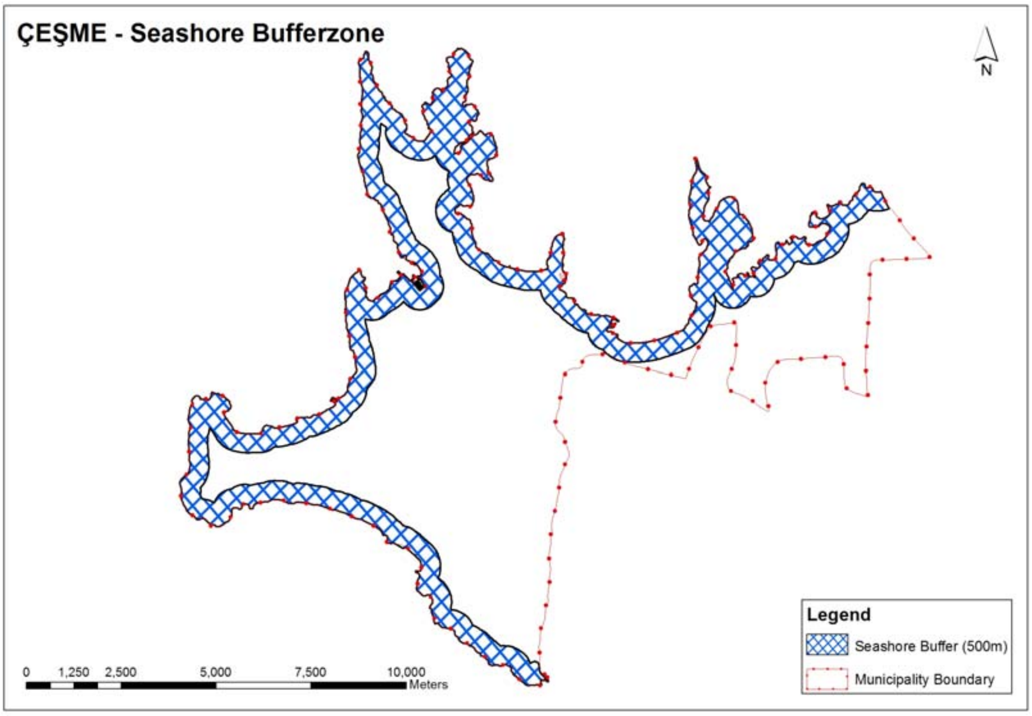


Figure 4.22. Seashore Buffer zone (500 meters)[6]

[6] It is assumed that the areas near to the seashore (within the 500 meters buffer zone) are more advantageous for settlement and recreational facilities (also could be regarded as proper walking distance to seashore) in Çeşme region.

CONSERVATION ZONES: The latest (2006) archeological and natural site zones and classifications of Çeşme.

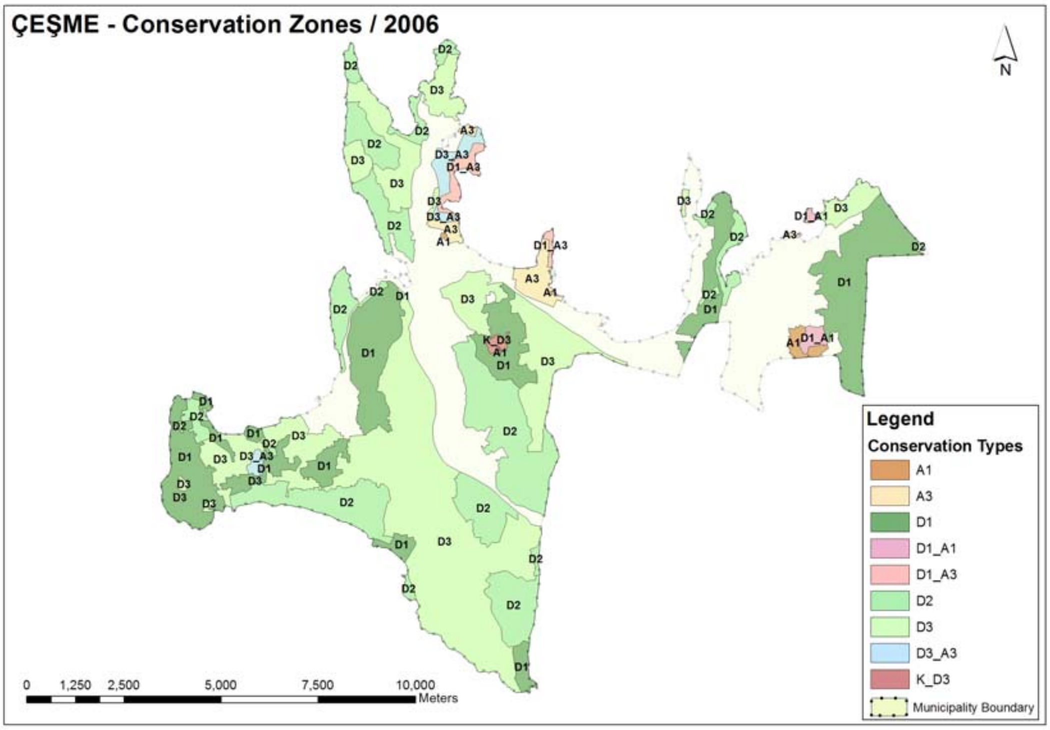
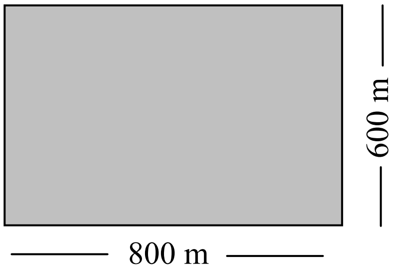


Figure 4.23. Conservation Zones – 2006
(Source: Ege Planlama, 2006)

4.4.3. Geoprocessing for Case Generation

Although the domain of city planning contains many cases, it is difficult to acquire complete (due to the lack of analyses, incomplete data, out of date information, etc.), digital and well documented real cases. So it is decided that an experimental case generation process could be organized to overcome this limitation and semi automatic case generation process is devoted to develop a unique case and their unity. To represent the spatial features by cellular representation is not a new idea in urban studies. According to Chadwick (1971), we can map our spaces as smaller sets of material on a uniform basis. The way may be conceptual and has operational difficulties, but much of the labor can be obviated by computer methods. This method includes the input and output of material on a spatial basis via a matrix of a map based coordinate grid.

GRID Layer: It is assumed that, 800m X 600m (48 hectares each) dimensioned rectangular **cell** which was derived from 1/1000 scale map units could build the spatial extent of the **unique case** in the CBS model.



There are 284 cells (rectangular polygons) joined together to generate the **grid layer** that overlays the Çeşme Municipality boundary. Grid layer is created by the "vector grid" function of an ArcGIS extension; ET Geowizards LT (ET Spatial Techniques, 2008). In the next step, only required cells are selected and extracted by "select by location" (which completely within the Çeşme municipality boundary) function of ArcGIS.

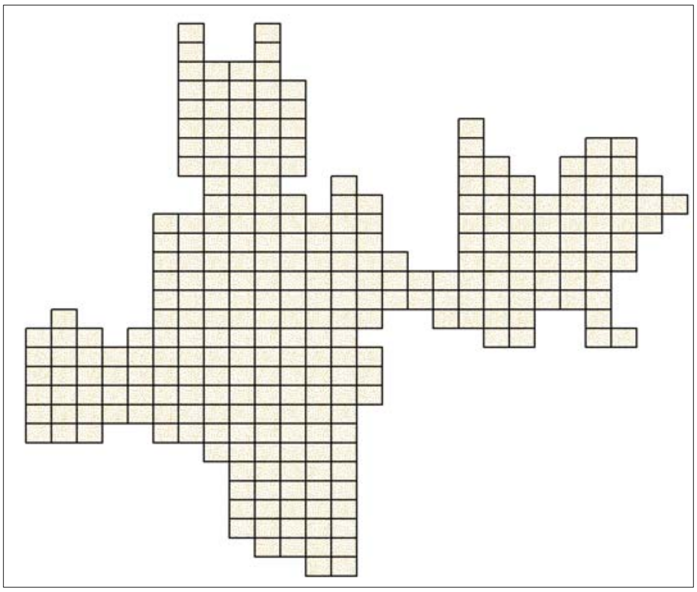


Figure 4.24. Grid layer

In this manner, a geoprocessing model (see Figure 4.25) - intersection of grid layer with other GIS data layers- is applied to compute analysis information, which drops to each cell unit. A sample geoprocessing result is presented in Figure 4.26. By the finishing of this step, cellular representation of GIS based project archive (main part of the case library) will be completed. Cellular representation is used only to generate "GIS based spatial unique cases" for urban spatial structures, so it should not be confused with cellular automata technique[7].

[7] A cellular automaton is a finite state machine (an engine of sorts) that exists in some form of tessellated cell-space. The state of each cell in the regular spatial lattice depends on its previous state and the state of the cells in its neighborhood. The states of the cells are updated according a set of deterministic or probabilistic local rules (Torrens, 2003; Malczewski, 2004).

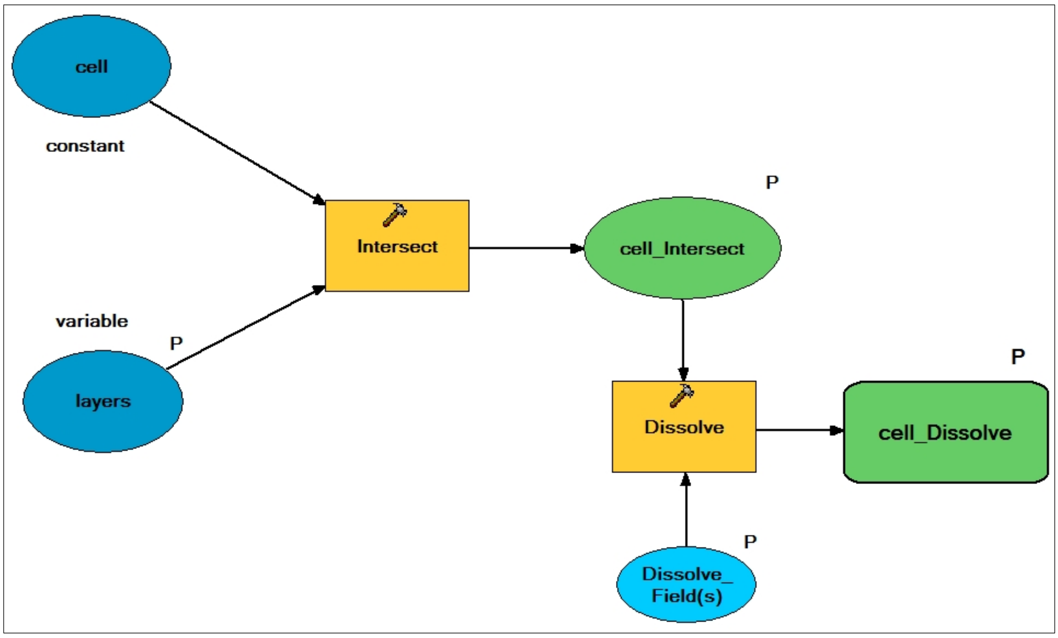


Figure 4.25. Intersection of two layers by ArcGIS Modelbuilder

This lattice space and other data layers are used to build a geodatabase which constitutes the spatial core of the case library. Another advantage of using this geoprocessing function is structural flexibility of the case library. For instance, if an additional data layer is added (or removed); case library could be updated by the execution of the model.

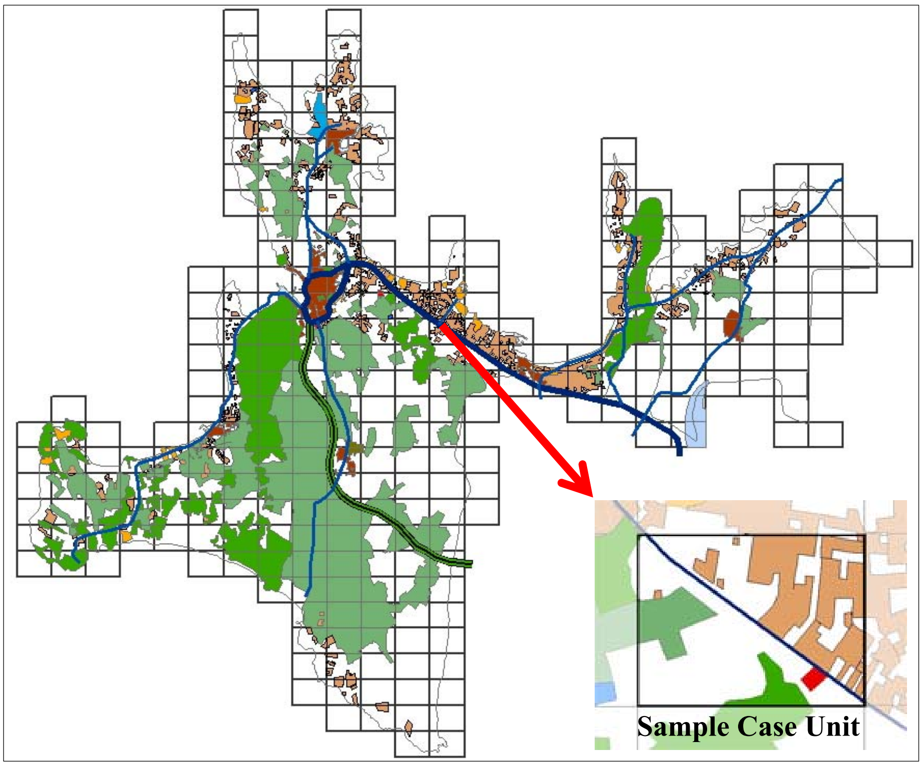


Figure 4.26. Intersection of Grid + Land-Use= areas within each case unit

After the intersection process completed, final project database (non-spatial) is produced by joining the necessary columns of all intersected layers (see Table 4.1). Another simple geoprocessing model is utilized to perform this joining operation to create the database.

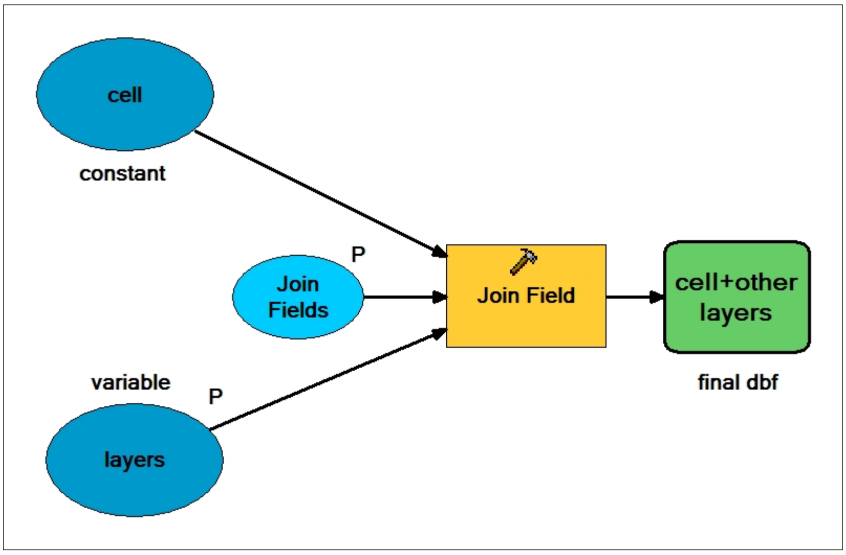


Figure 4.27. Joining the required fields of layers by ArcGIS Modelbuilder

The database can be defined as an organized collection of non-redundant data in a computer so that it can be expanded, updated, retrieved and shared by various applications (Malczewski, 2004). Feature values are stored in a table file "cell.dbf" (dbase data file format) in ArcGIS software but this table file type is independent from both ArcGIS and jCOLIBRI.

Table 4.1. Final database (dbf file) after joining all intersected layers

CaseID	Land_Use	Road_Type	Cons_Type	Ownership	Geological	Slope_perc	Sea_buffer
110	Secondary_Housing	Road_secondary	null	Private_Property	Alluvium	Slope_0_2	TRUE
110	Secondary_Housing	Road_secondary	null	Private_Property	Alluvium	Slope_2_5	TRUE
110	Secondary_Housing	Road_secondary	null	Private_Property	Alluvium	Slope_5_10	TRUE
111	Forest	Road_secondary	D1	Governmental	Alluvium	Slope_0_2	TRUE
111	Forest	Road_secondary	D1	Governmental	Alluvium	Slope_10_15	TRUE
111	Forest	Road_secondary	D1	Governmental	Alluvium	Slope_15_20	TRUE
111	Forest	Road_secondary	D1	Governmental	Alluvium	Slope_2_5	TRUE
111	Forest	Road_secondary	D1	Governmental	Alluvium	Slope_5_10	TRUE
112	Forest	null	D1	Governmental	Alluvium	Slope_0_2	FALSE
112	Forest	null	D1	Governmental	Alluvium	Slope_10_15	FALSE
112	Forest	null	D1	Governmental	Alluvium	Slope_2_5	FALSE
112	Forest	null	D1	Governmental	Alluvium	Slope_5_10	FALSE
113	Agriculture	Highway	D3	Governmental	Alluvium	Slope_0_2	FALSE
113	Agriculture	Highway	D3	Governmental	Alluvium	Slope_2_5	FALSE
114	Agriculture	Highway	D3	Governmental	Alluvium	Slope_0_2	FALSE
114	Agriculture	Highway	D3	Governmental	Alluvium	Slope_2_5	FALSE
115	Agriculture	null	D1	Governmental	Alluvium	Slope_0_2	FALSE
116	Agriculture	null	D1	Governmental	Alluvium	Slope_0_2	FALSE
116	Agriculture	null	D1	Governmental	Alluvium	Slope_2_5	FALSE
117	Agriculture	null	D1	Governmental	Agglomerate_Tuff	Slope_0_2	FALSE
117	Agriculture	null	D1	Governmental	Agglomerate_Tuff	Slope_10_15	FALSE
117	Agriculture	null	D1	Governmental	Agglomerate_Tuff	Slope_2_5	FALSE
117	Agriculture	null	D1	Governmental	Agglomerate_Tuff	Slope_5_10	FALSE
118	Agriculture	null	D3	Private_Property	Agglomerate_Tuff	Slope_0_2	FALSE
118	Agriculture	null	D3	Private_Property	Agglomerate_Tuff	Slope_10_15	FALSE
118	Agriculture	null	D3	Private_Property	Agglomerate_Tuff	Slope_15_20	FALSE
118	Agriculture	null	D3	Private_Property	Agglomerate_Tuff	Slope_2_5	FALSE
118	Agriculture	null	D3	Private_Property	Agglomerate_Tuff	Slope_20plus	FALSE

The CaseID is a number that uniquely identifies the case; also all cells have a unique name/number, for instance “10”. The descriptive features (columns) are critical parts of the case and they represent the key feature of a case, such as “Land_Use”, “Road_Type”, “Conservation Type”, “Ownership”, “Geological Formation”, “Slope Analysis” and “Seashore Buffer”.

4.4.4. Calibrating the CBR Tasks in jCOLIBRI 1

jCOLIBRI 1 software platform features a semiautomatic configuration tool that guides the instantiation process through a graphical interface. Required configurations:

Managing Connectors: Main structure of the case library should be imported to jCOLIBRI software for executing the CBR process. In this step, JCOLIBRI software demands sql[8] database (see Figure 4.28). In this respect, “dbf” file that generated before in ArcGIS software, converted to sql file (see Table 4.2) and imported to system by MySQL[9]

Table 4.2. Screenshot from internal structure of the utilized SQL file

```
final.sql - WordPad
Dosya  Düzen  Görünüm  Ekle  Biçim  Yardım

CREATE TABLE final (
      CaseID       Numeric(4),
      Land_Use     Character(20),
      Cons_Type    Character(10),
      Ownership    Character(20),
      Geological   Character(20),
      Road_Type    Character(20),
      Slope_perc   Character(20),
      Sea_buffer   Character(10)
      );

INSERT INTO final  values (   1, 'Secondary_Housing', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_0_2', 'TRUE');
INSERT INTO final  values (   1, 'Secondary_Housing', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_10_15', 'TRUE');
INSERT INTO final  values (   1, 'Secondary_Housing', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_15_20', 'TRUE');
INSERT INTO final  values (   1, 'Secondary_Housing', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_5_10', 'TRUE');
INSERT INTO final  values (   2, '', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_0_2', 'TRUE');
INSERT INTO final  values (   2, '', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_10_15', 'TRUE');
INSERT INTO final  values (   2, '', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_5_10', 'TRUE');
INSERT INTO final  values (   3, 'Secondary_Housing', 'D3', 'Improper_Land', 'Clay_Limestone', '', 'Slope_0_2', 'TRUE');
INSERT INTO final  values (   3, 'Secondary_Housing', 'D3', 'Improper_Land', 'Clay_Limestone', '', 'Slope_10_15', 'TRUE');
INSERT INTO final  values (   4, 'Secondary_Housing', 'D3', 'Improper_Land', 'Clay_Limestone', '', 'Slope_0_2', 'TRUE');
INSERT INTO final  values (   4, 'Secondary_Housing', 'D3', 'Improper_Land', 'Clay_Limestone', '', 'Slope_10_15', 'TRUE');
INSERT INTO final  values (   4, 'Secondary_Housing', 'D3', 'Improper_Land', 'Clay_Limestone', '', 'Slope_15_20', 'TRUE');
INSERT INTO final  values (   4, 'Secondary_Housing', 'D3', 'Improper_Land', 'Clay_Limestone', '', 'Slope_2_5', 'TRUE');
INSERT INTO final  values (   4, 'Secondary_Housing', 'D3', 'Improper_Land', 'Clay_Limestone', '', 'Slope_20plus', 'TRUE')
INSERT INTO final  values (   4, 'Secondary_Housing', 'D3', 'Improper_Land', 'Clay_Limestone', '', 'Slope_5_10', 'TRUE');
INSERT INTO final  values (   5, 'Secondary_Housing', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_0_2', 'TRUE');
INSERT INTO final  values (   5, 'Secondary_Housing', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_10_15', 'TRUE');
INSERT INTO final  values (   5, 'Secondary_Housing', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_15_20', 'TRUE');
INSERT INTO final  values (   5, 'Secondary_Housing', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_20plus', 'TRUE')
INSERT INTO final  values (   5, 'Secondary_Housing', 'D1', 'Improper_Land', 'Clay_Limestone', '', 'Slope_5_10', 'TRUE');
```

[8] SQL (Structured Query Language) is a database computer language designed for the retrieval and management of data in relational database management systems (RDBMS), database schema creation and modification, and database object access control management.

[9] MySQL is a type of RDBMS. The program runs as a server providing multi-user access to a number of databases. MySQL Server is available as free software under the GNU General Public License (GPL).

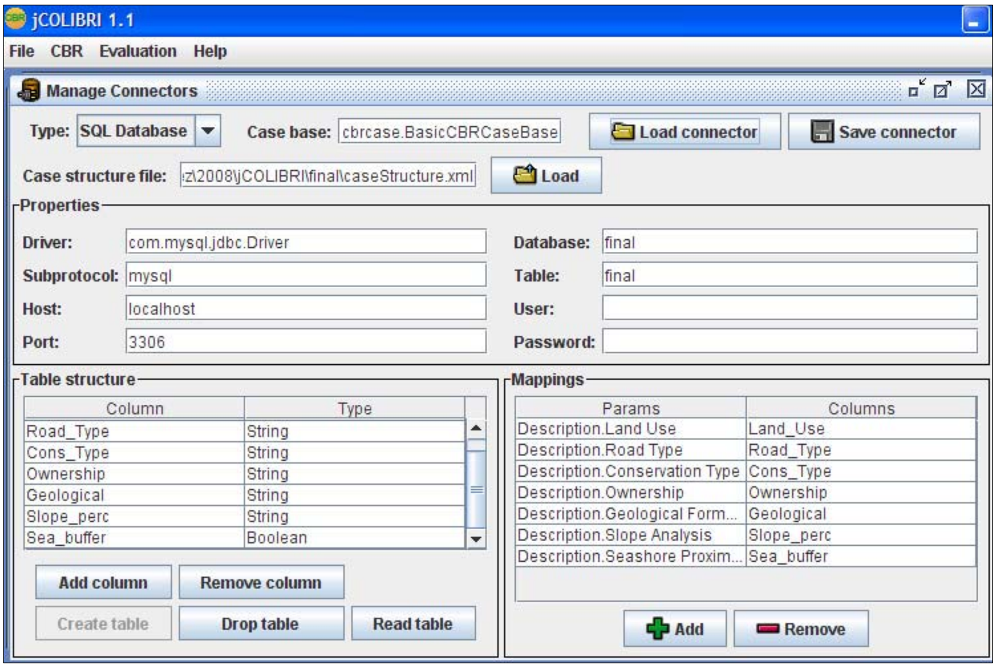


Figure 4.28. Managing case base connectors

Managing Case Structures: Sample structuring process attempt is presented in Figure 4.29. The index constraints are taken from the field values (columns of ArcGIS dbf file-see Table 4.1) input by the user for creating retrieval subsets.

Also weights for the features are assigned. When defining the case structure, a similarity measure is associated by the user to each attribute within the software.

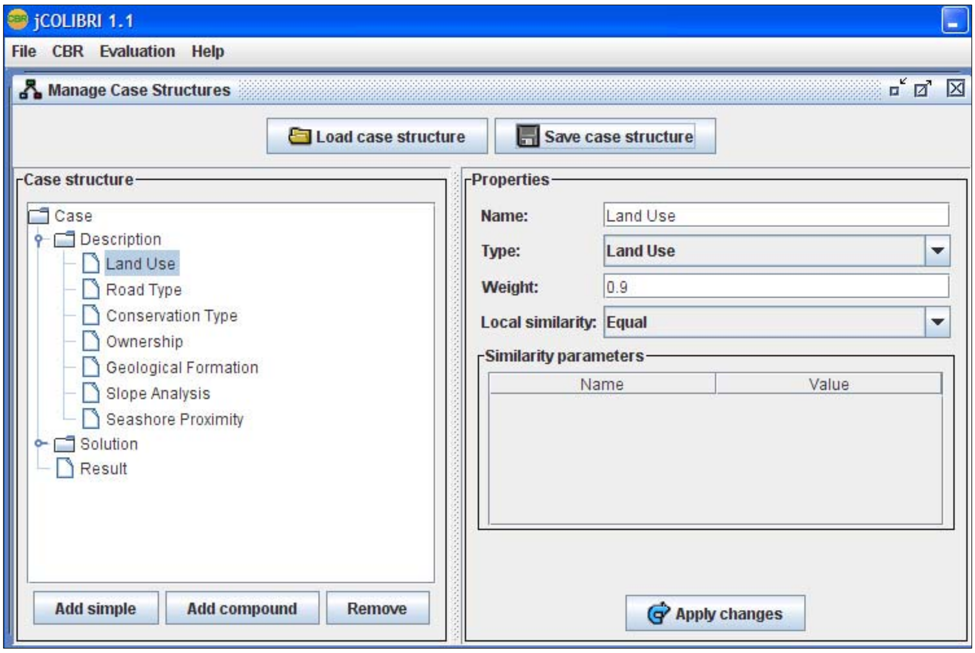


Figure 4.29. Defining the case structures (and indexing)

In calibration steps, jCOLIBRI uses the JDBC[10]/SQL connector to communicate with sql database and also user creates the case structure with enumerated data types[11].

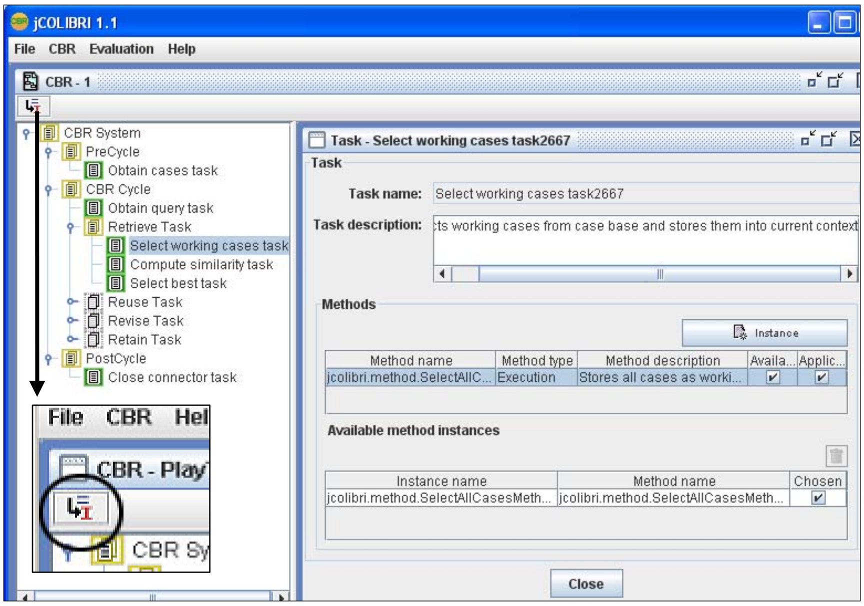


Figure 4.30. Deploying the CBR application

Configurations and also total CBR task could be saved for future use and modifying. On the main window (see Figure 4.30), each one of the four CBR tasks involves a number of more specific sub-tasks (see Appendix A). The configuration of CBR application is finished when all the tasks have been performed. You can test the system from inside the graphical interface selecting the tasks that are going to be executed in the tasks tree and pushing the "*Solve to*" button (see Figure 4.30). The effects of the execution are shown in the results window (Recio-Garcia et al., 2005).

In the next step, user (actually planner) must start to query if there is a recent case relevant to the new case (see Figure 4.17). In this respect, user must execute the jCOLIBRI tool and obtain and fill query form to compute similarity measurement. After assigning values and weights to given parameters, CBR system retrieves the similar case/cases from the case library (see Figure 4.32-4.34). In this study, retrieval process is based on tabular features of the spatial cases (non-spatial retrieval) which were generated semi-automatically within GIS software before.

---

[10] JDBC: Java Database Connectivity is an application programming interface for the Java programming language that defines how a client may access a database. It provides methods for querying and updating data in a database. JDBC is oriented towards relational databases.

[11] Enumerated Type: In computer programming, an enumerated type is an abstract data type used to model an attribute that has a specific number of options (or identifiers) such as the list of weather conditions (i.e. Rainy, Cloudy, Snowy, Sunny, etc). Using this type allows the program (and the user) to handle the attribute more efficiently than a string while maintaining the readability of the source code.

4.4.5. Testing the Scenario Based Sample Application in jCOLIBRI 1

For developing and testing the scenario, first of all case library and calibration of the jCOLIBRI 1 software should be completed. After finishing the configurations (see Chapter 4.4.4), the testing session begins by when planner outlines a set of requirements for a new plan. "Features of a new case" are entered by choosing required parameters from enumerated types (inputs) and weights are assigned. Then jCOLIBRI retrieves most similar case(s) from the case library (output) when the interface executed.

The objective of this trial is to investigate whether CBR can figure out the previous real cases to planner for aiding the spatial decision support process. At the beginning, there are assumptions before testing the application:

- Planners encounter similar cases when conditions are similar within the local district,
- General planning policies and procedures are often similar,
- All used GIS data layers and also case library are up to date,
- Optimized policies and allocations are already outlined by the structure/master plan.

Scenario:

When testing the local CBR application in jCOLIBRI, assume that we have a semi-structured scenario and we need to develop a "new case" -an incremental implementation- in one of the cell within or adjacency of the study area Çeşme Peninsula and we demand to find recent similar applications to use their knowledge in decision support.

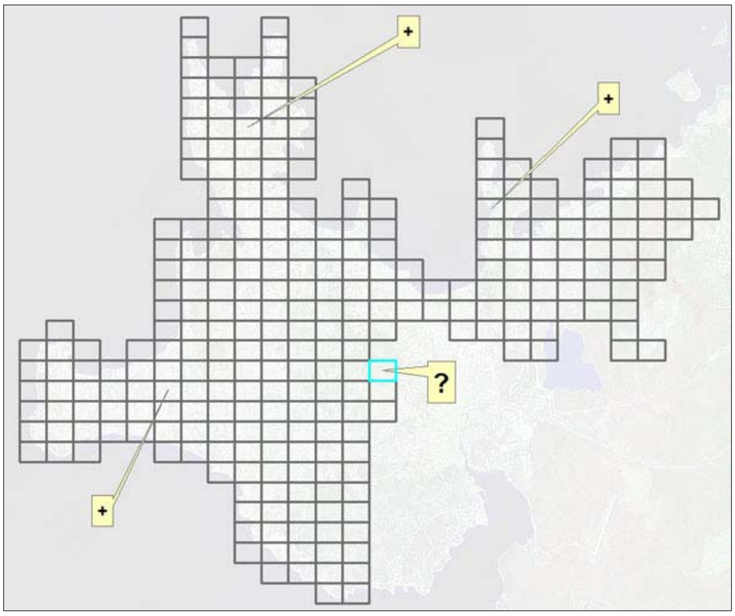
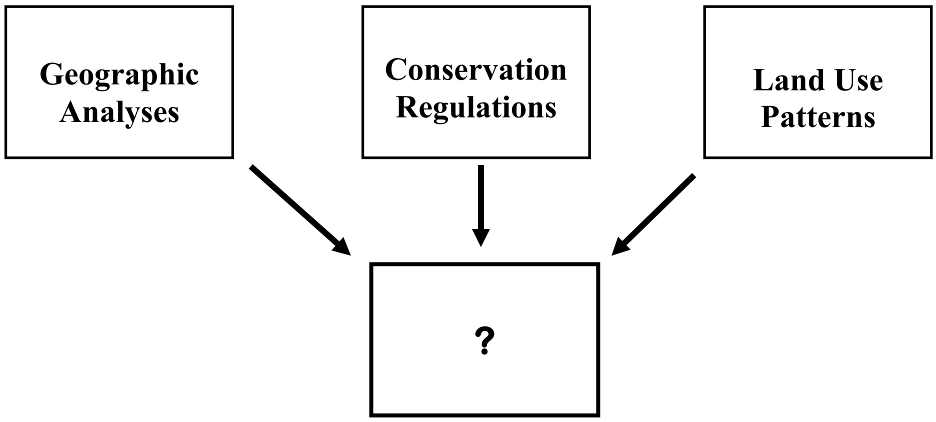


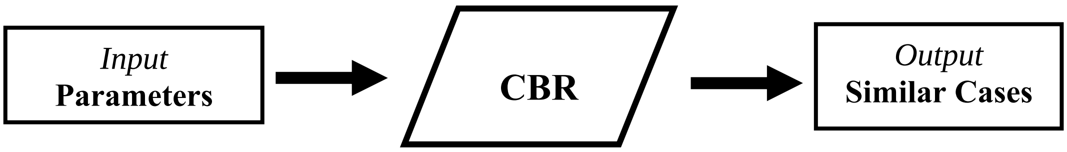
Figure 4.31. Scenario of a new case

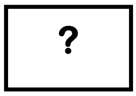
The details of the scenario could be clarified step by step as:

1) The location of the new case is within or adjacency of the Çeşme Peninsula,
2) We already know the existing features (geographic analyses, conservation regulations and land use pattern) of the “new case”,
3) There is no implementation plan generated for the new case unit yet,
4) And finally, we demand to find what kind of works done and decisions were given in most similar recent cases to develop an implementation.



Basically land use, geographic analyses and conservation regulations are used as an input query to search which decisions were given under the same situations in most similar cases. Another desired result of the scenario would be to distribute planning policies and regulations of the structure plan on minor/incremental ones equally by providing CBS model.



Descriptions of the new case: 

Input parameters	Feature values
Land Use	Secondary Housing
Road Type	2nd degree
Conservation Type	D3 (Natural Site Conservation-3rd degree)
Ownership	Municipal
Geological Formation	Alluvium
Slope Analysis	2-5 %
Seashore Buffer	True (within the 500m zone)

How it operates?

Parameters and features are derived from the jCOLIBRI case structure. Enumerated types/weights are assigned by the user.

$$s = \frac{\sum_{i=1}^{n} w_i \times sim(f_i^I, f_i^R)}{\sum_{i=1}^{n} w_i}$$

Nearest neighbor algorithm (knn) is used to find the similarities between cases.

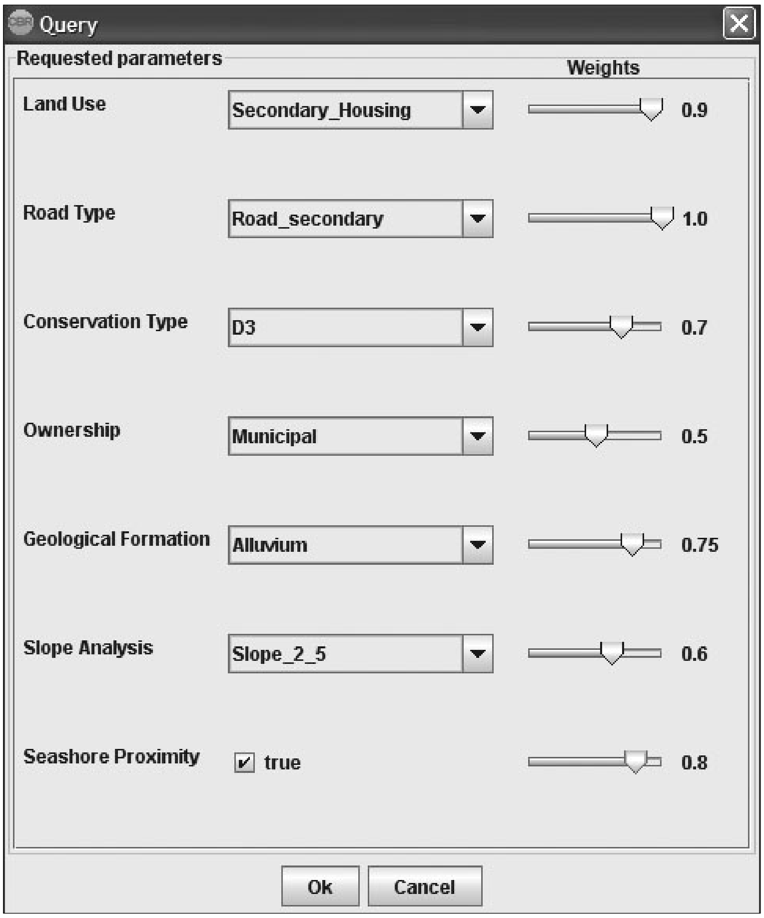
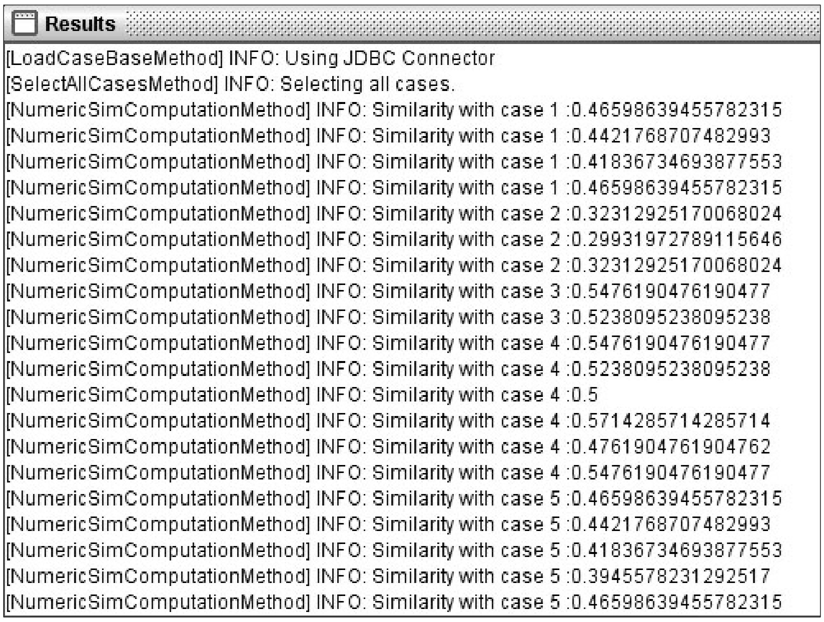


Figure 4.32. Configuration of a sample input query

Due to the given parameters and weights, jCOLIBRI searches the library by similarity computing method (knn) and gives the similarity results between 0-1 interval.



Results

[LoadCaseBaseMethod] INFO: Using JDBC Connector
[SelectAllCasesMethod] INFO: Selecting all cases.
[NumericSimComputationMethod] INFO: Similarity with case 1 :0.46598639455782315
[NumericSimComputationMethod] INFO: Similarity with case 1 :0.4421768707482993
[NumericSimComputationMethod] INFO: Similarity with case 1 :0.41836734693877553
[NumericSimComputationMethod] INFO: Similarity with case 1 :0.46598639455782315
[NumericSimComputationMethod] INFO: Similarity with case 2 :0.32312925170068024
[NumericSimComputationMethod] INFO: Similarity with case 2 :0.29931972789115646
[NumericSimComputationMethod] INFO: Similarity with case 2 :0.32312925170068024
[NumericSimComputationMethod] INFO: Similarity with case 3 :0.5476190476190477
[NumericSimComputationMethod] INFO: Similarity with case 3 :0.5238095238095238
[NumericSimComputationMethod] INFO: Similarity with case 4 :0.5476190476190477
[NumericSimComputationMethod] INFO: Similarity with case 4 :0.5238095238095238
[NumericSimComputationMethod] INFO: Similarity with case 4 :0.5
[NumericSimComputationMethod] INFO: Similarity with case 4 :0.5714285714285714
[NumericSimComputationMethod] INFO: Similarity with case 4 :0.4761904761904762
[NumericSimComputationMethod] INFO: Similarity with case 4 :0.5476190476190477
[NumericSimComputationMethod] INFO: Similarity with case 5 :0.46598639455782315
[NumericSimComputationMethod] INFO: Similarity with case 5 :0.4421768707482993
[NumericSimComputationMethod] INFO: Similarity with case 5 :0.41836734693877553
[NumericSimComputationMethod] INFO: Similarity with case 5 :0.3945578231292517
[NumericSimComputationMethod] INFO: Similarity with case 5 :0.46598639455782315

Figure 4.33. Similarity computing and retrieval: Search results between 0-1interval

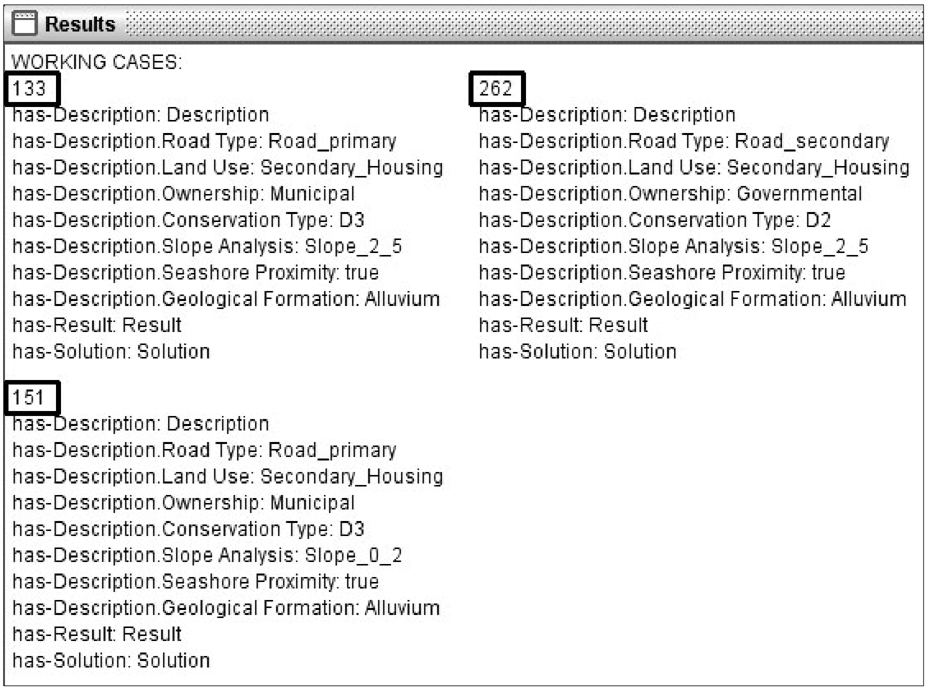


Figure 4.34. Retrieval: Selected cases due to the given threshold or amount

Similar cases are retrieved over the predefined threshold or which have highest scores, for example 3 cases are demanded in jCOLIBRI configuration and so 3 cases are retrieved (see Figure 4.34). Similarity score for most similar 3 cases are:

Similarity with case133 = 0.95
Similarity with case151 = 0.92
Similarity with case262 = 0.83

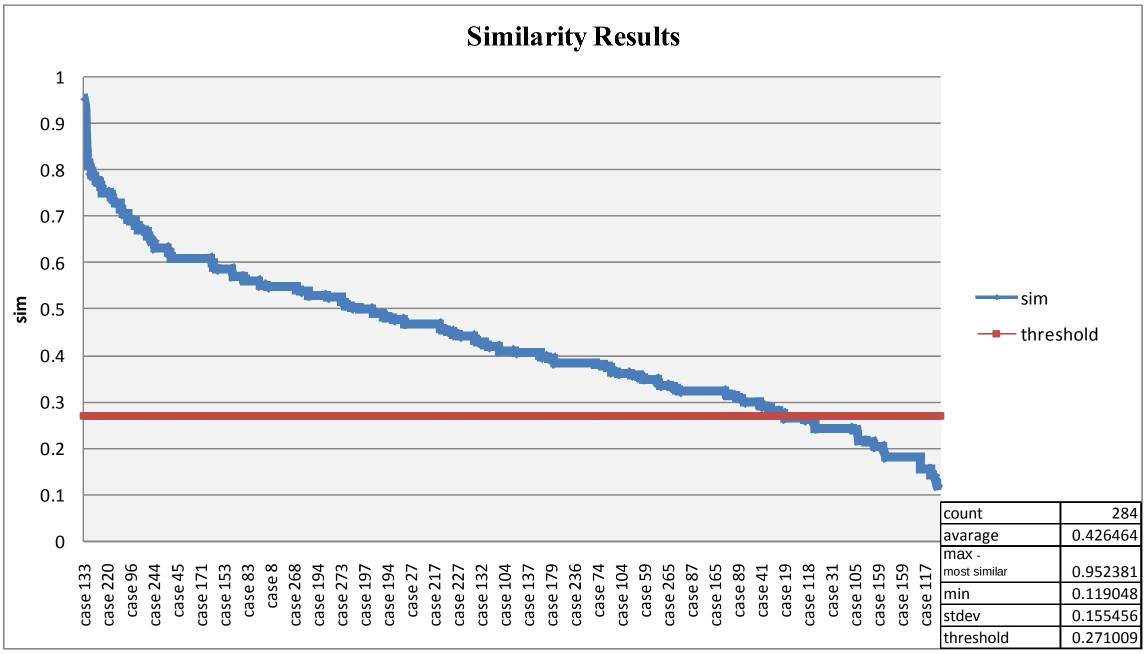


Figure 4.35. Similarity results graph

4.4.6. Testing the Scenario Based Sample Application in Customized GUI

Developments in software engineering such as object oriented programming languages have enabled the increased reuse and improved modularity of code written for specific purposes. Customizations and modifications may include the development of graphic user interface (GUI) and specialized tools relating to a particular application (for instance GIS).

jCOLIBRI 2 platform offer a framework for implementing customizations through java programming language. In this manner, an effective customized GUI which is based on jCOLIBRI 2 core architecture is developed in java development environment Eclipse. This GUI is also developed for seamless integration and user interaction.

Features:
Platform Independent Java Executable, LGPL

Java Development Environment: Eclipse
Developer: Software Engineer Gürcan Gerçek
Algorithm/Workflow Design: Gürcan Gerçek&Ali Kemal Çınar
Consultant: Assist. Prof. Dr. Tuğkan Tuğlular
Source Code: Software Engineer Recio-Garcia Juan (jCOLIBRI 2/Test 8&Test 17)

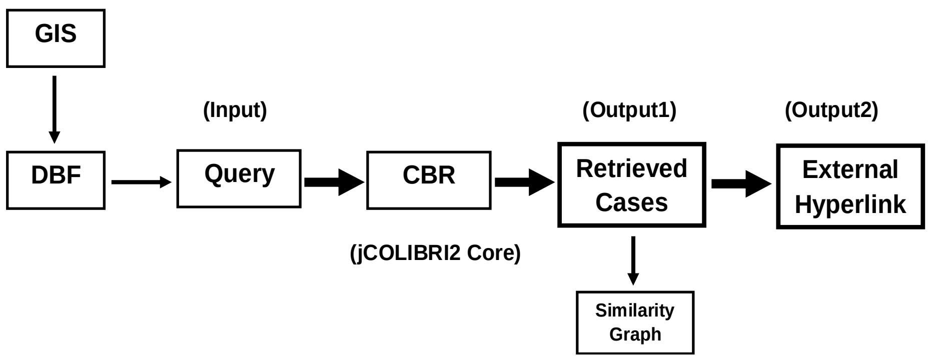


Figure 4.36. Workflow of the GUI

One of the distinguishing capabilities of the modified GUI is about the dbase file connector. This GUI utilizes the dbf file (which is generated by GIS software) as a case library. At the beginning, this tool obtains the user preferences using a form (uses form-filling) in query (input), and then it computes Nearest Neighbour scoring (whose similarities are above a predetermined threshold or elicitation of desired number of top similarity scored ones) for retrieval in CBR core and presents most similar cases on the first template (output1) and presents extra media about these cases on another template (output2). If the user does not find the desired item, he/she must return and refine the requirements of query form once more. And additionally, a similarity evaluation graphic is presented after the retrieval process.

We can try the GUI with the same input parameters which were used in Chapter 4.4.5/jCOLIBRI 1 platform.

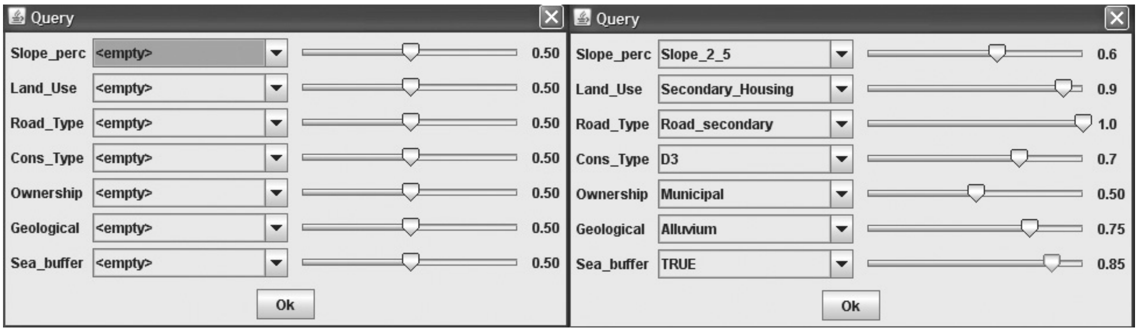


Figure 4.37. Configuring the input query by GUI

After configuring the parameters by choosing required parameters from enumerated types (input) and assign weights, the testing session begins when clicking the “Ok button”. Then GUI retrieves most similar case(s) from the case library (output) when the interface executed.

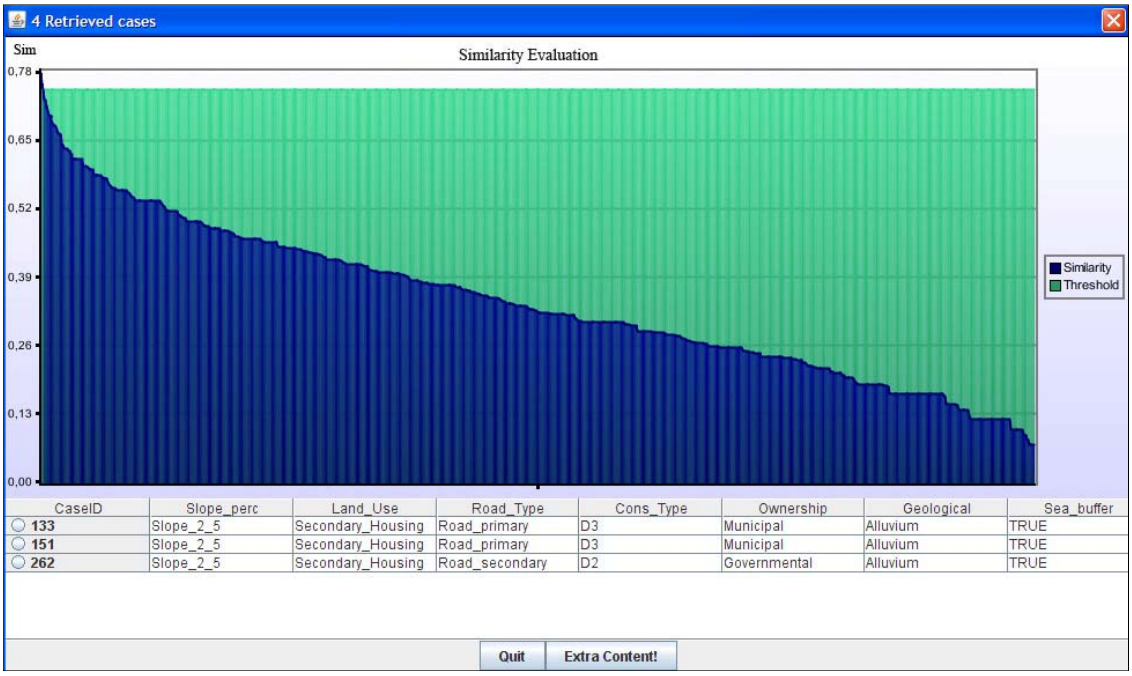


Figure 4.38. GUI Output Form 1

Another noticeable feature of the customized GUI is extended case library connection. User can reach to extra information about the retrieved cases (user should select one case from the list) by triggering "Extra Content" button on the first template (output form 1/see Figure 4.38). An extended part of the case library which contains project files of cellular cases is shown in another template (output form 2/see Figure 4.39).

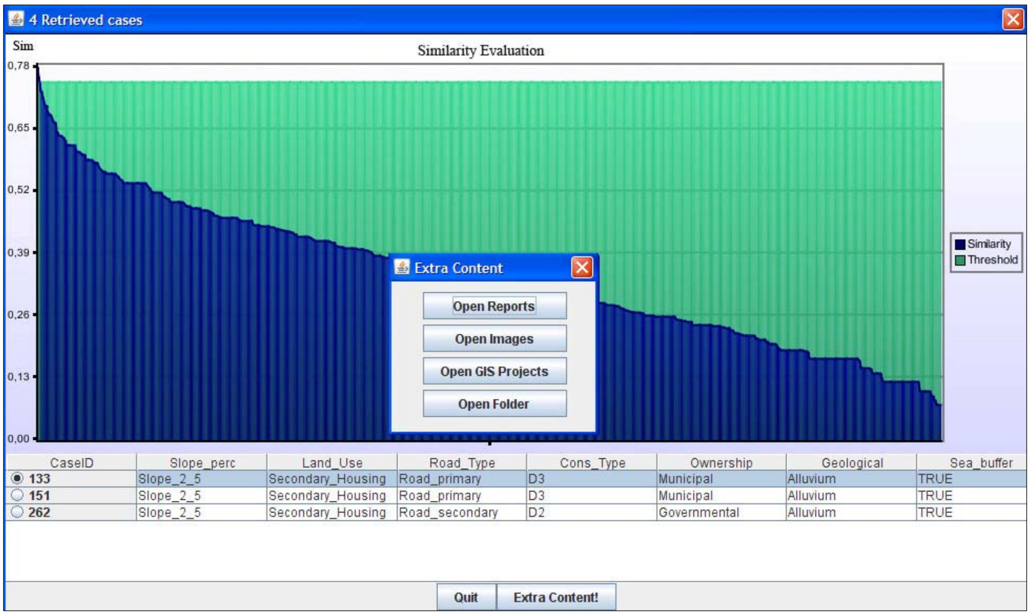


Figure 4.39. GUI Output Form 2

User can reach to reports, aerial/satellite images, GIS analysis, maps, plans by simply clicking the extra content buttons. The directory which contains the files of selected case (e.g. case133) is accessed by hitting the "Open Folder" button.

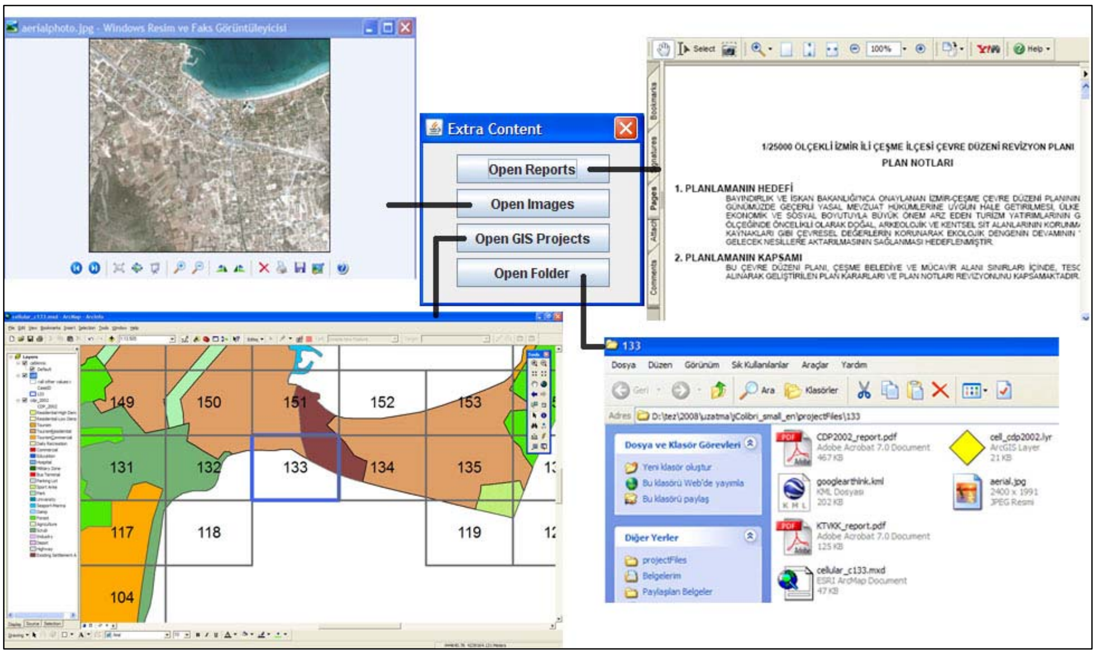


Figure 4.40. Extra content

The default result window of jCOLIBRI 1 platform shows the retrieved cases in a simple textual format only. If the jCOLIBRI 1 platform is used, user should reach to extra information manually by indexed and hyperlinked structure of cellular cases in GIS software (see Figure 4.41&4.42). If the customized GUI is used, user can easily access to the extra content and no manual effort or links are needed (see Figure 4.40). Consequently, this is the main advantage of the customized GUI when compared to default execution and result of the jCOLIBRI 1 software.

Although retrieved cases are the same in testing the scenario (133-151-262) by jCOLIBRI 1 platform and the customized GUI, when various parameters and weights (another scenario) are executed, results might be different. Because, similarity evaluation procedures are based on different matching techniques. Thus, domain dependent (e.g. city planning) similarity matrices are implemented (rather than default string equality or distance) to certain parameters to gain better and realistic results in the customized GUI.

Briefly customized GUI differentiates from jCOLIBRI 1 platform by using dbase file format, domain specific similarity matrices and extended library connection.

4.4.7. Evaluation of Findings After Retrieval Step

If the system will be used as a PSS, the ability of CBS model should be to handle previous judgments involved in the planning process. The main aim of the CBS model is to help planners to prepare reasonable, comprehensive and consistent recommendations on planning applications (Shi & Yeh, 1999).This approach calls for a representation of the values, arguments and opinions in the system. Also, descriptions of the cases and outcomes of the retrieval should be understandable to the user.

This pilot study attempt was made to answer the following questions:

- Can the most similar case(s) be found by the system?
- Are there any lessons to be learned from the cases?
- Can both good and bad practices (if any) be inferred?
- What are the advantages and limitations of the model?

From the pilot project, this study finds that this experimental model approach has achieved its main objective because it can retrieve the useful cases to the planners in PSS manner. Hence the system has the potential to be an aiding and advisory system.

While the retrieval process is built on tabular data (very common in previous studies and is used in this study), user can reach the remaining spatial and additional data (gis maps, satellite images, plans, reports, etc.) after the similar cases are found. Even though land use, geographic analyses and conservation regulations are utilized during the CBR process, user can reach to extended information (e.g. structure&implementation plans). First, user can access the work of previous plans and extract knowledge about the goals, methods, outcomes, and lessons of past cases. Second, by providing access to the experts' views via the CBS model, planners could critique, predict and propose for their new work in decision making process.

For instance, after learning the most similar cases from jCOLIBRI 1 or customized GUI results (case133-151-262), user can see and make comparison between the input query and the retrieved cases in ArcMap through the formerly structured spatial part of the case library (see Figure 4.15&4.41).

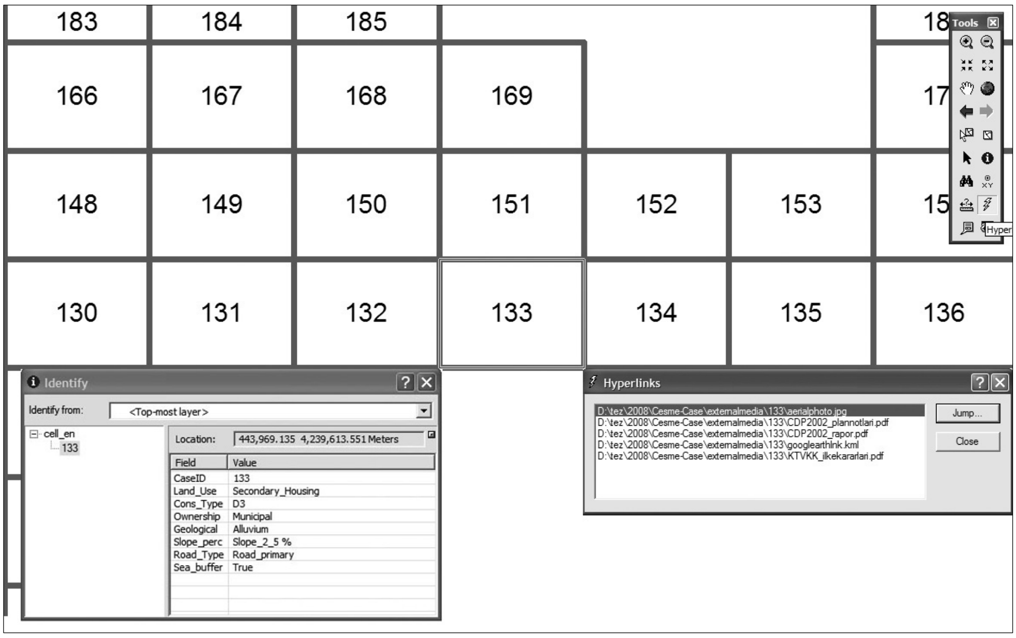


Figure 4.41 Cellular representation of retrieved cases in ArcMap

Browsing through the retrieved cases in GIS software (and other linked hypermedia), planners see how other planners solved similar problems and combine solutions from several cases to create a proposal/decision. An efficient CBR process could facilitate detailed information within a narrowed context. This process of retrieving, critiquing/evaluating the situation might continue until the planner is satisfied with his/her decision.

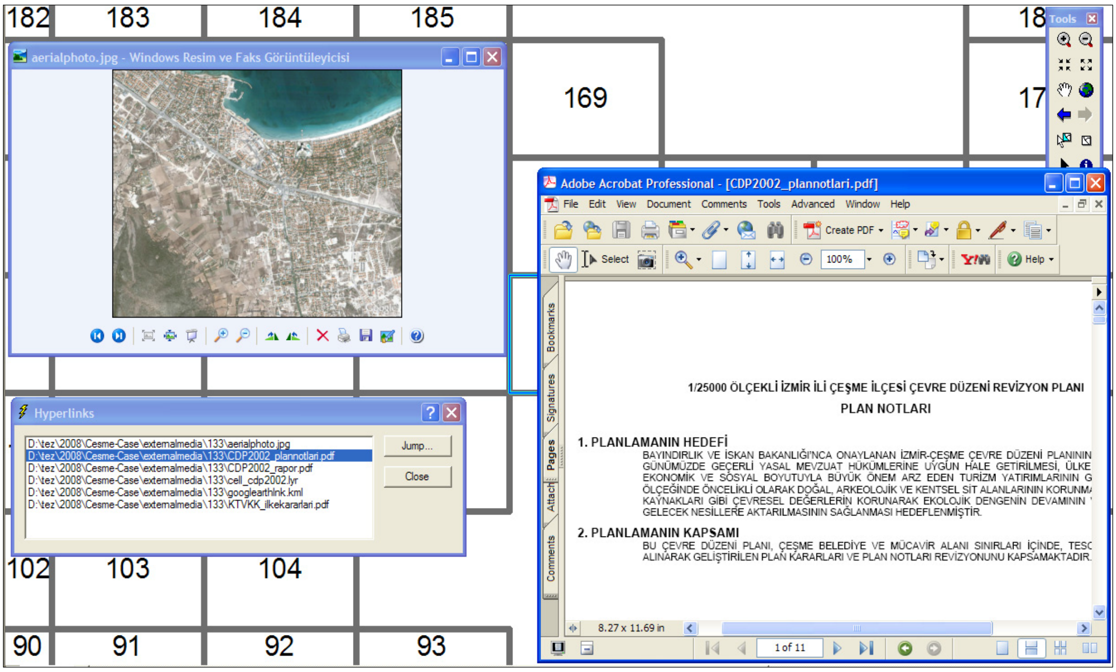


Figure 4.42. Reaching extra media of Case133 by hyperlinks in ArcMap

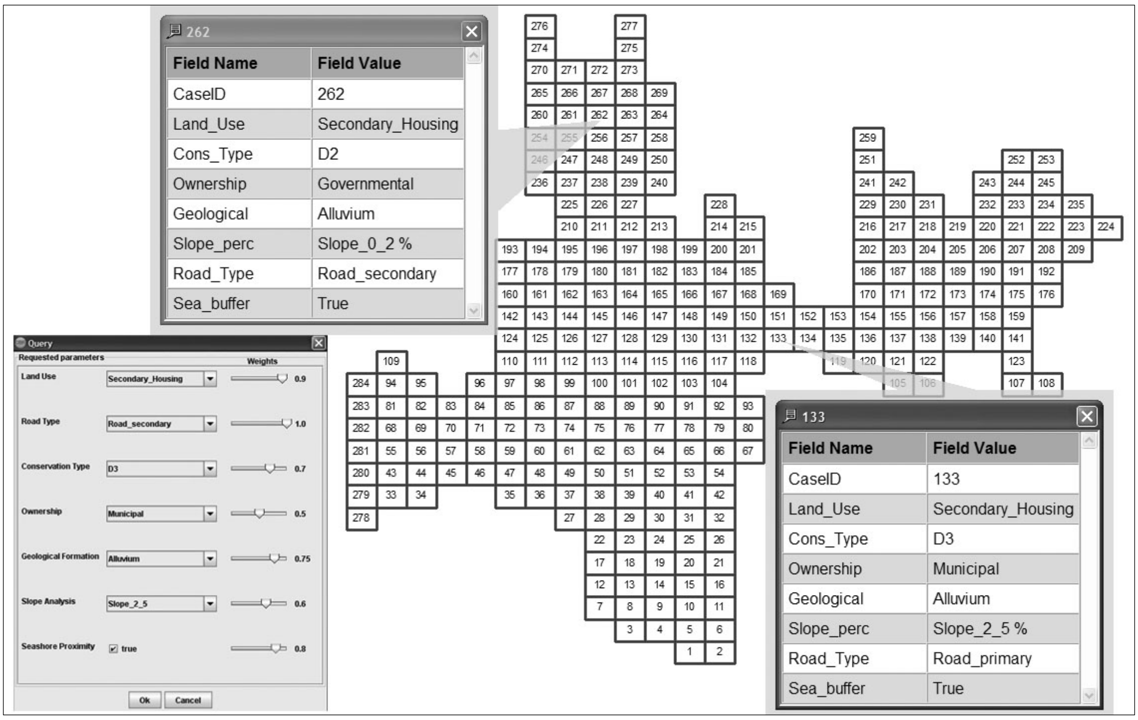


Figure 4.43. Retrieved cases: Cases 133&262 in ArcMap

If the purpose is to learn lessons and experiences from previous cases in city planning process, both good practices and bad practices are certainly very important for decision maker. Contrary to CBR, within a planning context, the difference between good and bad cases is not in similarity evaluation and retrieval but in how to use them. Even though there are bad planning applications in Çeşme region, they are not used in pilot study.

Another underlying issue is about the utilized case numbers in CBR model. 284 cellular cases are used in case library for using in experimental pilot study. It is decided that this case number is sufficient to test the model. Shi & Yeh (1999) used approximately 100 cases and Domeshek & Kolodner (1993) used 20 cases at the beginning of "Arhie" and grew up to 150 cases in 2nd version.

In this study the whole model approach is proposed to reach planning support, so it is decided that the final decision maker should be human planner. In this manner auto reuse/adapt cycles of CBR process are not used after retrieval. Adaptation process has also some operational difficulties in using complex domains. According to Shi & Yeh (1999) the main objective of a CBR model which deployed for city planning domain is to search and represent useful cases for the user; the further inference such as auto adaptation can be optional. The system can be used in order to transfer expertise and render advice or recommendations, much like a human expert. Urban planning often requires the experiences and expertise of planners and assistance of planning models and analytical methods in its complicated decision-making process. By integrating CBR technique with powerful capabilities of GIS can facilitate this process.

General evaluation of PSS and CBR concepts and benefits, advantages and limitations of the CBS model will be discussed in the Chapter 5: Conclusion.

CHAPTER 5

CONCLUSION

This dissertation has presented the developments and findings of applying an integrated model of CBR&GIS in city planning domain. Application of CBR technique has been utilized by CBR software jCOLIBRI 1 and a customized GUI which was developed on jCOLIBRI 2 platform. Çeşme Peninsula was selected as a case study area and GIS data belonging to Çeşme Peninsula was used to test the model. Case library has been generated semi automatically (and partly hypothetically) within a GIS environment. Hence, CBS model has been developed by integrating both CBR and GIS techniques to support planning process.

5.1. General Discussion on PSS, CBR and GIS

Advances in ICTs have transformed space, technique and even daily life. Thus, perceiving the new form of space and to plan the future cities, we must redefine our methods and set new planning tools. City planning should transform and adapt itself to a new state to overcome challenges and cope with uncertainty. With the proper selection and addition of new tools, planning discipline could improve its effectiveness for making analysis, synthesis, strategy making, decision-policy making, governing, design and operation. To plan the future cities, we will have to complement our set of planning tools with those that involve the selection of different types of techniques.

After the 1990s, rapid evolution in hardware capacity has been matched by the design of sophisticated software for mapping, simulation and visualization. Underlying thematic elements for the development of PSS could be defined as hardware, software, data, internet and operator. PSS tools are developed to support planning activities such as land use planning, strategic planning, urban modeling and collaborative planning. PSS strengths and also facilitates new perspectives in planning theory such as participation, collaboration, community planning, interactive-community planning/decision making. At the moment, people at a diversity of scientific, research and/or planning institutions worldwide are involved in the development, testing and application of a whole range of PSS. However, emerging critical issues to start a PSS research will center on data availability, quality and storage. And accordingly, the extent of the developments, implementation, efficiencies and deficiencies of PSS is not well known (Brail & Klosterman, 2001; Geertman & Stillwell, 2004).

PSS should also not be viewed as a closed black-box collection of computer models which can accept raw data and automatically generate plans, forecast future land-use patterns or identifying optimal policies and actions. Instead it must be seen as providing the information infrastructure for planning that facilitates interaction, between planners and other actors, both within and outside of government. The PSS must contain structured and accessible information about the real world features and must also support analysis, modeling, forecasting and decision making (Klosterman, 2001).

Although most of the recent PSS studies suggest that the future of PSS tools is bright indeed, the future role of PSS in "professional planning practice" is less clear. Inventories show that currently a large diversity of PSS exists, but that the implementation in spatial planning practice is far behind the supply of tools. Vonk & Geertman (2007) states that improving the instrument quality, improving the tools' awareness, improving the experience, improving the collaboration between planning organizations, improving the user appreciation and acceptance could facilitate the performance and efficiency of PSS in planning practice. Also researchers contribute more effort especially on urban issues to reduce knowledge gap and lack of empirical studies. Hopefully, we can expect to see more efficient and powerful systems in the future and PSS tools could be useful for planners, academicians, students, government, private sector and the community.

CBR is a family of AI techniques that simulates the human behavior in solving a new problem. Thus in CBR, reasoning is based on remembering. CBR tries to retrieve most relevant/useful case(s) and utilize existing knowledge (if fits the situation). CBR has developed into a mature and important field of AI and used by various researchers from various countries.

There is a perceived need to integrate spatial information systems with additional reasoning approaches. Previous studies of CBR technique showed that, it is a promising way to build and apply the model as a PSS. Therefore, CBR is proposing a methodology for building and applying more practical PSS for planning. The results derived directly from real cases in CBR process are more convincing and acceptable to planners. Urban planning often requires the experiences and expertise of planners and assistance of planning models and analytical methods in its complicated decision-making process. Hence, a system that integrates CBR as an AI reasoner and GIS as a spatial analyst and visualization tool could be very helpful to support planning process and assist planners.

There are also critics about the use of GIS in planning process and integrated models. This view involves a question about the accuracy of representing the real-world situation in a GIS. According to Malczewski (2004), the notion of representational accuracy has two elements: an accurate representation of geographical objects (the hard data) and accuracy in representing social, economic, cultural, political elements (the soft data) of the environment. GIS is focused on representation and visualization which is structured towards seeing the world as composed of geographic layers containing objects (pixels, points, lines, and polygons) along with associated attributes. At the fundamental level, GIS systems are based on certain conceptualization of space (particularly a geometric and relative space) and certain forms of reasoning which lacks some certain parts of urban space. Such conceptualization provides the impression of a value free and rigorous view of the world.

According to the critics of GIS, the users of GIS will be misled into thinking it is entirely objective and value free technology. In order to avoid this and correctly represent a particular planning problem, one has to focus on the right combination of both objective and subjective data/information representing the values, opinions, preferences, priorities, judgments, etc. of these involved in planning process. Some of the issues related to accurate representation of planning problems have recently been addressed by public participatory GIS and PSS. It is expected that the trend towards enhancing public participatory approach to system design and application development will be of critical importance for a successful use of GIS/PSS (Malczewski, 2004; Geertman & Stillwell, 2004).

5.2. Critiquing the CBS Model: Advantages and Limitations

This study has tried to find out whether the CBS model could support planning process and human decision making in complex task like city planning. One of the conclusions emerging from this study is while the CBS model met predefined goals and beneficiary approach for city planning, we learned both from its advantages and limitations.

One major contribution of this dissertation is to fulfill a knowledge gap generally with PSS but especially with a CBS model implementation locally. This dissertation is trying to differ from other studies by integrating CBR and GIS for providing a geo-spatial planning support in Turkish city planning practice through a practical example. Another contribution is the customized GUI which presents better result in testing different variations of CBR inference scenarios when compared to results of standard/generic CBR software.

5.2.1. Advantages

- Working style of a planner could be simulated by utilizing existing knowledge,
- The usage of the model could reduce the time in similar planning applications and overcome uncertainty by avoiding to start from the beginning every time (enables fast introduction),
- Knowledge representation logic is based on local and real past cases rather than generalized rules/guidelines,
- Experiences and lessons could be derived both from good and bad practices,
- All internal algorithm and 4RE cycle are openly structured (contrary to black-box models),
- More effective CBR applications could be developed by using object oriented programming languages and customized GUI,
- To develop integrated/hybrid models could facilitate to establish domain specific systems such as CBR&GIS, CBR&CAD, CBR&ICTs,
- Besides its' knowledge inference capabilities, it could be used as a digital archive, automation system and corporate memory.

5.2.2. Limitations

- Although the city planning background contains many cases, it is difficult to acquire complete (due to the lack of analyses, incomplete data, out of date/irrelevant information), digital and well documented real cases to build a case library,
- New tools/models are currently under development in academic circles, and it is tough to find a fully appropriate one in practical context. There are also difficulties in building the system and acceptance of users to the system,
- If the quality of the tool is not satisfactory or understandable to the domain user, this situation cause another deficiency,
- CBR technique is more appropriate for using quantitative and objective domains like engineering (CBR is mostly used by software/knowledge engineers), current versions of integrated/hybrid CBR models could partially support complex domains as city planning, architectural design, medical treatment, etc,
- CBR only uses local information and inference, some researchers call it lazy learning. In some situations CBR technique must derive external rules/models to empower itself,
- Similar problems may not have similar solutions, every case may be unique,
- CBS model approach is mostly feasible for incremental planning applications.

5.3. General Evaluation

It may be argued that the systems which city planning deals are different and even more complex than other disciplines like engineering. Planners may need skills of a different order of objectivity and creativity for certain aspects of synthesis. Planners have to deal with incompletely structured (uncertain) problems that involve both quantitative and qualitative aspects (Chadwick, 1971). This phenomenon could partly be overcome by PSS tools like model representations, intelligence/reasoning techniques or GIS.

City planning is a political expertise. Unfortunately, it is not value free and totally objective domain. You can not quantify every factor and you can not simply abstract all urban entities to geographic or urban model representations. There are plenty of planning problems are laying behind unsolved such as urban renewal, jurisdiction conflict between authorities, squatter housing, corruption, unequal development, transportation and infrastructure problems, etc. Also circumstances are changing rapidly in urban environment. For example land and real estate prices are often dynamic and sensitive to macro economic situations. Under the PSS framework all tools and techniques should be regarded as aiding and supporting methods which try to improve the planning practice and assisting the decision maker/planner.

Consequently, the key feature of any PSS should not replace user's judgments. The purpose of such a system is to support a user in achieving better decisions. To improve decision making, PSS involves the knowledge, intuition, experience, initiative, creativity, etc. of the user/expert. The system/model should help the users to explore the decision problem in an interactive style.

As a matter of fact, new information-technology based applications will transform the practice of planning, our solutions and design issues. Undoubtedly, there are changing context and debates in city planning via new tools and techniques. However, technology serves as a means to an end-not an end in itself. As Chadwick (1971) suggests that expression of these concepts and computational experience are meaningful and worthwhile if the purpose is justified in planning process.

5.4. Recommendations for Future Studies

In chapter 4, operational pilot study has presented findings that support planning process. Additionally advantages and limitations of the model have been argued in conclusion. But there are also recommendations for further studies to decrease the knowledge gap in PSS&CBR studies.

There should be more parameters/attributes in knowledge inference and representation schemes of CBR based models. For instance representations/abstractions of real world situations or urban entities should be considered within models such as environmental aspects, historical conditions, social aspects, demographic data, land/real estate prices, etc. Both spatial and non-spatial local knowledge should be regarded in evaluations.

Additionally, there might be different ways to measure similarity/relevance for particular domains. Retrieval is basic but fundamental cycle of CBR, so there could be specialized/customized quantitative or functional ways to grab most relevant cases for a domain specific problem. This could be done by sophisticated software codes and also within a technical computing environment such as MATLAB.

There is also a need to explore the integration of CBR with rule-based reasoning. Integrated usage of reasoning models can be complementary to each other. For example RBR can be used when there is no case in the case library or when new regulations/circumstances are introduced which make previous cases irrelevant.

CBR models should consider how the system could learn from iterations. By the use of 4R function of CBR process, an internal learning algorithm could be achieved. Besides saving the solution of new cases to the case library, one way would be to develop ontology based, logical flow maps for future CBR queries. Perhaps this could be done when satisfied iterations practiced by the CBR system. For instance, querying certain parameters with certain assigned weights composes a robust solution and this robustness could be presented by ontology. Then this framework could be developed as a reusable problem solving method recommender system.

Using the spatial similarity concept for exploratory spatial analysis and planning needs further research, because the concept have not been totally clarified and identified. The capability of matching and adapting cases based on spatial similarities and relationship is another important topic that should be investigated in order to progress the technique.

Specifically, it would be more efficient to create and maintain the case library in web based environment rather than local or internal one. To implement a CBR inference process within GIS softwares, designing customized GUI and extensions, deploying web based applications are other topics which deserves further research. Hence, findings of the study are encouraging in terms of development of such enhancements. Moreover, improving the quality and usage of CBR tools should be another research area.

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APPENDIX A

JCOLIBRI SOFTWARE

Java Cases and Ontology Libraries Integration for Building Reasoning Infrastructures (jCOLIBRI) is an object-oriented framework in Java for building CBR applications. A framework is a reusable, semi-complete application that can be specialized to produce custom applications. Application frameworks are targeted at a given application domain providing the design for a family of applications within that domain.

jCOLIBRI 1 Platform

jCOLIBRI is built around a task/method ontology, a knowledge level description that guides the framework design, determines possible extensions and supports the framework instantiation process. Task and methods are described in terms of domain-independent CBR terminology which is mapped into the classes of the framework.

Each one of the four CBR tasks involves a number of more specific sub-tasks. There are methods to solve tasks either by decomposing a task in subtasks or by solving it directly. The task structure identifies a number of alternative methods for a task, and each one of the methods sets up different subtasks in its turn. This kind of task-method-subtask analysis is carried on to a level of detail where the tasks are primitive with respect to the available knowledge.

jCOLIBRI is an evolution of the COLIBRI architecture, that consisted of a library of problem solving methods (PSMs) for solving the tasks of a knowledge-intensive CBR system along with an ontology, CBROnto, with common CBR terminology. The CBR ontology is already populated in the framework with a number of pre-packaged realizations of the CBR abstract entities that can be extended for particular applications.

The architecture of the jCOLIBRI framework comprises a hierarchy of Java classes plus a number of XML[1] files that configure the generated CBR applications. Next figure illustrates jCOLIBRI architecture:

[1] XML: Extensible Markup Language (XML) is a method for putting structured data (such as that in a worksheet) in a text file that follows standard guidelines and can be read by a variety of applications. Designers can create their own customized tags, enabling the definition, transmission, validation, and interpretation of data between applications and between organizations.

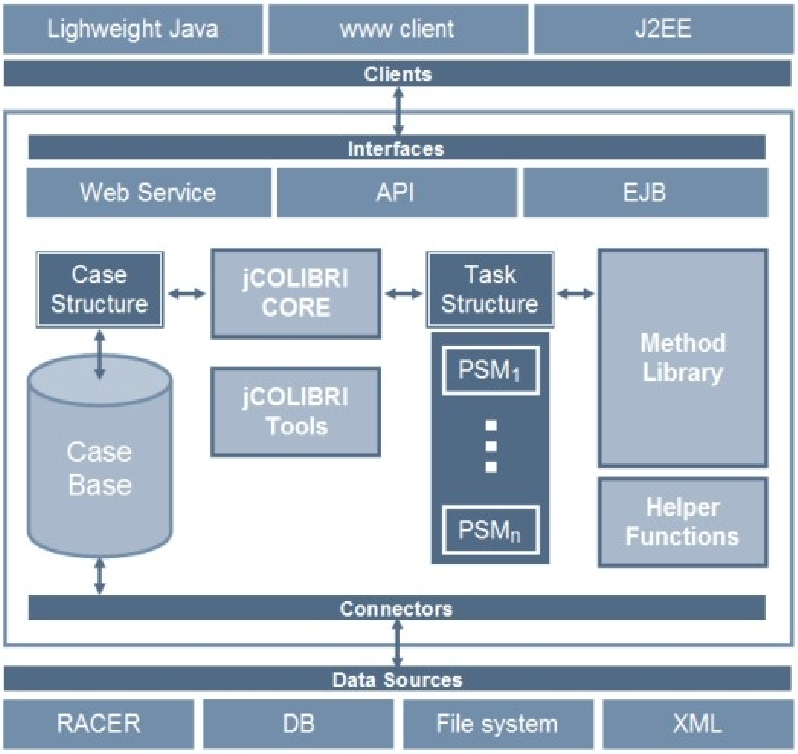

Figure 1. jCOLIBRI 1 detailed architecture

Developing CBR systems using jCOLIBRI Tools

Developing a CBR system is a complex task where many decisions must be made. When using jCOLIBRI some of these decisions are:

- Representation of the cases: we can use simple plain cases, textual cases, or we can define the cases as complex hierarchical structures where attributes are connected.
- Case base: the cases can be stored in relational databases, ASCII text files, XML files, etc. The designer has to define the storage and retrieval mechanism, and how to index the cases in memory to increase the speed of the queries.
- Similarity measures: one of the most important tasks to be solved in a CBR system consists on finding the most similar cases to one given. Usually different similarity functions are used to compare the attributes of the cases.
- Behaviour of the CBR system through tasks and methods: a CBR application can be structured as a sequence of tasks that must be achieved. A CBR designer should choose these tasks and select the methods that will solve them.

jCOLIBRI stores all the configuration data using different XML configuration files. When the application is executed, the framework core reads these files to know how to configure the CBR system. You can write or modify this configuration files by hand, however it can be a very tedious task. XML intends to be a standard interchange language of data between computers, not to be managed directly by humans. For that reason, we have developed several tools that will help users in the configuration task, providing graphical and intuitive interfaces.

Definition of case structures

Figure 2 shows a visual tool provided with jCOLIBRI that can be used to define case structures easily. As you can see, the window is divided in two regions. The left panel displays the structure of the case as a tree, and the right panel shows the property values of the selected attributes. A *Case* has a *Description*, a *Solution* and a *Result*. *Description* and *Solution* are sets of *Attributes*, and there are two types of attributes: simple and compound. Simple attributes are described by the following characteristics: *name*(Raining), *type*(Boolean), *weight*(1.0) and *local similarity function*(Equal). Compound attributes collect other simple or compound attributes allowing complex case structures. The properties of the compound attributes are the name and the global similarity function.

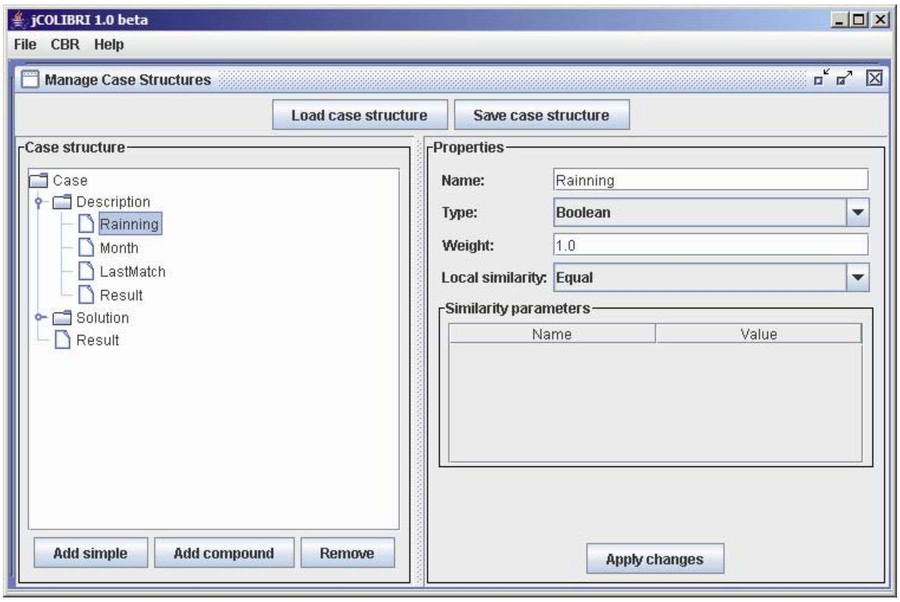

Figure 2. Defining the case structure

Persistence of cases: Connectors

In jCOLIBRI we propose to separate the case storage from the indexing structure and from the PSMs that reason with cases like retrieval or adaptation methods. That way, indexes can be built and methods can be configured without knowing how and where the cases are stored. Moreover, different indexes can be defined upon the same set of cases to allow the evaluation of different indexing techniques, or the adequacy of different retrieval or adaptation methods.What we need to know for building an index structure or choosing and configuring a method is the structure of the cases, i.e., which attributes will be used to describe each case.

We propose an architecture using two layers: persistence mechanism and in-memory organization. Persistence of cases in jCOLIBRI is built around the concept of Connector. Connectors are objects that know how to access and retrieve cases from the storage media and return those cases to the CBR system in a uniform way. Therefore connectors provide an abstraction mechanism that allows users to load cases from different storage sources in a transparent way. jCOLIBRI includes connectors that work with plain text files, XML files, relational data bases and DLs systems. Other connectors can be included depending on the specific application requirements by means of the jcolibri.cbrcase.Connector java interface. Figure 3 illustrates these ideas. jCOLIBRI offers a graphical tool that is used to easily configuring connectors to load existing case bases in different formats.

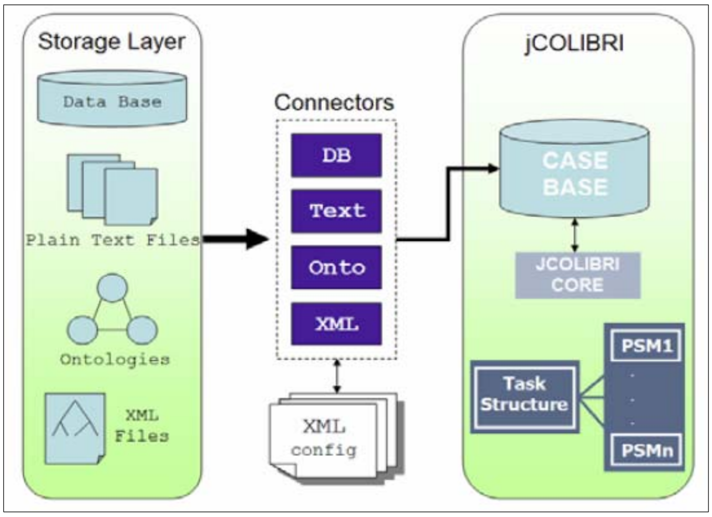

Figure 3. jCOLIBRI connector architecture

Managing the similarity measures

When defining the case structure a similarity measure is associated to each attribute. The available similarity measures are listed in a configuration file, and can be managed using the tool shown in Figure 4. In the framework, each similarity measure should be associated to a java class that computes the similarity values when the application is running. These classes should implement the *jcolibri.similarity.SimilarityFunction* java interface.

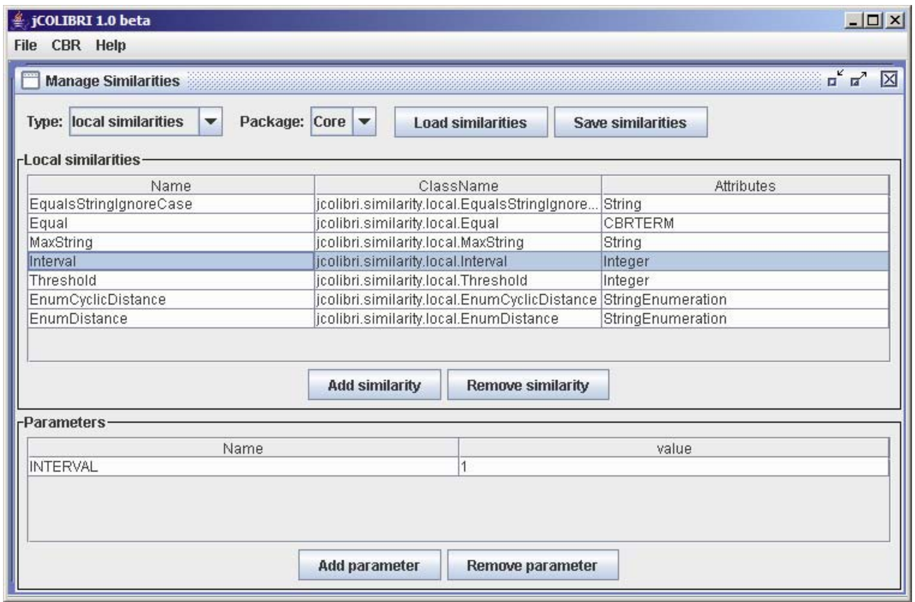

Figure 4. Managing the similarity measures

Behaviour of the CBR system

After defining the data structures of the CBR systems, like the case structure, the configuration of the connectors to load and store the case base and the similarity measures to compare attributes of the cases; it's time to configure the more dynamic part of the CBR systems: the behavior of the CBR processes (Recio-Garcia et al., 2005).

Each one of the 4R CBR tasks involves a number of more specific sub-tasks. There are methods to solve tasks either by decomposing a task into subtasks or by solving it directly.

The CBR system designer creates a CBR application following an iterative process:

1. Select one of the not configured tasks of the system,
2. Choose from the library of reusable methods one that is suitable to solve the selected task. There are dummy methods assigned to the tasks that we do not require to solve it in a particular CBR systems configuration. For instance, retrieval only systems skip the solving the adaptation task.

Note that task/method constraints are being tracked during the configuration process so that only applicable methods in the given context are offered to the system designer.
At the beginning of the process the only unsolved task is CBR Task (solve a problem using previous experiences). When we choose the CBR method to solve the CBR Task, we obtain the CBR cycle into a task sequence: retrieve, reuse, revise, retain. While the system is not complete, select one of the not configured tasks and choose and configure a method that resolves it.

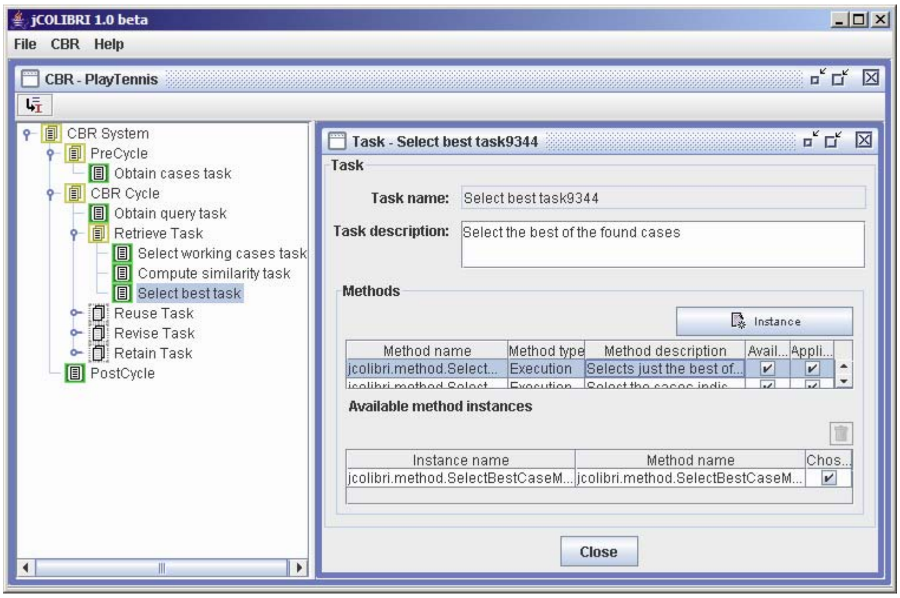

Figure 5. Selecting tasks/methods of the CBR application

You can develop a CBR system using and instantiating the jCOLIBRI framework classes directly, however this can be a hard process if you are not acquainted with the framework. In order to alleviate framework instantiation effort, jCOLIBRI features a semiautomatic configuration tool that guides the instantiation process through a graphical interface (see Figure 5).

Deploy the CBR application

The CBR application is finished when all the tasks have been configured. You can test the system from inside the graphical interface selecting the tasks that are going to be executed in the tasks tree and pushing the *"Solve to …"* button.

The effects of the execution are shown in the *results window*. This feature provides an easy way to test the system before generating the java code that is needed to run your system as an independent java application.

The first task of the CBR system, *Obtain query task*¸ obtains the query that is going to be used to retrieve the most similar cases. The framework supplies a useful and general method, named *Configure Query Method*, to solve this task. This method reads the case structure from the XML file that stores the case structure, and dynamically generates a visual form that can be used to introduce the query data. This form takes advantage of the best graphical components available according to the case structure and the types of the attributes.

Once you have created and tested the application, you can generate a code template with most of the code that you need to run your system as an independent application. This template will contain the tasks and methods invocation code and can be modified as needed.

jCOLIBRI has been designed as a wide spectrum framework able to support several types of CBR systems from the simple nearest-neighbor approaches based on flat or simple structures to more complex knowledge intensive ones.

Travel Domain Example

The travel domain case base that is available for download from the AI-CBR website (http://www.ai-cbr.org/cases.html) offers a set of 1024 cases that represent travels. We are using jCOLIBRI to design a travel recommendation system based on this case base.

1. Create a new CBR system and name it as desired.

Figure 6. Creating a new CBR system

2. Create the case structure defining simple and compound attributes that describe the cases together with their types, weights, similarity measure that is chosen from a library of existing similarity functions and parameters (if any). jCOLIBRI offers a graphical tool to include new similarity functions (see Figure 4). The case structure can be saved/loaded in/from a XML file. 9 simple attributes were created as a case structure and shown in Figure 7.

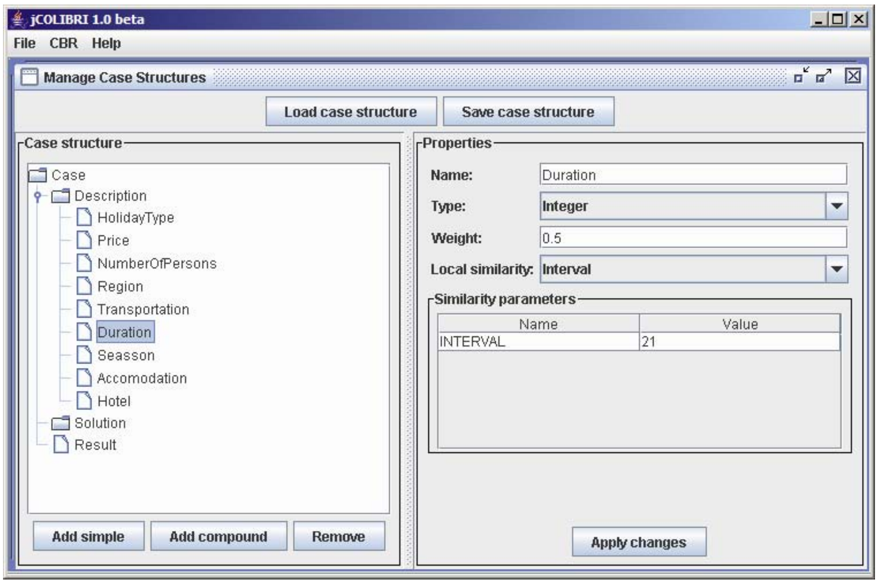

Figure 7. Creating the case structure

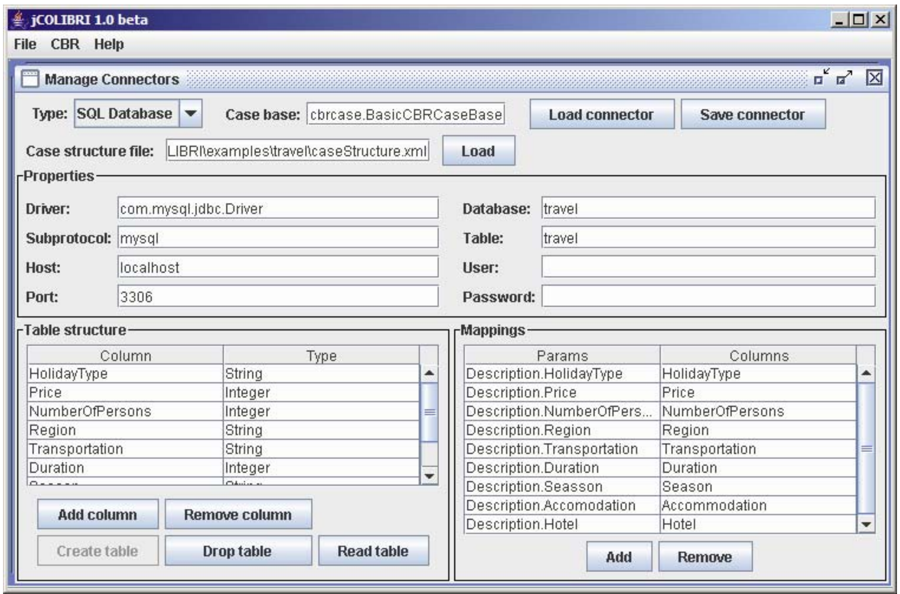

Figure 8. Configuring the connector with the case base

3. Once the case structure is defined we could define new cases following this structure. Instead doing this, since we have a previously existing case base, we configure a connector to read in the travel cases from a MySQL database. The graphical interface helps mapping the case structure defined in step 2 with the tables and columns from the database scheme. Like the case structure the connector

configuration can be saved/stored in/from a XML file. In this example we are configuring a connector to work with cases stored in the table travel of the data base travel. In the top of the window you can select the type of connector that you wish to configure: database, XML files, etc. Each kind of connector has its own properties that must be configured. In Figure 8 we are creating a connector for a relational database and the form is divided into 3 sections: properties, table structure and mappings. The properties panel shows the information required to access to the database. The table structure panel allows managing the structure of the table containing the cases. Last, the mappings panel connects each column of the data base table witch an attribute of the case structure.

4. Configure the task and methods. Note that some of the methods could require parameters. For example, to obtain cases we provide with the name of the connector configuration XML file, and to create queries, we use parameterized methods that require the name of the XML file where the system stored the case structure (see Figure 9). JCOLIBRI automatically defines a graphical interface based on this structure to let the user introducing new queries (see Figure 10).

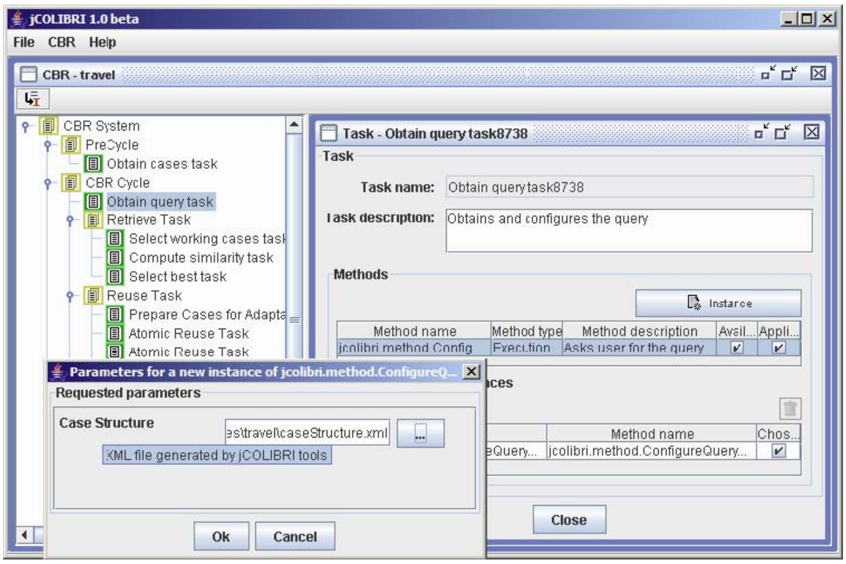

Figure 9. Configuring tasks and methods

5. Once every task is configured by a method that solves it we can run the CBR deployed system where  the tasks are solved using the given sequence. You can also use the (solve to) button in the GUI to execute a selected set of tasks. The result for the query is shown in the right area of the graphical interface.

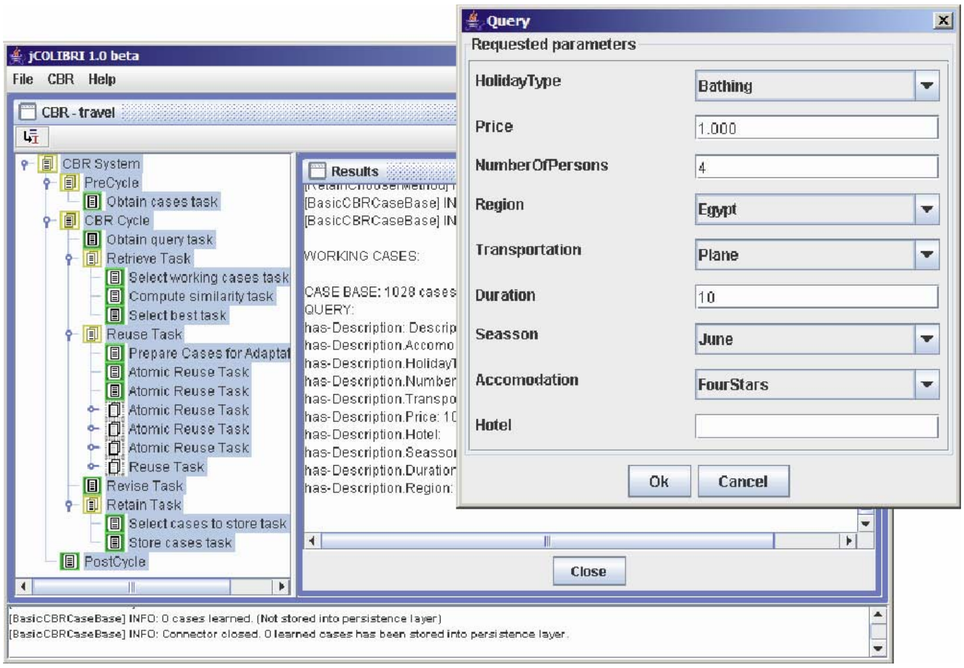

Figure 10. Testing the CBR system

jCOLIBRI 2 Platform

jCOLIBRI 2 is the result of the experience acquired during the development of the first version. It solves many drawbacks like case representation, management of metadata, development problems, etc. But the architecture of this new version is very different (although compatible) as is based on a complete revision of CBR systems and frameworks.

For classifying a framework we can distinguish several types. A white-box framework is reused mostly by subclassing and a black-box framework is reused through parameterization. The usual development of a framework begins with a design as a white-box architecture that evolves into a black-box one. The resulting black-box framework has an associated builder that will generate the application's code. The visual builder allows the software designer to connect the framework objects and activate them. The first version of jCOLIBRI is closer to a black-box framework with visual builder and lacks of a clear white-box structure. The new design of jCOLIBRI 2 attempts to remodel the architecture into a clear white-box system oriented to programmers, and a white-box with builder layer that is oriented to designers.

The key idea in the new design consists of separating core classes and user interface. That separation will give us the two layer architecture shown in the following Figure 11:

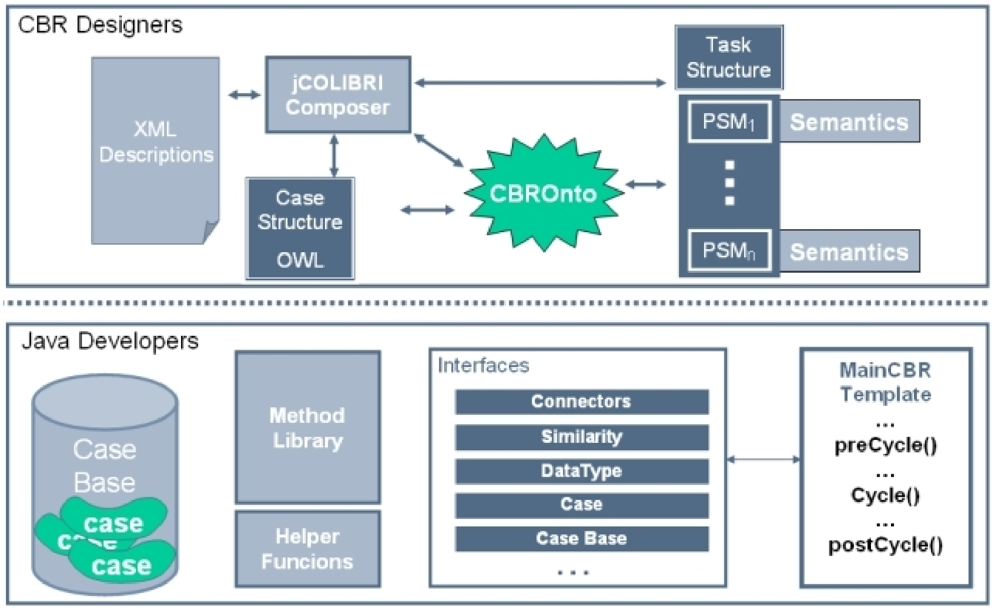

Figure 11. jCOLIBRI 2 architecture

The bottom layer contains the basic components of the framework with well defined and clear interfaces. This layer does not contain any kind of graphical tool for developing CBR applications; it is simply a white- box object-oriented framework that must be used by programmers. The top layer contains semantic descriptions of the components and several tools that aid users in the development of CBR applications (black-box with visual builder framework).

For more information about jCOLIBRI, please visit: http://gaia.fdi.ucm.es/grupo/projects/jcolibri/

References:

Recio-Garcia, J. A. (2008). *jCOLIBRI: A Multi-Level Platform for Building and Generating CBR Systems.* Phd Thesis, Department of Software Engineering and Artificial Intelligence, Facultad de Informática, Universidad Complutense de Madrid, Spain.

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jCOLIBRI. (2008). Retrieved June 2009 from GAIA - Group for Artificial Intelligence Applications: http://gaia.fdi.ucm.es/grupo/projects/jcolibri/

APPENDIX B

GLOSSARY

Application: An automated system or part of an automated system, which provides the end user with access to and processing of stored data. An application may be a manual process, which has been automated.

ArcGIS: ArcGIS is an integrated collection of GIS software products that provides a standards-based platform for spatial analysis, data management, and mapping. ArcGIS can be integrated with other enterprise systems such as work order management, business intelligence, and executive dashboards.

ArcView: Geographic Information System Software produced by Environmental Systems Research Institute (ESRI). In ARGIS, ArcView provides the geographic context on which Smart Places operates.

Area: A two-dimensional graphic element made up of a series of arcs, which form a closed figure.

Artificial Intelligence (AI): AI is the area of science which focuses on creating systems that can engage on behaviors that humans consider intelligent. Additionally, intelligence is the computational part of the ability to achieve goals in the world.

Attribute Table: A table containing rows of geographic elements (objects) and columns (vertical fields) of attributes (non-spatial characteristics) describing the object.

Attribute: Information stored about a graphic element. Usually, a specific and non-spatial characteristic of an object or entity.

Black Box: A System or a part of a system concerning which nothing is known except its input and output characteristic: internally it is black

CAD: Computer Aided Drafting or Computer Aided Design (sometimes CADD).

Calibration: The business of finding values for the parameters of a model in a particular case.

Cartography: The art or work of making maps.

Case Based Reasoning (CBR): To use previous similar cases to solve, evaluate or interpret a current new problem.

Case Based System (CBS): A system (model) approach that based on case based reasoning.

Case Library: It is the core of the CBR system. The cases should contain case specific (also domain specific) details as much as possible.

Column: A vertical field in an attribute table or A vertical group of cells in a grid or pixels in an image.

Computer Simulation: Computer simulation involves computer modeling and photographic imaging techniques designed to illustrate the potential results of planning, development and design projects. This technique provides participants with an ability to visualize the outcome of a design or planning action and assess its desirability before implementation. Computer simulation can be effective for modeling community plan alternatives.

Coordinate System: A reference framework consisting of a set of points, lines, and/or surfaces, and a set of rules, used to define the positions of points in space in either two or three dimensions. The Cartesian coordinate system and the geographic coordinate system used on the earth's surface are common examples of coordinate systems.

Database: A collection of interrelated data sets stored together in an organized manner, usually as related tables.

Datum: The reference specifications of a measurement system, usually a system of coordinate positions on a surface (a horizontal datum) or heights above or below a surface (a vertical datum).

DBF: dBase data file format

DBMS: Database Management System

Decision Support System (DSS): Can be described as an interactive, computer-based system designed to help decision makers solve poorly structured problems. Using a combination of models, analytical techniques and information retrieval, such systems help develop and evaluate appropriate alternatives. Decision support systems should focus on strategic decisions, not operational ones. More specifically, they should contribute to reducing the uncertainty faced by managers when they need to make decisions regarding future options.

Digitizing: The process of converting hard-copy maps into electronic or digital maps by storing X, Y coordinates of points, lines and polygons using a digitizing tablet. This process can be performed semi-automatically by scanning, manually by marking points with a digitizer puck on a tablet, or manually entering co-ordinate values (X, Ys) at a data entry terminal.

Eclipse: Eclipse is a multi-language software development platform comprising an integrated development environment and a plug-in system to extend it. It is written primarily in Java and can be used to develop applications in Java and, by means of the various plug-ins, in other languages as well, including C, C++, COBOL, Python, Perl, PHP, and others.

Element: The lowest (order) part of a system, sometimes minor part of a case

Entity: An object category, which can be geographic. Examples of entities are roads, wells and people.

Enumerated Type (Enum): In computer programming, an enumerated type is an abstract data type used to model an attribute that has a specific number of options (or identifiers) such as the suit of a playing card (i.e. a Club, Diamond, Heart or Spade). Using this type allows the program to handle the attribute more efficiently than a string while maintaining the readability of the source code. At run-time, enumerated types are often implemented using integers (each identifier has a distinct integer value). However, compared to using just integers, enumerated types make program source more self-documenting than the use of explicit magic numbers. Depending on the language, the integer representation may not be visible to the programmer; this prevents the programmer from doing absurd things, like performing arithmetic on enumeration values.

ESTEEM: ESTEEM is a Windows-based software tool that enables individuals (both non-programmers and programmers) to quickly construct decision enabling applications which utilize case-based reasoning technology.

Event: Phenomena such as changes in attributes, which take place along a route. It is a complex entity defined one-dimensionally along a route.

Features: Features and components are used interchangeably in GIS. Both terms refer to elements of a land use scenario, such as buildings, roads, etc.

GCS: Geographic Coordinate System uses a three-dimensional spherical surface to define locations on the earth. A GCS is often incorrectly called a datum, but a datum is only one part of a GCS. A GCS includes an angular unit of measure, a prime meridian, and a datum (based on a spheroid). A point is referenced by its longitude and latitude values. Longitude and latitude are angles measured from the earth's center to a point on the earth's surface. The angles often are measured in degrees (or in grads).

Geodatabase: The geodatabase is the common data storage and management framework for ArcGIS and can be utilized wherever it is needed—on desktops, in servers (including the Web), or in mobile devices. It supports all the different types of data that can be used by ArcGIS such as attribute tables, geographic features, satellite and aerial imagery, surface modeling, data survey measurements.

Geographic (Data) Model: A data model in geographic information systems is a mathematical construct for representing geographic objects or surfaces as data. For example, the vector data model represents geography as collections of points, lines, and polygons; the raster data model represent geography as cell matrixes that store numeric values; and the Triangulated irregular network (TIN) data model represents geography as sets of contiguous, nonoverlapping triangles.

Geographic Feature: An object, real or imaginary, with geographic position classed by point, line or area; for example, a valve, road centerline, or an in-place utility pole.

Geoprocessing: Geoprocessing is based on a framework of data transformation. A typical geoprocessing tool performs an operation on a dataset (such as a feature class, raster, or table) and produces a new dataset as the result of the tool. Geoprocessing also supports the automation of workflows by providing a rich set of tools and a mechanism to combine a series of tools in a sequence of operations using models and scripts.

Georeferencing: To georeference something means to define its existence in physical space. That is, establishing its location in terms of map projections or coordinate systems. The term is used both when establishing the relation between raster or vector images and coordinates but also when determining the spatial location of other geographical features

Geo-Technologies: That group of technologies which are applied to and support, research, management and charting of the earth, natural resources, ecosystems and infrastructure.

GIS: Geographic Information System(s). Describes any automated system for spatially managing and analyzing geographic information.

Global Positioning System (GPS): A technology that enables an individual to identify the location of an object by triangulating his/her coordinates from a network of satellites.

Graphical User Interface (GUI): A human-machine interaction that relies on graphic symbols and a pointing device to control a computer rather than entry of text from a keyboard.

HTML: Hypertext Markup Language. The coding language used to make hypertext documents for use on the WWW.

ICTs: (Information and Communication Technologies) ICT is to consider all the uses of digital technology that already exist to help individuals, businesses and organizations use information. ICT covers any product that will store, retrieve, manipulate, transmit or receive information electronically in a digital form. For example, personal computers, internet digital, television, robots.

Image: A graphic representation or description of an object that is typically produced by an optical or electronic device. Common examples include remotely sensed data such as satellite data, scanned data and photographs. An image is stored as a raster data set of binary or integer values representing the intensity of reflected light, heat, or another range of values on the electromagnetic spectrum. Also, generic term for pixel-based representation of a document.

Internet: The global network of computers that communicate through a common protocol, TCP/IP.

Intranet: A network based on TCP/IP protocols inside an organization‘s firewall accessible only by the organization‘s members, employees, or others with authorization.

Java: Java is a programming language originally developed by James Gosling at Sun Microsystems and released in 1995 as a core component of Sun Microsystems' Java platform. The language derives much of its syntax from C and C++ but has a simpler object model and fewer low-level facilities. Java applications are typically compiled to bytecode that can run on any Java virtual machine (JVM) regardless of computer architecture. There were five primary goals in the creation of the Java language: It should be "simple, object oriented, and familiar", "robust and secure", "architecture neutral and portable", "interpreted, threaded, and dynamic" and it should execute with "high performance".

jCOLIBRI: “Java Cases and Ontology Libraries Integration for Building Reasoning Infrastructures” is an object-oriented framework in Java for building Case-Based Reasoning (CBR) systems. It includes mechanisms to Retrieve, Reuse, Revise and Retain cases and is designed to be easily extended with new components.

JDBC: Java Database Connectivity (JDBC) is an application programming interface (API) for the Java programming language that defines how a client may access a database. It provides methods for querying and updating data in a database. JDBC is oriented towards relational databases. JDBC API is the industry standard for database-independent connectivity between the Java programming language and a wide range of databases – SQL databases and other tabular data sources, such as spreadsheets or flat files. The JDBC API provides a call-level API for SQL-based database access. JDBC technology allows you to use the Java programming language to exploit "Write Once, Run Anywhere" capabilities for applications that require access to enterprise data. With a JDBC technology-enabled driver, you can connect all corporate data even in a heterogeneous environment. http://java.sun.com/javase/technologies/database/

KBS: (Knowledge Based Systems) A system that uses stored knowledge to solve problems in a specific domain. KBS is a program for extending and/or querying a knowledge base. The Computer User High-Tech Dictionary defines a knowledge-based system as a computer system that is programmed to imitate human problem-solving by means of artificial intelligence and reference to a database of knowledge on a particular subject. KBS are systems based on the methods and techniques of AI. Their core components are the knowledge base and the inference mechanisms.

Keyhole Markup Language (KML): KML is an XML-based language schema for expressing geographic annotation and visualization on existing or future web-based, two-dimensional maps and three-dimensional earth browsers like Google Earth. KML was developed for use with Google Earth, which was originally named Keyhole Earth Viewer. It was created by Keyhole, Inc, which was acquired by Google in 2004. KML files are very often distributed as **KMZ** files, which are zipped KML files with a .kmz extension. When a KMZ file is unzipped, a single "doc.kml" is found along with any overlay and icon images referenced in the KML.

KNN: The k-nearest neighbors algorithm (k-NN) is a method for classifying objects based on closest training examples in the feature space. k-NN is a type of instance-based learning, or lazy learning where the function is only approximated locally and all computation is deferred until classification. The k-nearest neighbors algorithm is amongst the simplest of all machine learning algorithms. An object is classified by a majority vote of its neighbors, with the object being assigned to the class most common amongst its k nearest neighbors. k is a positive integer, typically small. It can be useful to weight the contributions of the neighbors, so that the nearer neighbors contribute more to the average than the more distant ones. The neighbors are taken from a set of objects for which the correct classification (or, in the case of regression, the value of the property) is known. This can be thought of as the training set for the algorithm, though no explicit training step is required. In order to identify neighbors, the objects are represented by position vectors in a multidimensional feature space. It is usual to use the Euclidean distance, though other distance measures, such as the Manhattan distance could in principle be used instead. The k-nearest neighbor algorithm is sensitive to the local structure of the data.

Layer: A logical collection of geographic entities among which a compulsory physical relationship exists.

LGPL: The GNU Lesser General Public License (formerly the GNU Library General Public License) or LGPL is a free software license published by the Free Software Foundation. It was designed as a compromise between the strong-copyleft GNU General Public License or GPL and permissive licenses. The LGPL places copyleft restrictions on the program itself but does not apply these restrictions to other software that merely links with the program. There are certain other restrictions on this software. The LGPL is primarily used for software libraries;

although it is also used by some stand-alone applications. You can use/modify these packages under the terms of the LGPL rules.

Library: An organized, uniformly defined collection of spatial data partitioned by layers and tiles into components. Map libraries may organize geographic data spatially as a set of tiles and thematically as a set of layers. The data in a map library is indexed by location for optimal spatial access.

MatLab: MATLAB is a high-level language and interactive environment that enables you to perform computationally intensive tasks faster than with traditional programming languages such as C, C++, and Fortran (www.mathworks.com).

Meta Data: Data about data. For example, the title, subject, author and size of a file constitute Meta data about the file. The content of a data dictionary is considered Meta data.

Model Builder: Model Builder is an application in which you create, edit, and manage models within ArcGIS software. It is also useful for aoutomated geoprocessing.

Model: Model is a pattern, plan, representation (especially in miniature), or description designed to show the main object or workings of an object, system, or concept. Basically a model is a simplified abstract view of the complex reality. Model may also refer to abstractions of concepts and theories.

MySql: MySQL is a relational database management system (RDBMS). The program runs as a server providing multi-user access to a number of databases. MySQL is owned by a single firm, the Swedish company "MySQL AB", now a subsidiary of Sun Microsystems, which holds the copyright to most of the codebase. MySQL Server is available as free software under the GNU General Public License (GPL). The project's source code is available under terms of the GNU General Public License.

Network: A group of computers and associated devices connected by communications facilities.

Ontology: In computer science and information science, an ontology is a formal representation of a set of concepts within a domain and the relationships between those concepts. It is used to reason about the properties of that domain, and may be used to define the domain.

Photogrammetry: The science of deducing the physical dimension of objects from measurements on photographs.

Pilot Study: An application built to demonstrate the feasibility of a larger application.

Pixel: An acronym for picture element.

Planning Support System (PSS): Constellation of digital techniques which were emerging to support the planning process (Harris, 1989, Batty, 2003). Briefly, PSS means combining information with models and visualization.

Planning: Future arrangement in time and space.

Point: A graphic element identifiable by a single co-ordinate pair.

Polygon: A multisided figure representing an area on a map. A polygon is a spatial feature defined by the series of arcs comprising its boundary and a label-point establishing its centroid. A closed plane figure usually with more than four sides but in GIS, any closed plane figure, such as parcels, boundaries, etc.

Projected Coordinate System: A projected coordinate system is defined on a flat, two-dimensional surface. Unlike a geographic coordinate system, a projected coordinate system has constant lengths, angles, and areas across the two dimensions. A projected coordinate system is always based on a geographic coordinate system that is based on a sphere or spheroid. In a projected coordinate system, locations are identified by x,y coordinates on a grid, with the origin at the center of the grid. Each position has two values that reference it to that central location. One specifies its horizontal position and the other its vertical position. The two values are called the x-coordinate and y-coordinate. Using this notation, the coordinates at the origin are x = 0 and y = 0.

Projection: A method by which the curved surface of the earth is portrayed on a flat surface. This generally requires a systematic mathematical transformation of the earth's graticule of lines of longitude and latitude onto a plane. Some projections can be visualized as a transparent globe with a light bulb at its center (though not all projections emanate from the globe's center) casting lines of latitude and longitude onto a sheet of paper. Generally, the paper is either flat and placed tangent to the globe (a planar or azimuthal projection) or formed into a cone or cylinder and placed over the globe (cylindrical and conical projections). Every map projection distorts distance, area, shape, direction, or some combination thereof.

PSM: (Problem Solving Method) Problem solving has been defined as higher-order cognitive process that requires the modulation and control of more routine or fundamental skills. It occurs if an organism or an artificial intelligence system does not know how to proceed from a given state to a desired goal state. It is part of the larger problem process that includes problem finding and problem shaping.

Raster: Data displayed as discrete picture elements (pixels). A cellular data structure composed of rows and columns. Groups of cells represent features. The value of each cell represents the value of the feature. Image data is stored using this structure.

RBR: (Rule Based Reasoning): A particular type of reasoning which uses "if-then-else" rule statements. As mentioned above, rules are simply patterns and an inference engine searches for patterns in the rules that match patterns in the data.

Relational Database Management System (RDBMS): A database or database management system that stores information in tables (rows and columns of data) and conducts searches by using data in specified columns of one table to find additional data in another table. Most GIS systems are RDBMS oriented. In a relational database, the rows of a table represent records (collections of information about separate items) and the columns represent fields (particular attributes of a record). In conducting searches, a relational database matches information from a field in one table with information in a corresponding field of another table to produce a third table that combines requested data from both tables. For example, two attribute tables can be linked to a spatial data table via the postal code.

Remote Sensing (RS): RS is defined as the acquisition of information about an object without being in physical contact with it RS is any of the technical disciplines for observing and measuring the earth from a distance, including satellite imaging, global positioning systems, radar, sonar, aerial photography, etc.

Row: A record, instance, or occurrence of attributes in a table or a horizontal group of cells in a gird or pixels in an image.

Scenario: A method of reproducing "alternative futures" by starting from the present and following a complete range of alternative choices or happenings at successive points in the future

Server: A computer or device on a network that manages network resources. For example, a file server is a computer and storage device dedicated to storing files. Any user on the network with permission can store files on the server.

Shapefile: A shape file is a simple, non-topological format for storing the geometric location and attribute information of geographic features.

Simulation: A method of reproducing the behavior of a system without reproducing the system itself.

Spatial Data: Information about the location, shape and relationships among geographic features.

Spatial Decision Support System (SDSS): Spatial Decision Support System is a framework for integrating database management systems with analytical models, graphical display and tabular reporting capabilities and the expert knowledge of the decision-makers. Such systems can be viewed as spatial analogues of decision support systems developed in operational research and management science to address business problems.

SQL: SQL (Structured Query Language) is a database computer language designed for the retrieval and management of data in relational database management systems (RDBMS), database schema creation and modification, and database object access control management.

System: A set of relationships

Table: A collection of columns and rows. It is often represented in a single database file.

Topography: Shape or configuration of the land surface; represented in map form by contour lines.

Topology: Descriptions of geographical relationships of features; especially which features are adjacent to or connected to other features. The explicit representation of the position of a feature, relative to features it defines, or is defined by.

UTM: Universal Transverse Mercator system is a specialized application of the Transverse Mercator projection. The globe is divided into 60 north and south zones, each spanning 6° of longitude. Each zone has its own central meridian. Zones 1N and 1S start at -180° W. The limits of each zone are 84° N and 80° S, with the division between north and south zones occurring at the equator. The polar regions use the Universal Polar Stereographic coordinate system.

Vector: A geometric element, stored as a point with X, Y coordinates within a computer database. A coordinate-based data structure commonly used to represent linear map features. Each linear feature is represented as x,y coordinates. Attributes are associated with the feature.

Virtual Reality (VR): VR is a technology which allows a user to interact with a computer-simulated environment, even real or imagined one.

Web Browser: Client software that is used to look at various kinds of Internet resources. The two most popular browsers are Netscape and Internet Explorer.

WGS 1984: World Geodetic System 1984 using the WGS 1984 spheroid

XML: Extensible Markup Language (XML) is a method for putting structured data (such as that in a worksheet) in a text file that follows standard guidelines and can be read by a variety of applications. Designers can create their own customized tags, enabling the definition, transmission, validation, and interpretation of data between applications and between organizations.

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