Proposals for public infrastructure investments invariably exceed the resources available. The systematic appraisal and professional management of all projects helps to ensure that the best choices are made and that the best value for money is obtained. Government institution responsible for public project life-cycle management should collect, analyse and use relevant information for the effective management of their investment projects and programmes. Institutions process protocols have to set out the main steps which should be followed in evaluating and managing national infrastructure investment plan. Case Based Reasoning System applied for selection and retrieving of quality Integrated Project Databases stored at public projects Knowledge Base could be considered as a decision support for selection and appraisal phase. Development of public projects Knowledge Base, aims to assist public sector managers dealing with infrastructure projects to ensure that experience gained can be used for better project appraisal and management.

KEYWORDS: case based reasoning, knowledge base, public sector, infrastructure, process protocol.

1. INTRODUCTION

Ministry for National Investment Plan – NIP, Government of the Republic of Serbia, is responsible for all the phases of public projects life-cycle management: project appraisal and approval (according to development and transition impact), NIP funding (public funds, IFI soft project loans and grants), project financing (different funding streams and structures for national, regional and local projects), procurement procedures and project monitoring (NIP and IFI procedures) and post-project review.

According to EBRD Transition Report for 2008, Serbia needs to build infrastructure, face essential reforms in energy, transport and telecommunications sector and consider soft project loans and PPPs for infrastructure development. IFI project loans and IPA and IPF grants are new investment mechanisms and sources of finance for NIP projects. Project appraisal, selection and approval need to be redesigned according to national and IFI standards. New NIP application form is developed according to international standards. NIP public project monitoring is going to be implemented according to IFI procedures. Post-project review will give important feedback information for new NIP project cycle for 2010. NIP 2009 project portfolio consists of 431 projects (64% are infrastructure projects). The five stages of NIP projects appraisal and management process (set out in Figure 1) are:

1. Initiation and application – NIP application form, Public invitation for project proposals, project proposals submitted on-line through tailor made IT application.
2. **Selection and Appraisal** - Preliminary Appraisal aims to assess if the project has sufficient merit to justify a full detailed appraisal, aims to provide a basis for a decision on whether to drop a project or to approve it in principle.

3. **Planning and Approval** - This involves detailed planning and costing of the project, no commitment to finance a project should be made until this stage is completed and a decision taken on whether to proceed is taken.

4. **Implementation and monitoring** - This requires clear arrangements for monitoring progress and cost control, securing project standards and timely delivery.

5. **Commissioning and Post-Project Review** - A review to confirm whether project objectives have been met, the project has been delivered to required standard, on time and within budget and to ensure that experience gained can be used on other projects and possibly in the continued use of the new asset.

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**Figure 1: Five stages of NIP project appraisal and management process**

It is very important to be more strategically oriented in IT management in construction industry, using process approach to activities (Betts et al., 1995). Development of process and IT protocols, and the results of post-project review (whether project objectives have been met and delivered to required standard, on time and within budget), aims to assist public sector managers dealing with infrastructure projects. Different off-shelf and tailor made IT tools is going to be implemented in IT Protocol. Case Based Reasoning – CBR System applied for selection and retrieving of quality Integrated Project Databases - IPDB stored at public projects Knowledge Base – KB could be considered as a decision support for project management. Above presented IT support is one kind of process approach to investment project activities.
2. PUBLIC INFRASTRUCTURE PROJECT LIFE-CYCLE

Ministry for NIP has developed a new application form according to European Commission Instruments for Pre-Accession Assistance - IPA standards. Project proposals are submitted on-line through tailor made IT application. Project centre and project applicants are responsible for this stage. An important task of any public sector organisation is continually to reassess public needs and objectives. New projects should only be undertaken where there in a clearly established public need for the projects or service provided. Existing services should be reviewed to ensure that the kind of service provided is the kind of service required, and is on the appropriate scale. Important data from initiation and application phase have to be stored in IPDB. Project centre, independent Appraisal Institution and Coordination Body are responsible for selection and appraisal phase. The basic purpose of systematic public infrastructure project appraisal is to achieve better investment decisions. The appraisal stage normally involves two separate tasks, preliminary and detailed appraisal. The preliminary appraisal leads to a recommendation on whether to proceed to the detailed appraisal stage. Detailed appraisal leads to a recommendation on whether to approve a project in principle. All data from selection and appraisal phase have to be stored in IPDB.

At detailed appraisal stage, it is important to select appropriate national or IFI procurement procedure to be used. The planning stage involves seven steps: establishment of project management structure, preparation of a project brief, detailed planning and design, review of proposal, using information provided by the planning process, obtaining approval, obtaining tenders for projects, review of proposal and using tender prices. The information system should reflect the nature of the public infrastructure project but should deal with all of these points. Data from planning and approval phase have to be stored in IPDB.

The implementation stage begins once final approval for the award of a contract has been secured. The critical tasks at this stage are to manage and monitor the project to ensure that it is executed satisfactorily. Implementation of the project is the responsibility of project centre, Project Management Unit - PMU, Project Implementation Units - PMI, Project Management Committee and Coordination Body.

Contract Placement should arrange to procure the services of a contractor in accordance with EU and national procurement requirements. All public projects must be monitored according to NIP and IFI procedures on an on-going basis to ensure that they are being completed to the required cost, quality and time profiles. Project data from implementation and monitoring phase have to be stored in IPDB. A post-project review aims to draw lessons for the future. A post-project review should be undertaken once sufficient time has elapsed to allow the project to be properly evaluated with sufficient evidence of the flow of benefits and costs from it. There are two separate focuses of review: project outturn and appraisal and management procedures. Post-project review conclusions can be applicable to other project, to the ongoing use of the asset, or to associated policies. Data from commissioning and post-project review phase have to be stored in IPDB.

3. PROCESS PROTOCOL

There are three main elements in all definition of Business Process Re-engineering – BPR: Process, Redesign and Information Technologies–IT. According to Venkatranam (1991) "BPR involving the reconfiguration of the business using IT as a central lever. Instead of treating the existing business processes as a constraint in the design of an IT infrastructure
the business process itself is redesigned to maximally exploit the available IT capabilities. IT will only achieve profound change if its introduction and use are linked to changes in the overall conduct of the design and construction processes. Development of appropriate Process and IT protocols can support an improved design and construction processes. Working within a process framework/process protocols context is becoming the norm in many manufacturing firms. Process protocols can be defined as a way in which the processes involved in infrastructure public investments are arranged so as to produce an efficient, effective and economical way of undertaking realization of projects.

Process protocols can help in the development of their equivalent IT protocols that position the technologies which enable and support the processes involved within the business environment (Aouad et al., 1998). NIP process protocol is shown at figure 2. NIP IT protocol is going to implement following IT tools: Off-shelf Computer Aided Planning - CAP software, Tailor made Project Management software, Risk analysis and "What if ?" Analysis software, Project simulation techniques, CBR, Multimedia software, Cost planning software, CAD, Visualisation and Cost control software. Process wide IT applications are: KB, IPDB, Internet/intranet and Document management.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Phase - Public invitation for project proposals</td>
</tr>
<tr>
<td>2.</td>
<td>Phase - Application for public project</td>
</tr>
<tr>
<td>3.</td>
<td>Phase - Project selection</td>
</tr>
<tr>
<td>4.</td>
<td>Phase - Preliminary appraisal</td>
</tr>
<tr>
<td>5.</td>
<td>Phase - Detail appraisal</td>
</tr>
<tr>
<td>6.</td>
<td>Phase - Project and procurement planning</td>
</tr>
<tr>
<td>7.</td>
<td>Phase - Readiness report and Project approval</td>
</tr>
<tr>
<td>8.</td>
<td>Phase - NIP and IFI procurement procedures</td>
</tr>
<tr>
<td>9.</td>
<td>Phase - NIP and IFI project monitoring</td>
</tr>
<tr>
<td>10.</td>
<td>Phase -Commissioning</td>
</tr>
<tr>
<td>11.</td>
<td>Phase - Post-project review</td>
</tr>
</tbody>
</table>

**Figure 2: NIP Process protokol**

Model breaks down project process into eleven distinct phases which are grouped into four broad stages. A soft and hard gate ensures that major decisions are assessed and evaluated. The soft gate implies that decisions could be conditional, in that public project is not stopped for one or two non-critical activities, thus ensuring concurrency and reduced timescales. The hard gate indicates firm and final decisions regarding whether or not to proceed to the next
phase within the process (Cooper et al. 1998). After the study at University of Salford (Aouad et al., 1997), communications and networking will be a major topic in construction IT over the next ten years. IT applied in IT protocols are coordinated with results of this study, but process phases are based after NIP procedures. IT tools presented in IT protocol must be integrated to provide the right mechanism for a technology push of the process and will finally result in improved interface process which will take advantage of the technology and the new ways of performing businesses (Kaglioglou et al., 1998).

4. IT SUPPORT FOR PORTFOLIO MANAGEMENT

Government institution responsible for public project life-cycle management should collect, analyse and use relevant information for the effective management of their investment projects and programmes. The quality-related NIP Information systems - IS are expected to cover the institution’s own key performance indicators to compare themselves with other similar organisations and to extend the range of their self-knowledge.

4.1 Integrated Public Project Database and Knowledge Base

Integrated public project database - IPDB is integrated database containing data from appraisal, selection, planning, approval, implementation, monitoring, commissioning and post-project review phases of public project life cycle (Figure 3).

![INTEGRATED PUBLIC PROJECT DATABASE](image)

In order to preserve, spread and manage the knowledge accumulated in previously realized public projects, all IPDB can be gathered and stored in a newly created Knowledge Base – KB. KB Systems should preserve developed and rare knowledge in such form that can be efficiency distributed to anyone who needs it (Dutton et al. 1996). KB is shown in Figure 4. KB is intended to be connected with NIP Information system.

![PUBLIC INVESTMENT PROJECT KNOWLEDGE BASE](image)
The basic concept of the KB is that of “Information Gateway” acting as a single entry point to a set of distributed databases. KB should preserve developed and rare knowledge in such form that can be efficiency distributed to anyone who needs it. The aim is to realize more robust, more general, more efficient and more effective KB that perform more complete reasoning cycles and cope with deficient data and other anomalies. Mathematical theory that can provide such approach is RST.

### 4.2 Case Based Reasoning

One of the less well-known sub-fields of Artificial Intelligence-AI is Case-Based Reasoning-CBR. With CBR, past problems and their solutions are stored as individual case histories, and reasoning is based upon the retrieval and use of similar problem descriptions. In this manner, CBR systems in their simplest form can be thought of as external memories for humans, thus providing decision support (Dutton et al., 1996).

CBR offers a different slant to the more conventional KBSs, e.g. Rule-Based Systems-RBS, and may overcome some problems associated with rule-based systems (e.g. Knowledge Acquisition-KA), and encoding this knowledge in rule form. Thus it would appear that CBR offers the potential to develop true 2nd generation expert systems which employ multiple representation and reasoning methods (David et al., 1993). As a Decision Support for projects appraisals phase, NIP is planning to implement CBR and KB systems (Figure 6).

To make that possible, this model should be based on the following hypothesis: Past project proposals and data from whole public project life cycle have been stored as individual case histories in IPDB; KB can be created by gathering and storing IPDB from previous public projects; KB and retrieval of earlier project proposals using CBR system can be used as IT support for public projects selection process; It is possible to create and use CBR model based on RST; Reasoning is based upon the retrieval and use of similar project descriptions; Using this model it is possible to discover quality proposals stored in historical IPDB, which according to its salient characteristics best match present public needs, criteria and priorities characteristics;

### 4.3 Rough Sets Theory

Data from KB can be interpreted using the Rough Sets Theory-RST, which is one of the latest mathematical approaches to definition and analysis of imprecise, unreliable and indefinite data (Pawlak, 1982). Indefinite notions differ from precise notions since they could not be characterized as information.

This Relation of Undifferentiating is the mathematical foundation for RST. According to that, Elementary Set represents any set of objects that do not differ from each other. Sharp (precise) set is any union of some elementary sets; on the contrary the set is rough. Sets of objects that could not be precisely characterized as set members, or his complement, represent boundary examples of Rough Sets – RS (and are situated on the boundary line). On the other hand, sharp sets do not have boundary elements. Any indefinite notion is characterized with couple of definite notions: lower and upper approximation of indefinite notion. Lower approximation consists of all objects that certainly belong to the set. Upper approximation consists of all objects that could belong to the set. Difference between these two approximations represents boundary area of indefinite notion. Undifferentiating and approximation in RS can be presented in mathematical way. From the calculation point of view RS application philosophy is represented as Tables of Data, or Attribute-Value Tables, or Decision Tables. Conditional and decision attributes are presented in these tables. The main advantage of RST is that it does not require any previous or additional information about data, as is the case with possibility degree in Fuzzy Sets Theory (Zadeh, 1965) or
### 4.4 CBR and KB as a Decision Support for Public project proposals selection

Using similar descriptions CBR selects IPDB and makes possible to retrieve proposal with best match of characteristics with current problem.

**Figure 5**: CBR and KB as a Decision Support for Public project proposals selection

### 5. WORKED EXAMPLE

Public need for urban bridge is stated in this paper as a worked example for CBR system. In selection phase manager has to make decisions about appropriate project proposal for urban bridge, which are most suitable to meet current public needs. Considering the public needs and established NIP criteria and priorities, public manager states criterions and salient characteristics for urban bridge design that have to be matched with salient characteristics of previous projects. Similar problem description and CBR model make it possible to retrieve projects with best match of salient characteristics.
Result of the application of CBR model is one potential solution for the current public needs. Solution suggested by CBR system could be considered as IT support for decision-making process. CBR model is intended to discover and retrieve quality IPDB stored in KB. Manager describes public needs with its salient characteristics, and CBR system matches salient characteristics of present problem with salient characteristics of project proposals stored in KB. IPDB of previous project proposals with best match of salient characteristics are retrieved, becoming possible solution for the current public needs. CBR system could be based at RST (Cirovic and Cekic, 2002).

Criterions stated in this example are: Fast Construction - FC, Low Construction Cost - LCC and Possibility for Prefabrication - PFB (assembling). These criterions represent conditional attributes. Applicability of previous projects for present public needs represents decision attribute. Values of attributes are presented linguistically. In this example it is assumed that there are four bridge projects in stored in KB: Pre-stressed concrete bridge, Composite steel and concrete bridge, Reinforced Concrete Bridge and Steel Bridge.

Conditional attributes and decision attributes are presented in table 1. This table represents attribute value table or decision table. Columns in the table represent attributes (characteristic of projects). Every row of the table is considered as information about particular bridge design. For example, Pre-stressed concrete bridge is characterized with the following set of attribute-value: (Fast Construction, Yes), (Low Construction Cost, No), (Possibility for Prefabrication, Good). This set of attribute values represents the information set about bridge project 1.

<table>
<thead>
<tr>
<th>Previous bridge projects</th>
<th>Fast Construction</th>
<th>Low Construction Cost</th>
<th>Possibility for Prefabrication</th>
<th>Applicability of bridge design</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Pre-stressed concrete bridge</td>
<td>Yes</td>
<td>No</td>
<td>Good</td>
<td>Yes</td>
</tr>
<tr>
<td>2) Composite steel and concrete bridge</td>
<td>Yes</td>
<td>No</td>
<td>Good</td>
<td>No</td>
</tr>
<tr>
<td>3) Reinforced concrete bridge</td>
<td>No</td>
<td>Yes</td>
<td>Poor</td>
<td>No</td>
</tr>
<tr>
<td>4) Steel bridge</td>
<td>Yes</td>
<td>No</td>
<td>Excellent</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Solutions 1, 2 and 4 do not differ from each other compared to attributes Fast Construction and Low Construction Cost, while solutions 1 and 2 do not differ from each other compared to attributes Fast Construction, Low Construction Cost and Possibility for Prefabrication. Attributes Fast Construction and Low Construction Cost generate two elementary sets \(\{1, 2, 4\}\) and \(\{3\}\), while attributes Fast Construction, Low Construction Cost and Possibility for Prefabrication generate three elementary sets \(\{1, 2\}\), \(\{3\}\) and \(\{4\}\). Solution 1 represents applicable solution, while solution 2 represents inapplicable solution, although these solutions do not differ from each other compared to attributes Fast Construction, Low Construction Cost and Possibility for Prefabrication.
That means that it is not possible to characterize applicability of solutions 1 and 2 compared to attributes \textit{Fast Construction}, \textit{Low Construction Cost} and \textit{PFB}. Analyzing decision table the following conclusions can be drawn. Solutions 1 and 2 are \textit{boundary cases} (situated on boundary line) and could not be correctly classified according to accessible knowledge. Remaining solutions show characteristics according to which they can be classified. It is obvious that solution 4 is applicable. It is also obvious that solution 3 is not applicable. For solutions 1 and 2 it is not possible to exclude that they are not applicable. \textit{Lower approximation} of "\textit{Applicable Solution}" (solution that can be retrieved during the work on present project) is set \{4\}. \textit{Upper approximation} of these sets is set \{1, 2, and 4\}. Boundary cases are solutions 1 and 2. Solution 4 is applicable and decision is to retrieve it, while solution 3 is not applicable and decision is not to retrieve it. Lower approximation of notion "\textit{Inapplicable Solution}" is set \{3\}. \textit{Upper approximation} of this notion is set \{1, 2, and 3\}. \textit{Boundary area} in this case is set \{1, 2\}.

Selection and retrieving of quality IPDB, stored in KB, facilitate the shortening of project selection and appraisal process. Projects suggested by CBR system sets the Standard of Quality for public manager, which should be maintained or exceeded during the selection and appraisal process. Although the application of created model is in selection phase, the results of this application are far-reaching and continue in the next phases of project life cycle.

Direction for further development of the suggested model is in the further expertise of the existing project solution, which has to adopt previous experience to the current needs, since CBR systems could not rely only on the historical cases of project solutions. That can be achieved using the general rules, models, etc. In that way it is possible to provide responses in cases where similar project solutions in the past do not exist. One of possible solutions, which can provide further development of KB, is in application of RST in CBR systems, for overcoming the problem of imprecise, unreliable and indefinite data.

6. CONCLUSIONS

Government institutions in charge of public project portfolio management have to develop and implement a strategy for the continuous enhancement of quality of their process and IT protocols. Different off-shelf and tailor made IT tools could be implemented in IT Protocol. Case Based Reasoning System applied for selection and retrieving of quality Integrated Project Databases stored at public projects Knowledge Base could be considered as a decision support for selection and appraisal phase of public infrastructure projects. The systematic appraisal and professional management of all public projects helps to ensure that the best public infrastructure project proposals have been selected and that the best value for money is obtained.

LITERATURE


