The Application of Case-Based Reasoning In the Construction Industry

(Application paper)

Gihan L.Garas [1],Ahmed R.Anis [2],Adel El Gammal [3]

ABSTRACT

Case- Based Reasoning (CBR) is a relatively recent problem solving technique used in various applications in engineering. However, few have addressed problems relating to construction and its impact on the overall end cost of the project, as well as its negative effect on the environment. This paper aims to develop a CBR application that would provide participants in the construction industry with an estimate of the % of waste in materials of a project under certain conditions. Proposals of procedures undertaken from previous experience to minimize the amounts of expected wastes would be discussed. CBR- works 4 tool is used to develop the prototype. This is used to examine a user's free form text entry through answering a set of weighted questions. Answers to these questions help narrow the number of cases and match them against cases (projects) from the actual life projects undertaken by contractors in the Egyptian Construction industry. The most accurate solution is then presented to the user. The paper concludes the applicability of CBR in affecting the amounts of material waste generated in the construction process.

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KEY WORDS: Case-Based Reasoning, materials waste, construction industry, and environment

1-Associate researcher, National Research Center, Ph.D. student Cairo University, Faculty of Engineering, garas-g@online.com.eg
2-Professor, Civil Engineering Department, Cairo University, Faculty of Engineering, aanis@masrawy.com
3-Professor, Civil Engineering Department, National Research Center, ElgammalAdel@hotmail.com

INTRODUCTION

The construction industry worldwide have been criticized recently for low performance. Apart from criticism on the performance of traditional determinants, like time, cost, quality, and client satisfaction (Poon , 1999;Ridout ,1999) there is also criticism from uncontrolled material consumption and the need to manage it inorder to reduce the overall projects' costs and to protect our environment (USGS Fact sheet ,1998).

The Egyptian construction industry is one of the fastest –growing sectors of the economy in Egypt, with an average annual growth of 20-22% (Abdel Aziz ,2000; Industry analysis Egypt : Construction Fact sheet ,1999). Demand for construction materials and engineering services has been high since 1995 due to extensive private sector construction requirements. An example of the increase in material consumption is the cement consumption with an increase of 10% annually, rising from a per capita level of 95 Kg in 1979, to an estimate of 396 Kg in 1988 (Industry analysis Egypt: Construction fact sheet ,1999). On the other hand, cement production capacity has risen from 9 million tons in 1986/87 to 18 million tons in 1996, while local consumption is projected to rise to 21 million tons by the year 2000 (Egypt Economic profile- Construction Industry report ,1999). Shortages over the last two years have meant revised plans for expansion in Egypt's five major cement plants. These analyses identify the need to reduce material waste from its source while increasing contractors' awareness of the amounts of waste expected to be generated under their various projects' conditions.

AIMS AND OBJECTIVES

Construction contractors invest a great deal of time, money and resources to come up with the most effective construction procedure that would decrease the project overall budget. Considering the complexity and uniqueness of each project as a special case, there rises the need to store projects' data or information effectively to benefit from previous experiences instead of beginning each project from scratch.

Expert or knowledge- based systems (KBS) are one of the success stories of Artificial Intelligence (AI) research that has been developing for many areas of Construction management, architecture design, and planning (Watson and Abdullah ,1994;Brandon and Watson, 1994; Maher et al ,1995; Abdulkadir and Aouad,1997). Among the various (AI) problem solving techniques , arise Case- Based Reasoning (CBR) as a reasoning paradigm for problem solving based on the recall and reuse of previous specific experiences.

It is the aim of this paper ***to develop a CBR application that would provide participants in the construction industry with an estimate of the % of waste in materials of a project under certain conditions.***
In addition, it is intended to propose successful procedures undertaken from previous experience to minimize the expected amounts of waste in materials. The paper concludes with the applicability of CBR tool as reasoning and learning method in the construction industry.

WHAT IS CASE-BASED REASONING?

"Case- Based Reasoning is a general paradigm for problem solving based on the recall and reuse of specific experiences" (Maher and Garza ,1997). At its simple definition , "Case-based reasoning is based on the observation that when we solve a problem we often base our solution on one that worked for similar problem in the past" (Watson,1996). In other words, CBR enables solutions to a problem –in a specific domain-to be obtained through the retrieval of relevant experience (case histories) from previous similar situations (Watson and Abdullah, 1994; Watson 1996).
(Riesbeck and Scank, 1989) had described a CBR developer as one who solves new problems by adapting solutions that were used to solve old problems. In effect, CBR is a cyclic integrated process of solving a problem, learning from this experience, and solving a new problem ,etc. (Aamodt ,1994).
Originating in the US, the basic idea has spread from research area to application fields.

WHY CHOOSING CBR TOOL?

CBR is fundamentally different from other major AI approaches (Aamodt, 1994):

- It is very seldom that two problem situations will be exactly alike. This is the case in the construction projects. "CBR is especially useful in domains that are ill-defined and have no strong causal theories or well understood empirical regularities"(Sycara, 1988).
- Instead of relying on general knowledge of a problem domain, or making association between problem descriptors and conclusions, CBR utilize the specific knowledge of previously experienced concrete problem situations (cases) (Aamodt , 1994).
- CBR is an approach to incremental, sustained learning, since a new experience is retained each time a problem has been solved, making it available for future problems (Aamodt, 1994).
- Both CBR and expert systems rely on the explicit symbolic representation of experience- based knowledge to solve a new problem. However, expert systems use past experience stored as rules of thumb or logical inferences. CBR uses an abstraction of specific problem solving experience usually including the "problem" and its "solution" to learn to solve a new problem (Maher, 1997).
- Implementing Knowledge Based Systems (KBS) is a difficult process requiring special skills while CBR is reduced to identify significant features that describe a case which is an easier task (Watson and Marir, 1994).
- KBS once implemented they are difficult to maintain (Bachant and Mc Dermot, 1984; Coenen and Bench-Capon, 1992; Watson ET al., 1992b). While CBR systems can learn by acquiring new knowledge as cases thus making maintenance easier (Watson and Marir, 1994).
- One major advantage of CBR over other conventional rule- based, and model-based expert systems is that diagnostic knowledge is represented in English, not in program code. This would ease the domain experts' validation process and speeds up development (Watson and Abdullah, 1994).

THE CBR CYCLE

A general CBR cycle can be represented as a cyclic process comprising the four REs (Watson and Marir, 1994:Aamodt and Plaza, 1994):

1. RETRIEVE the most similar case(s)
2. REUSE the case(s) to attempt to solve the problem
3. REVISE the proposed solution if necessary, and
4. RETAIN the new solution as a part of a new case

A new problem is matched against cases in the case-base and one or more similar cases are retrieved. Among those retrieved cases there will be one suggested solution that will be reused and tested for success. Unless the retrieved case is a close match to the problem solution, the solution will be probably revised producing a new case that can be retained in the case-base. (Watson ,1996).

CBR-WORKS TOOL

- **System Description**

Many case-based applications or systems have been developed in the domain of civil engineering. This paper presents an application operating within the CBR-Works4 tool developed at tec:inno GmbH in the domain of construction management .This domain specifically addresses ***waste of building materials in the Egyptian Construction Industry*** during the construction phase. The application consists of a "Case Base Model", and a "Domain Model"(Fig1).

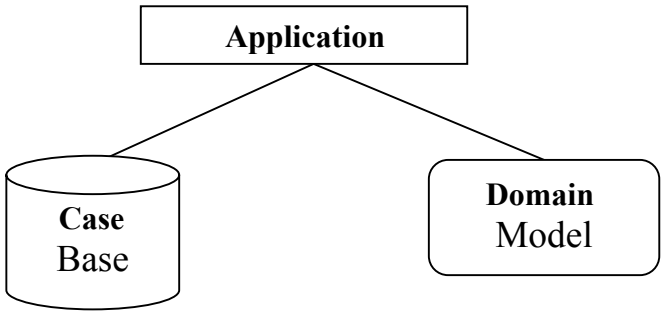

Fig 1 Basic Structure of a CBR Works Application

- **Case Base Model**: It is the database where the case data (from previous projects) is stored.

- **Domain Model**: Contains all information describing the relations among case data and the terminology of a domain. The domain model will be described in terms of "concepts", "attributes", and "types".

- **Concepts**: The main concept in this prototype is "Materials Waste Estimate". This concept diagnosis 3 types of projects: "Residential", "Building", and "Engineering" projects.

- **Attributes**: These are the features representing each project (case). Fig2 demonstrates the attributes associated within this domain.

- **Types**: A type gives the value-range of an attribute. This type contains all values valid for the features, which the attribute represents, e.g. Fig 3 represents the type of attribute "Total project budget" as an "integer" ranging between 1,000,000 and 50,000,000 LE.

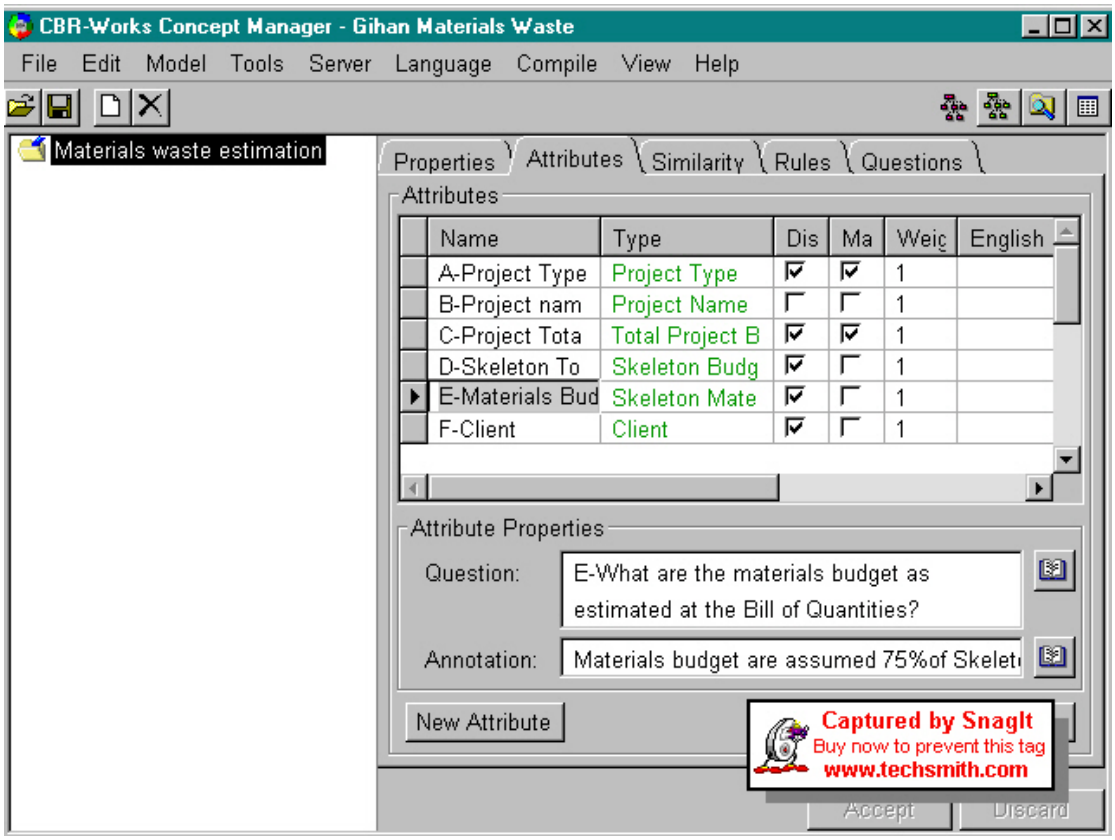

Fig2 Concept Manager screen indicating main concept, Attributes, and Types

- **Basics on using CBR**-works

CBR works navigate through four screens. Two screens allow the entrance of data relating to the Domain Model, and the other two screens allow the entrance of data relating to the Cases Database.

1. CBR-works Concept Manager: In this screen we enter concepts and their properties.
2. CBR-works Type Manager: Here we define the types assigned to each attribute.
3. CBR-Works Case Explorer: Allows the entrance of case data and organize the case data (Fig 4).
4. CBR-works Case Navigator: This is where we can test the retrieval properties of our application (Fig 5).

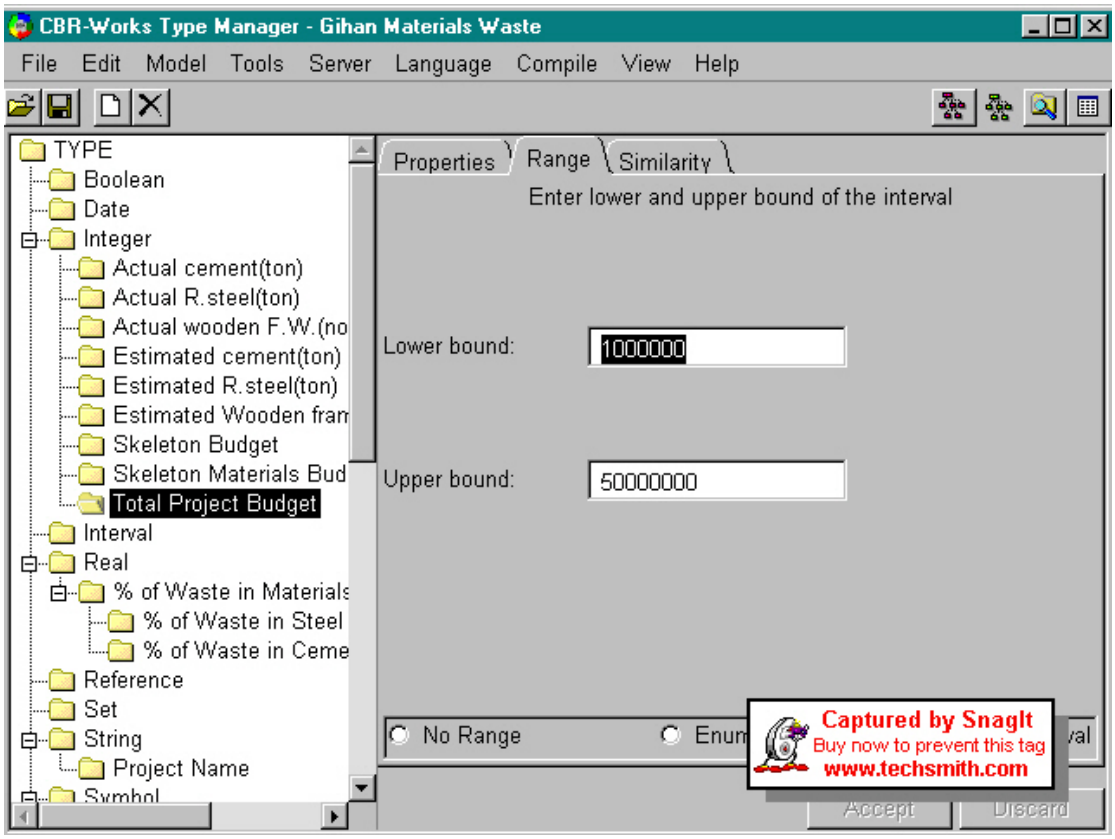

Fig3 Type Manager Screen indicating upper and lower bounds

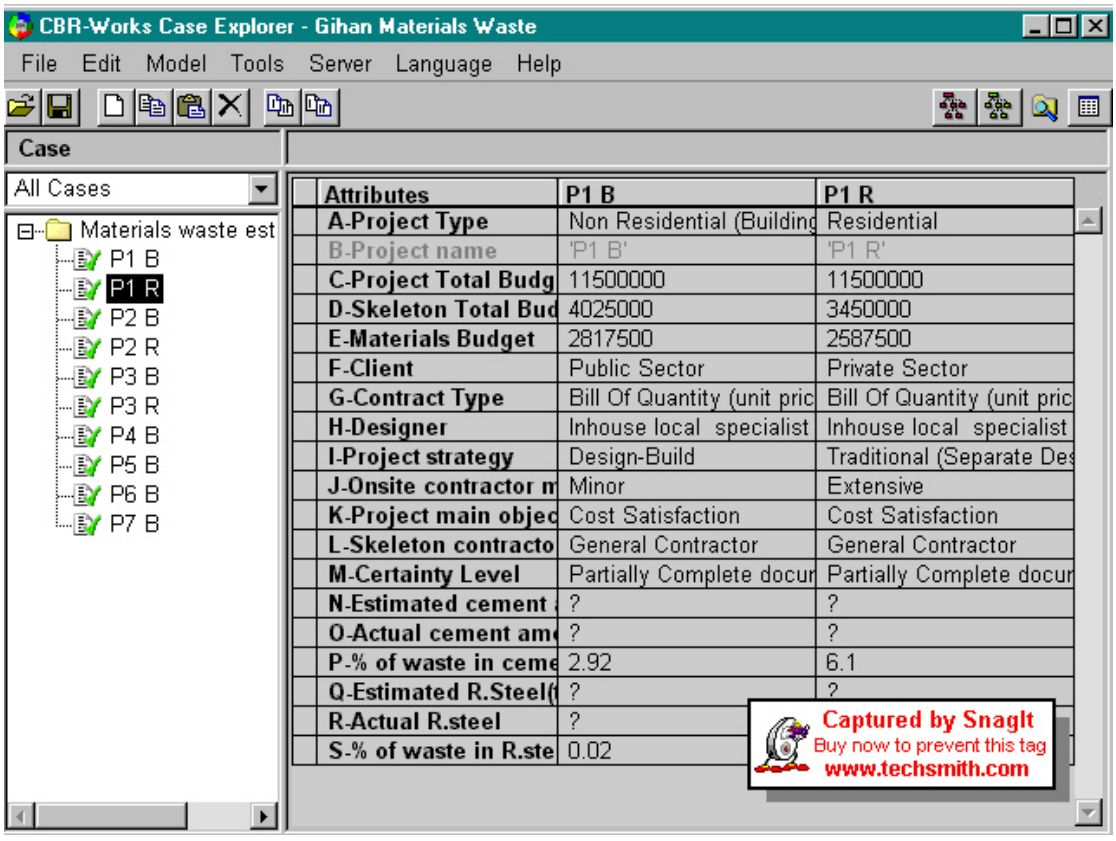

Fig 4 indicating cases (projects) illustrated from the Egyptian Construction Industry

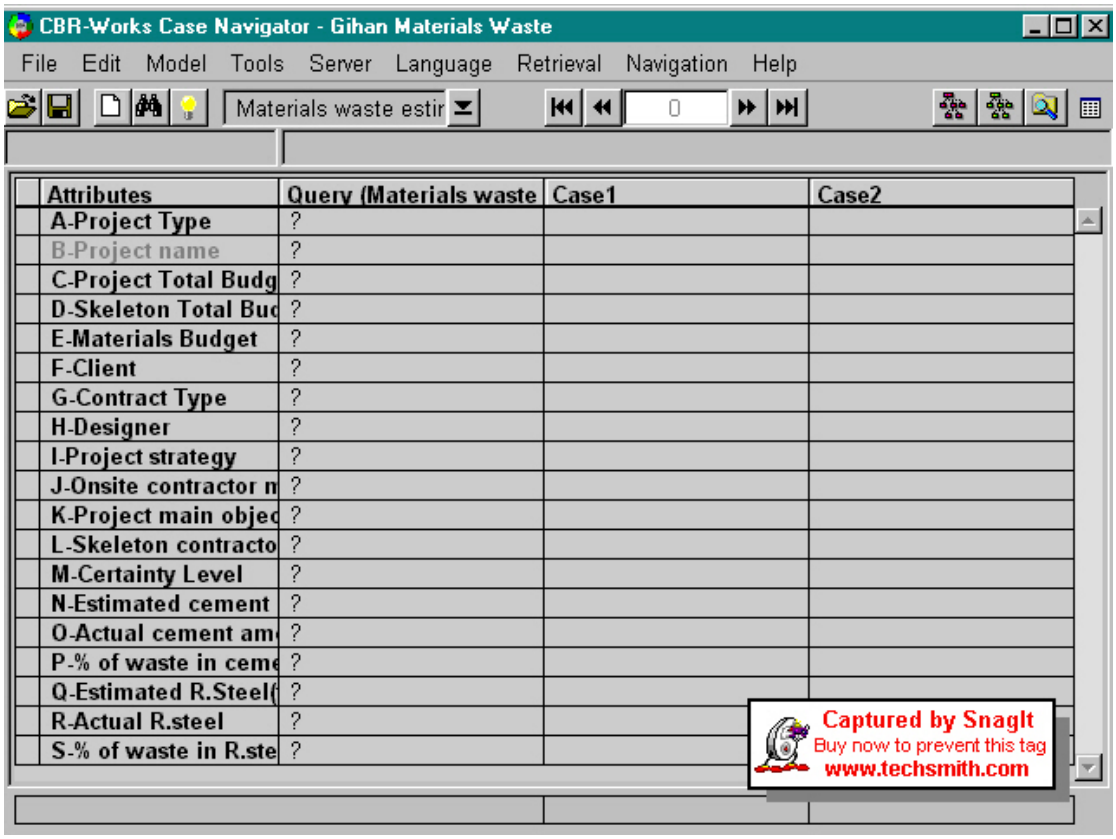

Fig 5 Navigator Screen showing the query used for case retrieval

SYSTEM DEVELOPMENT

The first step in the system development relied on professionals' previous experience in the domain of construction specifically contractors. The dominant factors affecting the material waste generation rates in the Egyptian Construction Industry had been compiled (Garas ET al. ,2000) and incorporated into an extensive Data Sheet. The Data Sheet was designed to analyze the problems associated to materials waste in each project(as a unique case) as well as the procedures tackled to reduce this amount throughout the life period of the project. Each Data Sheet represents a case (project from the life experience of a 1st class contractor). The cases were fed inside the system to form the "Case Base Model". Fig 4 demonstrates the Case explorer screen where a sample of the cases is shown.

SYSTEM VALIDATION

In order to validate the system a set of questions were built inside the Case query represented in the Case Navigator screen Fig5.These questions were used by professionals in the construction industry (who were neither experienced in AI, nor programmers). Each question could be set a weight according to the projects' conditions. The system would Retrieve the most similar cases ranked according to their similarity to the weighed questions. The proposed solution would then be Revised and tested for success. The final step, the system would Retain the proposed solution to the case base memory to be added as a new case.

CONCLUSION

The uniqueness and complexity nature of construction projects have demonstrated the use of CBR as a general paradigm for problem solving based on the recall and reuse of previous experiences (cases). The CBR Works 4 tool –developed at tec:inno GmbH- was used to build the prototype. The system successfully provided the users with an estimate of % of waste in materials based on the types of projects and the conditions associated to each project.
CBR works was successful in demonstrating that:

- An engineer (who is not a programmer)could develop a CBR system much easier and quicker than using any other AI approach for problem solving.
- CBR can be easily maintained and modified.
- Query weights expressed users' preferences.
- System validation was easily implemented using experts in the construction who were not specifically professionals in expert systems.

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