KBSs, including the following:

- the lack of an effective process model for KBSs,
- insufficient guidelines about when to use various knowledge-engineering methods and techniques, and
- the bottleneck produced in acquiring expert knowledge.

In addition to research in the field of industrial systems, the European Union has also focused on multidisciplinary integration in the field of commercial construction. This focus has led to the initiation of programs such as the Computer Models for Building Industry in Europe (COMBINE) research project conducted by the VTT research organization in Finland. The COMBINE 1 project, which was completed in November 1992, identified all essential building energy, service, functional, and performance characteristics so that they could be linked into the same computer modeling process (VTT 1999). This linkage allowed for the construction of an integrated data model (IDM) that provided for the interface of six performance tools covering heating, ventilating, and air conditioning; internal space planning; thermal simulation; energy analysis; energy-economic design; geometric modeling; and the design of external building elements. The COMBINE 2 project that followed utilized the IDM created in COMBINE 1 to develop an operational integrated building design system (IBDS) that could be used for both architectural design and building services engineering.

Subsequent projects, including the Product Model Based Integrated Simulation Environment (PROMISE) project and the object-oriented CAD tool (OOCAD) project (Figure 2.4), have been conducted to further refine and expand the VTT modeling process.

One of the most inclusive of the object-oriented systems is OSCONCAD, an integrated system for combining CAD and construction-related applications. This system, developed in the United Kingdom in 1998, "addresses the problems of design fragmentation and the gap that exists between construction and design processes. It provides a vehicle for storing architectural design information in an integrated construction object-oriented database that can be shared by a range of computer applications" (Eastman 1998). The OSCONCAD model uses an object-oriented modeling approach to create standard architectural models complying with both industry foundation classes (IFC) for common interpretation of construction design objects and common object request broker architecture (CORBA) for distribution of the objects within construction applications. It also attempts to produce independence from the display environment by providing a set of abstract factory and abstract design classes that can be used by the design model classes to render themselves in any display environment. A distinct advantage of this system is that graphical and textual information about the building design components is directly saved in an object-oriented database as instances without passing through the existing CAD databases.

Current US Efforts in Building Technology

Several notable efforts are currently under way in the United States to provide a greater return on investment for residential housing dollars spent. Most seem to involve some sort of optimal value engineering or systems engineering process, while others are focused on the discovery
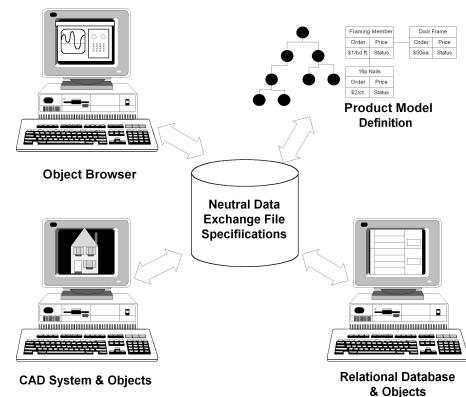
Figure 2.4: Object-oriented CAD project. *Source:* Seren et al. 1993.