

**Integration of Microcomputer Applications -
Current and Future Approaches**

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Abstract

The degree of integration of microcomputer applications used on a construction project varies widely. The range goes from stand-alone applications on a single micro to multiple applications that share a single database stored on a server in a local area network that is in turn linked to a corporate database stored on a mainframe at headquarters. This paper explores the current options available for integration and the changes that may occur as new technology is introduced for databases, communication and CAD/CAE. These changes will have a profound impact on the type of applications that are integrated and on the nature of the interactions among field engineering and management personnel.

Integration - Definition

A CII Design Task force committee [1] has defined integration as follows: "Integration provides a common database that is accessed, used and updated by multiple applications or users. The information in an integrated system is organized in a logical way and demonstrates a centralized behavior with consistent and non-redundant data". This definition does not require that all the information be in a single database or at a single location, just that the systems exhibit a "centralized behavior".

Integration - Current Options

A wide range of options for integration are currently available. Although the stand-alone use of microcomputers is still the most widely used, the rapid growth of local area networks (LANs) has encouraged the growth of greater integration so that systems can more effectively serve a number of users with timely and accurate data and more comprehensive and useful outputs. Database and disk technology have also made advances which allow larger databases to be stored and used in a secure manner. The limitations in developing larger integrated systems are

often caused by the additional complexity of such systems and the associated cost and time required. In response to these challenges, firms are turning to more powerful development tools such as fourth generation languages (4GL) and packages that automate the system analysis and in some cases the programming aspects of development. These computer aided system engineering (CASE) tools provide a methodical approach to capture user requirements and generate outputs that can either be used by programmers or to generate code directly.

Figures 1 through 4 illustrate a range of integration options from multiple stand-alone applications on a single microcomputer to multiple applications that share a common database on a LAN that communicate with a centralized corporate database. Each figure represents a higher level of integration.

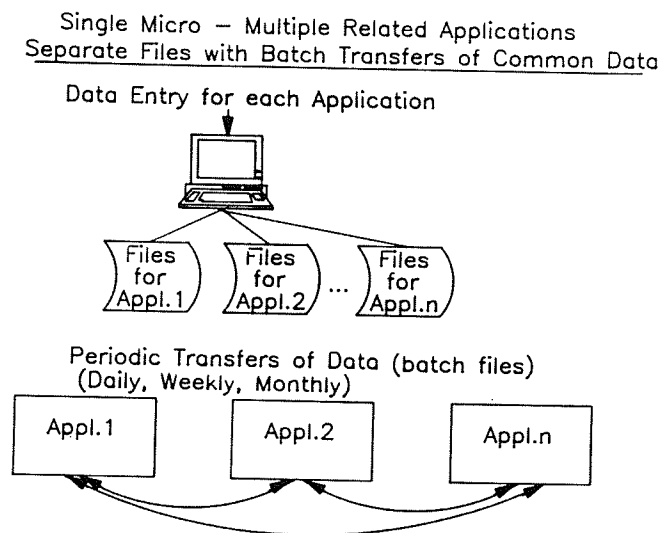


Fig. 1 Single Micro - Multiple Related Applications
 Separate Files with Batch Transfers of Common Data

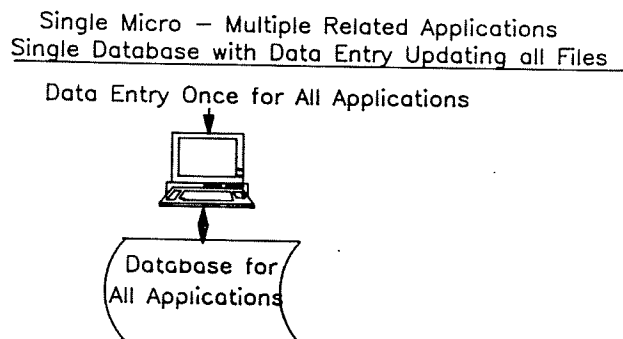


Fig. 2 Single Micro - Multiple Related Applications
 Single Database with Data Entry Updating all Files

Multiple Micros - Multiple Related Applications
Single Database with Data Entry Updating all Files

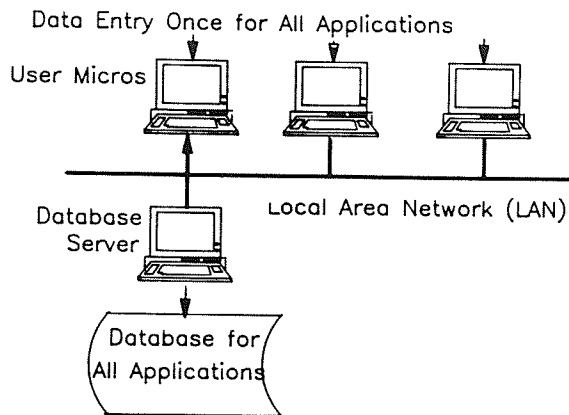


Fig. 3 Multiple Micros - Multiple Related Applications
Single Database with Data Entry Updating all Files

Multiple Micros - Multiple Related Applications
Single Database with Data Entry Updating all Files
With Link to Corporate Database at Headquarters

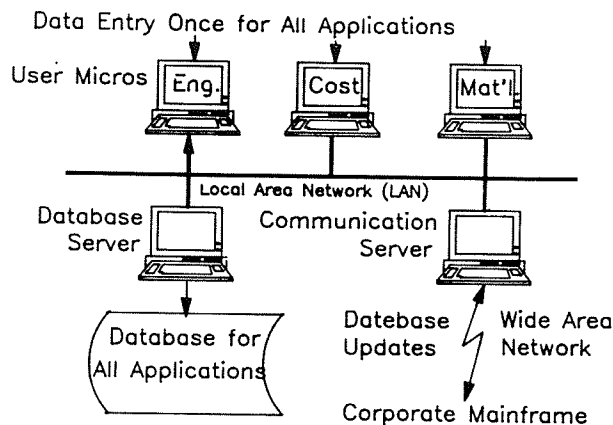


Fig. 4 Multiple Micros - Multiple Related Applications
Single Database with Data Entry Updating all Files
With Link to Corporate Database at Headquarters

The software options currently available for integrating a set of typical administrative applications, e.g. procurement and inventory control with cost control, include the following:

1. Using a commercial database package such as dBase or Oracle to develop all aspects of the applications. The relational files and operators provided by the package are the mechanism for linking the applications. This approach

is limited by the capabilities of the database and development tools, but provides a rapid and incremental development path.

2. Using lower level programming languages such a C or Cobol with a database that is accessed from "calls" by the application programs. This approach lacks the development speed and coordination that a central data dictionary provide, but allows greater flexibility. Because the individual programs are not linked to a central data dictionary (which contains the information about all the data and data relationships supported by the system), both the initial development and subsequent changes to the system require that complete written documentation and standards be developed. Without this external control, a large system quickly becomes unmanageable.

Regardless of the development tools used, integration in a multi-user (LAN or mini) requires that careful attention be paid to record locking so that users see consistent information and files are not corrupted by multiple concurrent updates. In addition, there must be provision to automatically back out partial updates if power fails during the middle of a transaction. These tools are provided by some, but not all, database packages. It is a challenge to develop a large integrated system that is both secure from user errors and power failures. It is doubly challenging to develop such an application for construction field use where technical knowledge is often absent and the environment may be difficult.

Typical Applications

The most frequently integrated applications are those that couple accounting and control. These involve a large number of transactions which should be entered only once and used for all functions. Examples of these include:

- . Payroll with Cost and Productivity control
- . Procurement with Inventory Control
- . Procurement and Inventory Control with Cost Accounting and Cost Control
- . Accounts Payable and Receivable with Cost Control
- . Accounts Payable, Accounts Receivable, Payroll, Procurement, Inventory Control and Cost Control with General Ledger Accounting.

These applications all share the following characteristics:

- . Many transactions on a daily basis

- . Time sensitive
- . Require high accuracy of data entry
- . Require large databases
- . Transactions can occur either at field or home office locations
- . Raw or summarized transactions must update files at both field and home office locations
- . History information is created which must be retained for many years
- . Traceability of output values is required back to input transactions via unique source code identifiers.
- . All interact and contribute to an overall picture of a project's cost and budget status.

The above requirements are difficult to meet, particularly when transactions can be generated at more than one location and must update database files in more than one location. In this situation, strict controls must be established to ensure that the database files at each location are equal, i.e., are updated by the same transactions. One way to deal with this problem is to have one of the databases be the "control" and periodically refresh the other databases from this one to ensure conformity.

Integration of Schedule Control (and why it is difficult to accomplish)

Given the above requirements, it is not surprising that there are relatively few construction firms that have implemented systems that have integrated all the above applications. It is less surprising that even fewer have integrated cost, schedule and material control, despite the advantages to be gained. These advantages include the ability to have better communication between the engineering, administrative and material management personnel responsible for a project. Schedule changes should be reflected in the forecast cost of a project and the required material delivery dates. Schedule calculations and analysis should reflect the latest forecasts of resource usage. While this seems self evident, it is the writer's experience that it is difficult to achieve integration of the above three applications. There are a number of reasons why this is the case:

- . The definition of activities in the network is not the same as that used for cost accounts. There may be a need for many activities for a given cost account, e.g. 1 per location for a given type of work. There may also be a need for many accounts contributing to a given activity,

e.g. the activity "build wall" may be composed of the accounts "erect forms", "set rebar", "place concrete" and "strip forms". Thus, a many-to-many relationship exists between cost accounts and activities to avoid restricting the definition of either. Most scheduling packages assume only a one-to-one relationship and do not have adequate flexibility.

. The updating of schedules is not frequent enough, e.g. monthly, to provide adequate timeliness for use for cost and material functions control functions.

. The schedule is not accurate because it is being used for some purpose other than internal management control, e.g. to satisfy owner requirements, protect contractor in a claim, or because the updating is not being done in a thorough manner. In either case, the computer schedule cannot be used for internal control.

. The schedule personnel are not linked closely to the cost and material control personnel on the project. Thus, they have little incentive to work together in an integrated manner.

In the above list, only the first item is technical in nature, the others reflect issues that are under management control. These management issues often slow down the implementation of integration, even when there are significant advantages.

Integration of CAD/CAE with Construction Applications

The emerging area of integration is that of CAD with engineering analysis (CAE) and construction (CAC). While the initial use of CAD was to automate the drawing function, today's CAD systems stress the use of 3D graphics and integration with engineering analysis, quantity takeoff, estimating, etc (see Fig. 5).

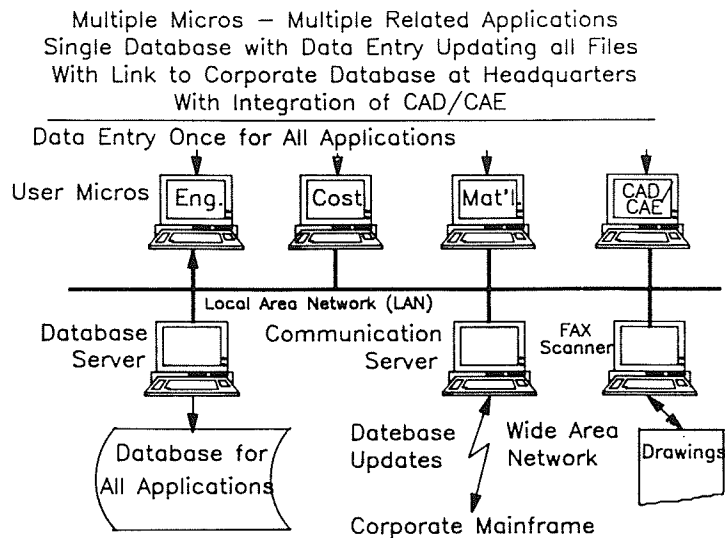


Fig. 5 Multiple Micros - Multiple Related Applications
 Single Database with Data Entry Updating all Files
 With Link to Corporate Database at Headquarters
 With Integration of CAD/CAE

The CAD database is increasingly linked to other databases (normally relational) to provide storage and retrieval of information about the facility that can be used for other (than drawing) functions. This allows various equipment and material lists to be generated from the database. Perhaps even more important, it allows logical queries to be made that link both geometry and object data, e.g. where are all the connections between beams and columns that have stresses above a given value, or where are the valves of a given size and larger that have not yet been tested. This linkage allows the CAD/CAE database to be used for a wide variety of downstream functions. As CAD systems become the starting point for many engineering and construction applications, planning for integration will become even more important. Without this integration, it will be difficult for design-construct firms to extract the construction benefits from the design process. These include [1,2]:

- . Better materials management and control; avoidance of shortages and surpluses
- . Improved constructibility through easier incorporation of construction knowledge into the design

- . Improved construction schedules and ability to reflect design changes into the schedule
- . Ability to use 3D model to simulate construction methods and assembly sequences in order to ensure success in the field, show to field personnel and generate detailed schedules
- . Less field rework and fewer change orders
- . Improved plant operability and maintainability because of ability to reflect these factors in the design
- . Ability to use the "as built" database as the starting point for facility management
- . Ability to better respond to client and outside agency requirements
- . Ability to use the design database for quantity takeoff, estimating and bidding
- . Ability to use the design database for field automation equipment.

The above list of benefits (some are futures) is driving the A/E/C industry toward greater integration both with respect to systems and business relationships. As the benefits from integrated systems become significant, firms are finding ways to form partnerships (internal or external) that allow them to take advantage of these capabilities. Architectural firms may integrate interior design, certain engineering functions (mechanical, electrical, structural) and facility management. Engineering firms may form partnerships where the use of common systems allows improved communication among design professionals. Design-construct firms will emphasize the construction and life cycle benefits derived from the use of a single firm for the entire project. Large owners may start to require that the "as built" 3D model of a project be delivered with the project in a specified format. All of these changes are starting to occur and will become common in the coming years.

Technology Requirements to Achieve CAD/CAE/CAM Integration

The challenge of achieving this greater degree of integration between CAD/CAE and the various control applications used in construction will require significant new capabilities in a number of technologies. These include[3]:

Distributed Databases

Since the design for a project may be done at more than one location (even within a single firm), it will be necessary to communicate design changes in a secure and rapid manner. Today this is done by either transmitting on express mailing tape or disk files daily. These files are used to replace or update the files at another location. In the future, this capability will become an on-line function subject to security and updating controls. It will be necessary to provide for distribution and control of the CAD/CAE database.

Standards

To enable the sharing of data among those participating in a project, it will be necessary to develop standards for representing graphic and non graphic data. These standards should cover both the data representation and naming conventions. Codes for identifying material should be developed to allow electronic use of the data for estimating, procurement and inventory (similar to retail stores and super markets). Data representation standards are being worked on by a number of groups. The most well known is the Product Data Exchange Specification (PDES) effort[5]. The PDES standards will cover non-graphic as well as graphic information. At the present time, The author is not aware of any group developing material naming standards for the construction field.

Translators

Translation of CAD/CAE data from one specific format to another format is the most secure method available today because it accounts for the particular characteristics of each system. Translation to and from a neutral format such as IGES is more difficult because the particular characteristics of a given system might not be able to be translated to the neutral format. In addition, when the translation fails to work properly, it is difficult to find a single vendor who will take responsibility for the

failure (both the source and target system vendors will point a finger at each other). Finally, it is not to the economic advantage of a CAD vendor to provide translation from its system to another system (to keep its customers captive). Despite these difficulties, it seems likely that the increasing importance of integration to the A/E/C industry will push the CAD software vendors towards better support of a neutral standard once one is developed and shown to work. Until that time, the current file conversion problems are likely to continue.

. Knowledge Based Systems (and other AI approaches)

In an effort to develop "smarter" CAD/CAE systems, vendors and users will increasingly incorporate Expert Systems into their CAD/CAE products. Potential applications of such systems include: automation of detail design of particular portions of a facility, inclusion of constructibility, operability and maintainability concerns into the design, development of project schedules from the design, making cost saving suggestions for reducing costs by changes to tolerances, materials, etc. The Expert Systems shells available today do not easily integrate into other systems nor do they provide for extensive calculations based on CAD data. In addition, reasoning about 3D space will require new logical operators such as "above" "under" "behind" "near" etc. similar to those used in current systems ("and" "or" "not" etc.)

Summary and Conclusions

Although the majority of microcomputer applications used in the construction industry are stand alone, there is a significant push toward greater integration. The applications that are most likely to be integrated are accounting and cost control because these share many transactions that are entered with daily frequency. Other applications that benefit from integration are scheduling, productivity control, procurement and inventory control. Of these, significant progress has been made in all except scheduling which presents particular problems for integration. The greatest of these is the fact that the definition of activities often differs from that used for cost accounts thus making allocation of resources from cost accounts to activities difficult.

Current tools available to implement integrated systems include database packages with comprehensive data dictionaries and development tools, local area networks, fourth generation languages and CASE systems. These tools allow cheaper and faster development and maintenance of large integrated systems. With the integration of CAD/CAE with management and accounting systems, additional technology is required. New capabilities include the ability to integrate and distribute CAD/CAE data with the data for other applications, the ability to integrate Expert Systems capabilities into other systems and the ability to reason about these combined databases with new logical operators. Significant research is required before these tools will be available for practical use.

Finally, the need for standards cannot be over emphasized. These standards include data organization for 3D graphic and non graphic data and naming conventions for construction materials.

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