Development of an Integrated Construction Management System for Building Estimation

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Abstract

Project management are still depending on manual exchange of information based on paper documents. Where design drawings drafting by computer-aided design (CAD), but the data needed by project management software can not be extracted directly from CAD, and must be manually entered by the user. The process of calculation and collection of information from drawings and enter in the project management software needs effort and time with the possibility of errors in the transfer and enter of information. This research presents an integrated computer system for building projects where the extraction and import quantities, through the interpretation of AutoCAD drawing with MS Access database of unit costs and productivities for the pricing and duration of tasks, then exported to MS Project and MS Excel. The system was developed by using Visual Basic and ActiveX automation technology for combining the above software. The system, also, can calculate quantities of materials. The system includes digitizer (on-screen takeoff) calculates the lengths and areas of the drawings to which the form of an image and scanned. The integrated system has been applied to case study, a storages building for hospital 260 beds. The results proved the effectiveness of the system for the conversion of information from the graphical form *dwg* to numerical formulas *xlcx / xlc* and *mpp* can be handled easily pleased and software are covered.

Keywords: Construction Management, Integrated System, CAD, Estimation, Automation

الخلاصة

لا تزال إدارة المشاريع تعتمد التبادل اليدوي للمعلومات و بالاستناد على الوثائق الورقية. حيث يتم رسم الخرائط و المخططات التصميمية بمساعدة الحاسوب CAD, لكن البيانات المطلوب ادخالها لبرامجيات إدارة المشاريع لا يمكن استخراجها مباشرة من CAD بل يجب ادخالها يدويا من قبل المستخدم. ان عملية أخذ و تجميع المعلومات من المخططات التصميمة و ادخالها في برامجيات ادارة المشاريع تحتاج الى جهد و وقت مع احتمال حدوث اخطاء في نقل و ادخال المعلومات. هذا البحث يقدم نظاما حاسوبيا متكاملا لمشاريع المباني حيث يقوم باستخلاص و استيراد الكميات عن طريق ترجمة مخططات AutoCAD مع قاعدة بيانات MS Access بالكلف و الانتاجيات لحساب الاسعار و المدد الزمنية للفعاليات ثم تصديرها الى برامج MS Project و MS Excel. تم تطوير النظام بأستخدام Visual Basic و تقنية أتمتة ActiveX لربط البرامج اعلاه. بالاضافة الى حساب كميات المواد ، يتضمن النظام Digitizerلحساب الاطوال و المساحات للمخططات التي تكون بصيغة صورية. تم تطبيق النظام المتكامل على دراسة حالة لبناية مخازن لمستشفى 260 سرير. اثبتت النتائج فعالية النظام في تحويل المعلومات من صيغتها الرسومية dwg الى صيغ عددية xlcx / xlc، mpp يمكن التعامل معها بسهولة و يسر بالبرامجيات المشمولة بها.

Introduction

In each phase of project life cycle a lot of information is exchanged among project teams. This information can be graphical (drawings) or non-graphical information (bill of quantities). These two information as independent and are not linked to each other. Current estimating is limited by the lack of integration between electronic design and construction information. Integration of design and cost information is necessary to improve the estimating and to reduce the current fragmentation. New software technologies have been developed that will help to integrate design and cost information (Staub et al, 1998).

In USA, (Elzarka, 2001) had discussed a cost-effective approach for developing computer-integrated construction (CIC) systems by integrating stand-alone CAD (AutoCAD), spreadsheet (Excel), database (MS Access) and scheduling software (MS Project) packages using Visual Basic and ActiveX technology. In India, (Arun and Appa Rao, 2005) presented a simple methodology for integrating computer aided design with construction scheduling using Visual Basic and ActiveX. It makes use of the widely used standard software application packages namely AutoCAD and MS Project along with MS Access database. The integration was achieved by developing suitable interfacing modules and also by creating the knowledge based expert system for incorporating the construction expertise to be used for achieving integration.

In Iraq, Only (Ziyad, 2007) have been developed integrated system CIS (Computer Integrated System) for water Projects, to connect three software (AutoCAD, Excel and MS Project) using Visual Basic and ActiveX data transfer technology. This integrated system can extract the graphical information from an AutoCAD drawing and transfer it to a digital form suitable for processing in the project management software MS Excel and MS Project Due to the CIS does not have a database; unit cost, production rate, precedence of the activities should be entered by user. Passing information from AutoCAD to MS Project indirect, should be presenting it in Excel first. Measure only lengths and quantities that calculate by each, without area and volume.

Research Objectives

The aim of this research is to present a simple approach for integrating CAD with estimation and planning, and to apply it for the case of building projects, as an example. It presents an approach for integrating the existing software. The integration of stand-alone AutoCAD, MS Access, MS Excel and MS Project by using Visual Basic and ActiveX automation technology was proposed as an alternative approach to developing integrated system (InCADEP).

Software Applications in Construction

Computer Aided Design

Before the 1980s, most drawings were created using paper. In 1982, Autodesk introduced AutoCAD software, bringing CAD to the PC and changing the design world forever.

Its use however has been limited to drafting for so many years that it is sometimes referred to as “Computer-Aided Drafting” (Elzarka and Dorsey, 1999). The development of IT and its application in construction industry have brought about some changes to the industry. Such as, the application of CAD grants a CAD drawing with two meanings (Wang, 2001):

- To engineers, it consists of a series of graphic symbols representing a building;
- To computer, it is a process-able data file which contains data related to the building, and this makes it possible to interpret the CAD

drawing and to extract from it the data needed for construction management.

Estimating Software

The computation of construction quantities is one of those tasks which can be dealt with computer technologies. Generally, computing by hands or by evaluation computer software are two major methods for quantity calculation. There are few disadvantages with performing these two methods (Lin, 2007):

- Time consuming.
- Accumulative errors and typos produced from manually computing.
- Leaving some area out of consideration.
- Personnel's lack of graphic working experience to perform the calculation jobs.
- Original system limitations, such as format of input data, etc.

The accuracy of construction quantity is one of the most important factors for controlling building cost in construction industry (Lin, 2007).

The fundamental core of estimating is the takeoff process. Without the information obtained from a takeoff, an estimate can not be performed. While the level of detail varies, the need to know the information obtained in the takeoff process is still vital (Miller, 2001). In the takeoff phase, computer based systems have dramatically changed the available tools from pencils and papers to interactive digitizers (Elzarka and Dorsey, 1999). A simple digitizer was included in the presented system in this research.

In the pricing phase, where prices are assigned to the items selected during takeoff, computer based system have had a major impact. The database of these systems contains most of the pertinent information necessary to prepare an estimate such as unit price and production rate. Such information needs to be entered only once into the database, where it is stored for future use (Elzarka and Dorsey, 1999).

Spreadsheets

Large construction companies use estimating software that cost thousands or even tens of thousands of dollars to purchase (more money than most small-to-medium size builders can afford). However, there are inexpensive ways to do computer estimating. One way is to use computerized spreadsheets that have the power of programs costing thousands of dollars. The benefits of having computer spreadsheets are (Christofferson, 1999):

- Inexpensive
- Easy to use
- Can be customized to your style of doing business
- Very powerful.

(Christofferson, 1999) provides some helpful methods that can turn basic spreadsheets into powerful tools to accomplish estimates quickly and accurately. But main limitation, the estimating effort is centered on taking off quantities, while this research will tried avoiding this limitation.

Spreadsheets vs. Commercial Estimating Software

In 2002 a study (Information Technology Survey for the Construction Industry) in USA by CFMA shows that Microsoft Excel was the most popular estimating software even in the largest-companies group with a 33 percent. Others use specialized estimating software 26 percent use Precision Collection of Timberline. Up to 5 percent of estimating software were the result of companies' own development "Developed in house", Table (1).

In Iraq a questionnaire by (Al-Hadythy, 2006) shown that Timberline not available in the market and it is unknown to the estimators with 100 % percentage. However, the estimators concerns about software products are that they want them to integrate with project management and scheduling. They also want the ability to change the assumptions, such as work crew breakdowns and productivity rates that govern calculations (Farah, 2005).

Limitations of Current Software

Software are applications by commercial vendors and their internal data format are proprietary, which is why they can not communicate their information directly with each other unless they develop specific translators for this purpose.

An architect may use a CAD package to produce a set of drawings. A quantity surveyor/estimator will then use these drawings to produce costing information and bill of quantities. A construction planner/scheduler will also use the drawings and bill of quantities to produce a set of construction schedule. Participants use their preferred software package, maintaining their own subset of the project's information. This approach, although well established, does have a number of disadvantages (Marir et al, 1998):

- The existence of "information lag" between participants
- occurrence of errors when re-entering data
- The difficulty in gathering an overall view of the project for management purposes
- The difficulty in integrating software packages due to the lack of a common conceptual information model.

Architect's first responsibility is to meet the client's expectations in design quality as well as in budget. Widely used by architectural firms, CAD software like AutoCAD does not support any cost data storage on their platform. In order to generate the estimate, Architect/Engineer has to rely on other software. It could vary from a MS Excel spreadsheet to Timberline (Farah, 2005). Users need to calculate quantities by hands with their imagination due to the lack of data for quantity calculation (Lin, 2007).

The CAD graphic documents often exclude information needed for effective project planning. The information that is sufficient for project designs is often insufficient to meet the requirements of project planning (Chen and Feng, 2008). The major tasks of CAD are drawing and visualization (Lin, 2007). However, these are not considered as weaknesses of AutoCAD as this software is only a general drafting tool.

Therefore, the researcher has made an effort to help the practitioners in the construction management by developing the system that presented in this research (InCADEP), which will help the practitioners in the estimating and planning.

Integration in Construction

An increase in the scale and complexity of building production requires a larger number of participants and more efficient communication among them. Because of the fragmented nature of the construction process, construction organizations have always searched for new ways to integrate both inter and intraorganisational functions (Nam and Tatum, 1992) as mentioned by (Kanoglu and Arditi, 2004). Indeed, participants in the construction activity have always encouraged researchers to focus on integration issues with the hope that such research could eliminate the consequences of the currently existing fragmentation in the construction industry. Attempts to deal with fragmentation can be carried out at three levels, namely at the (Kanoglu and Arditi, 2004):

- Organizational level: including approaches such as partnering and design/build contracting,
- Process level: including methods such as lean production, supply chain management, just-in-time delivery, and
- Virtual level: including software and hardware packages aimed at integrating the activities of the parties such as the integrated system described in this research.

Computer Integrated Construction

The concept of Computer Integrated Construction (CIC) is mainly derived from manufacturing industry such as Computer Integrated Manufacturing (CIM). CIC defines a goal to make "better use of electronic computers to integrate the management, planning, design, construction, and operation of constructed facilities". In this context, "integrate" means to "combine" the individual elements to optimize the performance of whole facility (Sanvido and Medeiros, 1990). CIC describes a future target stage of the use of IT in construction. The key factor in CIC is the integrating of the different computing applications used in the life cycle of a building. Such integration will take place via automated digital data transfer between applications (Bjork, 1994).

It is well known that integration of computer applications in the areas of planning, design and construction would help in saving time and cost of construction and in improving productivity (Arun and Appa Rao, 2005). CIC systems automate many of the labor- intensive tasks associated with construction management of new facilities (e.g. building). The main objective of CIC systems is to communicate data to all project participants, throughout the project's entire life cycle and across business functions (such as design, estimating and scheduling). Information processing requirements for many of these construction business functions are currently handled by computer systems that are not integrated. This creates a situation, which many refer to as "islands of automation"**.** Through integrating individual computer systems, CIC systems improve the effectiveness of the entire management process by enabling the communication of information among all business functions through the entire project development process (Elzarka, 2001).

Many large construction companies use integrated systems that cost thousands or even tens of thousands of dollars to purchase (more money than most small-to-medium size builders can afford) (Christofferson, 1999), or have developed CIC systems in house (Elzarka, 2001).

Previous research has shown that at the heart of any effective CIC system is a 3D CAD model (Elzarka, 2001) (Arun and Appa Rao, 2005). Such a CIC system combines 3D CAD models with other project planning and management tools to integrate all parties involved in the project. Off-the-shelf stand-alone packages can now be integrated to develop cost-effective CIC systems that are as powerful and effective (Elzarka, 2001).

CAD Integration with Estimating

This automated model makes direct use of the original electronic CAD files for measurement. The benefits range from cost and time savings to improved flexibility in calculating the cost impact of different what-if scenarios (alternatives) (Staub et al, 1998). In the

Associate General Contractors (AGC) estimating text Construction Estimating and Bidding, several concerns are mentioned concerning integrating CAD with estimating (Miller, 2001) (Alder, 2006). These concerns are listed below (Miller, 2001):

- Who is responsible for quantification errors?
- What software will be universal enough for use?
- How does the architect and/or engineer preserve its copyright when it distributes its total design in a form that can be easily modified and copied by others?

Additionally, the AGC states that the technology may assist the estimator “but will always have many limitations” (Swenson et al., 1999) as mentioned by (Miller, 2001). The technology of CAD integration may in the future play a larger role in the takeoff process (Miller, 2001).

Several studies have been conducted at Stanford University to demonstrate the abilities of estimating using CAD. One study found that those who used CAD software for estimating recorded an 80% reduction in required time to complete an estimate with an accuracy margin of error of +/-3% (Schwegler et al, 2001) as mentioned by (Alder, 2006).

Proposed Approach

The results of design of building from CAD can be appropriately placed in the VB. The building may consist of several components. The CAD model can be used through the integrated system to extract the quantity of different components of the building. The quantity data extracted can be exported automatically to MS Excel spreadsheet. The database can also be modified interactively by the user to input the required data. The database contains information for crew/team productivity rate, unit cost and other parametric. The list of construction activities, their dependencies and estimated duration of activities can be exported automatically to MS Project for generating the construction schedule.

The integration approach described above, it contributes towards automation in construction. It may be noted here that the “approach” is conceptual in nature and it is possible to use it with different levels of details and sophistication.

System Development and Implementation
System Description

The Integration of Computer Aid Design with Estimation and Planning (InCADEP) was developed to facilitate the construction management of buildings projects by integrating the following off-the-shelf applications:

- AutoCAD for drafting the model. AutoCAD contains drawing and editing functions necessary to produce model of building components.
- Microsoft Access database for storing historical project information on crews, productivity and unit costs etc.
- Microsoft Project scheduling system to scheduling the project.
- Microsoft Excel spreadsheet to report the bill of quantities in a convenient spreadsheet format for subsequent manipulation and printing.

The integration of computer applications is carried out under Microsoft

Windows operating system. All components of the system are integrated by using Visual Basic and ActiveX automation technology, as illustrated in Figure (2)

This integrated system has been integrated with objects of the computer applications using VB and ActiveX automation technology. VB plays the role of “glue” that holds together many objects (individual software) applications and packages. Here in this system, VB provided the capabilities to construct user interfaces and access to other software. The operation of the Flow chart as shown in figure (3).

System Requirements and Limitations

- AutoCAD scale should be (1:1).
- All building components must be drawn in one drawing, i.e. one AutoCAD drawing file (*.dwg) and different specific layers names.
- Each door and window should be drawn as a block (for example Door1 drawn as block named 24D1 1_1).
- Need four elevations for building, stairs neglected.
- The cost of the activities is estimated using activity quantities that extracted from the AutoCAD drawing and the cost information stored in database or entered by the user. Information cost should be as unit cost/unit of measure.
- The production rate for an activity is assumed to be fixed along the activity duration (production rate should be as quantity/day).
- The duration of the activities is estimated using activity quantities that extracted from the AutoCAD drawing and the productivity rate information stored in database or entered by the user.
- The precedence of the activities collected from practical constraints governing the construction only and without overlap between activities. Note here the user can enter precedence before exporting data to MS Project.

developed system is represented by the overall system

- The schedule generation is for ground floor only.

System Operation

If the user does not saved database, the user should be enter the unit cost of each item (for example 12,000 ID per square meter for plaster) and enter the production rate per day for each item (for example finishing 100 m2 per day for plaster). The one how use the system can enter the cost by Iraqi Dinar "ID" or US Dollar "$", and the production rate consider in this case depend on the experience of the user.

If the user click on the "Import from ►AutoCAD", Figure (4), the "Open" file dialog box will appears, and the format of file type is limited to (*.dwg) to open only AutoCAD drawing. "Import from ►AutoCAD", allow for automatic extraction of quantities (length, area, volume, each/No. can be calculated) of various components of the building from the CAD model (like area of plaster, number of specific doors, etc). The user can perform the takeoff for the entire building; InCADEP will loop through all the elements contained in the model and calculate its quantities. The quantities will output in the table as shown in Figure (6). The unit cost is then retrieved from the database and the total price is calculated. In this menu "Import from ►AutoCAD", the graphical information convert to textual (non-graphical) information and the user can deal with this textual

Information in easy way more than the graphical information.

Data from this table can be exported automatically to MS Excel spreadsheets just by a click (File menu and then export to ► Excel), Figure (5), which can be kept as a separate file for bill of quantities. This can be used for further estimations. If user click on the "Export to ► Excel", the “Save As” file dialog box will appears, and the format of file type is limited to (*.xlcx \ *.xlc) to save as MS Excel spreadsheet. Then the user first enter “File name” and then click “save”, the InCADEP automatically open the MS Excel and fill the cells with the required information like (description, quantity, ….etc).

InCADEP also contain a "Digitizer" or "On screen takeoff", which can measure (length and area) for image\scanned drawings, support (*.jpg, *.wmf and *.bmp) data format. First, the user should enter scale of drawing (by input the known distance between two points), and then can measure distance between two points and the horizontal and vertical distance for this points; or the user can measure the area and the perimeter.

The Implementation Of The System (Incadep)

The developed system was designed for reinforced concrete building projects. However, the system can be easily modified to cover all types of projects, since the main code of data exchange system is already exist. The system was designed to find: the total volume of foundations, columns, beams, and slabs concrete; Total number of doors and windows; area and volume of brick; total length of DPC; area of plaster and cement plaster and ceramic; area of roof; area of floors etc. The output of system in MS Excel is as shown in Figure(6) & (7).

Conclusions

The following points have been identified as the overall conclusions of the research:

1. Design, cost, and time integration is possible with today’s off-the-shelf software products. The resulting benefits include faster estimating time, fewer takeoff errors, better documentation and reproducibility of the estimating process, and the ability to release a construction schedule electronically with the whole project prior to construction.

2. It is possible to prepare information of the BOQ and construction schedule for the building automatically (with least user interaction) by taking the results from the AutoCAD. A special feature of the system is the CAD modeling facilitating capability to extract quantity. A consequence of this is that project management software will be much easier to incorporate and also can have direct access to the design data from such integrated system.

3. The utilization of integrated systems will become more and more important as the popularity of the design/build project delivery system continues to increase. In the design/build approach, more business functions are performed by the same company and as a result, their integration to share data becomes more vital.

4. The integration of AutoCAD and computer based construction project management software can be utilized to reduce fragmentation and to bridge

existing gaps between disciplines within the AEC industry.

5. With the continuous development in BIM and improvement of programming capability (such as ActiveX automation technology), the potential application of an integrated system in construction practice can no longer be ignored. The industry is also eager to capitalize on this potential. This research provided a vision for meeting the vital, critical and urgent needs by the construction industry for integration tools that enhance the sharing of project information.

6. Integrating design, cost, and schedule information can help a project team to improve the efficiency of the planning and estimating processes. Design-cost integration supports the automatic calculation of quantities, thus shortening estimating time and eliminating the duplication of effort that exists in current estimating practices. In addition, it allows a project team to quickly evaluate the cost impact of different design and specification alternatives, and provides electronic validation that all the items in the CAD model have been included in the estimate. Decisions are expected to be made faster and to become more reliable.

Recommendations

1. The ability to develop integrated systems should entice the construction industry to use these systems. AutoCAD available today, with its ability to link to other software has made such development possible.
2. The IFC standards once fully developed will enhance such integration. However, it is vital to address integration within a business context which is mainly related to process, human and cultural issues.

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Table (1) Estimating software used by U.S. general contractors (CFMA, 2002)

Software (vendor)	**Used**
Excel (Microsoft)	33%
Precision Collection (Timberline, now sage)	26%
ICE-2000 (MC2)	11%
Heavy Bid (HCSS)	6%
Other	19%
Developed in house	5%

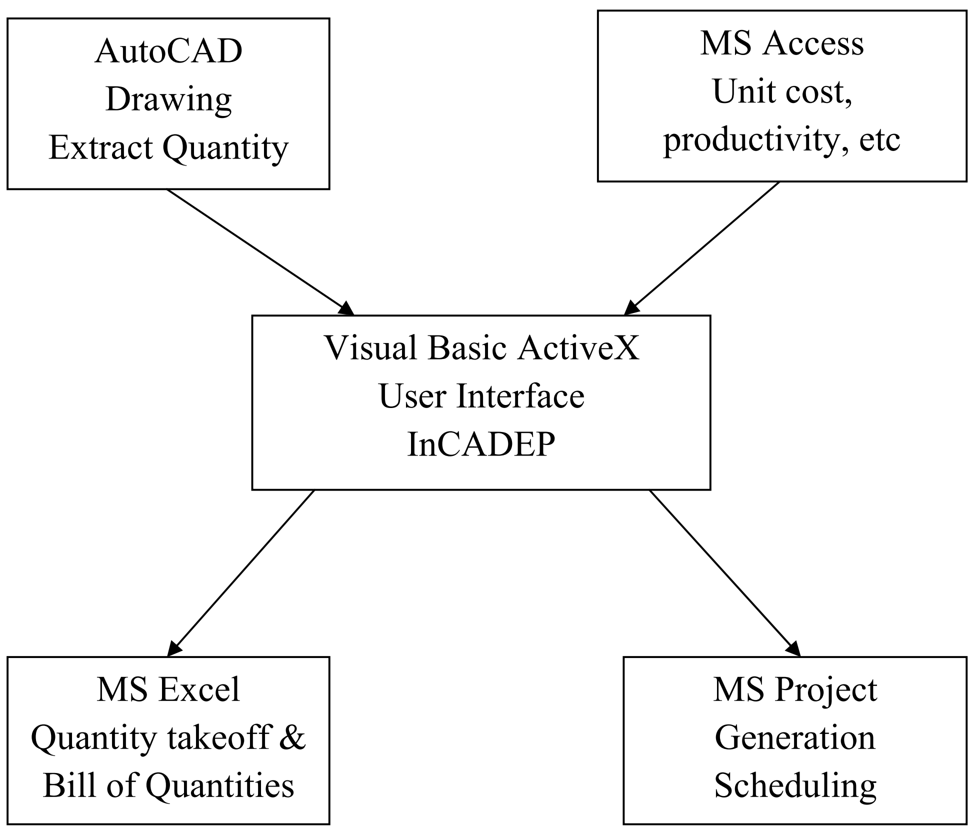


Figure (1) Architecture of Integration

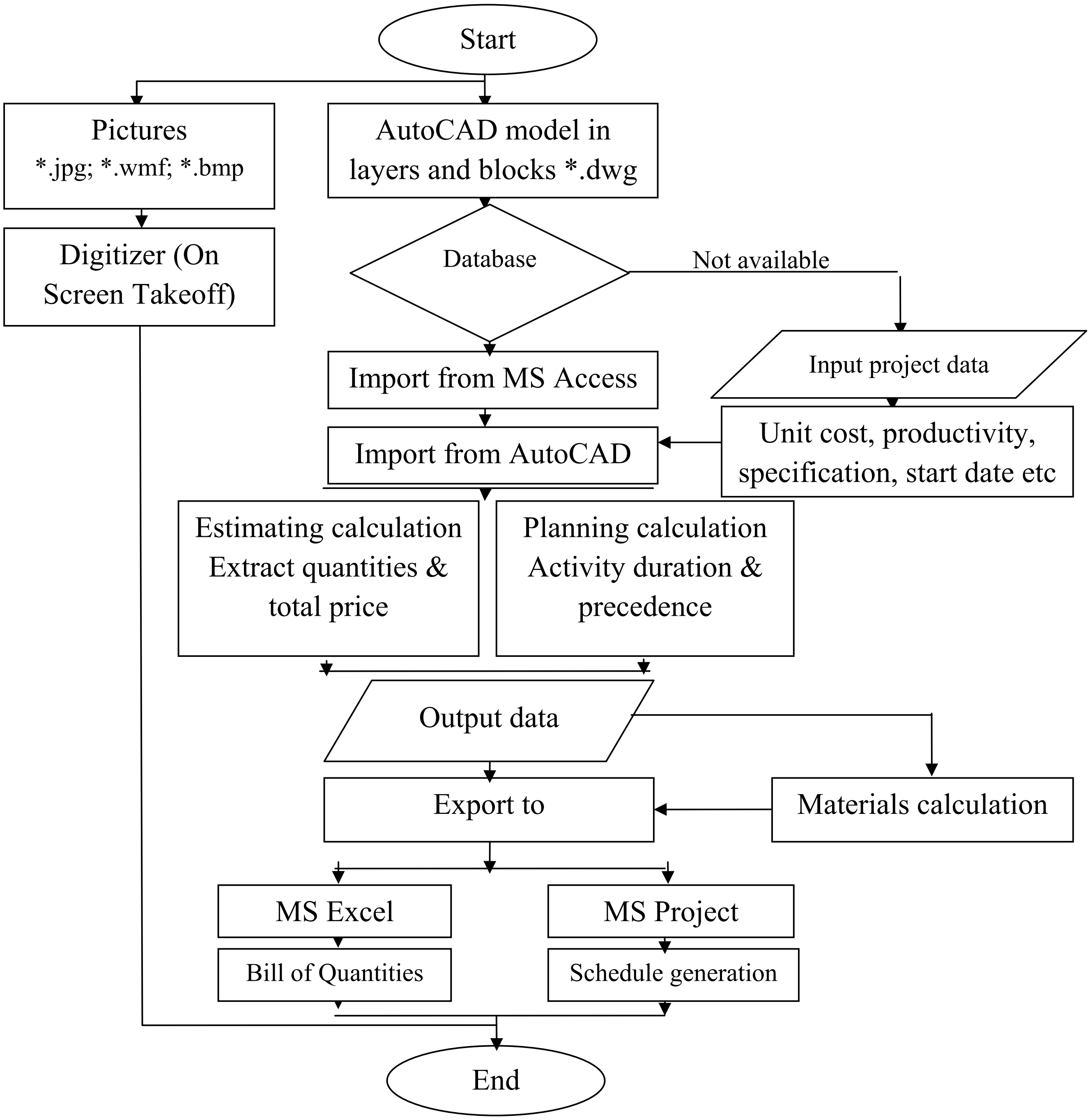


Figure (2) Overall system flow chart

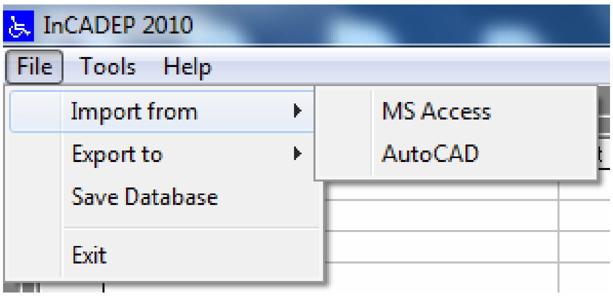


Figure (3) Import from menu

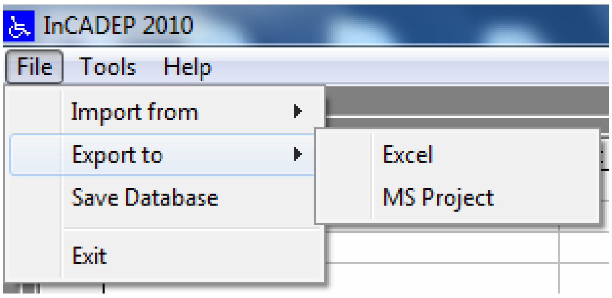


Figure (4) Export to menu

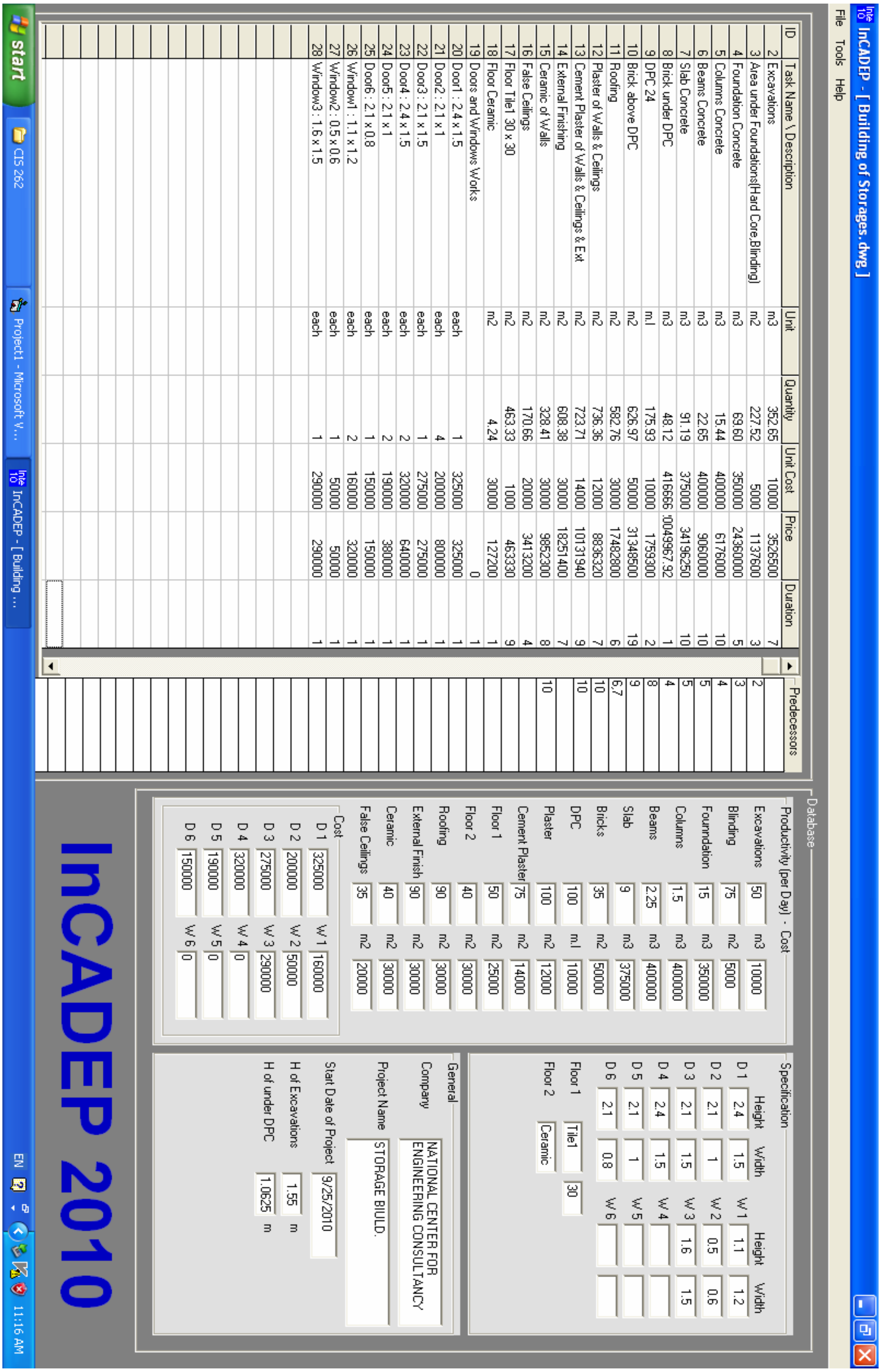
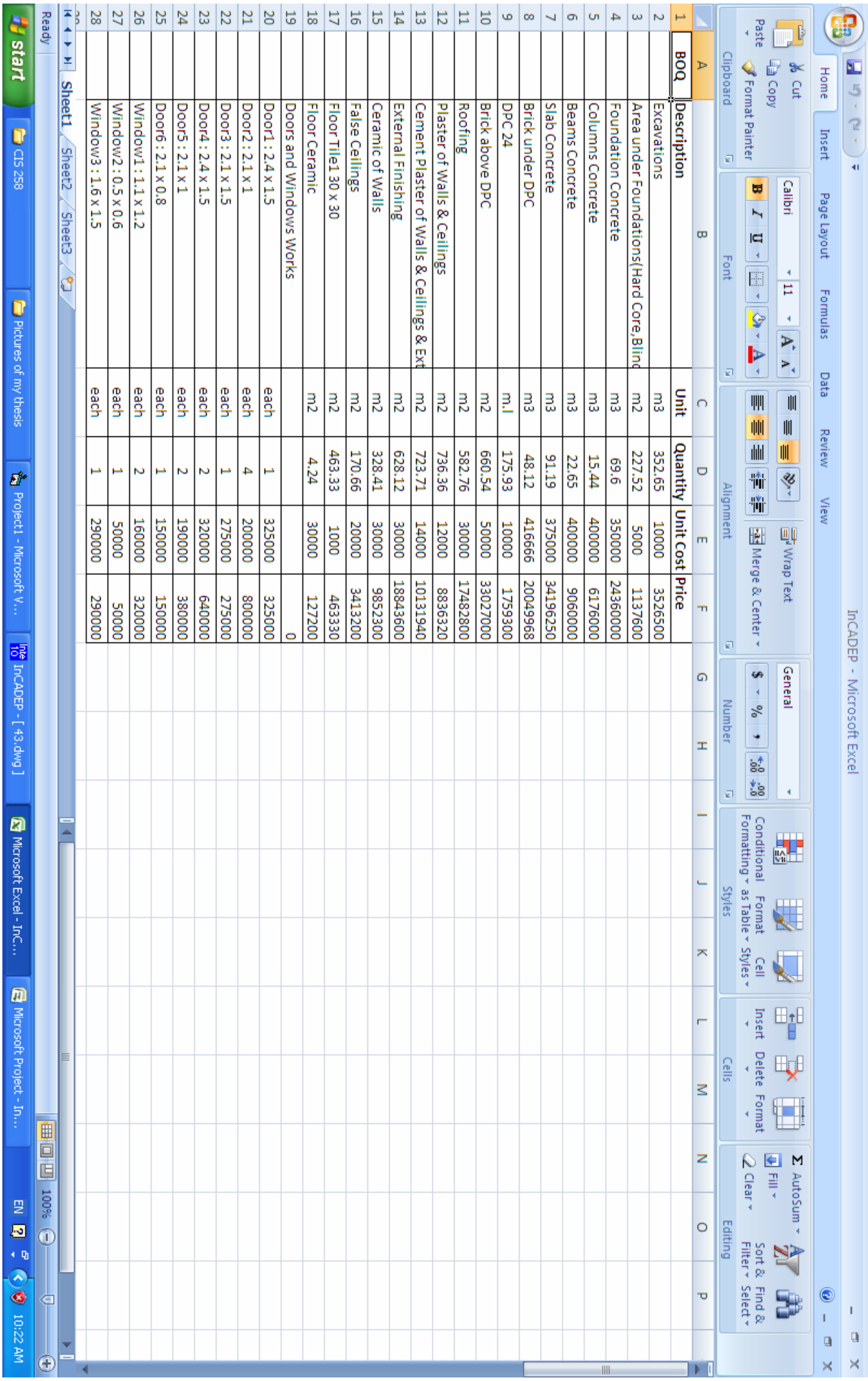


Figure (5) Output of InCADEP



BOQ	Description	Unit	Quantity	Unit Cost	Price
	Excavations	m3	352.65	10000	3526500
	Area under Foundations(Hard Core,Blind	m2	227.52	5000	1137600
	Foundation Concrete	m3	69.6	350000	24360000
	Columns Concrete	m3	15.44	400000	6176000
	Beams Concrete	m3	22.65	400000	9060000
	Slab Concrete	m3	91.19	375000	34196250
	Brick under DPC	m3	48.12	416666	20049968
	DPC 24	m.l	175.93	10000	1759300
	Brick above DPC	m2	660.54	50000	33027000
	Roofing	m2	582.76	30000	17482800
	Plaster of Walls & Ceilings	m2	736.36	12000	8836320
	Cement Plaster of Walls & Ceilings & Ext	m2	723.71	14000	10131940
	External Finishing	m2	628.12	30000	18843600
	Ceramic of Walls	m2	328.41	30000	9852300
	False Ceilings	m2	170.66	20000	3413200
	Floor Tile1 30 x 30	m2	463.33	1000	463330
	Floor Ceramic	m2	4.24	30000	127200
	Doors and Windows Works				0
	Door1 : 2.4 x 1.5	each	1	325000	325000
	Door2 : 2.1 x 1	each	4	200000	800000
	Door3 : 2.1 x 1.5	each	1	275000	275000
	Door4 : 2.4 x 1.5	each	2	320000	640000
	Door5 : 2.1 x 1	each	2	190000	380000
	Door6 : 2.1 x 0.8	each	1	150000	150000
	Window1 : 1.1 x 1.2	each	2	160000	320000
	Window2 : 0.5 x 0.6	each	1	50000	50000
	Window3 : 1.6 x 1.5	each	1	290000	290000

Figure (6) MS Excel window