A knowledge-based automated development permit approval process in the housing industry

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Abstract

Purpose – The residential construction industry has a major share in Canada's GDP. In spite of huge spending and technical advances in the residential construction sector, the current permit approval process still adheres to traditional manual permit approval process. Consequently, this has contributed to project delays and increased monetary costs to the stakeholders associated with the process. The research presented in this paper seeks to explore key issues related to the current housing development permit approval process.

Design/methodology/approach – This paper describes a proposed methodology for the automation of the residential construction development permit approval process. The proposed methodology has been incorporated into a computer system that integrates a knowledge-based expert system (KBES), database management system (DBMS), and computer-aided design (CAD). Various concepts related to the database structures, system architecture, process flow and user interfaces are introduced and described in the context of the development permit approval process.

Findings – This paper presents a knowledge-based prototype for the development permit approval process that can be customized as per the needs of various cities. A case study is also presented in order to demonstrate the effectiveness of the proposed method and to illustrate the implementation of the research.

Research limitations/implications – The prototype is application-independent and may be implemented anywhere in the AutoCAD environment. The research paves the way for the setting of drafting standards for the residential industry.

Originality/value – Prototype provides significant gains in productivity and accuracy over the current practices by minimizing the redundancies involved in the development permit approval process.

Keywords Construction operations, Residential property, Laws, Deductive databases, Automation

Paper type Research paper

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Introduction

In 2004, the construction industry contributed nearly 5.61 percent of Canada's GDP, with residential construction spending having a 2.04 percent share (StatCan, 2005). According to a Statistics Canada report, spending in the construction sector totaled $17.6 billion in the third quarter of 2003, an 11.1 percent jump from the third quarter of

2002. In 2003, the City of Edmonton issued 6,592 building permits with a total value of over $693 million (Al-Hussein *et al.*, 2005). Despite ever-growing technologies, the housing industry continues to utilize paper-based documents for the permit approval process. The shortcomings of the current development approval process include the residential industry's dependence on an individual's abilities to interpret city bylaws and building codes. With the large number of city bylaws and building standards, the designer (A/E) has to memorize all the laws or manually look into the most up-to-date version of the bylaws and building code provisions. The wrong interpretation or omission of these bylaws leads to delays in the development permit approval process and cost over-runs. Similarly, changes to the approved design requested by clients (prospective homeowners) at the builder's sales office, in order to meet their requirements, are again manually evaluated for their compliance with city bylaws and building code provisions. The requested changes are communicated to the designer's office, a process that takes four to six weeks. Due to the current practice of the development permit approval process and the communication gap that exists between the sales representative and the designer, builders are reluctant to allow prospective owners to propose changes to approved designs.

In recent years, researchers have contributed to methods of describing and designing a building in digital form (i.e. building product modeling; Murat, 2001). There are two international standardization efforts that address the representation of building design: STEP (STandard for the Exchange of Product model data), developed by the International Organization for Standardization; and the Industry Foundation Classes (IFCs), which are the specifications for a set of standardized object definitions developed by the International Alliance for Interoperability (IAI). Yang (2003) presents a method for IFC-compliant design information modeling for 3D architectural design using IFC technology and the IFC property set extension mechanism. Knowledge based systems and their various applications in construction have been widely described in the literature by Leeuwen (2002), Lawrence and James (1995), Sandberg (2003), and Korman and Tatum (2001). In the construction industry, knowledge based systems have been successfully used for the selection of ready mix concrete, quality assurance at construction sites, diagnosis and treatment of deteriorated structures, and the rule-based expert system designed to model the production of conventional concrete (Lawrence and James, 1995). Various researchers, such as Fellows and Liu (1997), Walker (1997), Cooke (1999), and Scott *et al.* (2000) discussed various aspects related to knowledge-based systems, such as research methodologies, knowledge acquisition, management processes, and so on.

Much of the research currently carried out regarding the automatic checking of CAD drawings centers on the development of an automatic checking module and the development of the building product model (Turk and Duhovnik, 1992; Sulaiman *et al.*, 2002). Researchers have addressed the need for the integration of CAD with databases in a variety of different ways, ranging from information modeling to knowledge-based interfaces linking several applications and multiple databases (Marir *et al.*, 1998; Yang, 2003; Navon, 1995). According to Al-Hussein *et al.* (2005), much of the research currently carried out in the field of automatic checking of CAD drawings centers on the development of an automatic checking module and the development of a building product model. Elzarka (2001) presented a cost-effective approach for developing computer integrated construction (CIC) systems by integrating stand-alone CAD, spreadsheet, database and scheduling software packages using Visual Basic for Applications (VBA). Nguyen and Oloufa (2001) presented a computer-based building design framework which emphasizes the engine; this framework is capable of automatically deducing topological information regarding building components which support various aspects of the building design, such as constructability analysis, construction planning and building code compliance checking. Han *et al.* (2004) developed "A client/server framework for on-line building code checking", which examines the structure and attributes of the product model and the building code model. Delis (1995) examined automatic intelligent fire-code checking, in which engineering code requirements are encoded in a knowledge-based expert system that evaluates a design for overall conformity.

This paper presents a knowledge-based automated system for the development permit approval process by providing a better CAD environment for drafting and automatically checking drawings with respect to city zoning bylaws. It is achieved by developing a central repository database that can be shared by the participants in the housing industry – i.e. the designer (A/E), the approving authorities and the sales representative – for their respective uses. A developed prototype focusing on the selection of building pocket locations within the lot, as per land use bylaws, is presented. A case study is also presented in order to demonstrate the system's features and the effectiveness of the proposed methodology. The aim of this paper is to explain the principles underlying the system's process flow, database structure, system architecture and user interface.

Methodology

This paper presents a methodology for an automated development permit approval process, which focuses on the development of ISCAD (an integrated system with CAD) and its utilization by the A/E, the approving authorities, and the sales representative at various stages in the construction project. The proposed methodology has been incorporated into a computer system that integrates an information-processing module, an automation module, a building information database and a city bylaw database. The IP module is placed in a central repository and checks the compliance of the site plan drawing with city bylaws. The details for the proposed buildings and existing facilities are provided by the A/E, leading to the completion of a site plan. Upon the completion of the drawing in specific layers, the drawing data is extracted and stored in a central database. The extracted information is attached to specific objects (polyline) with specific layers, which are recognized using Visual Basic for Application in AutoCAD. The information, which involves the lot shape, the site's characteristics, the building's characteristics, and design-drawing specifications, is stored in a central database that can be updated as new information becomes available. The information stored in the database is shared by the A/E, the approving authorities, and the sales representative and can be accessed at any time. The compliance of changes made to the drawing is instantly verified. The automation module allows the designer to accelerate the preliminary drafting process; it automatically draws the preliminary lot boundary and city bylaws compliance-building pocket in the CAD environment.

Current development permit approval process

House builders, on behalf of their clients, must obtain several permits before commencing construction. Municipal authorities approve housing project applications according to land use bylaws and building code standards. The municipality would have to issue both a development permit and a building permit for a project before construction could commence. Figure 1 shows the current permit approval process followed by the City of Edmonton. The requirements for the development permit are reviewed against the land use designation for the lot where on the construction is proposed. Typical criteria for zoning include building location, building size, building height, etc. The initial step in the permitting process is for the applicant to submit an application indicating the property's municipal address and legal description (plan number, block and lot). If the municipal address is unknown at the time of submission, one will be assigned by the municipality. Based on the address, the municipality provides the applicant with a zoning confirmation letter, if requested. The purpose of this letter is to provide the applicant with a better understanding of the building standards and restrictions on the property, based on the land use. This initial step can be omitted if the applicant is sure of the zoning. Otherwise, the next step in the current practice is for the applicant to provide the application fee, hard copies of the site plan, and construction plans meeting minimum drawing requirements such as scale, elevations, specifications and other relevant dimensions. A development officer will

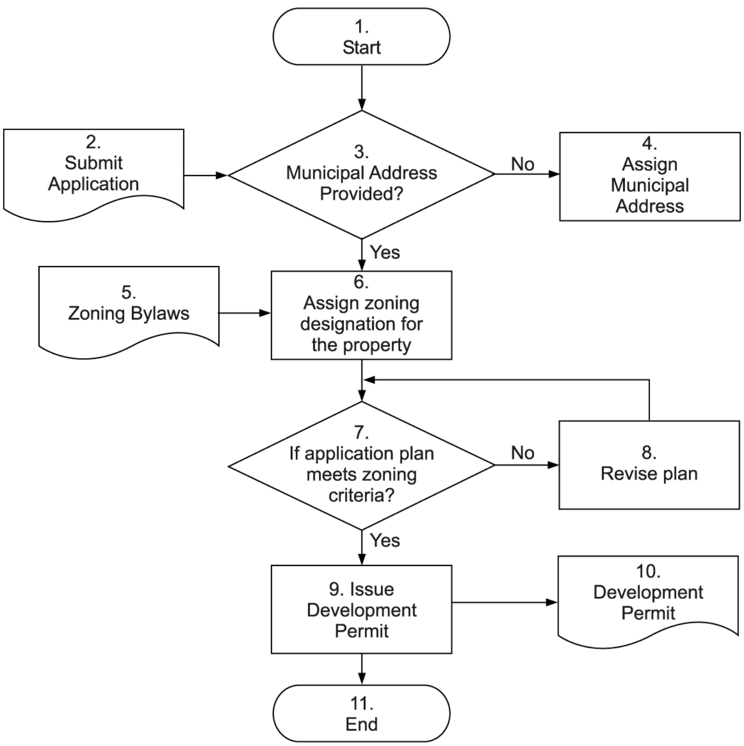


Figure 1.
Current permit approval process followed by the City of Edmonton

subsequently evaluate the plans against the zoning criteria. The review includes, but is not limited to, checking for the following:

- side-yard offsets;
- maximum principal building area;
- maximum accessory building area;
- front yard offset; and
- rear yard offset.

If there are no discrepancies, a development permit is issued to the applicant. If there are errors, the applicant is notified and required to re-submit the plans with the necessary changes. If changes are subsequently requested by a house builder's client after submission to the municipality, delays can occur with additional costs. According to the Washington Association of Realtors, one month's delay can increase the cost of the project by 1-2 percent of the total cost of the house (Washington Association of Realtors, 2005). This is very much applicable to Canadian cities as well, as the average cost of construction in Canadian cities varies between + 5 percent of the average cost of construction in the US cities.

Current system process flow

Preparation of the development permit application and its approval are carried out in three different environments:

(1) design office environment;

(2) city office environment; and

(3) sales office environment.

The sub-processes within the system are:

- storing lot data in a central database;
- checking the feasibility of the project;
- drafting the building pocket compliance with city bylaws in the CAD environment;
- extracting the drawing data;
- storing the drawing data in the database;
- checking the site plan drawings with reference to the city bylaws; and
- labeling the site plan drawing.

The approving authority accesses the site plan information from the central database and checks the site plan with respect to the city zoning bylaws. The aforementioned code checking is completed with non-compliant objects in the drawings being highlighted, and the subsequent development permit is issued instantly. In the sales office environment, the sales representative accesses the instances of the approved design stored in the central database and incorporates the design changes as requested by the client. These changes in the CAD drawing are completed and updated in the central database. Figure 2 illustrates the process flow in the sales office environment. The compliance of the changes made in the drawing is instantly verified by the system.

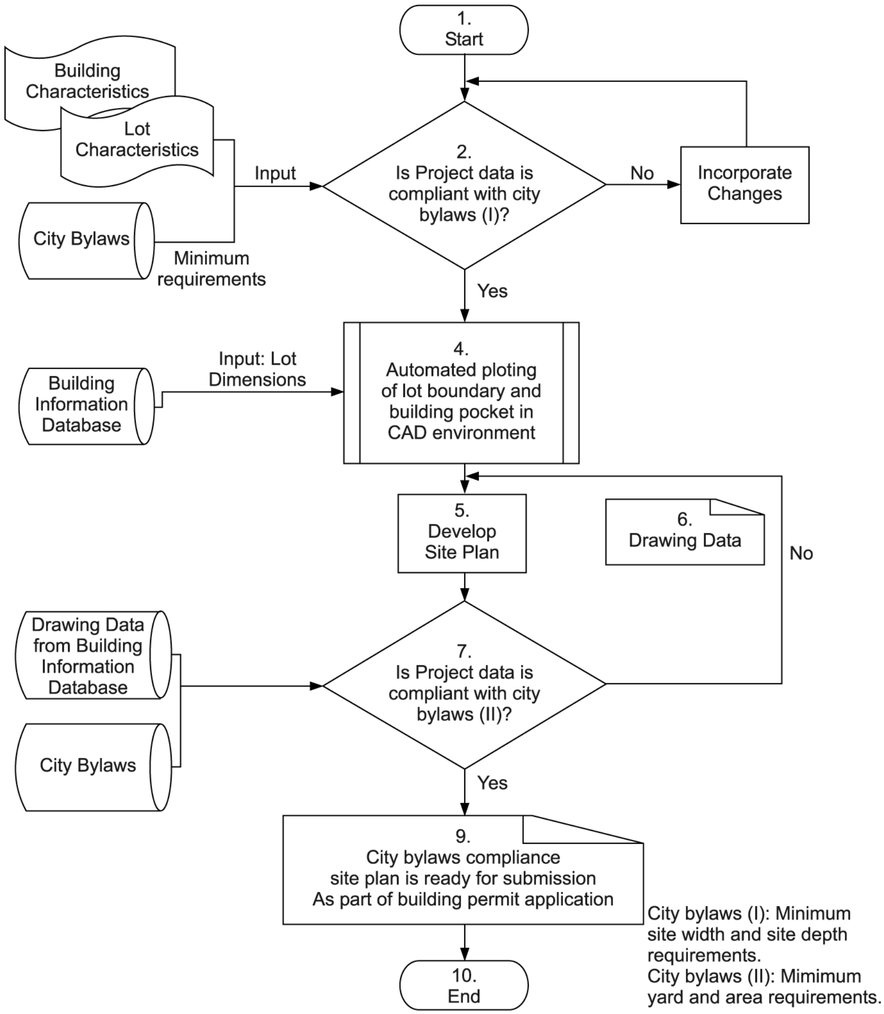


Figure 2.
Process flow in the sales
office environment

Proposed system architecture

AutoCAD is linked to the databases (central repository) using data access objects (DAO), which store drawings and project information. Automation in the CAD environment for the purpose of drafting is achieved by customizing AutoCAD, which takes care of routine and repetitive operations making them simpler in an automated manner. For automation in CAD, Visual Basic for Application (VBA) is utilized to automate the design of lot size. The building codes clauses for the design of a house are explained in the integrated building code assistance module, which provides a better drafting environment. The extraction module uses VBA programming to identify objects by layer and by properties such as the area of a closed polyline object. The IP module can be called from the interface to check the site plan drawing, which highlights and changes the color of non-compliant objects in the drawing. It rests in the central repository and acts as an interface between the two databases. Figure 3 illustrates the proposed architecture of the system.

Database structure

The two databases have been created to meet the requirements of the end user and to improve the system performance functions. Data flow diagram techniques were used to determine the functional requirements of the application. The databases were designed using MS ACCESS, and the schema was transformed from a conceptual level data model to an implementation data model.

Building information and city by-laws database

The building information database considers three criteria for the storage of the data:

(1) the data required in the development permit application form;

(2) the city zoning bylaws requirements for checking the site plan; and

(3) storage of the lot data (angles and distances for each side of the lot).

The conceptual design of the database provided a comprehensive description of the database requirements, its entities, and their respective relationships. The development was carried out using an entity relationship (ER) diagram as shown in Figure 4. The ER diagram serves two purposes:

(1) it provides effective dataflow throughout the prototype as per requirements; and

(2) it ensures that all the requirements are modeled without any conflicts between entities and relationships.

Entities are basic objects with an independent physical or conceptual existence. Attributes are the particular properties of the entity type. This database uses different types of attributes such as composite, single-value, multi-value, derived and key

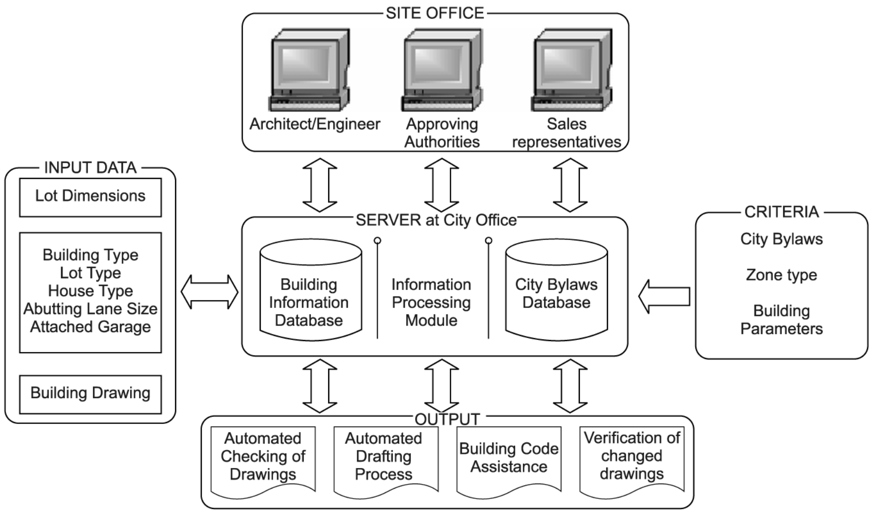


Figure 3.
System architecture

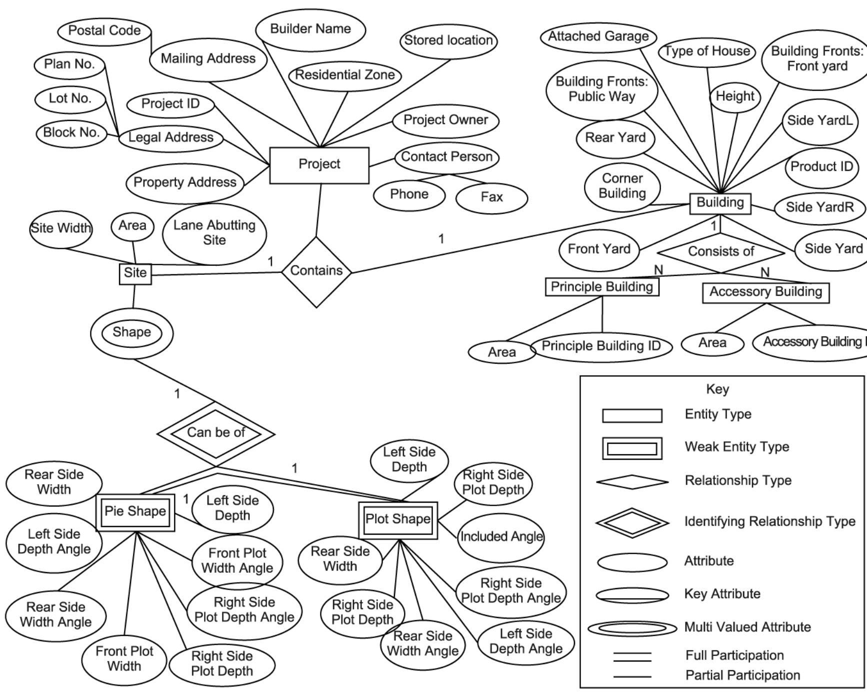


Figure 4.
ER diagram for the building information database

attributes. The city bylaws database stores the instances of city zoning bylaws provisions for residential zones. Having the city bylaws instances stored in the database makes it easy to incorporate future changes in the city bylaws. In this prototype, the city bylaws database consists of instances of provisions applicable to four residential zones:

(1) the single detached residential zone (RF1);

(2) the residential small lot zone (RSL);

(3) the low-density infill zone (RF2); and

(4) the planned lot residential zone (RPL).

The RF1 zone is the most frequently assigned for the housing industry, although there are 13 residential zones within the City of Edmonton.

Storing of lot data

The proposed prototype consists of a comprehensive database that contains information about all the lots in the city registered with the Alberta Land Title Office. In addition to information about the projects for which the building permits have been approved, the database also contains the physical attributes of lots (the length and angle of each side of a lot) for which building permits have not yet been approved. The legal information about the building being built on a lot can be populated later. The ProjectID, which is a combination of the plan, block and lot number (PIB), recognizes each project in the building information database. Lots in the subdivision plan have been classified according to lot shape. These shapes vary from simple (e.g. rectangular) to complex shapes, composed of combinations of arcs and lines. A new approach has been used to classify lot shapes: the line in the lot shape is coded as 1, while an arc is coded as 0. The name of the shape starts from the start point on the right side of the lot and runs counterclockwise. For example, the lot in Figure 5 is coded as 1110. The azimuth of the line with respect to north, and its length (either in the metric or the imperial system), describe the line, while the properties of an arc are represented by its length, its radius and its central angle.

The components of a proposed prototype are drawn using specific objects (polyline) with specific layers. Objects in the drawing are recognized using the Visual Basic Application in AutoCAD and the properties of the drawn objects are extracted. Layers are like overlays on which various types of information are kept; they are an efficient tool for organizing the drawing. Upon completion of the drawing in specific layers, the drawing data is extracted and stored in the central database. The Building Information database consists of 11 parametric queries, listed in Table I, which fulfill various functions in the prototype. Figure 6 illustrates the process developed for extraction of data from the CAD drawing.

The prototype utilizes the following specific software applications: AutoCAD (Architectural Desktop 3.3), Microsoft Access, Visual Basic Application in AutoCAD, and Data Access Objects. These applications are most readily available to small builders. AutoDesk's AutoCAD is software commonly used for drafting purposes in the residential industry. Microsoft Access was selected for the development of the DBMS. Visual Basic for Applications is designed specifically to provide development capabilities within an off-the-shelf application. AutoCAD provides full support for VBA with the release of R14 and can be customized to meet user requirements and integrated with other VBA-enabled applications. This provides additional functionality and program improvement, leading to the reduction of time consuming tasks, automation of repetitive tasks, query-links between applications, program features enhancement, low-cost options replacement and the use of verification tools. VBA's ability to link various programs together allows a user to share or access information, makes detailed queries and easily generates custom reports. DAO is an application program interface (API) available with Microsoft Visual Basic; it allows a programmer to request access to a Microsoft Access database. DAO is Microsoft's

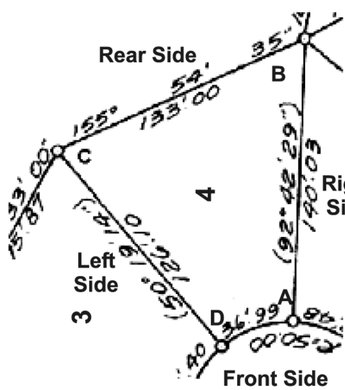


Figure 5.
Lot front view

No.	Type of query	Name of query	Function of query
1	Select query	ShapeQuery	Determines the lot shape
2	Select query	PieShapeQuery	Determines site and building characteristics, yard values for 1111 lot shape
3	Select query	PlotShapeQuery	Determines the site and building characteristics, yard values for 1110 lot shape
4	Select query	BuildingHeight	Determines the height of the proposed house
5	Select query	PieShapePlotData	Determines the lot data for lot shape 1111 from Bldb
6	Select query	ShapePlotData	Determines the lot data for lot shape 1110 from Bldb
7	Select query	FindLocation	Extracts the paths of the saved drawing from Bdlb
8	Select query	LabelQuery	Determines whether data from Bdlb and labels information are in the site plan
9	Update query	ProjectData	Stores the extracted drawing data in the Bldb
10	Update query	SiteConditions	Populates the site/building characteristics at the start of the project
11	Update query	UpdateQuery	Updates the extracted drawing data in the Bldb

Note: "Bldb" represents the building information database

Table I.
List of queries in the building information database

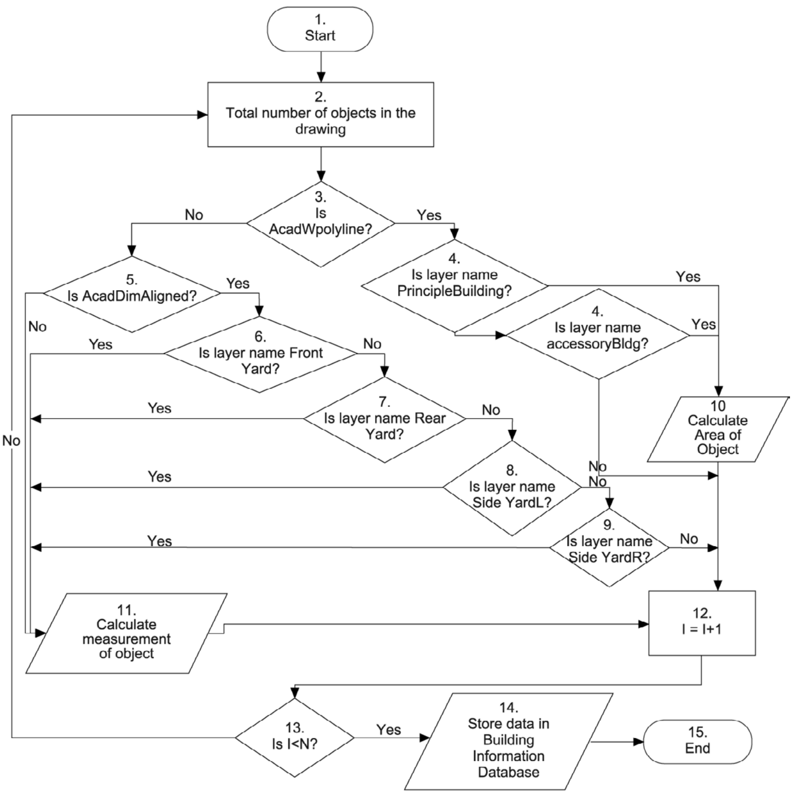


Figure 6.
Data extraction process

object-oriented interface with databases encapsulating Access's Jet functions; it can also access other Structured Query Language databases. In other words, one's choice of applications is not a restriction within the implementation. ISCAD is linked to both AutoCAD and Microsoft Access through Data Access Objects, and is supported by a user-friendly interface developed in AutoCAD VBA.

Case study – City of Edmonton development permit process

The following case study has been chosen to both illustrate and describe the essential features of the developed prototype. This example demonstrates how the system is used to prepare and check the drawing of the site plan for lot shapes that are available in the prototype. The project is located in Edmonton, Alberta, with the legal description of Plan 0225750, Block 8, Lot 144. It is a two-story house developed in the single detached residential zone (RF1), as illustrated in Figure 7. The Architect/Engineer (A/E) drafted the site plan for the proposed house. Drafting the site plan involved drawing the lot shape in a CAD environment. The lot data for the plan was extracted from the subdivision plan. Taking into consideration the residential zone, and conditions such as building on the corner, the height of the building governed the side yard calculations and the building pocket for the proposed house was drawn. Performing side yard calculations and drafting the building pocket manually is a time-consuming process. The plan for the building proposed on the site was drafted; the offsets for the proposed building were provided from the existing building. As required for the development permit, the application form, the site plan and the

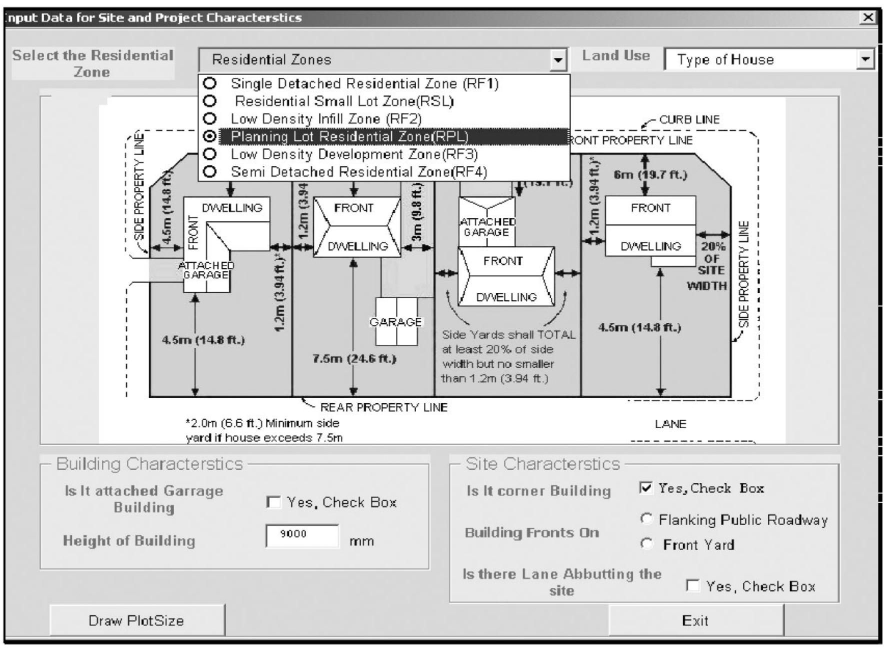


Figure 7.
Minimum yard requirements for RF1 zone

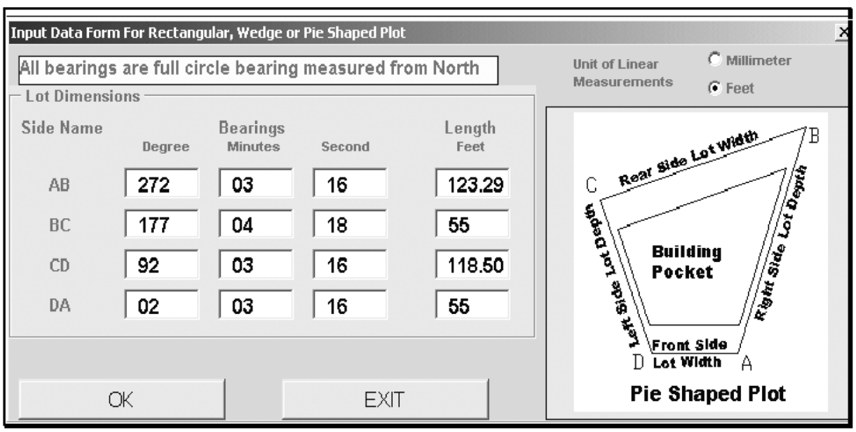
Source: Al-Hussein *et al.* (2005)

construction plans were submitted to the City of Edmonton office for approval. The submitted application will be added to the City of Edmonton database for the record. The approving authority (Development Officer) will verify the compliance of the site plan with the city zoning bylaws.

Preparation of the development permit with the KBES system

The case study utilized in this section takes into consideration the preparation of the development permit for a new house to be constructed on the site. To proceed with the integrated knowledge based system (IKBS), the existence of lot data in the database is checked. The building information database stores the dimensions of the lot data under the ProjectID, a combination of plan number, block number and lot number. As discussed in the previous section, the lot data not stored in the database needs to be entered using the storing lot data process described previously. The user interface provides the user with the option of inputting data for project and site conditions, as shown in Figure 8. After entering the project and site conditions, a drawing is opened in the AutoCAD environment and the lot size and building pocket are drawn automatically. The minimum side yard requirement calculations are performed by the KBES as shown in the Table II. As explained in the methodology, the calculated side yard requirements are sent to the automation module, which automatically draws the building pocket inside the lot. The site plan, which shows the dimensions of the proposed project site, the location of the proposed building, as well as the existing facilities (power line, gas line, sewer line etc.) on the site, is completed using specific CAD objects using specific layers. The principal building to be constructed on the site plan is represented by a polyline object in the principal building layer. Distances such as rear yard distance and front yard distance are represented in specific layers created by the automation module.

The process of saving the drawing data in the building information database involves the ProjectID combo box that lists the ProjectIDs stored in the database. The lot data is stored in the building information database, which involves two processes:



Source: Al-Hussein *et al.* (2005)

Figure 8.
Input data form for lot shape (type 1111)

Table II. Characteristics and requirements of Edmonton residential zones

	Residential zone characteristics								Maximum allowable site coverage		
			Use		Minimum requirements						
No.	Name of zone	Purpose	Permitted	Discretionary	Site area	Site width	SD (m)	MAHght (m)	PBAC (%)	ABAC (%)	TAC (%)
1	RF1	Provide SDH primarily	SDH	RSC, SemDH, DH, SS	360 m^2/dwelling	12.0 m	30.0	10.0	28	12	40
2	RSL	Provide smaller lot SDH with attached garage	SDH	RSC, SemDH, DH, SS	360 m^2/dwelling	10.4 m, 9 m for pie shaped lot	30.0	10.0			45
3	RF2	Retain SDH while allowing sensitive infill at a slightly higher density	SDH	RSC, SemDH, DH, SS	360 m^2/SDH, 200 m^2/DH or semDH, 100 m^2/SS	7.5 m for each DH or semDH, 12.0 m for each SDH with or without SS	30.0	10.0	28	12	40
4	RPL	Provide smaller lot SDH while allowing greater flexibility for infill developments	SDH	RSC	270 m^2, 258 m^2 when 8.6 $<$ site width $<$ 9.0 m	9.0 m, 8.6 m for up to 30 percent of the RPL sites within a registered plan of subdivision	30.0	10.0	35	17	47
5	RF3	Provide primary SDH and semDH while allowing small-scale conversion and infill development	DH, SS, SemDH, SDH	RSC, AH, RH, DH and SS other than in permitted areas	360 m^2/SDH, 300 m^2/DH or semDH, 200 m^2/RH, 150 m^2 RH internal dwelling, 100 m^2/SS, 800 m^2/AH or SRH	7.5 m for each DH or SDH, 12.0 m for each SDH with or without SS, 6.0 m for each RH end dwelling, 5.0 m for eachRH internal dwelling, 20.0 m for each AH	30.0	10.0	28	12	40
6	RF4	To provide primarily semDH	SemDH, SDH	RSC, DH		7.5 m for each DH or SDH, 12.0 m for each SDH with or without SS	30.0	10.0	28	12	40

Notes: RSC, residential sales venter; SDH, single detached housing; SemDH, Semi-detached housing; DH, duplex housing; SS, secondary suit; AH, apartment housing; RH, row housing; SRH, stacked row housing; MNbhd, mixed neighborhood; SD, site depth; MAHght, maximum allowable height; PBAC, principal building area coverage; ABAC, accessory building area coverage; TAC, total area coverage

(1) extraction of data from the CAD drawing; and
(2) its storage in the building information database.

Checking the site plan drawing against city zoning bylaws before its submission as a part of the development permit application process assures that the request will not be rejected. On the click event, the module checks the site plan drawing with respect to city bylaw provisions and a message notifies the user of the state of the project with respect to its compliance with city bylaws. A label drawing option aims to accelerate the labeling of drawings and the setting of drafting standards for the housing industry. The labeling process is divided into two parts:

(1) the basic data which needs to be provided for each project; and
(2) the information to be provided regarding the individual case.

The module labels the drawing with the basic information; input data for labeling is extracted from the building information database. Figure 9 shows the site plan with the basic information ready for submission to the city office in order to obtain a permit.

Approval of the development permit with the IKBS system

Completion of the development permit with the IKBS system is carried out in the city office environment where the approving authorities are informed that a new permit application has been submitted for approval. Approval of development is carried out in two steps:

(1) checking of the drawing; and
(2) generation of the development permit.

Checking the site for compliance with city bylaws, a process which uses the developed IP module, is completed. The interface allows the user to generate the development permit with a single button click. As explained previously, the IKBS provides instant feedback as to the feasibility of changes made to the site plan. After making changes in the drawing, the module allows the user to update the drawing information in the building information database. A click on the verification module verifies the changes made to the drawing.

Discussion and findings

This paper presents an integrated knowledge based system (IKBS) that proposes to automate the development permit approval process for residential construction. The IKBS minimizes the redundancy involved in the development permit approval process. IKBS instantly evaluates the compatibility of the proposed changes in the building pocket with respect to the city bylaws. The IKBS contributes to eliminating the paper-based development approval process, which is time-consuming and prone to errors. A typical reviewing process of proposed changes in house plans takes six to eight weeks. With the proposed system in place, the users will be able to evaluate the changes instantly. The storage of project information in a central database allows the project participants to access information and ensures the consistency, integrity and accuracy of various data types. The proposed system bridges the gap between development permit approval and IT application by automating the drawing of the

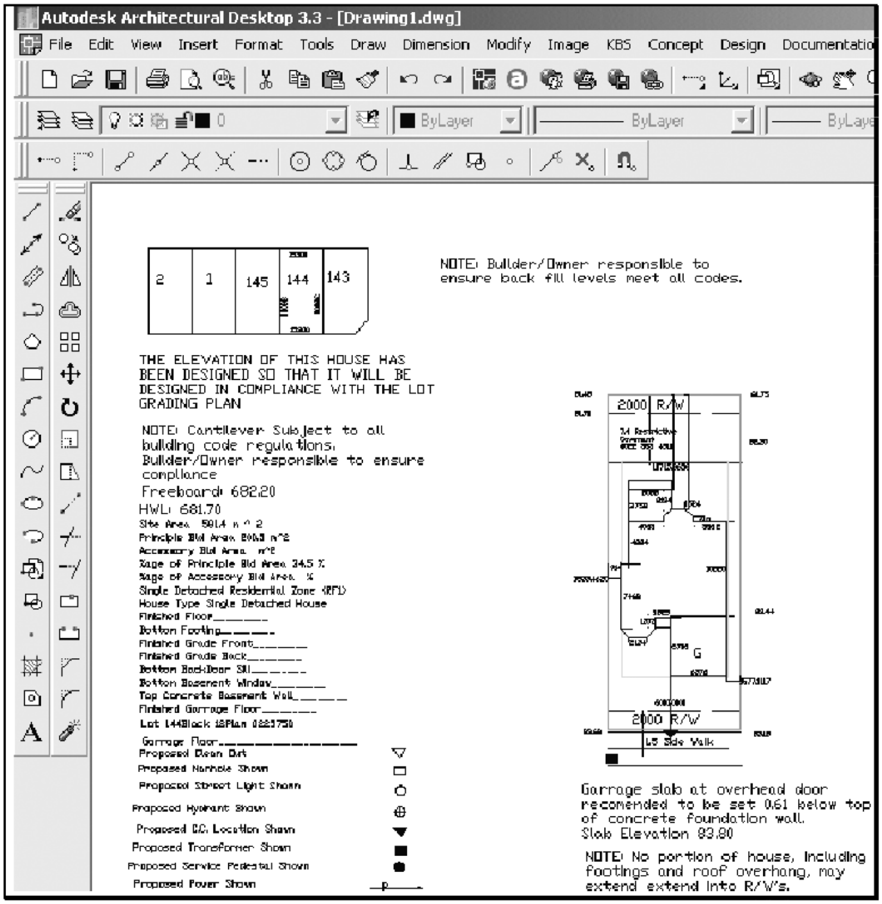


Figure 9.
Site plan ready for submission

Source: Al-Hussein *et al.* (2005)

preliminary lot boundary and a building pocket compliant with city bylaws. The system provides an intelligent CAD environment during the drafting of the site plan for the development /building permits applications. The research paves the way for the setting of drafting standards for residential construction. The IKBS has been developed utilizing commonly used drafting software and programming languages (i.e. Visual Basic for Application in the AutoCAD environment), and hence it can be adapted to other cities with slight modifications. Presently prototype functionalities are implemented only for certain types of lot shapes, which are most prevalent in the city. The system functionality can be extended by incorporating more lot shapes for the evaluation purposes. Presently IKBS provides the building codes assistance limited to the automatically checking of the offsets requirements of the building pocket within the lot.

Summary and conclusions

A computer integrated knowledge base system (IKBS) for the preparation and approval of development permits for housing has been developed and presented in this paper. The proposed process emphasizes the use of electronic documentation, automatic checking of drawings and automation by customization of the CAD model. The storage of drawing data in the central database makes it readily available to participants in the residential construction. The most significant advantage of IKBS is its capacity to integrate the processes carried out for drafting the development permit, undergoing the approval process and checking the feasibility of changes with respect to city bylaws. Errors and omissions are avoided by eliminating redundancies and automating the processes involved in the preparation, submission and approval of the development permits. Users of the proposed system include designer (A/E) and the approving authorities who are engaged in the development permit approval process, and the sales representatives who need to evaluate the compatibility of the changes requested by the potential house owners as per the local bylaws. Implementation of the system provides a tool, incorporating information processing (IP) module with a CAD model, to automate the city bylaws compliance drafting process. Any deviations from the city bylaws are automatically marked on the plan.

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