Electronic building control: an IT-enabled re-engineering process

Max Chi-chung Wong[1], Heng Li[2] and Qiping Shen[3]

ABSTRACT | Information technologies have been widely adopted to streamline the document management processes in the construction industry such as drawing production, contract management and material control. In this study, building plan preparation, submission and approval processes are examined in an operational approach and critically reviewed to explore how the process of re-engineering under the electronic environment is conducted. References are drawn from the latest development of various IT application packages in the construction industry to investigate their capacities for re-engineering the involved processes. Through a real case study of the Buildings Department (BD) of the Hong Kong SAR Government, the technologies and methods involved in the re-engineering process of building control are described. Recommendations and conditions for a successful implementation of IT enabled building control process are also summarized and concluded.

KEYWORDS | building plan submission, re-engineering, building control

1 Introduction

Process re-engineering represents an effort to redesign and re-organise a managerial or operational process in order for an organisation to obtain dramatic improvement in performance and competitiveness (Hammer et al. 1993). By definition process re-engineering radically departs from other popular practices, such as total quality management (TQM), downsizing, or other systems designated for continuous improvement. Instead of advocating incremental changes, process re-engineering examines fundamental assumptions and rules that impede radical changes of a functional process. In other words, re-engineering is a "start over" process aiming to "destroy tacit rules and assumptions which may be the stumbling block to substantial improvement" (Betts et al. 1994).

Initial research efforts have indicated that process re-engineering has its potential to dramatically improve the performance of the construction industry. Specifically, Betts et al. (1994) identified a comprehensive agenda for research in re-engineering construction as a new management research direction. A group of Australian construction companies already came together as a team to study process re-engineering in construction. The research team, which was codenamed as T40, proposed that by cutting down the number of subcontractors and rearranging work packages, the duration of a construction project could

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be reduced by 40 percent (Ireland 1994). Moreover, a case study explored the potential of time saving through the integration of three concepts, namely, concurrent construction, lean construction, and process redesign (Mohamed et al. 1995).

Among the construction processes, building control is a significant process for project teams, as it is critical to the timely commencement and completion of projects. The process of building control involves, among others, accepting submissions of building plans and drawings, ensuring the regulatory compliance of submissions and retrieving information relating to existing buildings. For the general public, it is also important in maintaining the standard of safety and health for people occupying the buildings. The practice of building control varies widely among different countries. Some countries have an elaborate and detailed set of requirements and procedures with a control role for government bodies. In other countries private parties are more dominant regarding the quality control of buildings (Meijer and Visscher, 1998). There is also a practice in the USA where for small communities the responsibility of building control is given to a consultancy firm (Onaran and Sancar 1998). A major part of the building control system is to do with quality assurance (QA) of building the process and the products. The government of the Hong Kong Special Administration Region delegates part of its statutory role to statutory agents to deal with the QA function (Chan and Chan, 1999). Similar to other foreign countries, the means of control starts to shift from prescriptive approach to functional approach in recent years owing to the advancement of building technologies. Moreover, owing to the pursuit for higher level of building quality, regulatory compliance is only considered as a minimum standard. There is a strong urge for both the project teams and the Government to re-engineer the building control procedures so that the quality of buildings can be improved.

This paper introduces the investigation of the current plan submission and processing procedures, the usage of computers in design and plan preparation, and the implication of electronic submission in the local construction industry through a detailed case study. It is also intended to identify other issues such as cost, training and legal matters. Furthermore, by drawing reference to successful examples in other countries, we recommend the way forward and further development necessary for Hong Kong.

2 Research Methodology

The aim of this study is to identify the major issues involved concerning electronic submission through a case study. The case study is selected as the authors have been engaged as consultants through the entire process. A case study can be simply defined as "methodology based on interviews, which are used to investigate technical aspects of a contemporary phenomenon with its real life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used" (Yin, 1989:3). The authors have based their methodological framework on theoretical replication. Yin (1989) supports this approach and specifically notes that cases should be regarded as multiple experiments and not multiple respondents in survey and so replication logic and not sampling logic should be used for multiple case studies. Numerous other researchers such as Eisenhardt (1989), Pettigrew (1988) and Gersick (1988) support this approach. The case study approach adopted is being used to capture the complexity and dynamism of the building control process, which the authors envisage will lead to a more informed basis for theory development with respect to re-engineering the building control and submission process (Yin, 1981a). A theory can provide a perspective and a way of seeing an interpretation, which may ultimately lead to understanding how quality systems can be made more effective (Agar, 1986). Thus "theory" can be defined as a set concepts and generalisations. Concepts, generalisations and interpretations that are derived from the case studies

will be used for assisting people engaged in similar situations in their practical decision-making (Chentiz and Swanson, 1986).

In this study, a single case of re-engineering the building control and submission process is examined through replicating the entire re-engineering process. The authors expect that by providing detailed information on the background of the traditional building control process, important steps and stages involved in the re-engineering process, as well as the pros and cons of the re-engineered building control process, other organizations can learn from the case study presented in this paper.

3 Conventional Processes of Building Control

3.1 Building Plan Submission

In the processes of project development, building plan submission is always an important step in ascertaining the development potential, validity of design assumptions and permissible concessions. Shortly after finalizing the preliminary design, the client would normally instruct their building professionals such as the architects and surveyors to submit building plans to BD for approval, so that the feasibility of the project development can be secured.

After the building design is developed up to a certain level of maturity and to the satisfaction of the clients, the architects will finalize their building plans and check against various statutory requirements to their best knowledge. The architects can then proceed with building plan preparation for the purpose of statutory submission. First of all, they need to incorporate further information such as general notes, door and window markings, critical dimensions etc. to demonstrate the compliance with relevant regulations and codes of practices. Calculations should also be done to indicate the development potential, fire safety provisions, health and hygiene standards etc. Finally the building plans will be duly coloured (Buildings department 2000) to indicate the elements of construction for easy identification by relevant government officers in the approval processes.

After the building plans have been prepared, they have to be signed by an authorized person (and registered structural engineers where necessary) certifying the plans are prepared by them and comply with regulatory requirements to their best understanding. Under the current Centralized Processing policy, adequate number of sets of plans should be provided for BD as the coordinator to distribute to other concerned government departments and collate their comments in the approval processes. It is not uncommon the architects have to supply about 8 to 12 sets of building plans depending on the complexity and the extent of interested government departments involved in the project.

Besides the drawings, the building plans should be submitted together with specified forms (Building Department 2001) signed by the authorized person. Other supporting documents such as comments from other departments, application for modification of the Buildings Ordinance etc. should also be submitted in conjunction with the plan submission. The building plan be folded (Building Department 1999) in a prescriptive manner and submitted to the Receipt & Dispatch counter of BD. The time stamp at the counter will serve as a basis for counting the statutory time limits and performance pledge for plan processing. The processes of building plan preparation and submission is summarized in Figure 1 below.

3.2 Building Plans Checking

Pursuant to Building (Administration) Regulation 30(3), there are statutory time limits for processing of new and amendment building plan submissions. The building professionals can assume approval of plans (‘deemed approval’) if they do not receive

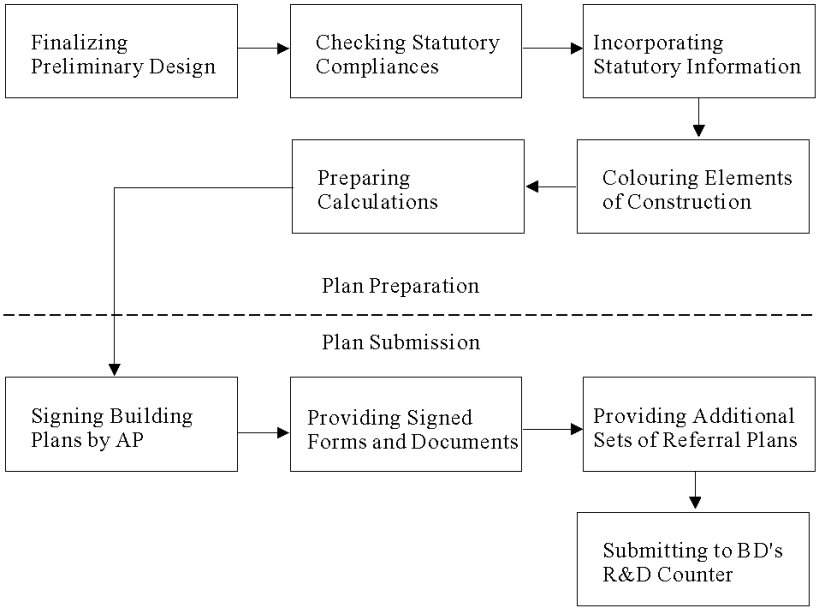


Figure 1. Flowchart of Building Plan Preparation and Submission Processes

any disapproval or refusal from BD. A building plan submission usually consists of 1) drawings such as layout plans, sections and elevations, 2) supporting information such as schedules and calculations, and 3) necessary documents such as certification of preparation of plans, application for modifications etc.

Upon receipt of building plan submission, the front line staff of BD will open the project file and refer copies of the plans to other identified government departments. The file will then be transferred to the chief professional officers for initial review to see if any imminent action such as consulting our departments or referral to various advisory committees is necessary. The case will be then passed to the senior professional and professional case officers for more detail checking. The case officers shall carry out site inspections to identify if there is any discrepancy between the information provided and the real site situation. Technical staff may also assist in checking the calculations to ensure they were properly prepared and the overall development intensity and provisions for safety and health standard are adequate. Where issues are identified which render the building proposal unacceptable, the case officers should refer the file back to the chief officers. In case the non-compliances are easily amendable or so minor as not to affect the fundamental issues, the project teams may be invited to make minor amendments to the plans to facilitate approval.

For the submitted documents and specified forms such as applications for modifications, the chief and senior professional officers will make their initial comment for the case officers' checking and verification. They will then recommend the approval or acceptance of the applications for the chief officers' endorsement. After receiving comments from other government departments, the case officers are responsible for collating the comments to see if the building proposal is acceptable to other departments. In the final approval or disapproval letter, these comments should also be addressed to the project teams.

After all these have been completed, the file, plans together with the approval or disapproval letter will be forwarded to the chief officers for signature. The

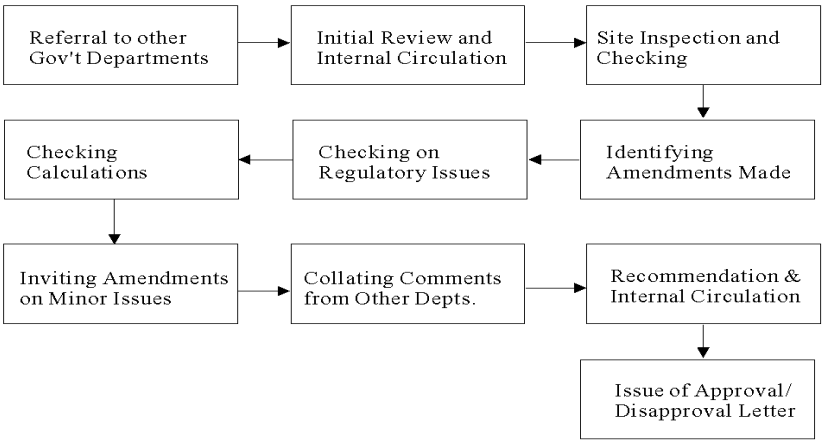


Figure 2. Flowchart of Building Plan Checking and Approval Processes

processes of building plan checking and approval is summarized in Figure 2.

3.3 Information Storage and Retrieval

New Buildings

Currently the control on new buildings is mainly enforced by a two-tier system: approval and consent. Under the Section 14 of the Buildings Ordinance, no person shall commence or carry out building works unless he had obtained from BD firstly approval of building plans and subsequently the consent to commence works. To be in line with such operational requirements, BD has to store a vast amount of documents including case files, approved plans, record plans and project registers. These documents will be retrieved along the building control processes for reference and further action:

a. When an amendment plan is submitted for approval, the case officer has to call out the project file to check against the original approved plans to identify the extent of proposed amendments. He also has to review the previous comments from other parties and government departments to see if the submission is readily approvable.
b. When consent to commence works is applied for, the officer has to retrieve the case file to check if the conditions imposed to the plan approvals have been fulfilled and there is no further adverse comment from other parties and government departments, so that the consent to commencement of works can be issued.
c. For submissions regarding alterations and additions to completed buildings, the case officer has to retrieve the record plans to determine whether the proposed works carry structural and fundamental building design issues. Where necessary, comments and advices from other parties should be sought before granting approval and consent for such works.
d. In certain cases, the information retrieval will be limited. For example, in dealing with confidential cases, only chief officers and the rank above are eligible for accessing to the files. Where necessary actions have to be taken by other officers, only the relevant abstract of the file can be copied to the concerned officer. Besides, there are some units in BD such as the Licensing Unit which works within tight time schedule, borrowing out of files are not permitted.

The building control documents are normally stored in designated filing rooms in the department. However these filing rooms are inadequate with respect to the ever-increasing backlog of submissions and

records. Hence from time to time, the department would set out a certain time limit such that projects completed beyond such time limit would be archived to government warehouse. Where necessary, the documents will be called out by the case officers for reference and further action. The retrieval process may take several days to a week.

Existing Buildings

Under the Buildings Ordinance, BD is empowered to take remedial action where any building is found to be have rendered dangerous or liable to become dangerous by fire, wind, rain, dilapidation or lack of fire escapes etc. BD can serve order for a building owner to repair the building or to close the building until satisfactory rectifications. For unauthorized building works identified, BD is vested with power to order the owner to remove such works or cause these unauthorized structures to be removed at the building owners' costs.

To cope with the control and enforcement works, BD should have efficient information storage system so that during routine inspections and upon receipt of complaints, the case officers can easily retrieve the record plans and check on site whether the suspicious structures are unauthorized building works and if necessary actions are to be taken.

4 Re-engineered Building Control Processes Under Electronic Environment

Computer Aided Drafting and Design (CADD) had been started to apply in the construction industry of Hong Kong since the 1990s. With the development history of more than a decade, it is expected that the CADD technologies can couple with newly devised software packages to streamline the building control processes so that building professionals can focus their efforts on building qualities. It is essential to evaluate whether the popularisation of computers in the construction industry and the latest advancement of computer technologies can contribute to enhance the efficiency of such exercises. As a tool in the design and drafting processes, computers can provide useful assistance in achieving the desired end results. CADD systems had been widely adopted by the construction industry for more than a decade and proved to be precise and reliable exhibiting a wide range of image creation and display capabilities.

The Electronic Transaction Ordinance (ETO) has been enacted since January 2000. Under this ordinance, digital records are given the same legal status as that of written records or paper-based counterparts. This ordinance provided the legal basis for electronic submission of building plans. Legal issues in ETO have also have addressed in eLEGAL (Loughborough 1999).

The preparation, submission and checking processes are resources consuming and labour intensive as the submission always involve a huge volume of drawings to be completed within a short timeframe. The taskforce involved in designing and implementing the electronic building plan preparation and submission has conducted 5 workshops in which consultations with a wide range of professionals from the construction industry were conducted. Based on a review of current available information technologies, and a wide consultation with over 200 senior professionals from the private and public sectors within the construction industry, the conventional processes in the preparation, submission and processing of building plans have been re-engineered to an IT enabled process as indicated in Figure 3.

4.1 Electronic Building Plans Preparation and Submission

In the re-engineered process, building plan preparation and submission are performed electronically. The tasks involved are further elaborated as follows.

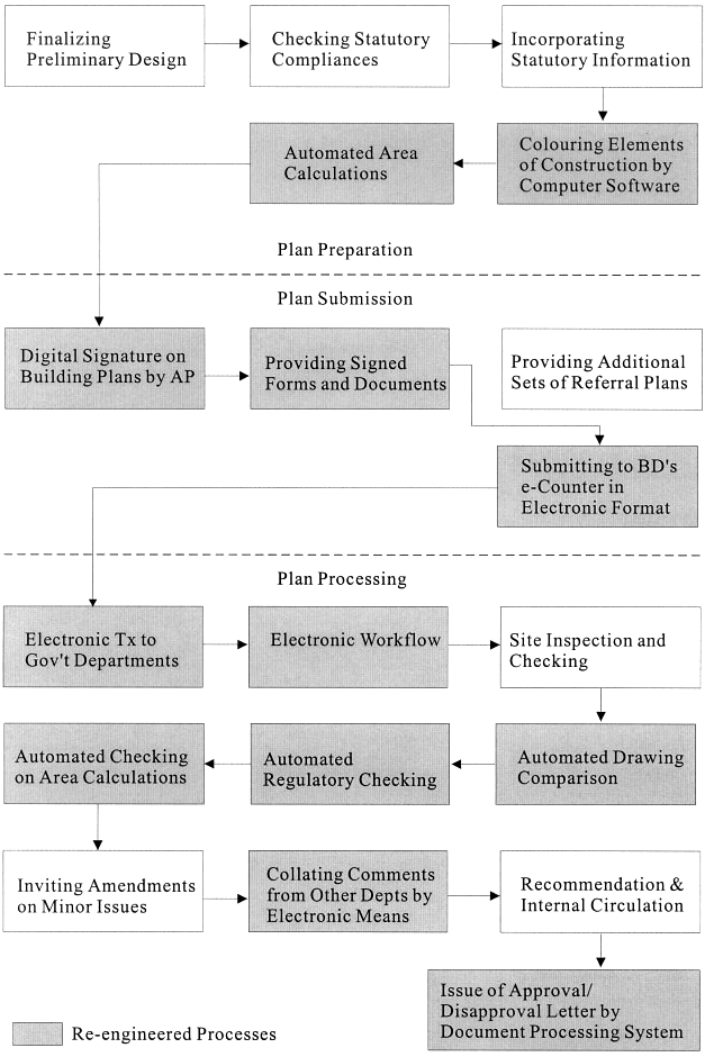


Figure 3. Re-engineered Building Control Processes

Colouring

In building plan submission, colouring of plans with conventional codes serves to identify different building materials and components for checking under various regulatory requirements. In fact, colours do communicate (Gerlach 1987). In handling massive amount of information contained in building drawings, multi-layers of data presented in multi-colours communicate better than monochrome, and facilitate both plan preparation and checking processes.

According to the feedback from the pilot tests conducted by BD, colouring and shading of different materials and use of building by computer was still uncommon among the construction industry (Lau 2000). Despite the ease of use of colouring functions,

output of large plans was more expensive and time consuming, hence the building professionals still preferred to handle the plans manually.

However the expenses of colour plotting and software support are coming down for CADD installations while the demand is up for data represented or displayed in colours. Besides, the time for generating coloured plans is almost halved in comparison to the past years. The plotting time for an A1 drawing by current models of plotters is normally within 45 seconds. For building plan submissions which usually consist of 10 to 30 drawings in average, the total production time of one set of submission will be less than half hour, which is insignificant with respect to the overall plan preparation time.

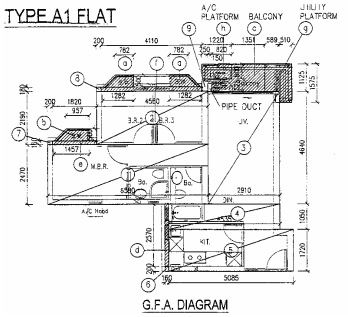
Regarding ease of handling, software packages are always well equipped with colouring features. By proper layering control and simple programming, designated areas will be automatically attributed and coloured matching the codes prescribed under regulatory requirements. These automated features offer more efficient colouring methods than the manual processes.

Calculations of areas

Besides presentation of building proposals by drawings, calculations are also important assessment criteria for approving a submission. It is crucial to demonstrate the regulatory compliance of development intensity control such as plot ratio, site coverage, concession areas etc. in form of calculations. However it is always tedious and time consuming to prepare the calculations in communicable format for information of both other project team members and government officers. The concerned area of the building is usually subdivided into basic geometrical portions, clearly dimensioned and with their areas further summated and deducted as appropriate (see example as illustrated in Figure 4 below). Owing to the complexities of building geometry and large area covered, it always takes a long time to furnish the calculation diagrams. For large scale and complex projects, it may take a week to prepare the required calculations.

Realizing the demanding resources requirement in the building plan preparation process, some companies in the construction sector experimented the use of automated features in preparing the calculations. 'LISP' functions are those built-in within computer drafting software packages to perform arrays of preset actions sequentially and automatically by simple keys and commands. After further development, some of the tailor-made LISP programmes were franchised and released for wide application in the construction industry.

With the aid of these automated programmes, the operator only needs to outline the envelope of the concerned building area, and then the software



G.F.A. CALCULATION

TYPE A1 FLAT AREA		
PORTION	CALCULATION (m)	AREA (s.m.)
①	6.580 x 2.470	16.253
②	2.190 x 4.560	9.986
③	2.910 x 4.640	13.502
④	1.050 x 4.535	4.762
⑤	5.085 x 1.720	8.746
⑥	0.160 x 0.200	0.032
⑦	0.160 x 0.200	0.032
⑧	0.180 x 0.200	0.036
⑨	0.250 x 0.440	0.110
TYPE A1 FLAT AREA		53.459

BAY WINDOW		
2 x ⓐ	2 x [(0.782 + 1.282) x 0.500] / 2	1.032
ⓑ	[(0.957 + 1.457) x 0.500] / 2	0.604
TOTAL BAY WINDOW AREA		1.636

EXEMPTED AREA		
BALCONY		
ⓒ	(1.351 x 1.125) + (0.820 x 0.525) + (0.150 x 0.185) + (0.250 x 0.085)	2.000
PREFABRICTED EXTERNAL WALL		
ⓓ	2.570 x 0.160	0.411
ⓔ	1.820 x 0.160	0.291
ⓕ	4.110 x 0.180	0.740
TOTAL PREFABRICTED EXTERNAL WALL		1.442
UTILITY PLATFORM		
ⓖ	(1.575 x 0.510) + (1.125 x 0.589)	1.466
A/C PLATFORM		
ⓗ	1.220 x 0.600	0.732
TOTAL EXEMPTED AREA		5.640

Figure 4. Typical Building Area Calculation Diagram

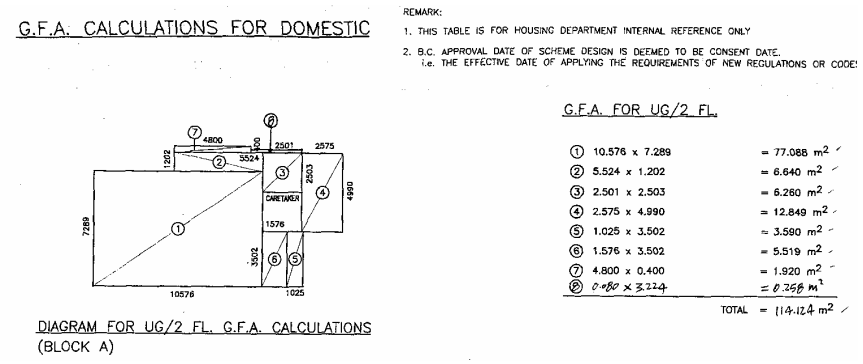


Figure 5. Area Calculations by Automated Programmes

package will automatically generate the block diagrams, dimensioned and performing summations and deductions as appropriate. With the arithmetic formulas evolved, laid out and spaced automatically, the outcome of automated calculations can be same as that performed step-by-step in the computer. Figure 5 illustrates an example of calculations performed by automated LISP programmes.

Signature

Under the Buildings Ordinance, regulatory compliances of building designed have to be certified by suitably qualified and registered persons under the Buildings Ordinance, namely *Authorized Persons* (AP) for building works and *Registered Structural Engineers* (RSE) for structural works. In making submissions to BD, AP and RSE have to sign the plans and specified forms accompanying the submission to certify the proposed works are in compliance with regulatory requirements to their best understanding. In order to facilitate more efficient plan submission process by allowing electronic submission, signatures must also be able to be accomplished in electronic format.

a. Digital Signature

According to Section 34 of ETO, the Postmaster General acts as the first recognized certification authority (CA) to issue digital certificates to individuals and businesses to authenticate the identity of subscribers. It also maintains a certificate repository and directory to allow the public to verify the validity of a particular e-cert prior to carrying out transactions.

A Public Key Infrastructure (PKI) is built up by the Hong Kong Post covering the use of public key cryptography and digital certificates as accepted means of authentication and access control over untrusted networks such as the Internet. On one hand, the issue of data integrity is addressed by public key cryptography. On the other hand, the authentication and access control are covered by the digital certificates. The system has the advantage of simple operation, yet effective to prove authentication of parties, integrity of transacted data and acceptance of terms. It also protects confidentiality of transactions.

ETO already spells out that if there is a legal requirement for a signature, a digital signature fulfils this requirement, provided that it is supported by a recognized digital certificate and the signature must be generated within the validity period of the certificate.

Therefore in principle, digital signature can serve the purpose of certification under the Buildings Ordinance. But under the current arrangement (BD 2000), submission of building plans and specified forms by electronic means is still exempted from ETO. Electronic submission is only optional and signatures

still have to be done in written form. The underlying reason may be the reliance limit set out in Section 41 of ETO. For the time being, the limit for e-Cert (Personal) Certificates is set a HK$500,000.00 (US$64,102). For the capacity of an AP or RSE in certifying regulatory compliances, it is difficult to determine whether the limit is adequate.

Despite the above, we can see there are potential for actual implementation of digital signature in building plan submission pending further exploration of related issues.

b. Signature on Electronic Drawings

If digital signatures are to be adopted in electronic submission, although visualized signatures will be omitted from digital drawings, they can still be attached in visualized manner by software packages. These packages enable viewing of drawings and other electronic documents in any format, and attach mark-ups, stamps and signatures to the electronic files. Users can be provided electronic signature capabilities that can also be used as plug-in for mark-up files, such that the record can be compatible with other submissions not made in electronic means. Figure 6 below illustrates an example of electronic signature application (Building Department 2000).

Submission

In making building plan submissions, the project team should check against the nature and complexity of their projects to ascertain the list of government departments where approvals need to be sought[17]. The project team should then supply adequate sets of plans in their submission to BD. Under the Centralized Processing System, BD will retain two sets of plans and refer the others to relevant departments and collate their comments in their consolidated approval.

Subject to adequate infrastructure support, proper authentication and registration system, electronic submission of building plans can significantly enhance the efficiency of onward procedures. The projectteam only need to send their plans, calculations and specified forms in document and image formats through e-mails to the e-counter of BD or handed the relevant information in computer diskettes or CD-ROMs. The whole process can be performed within office.

The most obvious benefit is perhaps the time saving in receipt and dispatch of submissions. Upon receipt of electronic submissions from project teams, BD can then immediately distribute the electronic files to the designated government departments, without complicated procedures and arrangement

Figure 6. Signature Capture as Plug-in Entity

for delivery services. That contributes to more efficient communication and shortening of comment consolidation time. Moreover, it also minimizes the delay due to mis-delivery as the circulation process is direct and performed computer-to-computer.

4.2 Electronic Plan Checking

The plan checking process commences after the electronic submissions are received. The tasks involved in building plan checking are viewing, desktop checking, and automated regulatory checking. These tasks are further elaborated as follows.

Viewing

It is necessary that various graphical file formats in image form (e.g. TIF, BMP, JPEG etc.) and electronic form (e.g. AutoCAD) should be permitted in the submissions. Hence proper software package should be provided to enable viewing of all types of drawing format. Recent releases of software packages already enable viewing of documents in more than 200 formats, even displayed in multiple windows (see Figure 7). The built-in macros can efficiently perform repetitive tasks and drawing and document files can be effectively reduced to thumbnails for easy browsing and navigation. These functions bring convenience to the project officers and save their time in cross-referencing.

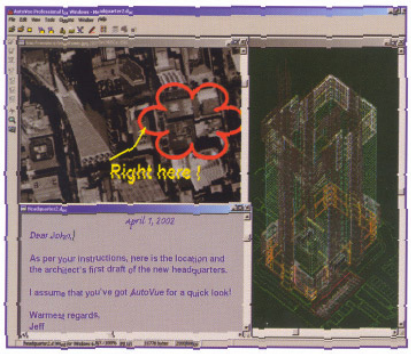


Figure 7. Multiple File Viewing

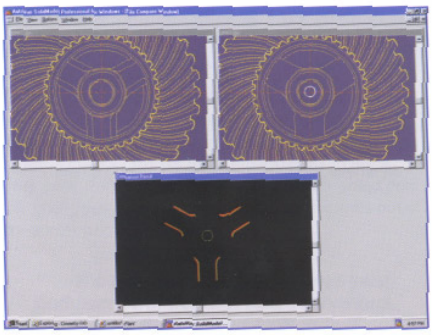


Figure 8. Automatic Drawing Comparison

Desktop Checking

In amendment plan submissions, only the revised areas need to be checked for regulatory compliance. While the amended areas are highlighted by proper colouring in the submission, the government case officers still need to counter-check to ensure there is no overlooked area. In this respect, if electronic submission is made in drawing format, the new software packages can also compare two drawings prepared in electronic format and highlight the identified differences (see Figure 8), so that the case officer can easily note the revisions made with respect to the last approval plans.

Besides automated comparison, the viewing software also enables superimposition and overlaying functions. By such features, several documents can be viewed and printed at the same time even in different formats. This is particularly useful for submissions adopting hybrid files or scanned document with a vector counterpart.

It is therefore clear that electronic submission facilitates the automation of many tasks involved in desktop checking of building plans.

Automated Regulatory Checking

Advancements in CAD technologies bring forth automated checking functions on the preset building regulations performed by computer workstations.

Expert systems adopting artificial intelligence and CAD technologies have already been employed by government of foreign countries to automate the checking of building plans for compliance with building control regulations.

The automated plan checking system accepts as inputs building plans with CAD software. The system captures extensively the knowledge of interpreting architectural design as well as the expertise of applying building regulations to the designs. It can automatically interpret the layout of floor plans through the use of semantic nets and derives spatial relationships among the various building components, then checks the design compliance with built-in regulations. Non-compliances will be highlighted so that project teams can amend the design accordingly. Building regulations and codes are built into the system as expert rules. Building objects and components organized in various layers can be viewed at users' preference such that the building design can be checked portion by portion. The process can repeat until overall compliance in the building design is achieved. Schematic process of automated checking is illustrated in Figure 9 below.

The obvious benefit of adopting automated regulatory checks is project teams have uninterrupted design and verification process. With the availability of checking software also in the designer office, they can perform automatic checks by themselves. This significantly reduces the waiting time for intermediate government approvals and associated overheads. The automated checking programme guarantees consistent application of building regulations in the checking of plans. The automated checking process ensures that all plans are checked thoroughly and accurately with only a small proportion of time for manual checking.

Building regulations and codes are established to safeguard the minimum safety and health standard in design and construction of buildings. Both the government and the project teams should endeavour to improve the quality of building projects beyond that set out in statutory requirements. With the aid of the self-checking tools, much human resources can be saved to perform more value-added activities.

There are also limitations and constraints in adopting automated checking under the current environment. First of all, the software packages are basically developed based on certain drafting packages. In order to enable automated checking, the submissions should be made in certain specified formats. But on the other hand, the Government must be prepared to accept submissions in various formats to avoid monopolization.

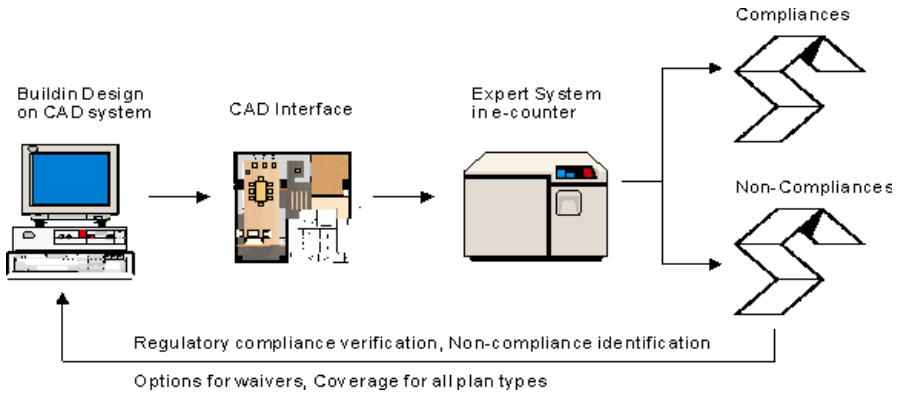


Figure 9. Automated Plan Checking Process

Secondly, under the current regulatory environment, more and more statutory requirements are shifting from prescriptive basis towards performance basis, i.e. the project team can propose innovative design and prove compliance with standards by alternative means. For the time being, BD has already accepted such engineering approach in the areas of lighting and ventilation requirements and fire safety standards. This restricts the use of automated checking as it can only perform checking based on built-in regulations and codes applicable to all projects.

4.3 Electronic Document System

With the dynamic development of digital information and communication technique, digital organizationhas become a compulsory element of strategic company management. In connection, the production cycle can be shortened and storage density enhancement can increase the documentation volume. For government drawing control offices, typical electronic document system is arranged as shown below in Figure 10.

In developing such a electronic document control system, the fundamental concern of government offices are improvements in document storage and circulation, enabling users to share and store information simultaneously without the threat of data destroy and loss. With the launching of the system, the drawing control office can be benefited by the features of the information system, workflow functions and imaging and storage capacities.

Information System

In the convention system of building control, all records are kept on paper file records. For completed projects, it usually takes a few days to retrieve the file from the archive. Besides, owing to the bulk volume of file size, information sometimes cannot be located due to loss of document or misfiling. With the implementation of electronic document system, an effective information system can be achieved with the benefits below:

- The system ensures all records are made available and easily retrievable, without the risks of loss, misplacement and destroy.
- It can generate simple statistical reports as it may be required by the management level for surveillance and monitoring purposes.
- It can generate reminders to case officers regarding the necessary actions according to the workflow procedures set out in the in-house guidelines.

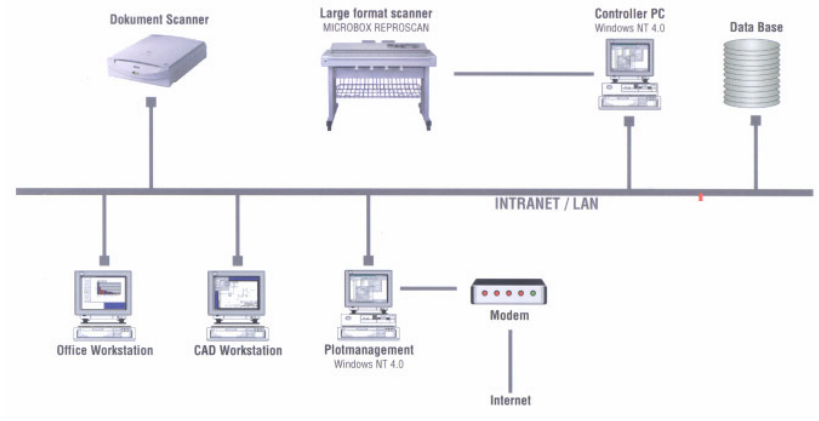


Figure 10. Typical Electronic Document System in Drawing Offices

User interface screen of a typical project management system in building control is shown in Figure 11 below:

Workflow Management

The electronic document system can enhance the efficiency of the building control procedures by its workflow features. By employing viewer software, officers can browse through various document types ranging from text files, images and computer drawing formats. They can also annotate, mark-up and insert hyperlinks in these documents and forward for other officers' further action. These can be accomplished simultaneously, instead of being done sequentially. As a result, the building control procedures can be streamlined and its quality of communication enhanced.

Imaging and Storage

It has been stated that the paper based storage system requires storing vast amount of documents including case files, approved plans, record plans and project registers to meet the operational needs. This limits the efficiency of information retrieval to certain extent. Imaging technologies has made it possible to scan building plans into electronic files. For example, a typical large size plan scanner can scan up to 7 A0 size monochrome plans per minutes with image density of 400 dpi. This enables easy conversion of submissions consisting of 30 plans typically to electronic images within 5 minutes. Also, the integrated scanner-plotter can output the plans in appropriate scale to suit the operational requirements of case officers such as drawing layering and site inspection etc., without needing to use the actual copy of the submitted plans.

Storage of electronic images in the format of CD-ROM, computer servers etc. can save the accommodation area significantly. Besides, the concerns on long-term data storage worth further review. As paper records are subject to deterioration, decay and damage, a more permanent way of storing information is always desirable. Although it also has its own life span, optical disks (such as CD-ROM or Magneto Optical Disks) with

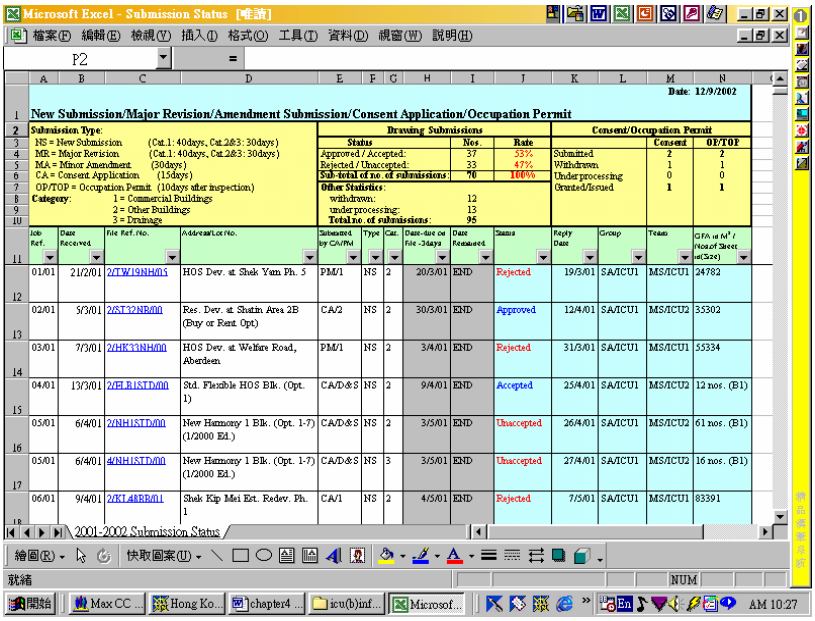


Figure 11. Typical Project Management System in Building Control

higher qualities can last for about 50 years. Specifically, electronic storage of information in image format has the following advantages over conventional storage:

- Longevity – enjoys longer life span of information storage so as to minimize the risks of loss of data,
- Obsolescence – image data can be universally retrieved in comparison to computer files which are subject to outdating or obsolescence of the original computer software package, and
- Migration – the easily compatible image data can minimize the risk of incompatibility after periodical transfer of data from one system to another.

5 Discussions and Concluding Remarks

This paper presents a real case study of re-engineering the building plan submission, checking and storing processes using information technologies. Using case study as the primary research method, this paper describes a pilot study conducted in the Building Department of the SAR Government in Hong Kong. We expect that the technologies and methods described in this paper will provide some guidance on how to implement an IT enabled electronic building control system. The advantages of the IT enabled electronic process are summarized in Table 1.

From this study, requirements and conditions for implementing IT enabled electronic submission system can also be identified as follows.

- *Establishment of e-submission Data Centre*. In order to implement an electronic submission system, the Government should prepare for the setting up of an e-submission data centre with powerful network and server support aiming at handling all types of submissions upon the readiness of the construction industry and maturity of technical environment. Building professionals only need to register and log in the e-submission system and submit the drawings and documents on line made secured by digital signatures.
- *Electronic Submissions*. At planning and construction stages, building plans should be submitted in electronic format to facilitate submission, distribution and automated checking. After completion of project, the plans should be submitted in image format for efficient record, storage and retrieval purposes. Noting the benefits of the re-engineered system, both the government and the private sector should endeavour to overcome the various difficulties in impediments.
- *Government Commitment*. Government participation and commitment are the keys to the success of re-engineering building plan submission. The government should review their position in the electronic delivery of building control services and set out short term and long-term objectives for actual implementation. Where necessary, incentives (such as shorter processing time) should be given to encourage project teams in adopting electronic submissions.
- *Technical Development*. Both the government and private practices should take the advantage of computer technologies in improving the performances in their business operations. In developing their strategies in computer development, considerations in electronic plan preparation and submission should be taken in parallel with other system enhancements, so that the re-engineered building control system can be actualised more readily and cost effectively.
- *Integrated Computer Application Package*. Up to present, the entire electronic submission system is devised based on individual computer applications in a fragmented manner. In the long run with a view to bridge up the gap between separate steps in building control, the government and the private sector should join force with the IT and computer industry to develop more sophisticated application packages to enable integrated and smooth operations. As a result, further enhancement in efficiency, time and manpower savings can be envisaged.

Table 1. Comparison between Electronic Submission and Conventional Submission Systems

Electronic Submission	Conventional Submission
Advantages/benefits	*Limitations*
1) One-stop service	1) Require frequent trips and delivery to various departments
2) Streamlining	2) Complicated and lengthy processes
3) Accuracy	3) Subject to manual errors
4) Time and manpower saving	4) Time and manpower intensive
5) Paper saving	5) Paper consuming
6) Automated features	6) Entirely manual processes
7) Enhanced communication and workflow management	7) Inefficient communication owing to lots of personnel involved
8) Easy Storage	8) Space demanding storage
9) Effective Information Retrieval	9) Difficult and time consuming in retrieving previous records
Limitations/considerations	
1) Legal aspects	
2) Training needs	
3) Cultural changes	
4) Technical requirements and cost investment	
5) Changing regulatory framework	

- *Sophisticated Computer Modelling*. It is obvious the automated regulatory checking function can only accommodate prescriptive statutory requirements. In the long run, it is expected the industry can develop more sophisticated computer modelling features based on well-recognized international standards on performance engineering, so that the performance based approach to building safety can also be addressed and verified.

In summary, in order to implement an IT enabled electronic building submission system, the government and the private sector should be open-minded in future development and re-engineering of the building control system. It may not be realistic to change the whole process in once, but the construction industry should have the vision to experiment and refine the system progressively so that it can be ultimately developed to better serve the industry.

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