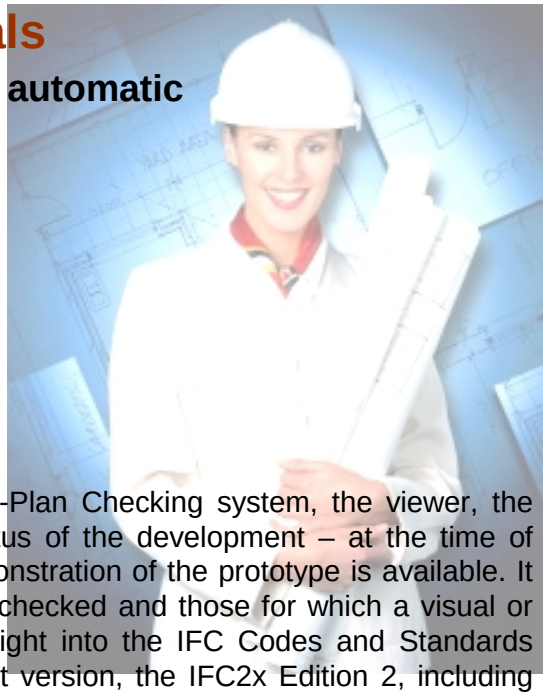
Speeding-up Building Plan Approvals

The Singapore e-Plan Checking project offers automatic plan checking based on IFC



Thomas Liebich, Jeffrey Wix, James Forester
AEC3 Ltd., 30 Northfield Road, Thatcham RG183ES, UK

Zhong Qi
novaMSC-novaCITYNETS

ABSTRACT: The paper describes the components of the e-Plan Checking system, the viewer, the clause selector and the clause checker and the current status of the development – at the time of writing the phase 1 of the project is complete and a live demonstration of the prototype is available. It also highlights the type of clauses that can be automatically checked and those for which a visual or manual check is provided. The paper continues with an insight into the IFC Codes and Standards extension project (CAS) leading to enhancements in the next version, the IFC2x Edition 2, including additional definitions of architecture and building services classes to better satisfy code checking requirements.

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1 INTRODUCTION

In Singapore there is a long lasting effort to increase the efficiency through the construction and real estate network (CORENET).

Under the CORENET framework plan, code checking is a flagship project. A previous prototype BP+ expert was presented in 1997/8 which enabled the automatic checking of disabled access to buildings based on 2D drafting data within an own proprietary file format.. While the BP+ expert system demonstrated the general feasibility of plan checking it also highlighted the bottleneck, i.e. the availability of high-quality CAD input data, which is essential for reliable checks. Therefore the new project, the Integrated Building Plan and Integrated Building Services (IBP/IBS) e-Plan Checking has been based on IFC technology to provide the necessary underlying data model and the latest product data technology to access, verify and manipulate that input data.

The current version of IFC, the release IFC2x, was selected as the development standard because it provides broadest coverage among the commercial CAD systems used by the practitioners and it is based on the stable platform approach, introduced for the first time in IFC 2x. It provides a core model that remains unchanged over time that facilitates the development of extension models on top of it.

2 SCOPE OF THE E-PLAN CHECKING

The e-Plan Checking system provides the building authority with a convenient tool to approve building plans submitted by the practitioner (the architects and building services engineers) electronically through a dedicated web service.

There are two different services offered, the automatic plan checking and the visual plan checking. In both cases the inspector from the building authority can view the electronic plan and provide his/her observations (remarks, waivers, requests for re-submission) electronically to the submitter.

Visual plan checking is provided for all acceptable input formats, currently including IFC, DWF, DXF, whereas automatic plan checking requires the submission of an IFC2x file.

After submittal the files are stored in a multi-user database at the plan checking server and all relevant authorities are notified. Each inspector can now access the building plan, view and comment on it, and (provided that an IFC file is

available) run an automatic check against the clauses from the building code relevant to his or her agency. The following agencies are involved:

- Building Construction Authority
- Civil Defence Services Bureau
- Fire Safety & Shelter Board
- Housing & Development Board
- Power Gas Department
- Public Utilities Board
- Urban Redevelopment Authority
- Ministry of the Environment

The building code concerned for automatic plan checking includes provisions for area and volumetric extent calculations, overall thermal performance, fire escape, fire compartmentation, disabled access, parking facilities, housing shelters, waste and drainage, sprinkler systems, fire fighting equipment, and others.

In order to enable automatic plan checking for selected clauses, the following criteria need to be matched:

- information needs to be entered by the practitioner as object information into the building model using object oriented CAD systems;
- the CAD systems need to be able to store that information within its own database and to provide a UI to the user;
- the IFC2x data model needs to allow exchange of that information by providing object definitions within the underlying product data model;
- the CAD systems need to be capable to convert the information from its own database structure into the neutral structure of the IFC2x file;
- the code checking system needs to be able to interpret the information, perform all necessary rule checking functions and to provide the output to the inspector by a suitable UI.

The following sections describe how the e-Plan Checking project is structured and how these criteria are met.

3 SCOPE OF THE UNDERLYING IFC MODEL

The populated IFC model provides the virtual building model as input information for the rule checking engine that executes the code check. The reasons for selecting the IFC2x model were based on the following criteria:

- IFC has the highest recognition of building model based standards in the construction industry;
- IFC2x as the latest specification provides a stable core, that provides stability of at least 4 years – as required by major undertakings, like e-Plan checking;
- IFC2x is currently implemented by the biggest vendors of object-oriented architectural CAD with strong indications of support by leading building service CAD related packages.

3.1 Clause Analysis

As part of the overall project each clause of the building regulation selected to be in scope of the e-Plan Checking was analyzed for its information input requirements. The required input was then compared with the information provided by the IFC2x product model. If information requirements were found that are not directly reflected by IFC2x, nor can be generated from other information within the model, then those will be dealt within the IFC extension project Code and Standards (CAS) and should be added to the IFC2x edition 2.

Example: The clause 2.2.7 from the "means of escape" building regulation stipulates: *"No exit, exit staircase or other exit facilities shall be narrower than the minimum width requirement as specified under Table 2.2A. The minimum clear width of an exit door opening shall be not less than 850mm"*.

Within the clause analysis all information that is required to establish the input for code checking was assessed: here "What constitutes the "clear width" (See Figure 1).

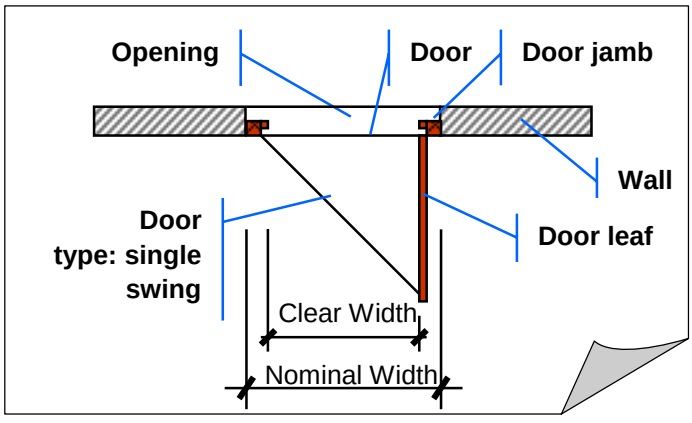

Figure 1 Clause Assessment

Next, the required input information was matched to the information available in IFC2x. For the quoted clause (which belongs to that group of clauses classified as 'easy to handle' using IFC) all information could easily be matched with IFC (See Figure 2).

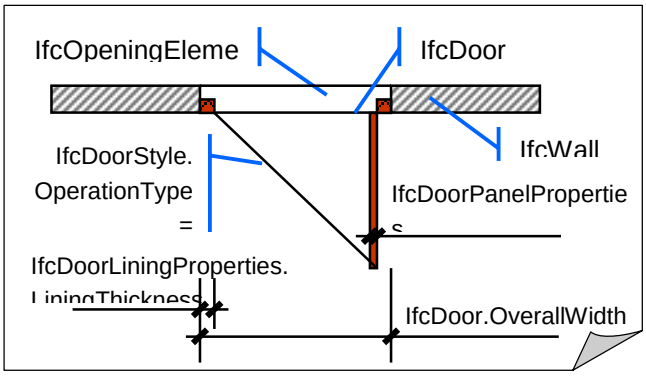

Figure 2 Analysis of Underlying IFC2x Model

If the clause analysis concluded that required input information, which in principle would be available from object-oriented CAD, could not be exposed through the IFC2x interface, than it has been forward to the IFC extension project CAS as model requirement.

Based on the clause analysis it was concluded, that the architectural part (IBP) is covered to about 75%, whereas the building services part (IBS) is covered to about 25% by current IFC2x. Whereas the geometry and spatial related information is provided almost 100%, functional requirements and additional property information are less likely to be available, partly through limitations within the model, but mainly through missing input capabilities within currently available systems.

3.2 IFC Extension Project CAS

There is a clear recognition within the e-Plan Checking project that not all of the facilities that are required to support automated code checking are currently available within IFC 2x. To enable the project to proceed, individual clauses within the target codes have been classified as follows:

EASY — capable of being handled by the existing IFC 2x model and proposed software implementations of IFC 2x using the 'coordination view'

MEDIUM — capable of being handled by the addition of property sets to the existing IFC 2x model and through the use of these property sets within proposed software implementations of IFC 2x

HARD — requires extensions to the IFC 2x model and new capabilities within software implementations to support these extensions.

A primary task within the e-Plan Checking project is to develop the model extensions that are required for the medium and hard classifications. For the purposes of Singapore, this is a relatively straightforward (though extensive) task.

However, a reason for using IFC within the project has been to ensure that there is widespread software support for the approach. Previous efforts have had only limited success due to their development of custom software with all the ongoing maintenance and development problems that are associated.

In this case, the client has determined that the final model used should be a worldwide industry accepted standard that is supported 'out of the box' by major software implementations. To ensure that this is the case, it has been determined that the models developed for e-Plan Checking should be fully coordinated with and be part of the IFC 2x Edition 2 release. It is the next major extension release of IFC2x (referred to as IFC2x2) and it is planned for release in Summer 2003.

Practically, this means that model developments have to be coordinated with other efforts that are likely to impact into the same areas of the model and also ensuring that they are accepted internationally. To this end, the CAS project has been established as an extension of e-Plan Checking.

As the draft model developments in e-Plan Checking are completed, CAS provides for their coordination and review by others. Major coordination is occurring with the IAI BS8 project which is also looking at building services; it will also coordinate with the recently defined IAI EL1 project for electrical services. Review will occur through a series of conducted workshops to be held in conjunction with the various IAI Chapters, the results of the reviews and coordination being fed back into the model.

Through their investment in the CAS project, the client intends that the IFC 2x Edition 2 model will support code checking not only in Singapore, but also more widely.

A major part of the CAS extension projects addresses the building services support by IFC.

3.3 Building Service Model Extensions

The building service concepts in the existing IFC2x model were originally introduced to accommodate HVAC equipment sizing, static thermal load calculations, and ductwork and HVAC piping systems. With little or no provisions for building automation controls or plumbing and fire protection, significant extensions in the form of two new domain schema extensions are required to accommodate the IBP/IBS use cases.

- *IfcBuildingControlsDomain* and
- *IfcPlumbingFireProtectionDomain*

These new schemas complement the existing *IfcHvacDomain* and *IfcElectricalDomain* extensions in IFC2x to complete the traditional trades associated with building services.
The *IfcBuildingControlsDomain* extension contains concepts related to building automation controls systems, including concepts such as sensors, actuators, controllers, etc. This schema does not attempt to provide for any of the communications protocols that are typically used amongst these components, relying instead on existing industry standards (e.g., BACnet) to fulfill these responsibilities.

The *IfcPlumbingFireProtectionDomain* extension expands the sanitary plumbing concepts found in IFC2x to now include waste, vent and drainage systems. Furthermore, fire protection concepts such as hydrants, alarms, fire suppression terminals, etc., are introduced.

Accompanying these new schemas are extensions within existing parts of the IFC2x model, notably the *IfcHvacDomain* and *IfcSharedBldgServiceElements* schemas. These two schemas were not a part of the 'frozen' parts of the IFC2x model and are therefore free to be modified to accommodate new extensions. Of notable significance within the *IfcSharedBldgServiceElements* schema is a more robust connectivity model that neutralizes concepts to accommodate connected systems of any type, not just liquids and gases. Similarly, the *IfcHvacDomain* schema has been extended to accommodate systems with fire life safety requirements.

At the time of writing the proposed building service model extensions reflect work in progress with the clear goal to roll into IFC2x2. To enable cross review and harmonization with other IFC extension projects, the CAS project had been initiated.

4 AUTOMATIC E-PLAN CHECKING

As defined, the Automatic e-Plan Checking system takes in the digital design as input, checks it against the building plan and building services codes and regulations.
The project development started in the late 2000 and will be completed in 2003.

4.1 Benefits of Automatic Code Checking

With the migration from the manual checking of blue-prints, which is widely practiced in most countries, the e-Plan Checking project will bring along the following benefits to the industry:

- To increase the productivity for both the practitioners and agency officers by shortening the "Plan Approval" cycle;
- To ensure the authorized and unambiguous interpretation of the building regulations;
- To ensure the up-to-date building regulations to be applied; and
- To provide a mechanism to reduce the cross-domain regulation conflicts.

4.2 Basic System Design

In order to tap on the latest information technology, the system has been designed to operate on the Internet. It ensures users, who can be anyone with authorized access right, to make use of the system from any place and at any time. As for a practitioner, the system will allow him:

- To verify his work at any stage of design by submitting the partial model to the system for checking; or
- To submit his final work to a regulatory agency for approval checking.

Figure 3 shows the basic design as a web-based system on the principle of a client-server architecture.

4.3 Code Checking Server

The code checking server is the heart of the e-Plan Checking system. It resides at the regulatory agency, maintains the latest building regulations and functions as a repository for all the building models submitted by practitioners in the IFC format. The code checking server undertakes the checking for all clauses, which are selected by the officer through the code checking client.

More precisely, the server is able to performs the following functions:
- To load in the building models in IFC format;
- To apply various rule engine, geometry engine, query engine to the building models; and
- To generate the checking results.

The code checking server is based on the EXPRESS Data Manager (EDM) from EPM, the Norwegian partner within the IBP/IBS consortium.

4.4 Code Checking Client

Both practitioner and regulatory agency will be able to access the system through a web client by Internet or Intranet.

The system allows the client:
- to view the building models in various ways;
- to select the applicable building regulations;
- to select the building sections (buildings, stories, etc.) or building components (walls, doors, etc.) deemed for checking;
- to proceed the checking; and
- to print out the checking results.

A key component is the code checking viewer providing the graphical front-end to the user. The code checking viewer displays the full building model of the submitted building, including its inherent structure, as transmitted through the IFC file.

This allows the user to select, switch on/off, etc. each individual building section or story, and individual types of building components.

The viewer also provides the UI for selecting the clauses to be perform and to highlight the results, i.e. redlining the non-compliant parts of the building.

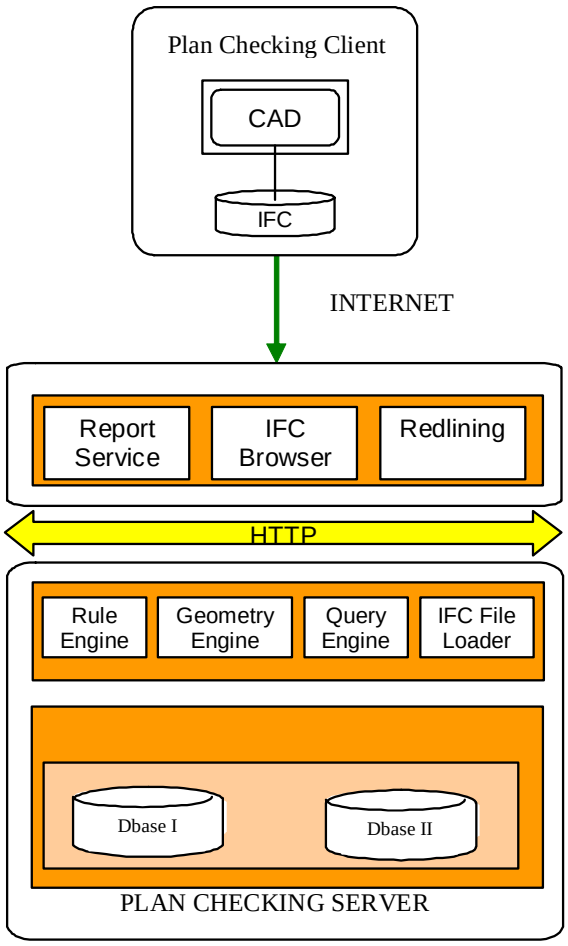

Figure 3 - System Architecture

5 OUTVIEW

The e-plan checking project has successfully delivered the first prototype and targets to deliver the phase 2 system by the end of year 2002. The prototype demonstrated the general feasibility of the approach, in particular:
- the use of modern, object-based CAD systems allows a new level of building model evaluations, including code checking,
- the IFC interface, based on the IFC2x data model, is mature enough for exchange of large, semantically rich building models,
- many clauses from the existing codes can be automatically checked,
- the code checking server application is robust for industrial usage,
- the client server architecture is suitable for multi-user approval (by the various agencies);

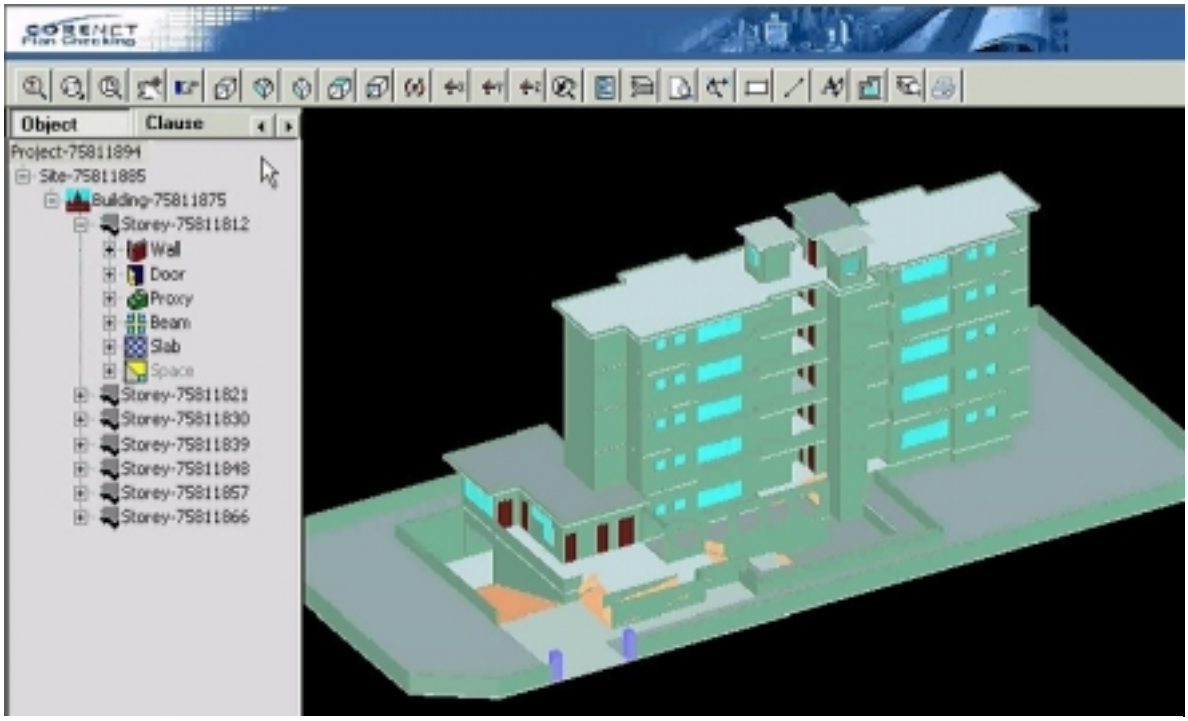

Figure 4 - Code Check Viewer

It also highlights areas of concern which needs to be addressed:

- the readiness of the average consulting firm (architects and building service engineers) to fully use the new generation of object-based CAD systems, taking into account the culture of drawing based design,
- the support of an enriched IFC based data exchange in the area of building service design,
- the current form in which part of the building code is written, which is indented for human interpretation rather than computer implementations,

Those questions are addressed in accompanying projects initiated by the Building Construction Authority, such as CAD familiarization, customization, etc. which are however outside of the scope of the paper.

Dr. Zhong Qi is the Vice President, Consulting in novaCITYNETS. He is a key team member of our team involved in the implementation of e-Plan Check project with Building and Construction Authority, Sinagpore. Before his current position, he was part of the team drafting the National Classification standard for E-commerce in the construction industry in the National Computer Board, Singapore.

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