CORENET e-PlanCheck: Singapore's Automated Code Checking System

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I first heard of Singapore's CORENET project way back in 1997, when I was doing my Ph.D. research in the field of computer applications in architecture at UC Berkeley. At a time when most architects weren't even aware that there was an alternative to drawing-based CAD technology and researchers like me were aspiring to develop more intelligent solutions for designing and evaluating buildings, a system which purported to automate the checking of building plans submitted online for code compliance seemed too ambitious to be true! Some further investigation into the CORENET system at that time revealed that it was "not quite working yet." In recent years, however, the CORENET project has moved from ambition to reality, and is inspiring similar developments in other countries around the world. This issue of the "Building the Future" series provides an overview of the CORENET project and takes an in-depth look at its automated code checking module, e-PlanCheck.

Overview of the CORENET Project

CORENET stands for COnstruction and Real Estate NETwork. It is a major IT (Information Technology) initiative that was launched in 1995 by Singapore's Ministry of National Development, to "propel the construction and real estate sector into the new millennium" by re-engineering the business processes with state-of-the-art IT to achieve a quantum leap in turnaround time, productivity and quality. It also aims to allow parties in the construction and real estate sector to communicate and exchange information seamlessly and efficiently. It is being implemented by Singapore's Building and Construction Authority in collaboration with several other public and private organizations.

Figure 1. CORENET's objective is to develop IT systems for fully integrating the four basic processes of a building lifecycle. (Courtesy: Building and Construction Authority, Singapore)

While the ultimate objective of CORENET is to create the IT infrastructure that will allow total integration across the four basic processes of a building life cycle—Design, Procure, Build, and Maintain (see Figure 1)—it started with the development of three modules for the Design Phase that have now reached maturity. These are briefly described below:

1. *CORENET e-Submission*

This is an Internet based system that enables AEC professionals to submit project related plans and documents to regulatory authorities for various kinds of approvals, including planning approvals, building plan approvals, structural plan approvals, temporary occupation permits, fire safety certificates, and so on. The benefits of this system over manual submission are obvious: it is digital as opposed to paper-based, eliminating printing of plans and forms; it can be used round the clock rather than being restricted to office hours; instead of dealing with multiple officials at multiple counters, it provides a one-stop point for qualified persons to submit plans to multiple approving authorities from anywhere and to check submission status online; it integrates application forms and fee collection; and it simplifies the work for approving authorities by providing them with a one-stop billboard to post submission status online. Overall, it leads to faster processing and turnaround time, improving public service through better efficiency and productivity in managing and processing electronic submissions. It also has the added benefit of harmonizing rules and streamlining forms among the different agencies involved.

Several regulatory authorities in Singapore are participating in the CORENET e-Submission system, including the Building and Construction Authority, Urban Redevelopment Authority, Land Transport Authority, Public Utility Board, Singapore Power, Housing & Development Board, etc., along with various industry associations including the Singapore Institute of Architects, the Institution of Engineers, Association of Consulting Engineers, Real Estate Developer's Association, and the Singapore Contractor Association (see Figure 2).

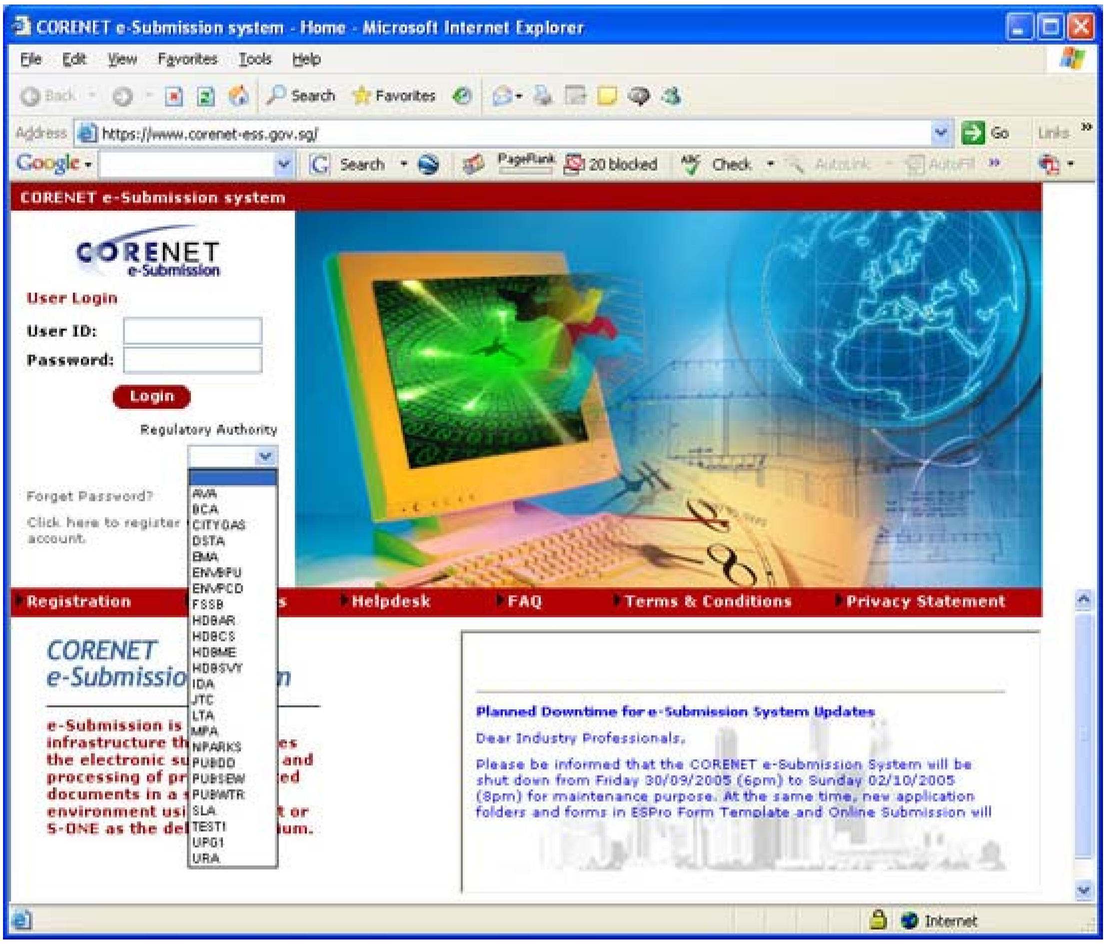

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Figure 2. The CORENET e-submission login page.

2. *CORENET e-PlanCheck*

The objective of this system, as originally proposed, was to provide a series of IT applications that could automatically check "electronic building plans" for compliance to regulatory requirements, using "Artificial Intelligence (AI) and Feature-based Computer-Aided Design (FB-CAD) technologies" (as quoted in the 1997 CORENET brochure I have still preserved). Needless to say, it would now be more accurate to use the term "models" rather than "plans" and "BIM" rather than "FB-CAD." One of the main advantages of BIM (building information modeling) over CAD is its ability to support analysis and evaluation of building design, of which code-checking stands near the top of the list as one of the areas ripe for automation. As we all know, the process of code-checking manually is very labor intensive and time consuming, prone to inconsistency because codes could be interpreted differently by different individuals, and is usually not comprehensive because of time constraints. It's easy to talk about automated code-checking now that BIM is becoming so pervasive, but it was truly visionary to think about implementing such a system 10 years ago. How the CORENET e-Plan Check system is actually being implemented is described in detail in a following section.

3. *CORENET e-Info*

The intent of this system is to provide a central repository of building and construction related information in Singapore that is accessible anytime, anywhere via the Internet. It replaces heterogeneous information from multiple sources in varying formats and different versions with a single source of integrated information that AEC professionals can refer to and find the needed information more quickly and efficiently, also eliminating the need for hard copy storage space and expensive content management systems. e-Info currently includes information on codes, regulations, guidelines, standards, product catalogs, contractor performance, and Singapore standards, and is supported by 12 regulatory departments spread across 8 Ministries (see Figure 3). It uses the industry standard XML (extensible mark-up language) to structure and harmonize its information resources.

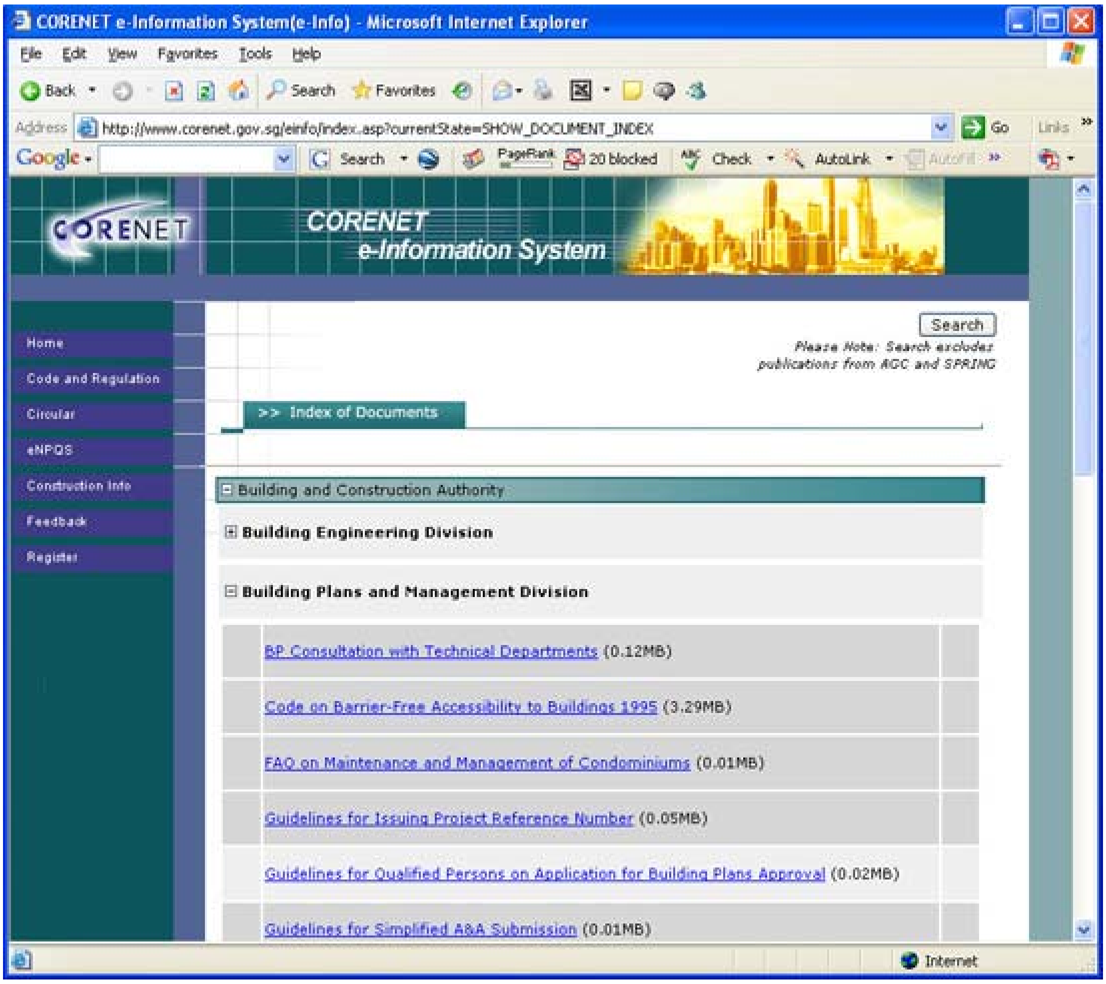

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Figure 3. An example of some of the documents available through CORENET e-Info.

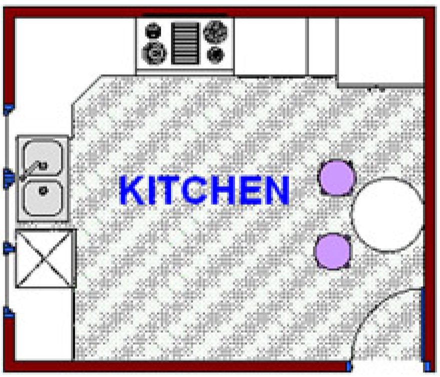
Let us now move on to look at the CORENET e-PlanCheck system in more detail.

How e-PlanCheck Works

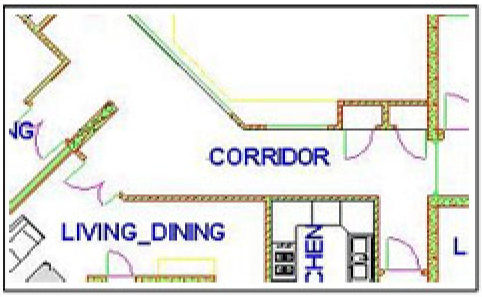
As mentioned earlier, the initial approach to automated code checking in the CORENET project was to use Artificial Intelligence (AI) and Feature-based CAD technologies for building plan checking, and it resulted in the development of an application called BP-Expert. This initiative did not prove to be successful because of varied reasons such as the focus on 2D drawings rather than a model, the proprietary nature of the application, its inability to handle inconsistent/bad data, its limited coverage of code clauses, and overall performance. However, it served as a good learning experience for the subsequent code-checking project, e-PlanCheck, which was officially started in September 2000 and focuses on the building model rather than on 2D representations. e-PlanCheck currently covers code-checking for specific aspects of Architecture and Building services and will eventually be expanded to include Structure and External works (GIS related) as well.

The key technology in the implementation of e-PlanCheck is the IFC building model, an open standard developed by the IAI (International Alliance of Interoperability) to support interoperability across the individual, discipline-specific applications that are used to design, construct, and operate buildings by capturing information about all aspects of a building throughout its lifecycle. It was specifically developed as a means to exchange model-based data between model-based applications in the AEC and FM industries, and is now supported by most of the major BIM vendors as well as by many downstream analysis applications. A detailed overview of the IFC standard is provided in the AECbytes feature article entitled "The IFC Building Model: A Look Under the Hood" published last year. Since automated code-checking can only work if the building is represented in an intelligent format and the relationship between the different components can be understood, the starting point for e-PlanCheck is a building model created in a BIM application and subsequently exported in the latest version of the IFC format, IFC 2x2.

However, the IFC format alone is not sufficient in implementing a code-checking application. This is because the IFC only represents the basic building information that can be modeled by a BIM application during the design stage. Basic building objects and their properties provide limited and static information for code compliance checking, and would make its implementation too tedious and prohibiting. For example, see the IFC representations of a kitchen and a corridor, shown in Figure 4. These representations are not adequate to verify the Singapore code requirements of a kitchen (must be compartmentalized with minimum 1 hr fire rating; must have enough ventilation if mechanical ventilation is not provided) or a corridor (walls and doors along exit corridor must have fire rating at least 1 hr; minimum clear width of 1.5 m is needed; ramp or staircase must be provided for any level difference; must be connected to an exit door that lead to safe external space).



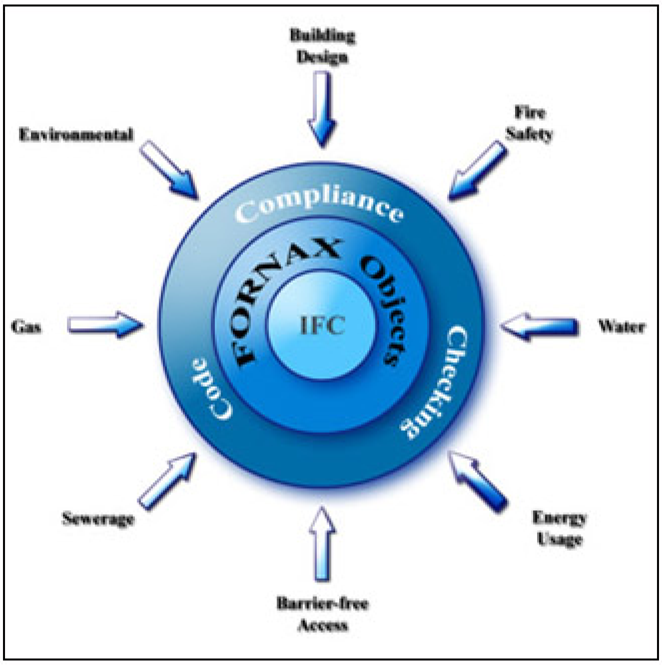
IFCSpace	
Name	KITCHEN
Geometry Representation	Extruded Area Solid
Space Boundary	All walls (IFCWall)
IFCWall	
PropertySet: Pset_WallCommon	
FireRating	1 hr



IFCSpace	
Name	CORRIDOR
Geometry Representation	Extruded Area Solid
Space Boundary	All walls (IFCWall)
IFCWall	
PropertySet: Pset_WallCommon	
FireRating	1 hr

Figure 4. The IFC representations of a kitchen and a corridor. (Courtesy: novaCITYNETS Pte. Ltd., Singapore)

What is needed are higher level semantics of building components, and in the case of the e-PlanCheck system, these are provided by an independent platform called FORNAX, developed by novaCITYNETS Pte. Ltd., an e-Government solution provider in Singapore. FORNAX takes the basic building model information from the IFC and adds to it higher level semantics that are relevant to code checking requirements. This is done by encapsulating building components into a set of FORNAX objects, each of which defines relevant attributes and behaviours. These objects are designed to be extendable for customization to handle the variance of requirements of building codes around the world, giving the FORNAX platform the ability to handle the code checking requirements for other countries as well. FORNAX essentially provides the development and deployment platform for e-PlanCheck, and the building codes are interpreted and built using FORNAX as an add-on to the platform (see Figure 5).



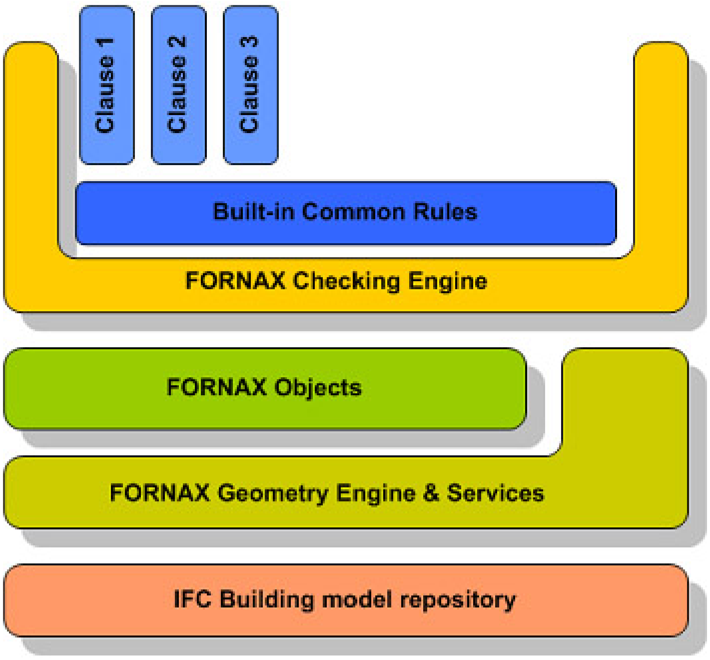


Figure 5. The FORNAX platform captures higher level semantics of building components for code checking and provides the development and deployment environment for the rules capturing building codes. (Courtesy: novaCITYNETS Pte. Ltd., Singapore)

We will now see how FORNAX objects are used in code compliance checking using the example of an apartment unit, a collection of spaces typically found in an apartment dwelling. In the IFC format, the apartment unit is simply represented as a collection of spaces, making it difficult, for instance, to check for the compliance of codes related to key fire-safety requirements, such as the travel distance of any point in the apartment unit to the nearest exit (which must not exceed 20 m in Singapore), and the area and volume of the unit to check the limitation of fire compartmentalization. Using the FORNAX platform, a FORNAX object called *FXApartmentUnit* is created for an apartment unit which includes various methods to perform calculations and define behaviors. Some of these methods that are used to evaluate fire safety requirements are listed below:

- *GetSpaces*: Get all spaces composing this apartment.
- *GetExit*: Get the exit door of this apartment.
- *CalculateRemotePoint*: Calculate the remote point in a space from its door(s).
- *CalculateTravelDistance*: Calculate the travel distance between the given point in the space and the nearest exit door.
- *CalculateArea*: Calculate the area of this apartment.
- *CalculateVolume*: Calculate the volume of this apartment.

This is how the travel distance calculation for a unit, using the methods listed above, would be performed:

- Get all the spaces from this unit (*GetSpaces*).
- For each space
  - Calculate the remote point in this space from its door(s) (*CalculateRemotePoint*).
  - Check the travel distance of the calculated remote point (*CalculateTravelDistance*) to the main exit (*GetExit*) of the apartment unit.

A snapshot of this travel distance calculation as done in FORNAX is illustrated in Figure 6. It shows a partial view of the apartment unit in the FORNAX viewer to illustrate the result more clearly.

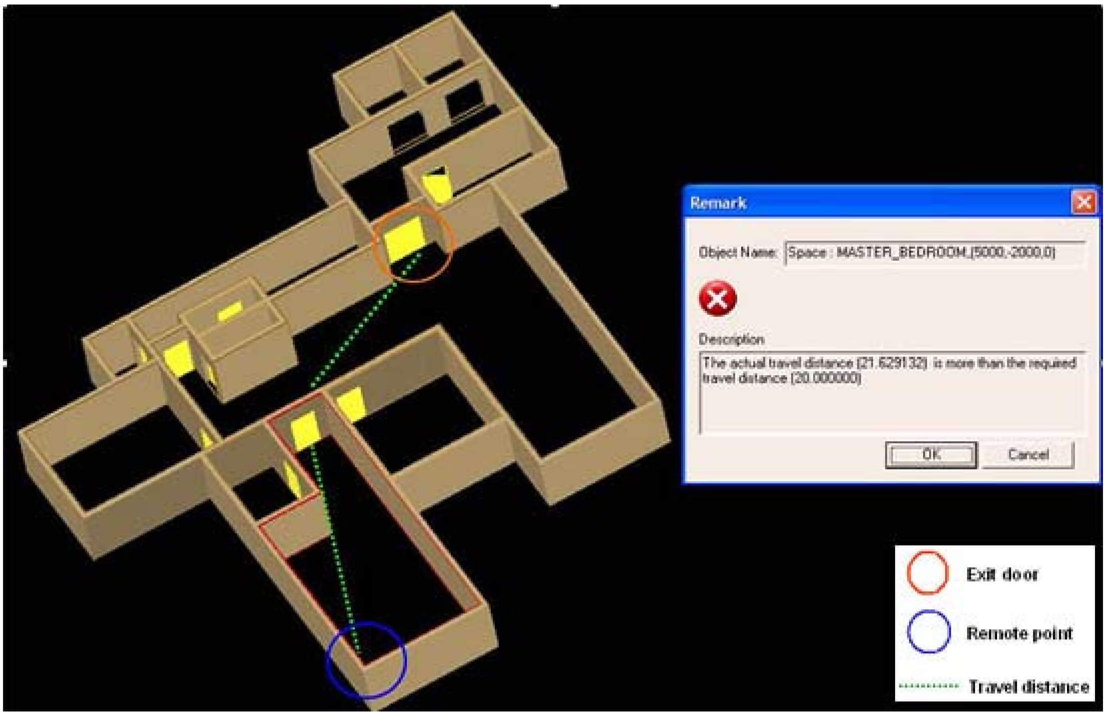


Figure 6. The travel distance calculation for an apartment unit as performed in FORNAX. (Courtesy: novaCITYNETS Pte. Ltd., Singapore)

The viewer shown above is part of a larger e-PlanCheck environment that includes a client assistant tool used to add some additional information to the IFC model necessary for processing it in e-PlanCheck; a web interface for users to upload the project, view it in 3D, check the project for compliance, and generate and view a compliance report; and the ability to download the model into a viewer used by the code-checking agency officers to view the model and verify the checking results. Figure 7 illustrates the e-PlanCheck web interface that shows the code-checking results of a specified clause for a project.

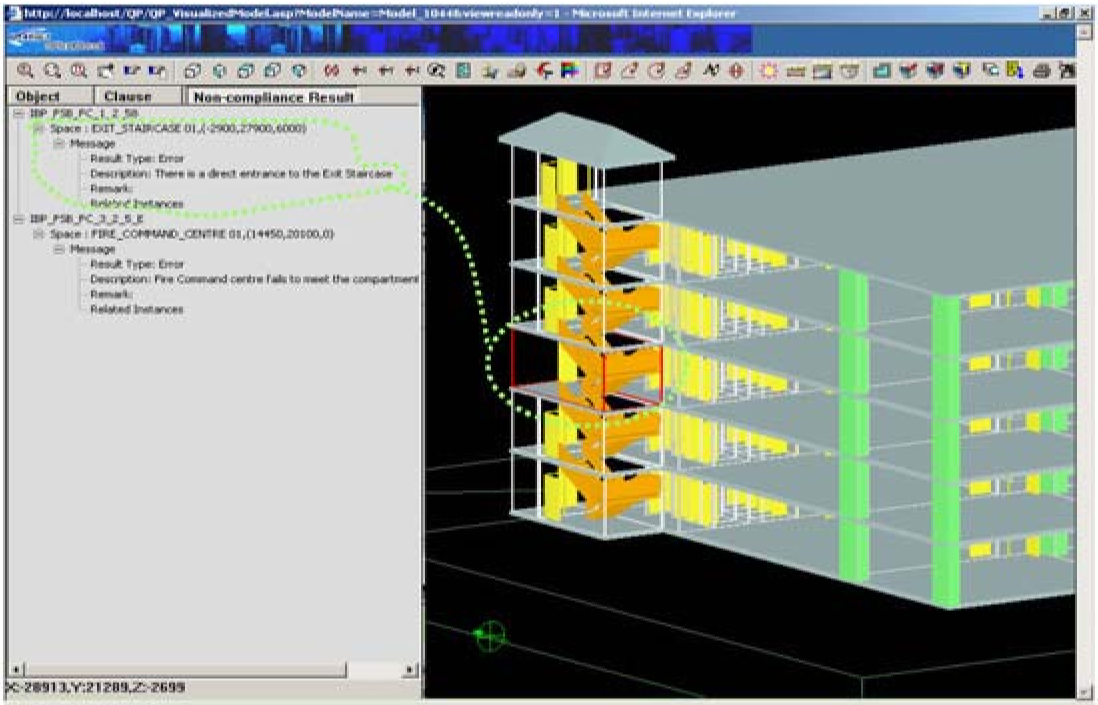


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Figure 7. The non-compliance results detected by e-PlanCheck for a specified clause in a building. The problem area is highlighted in red in the viewer. (Courtesy: novaCITYNETS Pte. Ltd., Singapore)

Current Status and Future Outlook

As mentioned earlier, the current scope of e-PlanCheck includes specific aspects of Architecture and Building services. Some of these are building control regulations, barrier free access, adherence to fire code, and so on. Now that the basic technological framework has been completed, work will continue on broadening the scope of the code-checking to more aspects of building design, and on integrating e-PlanCheck with the CORENET e-Submission system. Pilot projects with industry participation have already started in Singapore to test out the system thoroughly before a full public release.

At the same time, the initiative for automated code checking is also spreading to other parts of the world. This includes a pilot implementation in Norway using Singapore's CORENET e-PlanCheck as a base, with the code-checking rules replaced by those required in Norway. A pilot implementation in New York City using the ICC (International Code Council) codes has also been completed. In addition, testing is being done with Japanese and Australian models. All of these are being developed based on novaCITYNETS' FORNAX platform, which, in turn, works with the IFC building standard.

Code checking is not an easy application to develop since many clauses are quite complex, and often, even simple clauses are quite difficult to implement. For instance, take the clause, "Handrails are not required for any staircase having not more than 5 risers." Usually, the building model will represent the staircase as a single volume, and so it will be left up to the code checking application to decipher the number of risers, the location of the landing, and whether there is a handrail. What is needed is for the BIM application creating the model to represent the different components of the building and how they are related to each other, both at the macro as well as the micro level, and for the IFC model to be able to capture this information as well. Even then, it may be impossible to fully automate the process of code-checking, and the finer nuances of code-compliance may have to be left for manual checking by experts at the regulatory agencies. But even the ability to automate code-checking partially would bring enormous benefits to the building industry, including more consistency in the interpretation of regulatory codes and regulations, the ability to self-check designs for compliance before submitting them, more comprehensive checking, faster turnaround in feedback, and faster approvals for building.

One of the benefits outlined in the original CORENET code-checking manifesto was that it would spur the industry towards the adoption of object-oriented CAD. Fortunately, the AEC industry has not waited for code-checking systems to become reality before adopting object-based CAD or BIM. In fact, the increasing BIM adoption and the concomitant increase in interest in the interoperability potential of the IFC should prove to be the biggest catalyst in the successful adoption and further development of automated code-checking systems like e-PlanCheck.

Acknowledgments

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