A study on the effect of project coordinators' knowledge on the use of performance-based fire safety engineering design in buildings

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Abstract

Alternative fire safety design is *prima facie* permitted in Hong Kong's legislative context. It is further explicitly allowed through the 1995/1996 fire safety-related building codes, that is, a performance-based track has been initiated for the past decade. Hong Kong certainly cannot be regarded as the first city/country to engage in such an effort. United Kingdom, for instance, has explicitly allowed the use of fire engineering in the 1985 Building Regulations. However, it has been noted that the building projects' coordinators, architects, building surveyors, engineers, etc, do not usually have much knowledge on the use of fire safety engineering (FSE) design. Such a situation may affect the extent of projects using performance-based approach. This paper presents a simplified system dynamics model to examine the effect of project coordinators' awareness on the use of FSE design in Hong Kong.

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INTRODUCTION

All building works in Hong Kong should have prior approval given by the Buildings Authority.¹ Under the Buildings Ordinance (BO), every person, including developers, for whom building works are to be carried out, should appoint an Authorised Person (AP)² as the project coordinator. The project coordinator will be entirely responsible for submission of building plans, supervision of the building works and ensuring that the works are in compliance with the Hong Kong Buildings Ordinance. A chart showing the building control mechanism in Hong Kong is given in Figure 1.

Fire safety is one of the major safety issues that should be considered by the Hong Kong Building Authority. In general, the fire safety issue is controlled under two separate legislations, namely the BO and the Fire Services Ordinance (FSO). The spatial design and fire resisting construction are prescribed under the BO, whereas the fire services installation (FSI) requirements are prescribed under the FSO. However, the approval of FSI at building design stage is also through the BO in that every building plan should be endorsed with a certificate issued under the FSO by the Director of Fire Services before it can be approved.

The prescriptive requirements of fire safety are given in the Code of Practice on: (a) means of escape (MoE, 1996), (b) fire resisting construction (FRC, 1996) and (c) means of access for fire fighting and rescue (MoA, 1995) issued by the Hong Kong Buildings Department as well as the code of practice on minimum FSI (FSI, 1998) issued by the Hong Kong Fire Services Department. The building designers should design the fire protection measures in buildings in accordance with the prescriptive codes. Alternative fire safety design is also explicitly permitted in the codes. Fire engineering approach is considered as the means to demonstrate that the fire safety design in buildings is satisfactory.

Figure 1: Building control mechanism in Hong Kong

The aforesaid building and fire codes and the practice note (PNAP:204, 1998) provide a preliminary framework of what should be considered in the fire safety engineering (FSE) study. Up to this point however, the Hong Kong Government has published neither guidance material to explain the rationale behind each prescriptive requirement nor an engineering guide to illustrate the acceptable evaluation methods. Apart from the guidance provided for facilitating the fire engineering specialists to carry out FSE design, it has been noted that the building project leaders, the AP, normally do not have sufficient knowledge or awareness on the use of FSE design. This may have a significant effect on the development of performance-based FSE approach in Hong Kong (Lo *et al.*, 2002). In the circumstances, the authors have established a system model (Forrester, 1990) to examine how the project coordinators' knowledge and awareness affect the volume of projects using FSE design. From a system point of view, we may consider the building control mechanism as a state of system which consists of a collection of time-dependent variables (Coyle, 1996). Accordingly, a system dynamics (SD) model has been established to explore the dynamic behaviour of the building control system.

AN SD-BASED SIMULATION MODEL

In the spectrum of system approaches, SD is a successful method to model the dynamics nature of a social system (Forrester, 1961, 1990). It has been widely applied in many fields such as political, economic, managerial and production systems, among others (Wolstenholme, 1990; Sushil, 1993; Andrew, 1999; Coyle, 2000).

To formulate an SD model, we have to establish a qualitative model based on an influence diagram (Wolstenholme, 1990), in which the components and their links in the system are identified. The diagram will contain circular chains of cause and effect relationship. The process, through which the initial cause goes through a chain of causal relations to an indirect effect on itself, is called 'feedback'. Feedback is *positive* if an increase in a variable, after a certain delay, leads to a further increase in the same variable. For a *negative* feedback loop, an increase in a variable leads to a decrease of the same variable.

The modelling process conducted in this research focuses on the major factors that affect the development of a performance-based FSE design approach. Figure 2 shows a simplified influence diagram of the system in Hong Kong's perspective.

Having established the qualitative SD model, we may transform it into a simulation model by quantifying the changes with logical functions. Simulations in quantitative SD may usually give more insights into the problems. In order to understand the dynamic behaviour of the building control system over time, we could establish a stock-flow diagram based on the influence diagram. The stock-flow diagram for the building control system is constructed in Figure 3. The free-version of Vensim-PLE software is employed to execute the SD simulation in this study. The Vensim modelling package was selected for this research because:

- it supports a compact, but informative, graphical notation;
- the Vensim equation notation, including logical functions, is compact and complete;
- Vensim provides powerful tools for quickly constructing and analysing process models;
- a version is available free for instructional use over the World Wide Web at Uniform Resource Locator <http://world.std.com/~vensim>. A quick reference and tutorial for Vensim can also be downloaded.

Figure 2: Influence diagram of building approval system in Hong Kong. (In the causal loop diagram (influence diagram), a plus sign indicates that the variables at the opposite ends of the arrow tend to increase in the same direction while a minus sign indicates an inverse relationship.)

Figure 3: Stock–flow diagram of building approval system in Hong Kong

There are three stock variables identified in the system, which are indicated by rectangles, that is, *No. of Building Applications on the Waiting List*, *FSE Design Applications submitted to FSC*, *No. of accepted FSE applications*. The building approval system begins with the new building design applications based on the demand for urbanisation. The stock *Number of Building Applications on the Waiting List* represents all the formal

building applications submitted to the Building Authority for approval, including design in accordance with prescriptive building codes and using a performance-based approach. The stock *FSE Design Applications submitted to FSC* describes the amount of building applications in FSE design which are forwarded to the Fire Safety Committee (FSC), which is established in the Building Authority for vetting FSE design proposals. It is replenished by the flow 'Rate of Using FSE approach' and depleted by the flow 'Admission Rate' and 'Revision Rate'. 'Rate of Using FSE approach' is determined by the number of building applications using an FSE approach per period of time (time interval). 'Admission Rate' and 'Revision Rate' correspond to the amount of building applications whose designs could be accepted and whose design needs to be modified. The stock records the total applications that are considered satisfactory by the Building Authority. The change in *No. of accepted FSE applications* is driven by the 'Admission Rate'.

SIMULATION EXPERIMENTS

In order to examine the effect of project coordinators' awareness on the use of FSE design, the established SD model is adopted to simulate the changes with respect to different awareness levels.

To perform the simulation for comparison purposes, we have to make a series of assumptions to fix certain variables constant. It is assumed that the Government investment on technological development will be constant, and the number of building applications will also be constant for each year. To view the effect of different awareness level of project coordinators, the relative percentage of applications submitted to FSC for consideration is plotted against time and is shown in Figure 5. It can be seen that the effect of project coordinators' awareness levels seems more or less the same except that at poor awareness level, the increase in volume of applications for FSE design will be deferred for a small period of time. At all levels, it can be seen that the volume of applications for FSE design rapidly increases after 2–3 years of the performance approach being permitted.

Figure 5 shows the number of cases referred to FSC for vetting in Hong Kong. The trend of increase in cases using FSE design is similar to that predicted by the SD model. A sudden drop in the year 2001 (ie 72 months after the implementation of the performance FSE design approach) has been recorded and this may be due to the fact that Hong Kong has suffered economic depression. The volume of construction projects decreased significantly in that year.

Figure 4: Number of cases referred to FSC predicted by SD model

Figure 5: Number of cases referred to FSC for vetting in Hong Kong (Figures recorded by the Hong Kong Building Authority)

Figure 6: Number of cases referred to FSC predicted by SD model (with fire safety design specialist at a higher knowledge level)

To further examine whether the effect of project coordinators' awareness will be influenced by the knowledge level of fire safety design specialists, simulations with higher specialists' knowledge level is also performed (Figure 6).

It shows that Figures 4 and 6 are similar. This implies that the knowledge level of fire safety specialists may not have a significant effect on the volume of projects using FSC design.

CONCLUDING REMARKS

SD modelling technique is proposed in this study to provide an insight into understanding the implementation mechanism of performance-based fire safety design in Hong Kong. It treats the approval system as a dynamics system and analyses the relative components simultaneously. The approach provides a framework for modelling the building control system and may provide some insights into understanding the system behaviour using

influence diagram and simulations. This paper outlines the model establishment and initial simulations have been performed. Some interesting results have been noted:

- (a) A rapid increase in volume of projects using FSE design may happen 2–3 years after the implementation of the performance approach. This trend is similar to the recorded figures in Hong Kong.
- (b) The project coordinators' awareness level may not have significant influence on the volume of FSE design. This may be due to the fact that the number of cases using FSE approach will depend on a number of factors, including the 'passing rate of the applications', 'awareness level of the building officials' and workload of the vetting committee'.

The information given in this paper demonstrates a possible way to examine the effect of a government policy. This study serves as an initial attempt to use a system model to examine the effect of a regulatory means of control. It may serve as a reference for decision-makers. However, future work is necessary.

- (a) The components and structure suggested in the aforesaid model have been simplified. Further refinement of the model is necessary in order to provide more solid reference for the decision makers. It may require further study on how to establish the logical functions for the quantification of the descriptive information.
- (b) From a holistic view, the SD model needs further refinement before it can be used to explore complicated and complex phenomena, such as feedback, delays and non-linearity.

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Notes

- 1 The Director of Buildings Department is nominated as the Building Authority under Hong Kong's Buildings Ordinance.
- 2 Building professionals such as architects, structural engineers and building-related surveyors have to be examined and enrolled in the Government's Authorised Persons Register before they can practice as AP.

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