BIM/CIM Implementation in the Thailand Private Sector: Extension to 6D Analysis – Safety Simulation of A Railway Station

Saratchai Ongprasert[1*], Rapee Parichatrkanont[2]
Advanced Technology Center, TEAM Consulting Engineering and Management Co.,Ltd., Bangkok 10230, Thailand

* Corresponding author e-mail: *aratchai_o@team.co.th*
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Abstract

This paper presents the BIM implementation practices of the private sector in the Thai construction industry. The investigations were based on observation, literature review, interviews, and actual practices of the AEC organizations in Thailand. The problems encountered and success factors of BIM implementation were discussed based on our experience in practice. Furthermore, a case study demonstrates application of BIM in safety aspects, which seamlessly works with design and construction phase.

Keywords: BIM, CIM, BIM implementation, change management, CFD, evacuation simulation

1. Introduction

In present, it is widely asserted that BIM (Building Information Modeling) or CIM (Construction Information Modeling) is one of the most advanced technologies in infrastructure system development, ranging from the feasibility study, design, construction, and operation phases. Yet, most of the AEC organizations in Thailand, including the private sector and the public sector, cannot successfully implement BIM in their practice. Several factors contribute to such challenges. Most of BIM process are utilized for inspection and reporting of inferences during construction period (clash detection). Nonetheless, a great deal of information in BIM models are not exploited for operation and management. This paper also demonstrates applications utilizing BIM model of a railway station for safety planning regarding fire accident, including (1) CFD (Computational Fluid Dynamics), performing smoke spread simulation and (2) evacuation simulation.

2. BIM situation in Thailand

Despite various benefits of BIM, including clash-free design and accurate bill of quantities, the adverse consequences resulting from BIM implementation often repel its users. With significant financial and human resource investment, it is widely acknowledged that the returns for BIM implementation could not be assured in early years. Besides, conventional technologies, including CAD (Computer Aided Design), seem to meet the requirements of building and infrastructure project development. Furthermore, CAD is a prominent tool of most stakeholders, including designers, developers, consultants, and general contractors. All these reasons are major obstruction of BIM implementation.

BIM is impressively adoptable technology for all levels of modern construction projects. In Thailand, the Association of Siamese Architects (ASA) has drafted a BIM standard and guideline in Thai language since 2015. A number of BIM software distributors in Thailand have also arranged conferences to promote BIM software and its benefits in all levels of the construction industry. According to Jirajaroen (2017), 100% of samples in the Thai construction industry were willing to recruit newly graduated individuals who were able to use BIM. Furthermore, 98.3% of undergraduate students positively intended to acquire BIM skills. However, only few AEC organizations can successfully implement BIM in practice.

Kamolwatcharachai (2017) interviewed six leading AEC firms in Thiland, which successfully implemented BIM in their construction projects. The results clearly showed that all firms had one common factor, which is the tangible objectives of BIM implementation. In addition, the availability of in-house BIM experts or BIM users at the early stage can definitely reduce the complications of BIM implementation.

3. Global BIM situation

According to a number of international surveys, countless measures have been implemented in order to overcome challenging issues of BIM implementation. First, some organizations offered rewards to their staff members. This would accelerate the change from conventional methods to BIM processes. In addition, newly recruited staff members are educated about BIM, so they are ready to work with it. In some organizations, a pilot project is selected, in which both conventional and BIM-based practices were implemented and compared.

According to Yajima, man-power costs had significantly decreased after 2 years of BIM implementation. Prior to implementing BIM, 2D drawings had been regularly utilized for generating construction drawings, as shown in Figure 1. As can be seen, the manpower costs for the pilot projects in the first half of year 2012 were 200% because both 2D drawings and BIM processes had been operated in parallel. Precisely, the conventional method (2D drawings) had been utilized for actual projects, whereas BIM processes had been utilized as for data backup and the firm's learning and business growth. In the second half of year 2012, the project costs were reduced to 140% as the costs of the BIM part were reduced by 40% and it could reduce the cost of the conventional part by 20%. In 2013 and 2014, the costs had notably decreased to 90% and 50%, respectively, owing to knowledge management and human resources development.

4. Case studies

TEAM Group has been implementing BIM in our construction projects for more than four years. Our team, which consists of more than 30 BIM operators, have been involved with 30 BIM projects, including mega projects of infrastructure such as subways and hydro-power projects. Based on our extensive experience, the key success factors for the BIM projects can be summarized as follows.

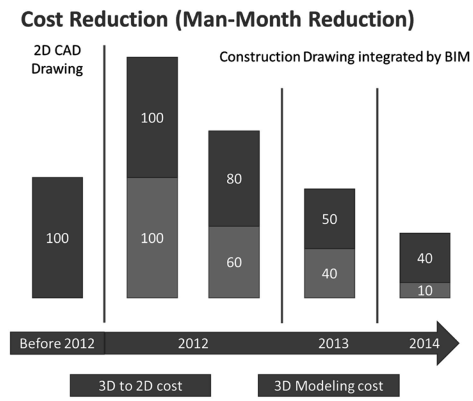


Figure 1. Development of cost reduction: a case study of a general contractor (Yajima)

4.1 New section and new staff members

Forcing current staff members to implement BIM is indeed challenging. Evidently, senior staff members do not voluntarily shift from their comfort zone, 2D CAD, and start learning about BIM. At the beginning of this implementation, senior staff members were educated and trained to use BIM, but it was not successful. A different option was adopted; that is, a number of newly graduated individuals were recruited. Their job description was solely BIM works. Those who did not know how to use BIM had been intensively trained, including a series of workshops and professional seminars. In addition, the BIM department has been established and is responsible for all BIM projects of the firm. All BIM users and experts belong to this department and staffs of the department are not allowed to handle 2D-CAD projects.

4.2 Educate senior staff members

Nevertheless, senior staff members, such as project managers, could not adapt to utilizing BIM tools for creating 3D models by themselves. BIM managerial concepts are indeed crucial, and must be forwarded to project managers, who are subsequently responsible for orchestrating their teams to implement the BIM concept.

4.3 Transfer staff to other departments

After the staff members in the BIM Department (e.g., architects and engineers) had been operating BIM projects for a year, they were transferred to other departments to strengthen the BIM workmanship of the departments and ultimately the firm.

4.4 Rewards

Owing to challenges of the transition from conventional 2D CAD to BIM workflow, additional payments have been awarded to individuals utilizing BIM. As a result, this issue could persuade individuals to experience BIM tools. Indeed, the firm also acquires value added from staffs' achievement so this issue is non-zero-sum game.

4.5 Recognize your investment

To implement BIM, computer software and hardware need to be upgraded. Apparently, they are more costly than conventional tools. Additionally, non- or low-productive work time commonly exists owing to a gradual learning curve at the beginning. Definitely, this investment budget is mandatory and must be well recognized.

4.6 Convince your clients

In some cases, key staff members are not convinced to implement BIM in projects. Time and again, individuals could find an excuse for not implementing BIM. The BIM requirement by clients seems to be the most effective motive. It is even more effective than the executive's orders.

4.7 Synergize with other strengths

In general, AEC firms adopt other advanced technologies, which can be integrated with BIM. For TEAM Group, water flow analysis, topographic survey, and traffic simulation were synergized with BIM. Since BIM software allows exporting 3D models to other different analysis software, we do not need to recreating the 3D models in other software. As a result, manpower can significantly be reduced.

Clearly, this advantage can persuade operational staff members to implement BIM. Some examples of our integration between BIM and other expertise are summarized as follows.

4.7.1 Topographic Survey

Recently, drone technologies have been introduced for topographic survey. These technologies can conform very well with the BIM design process because they provide a large number of data (big data), which are also in the form of 3D information. The drone-based survey could considerably reduce workforces, as compared with the conventional topographic survey. Figure 2 shows an example of drone- based survey results.

Figure 2. Integration between a drone-based survey and BIM

4.7.2 Structural Analysis

Modern structural analysis software allows users to import and export models to BIM software so individuals can effortlessly design and analyze structural works. Moreover, the revision in one software could be synchronized to the others. Figure 3 shows an example of integrating structural analysis with BIM.

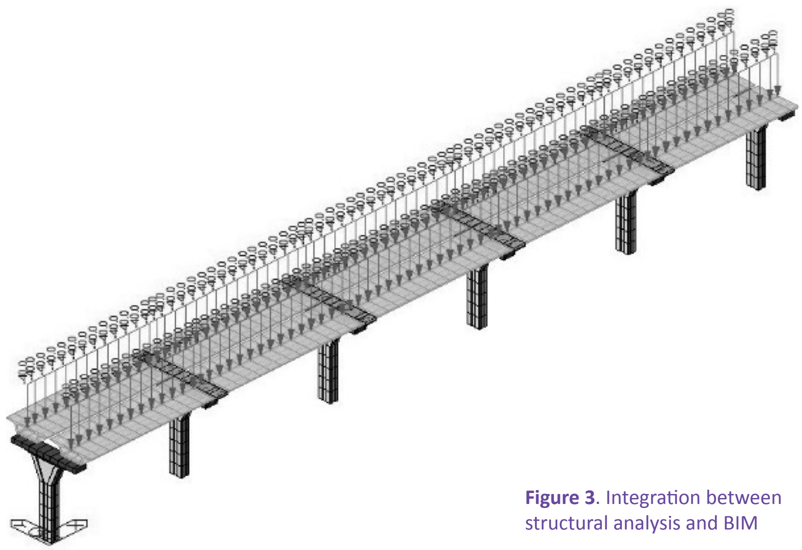


Figure 3. Integration between structural analysis and BIM

4.7.3 Water Flow Simulation

In hydro-power projects, dams can be designed by the assistance of BIM. The analysis of water flow speed is conducted to verify the life time of the dam. Figure 4 shows an example of water flow analysis by BIM.

4.7.4 Traffic and Pedestrian Simulation

The BIM models of buildings or infrastructure projects can be directly imported to traffic and pedestrian simulation software so the level of service for traffic (e.g., vehicles on the road) or pedestrians can be evaluated. Furthermore, the evacuation simulation in buildings can also be examined, as shown in Figure 5.

4.7.5 Presentation

Enhanced presentation software allows individuals to render BIM models to be more appealing. In addition, impressive animation could also be readily developed.

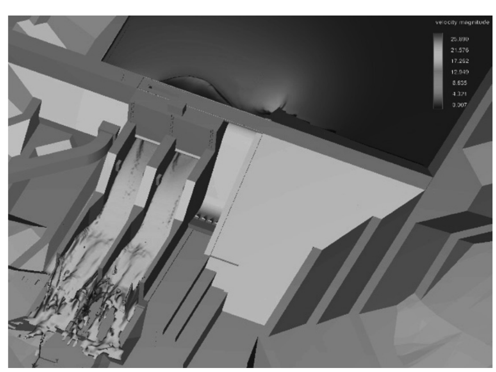


Figure 4. Integration between water flow analysis and BIM

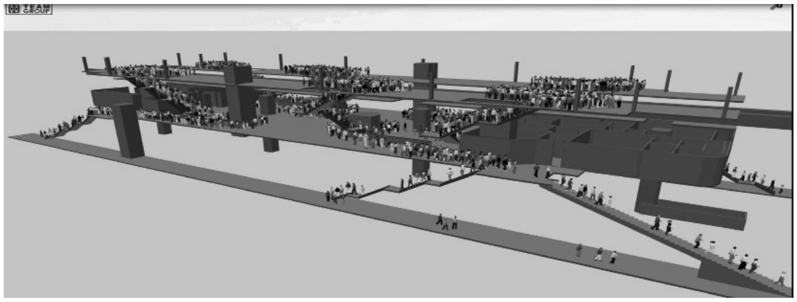


Figure 5. Integration between evacuation simulation and BIM

4.8 Advantages and Disadvantages of the Case Study

In general, utilizing BIM concept with the existing projects could develop better performance. In addition, the organization could also explore new opportunities in related business with existing and new potential clients. However, there are some challenges including initial investment cost - including software, hardware and human resource – and resistance of existing staffs. These issues must be managed properly, which are discussed in the next topic.

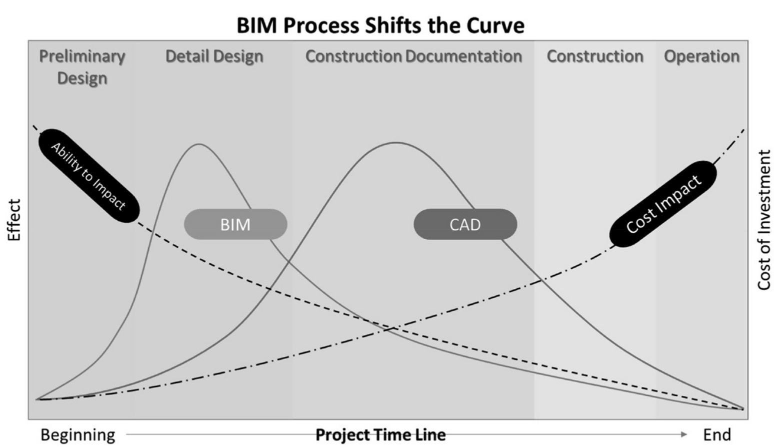


Figure 6. Comparison of cost and effect of BIM process to the conventional method (Fridrich)

5. Challenges of BIM Implementation

Although BIM can tremendously benefit every project stakeholder, a number of obstacles for implementing it should be recognized.

5.1 Price Competition

Price is one of the imperative factors in the Thai design industry. According to Figure 2, the manpower costs of BIM pilot projects are significantly more than those of the conventional method. Thus, in terms of price, project design by BIM is less attractive than the conventional process, except that BIM is demanded by the project owner.

5.2 Design-Bid-Build Contract

In Thailand, design-bid-build contracts are commonly prevalent, especially for public construction projects. In general, the design phase of BIM projects requires higher human resources than the conventional method does. Yet, BIM can significantly reduce waste in the construction phase. Thus, the design-build delivery method seems to be more conforming with BIM than the design-bid-build does because the cost savings in the construction phase can compensate the extra costs during the design phase, as shown in Figure 6.

5.3 Conventional Work Process

Implementing BIM in construction projects requires changing not only computer software but also work processes and the organization culture. However, most of the Thai AEC organizations have solely focused on changing their computer software. As a result, they have assigned draftsmen, rather than engineers or architects, to operate BIM software for creating BIM models. Consequently, they could not enjoy the benefits of several useful BIM uses, including scheduling and budget analysis.

6. A Case Study of Safety Simulation of a Railway Station

Railway station models are created by Revit 2019, including architectural works, structural works and MEP works in detailed design stage. The objectives of the Revit models include (1) clash detection (2) material takeoff, which the model could perform effectively. Then, the models are exported to IFC (Industry Foundation Classes) files. After that, the IFC files are imported to CFD simulation software and evacuation software.

6.1 CFD Simulation

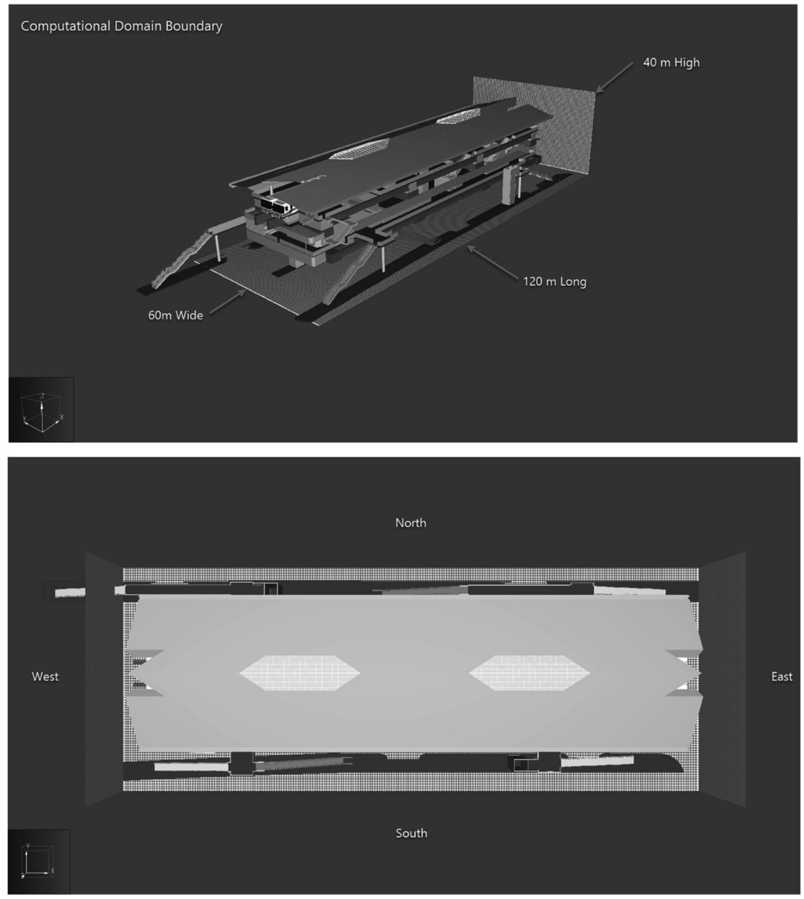
This part has been created to demonstrate compliance with clauses 5.3.3.1 and 5.3.3.2 of NFPA 130 which relate to station evacuation. Computational Fluid Dynamics (CFD) simulations of smoke spread and fire evacuation on a station were performed based on worst case scenarios: Combustion on the Concourse and Platform Level.

6.1.1 Methodology and Input

Numerical simulations of smoke spread and fire evacuation on the Pink Line Station were performed via a Computational Fluid Dynamics (CFD) fire model: PyroSim 2018. PyroSim 2018 was developed by Thunderhead Engineering, USA.

PyroSim 2018 is a computational fluid dynamics fire model designed to simulate fire and passenger evacuation in buildings and large structures. The program uses Large Eddy Simulation (LES) to simulation turbulence and mixture fraction model to simulation combustion.

From the station CAD drawings, a 3D Station Model for PyroSim 2018 was created as shown in Figure 7. A computational domain was 120 m long, 60 m wide and 40 m high to cover the station building. Based on a grid refinement study and numerical stability analysis, a mesh size of 0.5 m x 0.5 m x 0.5 m resulting in a total grid cell of 2.304x106 grid cells was employed in all calculations.



Station Plan View

Figure 7. A 3D Station Model created by PyroSim 2018

The sides and top boundary conditions were set as open to the surroundings. All the simulations were performed with the initial ambient temperature of 40°C (See figure 7). 3 Scenarios were conducted as follows (figure 8):

- Case 1 - Fire in Electrical Equipment Room at Concourse size 0.5 MW (TSS or AARU). The simulation was carried out for the AARU Room located on the concourse level (a fire located on the North-West).
- Case 2 - Fire in the wheel wells of the second car. The energy release rate of fire is shown in figure 3.The total area of the wheel wells are 2 m2.
- Case 3 - This case is similar to Case 2. Plus, the wind 7 m/s is added to the simulation.

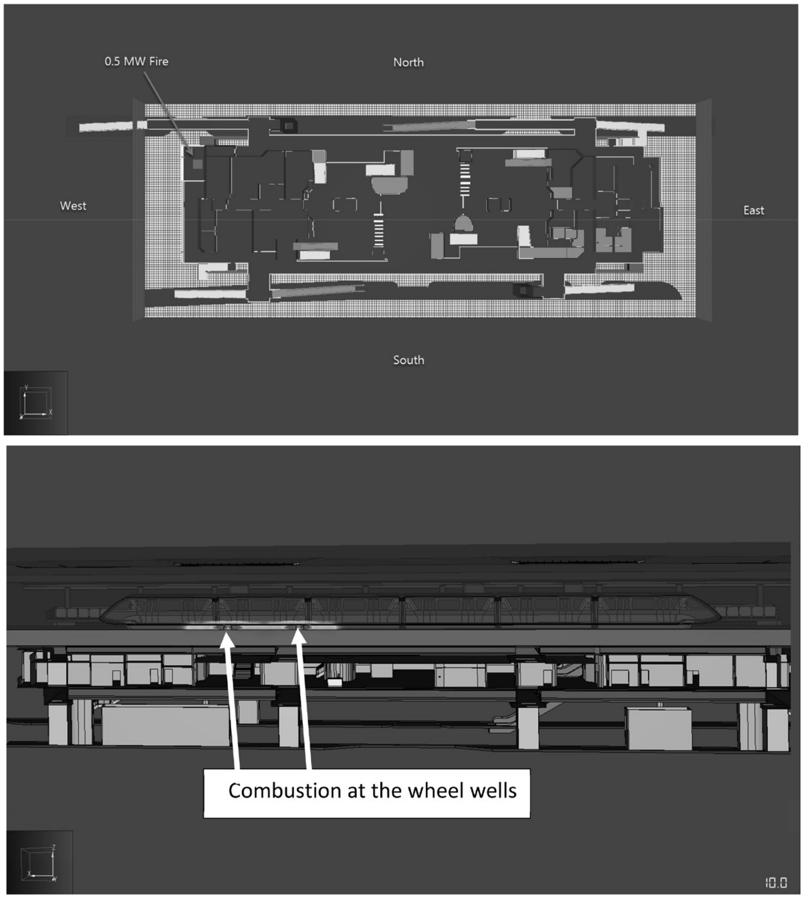


Figure 8. (Upper Figure) Fire Location for Case 1 - AARU Room on the Concourse Level and (Lower Figure) Case 2&3 - Fire at the Wheel Wells of the second car on the Platform Level.

Table 1. Gas temperature with the maximum exposure time

Exposure Temperature (°c)	Without Incapacitation (minutes)
80	3.8
75	4.7
70	6
65	7.7
60	10.1
55	13.6
50	18.8
45	26.9
40	40.2

6.1.2 Requirement of NFPA 130

Tenable Environments: NFPA 130 clause 3.3.48 defines tenable environment as an environment that permits the self-rescue of occupants for a specific period of time as follows:

Gas Temperature: In elevated temperature environment, the maximum exposure time without incapacitation is show in table 1.

CO Concentration: The maximum carbon monoxide (CO) content is as follows:

1. Maximum of 2,000 ppm for few seconds
2. Averaging 1,150 ppm or less for the first 6 minutes of the exposure.
3. Averaging 450 ppm or less for the first 15 minutes of the exposure.
4. Averaging 225 ppm or less for the first 30 minutes of the exposure.
5. Averaging 50 ppm or less for the remainder of the exposure.

Smoke Obscuration Levels (Visibility): Smoke obscuration levels should be continuously maintained bellow the point at which a sign internally illuminated at 80 lx is at 30 m and doors and walls are discernible at 10 m.

6.1.3 Simulation Outputs

The simulation results show that the environment inside the station conform the requirement of NFPA 130 in gas temperature, visibility and toxic gas aspects.

6.2 Evacuation Simulation

The objective of this part is to perform safety analysis on a station based on the PTV Viswalk simulation result. The analysis of the station evacuation is based on NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems : Edition 2014 [1]. NFPA 130 requires two evacuation time calculations to be performed, as required by clauses 5.3.3.1 and 5.3.3.2.

6.2.2 Station Layout

The Station is a 3-story station with its first floor based on road level. The second floor is the Concourse level, and third floor the Platform level. The first floor is connected to the Concourse level by 4 staircases and 2 escalators. Similarly, the Concourse level is connected to the Platform level by 6 staircases and 2 escalators.

The rail track separates the Platform area into two minor platforms, one for each direction. Each side contains 3 staircases and 1 escalator respectively. The Concourse level has an open layout with staircases and escalators evenly distributed in similarity to the Platform level. A station overview as well as the location of staircases and escalators are shown in Figure 9, Figure 10 and Figure 11.

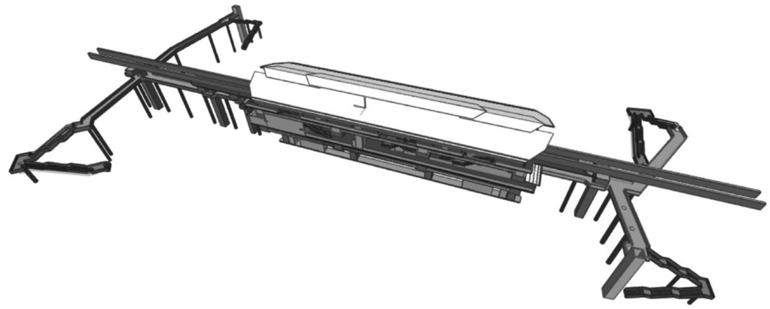


Figure 9. Station Overview

Figure 10. Platform Level

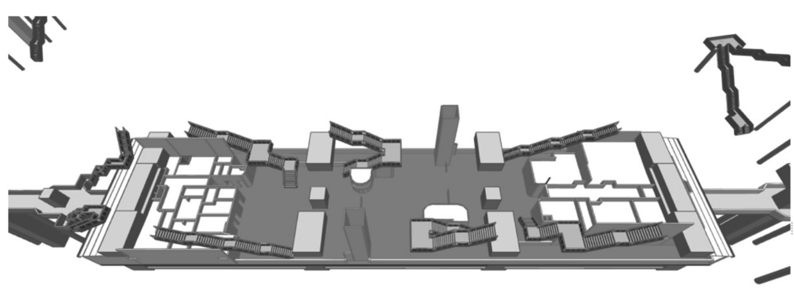


Figure 11. Concourse Level

6.2.3 Input and Methodology

The passenger load used in the simulation is based on the ridership, approximately 2,000. It was assumed that the passengers were uniformly distributed over the Platform area. Initially there are no passengers on the Concourse level of the station.

- A Point of Safety

This station can be considered as an open station per NFPA 130 clause 3.3.44.2. As permitted by NFPA 130 clause 5.3.3.3 for an above ground station, the Concourse level below from the platforms is considered a point of safety. NFPA 130 clause 3.3.35 also stated that an enclosed fire exit stair that leads to a public way can be defined as a point of safety. Therefore, the concourse of the station is also considered as points of safety.

- Out of Service Escalator

According to NFPA 130 clause 5.3.5.6 (1), one escalator at each level shall be considered as being out of service. However, during this simulation, all escalators present at the station, including Lower Platform, Concourse level and Upper Platform, were considered as being out of service.

6.2.4 Simulation Tool and Model Calibration

PTV Viswalk is utilized for simulations of this study. Before conducting the simulations, the models were calibrated with NFPA 130 standard confirming the results do not exceed maximum speed and capacity of NFPA 130. Table 2 shows that speed and flow of the simulation models are not higher than NFPA 130 maximum flow and speed.

Table 2. Comparing NFPA 130 Standard with the Simulation Results

	NFPA 130		Simulation	
Capacity	Maximum Flow (person/min)	Maximum Speed (m/min)	Avg. Flow (person/min)	Avg. Speed (m/min)
Platform		37.7		27.6
Stair (0.0555 p/mm.-min)	2.55m = 140 1.50m = 92	14.6 14.6	2.55m = 120 1.50m = 92	14.6 14.6
Concourse		61		49.2
Fare Gate	50		33	

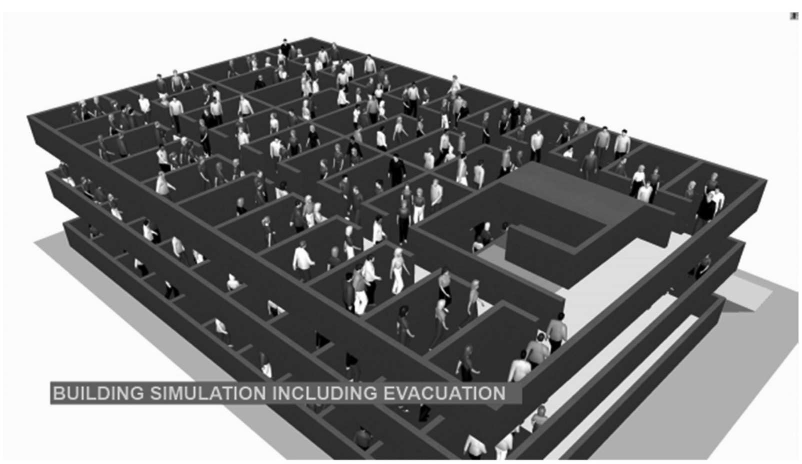


Figure 12. Example of PTV Viswalk

6.2.5 Simulation Software

PTV Viswalk enables to simulate and model the human walking behavior. Planners use this powerful software tool whenever pedestrian flows need to be simulated and analyzed - be it in and outside the building. (Figure 12)

PTV Viswalk is the ideal solution for all those who take the needs of pedestrians into account in their projects or studies, such as transportation planners and consultants, architects and operators of large buildings and large public spaces, event managers or fire protection engineers. PTV Viswalk has been widely utilized worldwide for the following cases :

• Pedestrian safety is of paramount concern, in particular in public places.

• Evaluate numerous structural and organisational measures aimed to reduce and control unmanageable behaviour of people in emergency situations.

• Analyse potential danger and plan pedestrian flows in buildings, stadiums and other facilities.

• Simulate escape routes and evacuation scenarios in highrise buildings and tunnels Evacuation analysis.

The movement is modelled by forces by no means implies that pedestrians are considered and treated like particles. By the specific form of the forces it is tried to model specifically human effects.

That forces, and by that in fact accelerations, and by hat in fact speed changes in a given time (simulation time step) are computed in first instance makes the Social Force Model similar to the Wiedeman model of road traffic which in Vissim describes the dynamics of cars, HGV, cyclists and PT vehicles. For the Wiedemann model one does not speak of forces. However, it is as well speed changes which are computed in first instance. Hence, it could be acknowledged that PTV Viswalk is also multi-direction simulation, both 2D and 3D, software. (Figure 13, Figure 14 and Figure 15)

6.2.6 Simulation Outputs

- Time for Clearing Platforms and Fare Gates

PTV Viswalk simulates each passenger's evacuation behavior independently, where each passenger has its own personal properties and escape strategies. The movement of the passengers is simulated using 3-dimensional planes representing the platform floors. The output parameters considered are passenger evacuation path, passenger movement speed, platform evacuation time, and station evacuation time. The platform evacuation time is defined as the time when all passengers left the platform area for that particular level. This refers to clause 5.3.3.1 of NFPA 130. The station evacuation time is defined as the time when all passengers reach a point of safety as defined by clause 5.3.3.2 of NFPA 130. As discussed earlier, the concourse level for an open station can be defined as a point of safety, and hence, the station evacuation time in this study equals the time when all passengers have left the Platform to reach the Concourse level. By the way, in this report, the time to clear fare gates are recorded as a representative of the time to reach a point of safety. The simulation results show that this station passes all requirements of NFPA 130. (Figure 16 and Figure 17)

- Traffic Flow at Unpaid Area

After leaving from the fare gates, passengers can go through unpaid area on concourse level. Moreover, passengers can access to staircases to the ground level without obstruction as in Figure 18.

6.3 Discussion of Pros and Cons

This case study demonstrates extensively beneficial issues of the simulation. First of all, the results and the model could be reviewed by all disciplines, who could observe and confirm the same information and model, because it contains all aspects of information including, architectural, structural, electrical, transportation, safety and mechanical. Plus, all details are considered in the analysis, including the

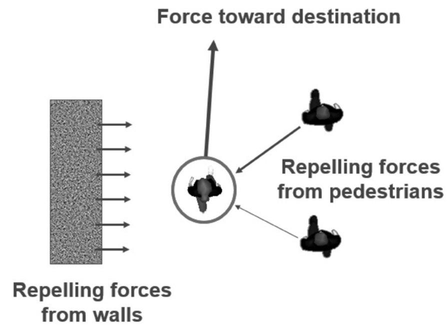


Figure 13. Social Forces in Simulation Software

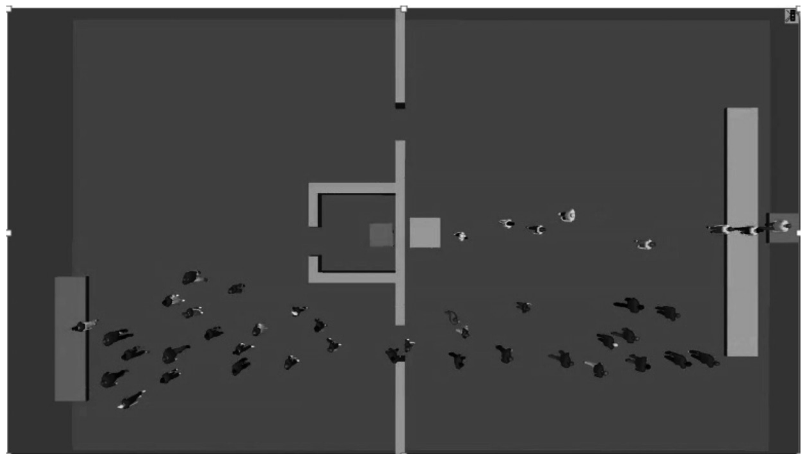


Figure 14. Example of Walking Through Doors in Simulation Software

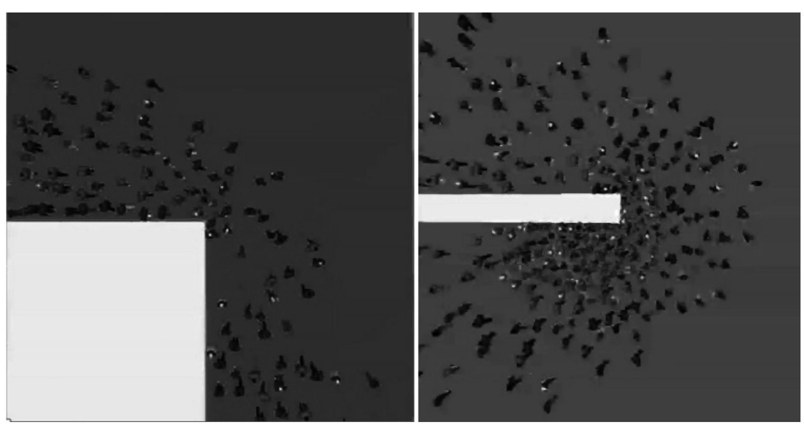


Figure 15. Example of People Walk Around a Corner and a U-turn.

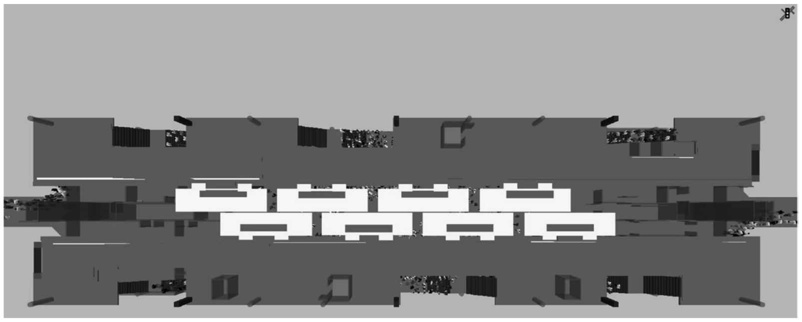


Figure 16. Clear Platform Clearing

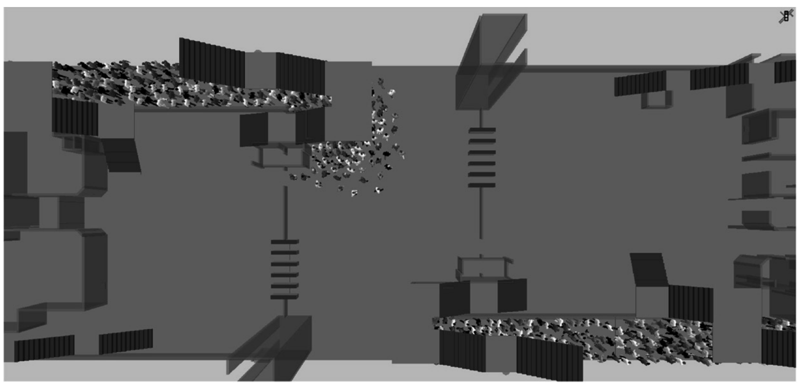


Figure 17. Fare Gate Clearing

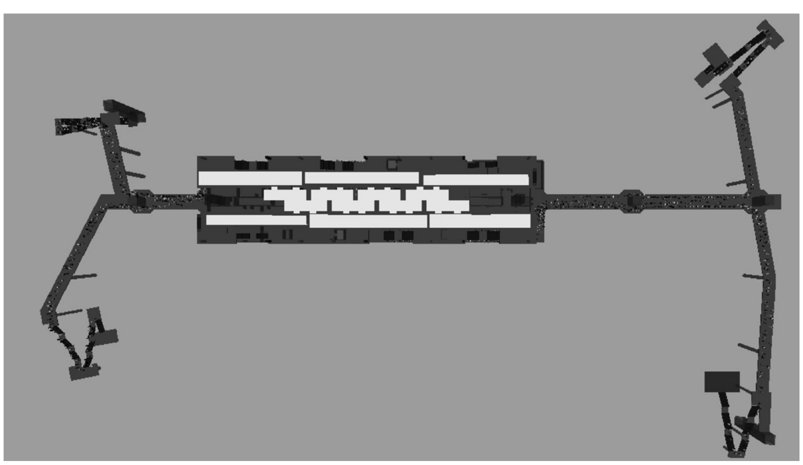


Figure 18. Evacuation Simulation from The Platform to The Ground Level

bottlenecks, the shape of the staircases, and the façade which may block the flow of the smoke. However, there are some small disadvantages because highly skilled of modeling human resource is required.

7. Conclusion

Even though the benefits of BIM have been widely accepted in the AEC business of Thailand for several years, BIM implementation is a challenging task for every project stakeholder. This stems from such factors as human resource and finance. This paper offers some measures from oversees firms that can be applied to the Thai construction industry. Furthermore, it also provides additional measures that we learned from implementing BIM in several infrastructure projects. In this study case, applications of BIM could be utilized from conceptual design, detailed design, and construction to operation phase. This paper shows that BIM models used in design phase could be transferred to analysis phase, and could be exploited in safety simulations on the same models. Therefore, this process could eliminate errors from using different information with less rework.

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