# Emergency Evacuation Simulation for Radiological Emergency; A Case Study of Gijang

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## 1. Introduction

Kori Nuclear Site at Gijang currently operates 6 nuclear plants and is building the third and fourth New-Kori plants. In addition, Nuclear Medical & Science Complex and new research reactors are being built at Gijang. The recent nuclear reactor accident at Fukushima caused the residents at Gijang to be concerned about the safety of their local nuclear plants.

The nuclear reactor-related accidents is very rare but may cause the serious consequences and last for significant period. Especially, Gijang is located next to Busan, at which most population is concentrated. Hence, the effective and efficient emergency evacuation plan cannot be overemphasized in addition to well-designed nuclear disaster prevention measures.

The central government has studied the safety issues of nuclear plants and developed the prevention systems. However, the local government also needs their emergency evacuation plan for its residents, considering its geographical and local factors such as various modes of transportations, transportation and shelters systems.

## 2. Backgrounds

Nuclear power plant are designed and built to withstand safely against various natural and other severe events and staffed by highly trained operators. An emergency plan must specify response capabilities and preplanned strategies that would be used in the event of a severe accident. An effective emergency response is the result of mutually supportive planning and preparedness among several entities: local and central agencies; and private and nonprofit groups that provide emergency services.

The U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency jointly concluded that the most significant impacts of a nuclear energy facility accident would be experienced in the immediate vicinity.

At greater distance from the facility—beyond a 10-mile radius—the principal health concern in the event of an accident would be consumption of contaminated water, milk or food. They recommended two planning zones; (1) a 10 mile emergency planning zone (EPZ) to protect communities near the facility from radiation exposure in the event of an accident and (2) a 50 mile zone within which food products, livestock and water would be monitored to protect the public from radiological exposure through consumption of contaminated foods. [1] Within the 10-mile EPZ, the immediate protective actions for the public would include instruction for sheltering in place and evacuation. This study has focused on this emergency planning of sheltering and evacuation in Gijang area.

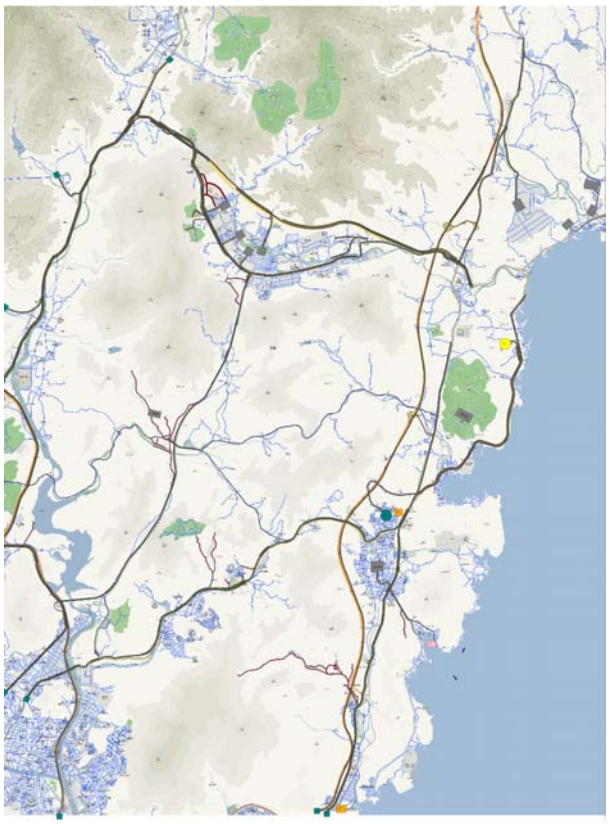

Fig. 1. Aerial map of Gijang area and the transportation systems in Anylogic Simulation Software

As part of emergency preparedness for nuclear power plant, Gijang government developed a plan and procedures for disastrous events, but their effectiveness have not been proved and the quantitative validation has not been done before. Hence, Gijang governments and people at Institute of Nuclear Safety and Protection, Pusan National University worked together to develop the simulation tools which can be used to validate the potential emergency evacuation alternatives. Simulation

tools are especially useful for these types of situations, where the real experiments or observations are virtually impossible to conduct. It is expected to be useful to develop detailed evacuation plans for the populations within Gijang areas. Fig. 1 shows the aerial map of Gijang area and its transportation system.

### 3. Evacuation Simulation

The emergency evacuation plans typically include several scenarios to reflect such variables as time of day, season, weather conditions and population group (general, transient and special facilities, such as schools and hospitals). The Gijang area is subdivided into emergency response planning areas, and population estimates are provided for each area. These plans and evacuation time estimates are updated periodically to reflect population shifts and changes in the transportation network.
Should officials decide to evacuate some areas near the facility, they will map the evacuation areas based on weather conditions and wind direction. In general, evacuation does not always call for completely emptying areas around a nuclear power plant. In most cases, the release of radioactive material from a plant during a major incident would move with the wind, not in all directions surrounding the plant. The release also would become less concentrated as it travels away from a plant. Therefore, the developed simulation tool can be used to verify and compare the evacuation effectiveness and efficiency for transportation strategic decisions in order to deal with various weather conditions and wind directions.

Fig. 2. A 3D screenshot of an emergency evacuation simulation scenario at the south of Gijang town hall.

The developed simulation tool considers protective actions for a radiological emergency, including evacuation and sheltering together. Under most conditions, evacuation may be preferred to remove the public from further exposure to radioactive material. However, under some conditions, people may be instructed to take shelter in their homes, schools, or office buildings. Depending on the type of structure, sheltering can significantly reduce a person's dose compared to remaining outside. Sheltering is a protective action that keeps people indoors, such as at home, the office, school, or a shopping mall to reduce exposure to radioactive material. It may be appropriate to shelter when the release of radioactive material is known to be short-term or controlled by the nuclear power plant operator [1].
In case of evacuations, various transportation strategies can be employed, including disabling the traffic signals, blocking the roads, keeping one-way traffics and reserving the lane for emergency vehicles. All these strategies has been used to generate various evacuation alternatives [2, 3, 4]. Those generated alternatives has been tested and compared in the developed simulation systems.

### 4. Simulation Results

To develop the customized simulation tool for emergency evacuation plans at Gijang area, various simulation software tools have been compared and tested; comparison results are omitted for brevity. The general-purpose discrete-event simulation tools are short of capabilities to satisfy all requirements which are defined at the initial analysis and user interviews with staffs at Gijang government. An agent-based simulation tool, Anylogic® has been adopted to conduct 2D and 3D visualization as well as the simulation statistical analysis. The developed simulation tool can be deployed as a form of Java applets which also can be configured by changing various probability distribution parameters.
The 3D snapshot and the statistical result of the best evacuation plan among many generated alternatives has been given in Fig. 2 and 3, respectively.

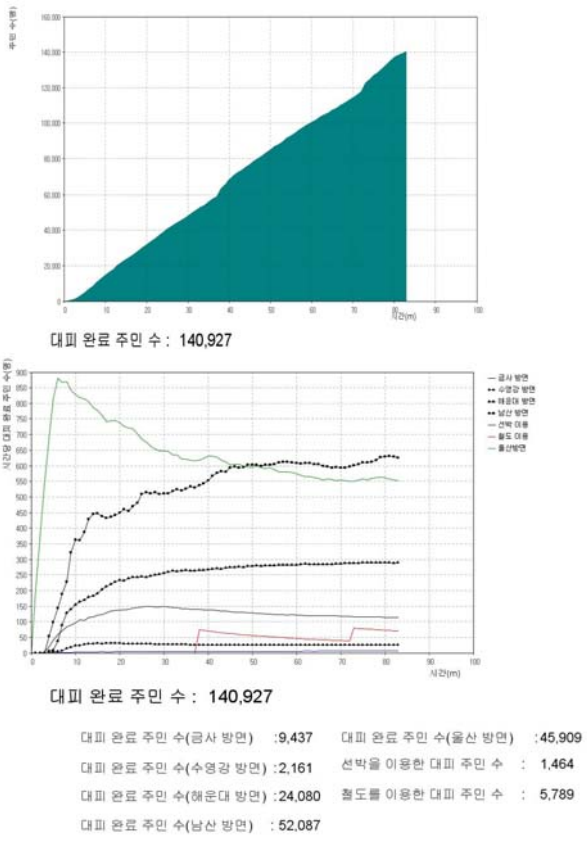

Fig. 3 shows the number of residents who escaped out of the Gijang area and their routes. The developed simulation results also provide the number of vehicles and different transportation modes as well. Currently, the railways and boats are also included in the developed simulation.

## 3. Conclusions

The disasters related to nuclear power plants is rare but their influence is considerable. Therefore, while maintaining the safe facilities, the disaster preparedness cannot be overemphasized. An agent-based emergency evacuation simulation tool has been developed and tested for Gijang area. The developed simulation tool has been verified as a useful one to prepare an effective and efficient emergency evacuation plans against various weather conditions and wind directions.

## REFERENCES

[1] U.S. Nuclear Regulatory Commission, Backgrounder on Emergency Preparedness at Nuclear Power Plants, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/emerg-plan-prep-nuc-power-bg.html
[2] M. Pidd, F.N. de Silva, R.W. Eglese, A Simulation Model for Emergency Evacuation, European Journal of Operations Research, Vol. 90, No. 3, pp. 413-419, 1996
[3] G. Santos and B.E. Aguirre, A Critical Review of Emergency Evacuation Simulation Models, University of Delaware Disaster Research Center, Prem. Paper #339, 2004
[4] M. Jha, K. Moore, B. Pashaie, Emergency Evacuation Planning with Microscopic Traffic Simulation, Transportation Research Record: Journal of the Transportation Research Board, Vol. 1886, pp. 40-48, 2007