Energy Conservation System for Distribution Outlets

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The amount of energy consumed by the distribution industry is increasing each year, due to the expansion in the industry's floor area. It is therefore considered that a need exists to reduce the load on the environment arising from such business activities[1]. The "Law Concerning the Rational Use of Energy" (Energy Conservation Law), as amended in 2008, obligated business and franchise operators engaged in convenience store and quick service restaurants, on a scale that exceeds a certain level, to submit reports on the energy consumption of their businesses.

Management methods for energy consumption by business operators are therefore becoming an issue for the retail industry, as well as energy conservation strategies at individual outlets. In order to resolve such issues OKI developed an "Energy Conservation System for Distribution Outlets" comprised of "Energy Conservation Controller" for controlling energy for the purpose of conservation at distribution outlets utilizing the "Context Awareness Technology" and the "Energy Management Service" to manage the energy consumption throughout the network of outlets using group management.

Field tests were conducted at actual retail outlets in collaboration with distribution outlet business operators in order to verify the energy conservation effects of this system.

It was possible to reduce the electric power consumption of individual retail outlets by over 5 % regardless of the scale of the distribution outlets. This paper provides outlined descriptions of the "Energy Conservation System for Distribution Outlets".

Background of research and development

The Japanese Government promised a 6 % reduction in greenhouse gasses by 2012 in keeping with the Kyoto Protocol. Preparations have been made in order to achieve the aforementioned reduction target in the legal arena, through such efforts as an amendment to the Energy Conservation Law.

The amended[2] Energy Conservation Law will be put into effect starting April 2010. This law requires action, such as the submission of energy consumption reports on the part of individual industries, with obligations imposed on business operators and franchise operators engaged in convenience store and dining businesses on a scale that exceeds a certain level, in order to manage energy consumption for the entire business.

A representative example of the distribution industry is the convenience store industry. Convenience stores are currently operating at approximately 42,000 locations nationwide in Japan, with approximately 115.5 billion Japanese yen (**Note 1**) spent on the consumption of electric power. In order to reduce costs and abide by the actions proposed by the Government, convenience store business operators are proactively implementing energy conservation strategies. Such efforts however have been primarily to improve individual facilities and the total management of all outlets for the purpose of energy conservation has thus far not been attempted. In fact many have not established appropriate conditions, such as proper temperature settings at locations where facility equipment is installed in the outlets subject to management. The current situation demonstrates that

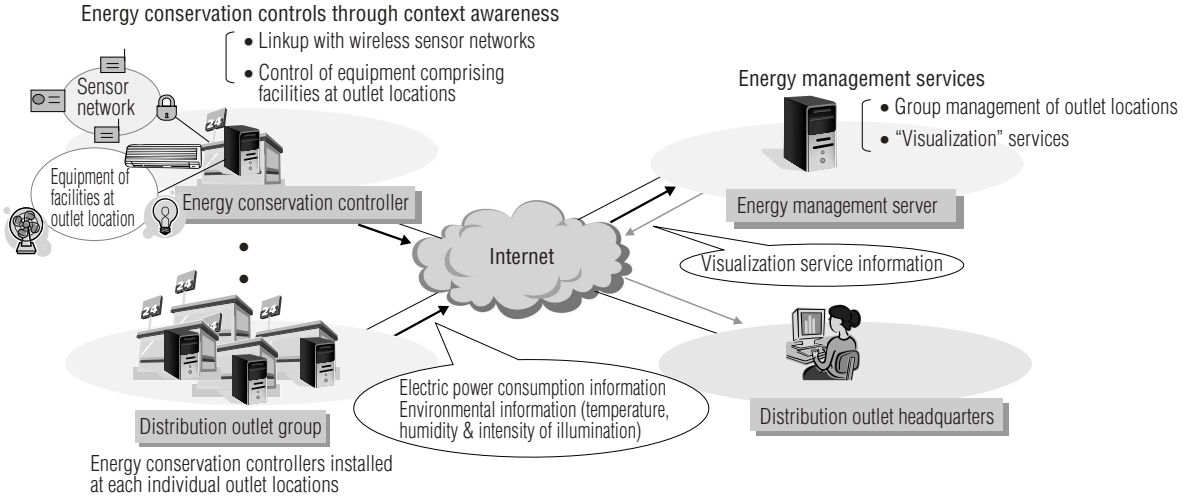

Fig. 1 Configuration of energy conservation system for distribution outlets

human error and other factors cause waste due to excessive warming or cooling. In the distribution outlet industry in particular, which includes convenience stores and often involves the establishment of numerous outlets, the ability to comprehend the energy consumption status is lacking at individual outlets.

The methods used for managing energy consumption by business operators is becoming a major issue for the distribution industry, along with energy conservation strategies for implementation at individual outlets.

It is against such a background that OKI developed the "Energy Conservation Controller" for realizing energy conservation at individual outlets and the "Energy Management Service", which offers energy management services for distribution outlet networks.

Note 1: Based on the document, "Energy Conservation Measures for Convenience Stores", prepared in March 2007 by the Planning and Coordination Division of the Bureau of Environment of the Tokyo Metropolitan Government:
- The average annual electric power consumption at a convenience store is 173,000 kWh per year (based on convenience stores in the Metropolis of Tokyo)
- The number of convenience stores nationwide in FY2007 was 42,000, according to the figures announced by the Japan Franchise Association
- The nationwide average electricity charges of "1kWh=JPY15.9" (for lighting and electric power) have been taken from the "Electricity Charge Transitions" provided in web pages covering electric power business reforms on the website of the Ministry of Economy, Trade and Industry.

The above values were used for the calculation.

Configuration of energy conservation system for distribution outlets

An "Energy Conservation System" (**Fig. 1**) is installed at each distribution outlet and is comprised of an "Energy Conservation Controller" and an "Energy Management Service", which realizes energy conservation at individual outlets, with energy conservation controls for each individual distribution outlet and energy management services for the entire distribution outlet network.

The "Energy Conservation Controller" installed at a distribution outlet conserves electric power at the location through a connection of the wireless sensor network that collects information on the electric power consumption and the environment, to the control network for controlling the equipment of the facilities at the location and controls the energy consumed.

The "Energy Management Service" collects information on the consumption of electric power and the environment of the distribution outlet from the "Energy Conservation Controller" and provides energy consumption and consumption trends for individual locations and the entire network of locations in a graph format to the distribution outlet headquarters. Such a service is called a "Visualization" service.

Characteristics of energy conservation system for distribution outlets

(1) Utilization of wireless sensor networks

In order to determine energy conservation methods for distribution outlets it was necessary to formulate strategies based on an analysis of the trends, once an understanding of the trends of energy consumption was gained.

Energy consumption at distribution outlets is closely related to environmental conditions both inside and outside each location, such as temperature and humidity. Through an analysis of the cross relationship between fluctuations in environmental conditions and energy consumption we were able to gain a clear understanding of the energy consumption trends at distribution outlets, making it easier to identify the causes of waste. The building of a sensor system was therefore vital for collecting information on electric power consumption and the environment at each distribution outlet location. It would have been difficult to build a wired environmental information collection system, since a power source for the sensors is often not available when the layout changes, such as the shifting of merchandise shelves, which takes place at distribution outlets. When costs relating to construction and maintenance are considered, it is certainly not a realistic option.

Wireless sensors, such as the ZigBee (**Photos 1** and **2**), were therefore adopted for the Energy Conservation Controller. Wireless sensors require no wiring and can be installed with simple installation work to create a sensor system, whether the intended location is a new or existing distribution outlet.

Photo 1 Environment measurement sensor component of wireless sensor

Photo 2 Wireless transmission component of wireless sensor

(2) Energy conservation controls through context awareness technologies

Numerous pieces of equipment have been installed into the facilities of a distribution outlet, such as air conditioners and fridge-freezer display cases. Action taken as energy conservation strategies at distribution outlets in the past had been implemented primarily by the replacement or altered settings of individual pieces of equipment for the facilities. The use of such strategies to make appropriate settings suitable for the installation conditions of the equipment proved to be quite difficult and often resulted in excessive warming or cooling due to human error in setting[3] the equipment.

An Energy Conservation Controller regulates conditions to levels that are considered comfortable by humans eliminating waste without sacrificing the comfort inside the distribution outlets. The levels of comfort are represented in seven levels, derived from evaluations for the level of comfort as sensed by humans. These figures are calculated in real-time, based on environmental information collected from the wireless sensor network installed inside the distribution outlet.

The Energy Conservation Controller is able to sustain a comfort level inside the location, controlling in real-time an optimum level for the air conditioners, fans and lighting equipment according to the conditions, such as the season or the time of day (**Fig. 2**). This made it possible to realize efficient and comfortable energy conservation, through the elimination of waste arising from excessive heating and cooling (**Fig. 3**).

For instance, a significant difference in the level of comfort is felt by persons inside two distribution outlets with the same temperature settings in Summer, depending on whether or not ceiling fans or other facility convection equipment are installed on the premises. When such equipment is available persons would feel comfortably cool, or otherwise hot. This means that energy conservation could be realized through the provision of air flow to persons inside a location according to the environmental conditions of the distribution outlet in order to increase the level of comfort while reducing the frequency of use for air conditioners, which consume a significant amount of electric power.

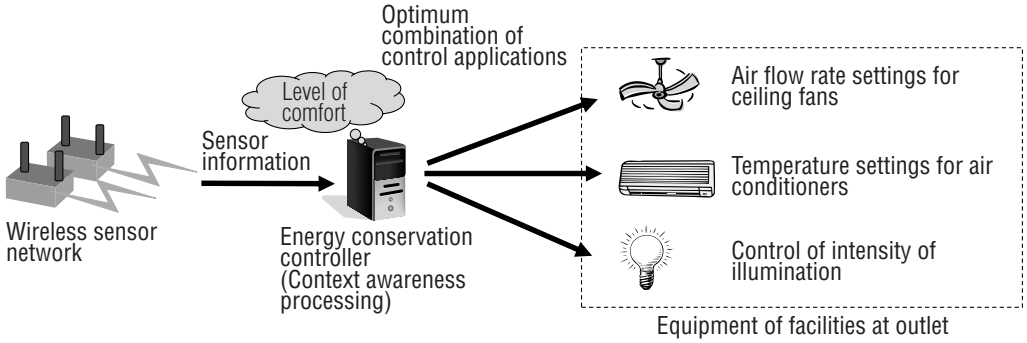

Fig. 2 Energy conservation controls using context awareness technologies

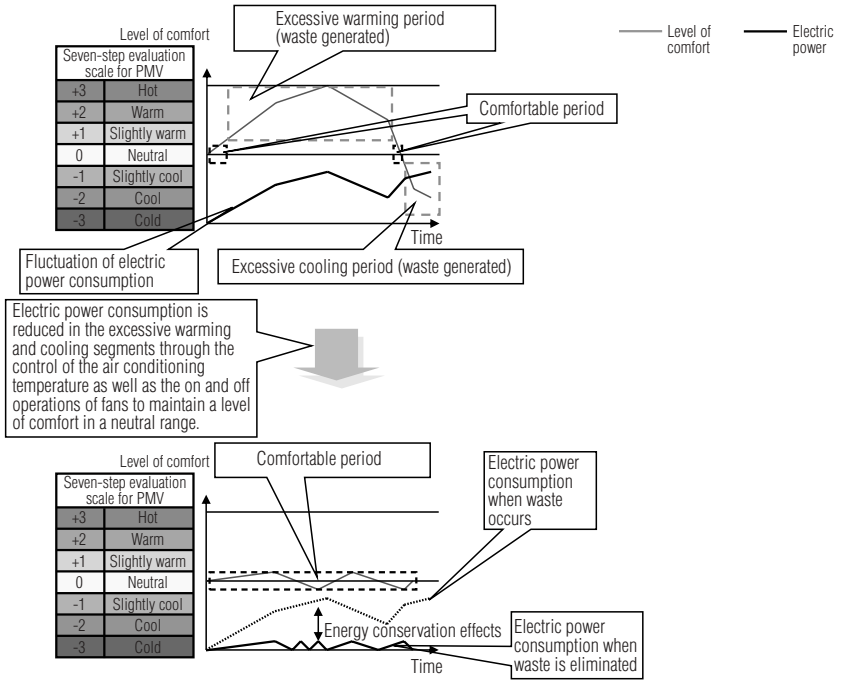

Fig. 3 Effects of energy conservation controls using levels of comfort

Such controls based on the levels of comfort had in the past been conducted in large scale buildings. This time it was possible to realize the same in smaller scale distribution outlets.

(3) Control network independent of facility equipment

A diverse range of facility equipment from various manufacturers is installed inside distribution outlets, such as air conditioners and fridge-freezer display cases. Control procedures used by such networks are of specifications unique to individual equipment manufacturers. In order to control the facility equipment inside a distribution outlet, it was necessary to provide numerous interfacing connections, which presented a significant dilemma for the purpose of developing control software. Since facility equipment types and configurations installed at individual distribution outlets are not unified for all locations, it was necessary to respond to each site individually. Integrated energy conservation controls for facility equipment inside distribution outlets, therefore, had not been a practical choice due to cost considerations.

In order to resolve such issues for the Energy Conservation Controller, LonWorks was adopted as the protocol for the control network. LonWorks has a long track record for automation in buildings and other areas and it is an internationally standardized protocol among control network protocols. The Energy Conservation Controller integrates all individual facility equipment networks via gateway units that support LonWorks, to realize a control method that does not rely on any individual manufacturer.

Sensor networks, IP networks and multiple control networks were connected and fused together to form a single information system (**Fig. 4**).

(4) Energy management services

Business operators with numerous distribution outlets established were faced with the necessity to perform integrated energy conservation management by gaining an understanding of the energy consumption status across the network of all distribution outlets, due to the nature of how the distribution outlets were established. Integrated energy conservation management was realized by "Group Management Function of Distribution Outlet Locations Provided by Energy Management Server" and "Visualization" services. This made it possible for distribution outlet headquarters to promote energy conservation plans and implement strategies required by the amended Energy Conservation Law, at each individual distribution outlet.

a. Group Management function

The energy management server collects information on the electric power consumption and the environment from multiple energy conservation controllers at individual distribution outlets and stores them on a database. The energy conservation controllers and collected data are managed by the Group Management function according to the management mode of the distribution outlet headquarters and in a structured manner by individual locations and regions (**Fig. 5**). This function is used for the "visualization" service intended for distribution outlet headquarters and used to provide users at the distribution outlet headquarters with information pertaining to the electric power consumption for regions, as well as individual distribution outlets. This made it possible to easily gain an understanding of the electric power consumption across all distribution outlet networks in order to perform energy management of the entire distribution outlet network in an efficient manner.

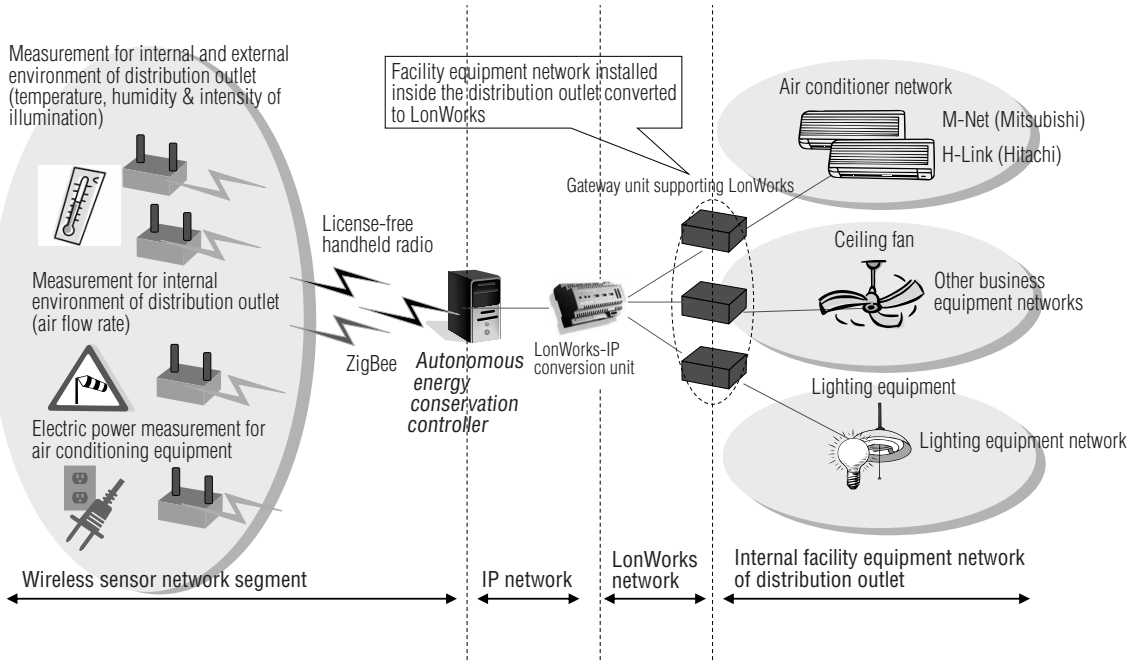

Fig. 4 Integration of facility equipment networks inside distribution outlets

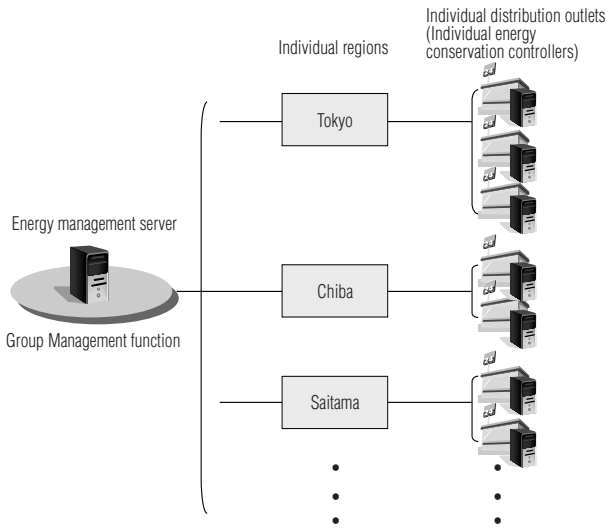

Fig. 5 Group Management function

b. "Visualization" services

The energy management server provides the "Visualization" service to enable managers at the distribution outlet headquarters to monitor information, pertaining to energy consumption and the environment, across all locations of the distribution outlet network.

This service makes it possible for managers at the distribution outlet headquarters to gain an understanding of the electric power consumption status of distribution outlets, which are grouped and managed by regions, with visual information provided in the format of maps and graphs (**Figs. 6** and **7**). It also enables the formulation of medium and long term plans for energy conservation as information pertaining to the environment at each individual distribution outlet, such as room temperature, can also be displayed (**Fig. 8**).

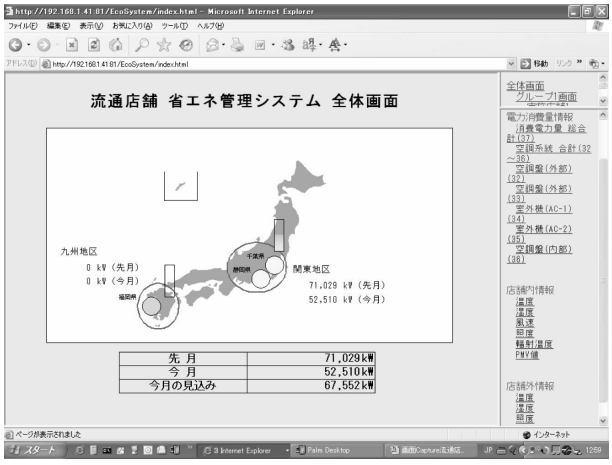

Fig. 6 "Visualization" service (group management display for distribution outlets)

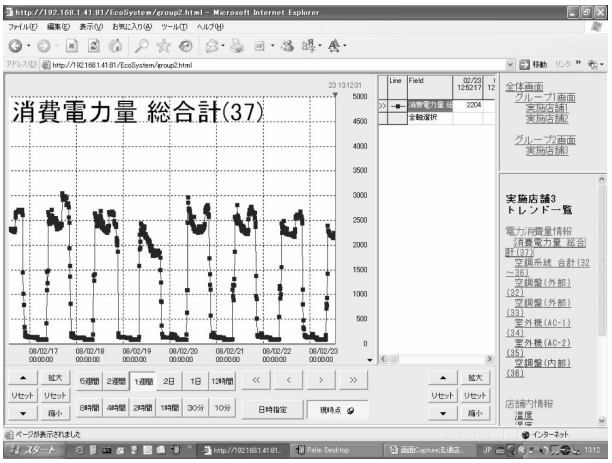

Fig. 7 "Visualization" service (electric power consumption at distribution outlets)

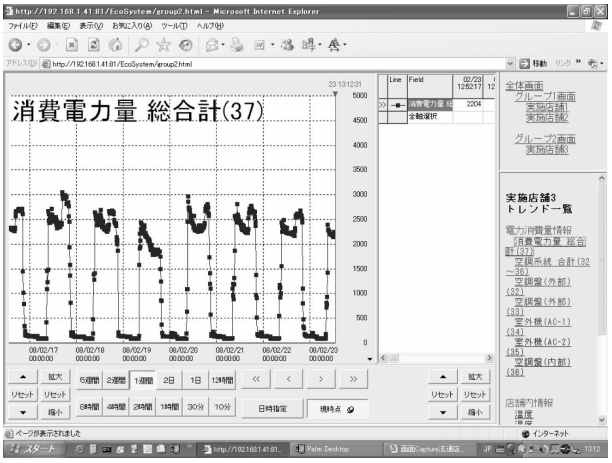

Fig. 8 "Visualization" service (environmental information for distribution outlets)

Energy conservation effects of energy conservation system for distribution outlets

Field tests on this system to verify energy conservation were conducted at two distribution outlets, in cooperation with a convenience store business operator and a home center (DIY shop) business operator.

The following processes were carried out at two distribution outlets:

a. Air conditioning controls by level of comfort

The temperature settings of the air conditioners inside the distribution outlets were controlled to maintain a certain level of comfort inside the sites.

b. Convection air flow controls with ceiling fans

The temperature settings of the air conditioners inside the distribution outlets and the air flow rate settings of the fans were combined for the controls to maintain a certain level of comfort inside the sites.

c. Simulation of lighting controls linked with external intensity of illumination

Simulations were conducted to verify the energy conservation effects for implementing lighting controls on lighting inside the distribution outlets, with the measurements of the intensity of illumination taken outside the sites.

Energy conservation effects exceeding 5 % were verified with regards to the overall electric power consumption for both the convenience store and home center as a result.

Conclusion

The results of the field tests indicated that the electric power consumption of individual retail outlets was reduced by over 5 %, regardless of the scale of each location. This system can offer an energy conservation solution suitable not only for convenience stores or home centers, but also for the entire distribution industry, including supermarkets and restaurants. A reduction in carbon dioxide emissions of about 200,000 tons could be expected, for example, if this system was adopted for a network of convenience stores (**Note 2**).

The "Energy Conservation System for Distribution Outlets" was given the "Judges' Special Award" of the "Green IT Award 2008", as an energy conservation solution. We intend to continue with our research and development of data mining technologies for energy conservation and highly efficient energy management systems, in order to realize even more efficient energy conservation in the future.

Note 2: The carbon dioxide emission reduction amount at 42,000 convenience stores has been derived based on the assumption that electric power consumption is reduced by 5 % annually per location and by applying the carbon dioxide conversion coefficient of 0.555 kg/kWh.

References

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3) Comfort Air-conditioning Control for Building Energy Saving, Fumio Yamada, Kenzo Yonezawa and Yuuichi Hanada, Toshiba Review, Vol. 59, No. 4, pp. 40-41, 2004.

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TIPS Basic Glossary

Levels of comfort (thermal environment performance index or "Predicted Mean Vote" [PMV], predicted performance on warm or cold sensations or "Predicted Percentage of Dissatisfied" [PPD], ISO7730)

Levels of thermal comfort for humans are related to the four environmental factors of room temperature, mean radiant temperature, relative humidity and average wind speed, as well as the two human factors of clothing worn by the person in the room and the amount of work being performed by the person in the room. The combined effect of these factors are entered into the level of comfort formula to obtain a seven-level figure indicating whether or not a person would feel warm or cold at a given moment.

Context awareness

A technology for performing processes in response to given conditions, based on information pertaining to the condition of the user, which is collected and processed dynamically by a computer.

LonWorks

A networking platform created for intellectual distributed control, developed by Echelon Corporation in the United States. The technology was submitted to and accepted by representative international standardization organizations, such as AAR, ANSI/EIA, ASHRAE, IEEE, IFSF and SEMI, as a network standard for homes, manufacturing plants, commercial buildings and traffic systems.