LIFELINE EARTHQUAKE ENGINEERING

Fumio Yamazaki

Institute of Industrial Science, The University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan.
Phone : 03-5452-6390, Fax: 03-5452-6389
Homepage: http://apollo.iis.u-tokyo.ac.jp/
Email: yamazaki@iis.u-tokyo.ac.jp

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ECENT EARTHQUAKES

JAPAN	USA
	1906 San Francisco (M8.3, Deaths 700)
923 Kanto (M7.8, Deaths 140,000)	
964 Niigata (M7.5, Deaths 26)	
	1971 San Fernando (M6.6, Deaths 65)
978 Miyagiken-Oki (M7.4, Deaths 27)	
983 Nihonkai-Chubu (M7.7, Deaths 104)	
	1987 Whittier Narrows (M5.0, Deaths 6)

Types of Urban Earthquake Disasters

Type A : Lifeline Outage

e.g., 1978 Miyagiken-Oki, 1993 Kushiro-Oki, 1993 Guam

Type B : Lifeline Outage + Structural Damage

e.g., 1964 Niigata, 1989 Loma Prieta, 1994 Northridge, 1999 Chi-chi (Taiwan)

Type C :

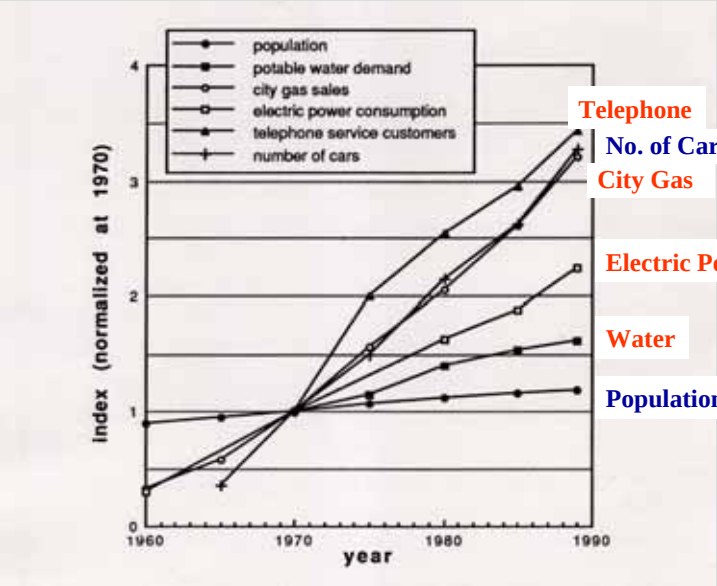
Lifeline Outage + Structural Damage + Spread Fires

e.g., 1923 Kanto, 1906 San Francisco

LIFELINES

- Electric Power
- City Gas
- Water & Sewage
- Telecommunication
- Traffic Systems

Growth of Utility Lifeline Consumption in Japan Normalized by that of 1970



Characteristics of Lifeline Systems

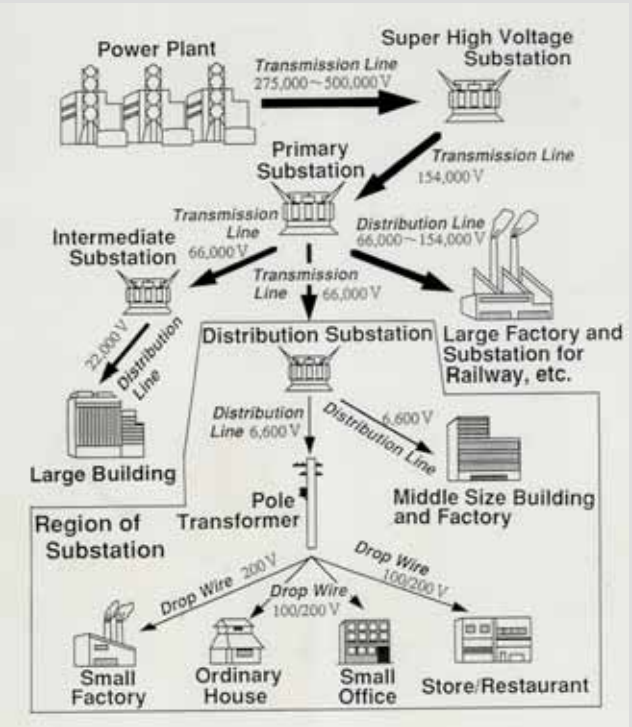
- Spatially Extended in Large Areas
- System Consisting of Numerous Structures
- Related to Urban Lives and Functions

-->Vulnerable to Earthquakes

Earthquake Countermeasures

1. Strengthening of Facilities
2. Redundancy and Backup Systems
3. Monitoring and Quick Response

Electric Power Systems

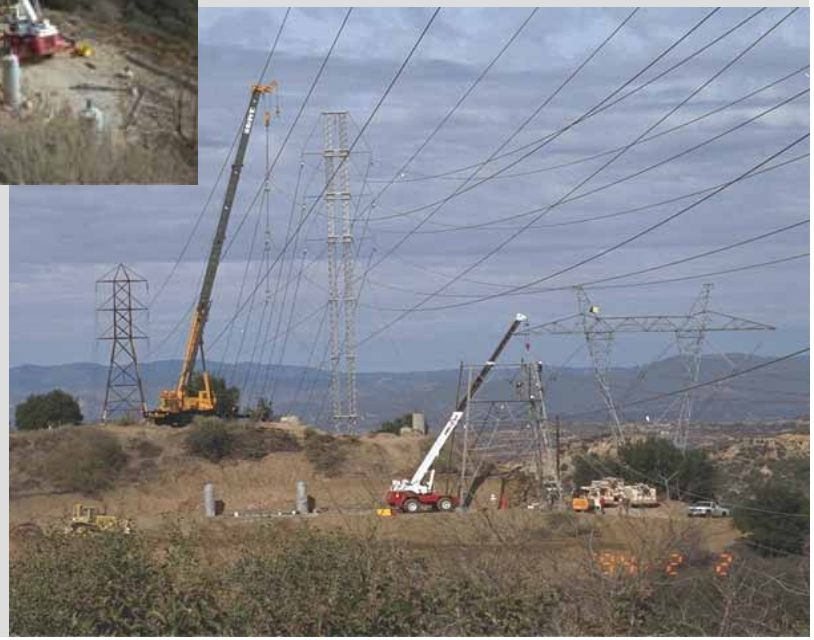


Electric Power Supply System

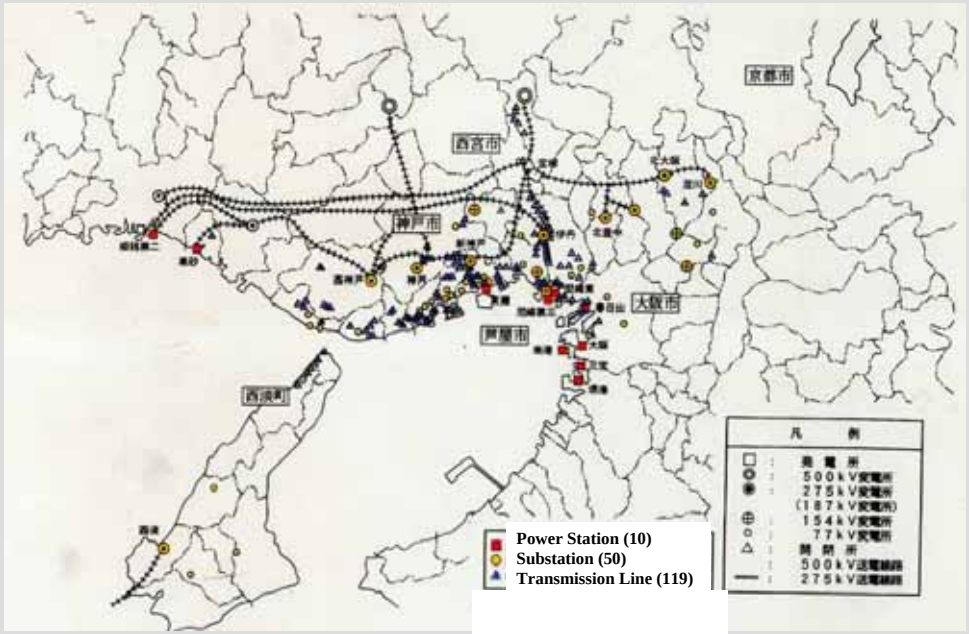
Weak Point: Substations

Sylmar Converter Station in the 1994 Northridge EQ

Transmission Tower Failure in the Northridge EQ



Damage of Power Systems in the Kobe EQ



Damage to Power Plants in the Kobe EQ

- 20 units of 10 thermal power stations
- Major damage to 8 units
- Automatic shut-off to 12 units
- 10 days for restoration

Damage in Amagasaki-East Power Plant

Damage to Substations in the Kobe EQ

- 50 substations including super-high voltage stations
- 23 major transformers and 9 circuit breakers
- Power supply stopped at 18 substations
- Temporary restoration in 25 hours

Shin-Kobe S. S.

Damage in High-voltage Substation

Shin-Kobe S. S.

Damage in High-voltage Substation

Damage to Transmission Lines in the Kobe EQ

- Troubles in 11 aerial transmission lines
- 20 cables in underground line
- 3.5 days for restoration

Transmission line across the fault in Awaji Island

Damage to Distribution Lines in Kobe EQ

Aerial system

- 11,000 poles (2.9%), 8,000 cables (1.9%), 5,000 transformers (1.9%)
- Cause of collapse of poles (building collapse 82.2%, shaking 12.0%, soil failure 5.2%)

Electric Poles after the Kobe EQ

Damage Distribution of Poles

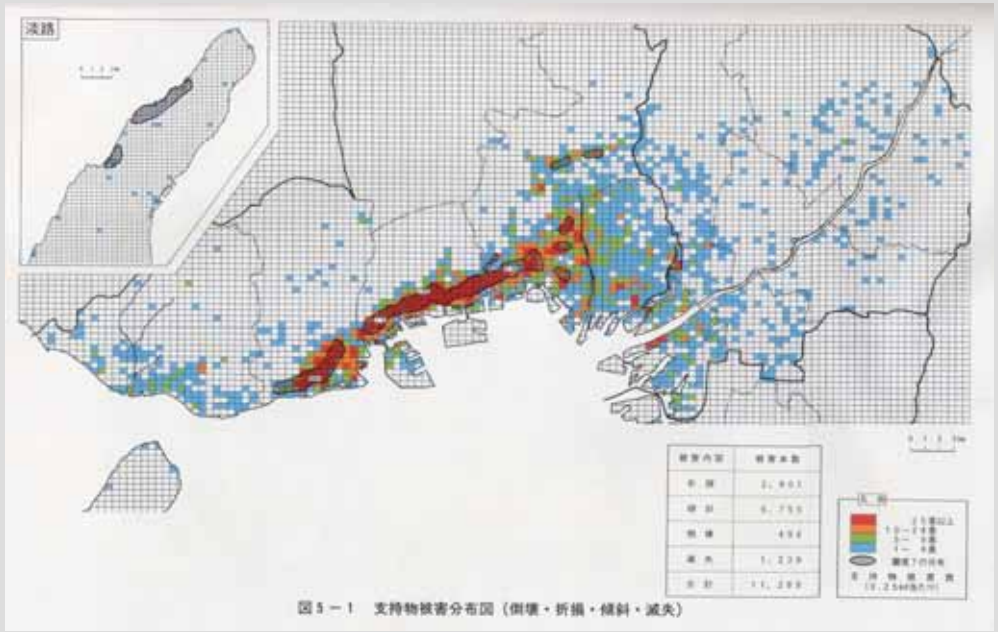


図５－１　支持物被害分布図（倒壊・折損・傾斜・滅失）

Damage to Distribution Lines in Kobe EQ

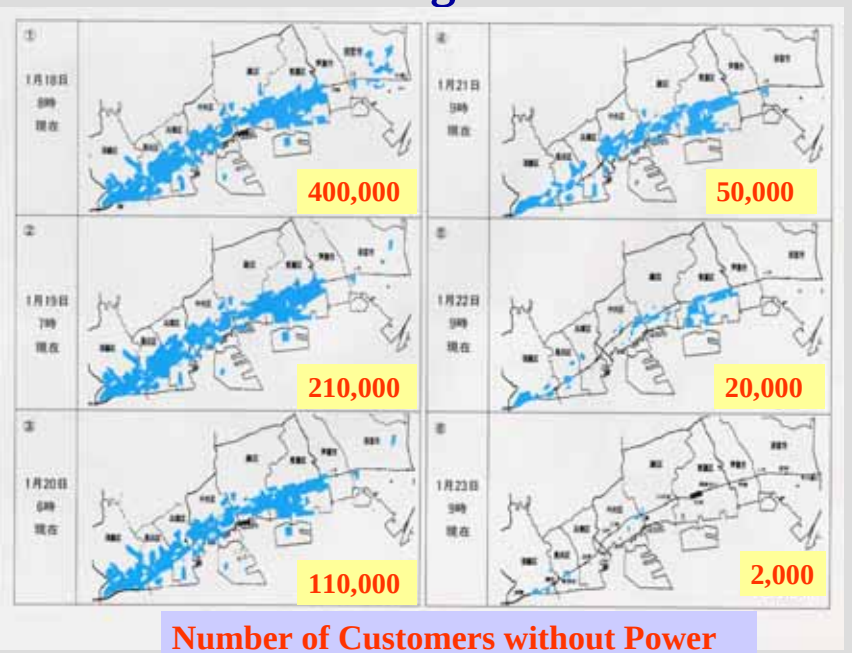
Under ground system

- 2,000 cables (30%), 400 cable ducts(24%), manholes (19%)
- Cause of line damage (building collapse 67%, ducts & manholes 20%, fire 7%)

Damage to underground lines

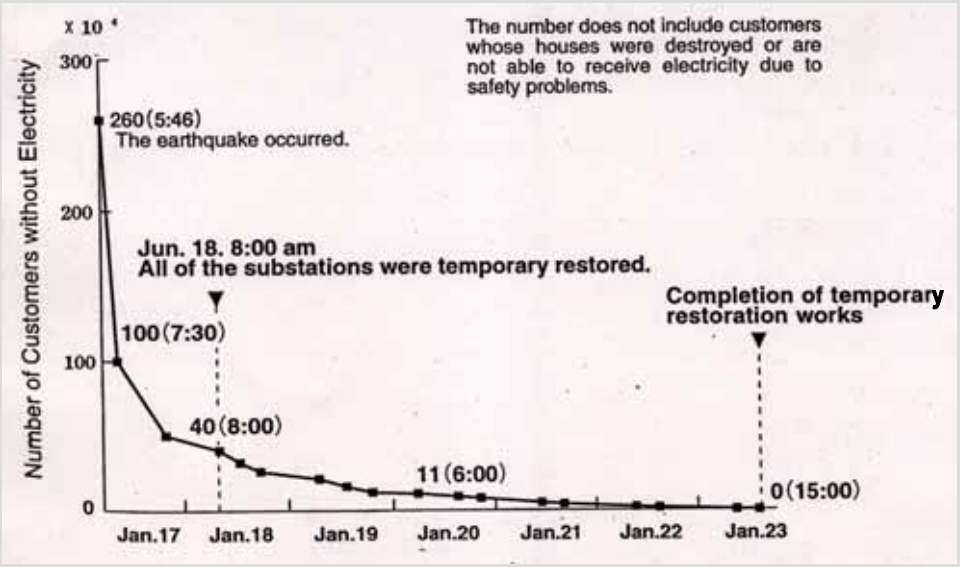
Temporary restoration using aerial cable

Area of Power Outage after the Kobe EQ



Number of Customers without Power

Number of Customers without Electricity after the Kobe EQ



Effects of Power Outage to Urban Functions

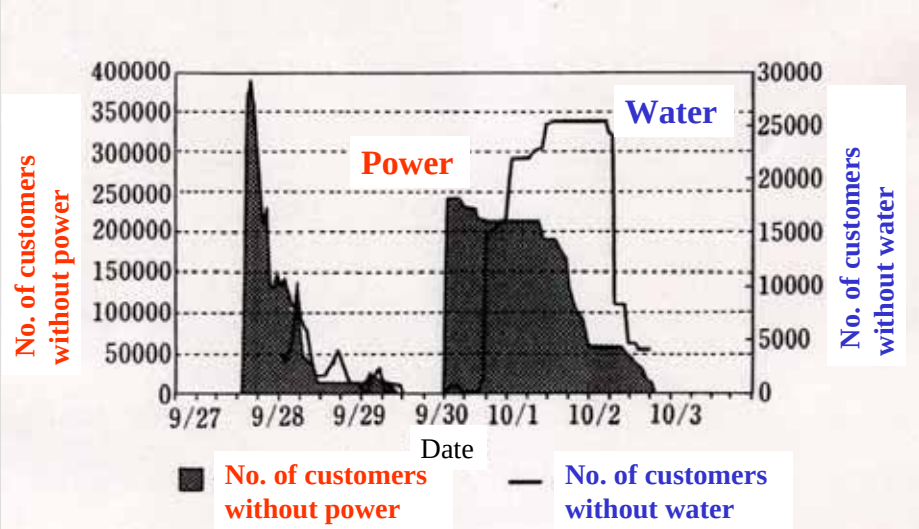
OTHER UTILITIES

- City Gas: Gas Production Plants
- Water: Filtration Plants, Pumping Stations
- Sewage: Treatment Plants
- Telecommunication: Switching Stations, Computers

TRAFFIC SYSTEMS

- Road Traffic: Traffic Signals, Computers
- Railway Traffic: Trains, Signals, Computers

Effect of power outage to water supply in the 1992 Typhoon in Hiroshima City



Effects of Power Outage to Urban Functions

- **INDUSTRIES AND BUSINESSES**
- Factories: Power, Lights, Air Conditioners
- Office Buildings: Lights, Air Conditioners, Elevators
- Commercial: Lights, Air Conditioners, Refrigerators
- Hospitals: ICU, Operations

Backup power is usually installed for important facilities.

But, 1) its capacity is often small.

Emergency Power Supply

Power outage due to the 1999 Chi-chi, Taiwan EQ

Damage in Chungliao Switching Yard