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SAN FRANCISCO
PLANNING + URBAN RESEARCH
ASSOCIATION

LIFELINES: UPGRADING INFRASTRUCTURE TO ENHANCE SAN FRANCISCO'S EARTHQUAKE RESILIENCE

SPUR REPORT

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INTRODUCTION

In disaster planning, much attention is paid to the role of buildings – how will they perform in a major earthquake? How long will they take to repair? Will people be able to stay in their homes after a quake, or will they need temporary shelter? Less attention is paid to the role of the infrastructure systems that support urban life, which we call our “lifelines.” By “lifeline,” we mean the utility systems that bring us our water, electricity and natural gas and the transportation systems that allow us to get around, including public transit, ports and airports, and road infrastructure. As with buildings, lifelines are critical to our ability to recover from an earthquake. If our buildings are not “serviceable,” nobody can live or work in them. San Francisco’s capabilities for response to, and recovery from, an earthquake are highly dependent on the condition of lifelines in the wake of such a disaster.

The importance of reducing the risk to lifelines cannot be understated. Imagine what would happen if even one of our lifelines seriously failed in an earthquake. How would people be able to shelter in place without drinking water? What happens if our natural gas lines cease to work – or worse – stoke the flames of a massive fire? How will emergency workers get to our city if the bridges fail? How will our economy recover if we can’t move people or goods around the region?

Lifeline owners in both the public and private sectors have made significant investments in designing, constructing, and retrofitting their facilities and systems to reduce the risk of damage in an earthquake and to facilitate restoration of services to their customers. However, the seismic performance standards for lifelines vary widely and are not tied to generally applicable public policies for reducing risk or for ensuring community resilience in the face of a major earthquake.

We need to know how our lifelines are going to perform in an earthquake. And we need to set performance targets based on “resilience” – i.e. our capacity to recover quickly and effectively from a major earthquake. To promote the city’s recovery from an earthquake, the services provided by lifelines should be restored as quickly as possible – within hours or days. However, as things now stand it may take months or even years for some systems to be restored to full operation due to the uncertainties associated with potential damage, the lack of clearly articulated goals for restoration, and the lack of consistent standards for achieving those goals.

The San Francisco Planning and Urban Research Association (SPUR) has developed this policy paper raise awareness of the City’s vulnerability and to encourage steps necessary to increase the City’s resilience to a major earthquake, with respect to lifelines.

This paper is a component of SPUR’s Seismic Hazard Mitigation Initiative. The initiative’s goals are to:

- define the concept of “resilience” in the context of disaster planning;
- establish performance goals for the “expected” earthquake that supports the definition of resilience;
- define transparent performance measures that help the City reach these performance goals; and
- suggest next steps for implementing policies that improve the City’s resilience.

IMPORTANCE OF LIFELINE SYSTEMS TO A RESILIENT SAN FRANCISCO

There are a number of reasons why the ability of lifelines to survive or recover from an earthquake is of the highest importance:

- Because lifeline systems spread across the region, they have weak links resulting from site specific conditions that increase the risk of partial or complete system shutdowns. For example,

the City's water system includes specific elements that may withstand earthquake damage. However, the City's water is delivered through the Hetch Hetchy system, which transports water from the Sierra Nevada through 280 miles of pipeline and 60 miles of tunnels that cross several earthquake faults, including the Hayward Fault. Further, the water distribution system within the City includes areas subject to differential settlement that could damage mains and service lines.

- The impact of damage to lifelines is compounded by the interdependency among lifeline sectors, both within San Francisco and in the region as a whole. For example, electric power is required to run water and wastewater systems, and the airport depends on jet fuel brought in via pipeline from petroleum refining and distribution facilities.
- In addition to supporting first responders, the expedient restoration of lifelines reduces the need for evacuation and sheltering of victims who would otherwise be without critical services.
- The recovery of communities and the economic base is dependent on the re-establishment of lifelines. If the services provided by these systems cannot be restored expeditiously, the recovery will be delayed as residents and businesses struggle with the lack of critical services and the inability to move people and goods around the region.

DESCRIPTION OF LIFELINES

“Lifelines” are defined as those essential utility and transportation systems that serve communities across all jurisdictions and locales. These systems share the attributes of being distributed systems, rather than isolated facilities; and of providing products or services that are transferred through networks that often cross legal and jurisdictional boundaries (ALA, 2005).

LIFELINE SYSTEMS AND COMPONENTS

Lifelines include:

- Water systems
- Wastewater systems
- Electric power systems
- Oil and natural gas systems
- Telecommunications systems
- Highways and roads
- Ports and waterways
- Transit systems
- Railroads
- Airports

Hospitals and other medical facilities are often considered to be lifelines; however, these facilities are addressed in the Existing and New Buildings papers.

In general, a lifeline system incorporates a wide range of elements necessary for system operation, including linear components; mechanical, electrical, and electronic equipment; buildings containing system components; operating centers; and other supporting elements. The circumstances under which individual elements may fail vary widely, as do applicable design guidelines and standards. The performance of the entire system is as critical as the performance of individual elements; however, damage to individual elements may be sufficient to shut down part or all of the system.

Lifeline systems are also distinguished by their interdependency. The continued operation of a lifeline system, such as the communications network, may be dependent on the operation of another system, such as the power system. Similarly, the ability for system owners to restore their respective systems following an earthquake may be dependent on the condition of highways and other transportation elements.

LIFELINES IN SAN FRANCISCO

As a major city, San Francisco is served by all major categories of lifelines, as described in Table 1 below. (The table includes lifelines that serve the City itself; it does not include lifelines serving the Bay Area region as a whole.)

Table 1: Lifelines Serving San Francisco

Lifeline System	Owner/Operator and Details
Water and Wastewater	San Francisco Public Utilities Commission (SFPUC) Systems include the Hetch Hetchy system, which serves not only San Francisco but nearly 2 million Bay Area customers outside the City; potable water treatment and distribution within the City; and wastewater collection and treatment systems within the City
Electric Power	Distribution to residential and commercial customers: Pacific Gas and Electric Company (PG&E) Power generation within the City: Mirant Corporation, which owns and operates the Potrero Generating Plant Municipal power, including power for transit, streetlights, traffic lights, and municipal buildings: SFPUC, which uses the Hetch Hetchy system to generate hydropower
Natural Gas	PG&E operates the distribution system within the City, including regulation, high- and low-pressure distribution lines, and service lines
Telecommunications	Numerous private sector entities, including AT&T and Verizon Systems include telephone, wireless, data, and cable networks
Highways and Roads	Interstate and state highways and the San Francisco-Oakland Bay Bridge: California Department of Transportation Golden Gate Bridge: Golden Gate Bridge, Highway, and Transportation District City streets: The Department of Parking and Traffic is responsible for traffic engineering and City-owned parking facilities; the Department of Public Works is responsible for street repair
Ports and Waterways	The Port of San Francisco owns all port facilities in the City Ferry services are provided by Golden Gate Ferry, Alameda Harbor Bay Ferry, Alameda Oakland Ferry, Vallejo Baylink, and various private sector ferry operators
Transit Systems	Bus, metro, and street car lines in San Francisco: Municipal Railway (MUNI) Bay Area Rapid Transit (BART) Other major bus systems serving San Francisco: Alameda-Contra Costa Transit; San Mateo County Transit; and Golden Gate Transit
Railroads	Caltrain: Peninsula Corridor Joint Powers Board

Lifeline System	Owner/Operator and Details
Airport	San Francisco International Airport

¹ Under state law, the Water Emergency Transportation Authority is slated to take over the operation of some of these ferry systems and is responsible for implementing regional improvements that will increase capabilities for use of the ferry system for response to regional disasters.

While some of these systems (such as MUNI and the Port) are wholly contained within San Francisco, most are part of larger regional networks, such as the regional freeway system; and the failure of these larger systems would paralyze San Francisco as well as the region. Additionally, San Francisco is critically dependent on lifelines within the region, but outside of the City. For example, finished petroleum products are either delivered by pipeline from outside the region or manufactured in the region from crude oil imported to the region; and damage to these systems would result in a shortage of gasoline, diesel, and aviation fuel. Interdependencies among systems will increase their respective vulnerabilities to shutdowns, regardless of level of damage or location.

POTENTIAL RISKS TO LIFELINES

The potential risk to lifelines varies widely, depending on the sector, the relative age of the system, the location of individual system elements and site-specific conditions at those locations, and the extent to which the system in question is vulnerable due to damage to lifelines in other sectors. Site-specific conditions that increase vulnerability to lifelines in the Bay Area include the following.

- Ground shaking: Ground shaking due to the earthquake may damage system elements or associated features (such as buildings in which lifeline elements are located).
- Liquefaction: Many of the Bay Area’s lifelines, such as ports and airports, are located in areas on the perimeter of the San Francisco and San Pablo bays that are susceptible to lifeline-damaging conditions related to liquefaction, such as lateral spreading and differential settlement.
- Displacement along faults: Key lifelines, such as the Hetch Hetchy system and major transportation elements, cross the Hayward Fault and other faults in the Bay Area.
- Landslides: Lifeline components may be displaced or closed due to earthquake-triggered landslides.

The 1989 Loma Prieta Earthquake provides the most recent example of widespread impacts of an earthquake to lifeline systems in the Bay Area. Examples of impacts to lifelines are described in Table 2 below.

Table 2: Examples Impacts of the Loma Prieta Earthquake on Bay Area Lifelines

Lifeline System	Example Impacts
Water	Approximately 1,200 breaks in water mains and connections in the Bay Area Damage to the Municipal Water Supply System in the Marina District resulted in total loss of flow to customers and fire hydrants, and required replacement of over 36,000 feet of pipe Damage to Auxiliary Water Supply System reduced water supply available for firefighting in the Marina District
Wastewater	Damage to collector sewers in the Marina District required replacement of nearly

Lifeline System	Example Impacts
	7,000 feet of pipe
Electric Power	Damage to two power plants (Hunters Point and Moss Landing) and five substations
Natural Gas	Damage to low pressure mains in the Marina District required replacement of over 42,000 feet of pipe Over 150,000 customers reported to be without gas service; approximately 90 percent of shutoffs were customer-initiated
Highways and Roads	80 bridges closed \$2 billion in damage to bridges and roads Collapse of upper deck section on eastern span of the Bay Bridge Collapse of Cypress Street Viaduct (Interstate 880) with 42 deaths
Ports and Waterways	The Port of Oakland experienced deformed rail lines, tilted container cranes, and cracked wharf piles, but remained in operation
Transit Systems	Disruption to BART and MUNI due to power outages
Airports	San Francisco International Airport closed for 12 hours to repair damage to control tower 3,000 feet of runway damaged at Oakland International Airport

Sources: U.S. Geological Survey, 1992, 1993, 1998; Disaster Recovery Journal, 1989; California Seismic Safety Commission (CSSC), 2002.

ADDITIONAL HAZARDS ASSOCIATED WITH NATURAL GAS SYSTEMS

As described in Section 1 above, the failure of lifeline systems can have widespread and enduring effects on services critical to the response, public health and safety, re-establishment of the community, and economic recovery. Just as significant are the risks of additional damage and injury resulting from lifeline failures – in particular, the potential for fires caused by damage to natural gas systems. Gas leaking from a damaged line may ignite or explode, either because the gas supply is not shut off or is restored despite the existence of leaks that have not been detected and repaired. Approximately 35 percent of fires in San Francisco following the 1989 Loma Prieta earthquake were gas-related; and 55 percent of fires in the Los Angeles area following the 1994 Northridge Earthquake were gas-related (CSSC, 2002). Gas supplies may continue to flow to users following an earthquake, unless the provider shuts down the system or individual customers shut off the supply at the interfaces between the supply system and buildings (such as closing a shutoff valve at a residence).

Currently, San Francisco does not require automatic shutoff valves for gas lines as they enter buildings; and in many cases in San Francisco the gas pressure step-down is located adjacent to, or within the footprint of, the building. Consequently, the potential exists for gas leaks within damaged buildings, often under high pressure, increasing the risk of ignition.

THE RISK OF MUCH STRONGER EARTHQUAKES

With a magnitude of 7.1 and a fault rupture in a remote location 60 miles from San Francisco, the Loma Prieta Earthquake had far less impact on San Francisco than large earthquake events that are anticipated

to occur closer to the City. As described in the Overarching Policy Paper, a reoccurrence of the magnitude 7.9 1906 San Andreas Fault Earthquake could result in regional losses of \$150 billion, or 10 times the total losses from the Loma Prieta Earthquake. Although many lifeline owners have made substantial investments in seismic retrofits and upgrades since Loma Prieta, it is likely that damage to lifelines, and the corresponding disruption to immediate response and long term reconstruction would be far greater – even to the point of inhibiting San Francisco's ability to ever fully recover. The possibility of such an earthquake in the near term heightens the urgency with which the City should address the vulnerability of lifelines.

SEISMIC PERFORMANCE OF LIFELINES

Guidelines, standards, and code requirements for the seismic performance of lifelines vary widely. The range of functions and designs of these systems, as well as the range of potentially damaging hazards, necessitates sector- and hazard-specific approaches to reducing damage, ensuring safety, and facilitating system restoration. Consequently, development of these standards occurs among numerous code development entities, other professional organizations and private sector entities, and Federal, state, and local government agencies. These entities have made great strides in developing standards to reduce risk to lifeline systems in all sectors.

Most sectors have progressed to system-based approaches in order to assess risk and reduce disruptions the performance of systems and delivery of services to customers. Nevertheless, achieving a consistent level of resilience is complicated by the many different regulating bodies to which system operators must answer. The general tendency toward sector- and hazard-specific development of standards results in the following problems:

- A lack of commonly understood definitions for acceptable seismic performance.
- Different standards for performance among different sectors.
- A lack of inter-sector coordination for the development of standards, setting of priorities, and implementation of mitigation.
- Limited understanding by political leadership and the general public of the potential performance of lifelines during an earthquake – and whether the performance of lifelines will meet expectations.

The sector-specific natural hazards provisions are generally based on varying levels of risk (for example, in terms of the design earthquake or probability of occurrence). Additionally, most sectors do not have standards for reliability – that is, practices that have been developed to ensure system restoration in accordance with goals set by stakeholders. According to the ALA, such standards have been developed only for highways/roads, ports, and railroads (ALA, 2004).

RESILIENCE IN THE CONTEXT OF LIFELINES

As described in the Overarching Policy Paper, SPUR defines San Francisco's "seismic resilience" as the City's ability to:

- Contain the effects of earthquakes when they occur.
- Carry out recovery activities in ways that minimize social disruption.
- Rebuild following earthquakes in ways that mitigate the effects of future earthquakes.

EXPECTED PERFORMANCE OF LIFELINES FOR RESILIENCE

SPUR recommends the establishment of clear, readily understood performance goals that define resiliency in infrastructure. Goals for the restoration of service are expressed in terms of the percentage of customers that have service after an earthquake.

Table 3 – Expected Performance for Lifelines

Category	Goals for Service Restoration
I	<p>Resume 100 percent of service within 4 hours, with backup systems if necessary</p> <p>Critical response facilities - including emergency housing centers – need to be supported by utility and transportation systems critical to their success. This level of performance assures that these systems will be available within four hours of the disaster. It requires a combination of well built buildings and systems, provisions for making immediate repairs as needed, and redundancy within the networks that allows troubled spots to be isolated.</p>
II	<p>Establish control of the system and resume 90 percent of service within 72 hours; resume 95 percent of service within 30 days; and resume 100 percent of service within four months</p> <p>Housing and residential neighborhoods require utility and transportation systems be restored quickly so that these areas can be brought back to livable conditions. There is time to make repairs to lightly damaged buildings and replace isolated portions of the networks or create alternate paths for bridging around the damage. There is time for parts and materials needed for repairs to be imported into damaged areas. These systems need to have a higher level of resilience and redundancy than the systems that support the rest of the city.</p>
III	<p>Resume 90 percent of service within 72 hours; 95 percent of service within 30 days; and 100 percent of service within three years</p> <p>The balance of the city needs to have its systems restored as buildings are repaired and returned to operation. There is time to repair and replace older vulnerable systems with new. Temporary systems can be installed as needed. Most existing lifeline systems will qualify for Category III performance.</p>

These goals assume the occurrence of the “expected” earthquake, defined as an earthquake that can reasonably be expected to occur once during the useful life of a system. For San Francisco's buildings, this earthquake is defined as having a 10 percent chance of occurrence in 50 years. As described in the Overarching Paper, "The Resilient City: Defining what San Francisco needs from its seismic mitigation policies", a magnitude 7.2 earthquake on the peninsula segment of the San Andreas Fault would produce this level of shaking in most of the City. Since lifeline systems generally serve cities and regions for well over 100 years, a larger "expected" earthquake should be considered.

LIFELINES: UPGRADING INFRASTRUCTURE TO ENHANCE SAN FRANCISCO'S EARTHQUAKE RESILIENCE

Categorizing lifelines in a meaningful way will require an assessment of those lifelines that are most critical to response and recovery. For example, Category I lifelines, which must be restored to service within 4 hours, would include those systems that are critical to the immediate response to an earthquake such as:

- water supply and electrical power to critical response facilities;
- water supply for firefighting;
- emergency communications systems; and
- critical transportation elements, such as roads to critical facilities and ferry landings.

This categorization may take into account the partial restoration of systems necessary to achieve the performance goals, rather than the complete restoration of those systems. For example, back-up systems may be implemented to restore services to critical facilities within the desired time frame and redundancies or bypasses in areas where ground failure is likely would allow for the restoration of services once control of the system has been established.

Additionally, the restoration of the transportation system may be achieved by shifting capacity among modes of transportation and among different providers. If damage to roads and bridges cannot be repaired within the timeframes described above, the capacity of other forms of transportation, such as buses, ferries, and rail systems, may be increased beyond pre-earthquake capacities to accommodate the additional load. In addition to measures necessary to reduce potential damage to transit facilities, this may require such mechanisms as modifications to equipment, establishment of service in areas previously not served by specific systems, or implementation of incentives for mass transit use and restrictions on vehicle travel that encourage use of transit systems.

GOALS FOR RESILIENCE OF LIFELINES

SPUR proposes to clarify the level of damage that is acceptable and suggest requirements to improve performance to achieve the level of resilience required. Goals for resilience of lifelines, as expressed in terms of target states for recovery, are provided in Tables 4a – 4d below.

Table 4a – Target States for Recovery Within 4 Hours of the Earthquake

Lifeline System	Target State Within 4 Hours
Municipal Water Supply System	Water service or temporary supplies available to 100 percent of facilities critical to response
Auxiliary Water Supply System	Water available for firefighting in 100 percent of City neighborhoods
Electric Power	Power restored, or temporary power available to, 100 percent of facilities critical to response
Natural Gas	Establish immediate control of the system and shut off service to quadrants in which damage is likely to be significant and result in hazardous conditions
Telecommunications	Telephone, wireless, and data service restored to 100 percent of facilities critical to response
Highways and Roads	All City-identified priority routes open and accessible to responders, assessment teams, and repair crews
Port of San Francisco	Critical ferry facilities available for transportation of first responders and evacuations

Table 4b: Target States for Recovery Within 3 Days of the Earthquake

Lifeline System	Target State Within 3 Days
Municipal Water Supply System	Water service restored to 90 percent of customers
Wastewater	Wastewater service restored to 90 percent of customers
Electric Power	Power restored to 90 percent of customers
Natural Gas	Restore service to 95 percent of customers in non-liquefaction areas
Telecommunications	Telephone, wireless, and data service restored to 90 percent of customers
Highways and Roads	All initial bridge safety evaluations completed; 90 percent of bridges open to traffic
Port of San Francisco	Initial safety evaluations of all ferry facilities completed; 90 percent of ferry capacity restored
Transit	90 percent of MUNI capacity restored
	90 percent of BART capacity restored
Railroads	Capability to use Caltrain lines for transportation of first responders, evacuation, and transportation of relief supplies restored
San Francisco International Airport	Airport open for emergency traffic and evacuation flights

1 Although systems may be operational and available for transportation services, personnel and equipment may be diverted to emergency response priorities.

Table 4c: Target States for Recovery Within 30 Days of the Earthquake

Lifeline System	Target State Within 30 Days
Water, Wastewater, Electric Power, and Telecommunications	Service restored to 95 percent of customers
Natural Gas	Service restored to 95 percent of customers, including those in liquefaction zones
Highways and Roads	90 percent non-priority routes in the City open to traffic
Port of San Francisco	Ferry service provided at 125 percent of pre-earthquake capacity
Transit	Service restored for 90 percent of MUNI customers
	Service restored for 90 percent of BART customers
Railroads	Service restored for 90 percent of Caltrain customers
San Francisco International Airport	Airport open for commercial traffic

Table 4d: Target States for Recovery 4 Months and Beyond

Lifeline System	Target State and Timeframe
Water, Wastewater, Electric Power, Natural Gas, and Telecommunications	Service restored to 100 percent of customers within 4 months
Highways and Roads	90 percent of highways and roads in the City restored to capacity within 4 months
Transit	Transit systems providing service equivalent to 125 percent of capacity within 4 months
All Lifelines	Complete restoration within 3 years

As described in Section 2 above, damage to natural gas systems heightens the risk of secondary incidents (fire or explosion) if gas supplies continue to flow to users in the presence of damaged system elements. Consequently, resilience of natural gas systems must account for the critical need to control the system in the wake of an earthquake, in addition to ensuring that system components are designed to reduce the risk of damage. The model for mitigation of the seismic risk to natural gas systems must expand to include both reliance on appropriate action at the interface with the customer and management of the system in such a way that risk can be controlled on system-wide basis after the earthquake and service restoration proceeds in a safe, orderly fashion.

RECOMMENDATIONS

SPUR recommends that the City implement a seismic mitigation program for lifelines through the following measures.

1. ESTABLISH A “LIFELINES COUNCIL” TO PROVIDE A MECHANISM FOR COMPREHENSIVE PLANNING.

The mayor should convene a Lifelines Council to:

- Establish standards for resilience in cooperation with the lifeline providers.
- Prioritize actions related to lifelines.
- Coordinate planning across sectors.
- Develop a comprehensive approach to coordinating the recovery of lifelines following an earthquake.
- Foster partnerships with regional, state, and private sector entities to improve lifeline performance in the City and across the region.
- Lead City efforts to pursue changes at the state and national levels regarding standards and requirements for lifeline performance.
- Given the expense of necessary upgrades to enhance resilience, develop a funding plan for modifications to City-owned systems and for assisting other system owners with modifications in areas of overwhelming public interest. For example, future bond issues proposed by the City should include components of the required work.

The Council should include representatives of city departments and agencies with responsibility for lifeline sectors in the City, such as the SFPUC and MUNI; as well as departments who have a coordinating role. It should also include state, regional, and private sector entities that operate or regulate lifelines serving San Francisco, as well as risk and industry experts. The Council should be chaired by a representative of the Mayor's Office, and its actions should be directed by an appointed leader who is given the authority, responsibility, and resources for delivering required results.

The Council should articulate the plan for implementing the additional recommendations described below.

2. CONDUCT A SEISMIC PERFORMANCE AUDIT OF LIFELINES IN SAN FRANCISCO AND ESTABLISH PRIORITIES FOR LIFELINE MITIGATION.

With the guidance of the Lifelines Council and with the cooperation of lifeline system owners, the City Controller's Office should conduct an assessment of the expected performance of lifelines, using the performance during the "expected earthquake" as the standard. This published study should inform the planning work being undertaken by the Lifelines Council. The assessment in each sector should:

- Be predicated on the concept of resilience and the need to achieve the desired timeframes for system recovery following earthquakes.
- Be conducted according to procedures set by the applicable standards organization or regulatory agency, such as the guidelines for implementing performance assessments published by the ALA.
- Account for ongoing programs for seismic mitigation. For example, SFPUC's ongoing initiative to upgrade the Hetch Hetchy system and the California Department of Transportation's program to retrofit bridges may result in levels of performance sufficient to meet the City's goals.
- Result in a preliminary report to the Board of Supervisors within six months, and a full report within two years.
- Be updated on a regular, yet reasonable, basis (every five years) to account for system improvements and the evolution of technology, design, and construction techniques.

The audit should enable San Francisco to establish priorities for modifications necessary to improve the seismic performance of lifelines. The Council should present these priorities to the Board of Supervisors and to the City's Capital Planning Committee. Priorities would be established by:

- Identifying lifeline systems or components of systems by performance category, as described in Table 3.
- Determining whether the lifelines can meet these targets, based on the assessment described in Recommendation #2 above.
- Establishing targets for modifications necessary to achieve performance goals.
- The prioritization should emphasize higher standards for life-safety, including:
- Reducing the risk of fires due to damage to natural gas and electrical systems.
- Protecting the water supply for fire-fighting.
- Ensuring that lifelines can support response operations.

This prioritization would take into account whether the City has the capability to make improvements (such as with City-owned systems) or mandate improvements through code requirements or other mechanisms; or must work through state and Federal regulatory agencies.

3. REQUIRE IMPROVEMENTS TO CITY-OWNED AND REGULATED SYSTEMS NECESSARY TO MEET PERFORMANCE GOALS AND DEVELOP A FUNDING PROGRAM TO MAKE THOSE IMPROVEMENTS HAPPEN.

The City has direct control of several major lifeline systems, such as the water and wastewater systems, the port, the airport, and Muni. Consequently, the Lifelines Council should recommend to the Board of Supervisors that the departments that operate these systems incorporate into their capital improvement plans the mitigation measures necessary to achieve performance goals.

For those systems that the City regulates through code requirements or other mechanisms, the Lifelines Council should recommend that the governing body require the improvements necessary to meet system-specific performance goals.

4. REQUIRE THE DESIGN AND IMPLEMENTATION OF IMPROVEMENTS TO THE GAS DISTRIBUTION SYSTEM THAT REDUCE THE RISK OF POST-EARTHQUAKE IGNITIONS.

Among lifeline systems, the gas distribution system is unique in that damage to the system has the potential for creating secondary impacts – ignitions and explosions – that could cause significant damage and loss of life. However, a complete shutdown of the gas distribution following an earthquake is not practical, given that resumption of service could take months, significantly delaying the City's recovery. Similarly, an unnecessary shutdown of the system in a moderate earthquake would have a devastating effect on the City's economy. Consequently, the City must undertake both near- and long-term actions to ensure that the gas distribution system ultimately incorporates features that reduce the risk of secondary impacts without compromising the continued operation of the system after earthquakes.

In the near-term (within 5 years), improvements to the gas distribution system should address those areas with the highest risk, including liquefaction zones and areas with a high concentration of buildings in which a high-pressure gas line enters the building. To meet the short term goal, the City should require:

- An assessment of areas and buildings that represent significant risk.
- Right-sizing of shutdown zones to target areas of significant risk.
- Installation of automated shutoff mechanisms to reduce risk of ignition in target areas. This component would include installation of shutdown mechanisms for the delivery system by PG&E and installation of shutoff valves by building owners.

The City should support the effort to assess risk. Additionally, through requirements for existing buildings and new construction, the City should strive to reduce the potential for building collapses, thereby reducing the potential for damage to gas lines entering buildings (refer to the Existing Buildings and New Buildings papers for discussion regarding buildings).

In the long-term (within 30 years), the City should sponsor the development and implementation of an improved, automatic gas distribution monitoring and control system that will allow effective control of the entire system following earthquakes without any risk of unnecessary shutdown and with the capacity to restart and avoid significant delays to recovery.

5. ESTABLISH PARTNERSHIPS WITH REGIONAL, STATE, AND PRIVATE SECTOR ENTITIES TO ADDRESS MULTI-JURISDICTIONAL AND REGIONAL SYSTEMS.

The multi-jurisdictional and regional nature of many of the lifeline systems that serve the Bay Area will compel San Francisco to work with other local jurisdictions, regional entities, state agencies, and private sector entities. Examples include the Metropolitan Transportation Commission; the Golden Gate Bridge, Highway, and Transportation District; BART; Caltrain; the Water Emergency Transportation Authority; and PG&E. In some cases, San Francisco has representation on the governing bodies that oversee these systems, but in other cases, it will be necessary to develop these partnerships.

6. ESTABLISH A PROGRAM FOR COMMUNICATIONS AND OUTREACH TO REGIONAL, STATE, FEDERAL AND PRIVATE SECTOR ENTITIES TO DRIVE CHANGE.

San Francisco does not have the authority or capability to regulate many of the lifeline systems that are critical to achieving resilience. Consequently, the City should establish a communications and outreach program to advocate for those changes that are in the City's self-interest while at the same time setting the standard for a comprehensive approach to addressing lifeline performance. Elements of this program, which would be coordinated by the Lifelines Council, should include the following:

- Raising the profile of public expectations for seismic performance of lifelines. By establishing readily understood measures for desired performance, San Francisco can communicate its goals to political leadership and the public more effectively, thereby encouraging demand for change. Additionally, this effort would encourage the public to accept increases in the costs of service that would be necessary to implement programs to improve lifeline performance.
- Enhancing cross-sector communication in planning for, and responding to, earthquakes in San Francisco. The interdependencies among lifelines may create post-incident circumstances in which decisions that are often made unilaterally may have critical and widespread implications. The City should work to increase the rapid and efficient exchange of information to promote the development of a common operating picture for lifeline systems and allow individual sectors to make decisions in a coordinated fashion.
- Developing recommendations for sector-specific organizations and state and Federal regulatory agencies. San Francisco should participate more actively in efforts by lifeline sectors to further the development of guidelines and standards, tools, and mechanisms for communication.
- Influencing the development of requirements at the state and national levels. San Francisco should work with the appropriate standards and regulatory organizations to encourage the adoption of standards for performance based on the City's model the development of requirements to achieve those standards. Further, San Francisco should work with the state regulatory agencies, such as the California Public Utilities Commission, as well as the legislature to drive requirements that will result in implementation by lifeline owners.

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