How to deal with aging sewers?
- Statistical Life Data Analysis of Sewer-

Yosuke MATSUMIYA*, Chizato MIYAUCHI, Kazuya FUJIU
National Institute for Land and Infrastructure Management, MLIT

1. Introduction

Japan has invested over 80 trillion yen in wastewater infrastructure. Sewer length has reached above 380,000 km. Some 2000 wastewater treatment plants are under operation. In recent years, sewer cave-ins have been reported in increasing numbers. It brings safety concerns among stakeholders. Preventive maintenance and asset management are being cried out. In this paper, statistical life data analysis of sewer is presented. It enables local governments, which are wastewater operators, to project future investment needs for sewer rehabilitation and replacement.

2. Method

Statistical life data analysis was conducted with 2-parameter Weibull distribution. Weibull functions are shown in Table 1 for sewers at the age of ***t***.

Table 1 Weibull Distribution

definition		Weibull Function
death rate	$\lambda_{(t)} = \dfrac{f_{(t)}}{R_{(t)}}$	$= \dfrac{b}{a} \cdot \left(\dfrac{t}{a}\right)^{b-1}$
probalility density on death	$f_{(t)} = \dfrac{\partial F_{(t)}}{\partial t_{(t)}} = -\dfrac{\partial R_{(t)}}{\partial t_{(t)}}$	$= \dfrac{b}{a} \cdot \left(\dfrac{t}{a}\right)^{b-1} \cdot e^{-\left(\frac{t}{a}\right)^{b}}$
cumulative distribution on survival	$R_{(t)} = 1 - F_{(t)}$	$= e^{-\left(\frac{t}{a}\right)^{b}}$
cumulative distribution on death	$F_{(t)} = 1 - R_{(t)}$	$= 1 - e^{-\left(\frac{t}{a}\right)^{b}}$

In the case of sewers, death is defined by having them rehabilitated or replaced. Rehabilitated or replaced sewers get 50 year of useful life newly in the account book. To know the death rate, a questionnaire survey was conducted to all the local governments with sewer systems on August 2006. The questions were how many kilometers of sewers survived and died during FY 2005 by age and material. The surveyed materials were concrete, clay, and PVC, which are the majority.

3. Result & Discussion

As of FY 2005 end, entire sewer length was 383,031 km. Out of this, 342,290 km, 89% of the total was analyzed, whose ages were identified and which agreed with any of the three materials. Coefficient **a** and **b** resulted in 99.30 and 3.048

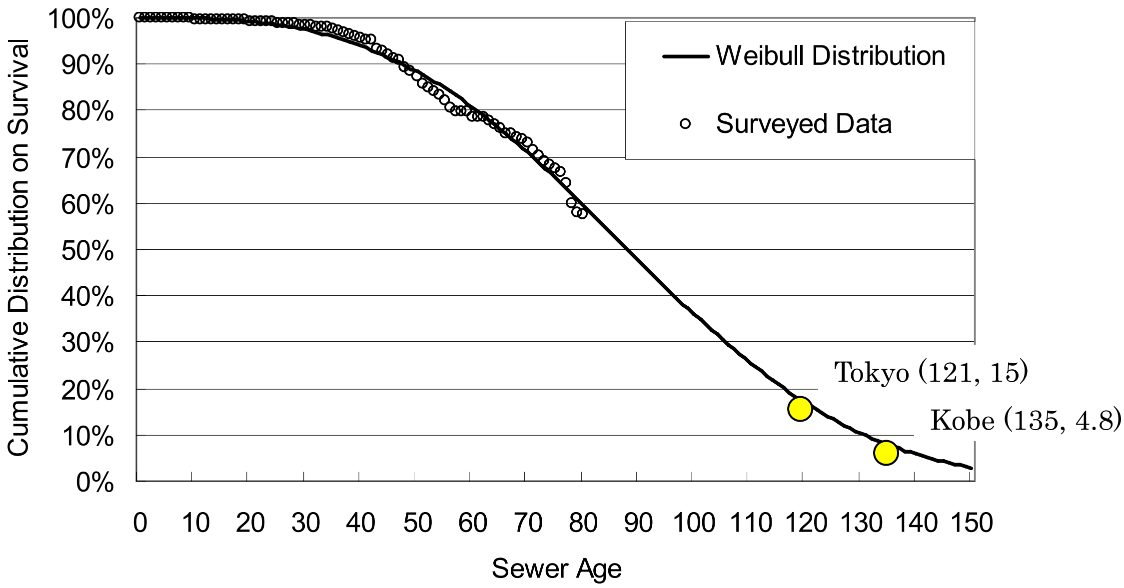


Figure 1 Survival Curve

To know the applicability of the curve to the more aged sewers, the oldest brick sewer data from two municipalities, Tokyo and Kobe were plotted. They are close to the approximation line. This analysis ignores specific factors influencing lives of sewers such as quality of the works, sewer standard of the times and how well or badly each sewer has been maintained. However, the curve is considered effective to project overall future investment needs if future investment decision is made similarly to the one in FY 2005.

Reference

Weibull distribution, http://en.wikipedia.org/wiki/Weibull_distribution

*1 Asahi, Tsukuba City, 305-0804, JAPAN Email: matsumiya-y92ta@nilim.go.jp

Jan. 22, 2007

20 min

How to deal with aging sewers?

Yosuke MATSUMIYA
Wastewater System Division
National Institute for Land & Infrastructure Management (NILIM)
MLIT, Japan

Mission

- **Sustainable Sewer Service**
- **Effective & Efficient Management**
- **Help LGs to do Asset Management**

Contents

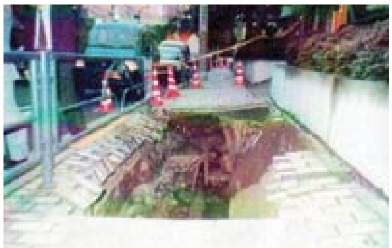
1. Current Issues
2. Proposed Sewer Management
3. Survival Curve
4. NILIM Research Projects Underway

Contents

1. Current Issues
2. Proposed Sewer Management
3. Survival Curve
4. NILIM Research Projects Underway

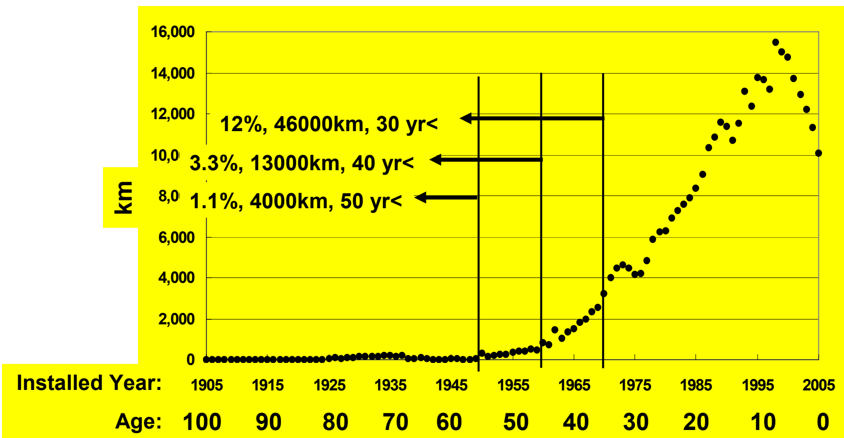
Cave-Ins Looming

- Number is increasing (5,000 cases/yr)
- Big cities account for majority
- Some of their sewers are over 50 yrs
- 50 is expected life time for depreciation.



Pictures from TMG Web Site

Age Distribution

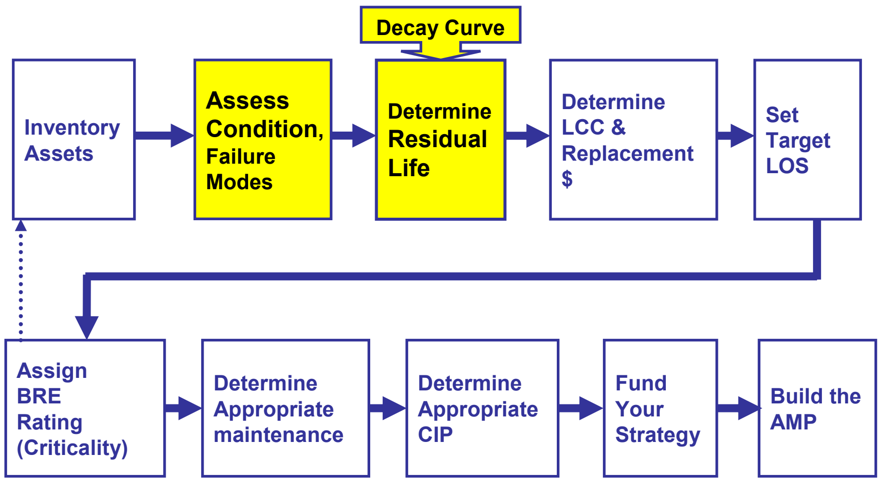


- More cave-ins expected as sewers age
- Feared traffic problems
- AM necessary!

Contents

10-Step AM Plan Process

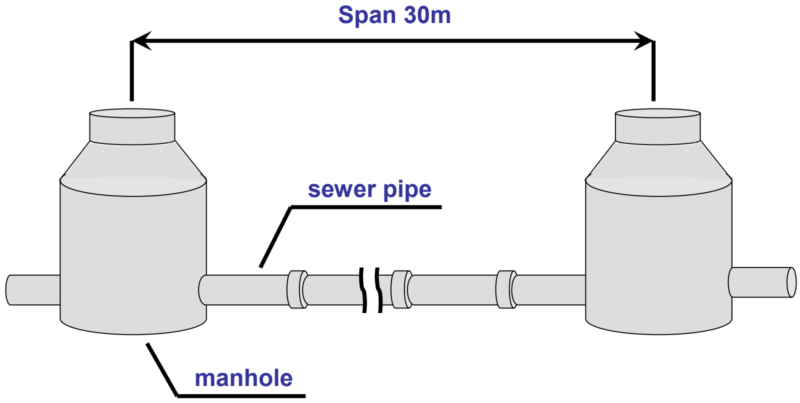
From USEPA Advanced Asset Management Training Workshops



Application to sewers is difficult.

Cost

(Problem-1 of Conventional AMP)



- Entire sewer length 380,000km (= 13million spans)
- 1500 local governments provide sewer service
- Each has 8700 spans on average.
- Costly to assess numerous spans periodically

Effectiveness

(Problem-2 of Conventional AMP)

- Sewers get damaged by unexpected external force.
- Construction works of other utility pipes are typical.
- Service not interrupted instantly by severe damage.
- Later, damaged sewers cause cave-ins.
- Assessments before damage cannot predict life.

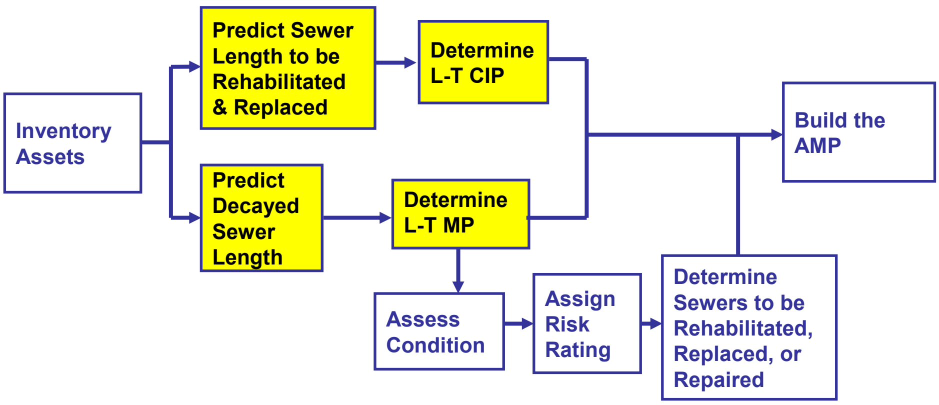
Technical difficulty

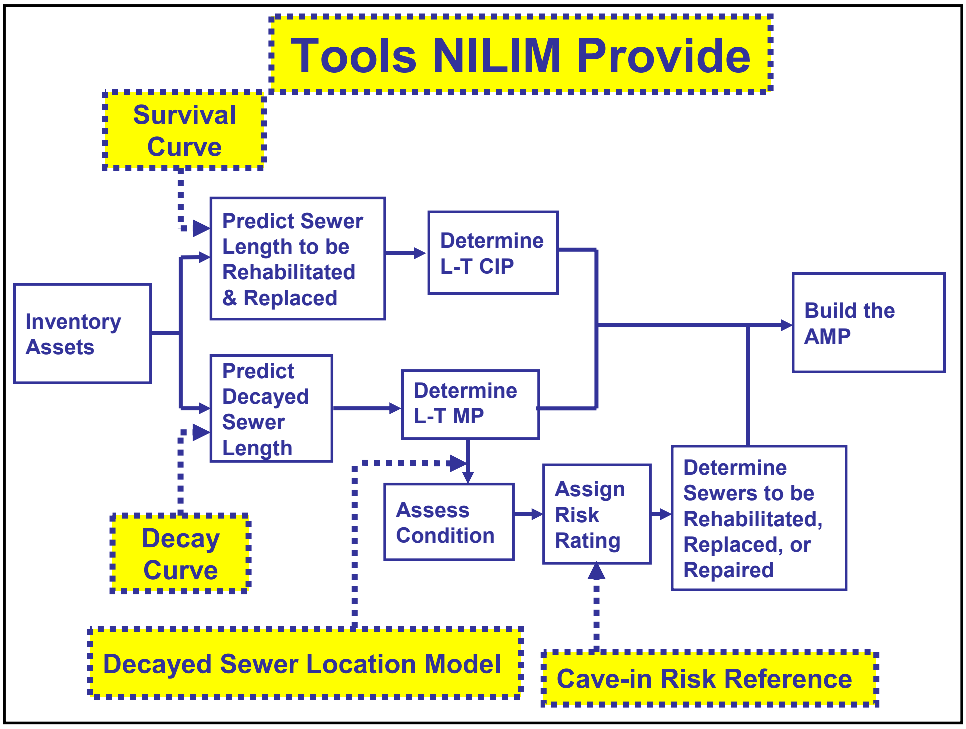
(Problem-3 of Conventional AMP)

- Most sewers are small & needs CCTV.
- Picture qualities of now, past, future different.
- Comparing between different times is misleading.
- Interpretation tend to differ from person to person.
- Time series analysis is questionable

- Frequency (CCTV + eye) is once/over 30 years.

Proposal on Process





Contents

1. Current Issues
2. Proposed Sewer Management
3. **Survival Curve**
4. NILIM Research Projects Underway

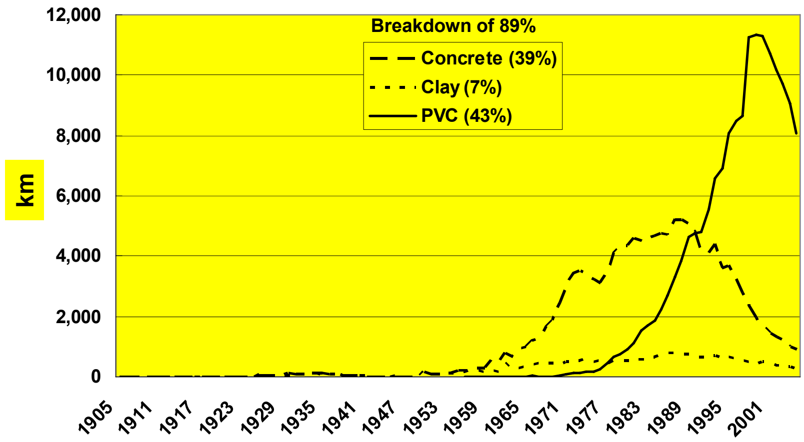
Survival Curve -Method

- Similar to Human Life Expectancy Calculation
- Unique approach as far as we know

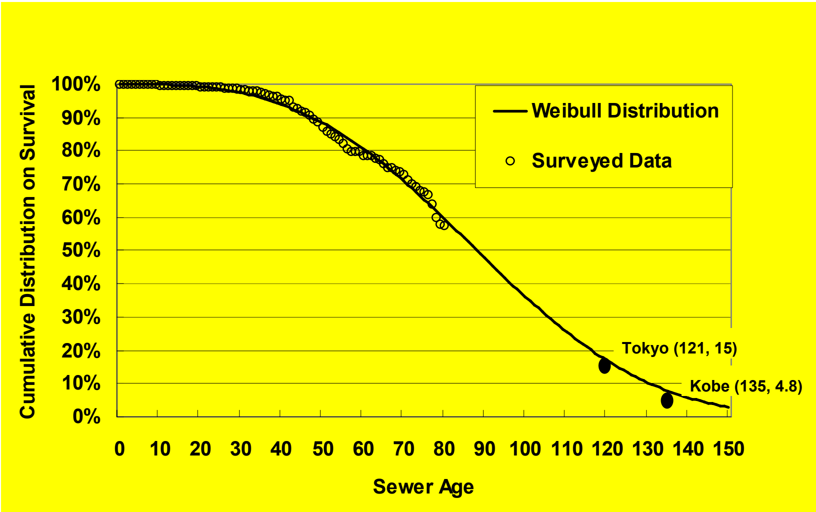
- Data
  - Questionnaire Survey to All
  - Death & Survival Lengths during FY 2005
  - Concrete, Clay & PVC chosen
  - Death means getting rehabilitated/replaced
  - R/R sewers get 50 year of new life

- Analysis
  - 2-parameter Weibull Distribution
  - 342,290 km, 89% of all, 383,031km, analyzed

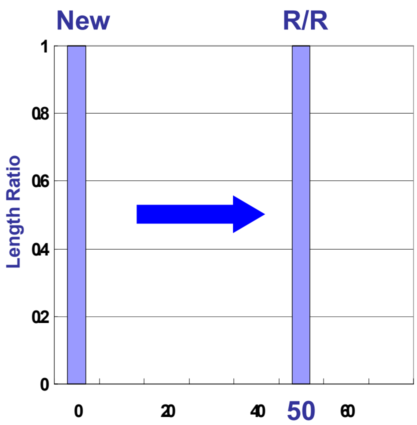
Sewer Material by Age

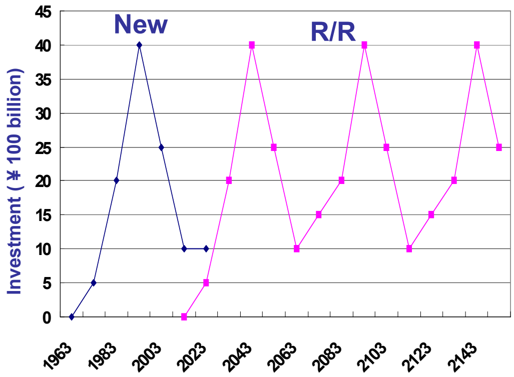


Survival Curve -Result



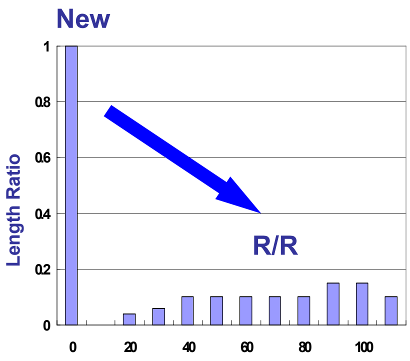
Benefits of the Curve

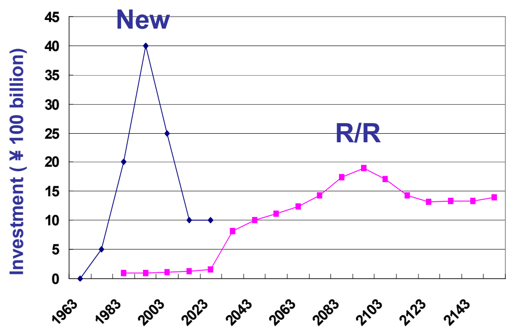




- Current L-T CIP: Every 50 years, sewers get R/R.
- No data. Expected lifetime in accounting used.
- CIP not Justified.

Benefits of the Curve





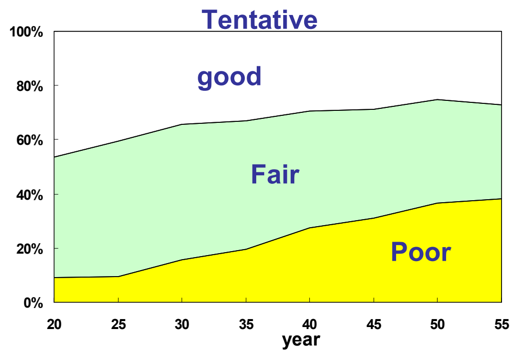
- ➢Sewer Lifetime distributes, not fixed.
- ➢R/R cycle on statistical life data analysis.
- ➢CIP Reasonable & Justifiable.

Contents

1. Current Issues
2. Proposed Sewer Management
3. Survival Curve
4. **NILIM Research Projects Underway**

Decay Curve

- DC useful for LTMP. Now collecting data from LGs.
- Assessment protocols differ among LGs.
- Data integration for application to most situations.
- Analyzing integration possibility.
- Applying different protocols to same CCTV pictures.



Decayed Sewer Location Model

- Sewer spans numerous. Assessment needs efficiency.
- Where to assess important.
- Model to predict where decayed sewer exists
- Statistical model with regression analysis employed.
- Dependent variable: results of condition assessment.
- Independent variables: age, diameter, material, etc
- Problem: inventory and condition stored separately.
- AM is not pervasive.
- Problem-2: integration of different protocol data.

(Condition) = f (Inventory Data; Age, Diameter, Material…)

Cave-In Risk

- Floods, back-ups, odors are risks too.
- Focus on cave-ins as it is life threatening.
- Damaged sewers neglected by budget lack
- Need to prioritize which sewers addressed first
- Prioritization based on criticality/risk
- Our research helpful for LGs.

Loading Test for Aged Sewers

Cave-in Risk Reference -1

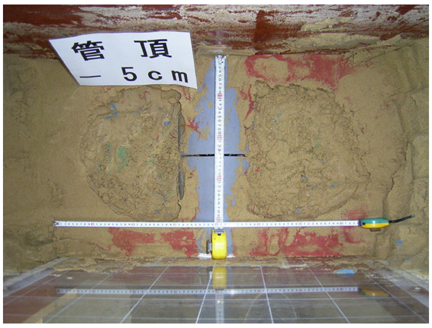
An aged sewer being removed for replacement

- Currently, collecting aged sewers
- Appearance & remaining strength will be studied

Experiment on Soil Infiltration

Cave-in Risk Reference -2

Soil Infiltration & Cave-in



Loosened soil on both sides of crack

- Low chances for ruptured sewers to cause cave-ins
- High chances for dislocation/openings to cave-ins
- Soil infiltration leads to cave-ins
- Intended to know the possibility of cave-ins
- Parameters: Backfill soil, openings, groundwater level

For better sewer management

- Long term planning
  - Downsizing policy restricts LTP.
  - LTP needed to spend wisely.
  - 10 to 20 planning norm US, Australia, New Zealand.

- Risk Based Management
  - Risk not considered schematically, but with intuition.
  - Sewer mains and laterals might be handled equally.
  - Avoid catastrophes while allowing inconveniences.
  - Thanks to USEPA trainings course & Mr. Albee.

Thank you!