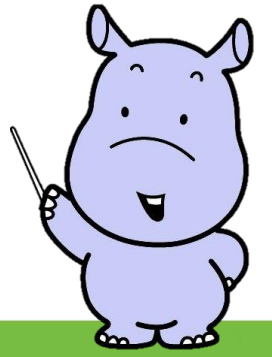
weftec 18
the water quality event™

JOIN THE REGENERATION

TECHNICAL SESSION

Approaches to Practical Sewer Pipe Inspection Technology Using Drones, Based on Public-Private-Academic Partnership

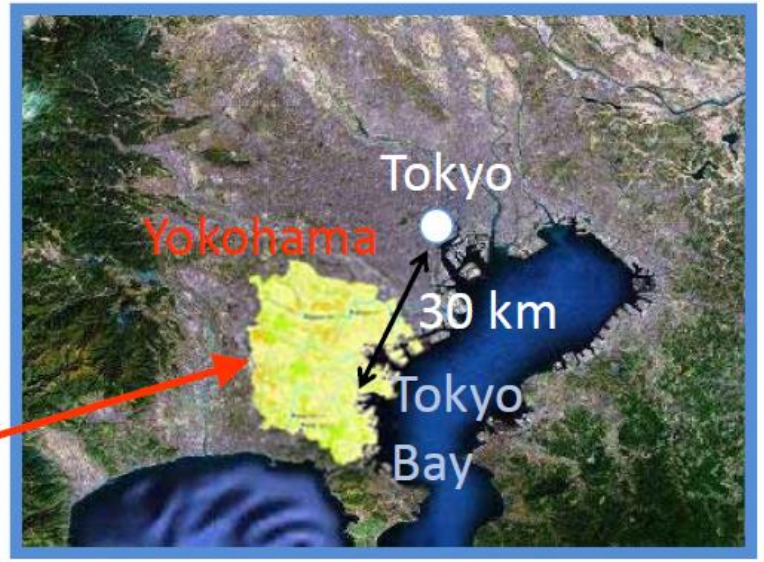
Masato Yasuda
Sewer Management Division,
Environmental Planning Bureau,
City of Yokohama



Flow of Today's Presentation

1. Current state of Sewer System Inspections in Yokohama city
2. Research Overview
3. Results and Conclusions
4. Future Plans

Outline of Yokohama



City Information	
Area	435km^2
Population	3.7milion
Sewer Coverage	99.9%

Yokohama Major Sewer System

✔Massive Number of the Sewer Assets

= 11,900km

Total Sewer Length

- 10,000 km
  - →Φ < 800 mm (small diameter)
- 1,900 km
  - →800 mm ≤ Φ (mid/large diameter)

× 530,000

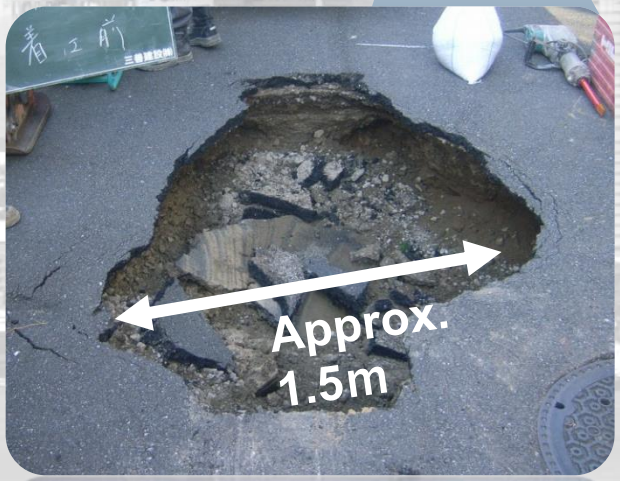
Manholes

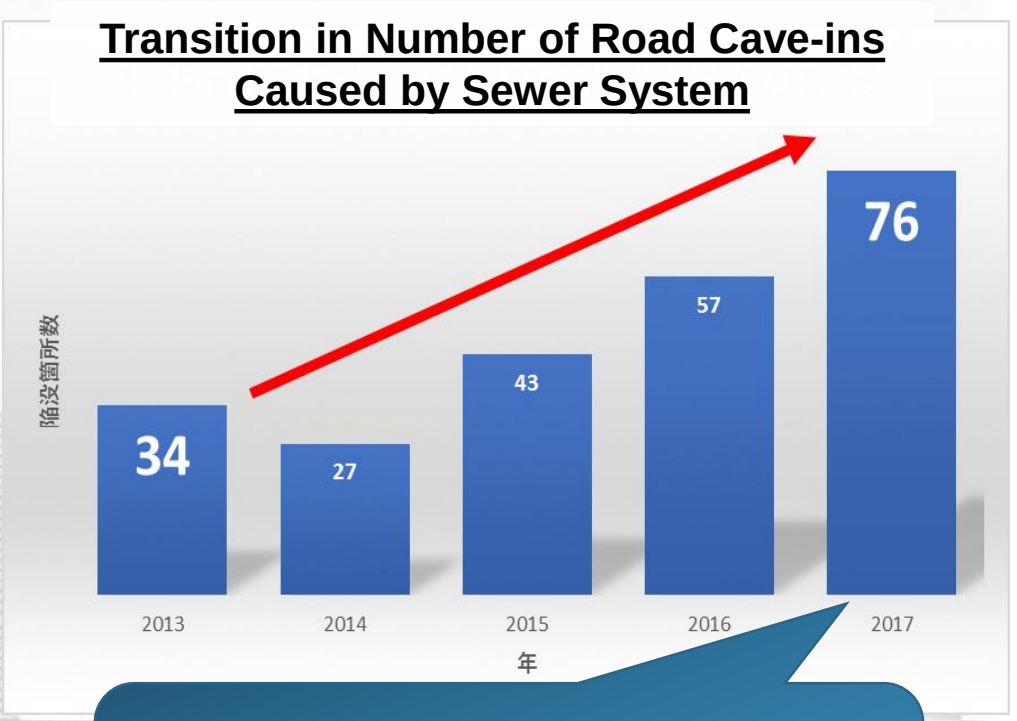
Transition in Number of Road Cave-ins Caused by Sewer System

Failures

Reinforcing steel exposed

Road sinkhole



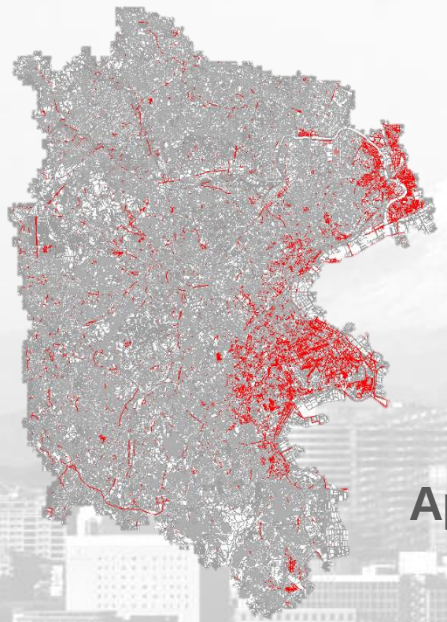


Number of Cave-ins are increasing.
The number doubled in four years!

Sewer Pipe Ageing

- **Sewer pipe ageing will progress rapidly**

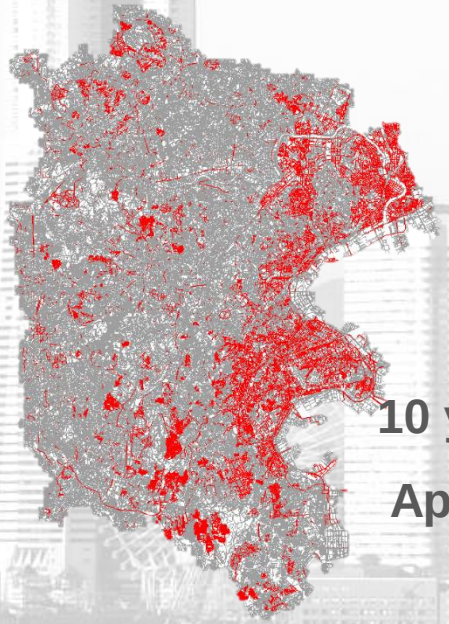
  → Effective planning, inspections, screenings and renovations are required.



At present

Approx. 800 km

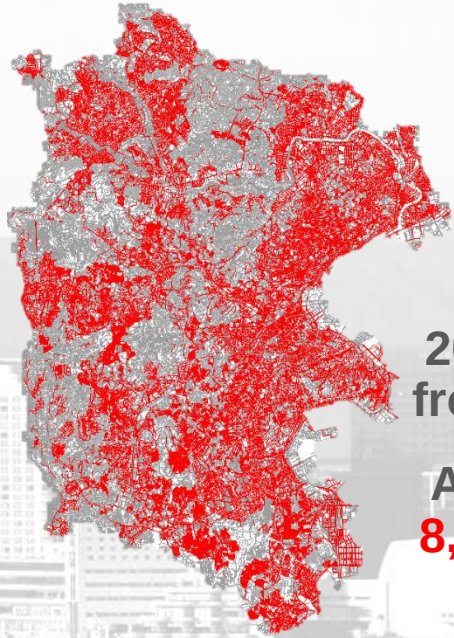
Approx. 7%



10 years from now

Approx. 2,800 km

Approx. 25%



20 years from now

Approx. 8,000 km

Approx. 67%

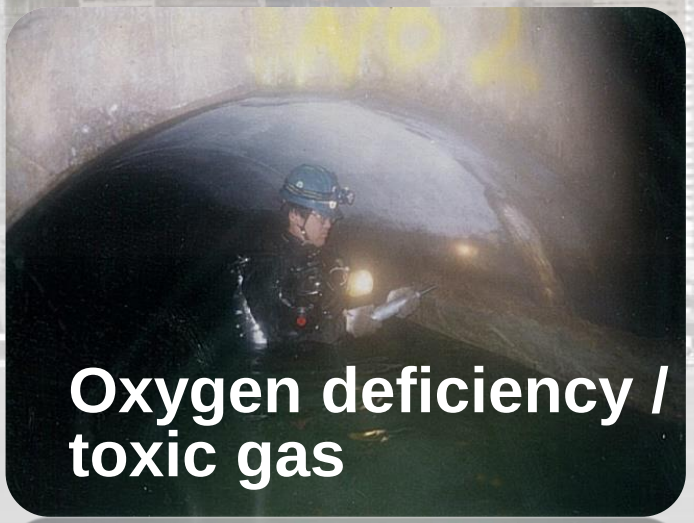
Distribution map showing over-50-yrs old pipes in Yokohama city

Screening/Inspection/Renovation Work Flow

✔Mid-to-large-diameter Pipes not Being Screened

Φ < 800 mm	800 mm ≤ Φ
Screening [Nozzle camera]	Screening [Not been implemented]
Detailed Inspection [CCTV]	Detailed Inspection [Mid-to-large sized CCTV, visual inspection]
Repair/Renovation	Repair/Renovation

Difficult-to-Inspect Medium-to-Large Diameter Pipes



✔Some medium-to-large diameter pipes are difficult to inspect

Issues in Inspections of Medium-to-Large Diameter Pipes

1. Screening for Establishing a More Efficient Inspection System

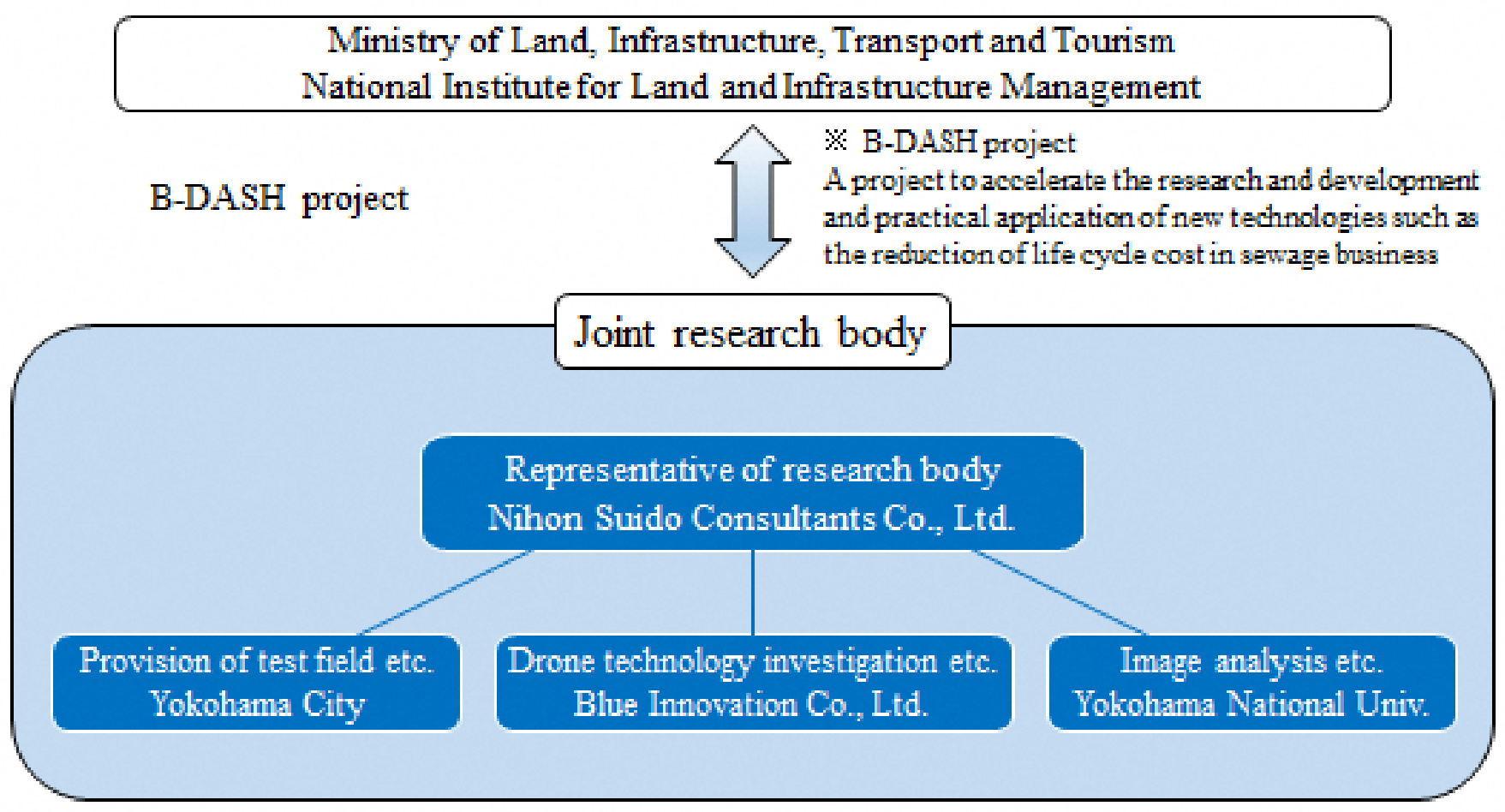
2. Inspecting Difficult-to-Inspect Pipelines

Using New Technology - Drones

- Developing an inspection method beyond the concept of conventional technologies.
- Almost no precedent in Japan.

The formation of a new research system
Public-Private-Academic Partnership

✔Division of roles to get the most from private, academic and public sectors

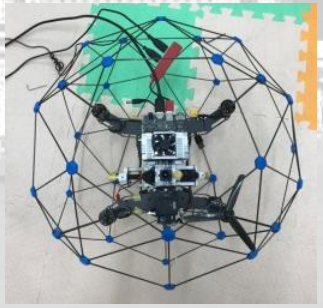


Drone Flight Types

- **Manual**
  - Operators control a drone with direct visual contact
  - Operators watch the monitor to control a drone
    - Customized from the commercial model




- **Automatic** → Thanks to the sensors mounted on a drone, Automatic flight is available.
  - Our originally developed drone



Inspection Accuracy

- Screening → Identify the existence of A or B
- Detailed Inspection → Evaluate the rank (A-C) quantitatively

Judgment item	Rank A	Rank B	Rank C
Pipe crack	Crack- width 5mm or more	Crack- width 2mm or more	Crack- width less than 2mm
Sagging	1/4 or more of inner-diameter	1/8 or more of inner-diameter	Less than 1/8 of inner-diameter
Infiltration	High	Moderate	Low

Issues Confronting Practical Application of Drones

- Non-GPS environments
- Darkness
- Sewer flows
- Confined spaces
- Carry-in of equipment though manholes
- Cost

Drone Flight Validation Tests

✔Flight Tested Under Various Conditions

Diameter	1,500 mm - 3,000 mm
shape	Circular or square
Line	Straight or curved
Water flow	Yes/No
Models tested	Five
Accessories mounted	Yes / No

Table of Flight Validation Test Results

1 .Long-distance stable flight

2 .Difficult-to-inspect pipeline

Classification	Manual flight		
Diameter	Φ2000	Φ3000	
Sewer type	Rainwater pipe	Rainwater pipe	Combined sewer
Line	Curve	Curve	Strait
Water flow	No	No	Yes(30cm)
Flight record	540m One way	500m One way	45m Round trip

Flight validation Experiment Video (1/2)

✔Confirming Long-distance Stable Flight

Flight validation Experiment Video (2/2)

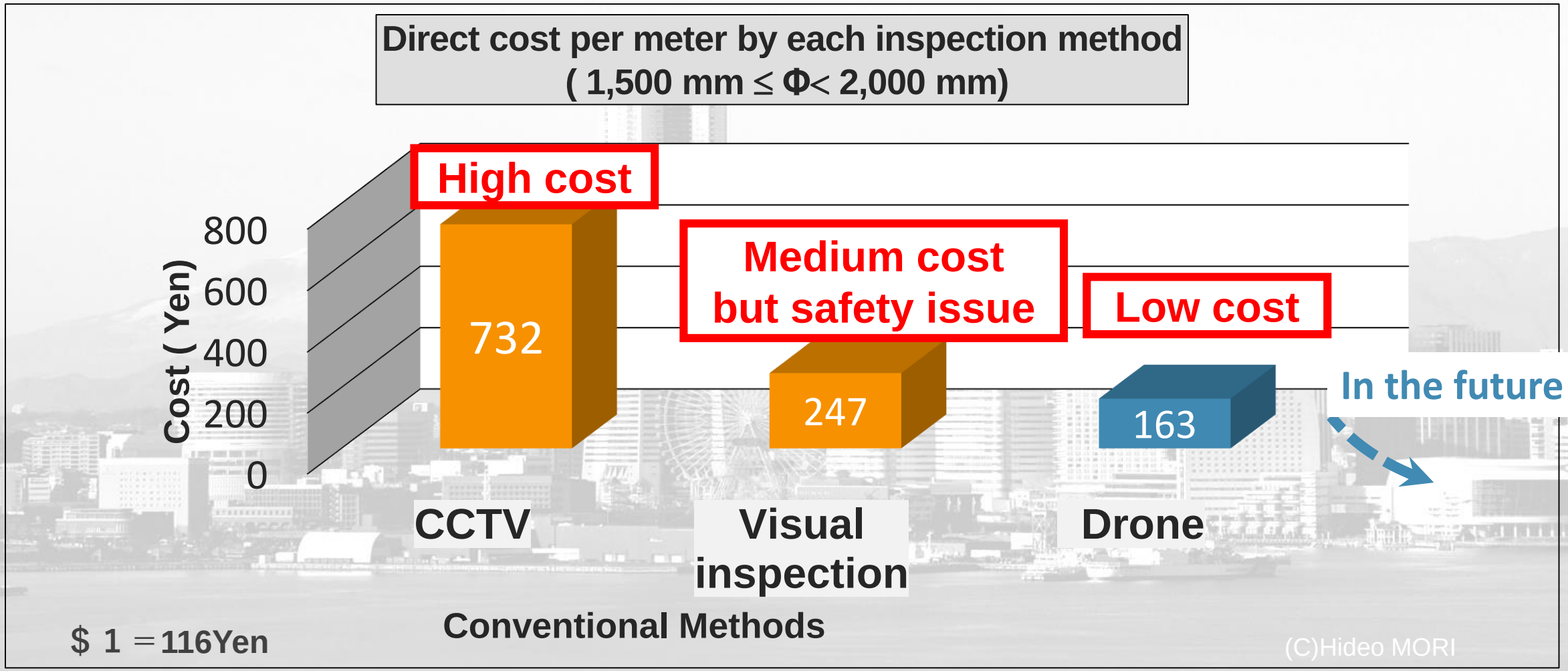
✔Confirming Stable Flight in Difficult-to-inspect Pipeline (Rapid Flow)

Video from drone camera

Video from starting point

Cost Comparison

✔Estimates show inspection cost to be approximately 2/3 of inspections using conventional technology



Results and Issues Obtained from Tests

- **Results obtained**
  - ✔Flight was stable in pipes Φ1,800 mm - Φ3,000 mm
  - ✔Judging abnormalities was accurate
  - ✔Cost was 2/3 of the conventional inspection
- **Issues raised**
  - ✔Waterproofing was insufficient
  - ✔Operator’s capability affected the performance
  - ✔Machine body was not stable due to reflection wind

Conclusion

1. Screening to Establish a More Efficient Inspection System

→ Manual flight-mode is effective

2. Inspecting Difficult-to-Inspect Pipelines

→Inspections available under certain conditions (space, reflection wind, etc.)

Future Plans

- **Short-term plans**

	Manual Flight	Automatic Flight
2018	Test flights in pipe	Improve mounted sensors
2019	**Practical application (Pipe-screening)**	Test flight in actual pipe
2020		Achieve independent flight across one span

- **Long-term plans**

  Complete automatic flight while judging failures at the same time.

  Automated Decision-maiking on repairs by utilizing AI.

OPEN
YOKOHAMA

Thank you for listening!!

Thank you for your kind attention

Nihon Suido Consultants.,Ltd.
Blue Innovation.,Ltd.
Yokohama National Univ.

Masato Yasuda