Digital Twin as Circularity Enabler of Façades in Maintenance

A Research into How A Digital Twin Can Facilitate the Circularity Maintenance of Façades

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Rijksvastgoedbedrijf
Ministerie van Binnenlandse Zaken en Koninkrijksrelaties

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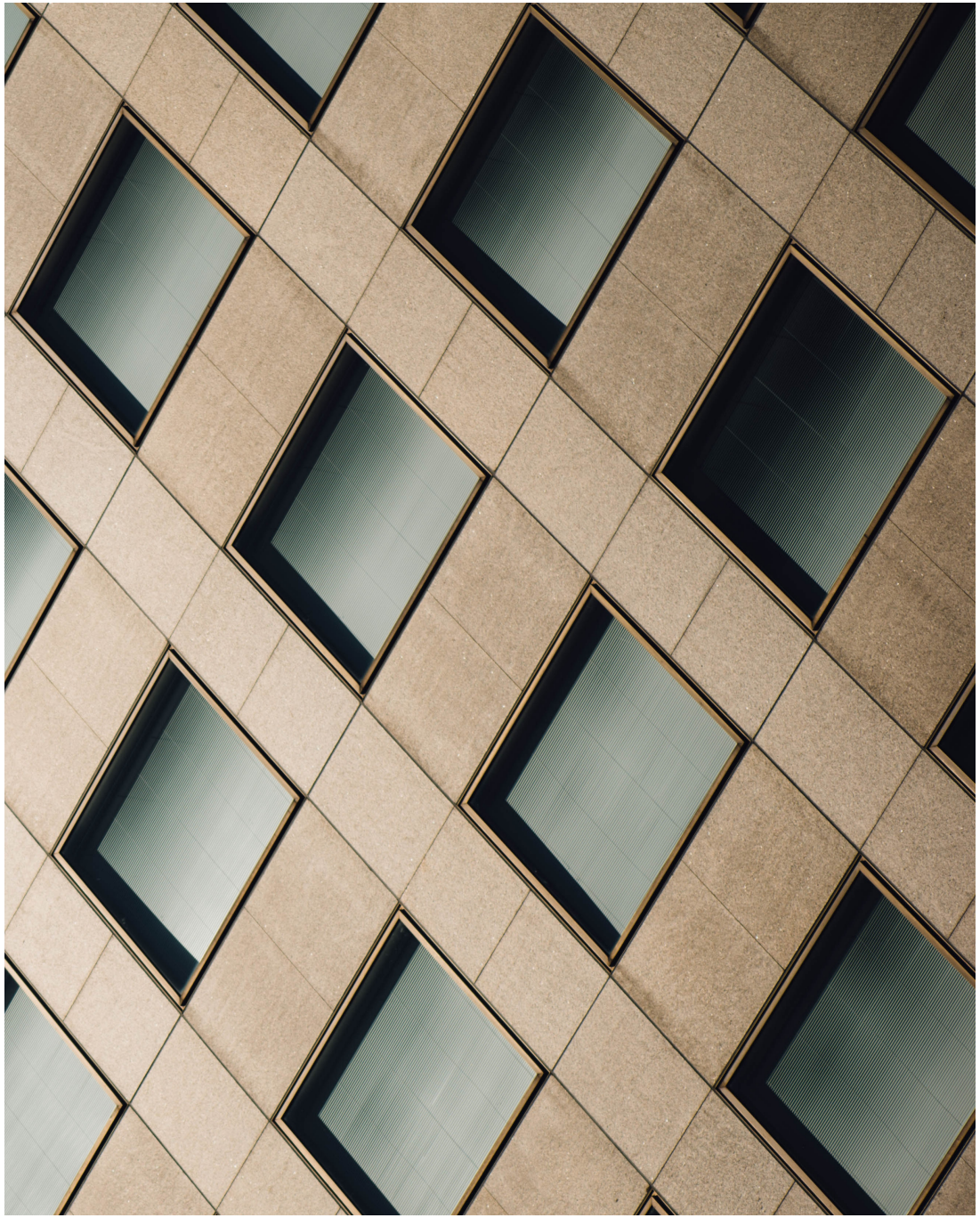

Part **1**

Introduction

Introduction

- Design phase, construction phase and maintenance phase
- 75-80% of the total costs occur during maintenance
- Complex: Maintenance deals with a variety of people and information
- Maintenance affects:
    - Real estate value
    - Building safety
    - Sustainability: Building lifespan

Introduction

- Design phase, construction phase and maintenance phase
- 75-80% of the total costs occur during maintenance
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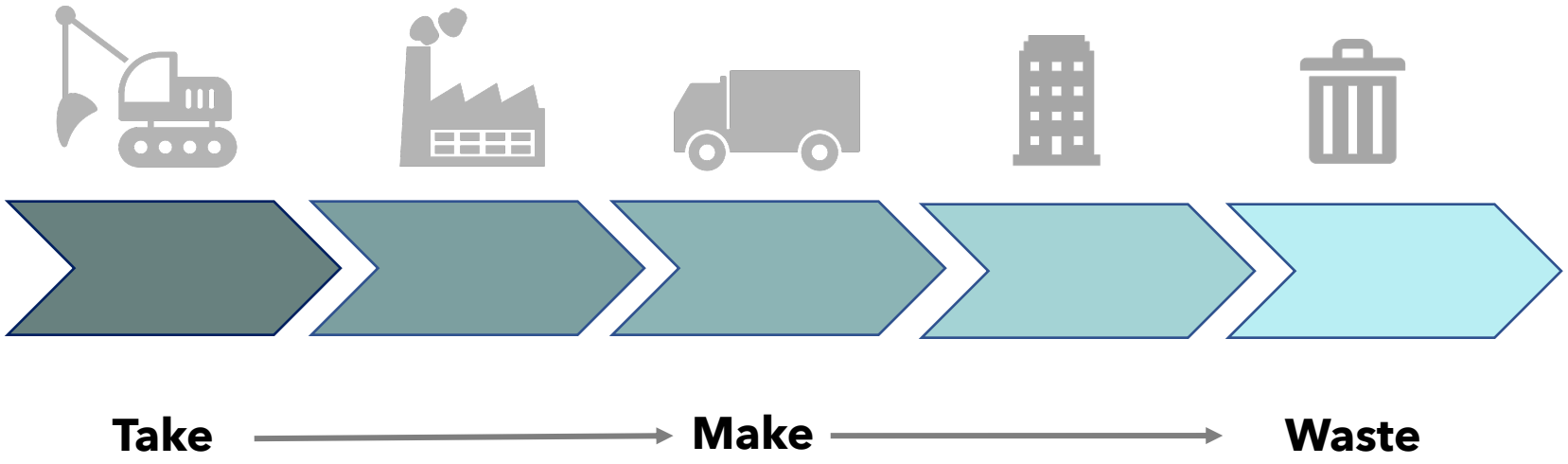
    - **Sustainability: Building lifespan**

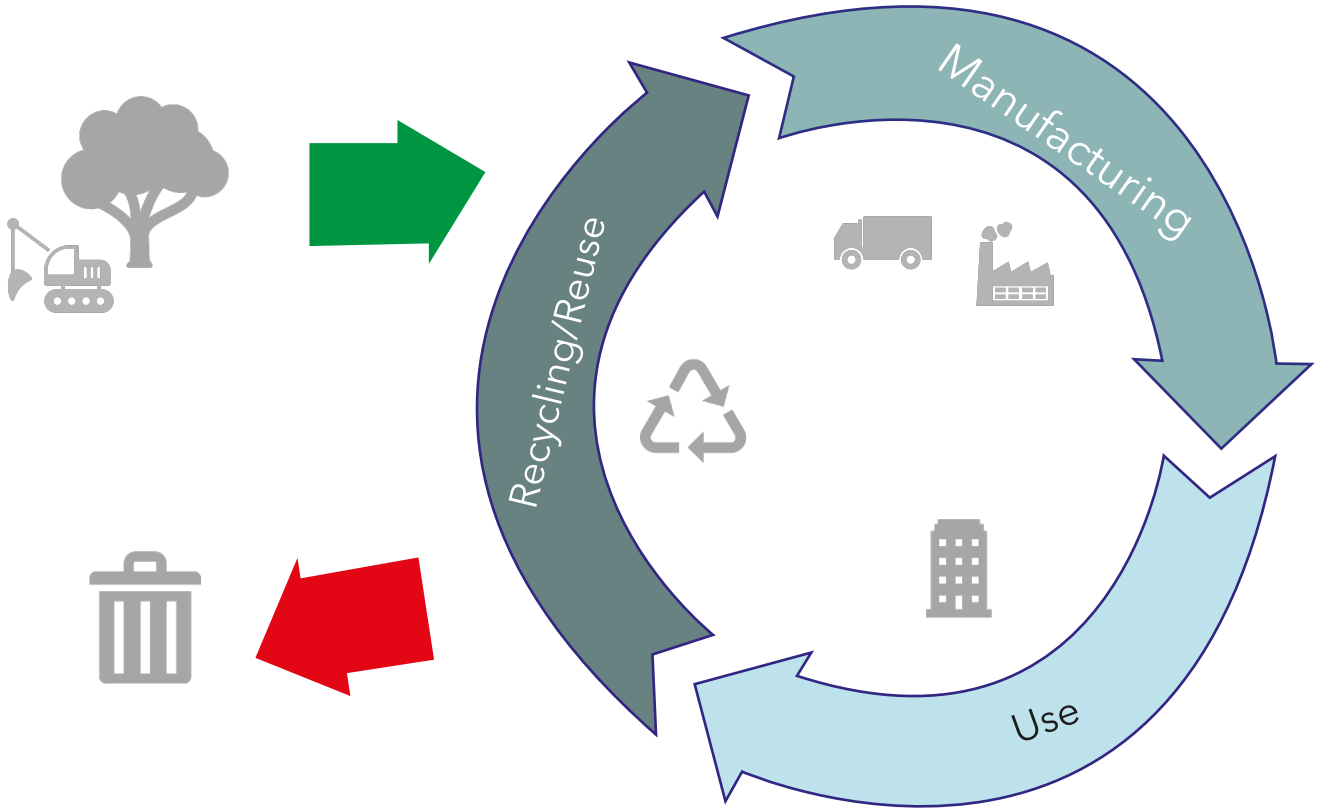
Linear Economy



Linear Economy

- 50% of all energy use
- 40% of all greenhouse gas emissions
- 50% of the materials going into the economy
- 30% of all water use

Circular Economy



In the **built environment**, the circular economy can be implemented on several levels:

- Site
- Structure
- Skin
- Services
- Space plan
- Stuff

(Brand, 1994)

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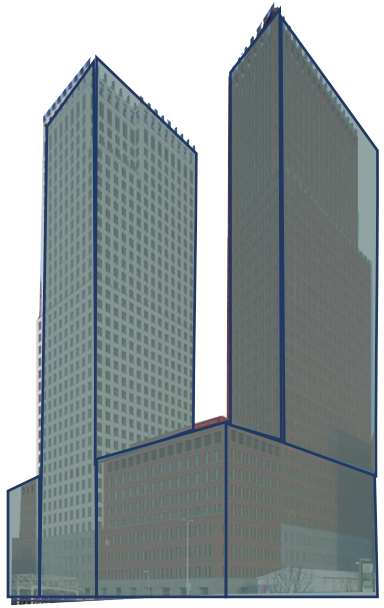


- Site
- Structure
- **Skin**
- Services
- Space plan
- Stuff

(Brand, 1994)

Circular skin or façades can stimulate the **energy efficiency** of a building in its use phase.

Also, it stimulates **resource efficiency** during construction, as less materials are necessary for production.

Circular façades are able to make an significant impact in both building phases

Adoption of circular façades in practice is infancy, **why**?

1) Low chance for reusability at end-of-life

2) Project complexity in circular projects due to a lack of information on condition quality

1) **Low Chance** for Reusability

Maintenance:
A façade is generally designed and **maintainted** for a lifetime of **30-50 years**

The façades' quality is **exposed the most** to external hazards

Practical:
Material **choice** and **demountability**

2) Project Complexity

During maintenance:

In- and outflow of large amount of data
- Components
- Technical specifications
- Connections

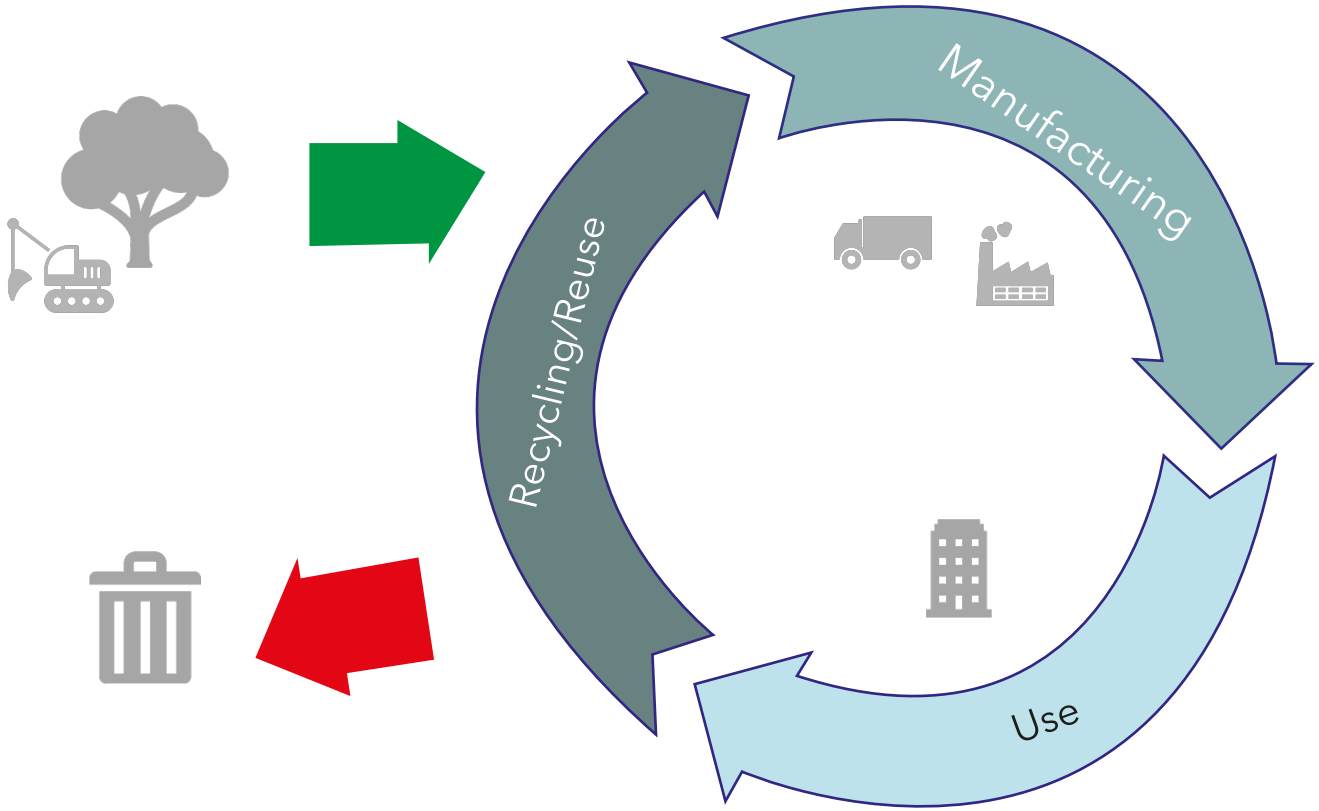
is in need of **management**, **digitization** and **automization**

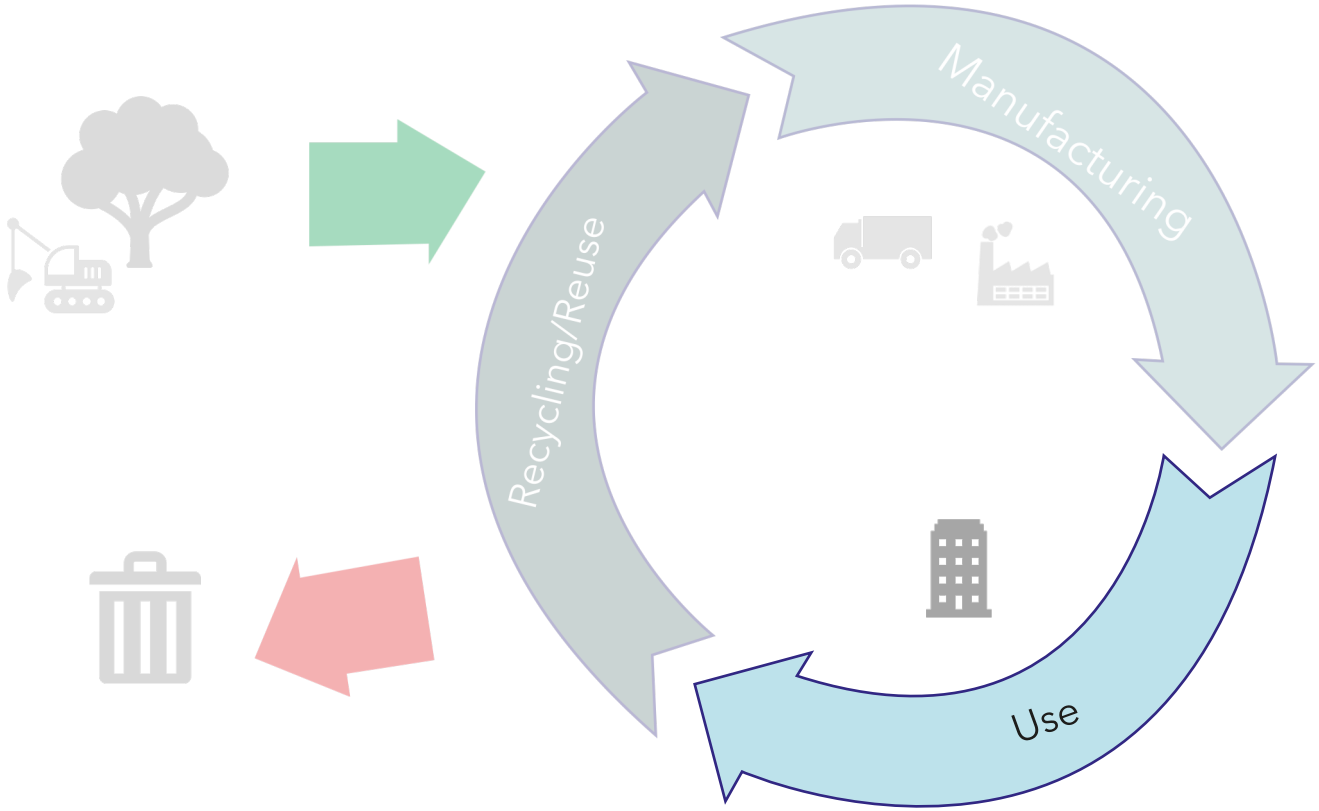
Poor tracking of condition quality

Problem **Statement**

The problem is that the development of circular façades is still **infancy.**

The condition quality at end-of-life is low or uncertain. Due to errors in a **maintenance system** by **poor keeping track** of information.


Manufacturing
Use
Recycling/Reuse


Manufacturing
Recycling/Reuse
Use

What is **necessary** to stimulate façade circularity?

1) As the façade is exposed the most to phycisal wear. Systematic **maintenance** is key in this situation.

2) **Digitization of** information on condition

1) **Circular** maintenance

System which aims to **extend** the elements' lifecycle

By **timely** maintenance, repair and restoration, large renovations and restorations are **prevented**

Aiming to prepare a façade for a **second life**

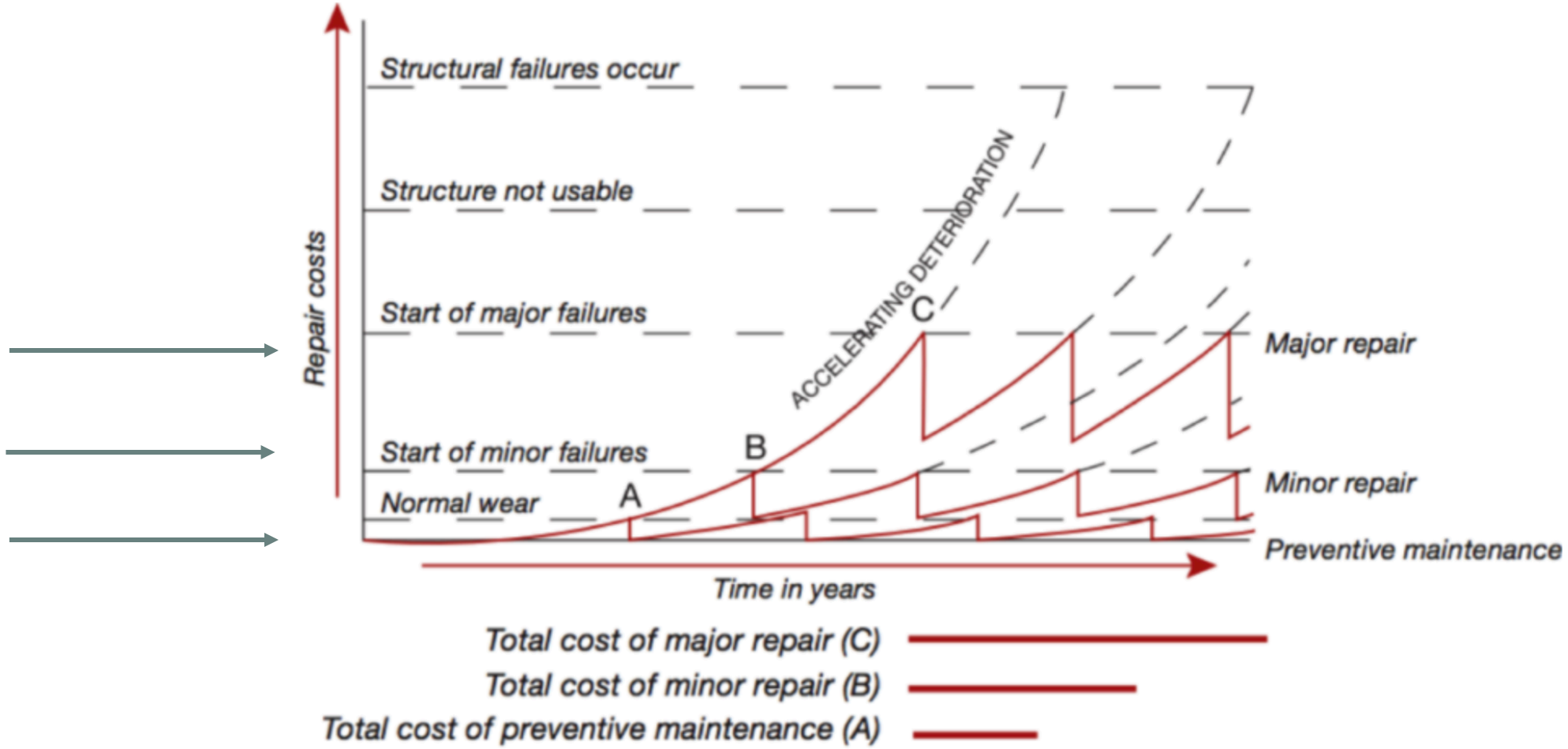
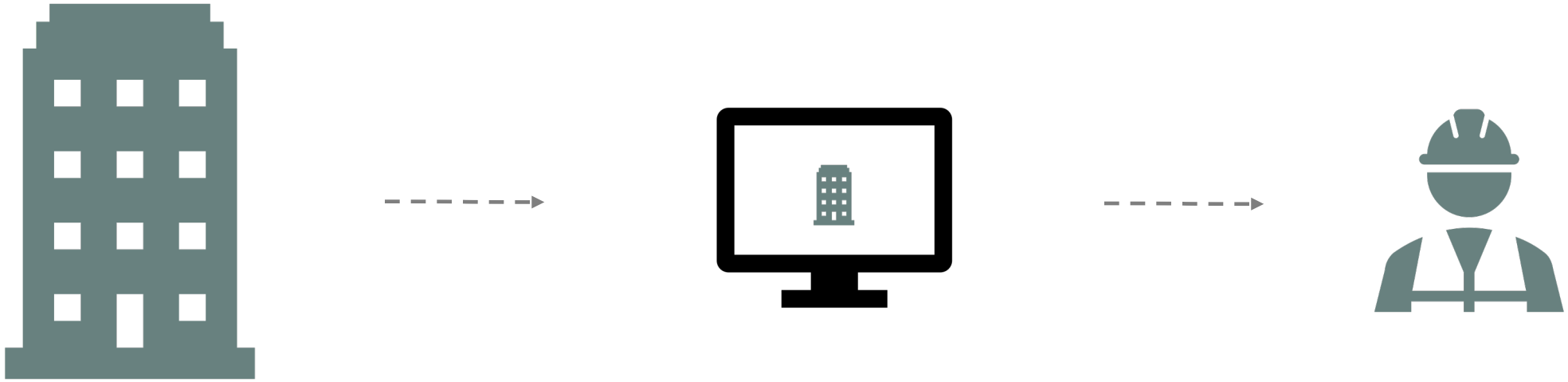


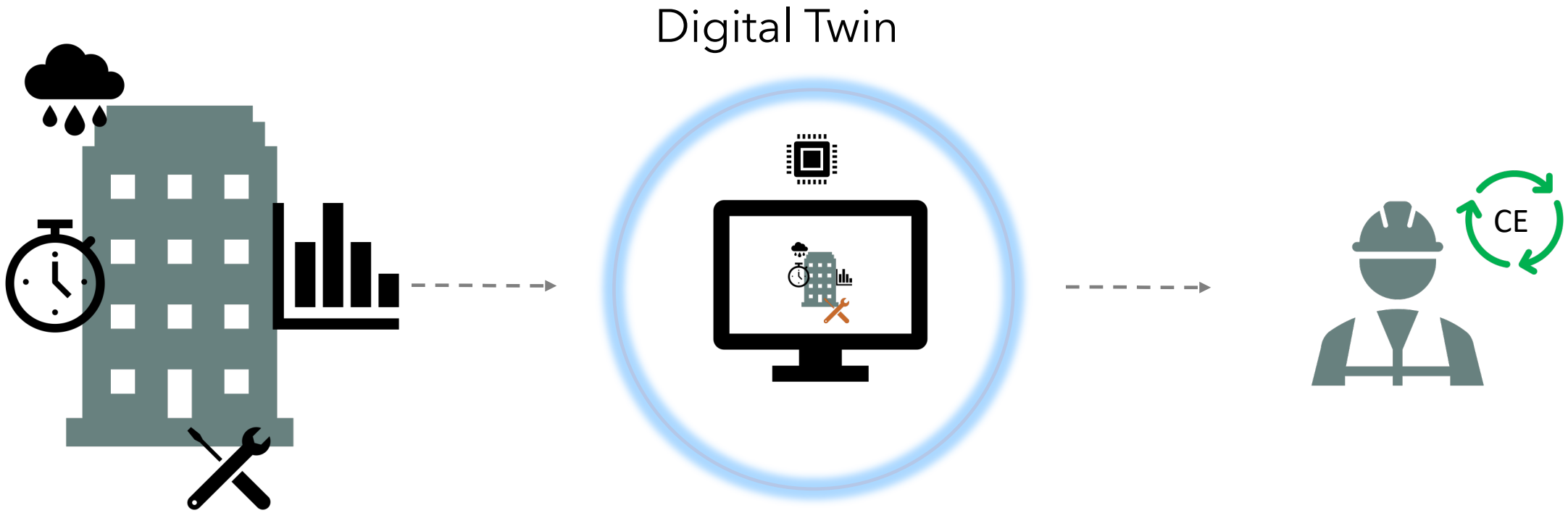
Diagram from Preventive Maintenance of Buildings, Van Nostrand Reinhold, New York, 1991.

2) **Digitization** of Information

BIM model



2) **Digitization** of Information



Digital twin

Virtual replica of the physical object

Consisting of **real-time condition data** measured by **sensors**

Data is collected in the cloud **and transformed into readable data,** to derive a **living simulation** of the physical object

Data analysis updates traditional maintenance plans and optimizes the **operation** of the object

Scope

- Use phase
- Building owner
- Maintenance process
- Condition quality
- Digital twin

Main **Question**

*How to facilitate **façade circularity** in **maintenance** using a Digital Twin?*

Sub-**Questions**

Desired future

1. *What are current goals of buildings owners with respect to circular maintenance and condition of facades?*

Sub-**Questions**

Existing situation

2. Which data is available on a facade's composition?

3. What is the current state of information management concerning façades?

4. Which data is available and necessary to map the condition of façades?

Sub-**Questions**

Recommended additions

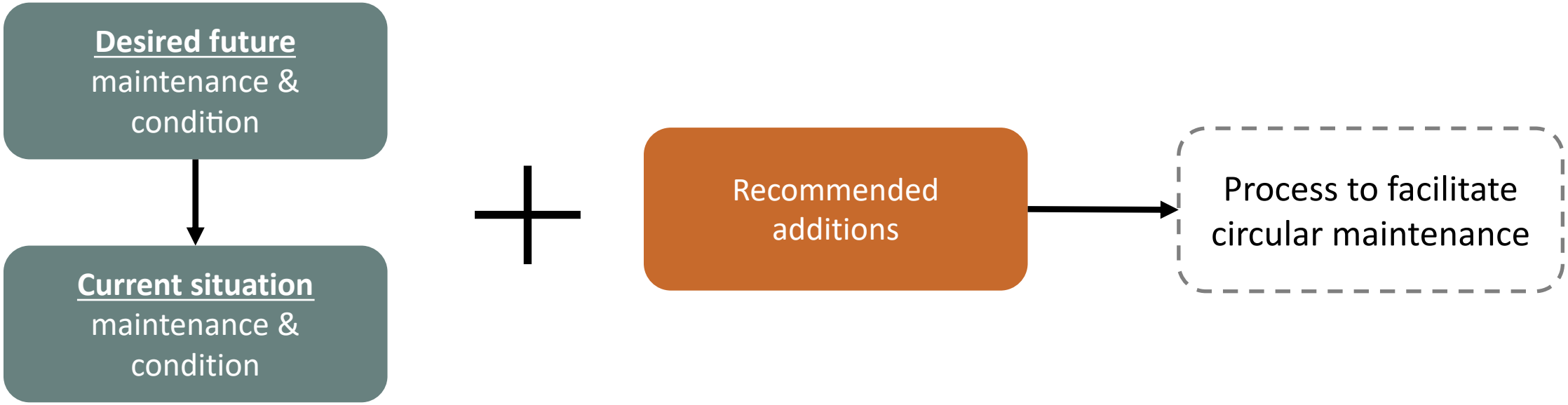
5. How to translate the minimum required data into a Digital Twin

Sub-**Questions**

Process to achieve circular maintenance

6. How can the Digital Twin assist the circular maintenance management of the façade?

Research **Structure**



Research **Aims**

- Informing building owners on how they can **address façade circularity**
  - Stimulating **efficiency** in **maintenance**

Background Information

Existing situation

Literature **Study**

- Started with collecting sufficient information on building elements' performance
  - Technical information
  - The most renowned anomalies and threats

- Supplement this with detailed inspections

Literature **Study**

Maintenance issues

- Maintenance is performed based on standard degradation models

- Physical intervention and poor information capture

- BIM lacks a real time view on the buildings' condition

Literature **Study**

Necessary to

- Bridge the gap between operations and data
- Digital measures require management

Main **topics**

- Façade condition
- Maintenance process
- Information capture

Part **2**

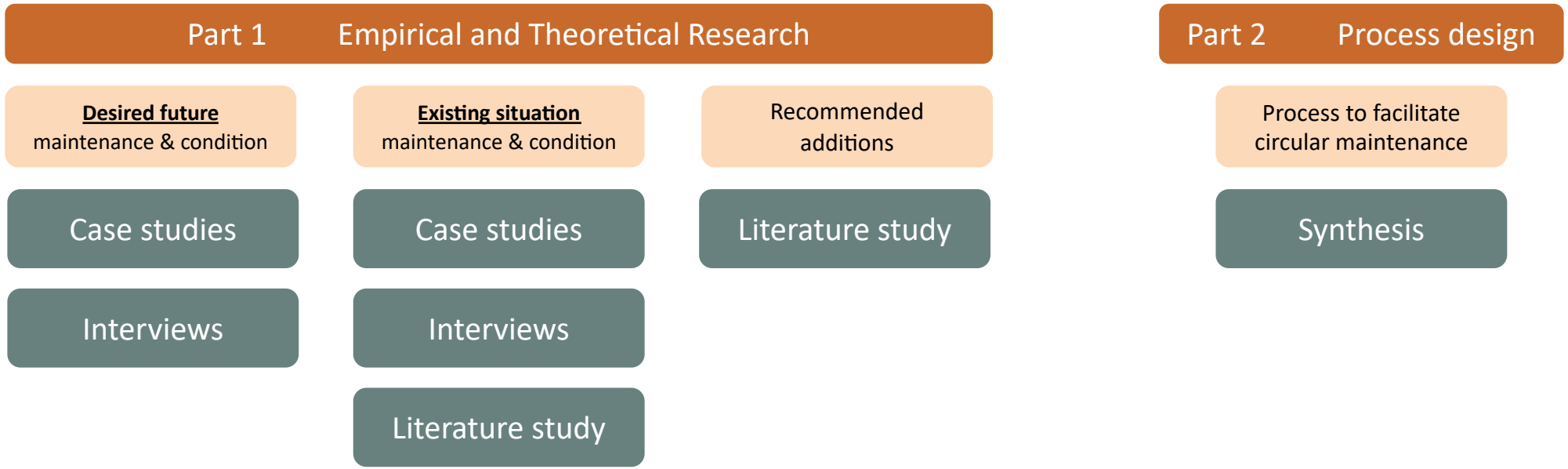
Research Methods

Research **Focus**

- Investigating a management issue

- Taking the **existing situation** and designing an **additional dimension** to it.

Research **Design**



Empirical research

Explored **Case Studies**

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Case study and semi structured interviews **goals**

- To understand the existing **maintenance process**
- To derive **issues** in the existing maintenance process
- To discover the existing situation and goals in **façade condition**
- To discover the **situation** and **issues** in **information capture**

Description **Case Study 1**

Rijksvastgoedbedrijf
Ministerie van Binnenlandse Zaken en Koninkrijksrelaties

JuBi towers

- Office building
- Delivered in 2012
- 147 meters
- 130.000 square meters
- 4000 workspaces
- Description façade

Desired future

- Maintenance free façade
- Compliance with building law
- Provide comfort for building activity

Existing situation

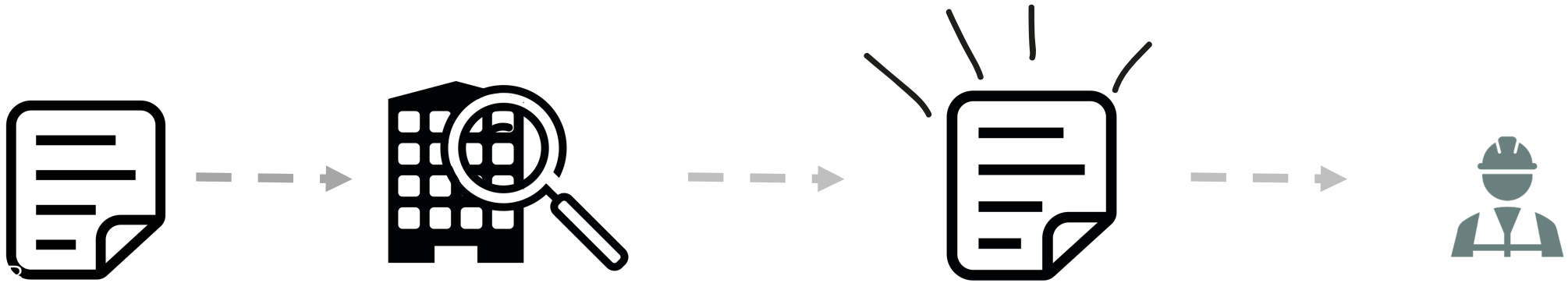
Sustainable materials, however:

- Crumbling bricks
- Cracks

Causing safety issues

Façade condition **Maintenance process** Information capture

Existing situation



Introduction Research Methods Findings Conclusion Discussion

Façade condition **Maintenance process** Information capture

Barriers

- **Large** façade
- **Visual** inspections
- Inspections are based on **standard models**
- Issues in **capturing** defect
- **Overlooking** defects

Façade condition Maintenance process **Information capture**

Existing situation

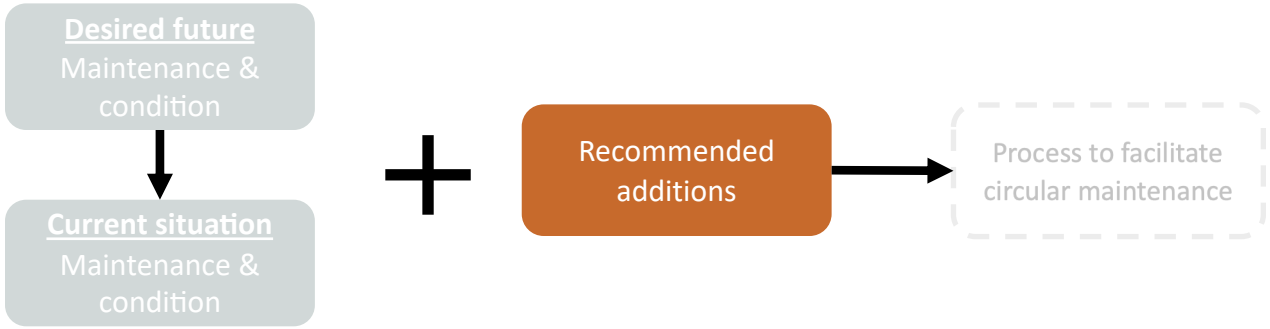
- **Inspections** are implemented in computer system
- **Technical specifications** are implemented in computer system
- High quality BIM

Barriers

- **Unclear description** of defects in inspection reports
- Not a clear image of **total** defects
- **Human error** in signing-out defects in computer system

Case 2 & 3

Theoretical Research



Goal

- To derive a suitable **technological alternative** to current inspection method

- Determine the **influence** on the existing maintenance process

Definition **sensors**

- Sensors consist of a **sending** and **receiving** element
- Measure **parameters** like vibration, water, temperature

- **Combination** of sensors can derive several insights
- Can provide evidence for defect characteristics

Recommended **Additions** Case 1

	Main building defects	Detection technology	Advantages	Challenges	Circularity
Existing situation	1) Crumbling bricks 2) Cracks		Clear and tangible method	Subject to errors	Maintenance when planned
Recommended additions		1) Infrared thermography 2) Piezo-electric sensors	1) Quick detection 2) Sensitive, location accurate	- Complex method -Sensors also need maintenance -Circularity effects	Can provide maintenance when necessary

Part **3**

Findings

Findings


Realtime versus planned inspections
Data needs a clear purpose
Decrease human intervention where possible
Clearly assigned tasks
Educated employees
Start with a strong foundation

Findings

- Compared to realtime inspections, planned inspections leave room for deterioration

Real time inspections…

- ..Can provide evidence on defects characteristics
- ..Can provide data for predictive maintenance

Findings

- To increase the value and utility of the data, it needs to have a clear purpose

This means:

- Parameters need to be carefully chosen
- Sensors need to be chosen carefully

Findings

- Human error is the contaminator of the computer system
- Human inspection can lead to lenghty procedures
- However, human intervention is necessary to analyse and anticipate situations

Findings

Several new tasks need to be clearly allocated

- Data needs to be **connected** to BIM
- Sensor data needs to be **stored**
- Sensor data needs to be **analyzed**
- **Feedback** to the system after repair

Findings

- Actors should **understand** the measurements
- **All actors involved** with maintenance should understand the process to provide input

Findings

- Circular maintenance can only succeed if the process **is well-prepared upfront**
- **Demountable** façade
- Sustainable materials
- **Detailed information** must be requested on maintenance needs, degradation time

Validation

Usability

- Process needs to be guided to avoid pitfalls
- Attract the right people
- Create new departments for data

Phasing

- New buildings rather than existing buildings
- Start with a single building rather than the entire portfolio
- Start with preparing for **future** implementation

Part **4**

Conclusion and Recommendations

Sub conclusion & synthesis

Sub-Conclusion & Synthesis

How can the Digital Twin assist the circular maintenance management of the façade?

Sub-Conclusion & Synthesis

Barriers to circular maintenance process

- Defects are subject to **interpretation**
- **Overlooking** defects
- Maintenance based on **standard models**
- **Human error** in the maintenance system

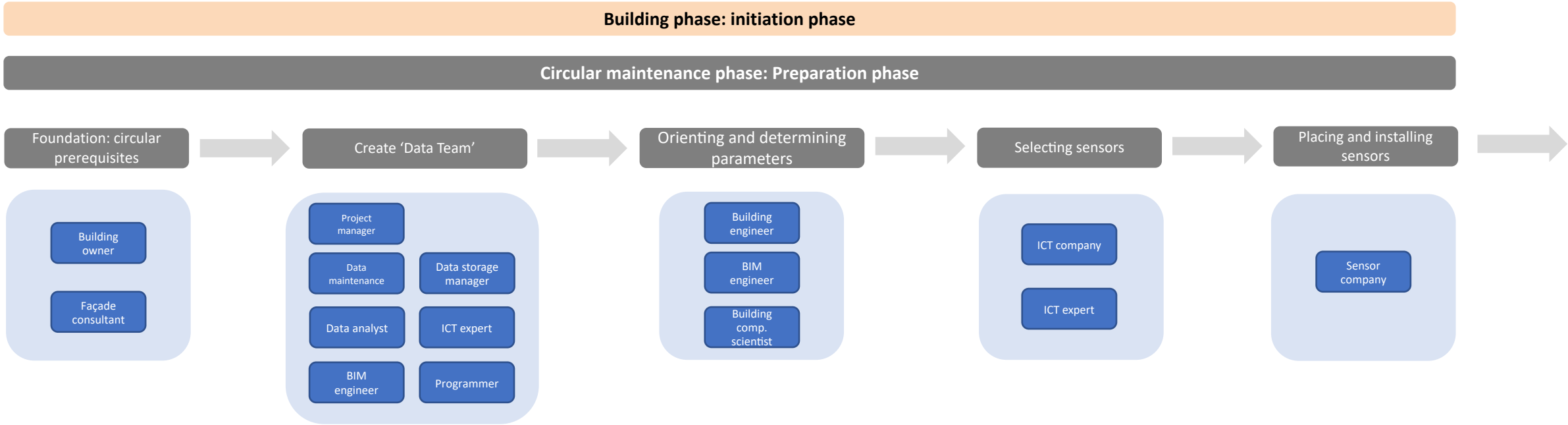
Sub- Conclusion & Synthesis

How can the DT facilitate this?

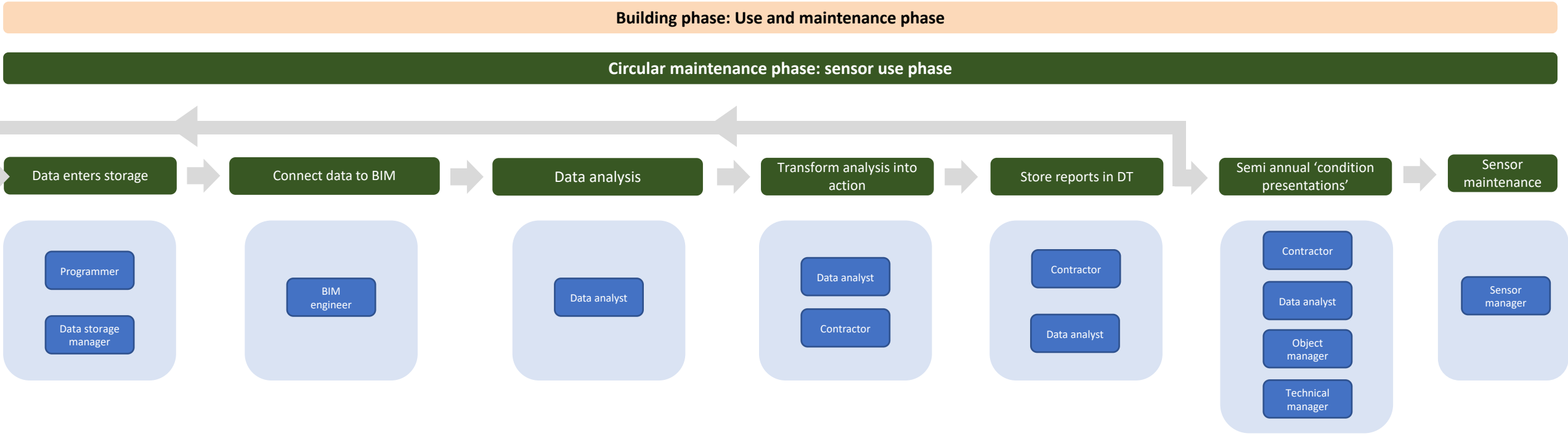
- By providing **strong evidence** on defect characteristics
- By exposing **all defects** on the façade
- Providing the chance to discover **connections** between defects
- Real-time updates pursues maintenance when **necessary** and pursues **preventive maintenance**

Conclusion and Recommendations

*How to facilitate **façade circularity** in **maintenance** using a Digital Twin?*



Conclusion and Recommendations



Introduction | Research Methods | Findings | Conclusion | Discussion

Recommendations

- Bring in a manager to **guide the process**
- **Retain** knowledgeable people
- **Emphasize the value** for the users
- Implementation in **new** buildings
- Consider interchangeability of sensors
  - Sensor and software **innovations**
  - **Broken** sensors
- Consider circularity of the sensors

Effect?

- Increased lifesecurity of façade elements
- Less pressure on the ecosystem
  - Resource efficiency
  - Energy efficiency
- Effective maintenance logistics

Part **5**

Discussion

Discussion

Limitations

- Case studies with limited sustainability characteristics
- Maintenance process of a single organisation
- Sensor literature review

Discussion

Future research

- Specific building type, building part or building size
- Influence on the construction sector
- Sensor circularity platform

Questions?

Brand, S. (1994). How Buildings learn. What happens after they’re built. 2nd Ed. London, UK: Phoenix Illustrated.