



# Towards a resilient hospital design

Emerging design considerations for  
future healthcare facilities after the  
different waves of COVID-19.

TU Delft  
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# Contents

**01**

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**Crisis overview**

**02**

---

**Background**

**03**

---

**Research design**

**04**

---

**General findings**

**05**

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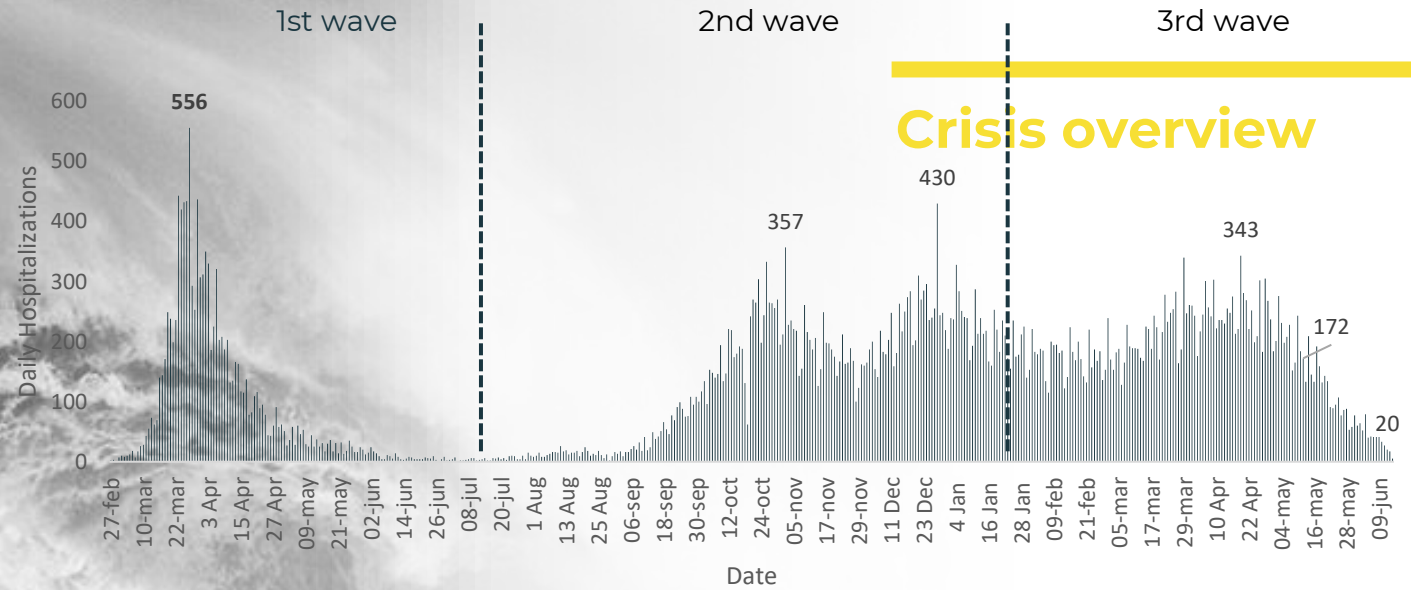
**Findings**

**06**

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**Recommendations**

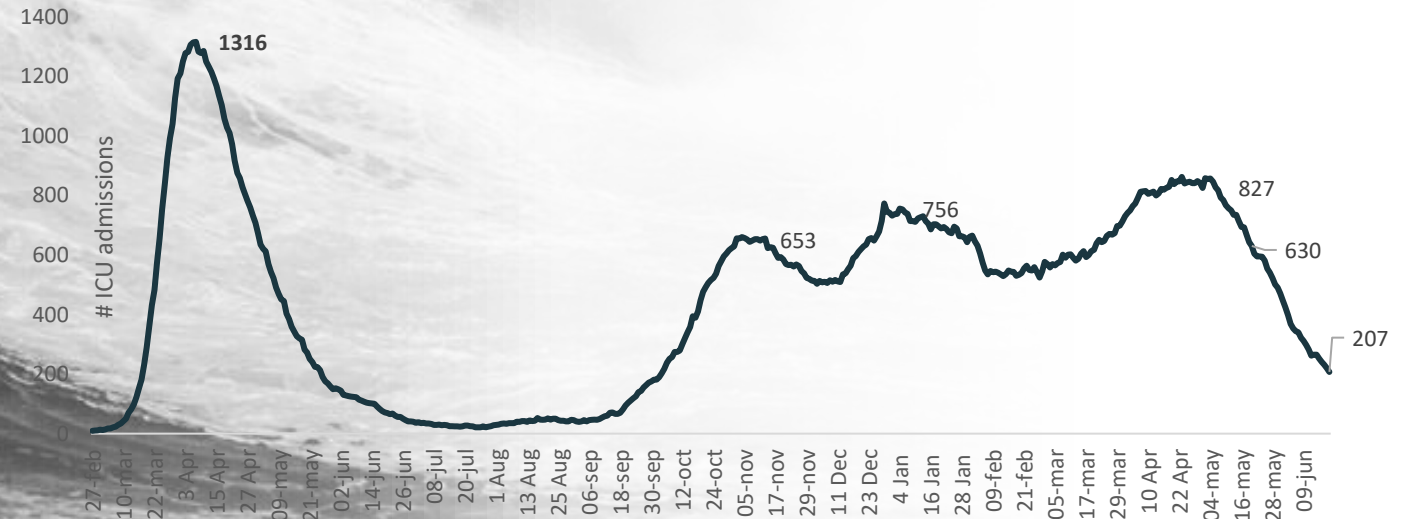
# COVID-19 Pandemic in Dutch hospitals



Coronavirus (COVID-19) hospitalized patients in the Netherlands Source: (Nationale Intensive Care Evaluatie, 2020; Statista, 2020)

Patients treated in Dutch hospitals	Number	%
Only in nursing ward	56,730	81.7%
Patients treated in the ICU	12,702	18.3%
<b>Total</b>	<b>69,432</b>	<b>100%</b>

Total number of patients admitted to hospitals Source: (National Intensive Care Evaluatie, 2020, June 22, 2021)



Coronavirus daily intensive care patients in the Netherlands, Source: (Nationale Intensive Care Evaluatie, 2020)

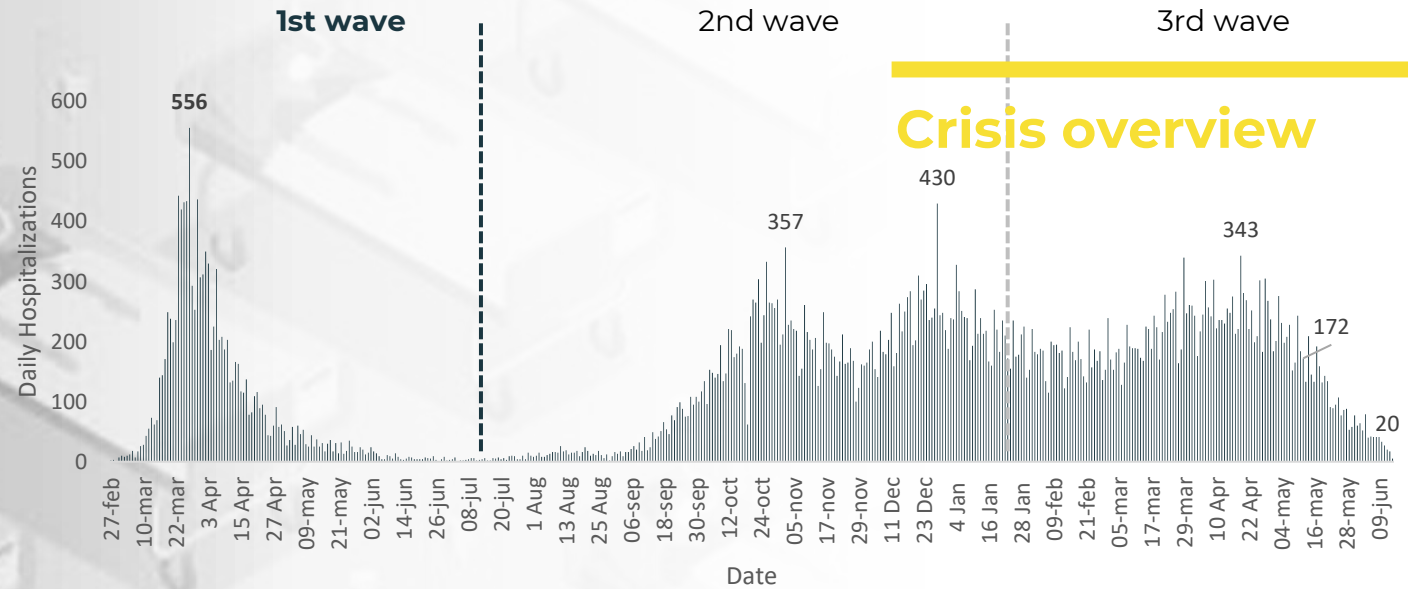
# COVID-19

## 1st wave

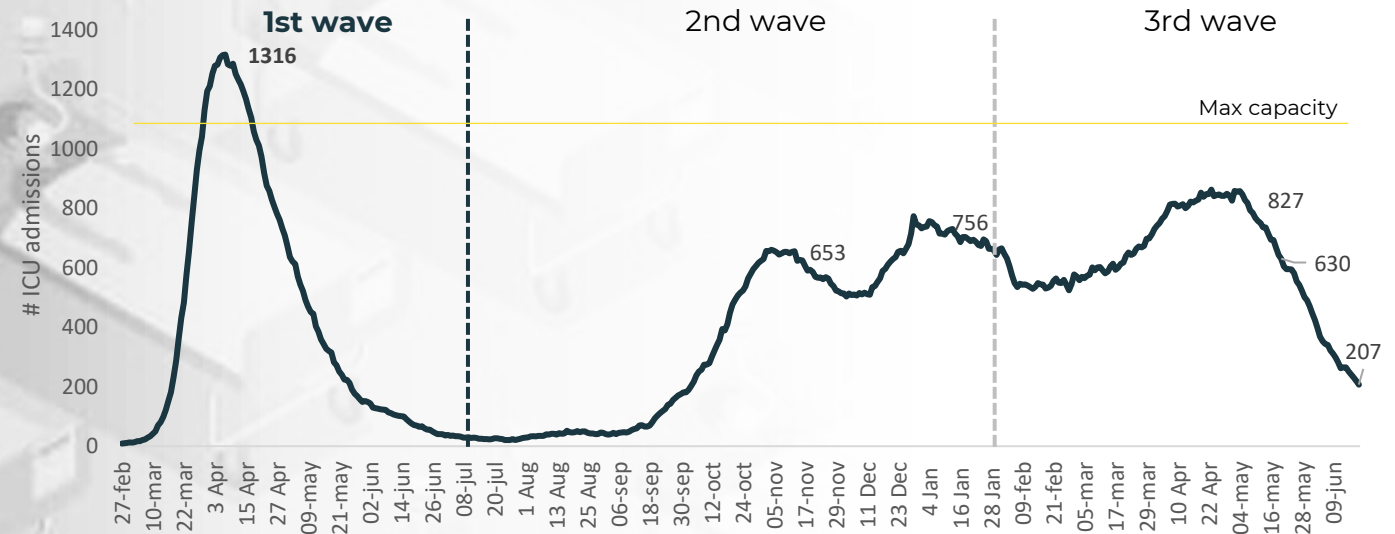
### 1st wave (Feb 2020 – July 2020)

- Quick overload of ICU
- Perceived need to adapt non-patient areas such as convention centers
- Capacity problems have been magnified on account of the unavailability of sufficient supplies of protective equipment.
- Regular care scale down significantly – Treatments postponed

(Gupta strategies, 2020; Rijksoverheid, 2020; Government of the Netherlands, 2020; Nederlandse internisten Vereniging, 2020)



Coronavirus (COVID-19) hospitalized patients in the Netherlands Source: (Nationale Intensive Care Evaluatie, 2020; Statista, 2020)



Coronavirus daily intensive care patients in the Netherlands, Source: (Nationale Intensive Care Evaluatie, 2020)

# COVID-19

## 2<sup>nd</sup> & 3<sup>rd</sup> wave



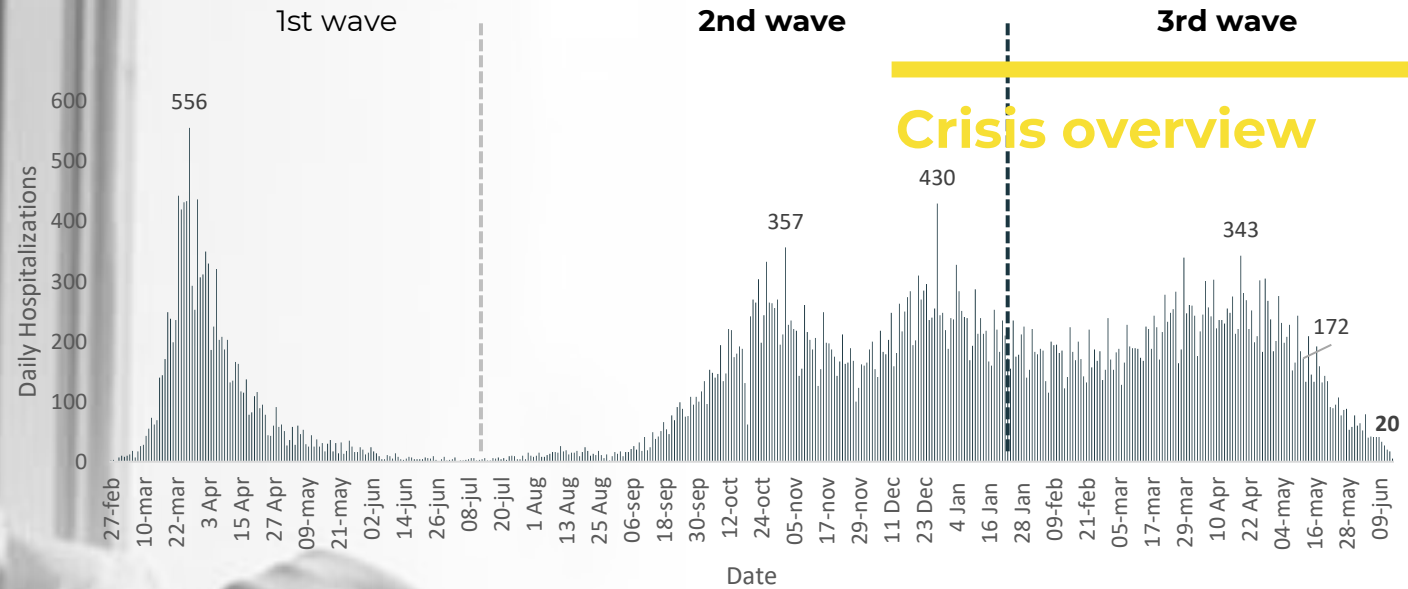
### 2<sup>nd</sup> wave (Aug 2020 – February 2021)

- More knowledge about the virus – Higher ratio-ward/ICU
- Reproduction number and length of stay have reduced
- Medical staff exhausted – prolonged and demanding situation
- Regular care has scaled down - Switch to digital consultations / backlog

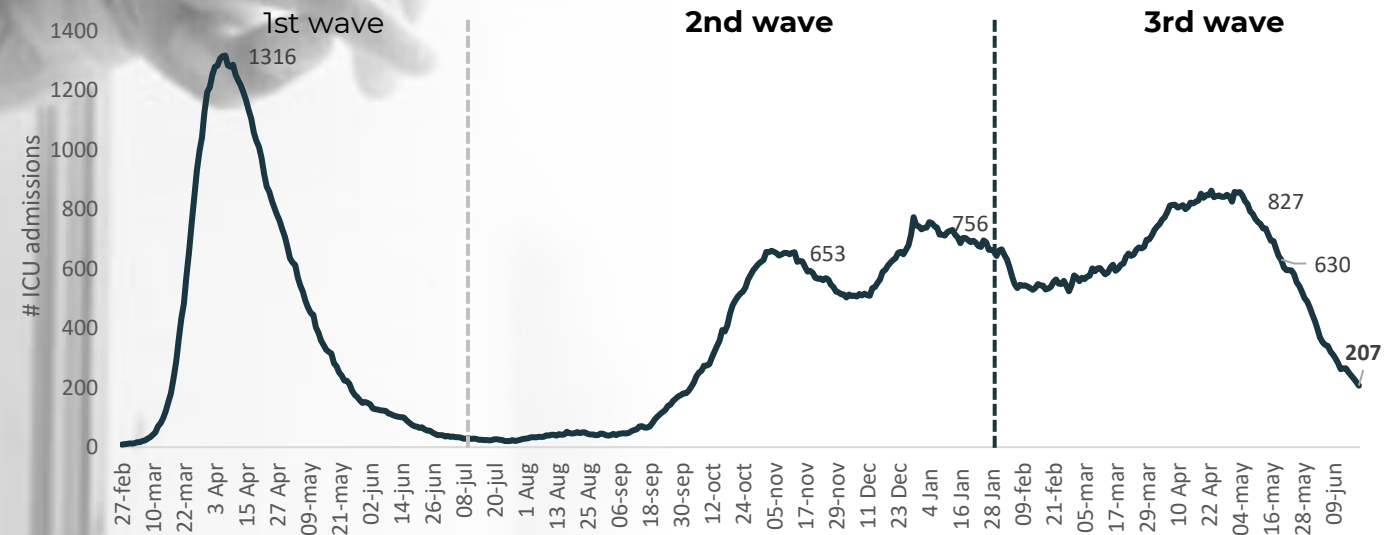
### 3<sup>rd</sup> wave (February 2021 – ongoing)

- Medical staff is not enough – problems poor mental health
- Regular care has scaled down - Switch to digital consultations
- Reproduction number = 0.79
- Government is implementing relaxation measures

(Gupta strategies, 2020; Rijksoverheid, 2020; Government of the Netherlands, 2020; Nederlandse internisten Vereniging, 2020)



Coronavirus (COVID-19) hospitalized patients in the Netherlands Source: (Nationale Intensive Care Evaluatie, 2020; Statista, 2020)



Coronavirus daily intensive care patients in the Netherlands, Source: (Nationale Intensive Care Evaluatie, 2020)

# Response in terms of the physical environment in Dutch hospitals

## Additional measures hospitals

- Minimize transmission risk
- Safe environment
- Increase capacity
- Support staff

## 1 Building interventions

Visual cues, hand-alcohol, cough barriers, enhance visual communication, repurpose of spaces into ICU capacity, segmentation of wards with infected and non-infected, segregation of flows, dedicated entrances for staff.

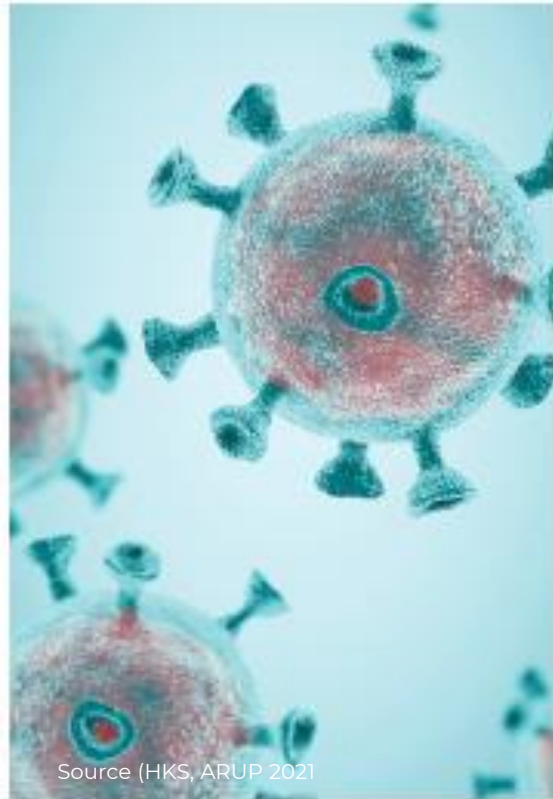
## Crisis overview

## 2 Technical interventions

Digital consultations, additional monitoring equipment, air-pressure barriers, extra communication systems (patient and staff), changes to the general ventilation systems, local filtration fixtures (HEPA).

## 3 Employee-focused interventions

Additional break rooms, additional attention for mental wellbeing, general support (childcare, additional/free parking shopping services), temporary accommodation in local hotels, non-essential staff working from home.



Source (HKS, ARUP 2021)



## Background

### Probably not the last pandemic

1918 -1920 : Influenza -2002-2003: SARS  
2009-2011 : Swine flu, 2018: Common flu  
2019: COVID-19 -2021: COVID-19 variants

(World Health Organization, 2020)

### Hospital's challenges

Hospitals are complex projects with low adaptive capacity and expensive to adequate in unforeseen circumstances.

(Nanda et al, 2020; WSP, 2020; McQuillan, 2020).

Prioritize patients and staff wellbeing while achieving the technological, operational and logistics requirements

(Ramboll, 2021)

# Resilience

## Background

*"The capability to maintain and adapt critical functions when faced with changes"*

(Ramboll, 2021)



### 1. Current situation

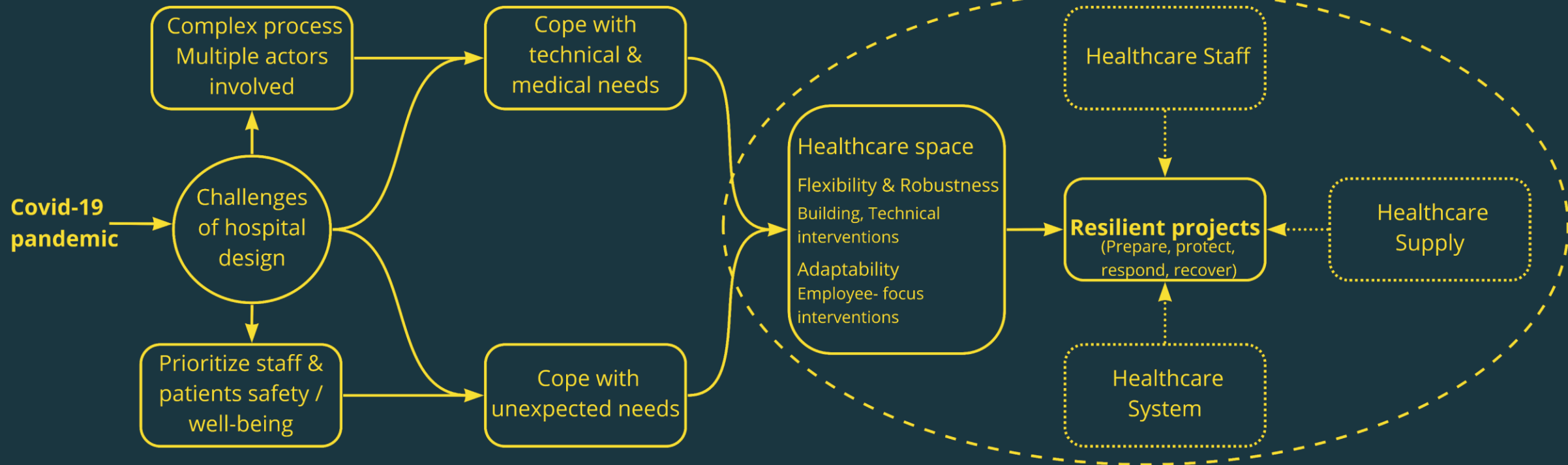
What is the **relationship** between the **spatial characteristics** of existing hospitals in the Netherlands and the **safety measures** taken by them during the different phases of the COVID-19 pandemic?

### 2. Future overview

Based on the pandemic experience, what interventions should be considered in hospital design to **future-proof projects** to virus-like covid-19?

# Conceptual model

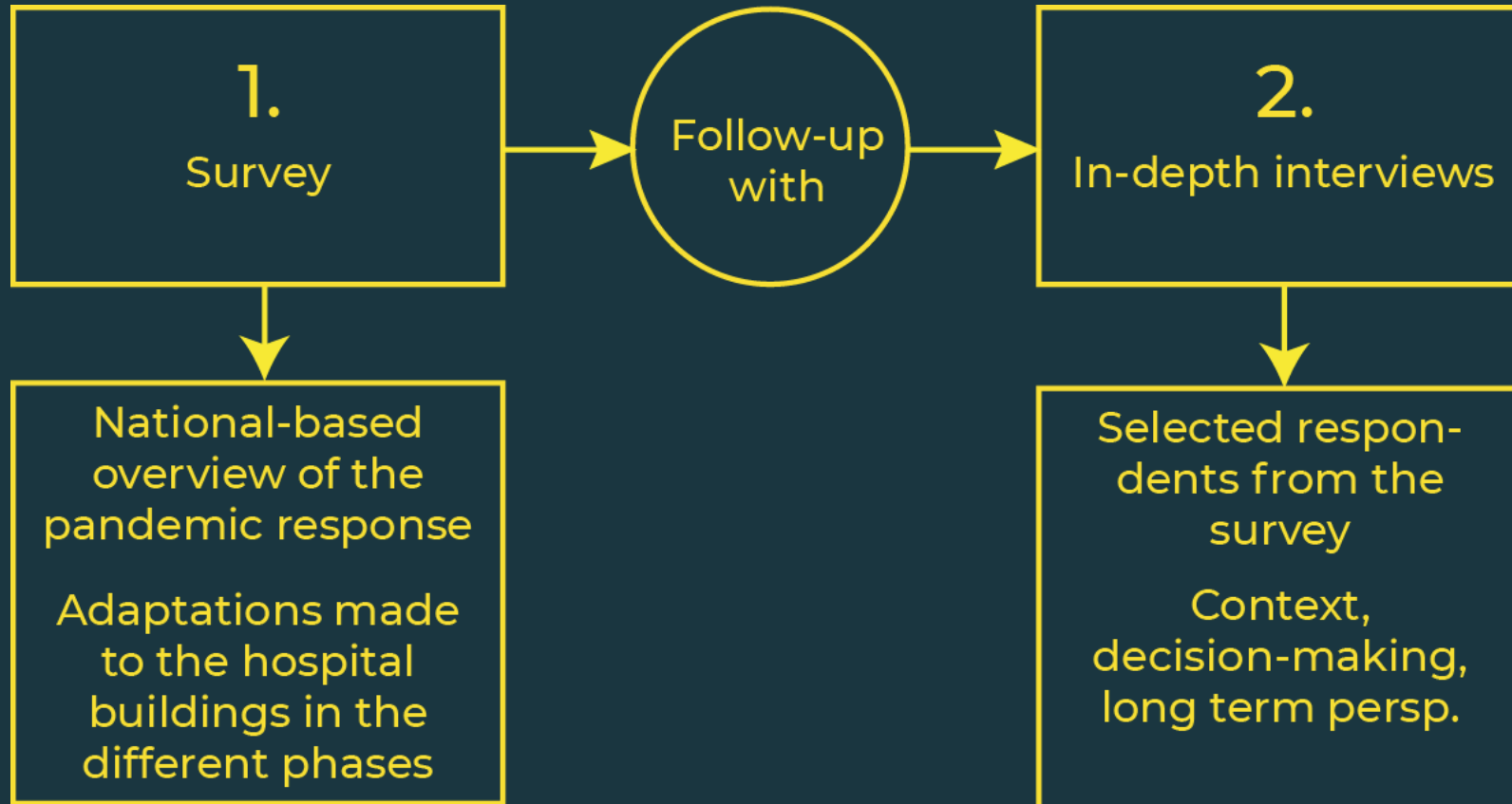
## Background



# Practice-based research

Facility and real estate managers – 68 hospitals

## Research design



Qualitative approach. Own diagram

n = 38

Net response 56%

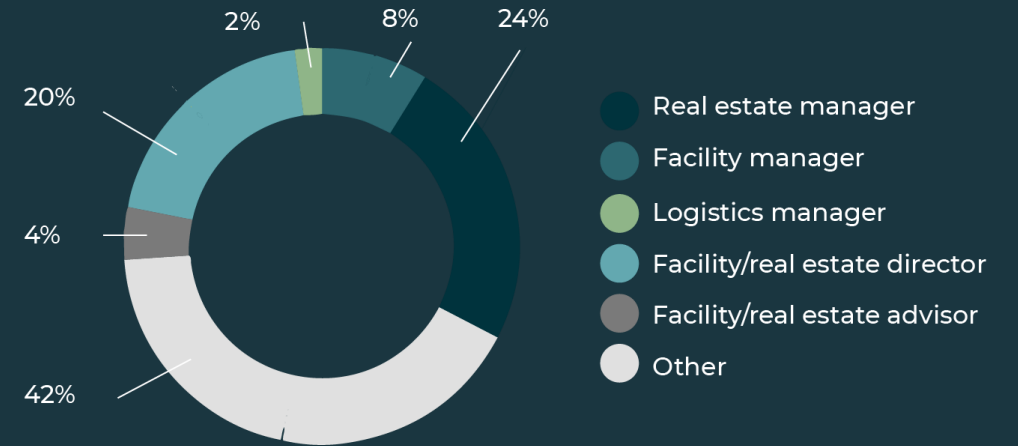
n = 4

# Descriptive information

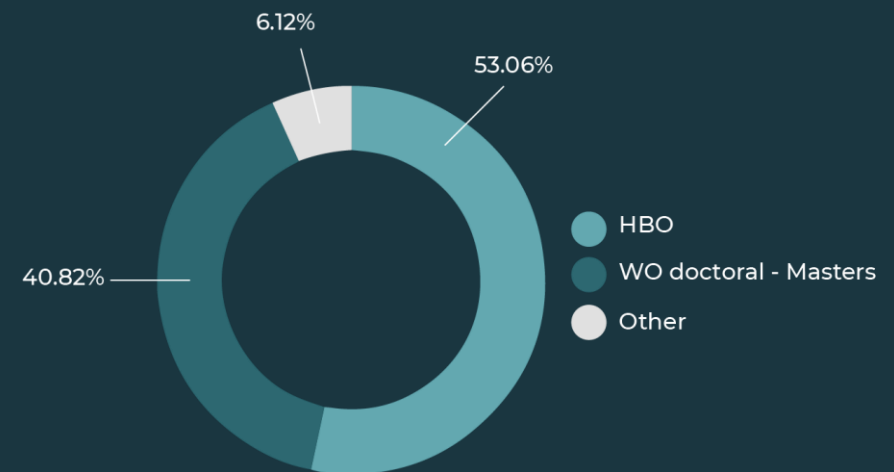


Location of hospitals that answered the survey with zip code registered in the RIVM database. Source: own diagram

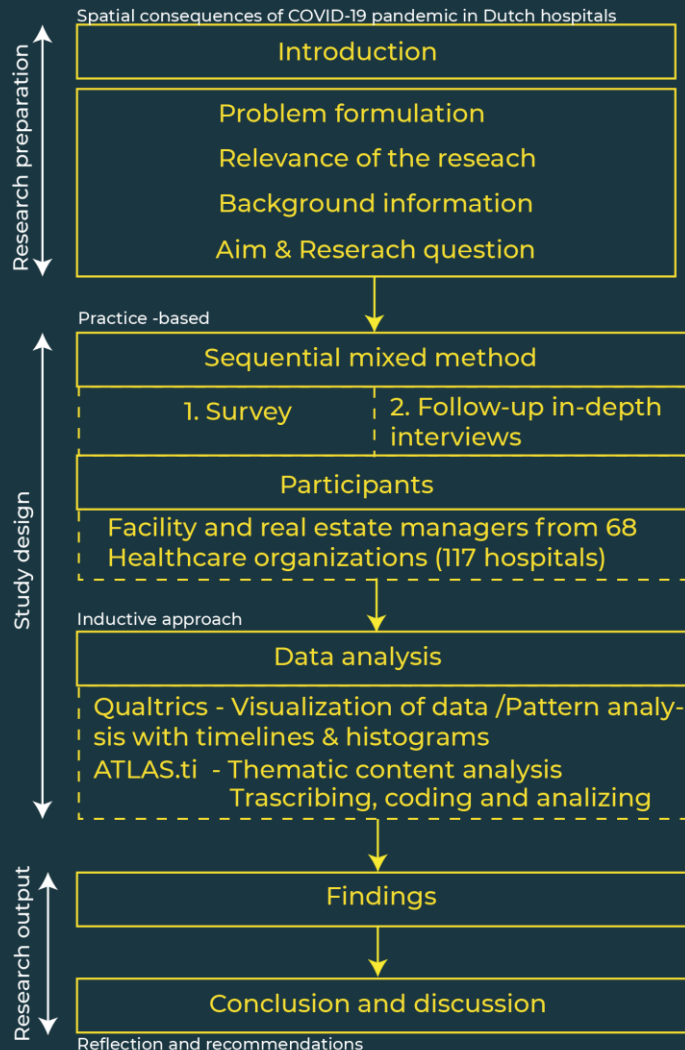
# Research design



Respondents' profession Source: own diagram



Respondents' education level Source: own diagram



### 1. Survey

- Qualtrics // raw data transformed
- Visualization and descriptive analysis in Tableau
- Pattern analysis with timelines and histograms
- No further statistical analysis will be done.

### 2. Interviews

- Inductive approach → Analyzing data with no predetermined theory.
- Interviews were be transcribed and labeled using ATLAS.ti.
- Open thematic coding → Identify themes, categories and relations between variables of interest.

## Deliverables

Recommendations to futureproof hospital design to virus like COVID-19.

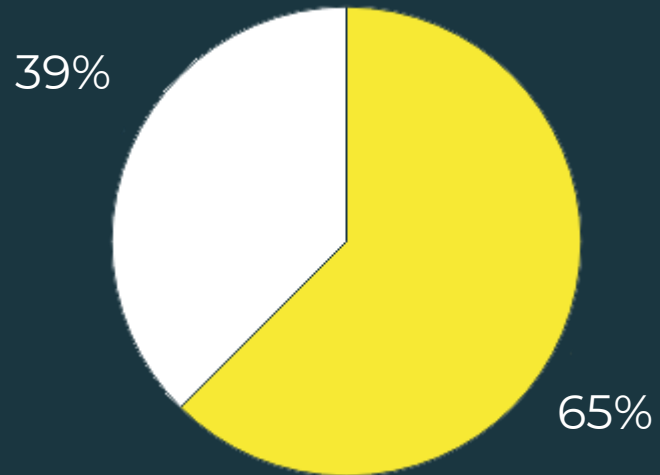
*“Do it quickly, do it together”*

- Increase cohesion and collaboration
- Clear guidance (RIVM + GGD)+ NOMT
- Smooth decision-making CMT

# Pandemic preparedness

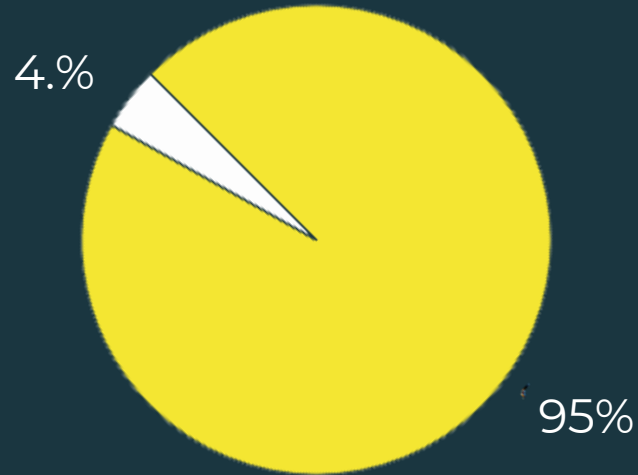
## General findings

### First wave



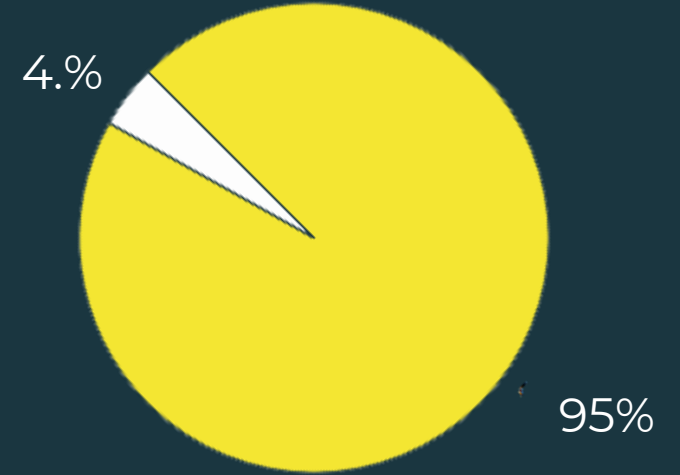
6/10  
Average

### Second wave



7/10  
Average

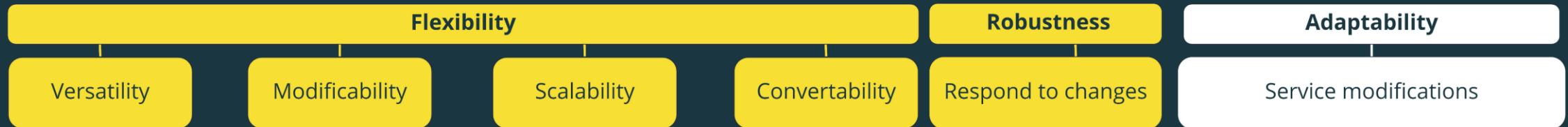
### Third wave



8/10  
Average

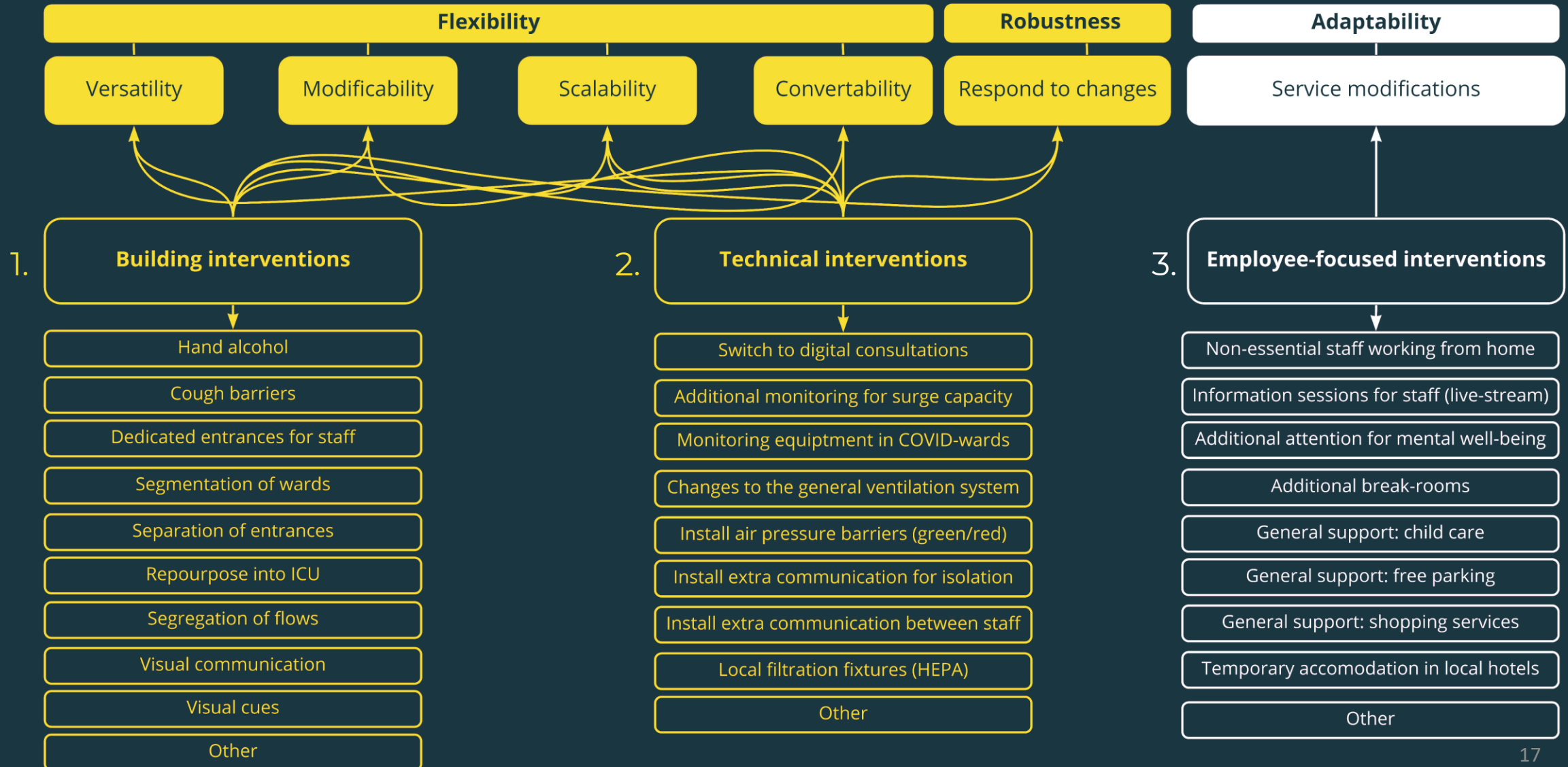
# Flexibility, robustness and adaptability

## Findings



# Safety measures

# Findings

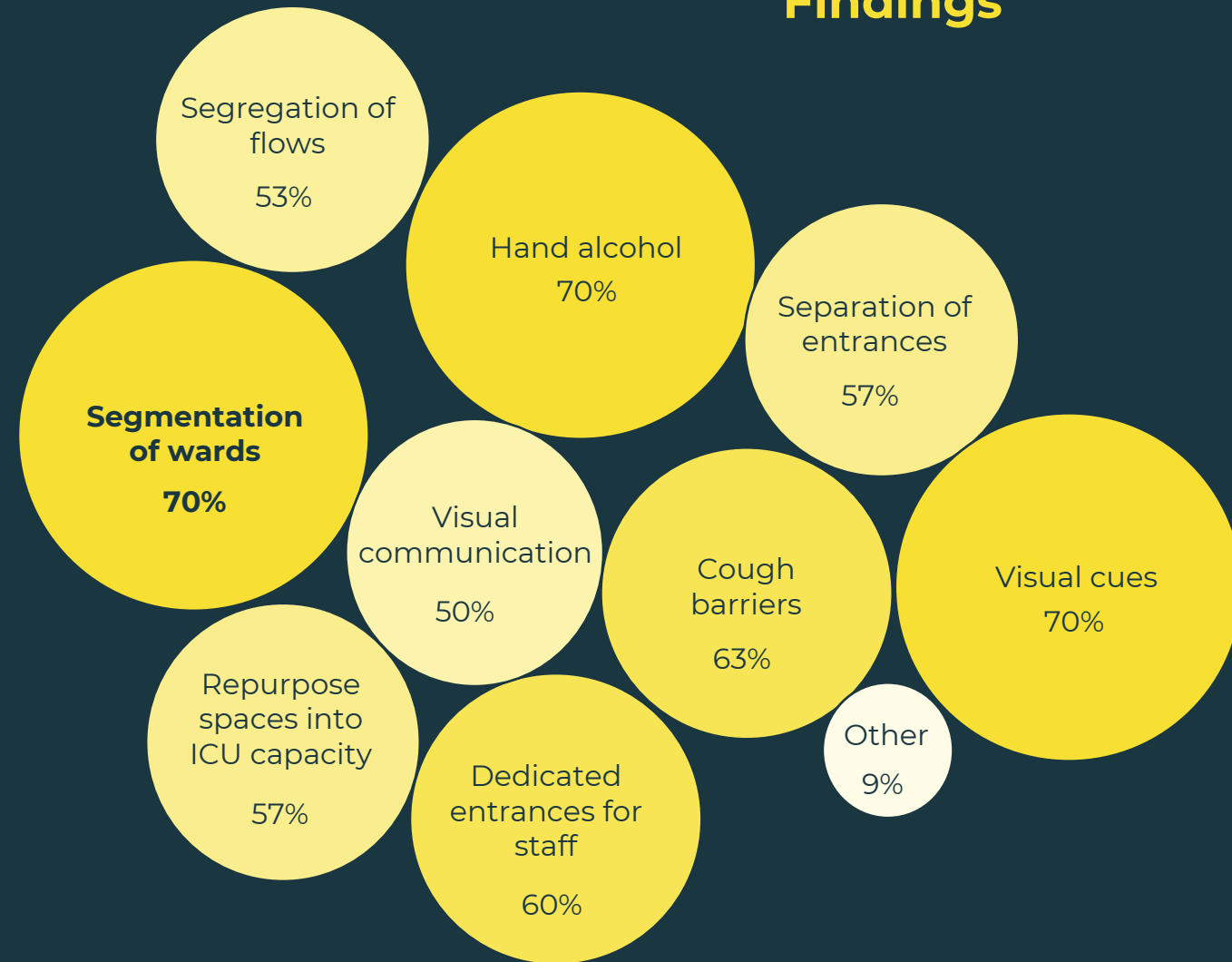
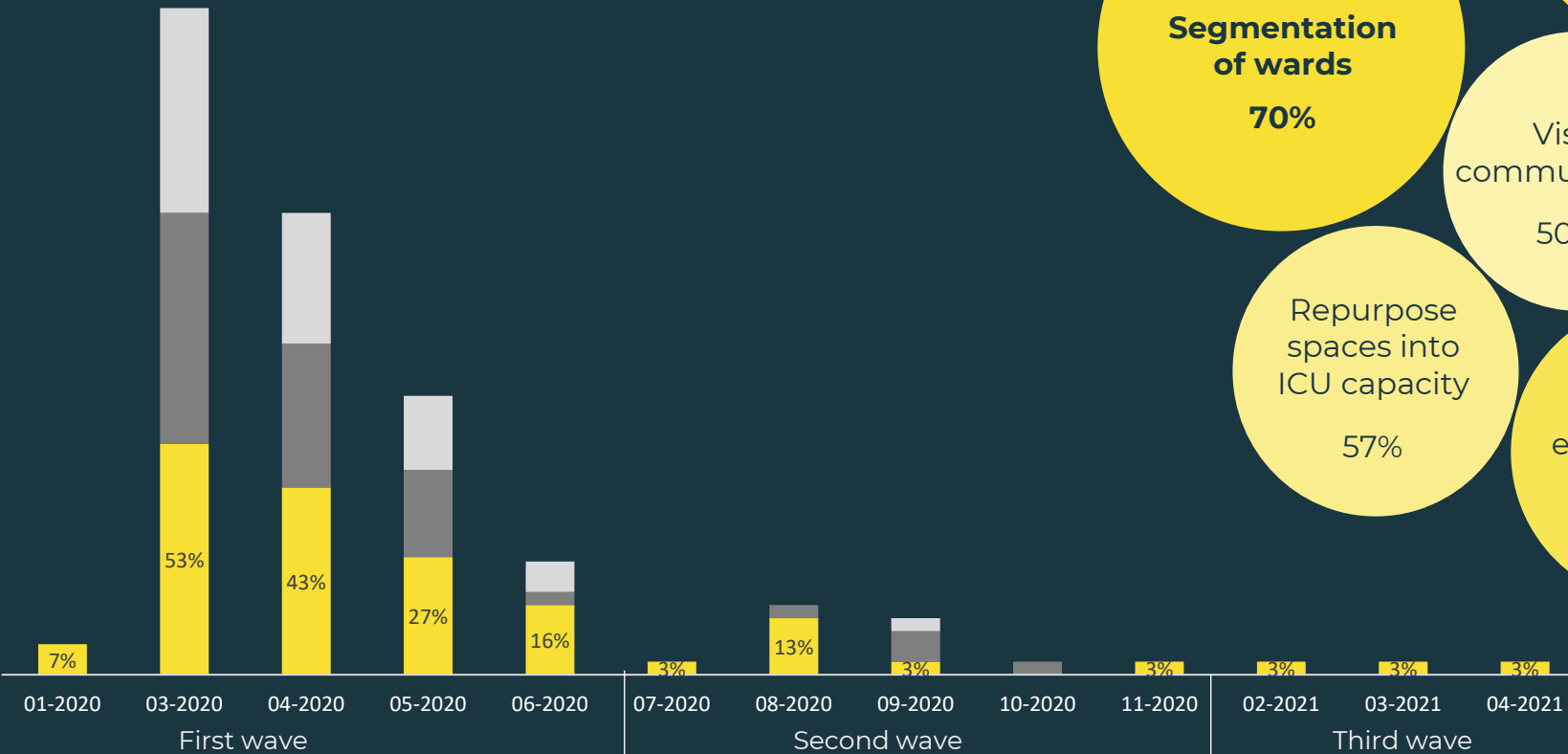


# Safety measures

## Findings

### 1. Building interventions

■ Building measures ■ Technical measures ■ Employee-focused measures



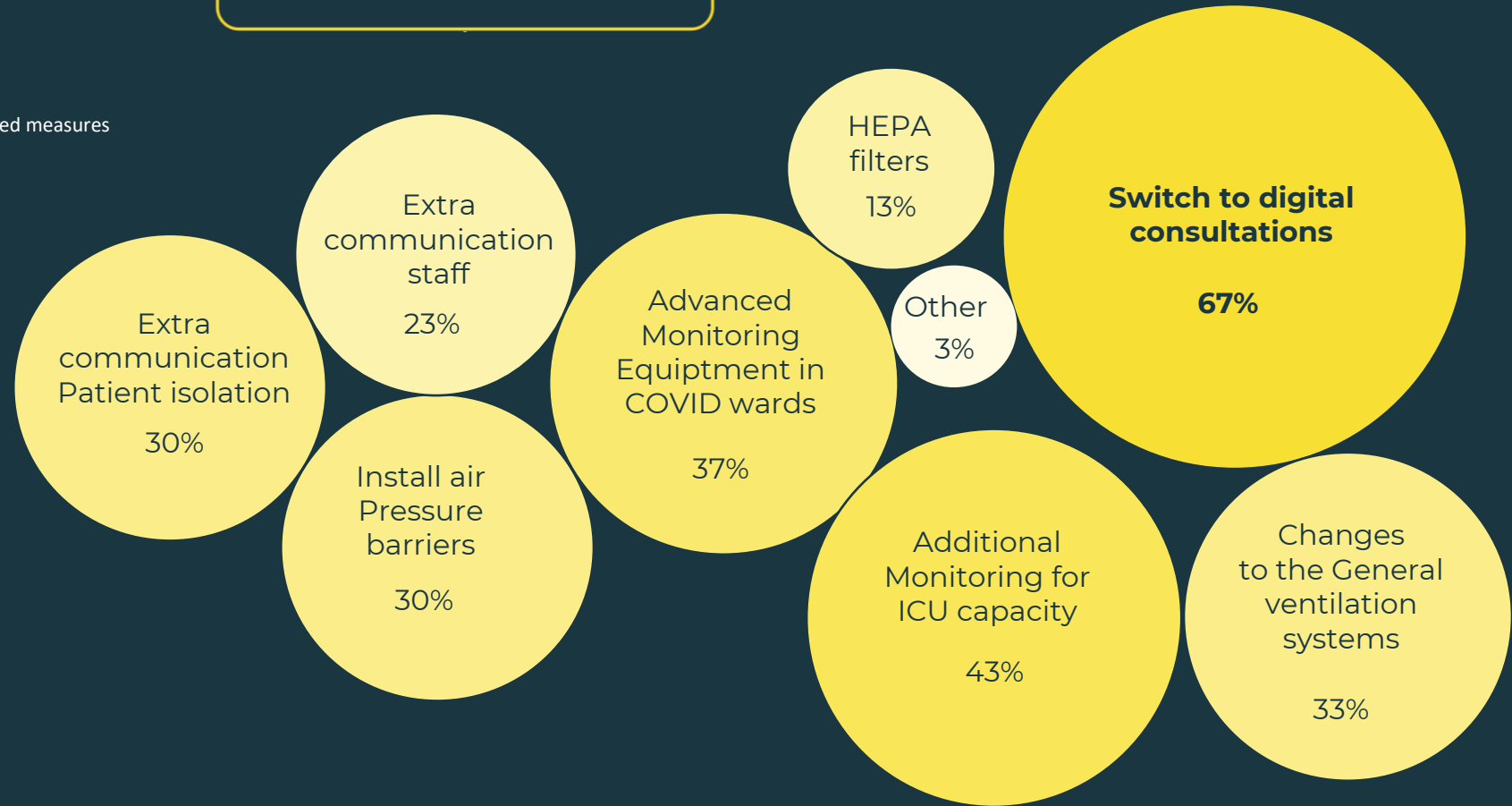
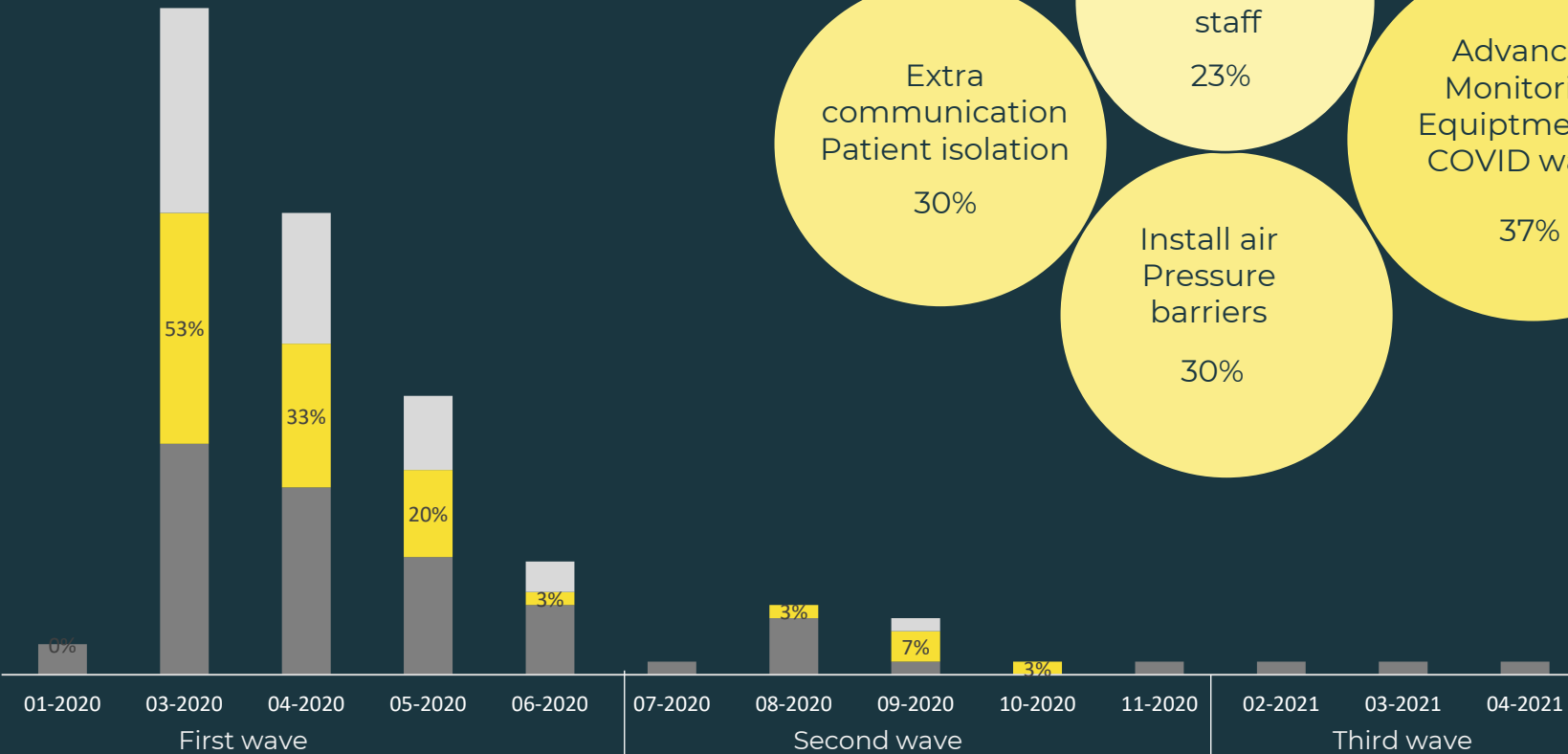
# Safety measures

# Findings

2.

## Technical interventions

■ Building measures ■ Technical measures ■ Employee-focused measures

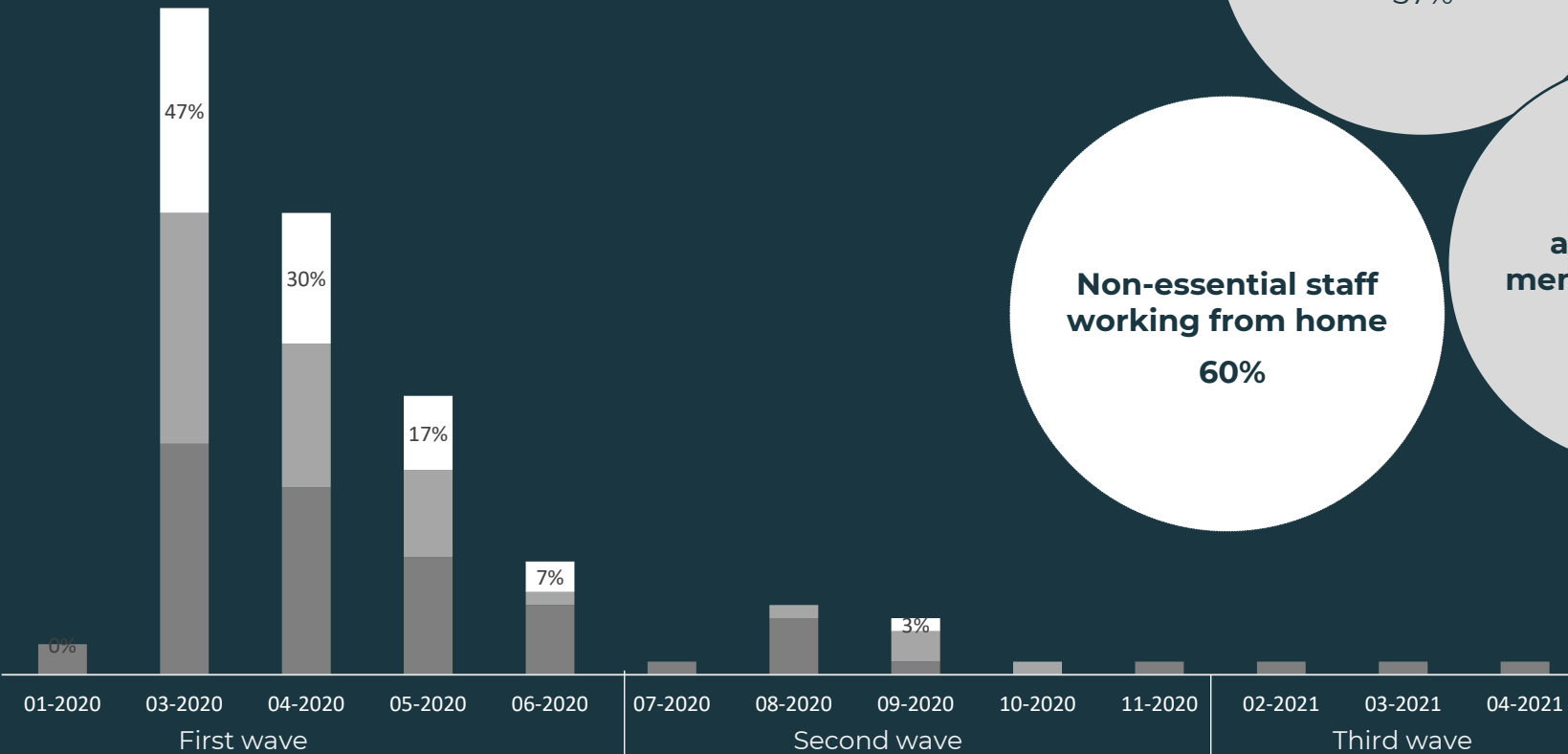


# Safety measures

## Findings

### 3. Employee-focused interventions

■ Building measures ■ Technical measures ■ Employee-focused measures



# Summary top safety measures

## Findings

1.

**Building interventions**

**Segmentation  
of wards  
70%**

Hand alcohol  
70%

Visual cues  
70%

2.

**Technical interventions**

**Non-essential staff  
working from home  
60%**

Additional  
Monitoring for  
ICU capacity  
43%

3.

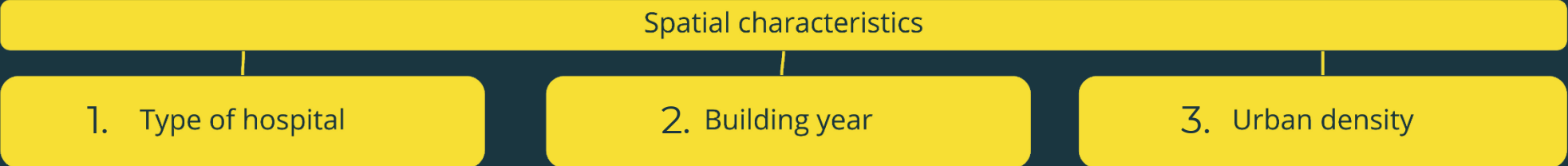
**Employee-focused interventions**

**Switch to digital  
consultations  
67%**

**Additional  
attention  
for mental  
well-being  
57%**

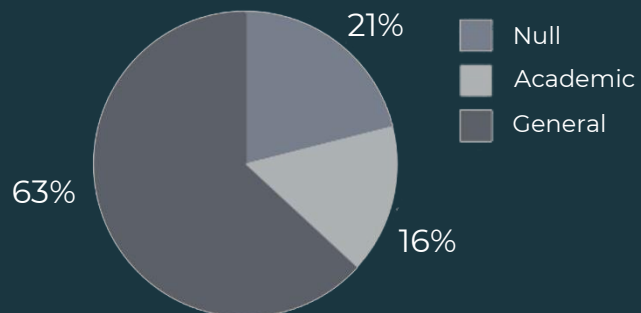
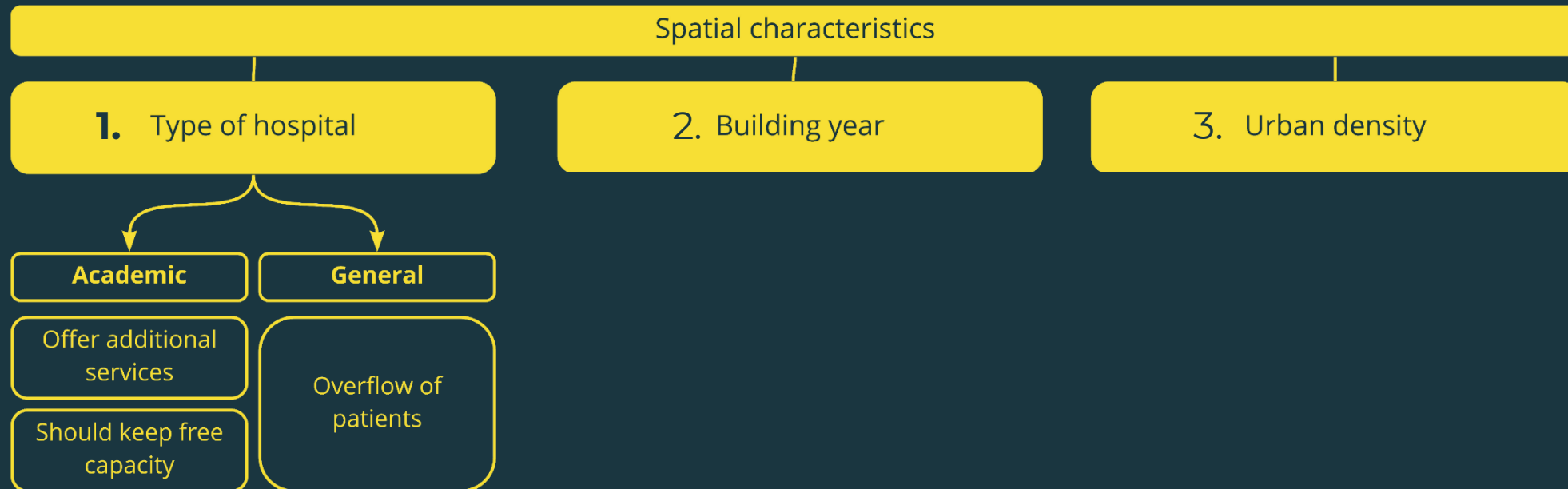
# Spatial characteristics

# Findings



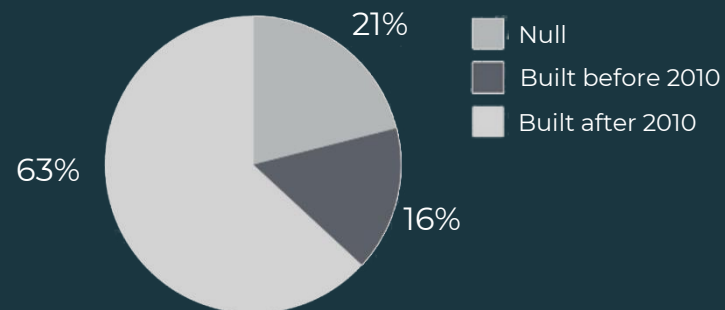
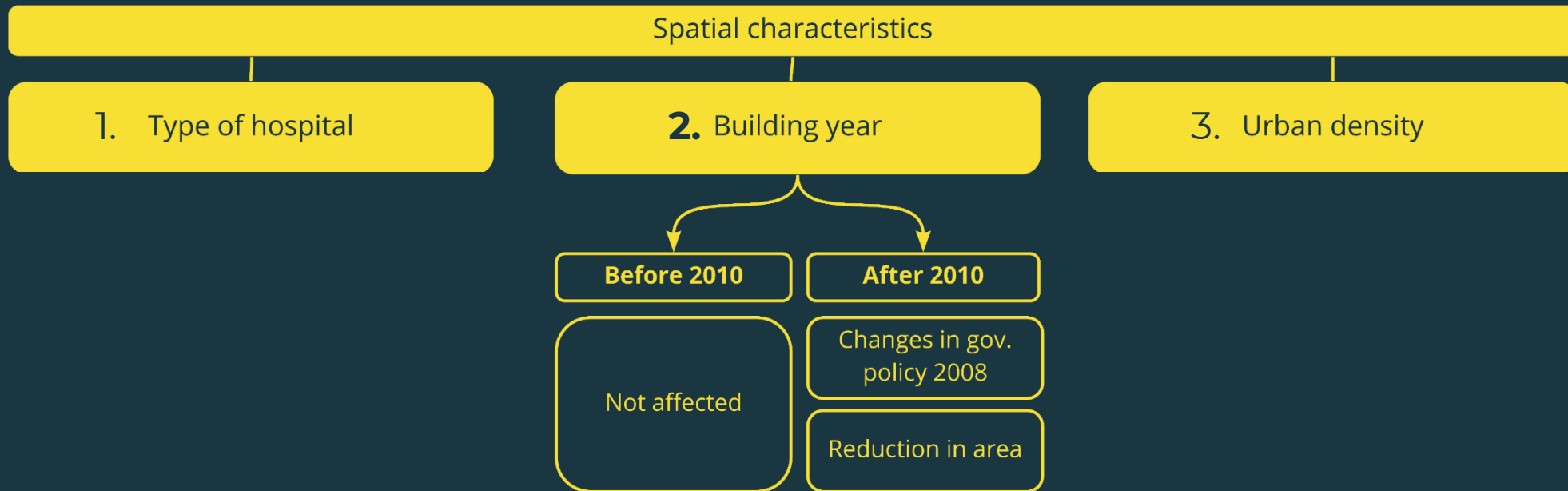
# Spatial characteristics

## Findings



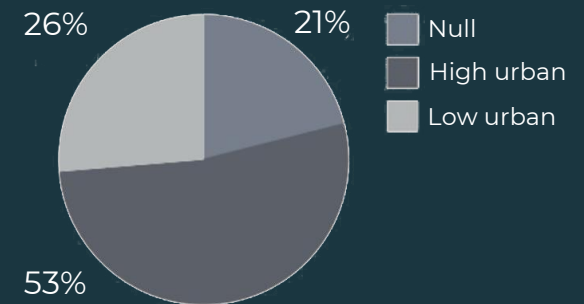
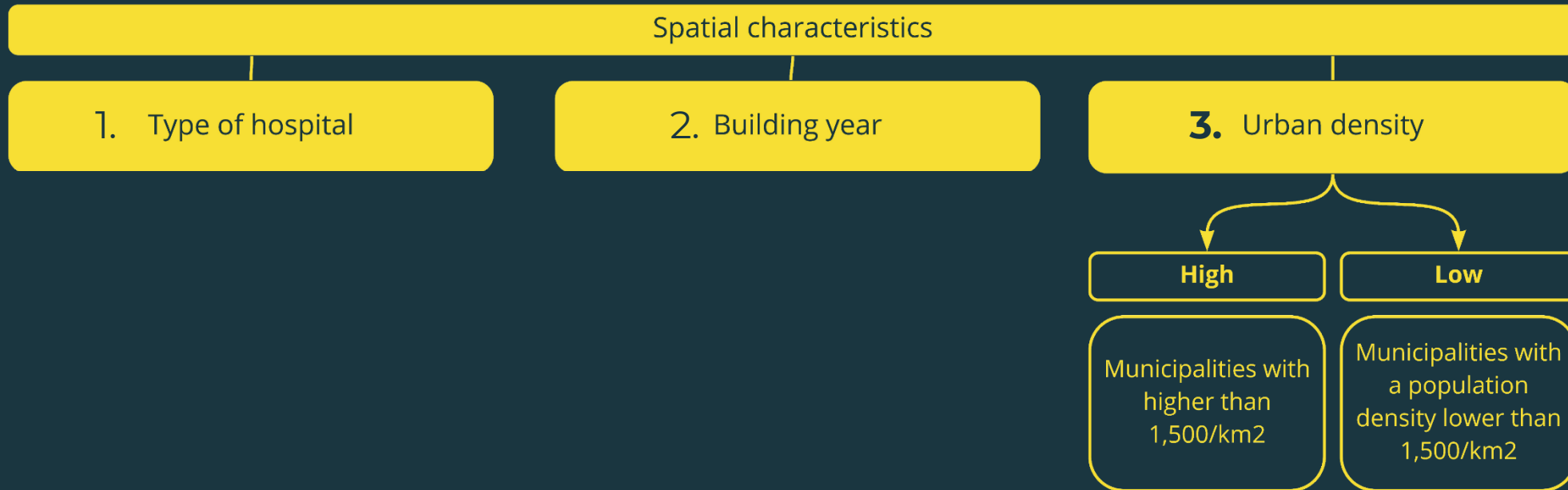
# Spatial characteristics

## Findings



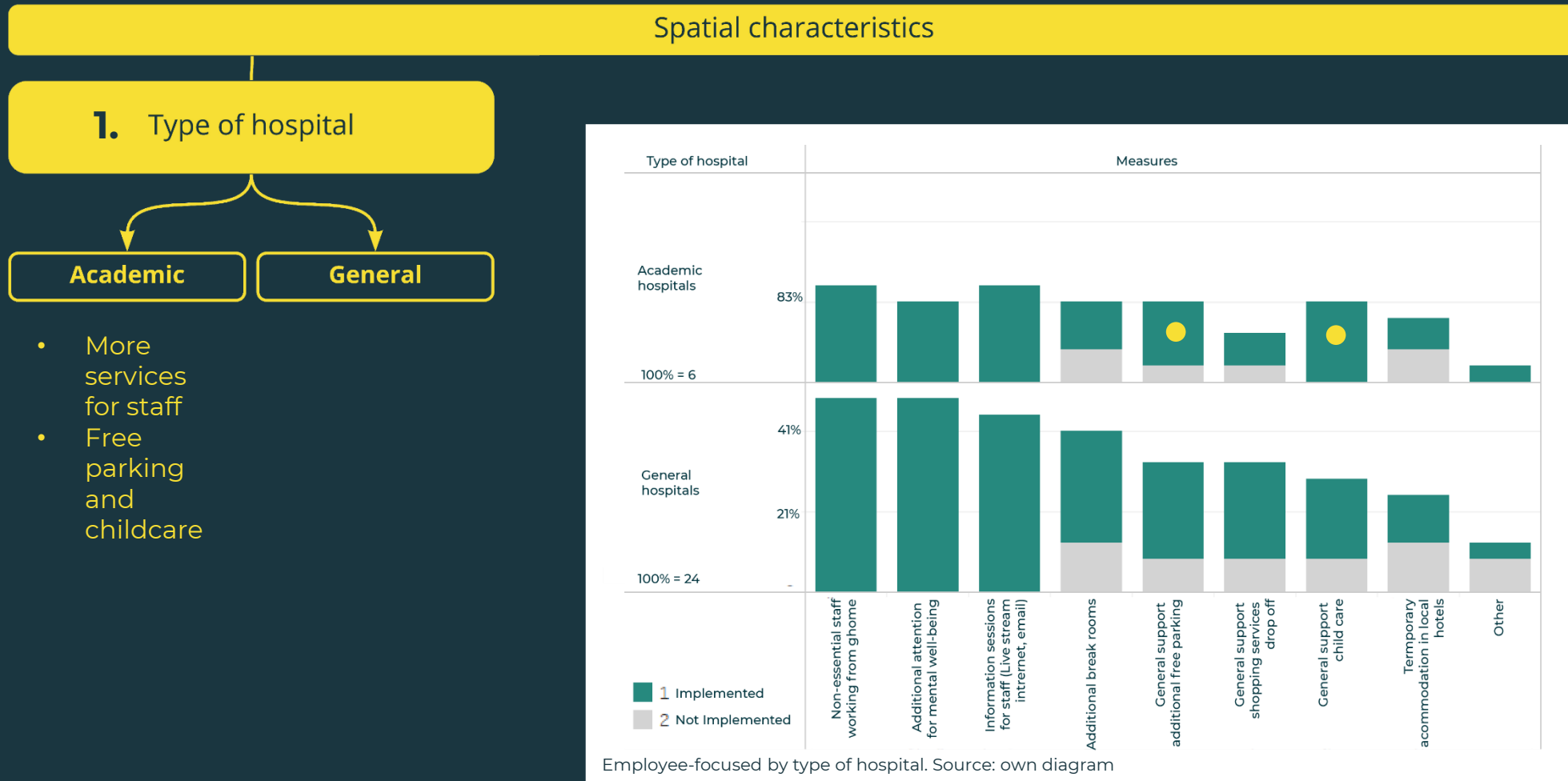
# Spatial characteristics

## Findings



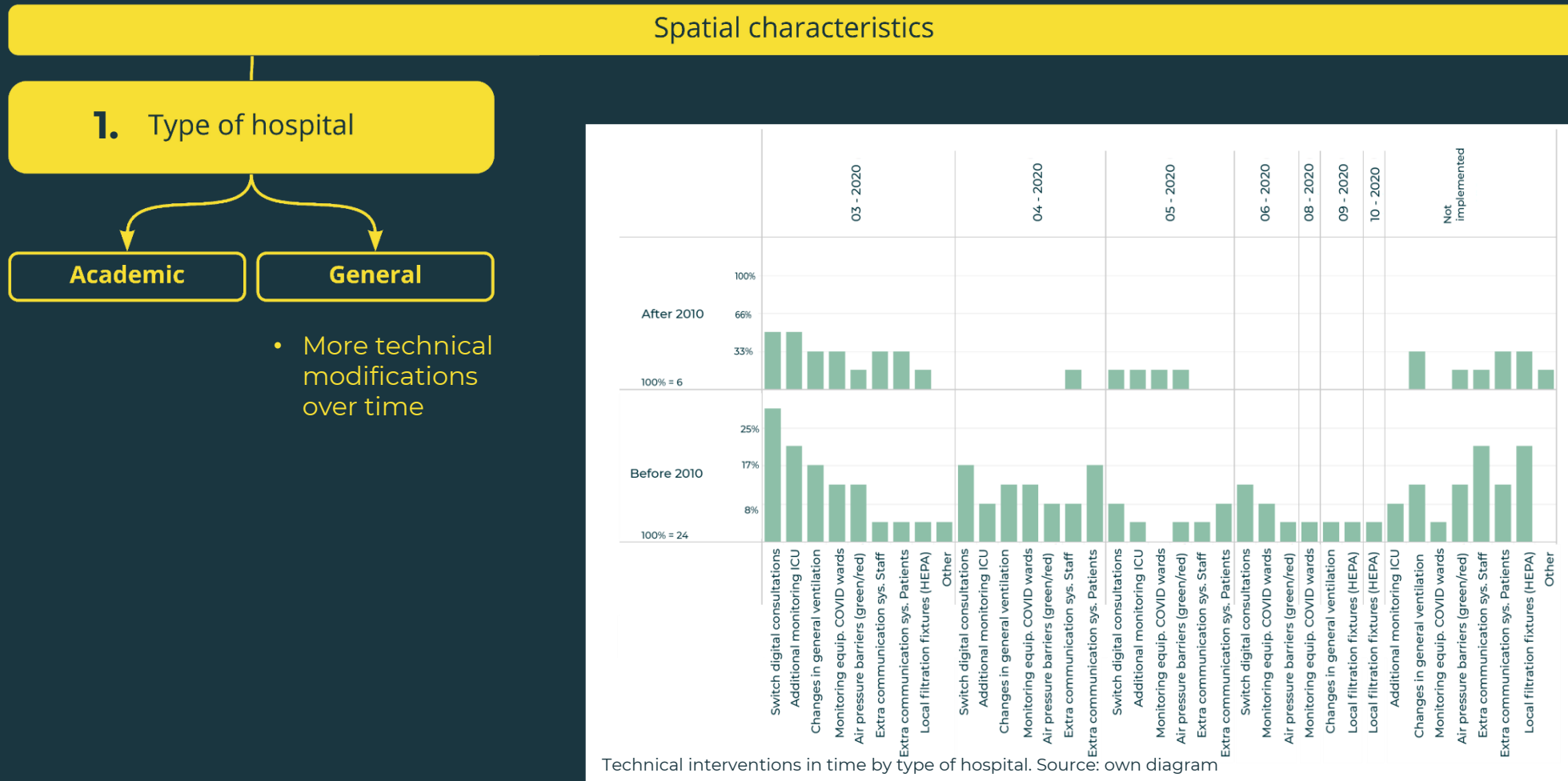
# Safety measures by spatial characteristic

## Findings



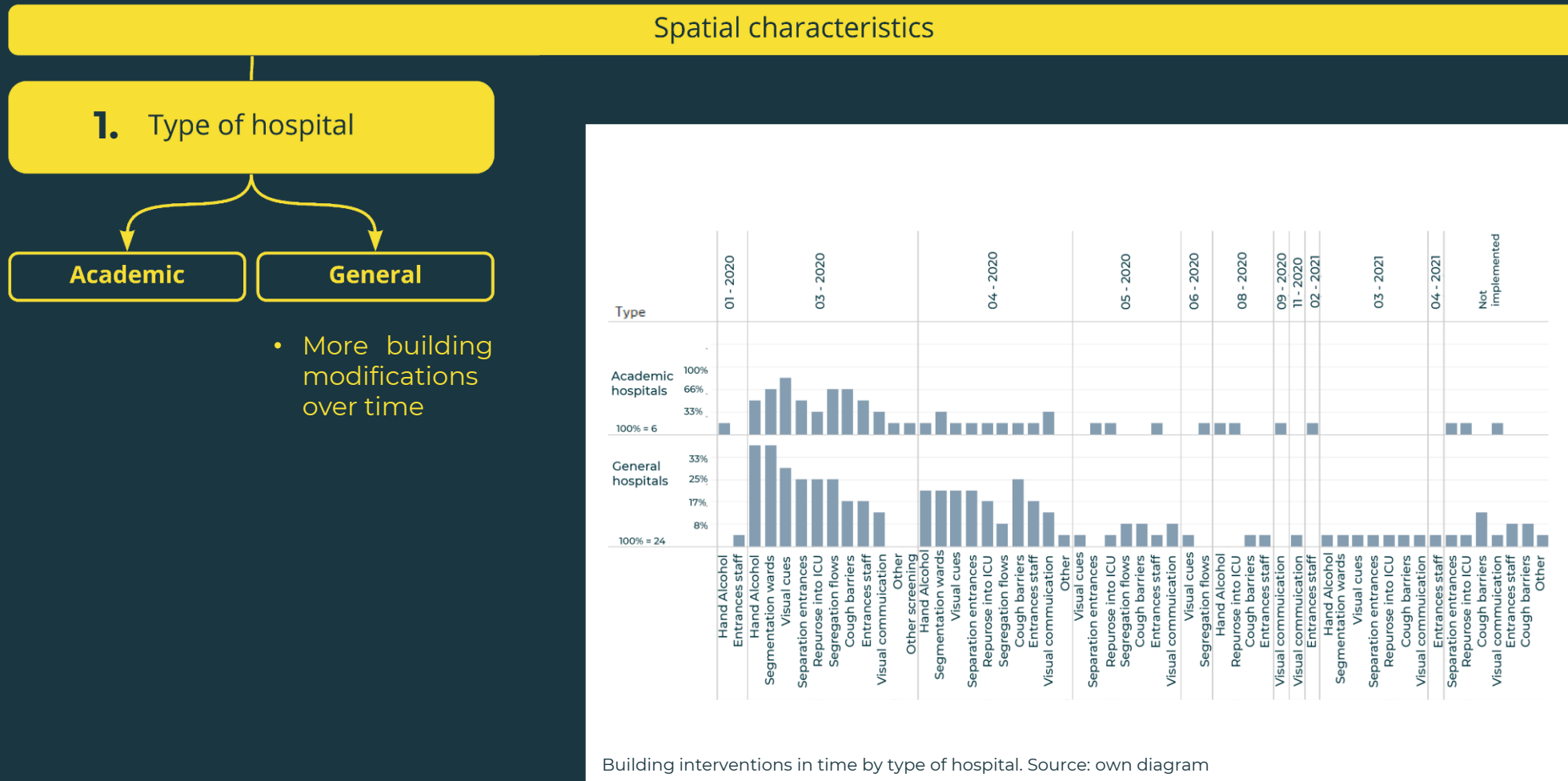
# Safety measures by spatial characteristic

## Findings



# Safety measures by spatial characteristic

## Findings



# Safety measures by spatial characteristic

## Findings

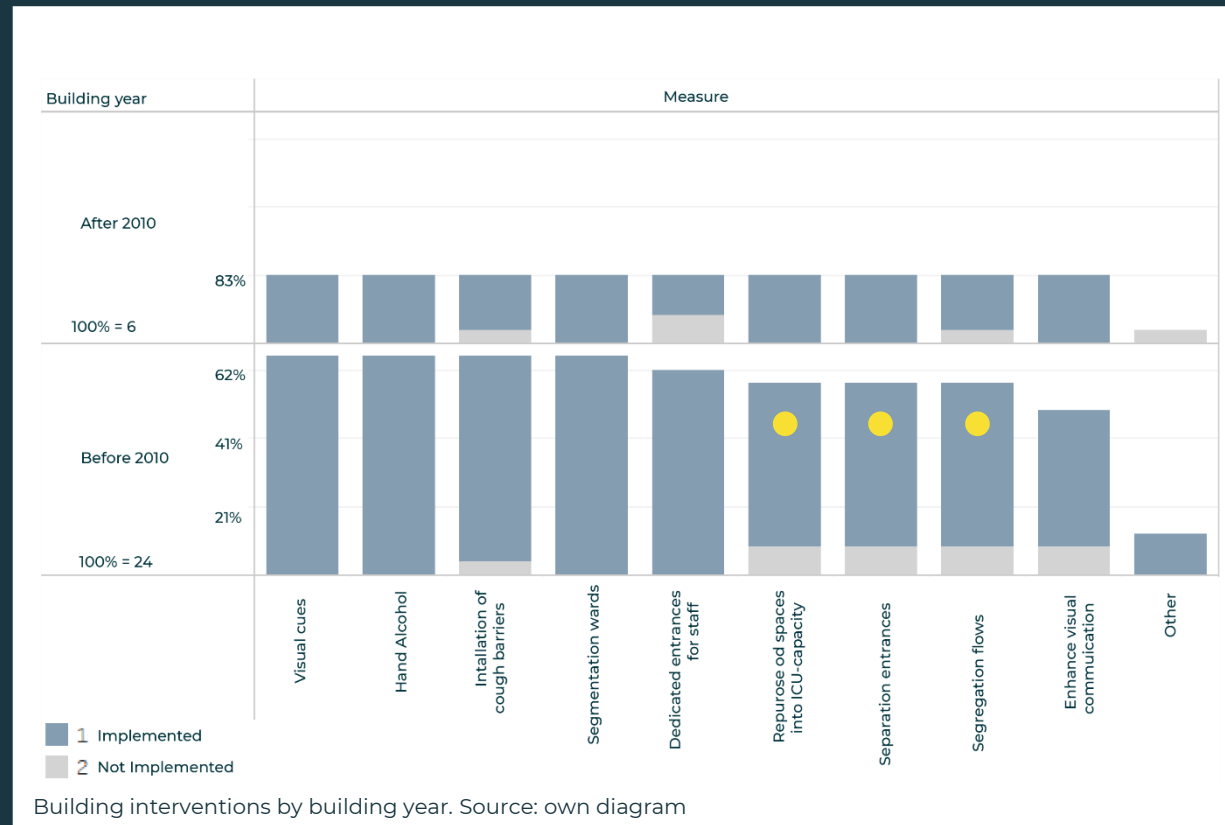
### Spatial characteristics

#### 2. Building year

Before 2010

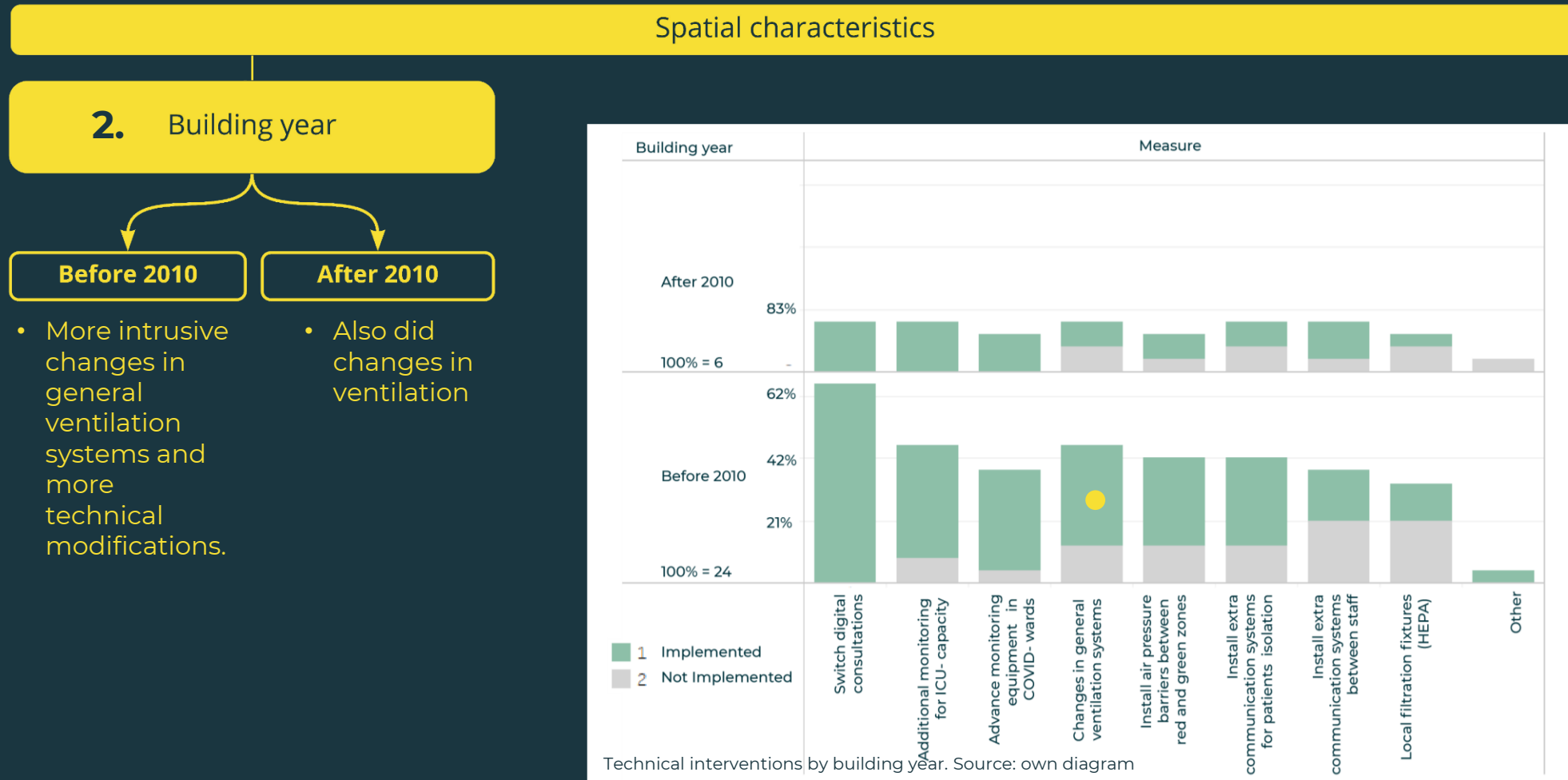
After 2010

- Less repurpose spaces into ICU capacity, separation of entrances and segregation of flows.



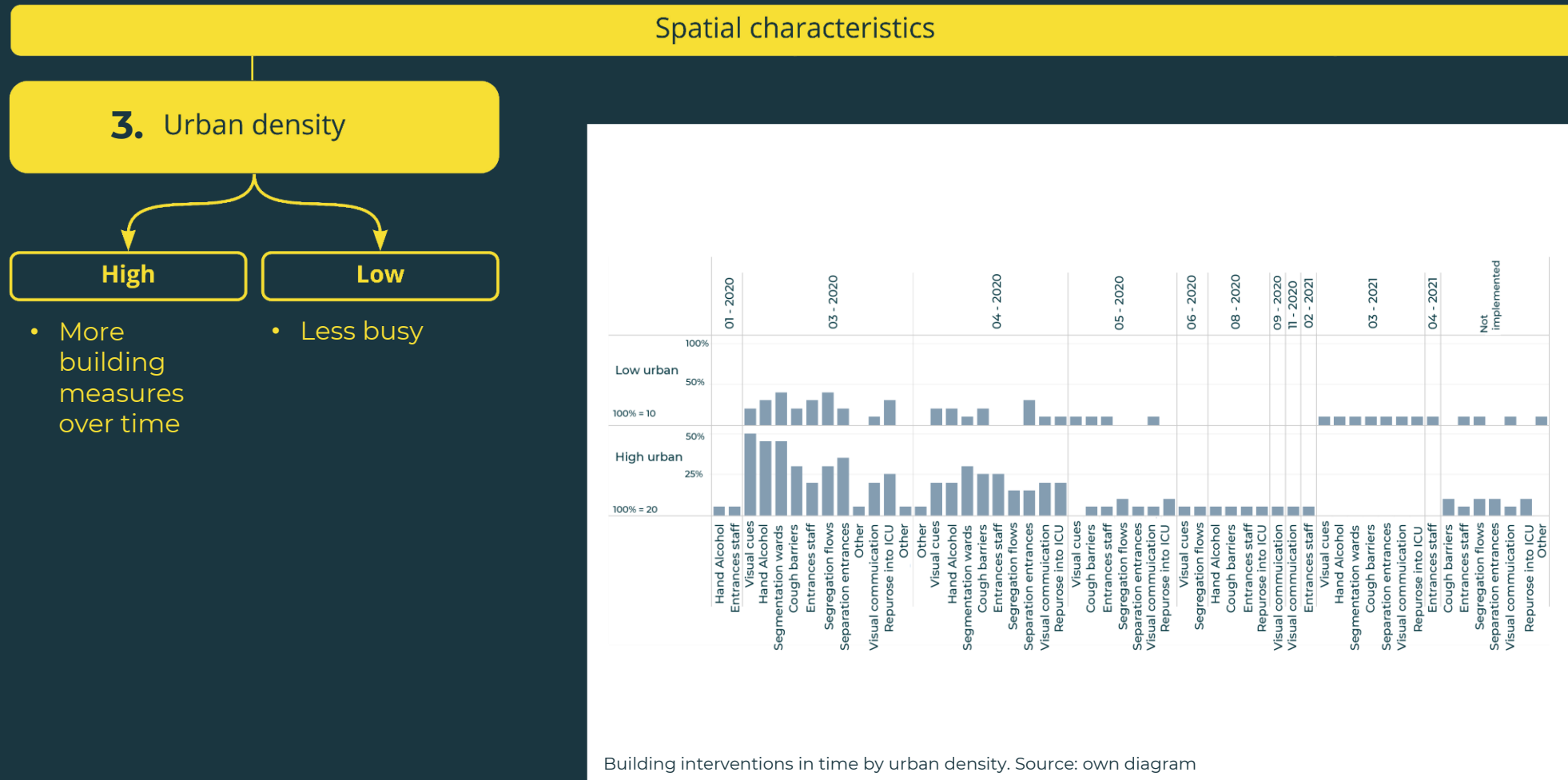
# Safety measures by spatial characteristic

## Findings



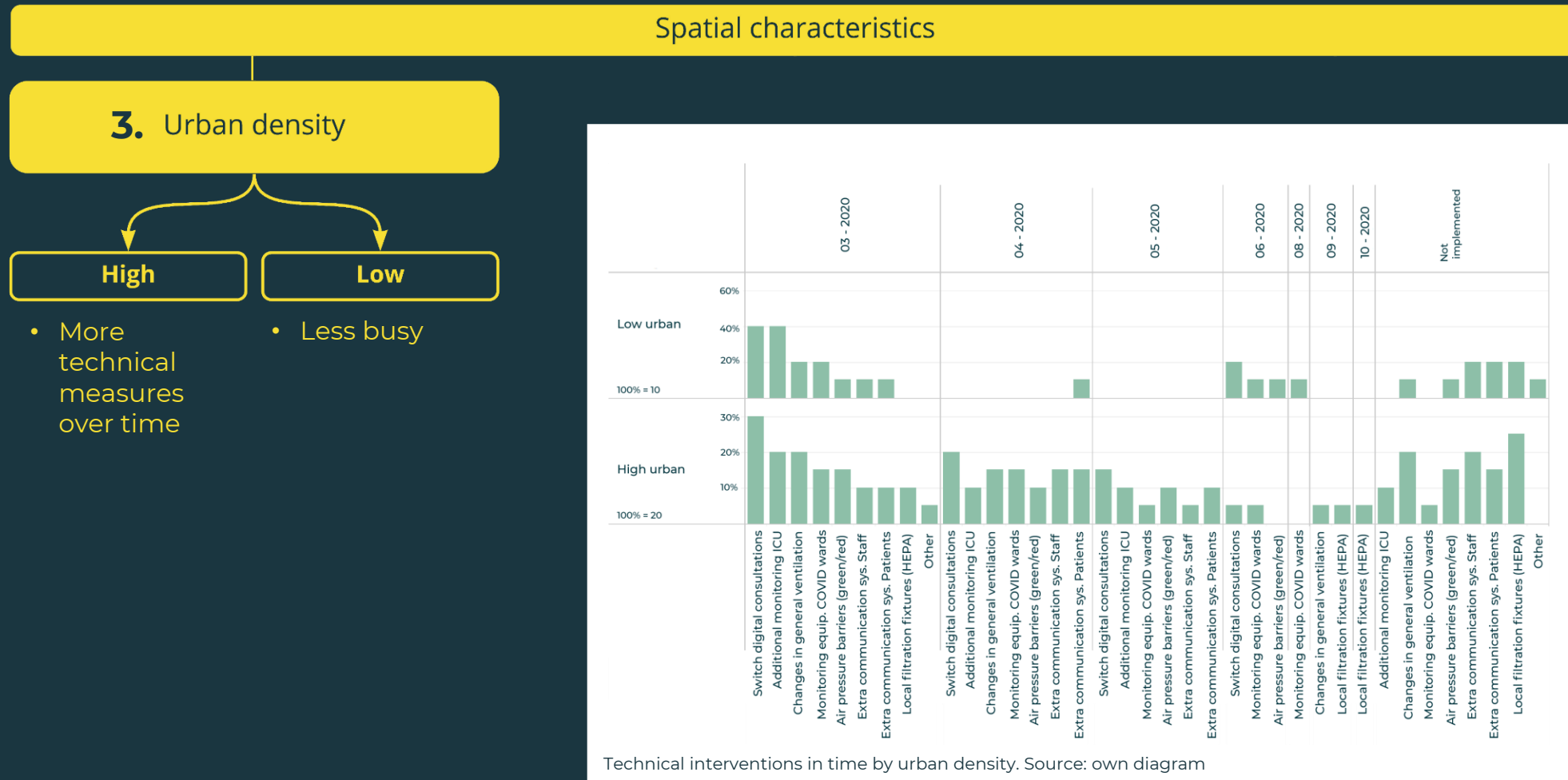
# Safety measures by spatial characteristic

## Findings



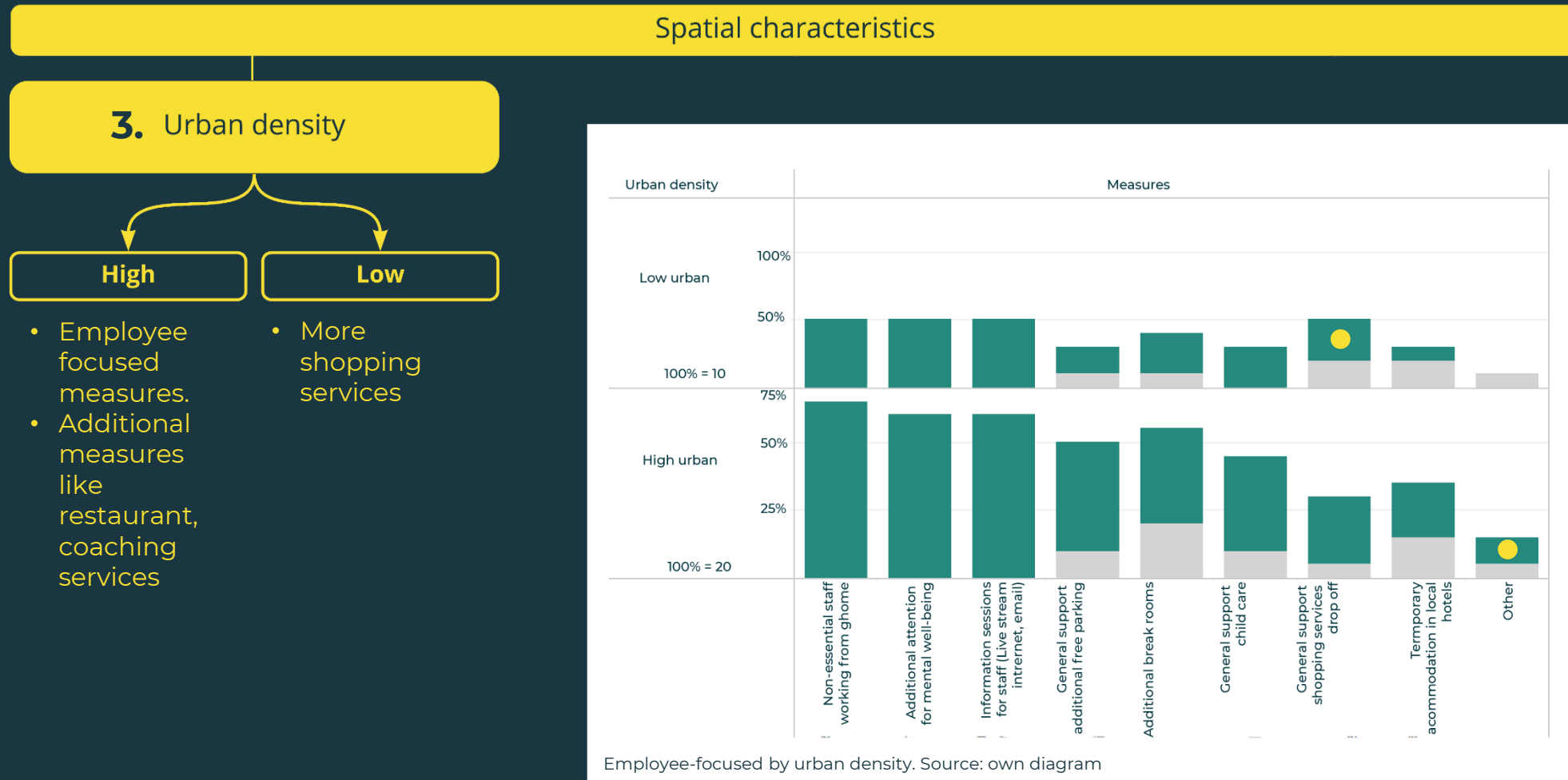
# Safety measures by spatial characteristic

## Findings



# Safety measures by spatial characteristic

## Findings



## Findings

### ★ Lung diseases

Future infections might be related to lungs and respiratory problems  
80% of the patients were treated in the NW with **Opti flow** mechanisms.

### ★ Technical difficulties in the nursing wards

Awareness of oxygen and power capacity

### ★ Possibility to expand

Single-patient rooms for double occupancy in a crisis

*“In the wards, we have now two-person room and single-person rooms, and the idea in the future is that we use the single-person rooms for one person and when we have a crisis, we could accommodate another person”*

1.

“Ventilation beds”

## Findings

### ★ Availability of space

*“There was a lot of equipment installed in the crisis, so they moved out offices and got in the equipment. Another thing is around our hospital we have space, most of the gardens or parking lots, and we claim them when we have to put on tents.”*

## 2.

### Pop-up services and temporary structures

## Findings

★ **Isolation of infected patients - Green & red areas**

*“The option to isolate infected patients within the building is essential to manage infectious disease”*

★ **Separation of airflows within departments**

*“The units can be divided quite easily by closing doors, but in the ventilation, it's a little bit difficult because it's all integrated and if you have to wonder, have special separated ventilation for these units, you have to adjust it in the structural.”*

**3.**

**Segmentation  
of wards**

**70%**

**Air pressure  
barriers**

**30%**

## Findings

### ★ Telehealth – growing trend

*“The video consultations have increased ten times after the crisis, and probably be something that continues to be there after COVID-19”.*

### ★ Space & infrastructure for virtual consultations

*“The goal for the outpatient department is to reduce 50% of the visits to the hospital and replace them by video consulting.”*

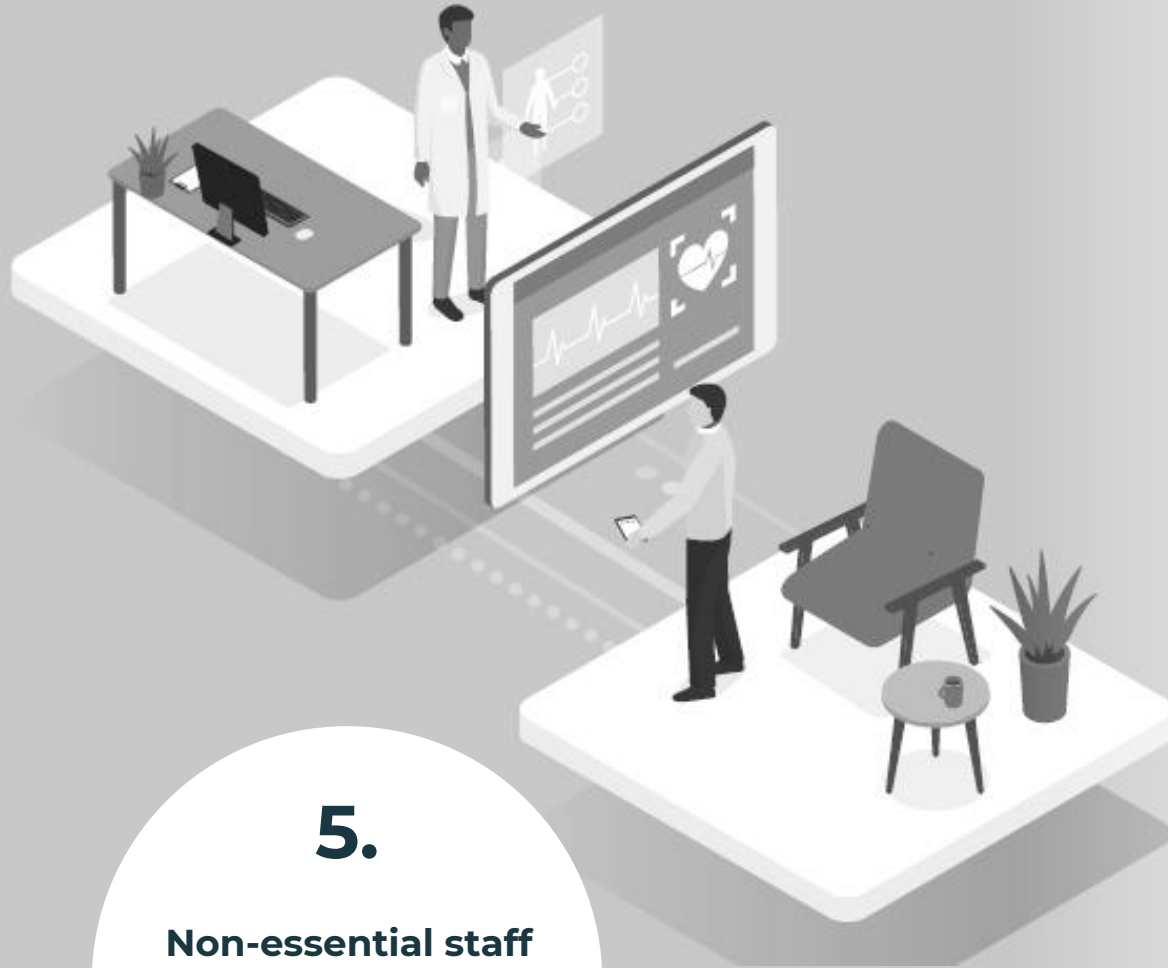
**4.**

**Switch to digital consultations**

**67%**



## Findings



**5.**

**Non-essential staff  
working from home  
60%**

### ★ Digital transformation

*“I think it will be a cultural change, and it was already going on. But it has been speeded up with the pandemic.”*

### ★ Digital functionalities

*“All the traditional staffrooms will be rebuilt and redecorated to video conferencing room.” “I think the meeting rooms will have far more better video facilities than they have now; in general, our ICT system is not suited for video conferencing.”*

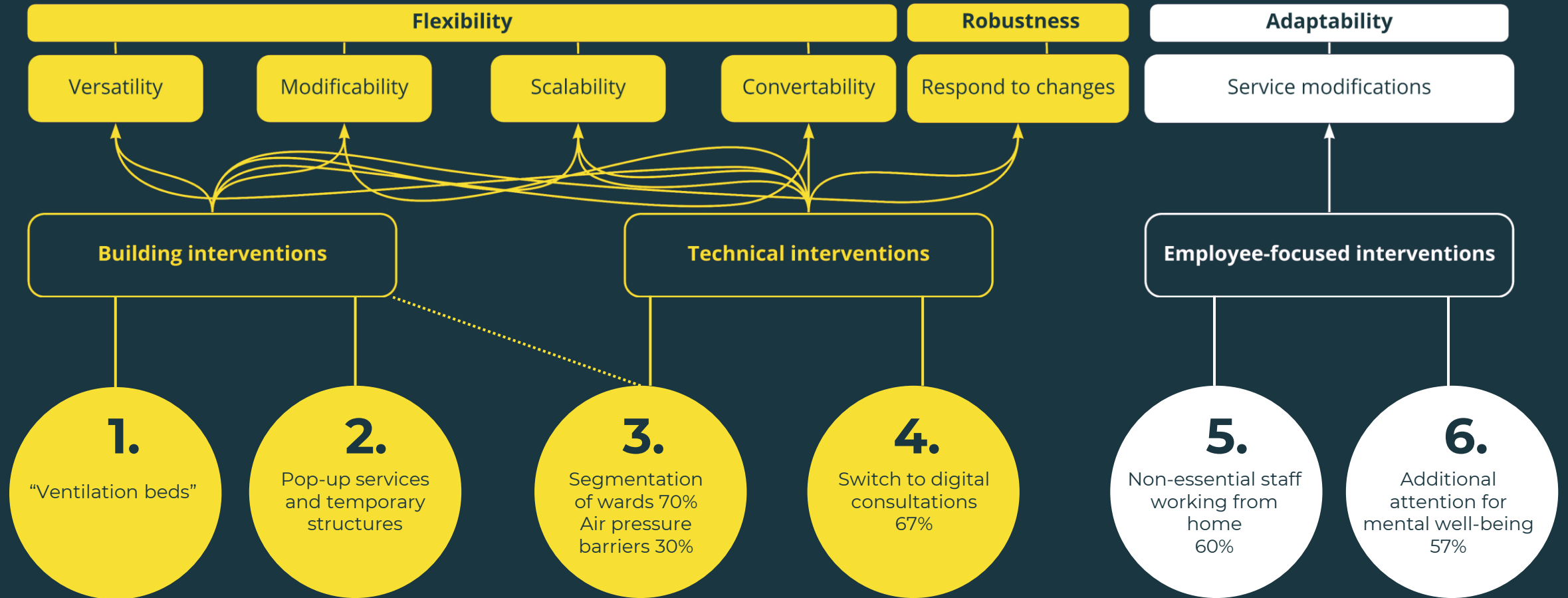
# Findings

★ **Resiliency involves multiple aspects!**  
Staff is a core asset for hospitals.

**6.**  
**Additional attention  
for mental well-being**  
**57%**



# Summary



## Recommendations

### Building interventions

1.

"Ventilation beds"

2.

Pop-up services  
and temporary  
structures

3.

Segmentation  
of wards 70%  
Air pressure  
barriers 30%

4.

Switch to digital  
consultations  
67%

### Technical interventions

### Employee-focused interventions

5.

Non-essential staff  
working from  
home  
60%

6.

Additional  
attention for  
mental well-being  
57%

### Surge strategies



- Oxygen and power capacity geared for high demand of ventilation beds,
- Single patient rooms for double occupancy

# Recommendations

## Building interventions

1.

"Ventilation beds"

Surge strategies



2.

Pop-up services and temporary structures

Multipurpose spaces



## Technical interventions

3.

Segmentation of wards 70%  
Air pressure barriers 30%

4.

Switch to digital consultations 67%

- Availability of indoor and outdoor space

## Employee-focused interventions

5.

Non-essential staff working from home 60%

6.

Additional attention for mental well-being 57%

# Recommendations

## Building interventions

1.

"Ventilation beds"

Surge strategies



2.

Pop-up services and temporary structures

Multipurpose spaces



3.

Segmentation of wards 70%  
Air pressure barriers 30%

Possible segmentation



- Red and Green areas
- Independent traffic flows, and installations

## Technical interventions

4.

Switch to digital consultations 67%

5.

Non-essential staff working from home 60%

6.

Additional attention for mental well-being 57%

## Employee-focused interventions

# Recommendations

## Building interventions

1.

"Ventilation beds"

Surge strategies



2.

Pop-up services and temporary structures

Multipurpose spaces



## Technical interventions

3.

Segmentation of wards 70%  
Air pressure barriers 30%

Possible segmentation



4.

Switch to digital consultations 67%

Virtual consultations



- Spaces for virtual communication.
- Adequate internet connectivity.

## Employee-focused interventions

5.

Non-essential staff working from home 60%

6.

Additional attention for mental well-being 57%

# Recommendations

## Building interventions

## Technical interventions

## Employee-focused interventions

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"Ventilation beds"

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Pop-up services and temporary structures

3.  
Segmentation of wards 70%  
Air pressure barriers 30%

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67%

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Non-essential staff working from home  
60%

6.  
Additional attention for mental well-being  
57%

Surge strategies

Multipurpose spaces

Possible segmentation

Virtual consultations

Digital functionalities



- Consider some workplaces as potential multipurpose spaces.

# Recommendations

## Building interventions

1.

"Ventilation beds"

Surge strategies



2.

Pop-up services and temporary structures

Multipurpose spaces



3.

Segmentation of wards 70%  
Air pressure barriers 30%

Possible segmentation



4.

Switch to digital consultations 67%

Virtual consultations



## Employee-focused interventions

5.

Non-essential staff working from home 60%

Digital functionalities



6.

Additional attention for mental well-being 57%

Staff's well-being



- More services in demanding periods

# Recommendations

## Building interventions

## Technical interventions

## Employee-focused interventions

1.

"Ventilation beds"

Surge strategies



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Pop-up services and temporary structures

Multipurpose spaces



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Segmentation of wards 70%  
Air pressure barriers 30%

Possible segmentation



4.

Switch to digital consultations 67%

Virtual consultations



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Non-essential staff working from home 60%

Digital functionalities



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Additional attention for mental well-being 57%

Staff's well-being



Flexibility & Robustness

# Recommendations

## Building interventions

## Technical interventions

## Employee-focused interventions

1.  
"Ventilation beds"

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Segmentation of wards 70%  
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Multipurpose spaces

Possible segmentation

Virtual consultations

Digital functionalities

Staff's well-being



Flexibility & Robustness

Adaptability



# Towards a resilient hospital design

Emerging design considerations for future healthcare facilities after the different waves of COVID-19.



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