Heart-Rate–Based Work–Rest Scheduling in Construction

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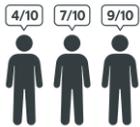**Fatigue Cycle**

Long, Physically Demanding Workday

Injuries & Errors
Slower Productivity
Overtime & Schedule Pressure

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Literature – Measuring Fatigue In Construction

Fatigue is often assessed using both **subjective** ratings and **objective** signals.*[1]

Fatigue scales vary widely across workers.[2]

Repeated reporting can be **disruptive** and **impractical** during construction tasks.[3]

→ *These limitations motivate continuous, non-intrusive monitoring using wearable sensors*

Research Gaps

Recent studies have explored wearable sensors for **work–rest** allocation and **micro-breaks**.

- Many frameworks rely on **simplified or simulated scenarios**.

- Limited studies use **continuous physiological data** from **real construction sites**.

→ Need for a practical framework that translates wearable physiology into work–rest scheduling decisions.

Simulated Scenarios

Simplified Scenarios

Limited Field Data
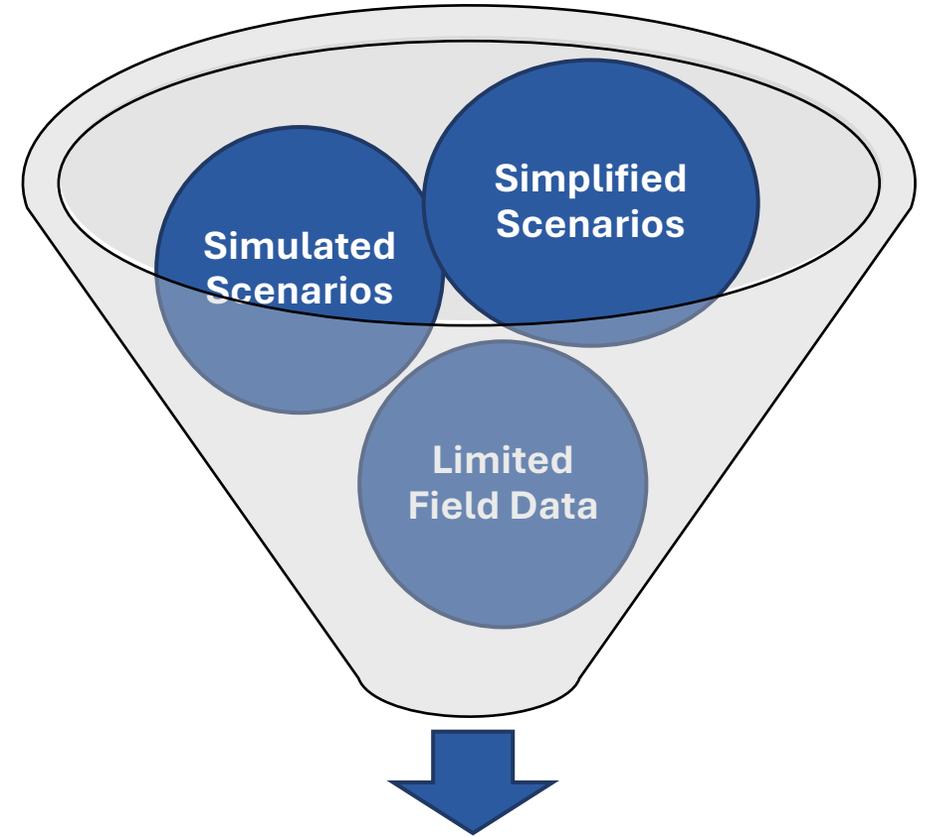
No practical physiology-guided work–rest scheduling framework for construction sites

Proposed Framework
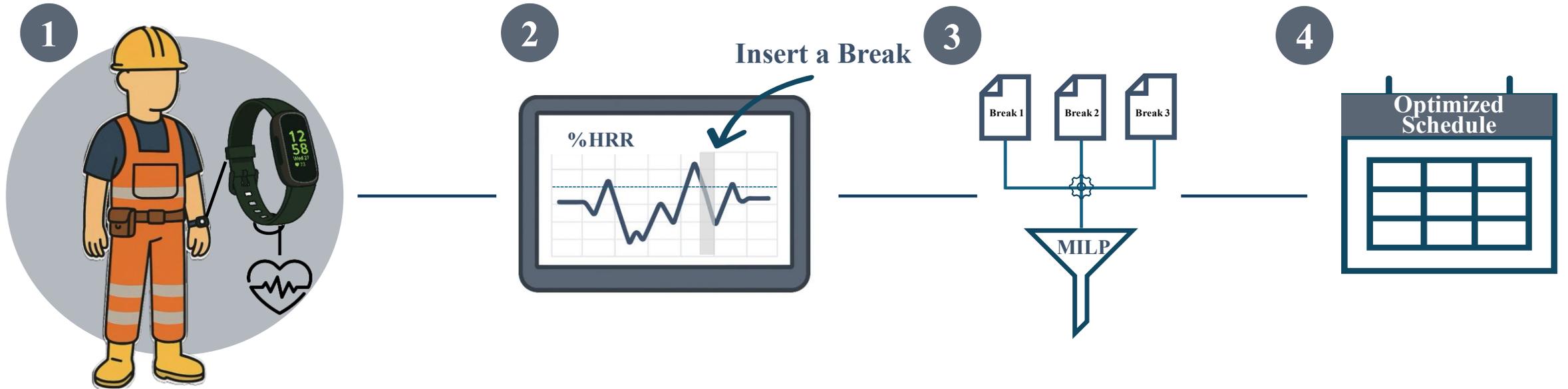
- Monitor workers' **heart rate** on **active** construction sites using **wearable** devices.

- Trigger and size rest breaks based on percentage **heart-rate reserve** (%HRR).

- **Optimize** break allocation using a model that **maximizes physiological recovery**.

Methodology

Field & Wearable Data | Physiological Metric | Work–Rest Scheduling

Sites & Workers

- **33** workers
- **3 active construction sites** in Beirut.
- Residential and institutional projects.
- Mixed trades and skills.

On-Site Data Collection

- **Full-shift monitoring** (Mon–Sat) during working hours.
- Continuous physiological monitoring on-site.

Wearable Device & Signals

- Fitbit Inspire 3 (wrist); minute-level HR.
- **Researcher synced** data, which is uploaded to an **AWS**.

Heart Rate Reserve (%HRR)

$$\%HRR = \frac{HR_{Work} - HR_{Resting}}{HR_{Maximum} - HR_{Resting}} \times 100\%$$

- $\%HRR$ expresses current HR relative to resting and maximal HR [4]

- $\%HRR$ is used instead of raw HR because it accounts for **differences** in resting and maximum HR, making **strain comparable across workers**.
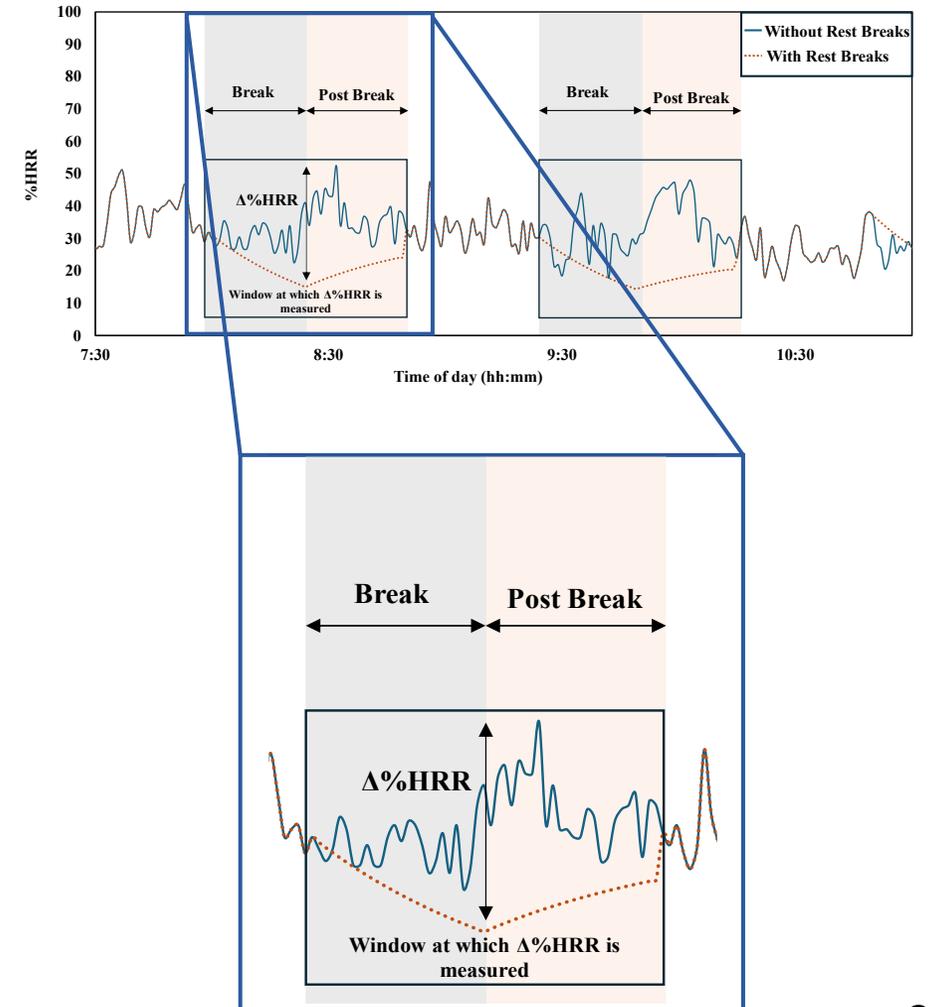
Rest Allowance (RA)

$$RA = \max\left(0, \frac{HR_{Work} - HR_{Endurance}}{HR_{Maximum} - HR_{Resting}}\right) \times \text{Work Duration}$$

- Time spent at high %HRR indicates physiological strain [5]

- A rest allowance rule converts accumulated strain into required break time.

- During a break, heart rate decreases toward resting levels.

Identifying Candidate Breaks

- RA is computed on a sliding **60-minute window** (1-minute step).

- Whenever RA > 0, a candidate break is created with **duration equal to the RA output**.

- For each candidate break, **Δ%HRR (benefit)** is computed:

  - Δ%HRR = (%HRR without break) – (%HRR with break),

  - expressed as a **minute-weighted average reduction**.

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Optimization of Break Selection

Candidate breaks are generated from the **rest allowance** rule, but only a **limited** number can be scheduled.

Constraints
- Daily rest budget per worker (e.g., 30 minutes excluding lunch)
- Minimum spacing between breaks
- Breaks must occur within the working hours

Objective
- The optimization model selects breaks that **maximize** physiological **recovery**.
- **Recovery** benefit is measured using **Δ%HRR** (marginal reduction in physiological strain).

Takeaway
The model prioritizes breaks that provide the largest recovery benefit per minute of rest.

Candidate Breaks

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Optimization Model
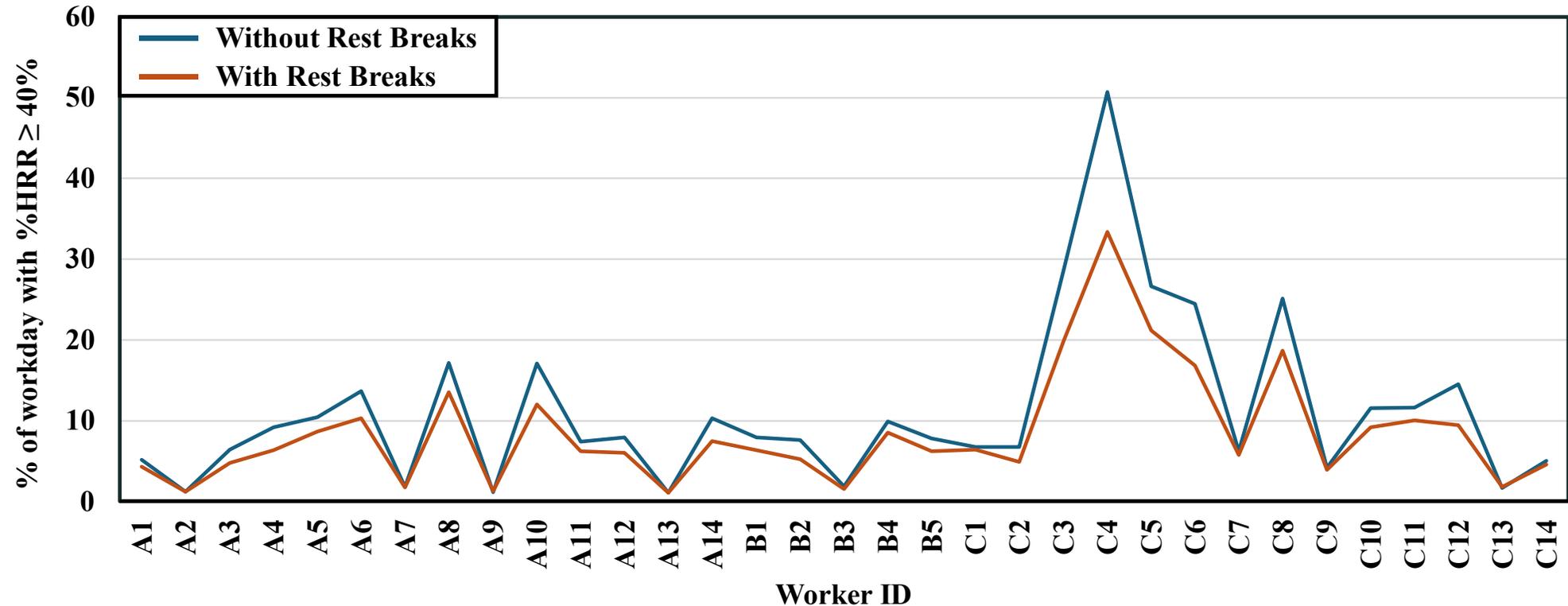
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Optimized Schedule
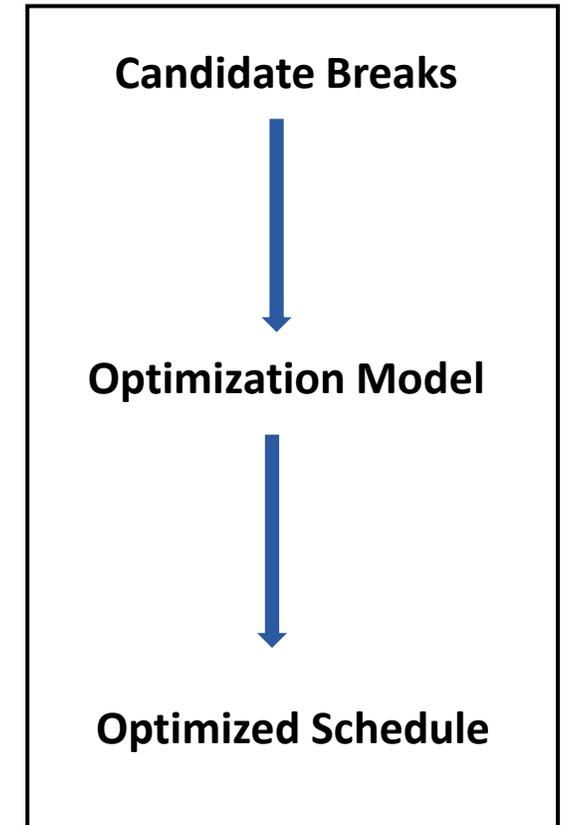
Results

Physiological Workload Patterns

- Mean worker age: **29 years**

- Worker mean workload ranged from **~17% to 41% HRR** [**Substantial variability between workers**]

- **92% of worker-days triggered at least one candidate break**
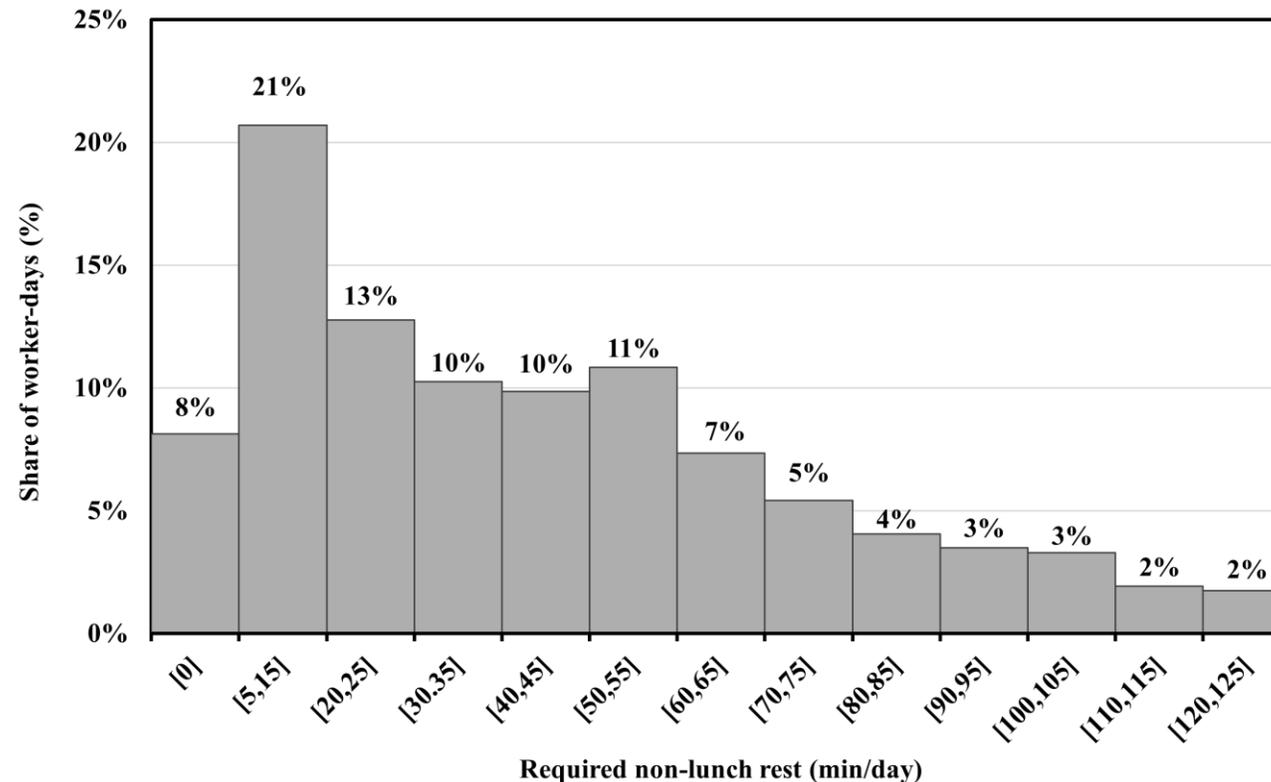
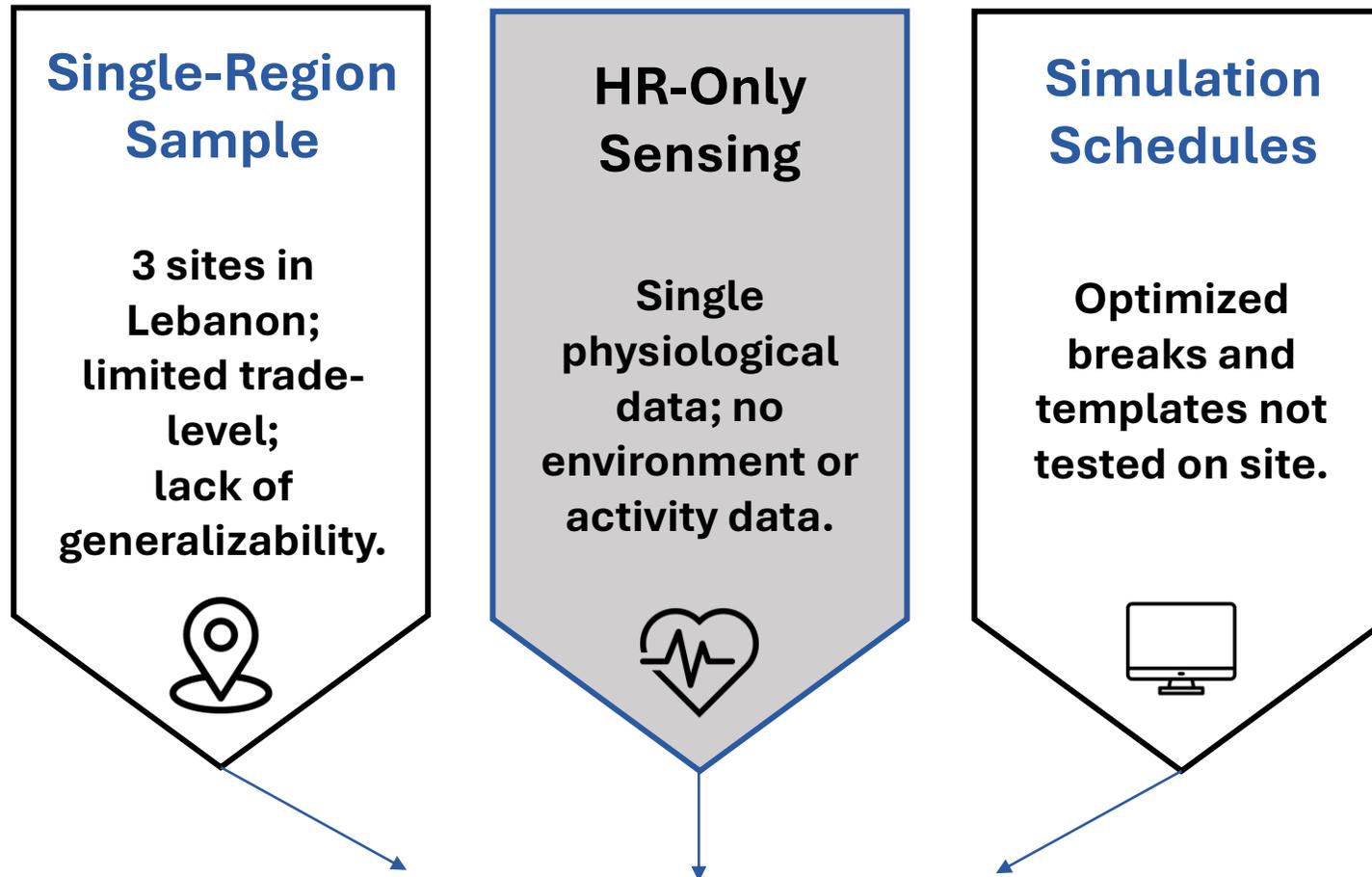# Effect of Optimized Break Scheduling

- Candidate breaks typically required **5–15 minutes** of rest per day

- Without limits, average required rest **≈ 40 minutes** per worker-day

- As shown in the figure, with a **30-minute daily cap**, optimized breaks **reduced the share of workday minutes with %HRR ≥ 40%** while keeping **average workload nearly unchanged**

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Conclusion

Limitations and Future Work

Single-Region Sample

3 sites in Lebanon; limited trade-level; lack of generalizability.

HR-Only Sensing

Single physiological data; no environment or activity data.

Simulation Schedules

Optimized breaks and templates not tested on site.

Incorporate **additional sensors** and contextual data

Test **real-world** implementation of **optimized** schedules

Key Findings

- Wearable **minute-level heart-rate data** can be used to monitor physiological workload on active construction sites.

- A **rest-allowance rule** converts physiological strain (%HRR) into candidate recovery breaks.

- An **optimization model** selects breaks that maximize physiological recovery under practical scheduling constraints.

➡ Targeted rest breaks **reduce high-strain exposure without increasing overall downtime**.

➡ **We could integrate AI into this scheduling approach to learn how and when workers need breaks.**

Thank You

References

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