

CARE-FLOW

Intelligent data-driven tools for cross-border
collaboration in healthcare

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Project: CARE-FLOW

- ▶ Regional & Cross-border collaboration
- ▶ Support decision making
- ▶ Accessibility to care
- ▶ Smoothen patient flow



Interreg



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Deutschland – Nederland

CARE-FLOW



Ministerium für Wirtschaft,
Industrie, Klimaschutz und Energie
des Landes Nordrhein-Westfalen



Versorgung: Deutschland und Niederlande im Fokus



Dutch COVID-19 patients transferred to Germany as

By Reuters

November 23, 2021 3:40 PM GMT+1

Kreis Borken: Rettungseinsätze in den Niederlanden

von Redaktion Rettungsdienst, 23. Mai 2017



Isselburg (rd_de) – Der Rettungsdienst des Kreises Borken kooperiert seit Anfang Mai 2017 mit dem niederländischen Rettungsdienst Witte Kruis. Die

NOS Nieuws • Maandag 6 juni 2022, 12:...

'Buitenlandse ziekenhuizen hard nodig bij wegwerken inhaalzorg en wachtlijsten'

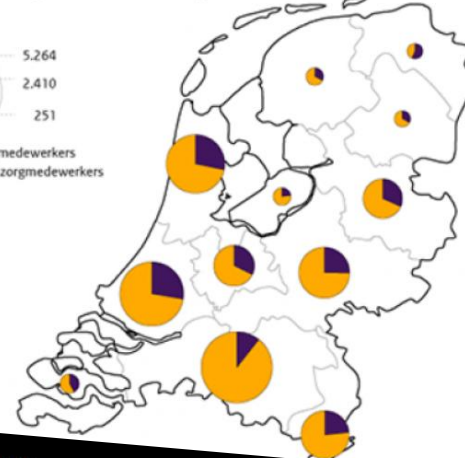
Wegen steigender Patientenzahlen: Niederlande verlegen Corona-Patienten nach Deutschland



...op het idee, om patiënten
...opereren, zijn voorzichtig

Publicatiedatum 10-04-2020 | 14:31

Per provincie, zorgmedewerkers vs niet-zorgmedewerkers, tm 10-4-2020: 10:00 uur

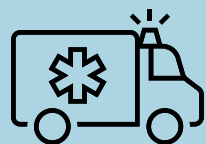


Dutch hospital airlifts patients to Germany amid virus surge

Duitse traumaheli ingezet vlakbij het MST: hoe zit dat?

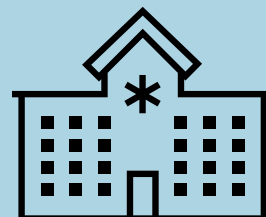
De Hogelandsingel in Enschede was woensdagmiddag enige tijd

EMERGENCY

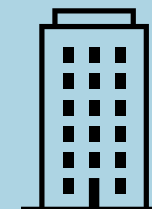


ELECTIVE

HOSPITAL



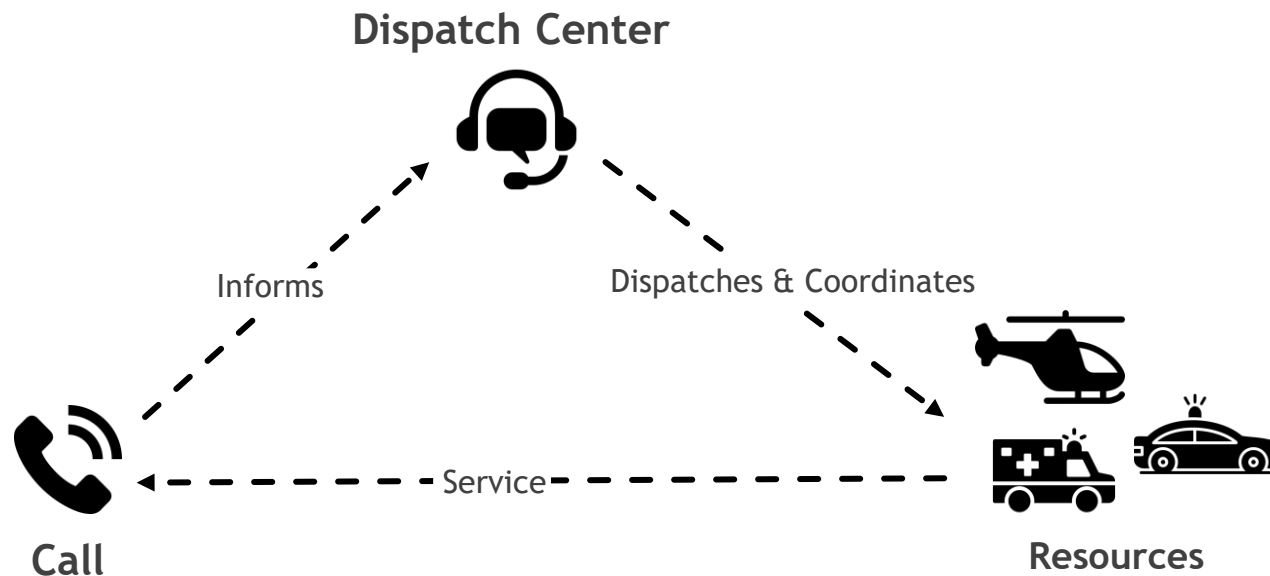
CENTRAL COORDINATION



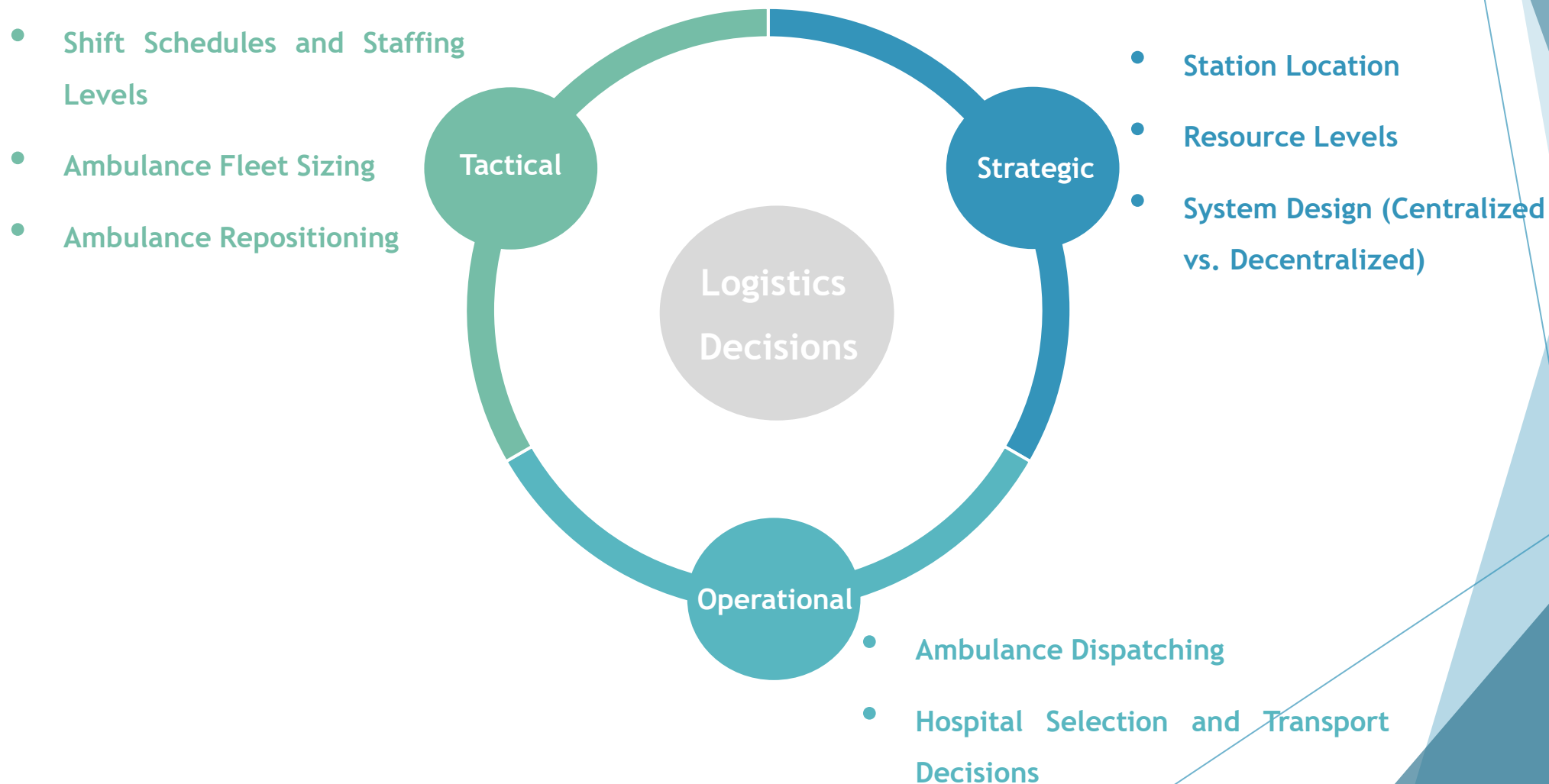
AFTERCARE

EMS Core Process

- ▶ EMS provides prehospital emergency care, including on-scene treatment and, if required, transport to definitive care facilities.
- ▶ EMS represents the first point of professional medical decision-making in the patient pathway.
- ▶ Early EMS decisions strongly influence patient outcomes and overall system performance.



Logistics Decisions in EMS



Ambulance Repositioning



Relocation

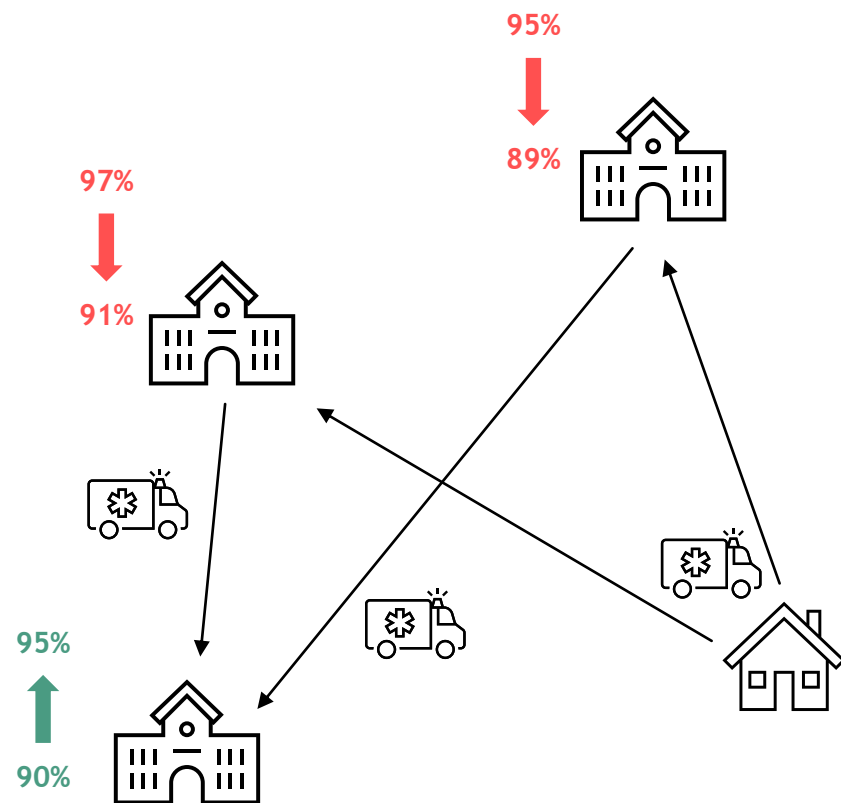
Moving an ambulance from its current base or standby location to another location while it is still idle.



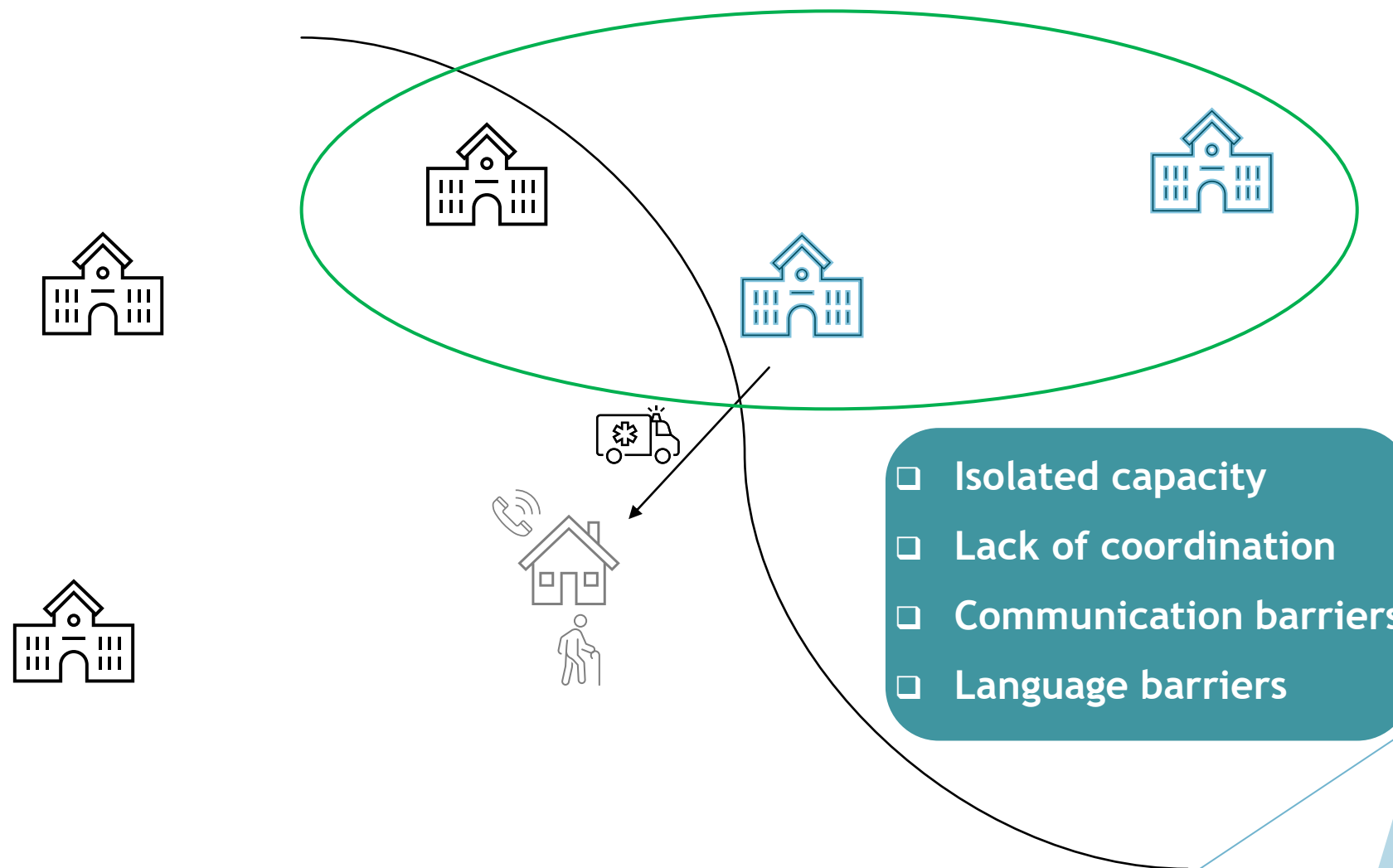
Redeployment

Assigning an ambulance to a new base or standby location after it completes a service or transport.

Gaps and Our Contribution



Gaps and Our Contribution



- Isolated capacity
- Lack of coordination
- Communication barriers
- Language barriers

Maximum Expected Coverage Location Problem

Model Assumptions:

Decision: **location** of ambulance bases and the **sizing** of the ambulance fleet.

- ❑ Fixed demand points
- ❑ Deterministic travel times
- ❑ Single-call service
- ❑ Ambulance unavailability
- ❑ Expected coverage

Maximum Expected Coverage Location Problem

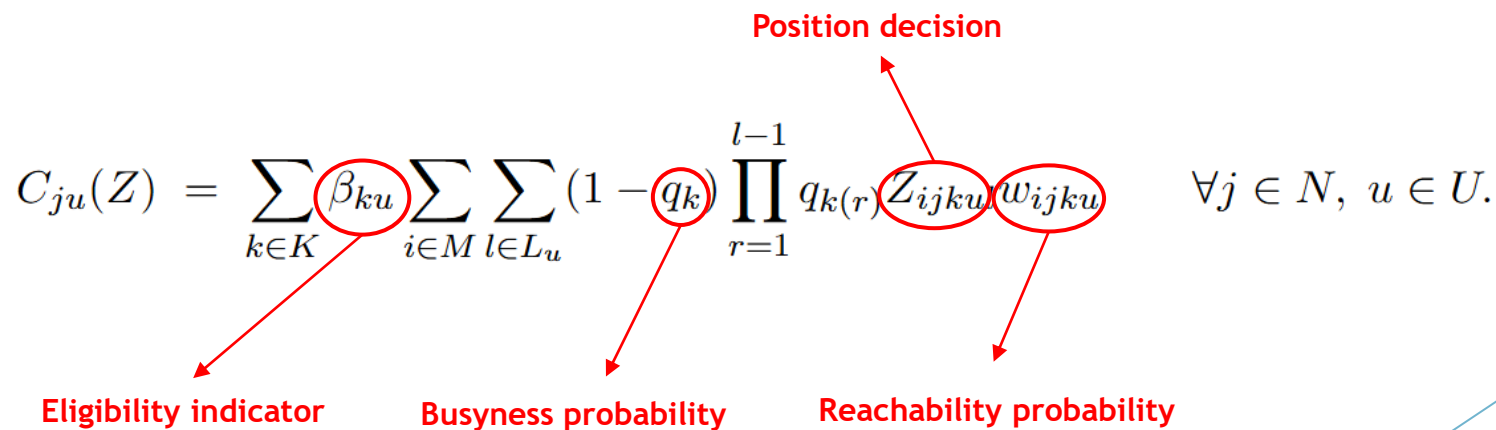
Compared to simple MEXCLP, this model adds:

- ❑ Multi-country demand and base structure
- ❑ Fleet sizing by ambulance type
- ❑ Multiple urgency levels with priorities
- ❑ Type-urgency eligibility constraints
- ❑ Type-specific busyness probabilities
- ❑ Joint response for highest urgency
- ❑ Cross-border coverage assignment decision
- ❑ Coverage-equity-workload trade-offs

Maximum Expected Coverage Location Problem

Coverage Calculation:

$$C_{total} = \frac{\sum_{j \in N} \sum_{u \in U} \alpha_u d_{ju} C_{ju}(Z)}{\sum_{j \in N} \sum_{u \in U} \alpha_u d_{ju}}$$

$$C_{ju}(Z) = \sum_{k \in K} \beta_{ku} \sum_{i \in M} \sum_{l \in L_u} (1 - q_k) \prod_{r=1}^{l-1} q_{k(r)} Z_{ijk_u} W_{ijk_u} \quad \forall j \in N, u \in U.$$


Eligibility indicator Busyness probability Reachability probability Position decision

Tactical and operational hospital planning



ER



Diagnostics



OR

MSS

	Monday		Tuesday		Wednesday	
	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
OR1	GEN	GEN	ORTHO	CARDIO	ORTHO	ORTHO
OR2	GYN	URO	GEN	URO	FLEX	CARDIO
OR3	ACUTE	ACUTE	ACUTE	ACUTE	ACUTE	ACUTE

- ▶ Tactical planning
 - ▶ Staffing (aggregated level)
 - ▶ Master schedule/Block plan
- ▶ Operational planning
 - ▶ Staff rostering (individual level)
 - ▶ Patient booking

Tactical and operational hospital planning



ER



Diagnostics



OR

- ▶ Tactical planning
 - ▶ Staffing (aggregated level)
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 - ▶ Patient booking

MSS

	Monday				Tuesday				Wednesday			
	Morning		Afternoon		Morning		Afternoon		Morning		Afternoon	
OR1	P834 P043 P734	S17 S09 S23	P175 P841	S17 S09 S23	P739 P259	S63 S05 S39	P112 P829 ??	S49 S15 S25	?? P275 P127	S22	?? P724	S63 S05
OR2	P945	S04 S37	P043 P734 ??	S63 S05 S39	P043 P734	S17 S09 S23			P043 P734			
OR3	P385 ??	S48 S85	?? GREG ??	S62 S85	P536 ??	S48 S45	??	S48 S12	??	S03 SS01 85	??	S48 S04



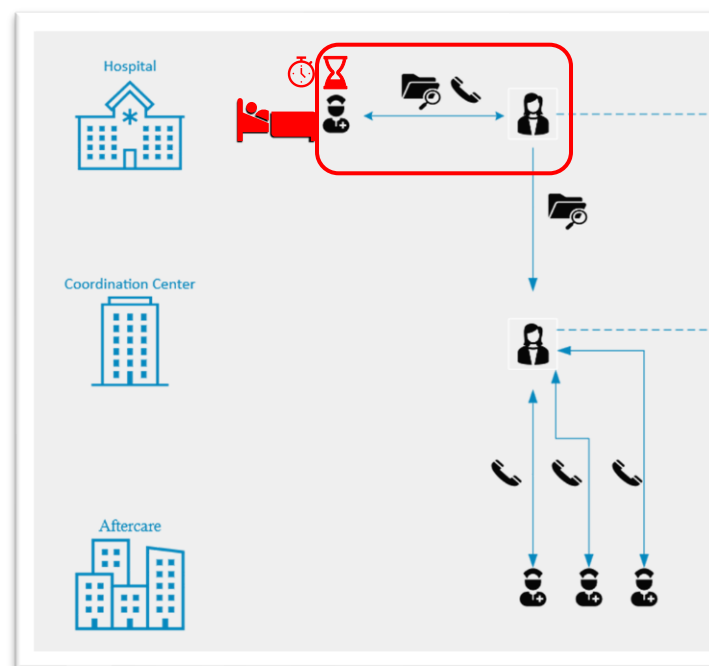
Discharge process

- ▶ Timely identification of aftercare need crucial



Discharge process

- ▶ Timely identification of aftercare need crucial

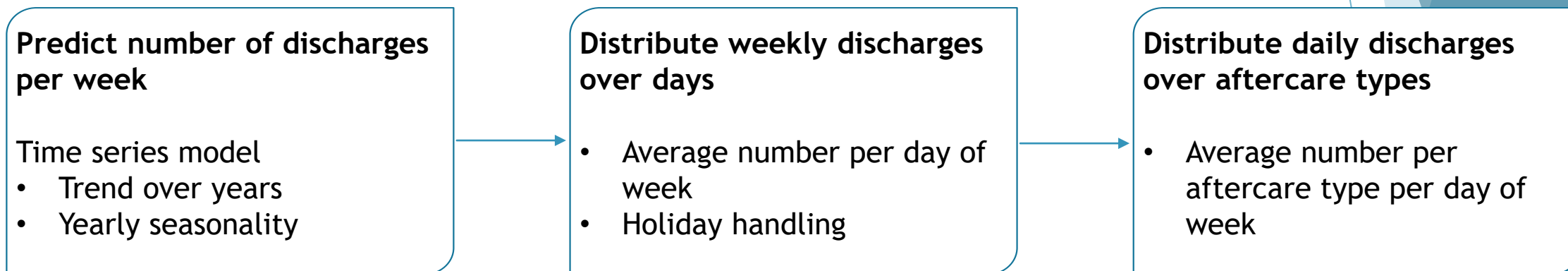




Discharge process

- ▶ Timely identification of aftercare need crucial
- ▶ Support nurse in recognizing aftercare need
 - ▶ System notification: *“Consider starting aftercare process for Greg!”*
 - ▶ Estimated discharge date
- ▶ Machine Learning
 - ▶ Detailed medical records
 - ▶ Evolution of scores over time (e.g., Delirium, Risk of falling, Malnutrition, Decubitus, Independence)

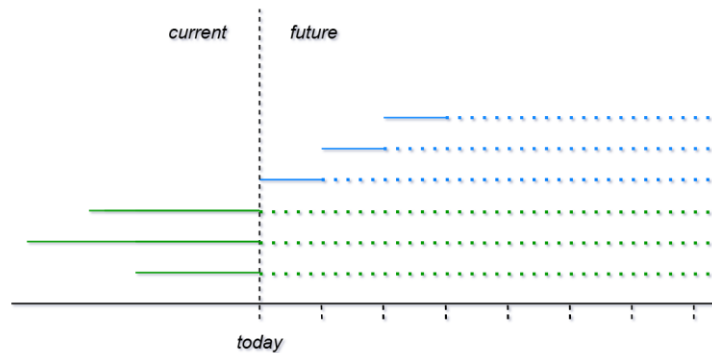
Patient flow prediction - Tactical level



Patient flow prediction - Operational level

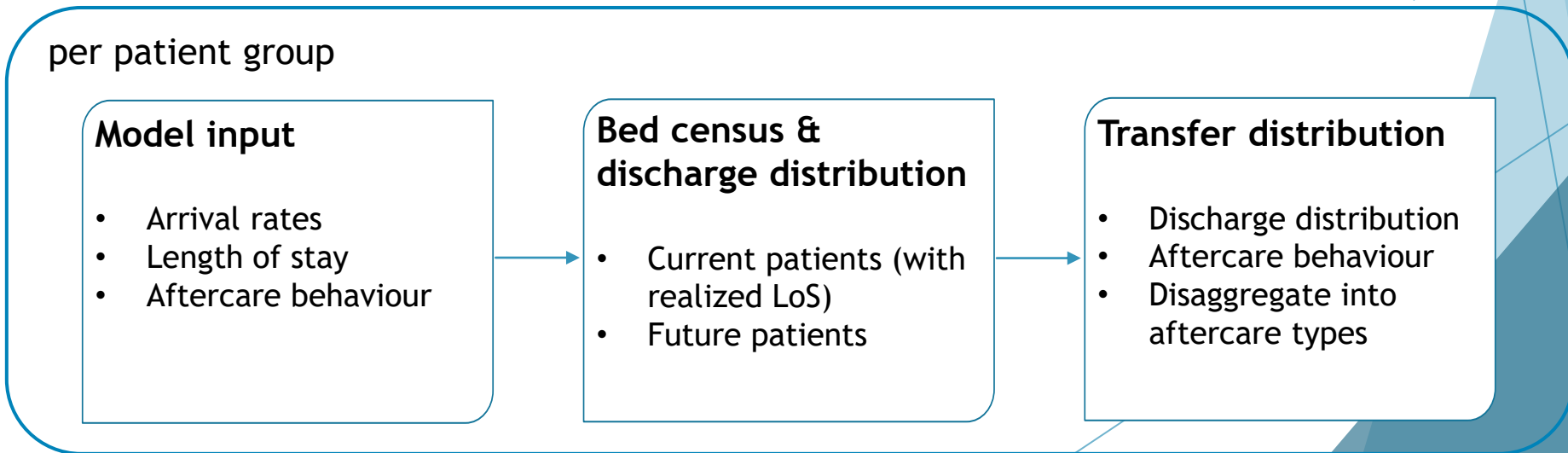
Patient grouping

- Emergency/elective
- Department
- Age group
- Gender

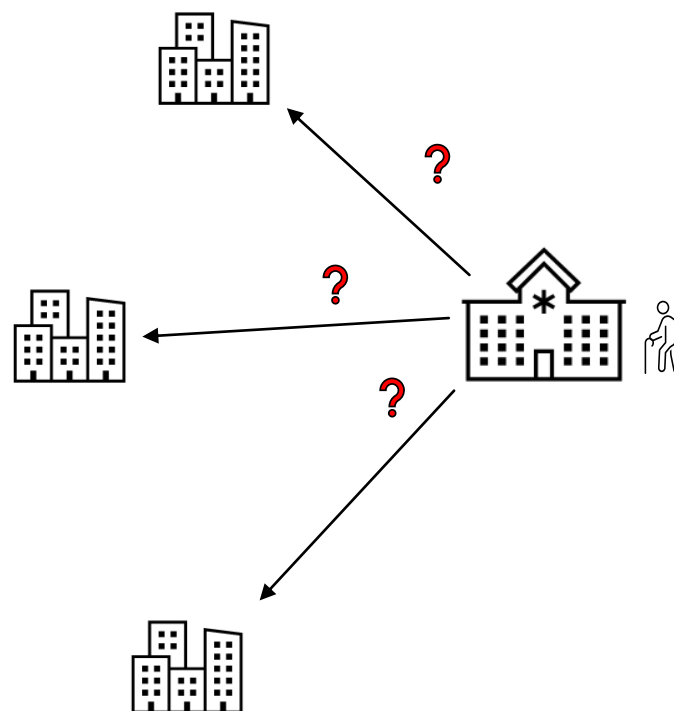


Transfer distribution for each aftercare type

- Convolute all patient groups



Requesting a patient transfer



Admission decision

max number of treated patients

min cost

min work-overload for available staff

Patient bed
census

Nurse availability

Do we accept a patient transfer request?





















Admission decision

Decision based on:

- ▶ Nurse availability
- ▶ Current patient census
- ▶ Expected inflow patients
- ▶ Internal flexible (& float) resources
- ▶ External flexpool

Admission decision

► Stochastic nurse availability

Monday	Tuesday	Wednesday	Thursday	Friday
				
				
				
				

Admission decision

R_j	Roster of nurse j
q_t	Probability of getting sick at time t
$p(t)$	Probability of getting healthy after being sick for t days
τ_j	Time nurse j has been sick at day 0

- ▶ Stochastic nurse availability
 - ▶ Healthy
 - ▶ Sick
- ▶ Current day (known)

Roster of nurse j

$$s_{0,X}^j = \begin{cases} \mathbb{1}(t \in R_j) & \text{if } X = \text{healthy} \\ 0 & \text{if } X = \text{sick} \end{cases}$$

- ▶ Future (unknown)

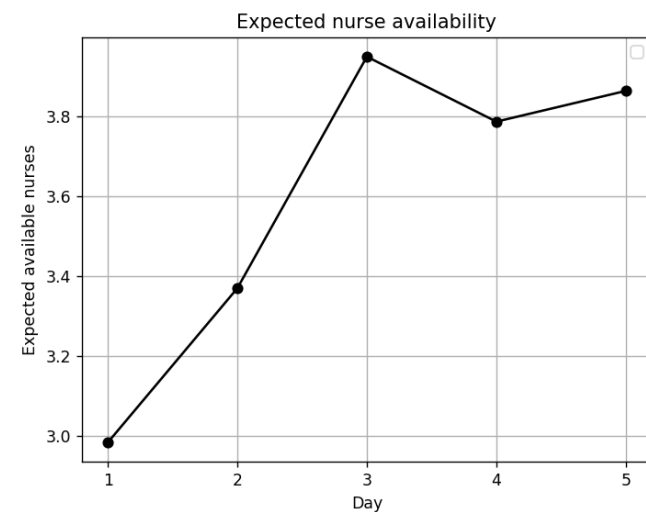
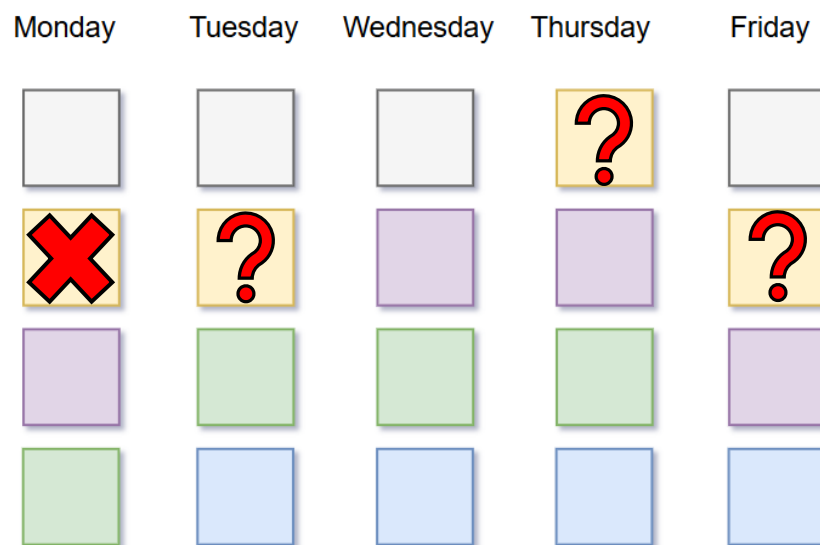
$$s_{t,X}^j = \begin{cases} \left[(1 - q_t) + \sum_{k=0}^{t-1} q_k p(t-k) \right] \mathbb{1}(t \in R_j) & \text{if } X = \text{healthy}, t \geq 1 \\ \sum_{k=0}^t p(\tau_j + k) \mathbb{1}(t \in R_j) & \text{if } X = \text{sick}, t \geq 1 \end{cases}$$

- ▶ Total

$$S_t = \sum_{j \in J, X \in \{\text{healthy}, \text{sick}\}} s_{t,X}^j$$

Admission decision

► Stochastic nurse availability



Admission decision

Nurse availability

Current patients

Flexible resources

Expected arrivals

MDP

max number of treated patients

min work-overload for available staff

min cost

Patient flow

Accept

Accept with delay

Reject

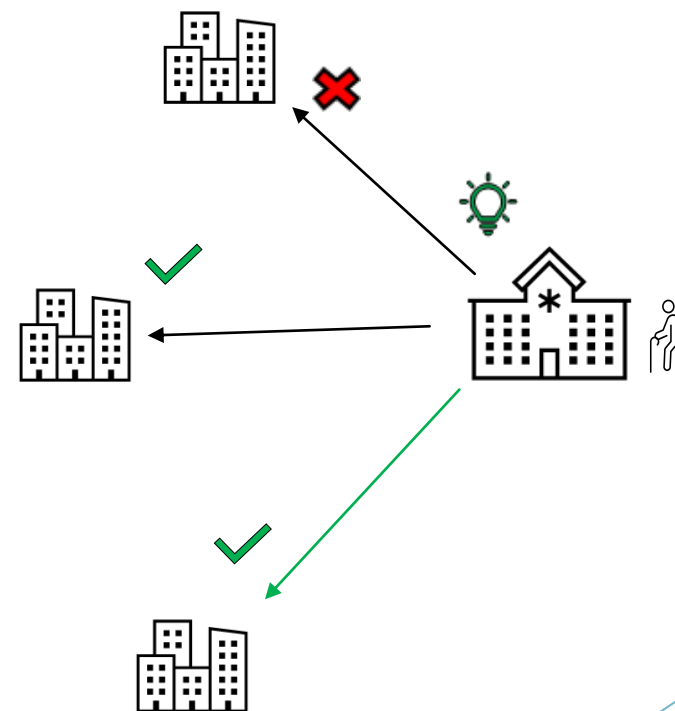
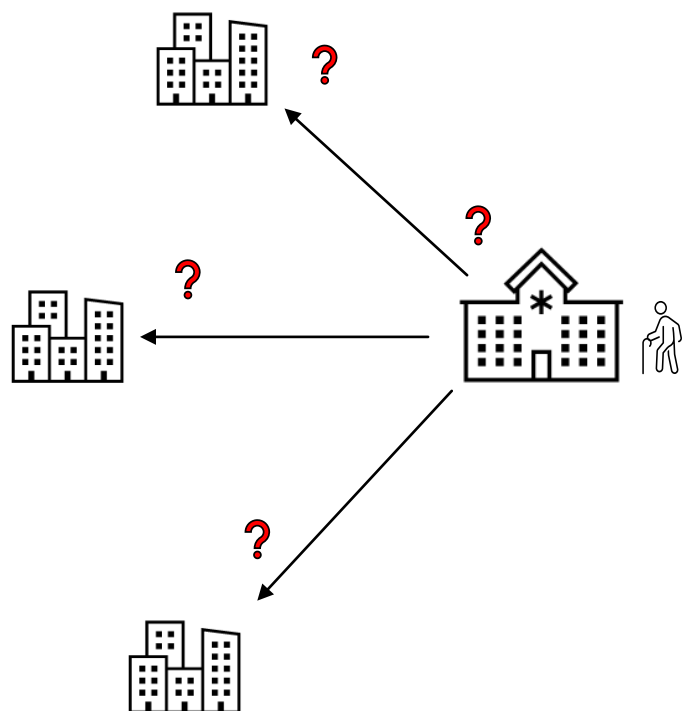
Capacity planning

Do nothing

Reallocate internal nurses

Hire external nurses

Choosing the right aftercare facility



Recap

- ▶ Patient flow is an end-to-end, interdependent system
- ▶ Decisions upstream shape capacity downstream
- ▶ Fragmented planning creates hidden bottlenecks
- ▶ Border regions amplify coordination failures
- ▶ Collaboration requires shared data and aligned decisions
- ▶ CARE-FLOW connects EMS, hospitals, and aftercare
- ▶ From isolated actions to coordinated patient flow

Thanks!

Question/Comments?

Ideas? Want to connect?

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