Modeling uncertain task compliance in dispatch of volunteers to out-of-hospital cardiac arrest patients

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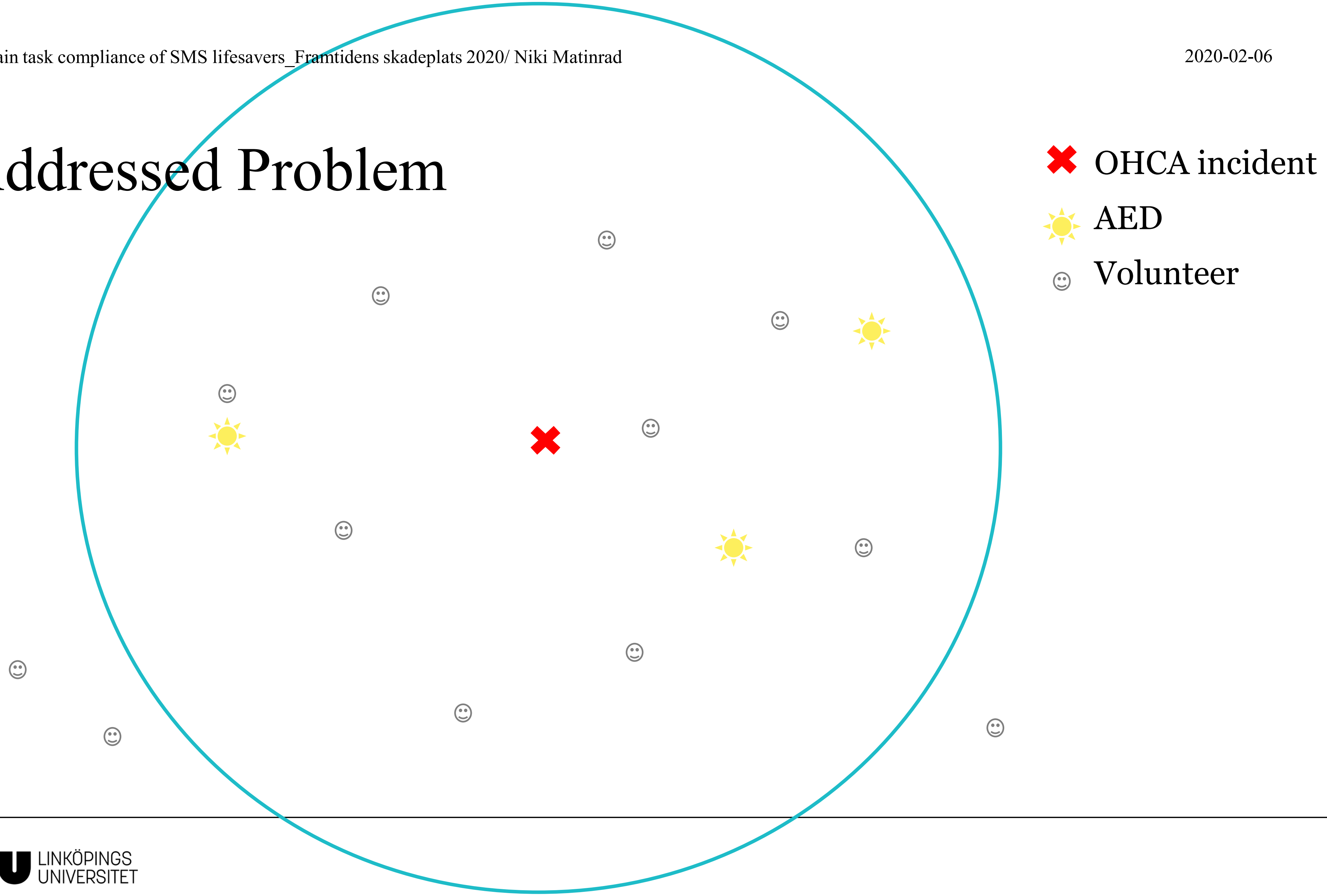
General Background

- One untraditional type of emergency resources that has been facing a rising interest in the past few years are volunteers.
- SMS lifesavers are registered volunteers for cardiac arrest cases, and they know how to perform CPR and use AED.

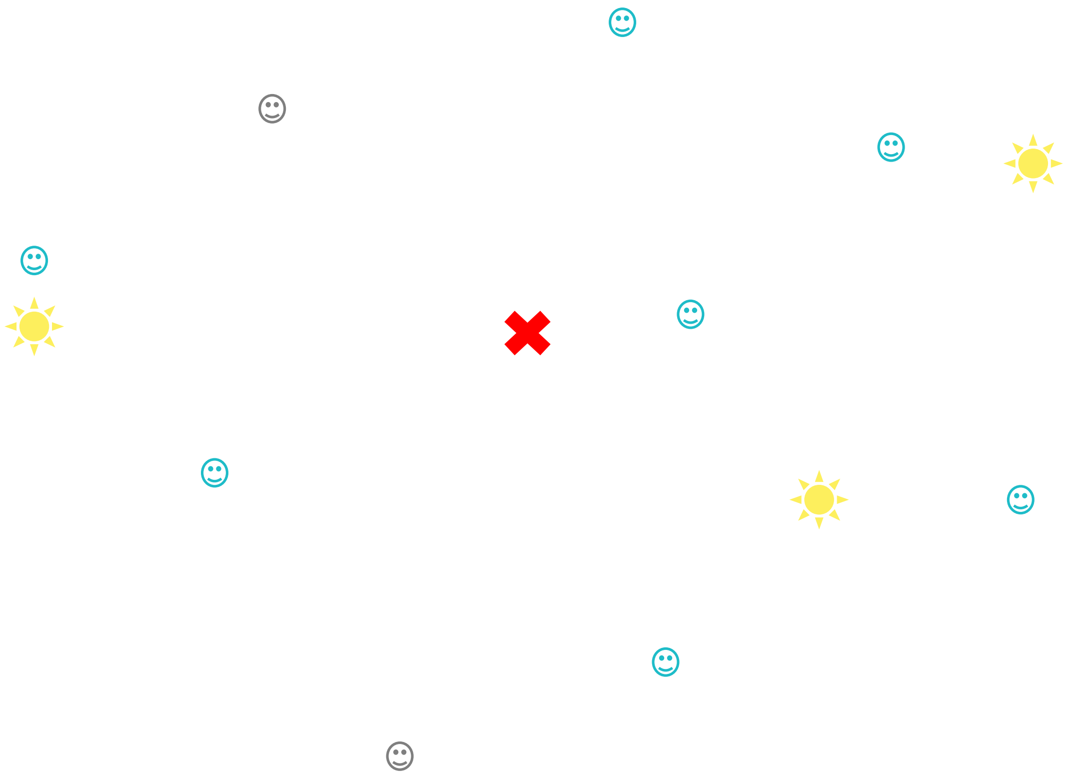
Volunteers Tasks

- Defibrillator (AED)
- Reviving (CPR, AED utilization)

Addressed Problem



Addressed Problem (Cont.)



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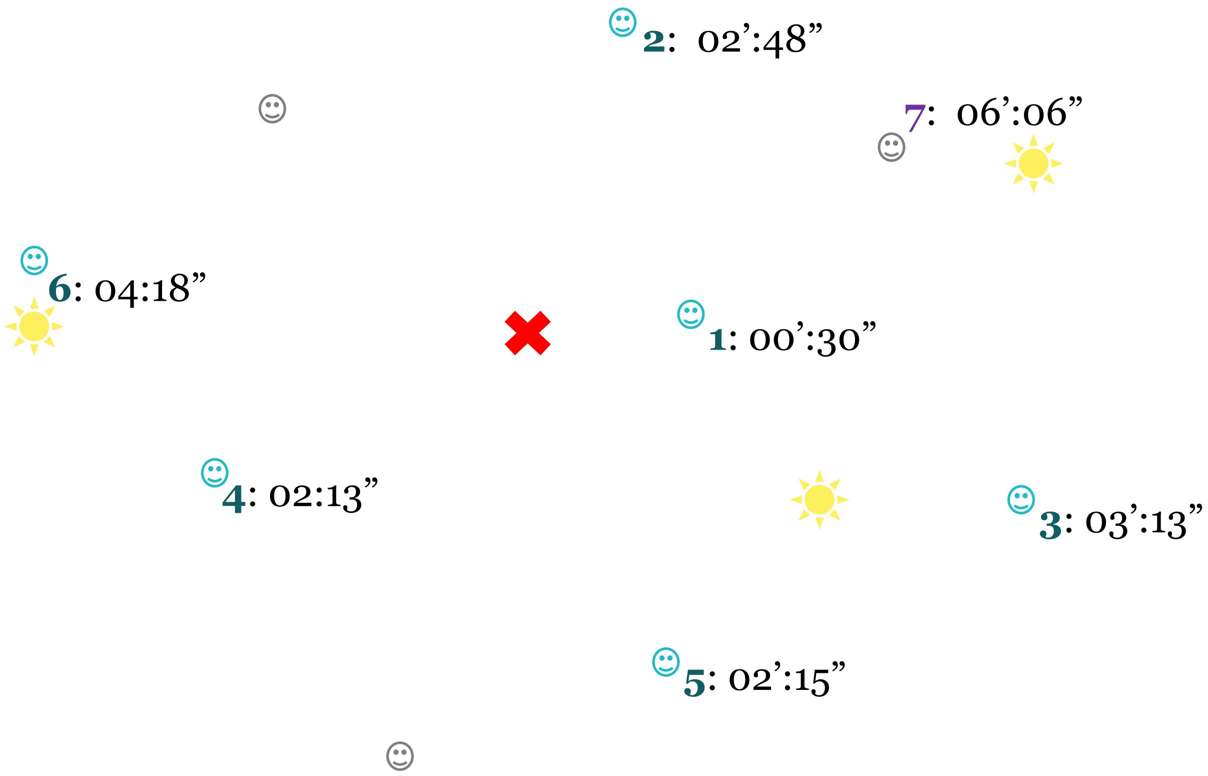


✖ OHCA incident

AED

Volunteer

Available Volunteer

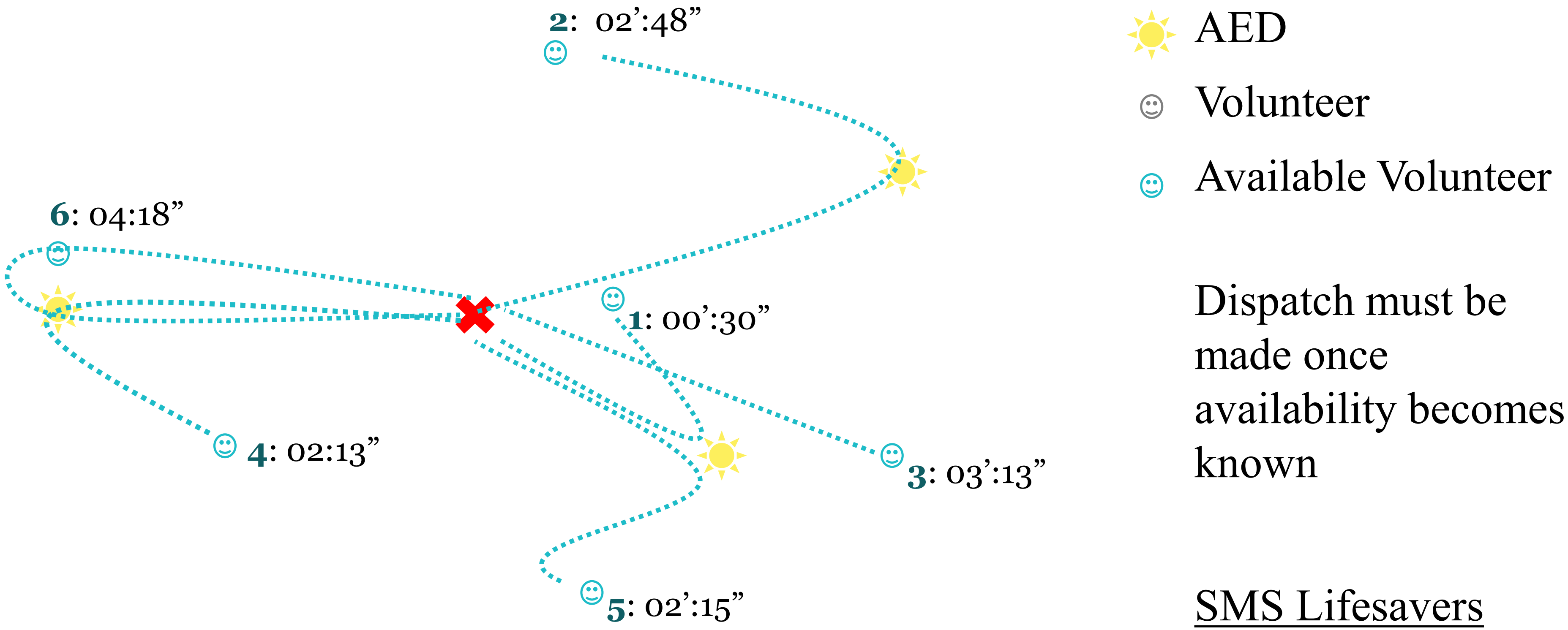
Dispatch must be made once availability becomes known

<u>SMS Lifesavers</u>

Dispatch Rule block

A A D A A

Addressed Problem (Cont.)



Dispatch must be made once availability becomes known

<u>SMS Lifesavers</u>

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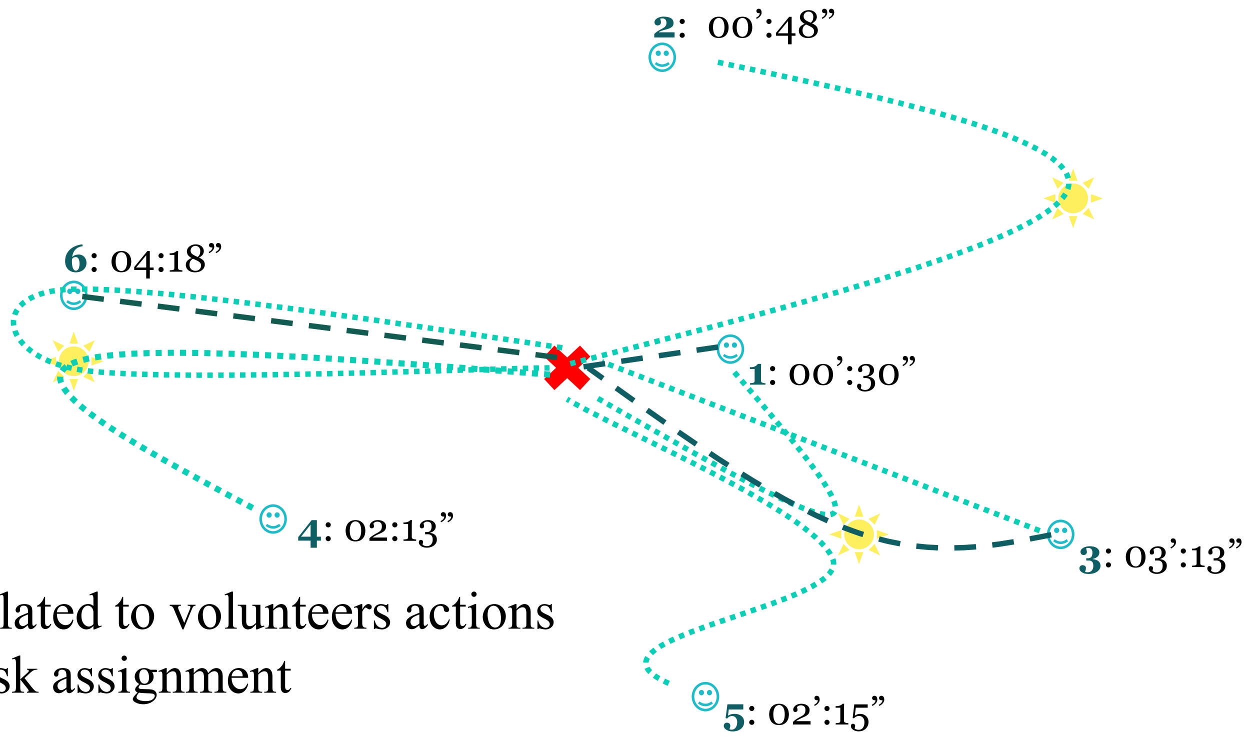


OHCA incident

AED

Volunteer

Available Volunteer

Uncertainties related to volunteers actions towards their task assignment

- Task compliance
- Task non-compliance
- Task rejection

Dispatch must be made once availability becomes known

SMS Lifesavers

Dispatch Rule block

A A D A A

Problem Formulation

Dynamically assign one of two tasks (pick up an AED or go directly to the patient) to a set of volunteers, in order to maximize the survival chance of the patient, under uncertain information about:

– Future volunteer responses and
– Volunteer actions after getting a task assignment.

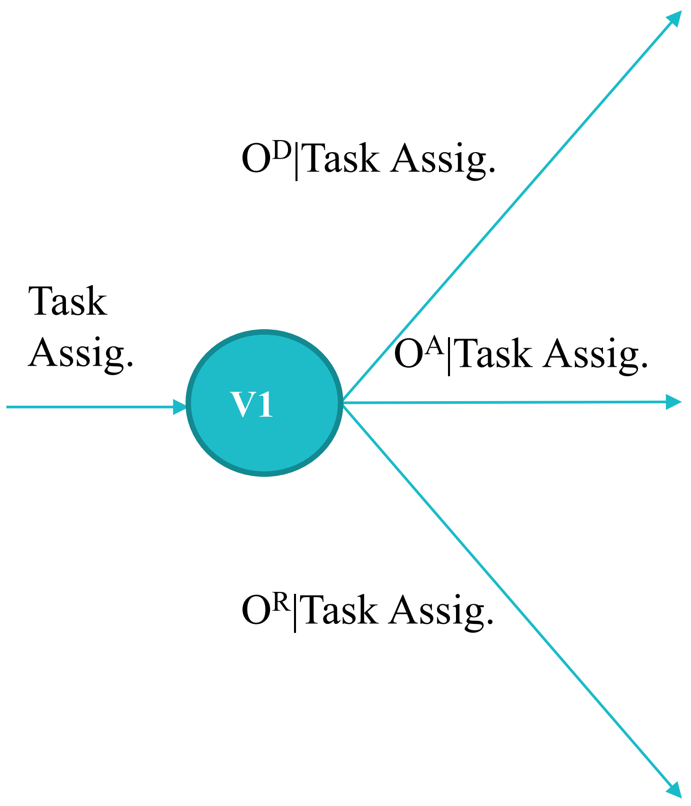
Problem Assumptions

- Deterministic travel times
- Known AED availability and functionality
- Identical volunteers
- Decision is made as soon as a volunteer has accepted a mission
- No information of potential future volunteers at the time of decision making

Decision Tree

Possible task assignments

- A_j: Volunteer *j* should pick up an AED
- D_j: Volunteer *j* should go directly to patient



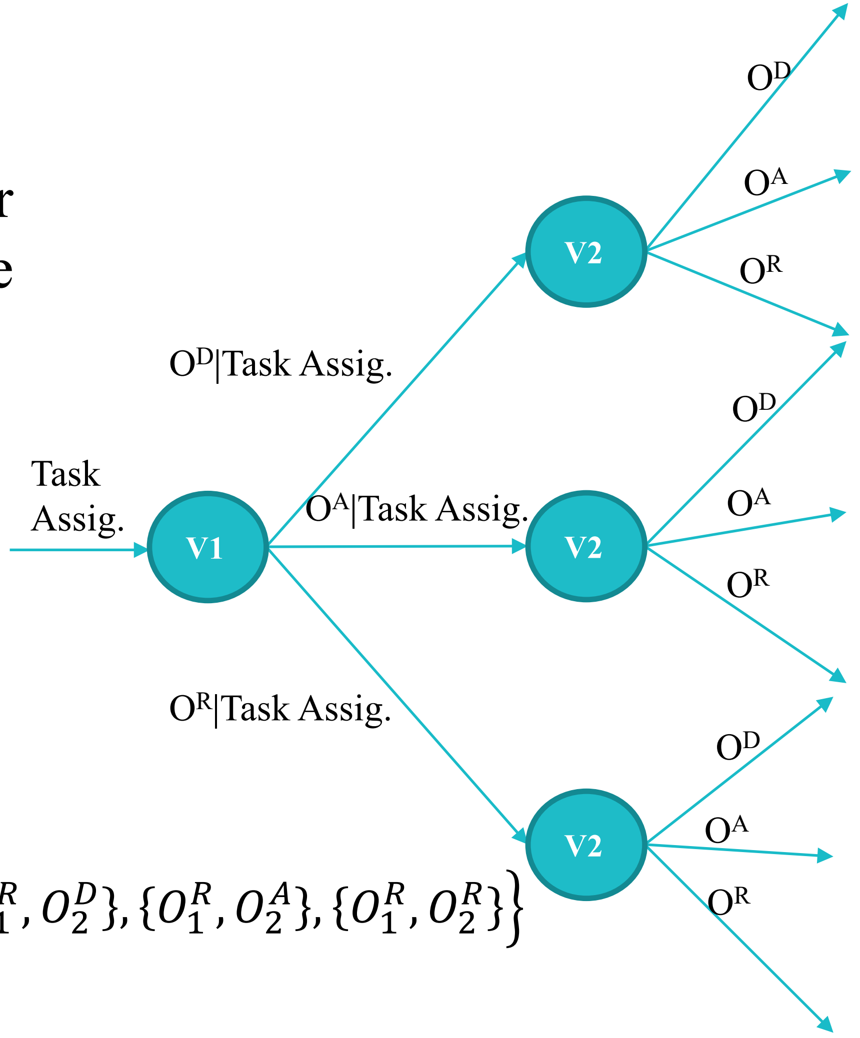
Possible outcomes

- O_j^A: Volunteer *j* picks up an AED
- O_j^D: Volunteer *j* goes directly to patient
- O_j^R: Volunteer *j* rejects (aborts) the mission

Possible Outcomes

When j volunteers have been dispatched, the number of possible outcomes becomes 3^j, i.e. all possible combinations of the individual outcomes.

In case of two volunteers that will be 3^2, i.e. 9, possible outcomes.



$$\left\{\{O_1^D, O_2^D\}, \{O_1^D, O_2^A\}, \{O_1^D, O_2^R\}, \{O_1^A, O_2^D\}, \{O_1^A, O_2^A\}, \{O_1^A, O_2^R\}, \{O_1^R, O_2^D\}, \{O_1^R, O_2^A\}, \{O_1^R, O_2^R\}\right\}$$

Probability of Outcomes

The probability for each outcome is conditional, depending on the assignment

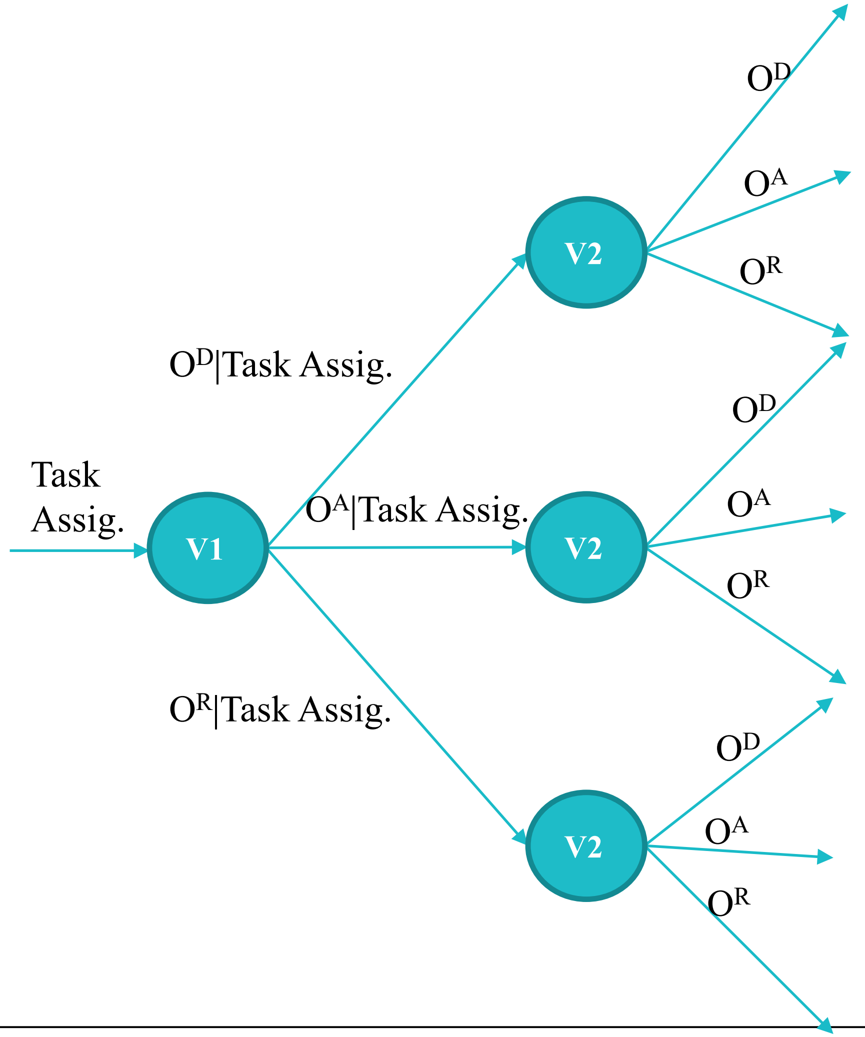
There will be 3^2, joint probability. For example:

$$P\left((O_1^D|A_1) \cap (O_2^A|A_2)\right) = P(O_1^D|A_1)P\left(O_2^A|A_2\right)$$

Also we hold:

$$P(O_j^A|A_j) + P(O_j^D|A_j) + P(O_j^R|A_j) = 1$$

$$P(O_j^A|D_j) + P(O_j^D|D_j) + P(O_j^R|D_j) = 1$$



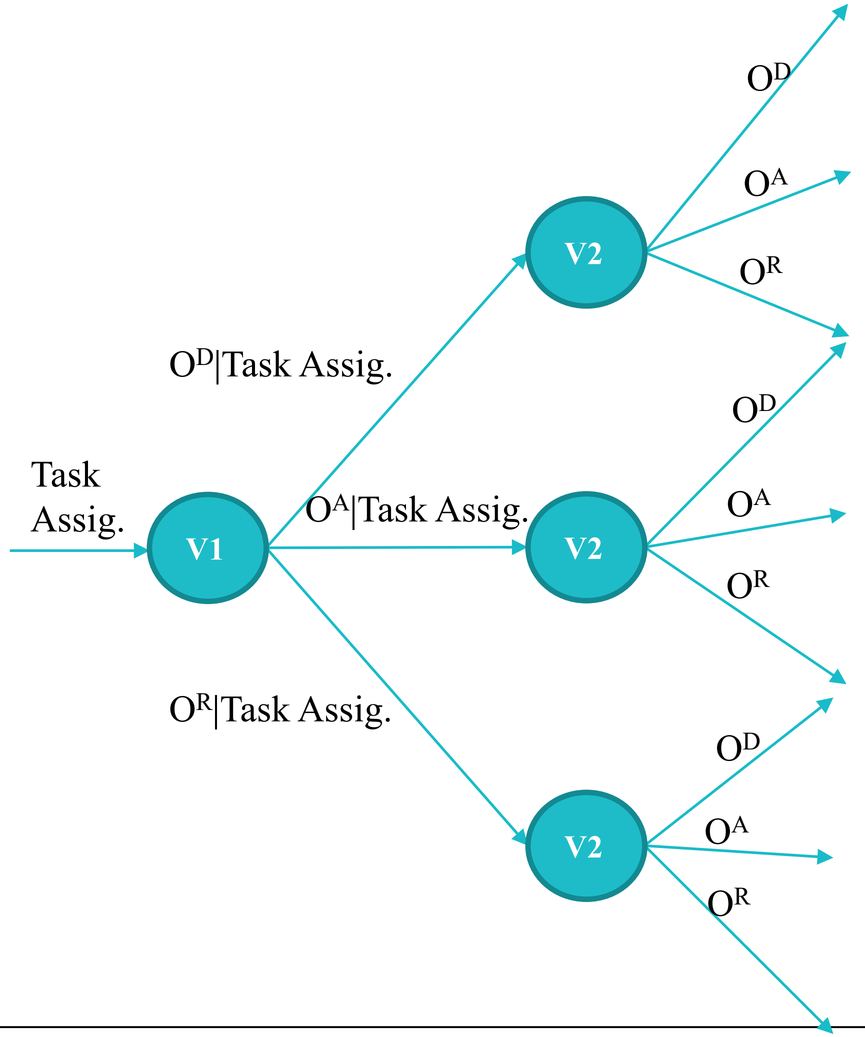
Travel Times

Each outcome is associated with a response time to the patient:

- T_{o_j}: Time until Volunteer j reaches the patient, given outcome o_j; $o_j \in \{O_j^A, O_j^D, O_j^R\}, j = 1, \dots, M$

$\boldsymbol{T_{O_j^A}}$ and $\boldsymbol{T_{O_j^D}}$ are calculated based on the Euclidean distance between Volunteer j and the patient and a travel speed of 2 m/s.

$\boldsymbol{T_{O_j^R}}$ can be set to a large number, since the volunteer will never reach the patient.



Survival Function

Utilizing the survival function of our work in [1]

$$f\ (t^*, s^*\ ) = \frac{1}{1 + e^{(-1.3614 + 0.3429t^* + 0.18633s^*)}}$$

- t^* is the time until start of CPR
- s^* is the time until defibrillation using an AED

[1] *Matinrad, N., Granberg, T. A., Ennab Vogel, N. and Angelakis, V. 2019. 'Optimal Dispatch of Volunteers to Out-of-hospital Cardiac Arrest Patients', in Proceedings of the Annual Hawaii International Conference on System Sciences, pp. 4088–4097.*

Data

The primary dataset provided by the SMS lifesavers project included information on missions for each day from 2018-May-03 to 2018-September-10, consisting of one or more missions per day. This data included detailed information of missions:

- **Positions** of patients, volunteers and AEDs,
- **Time** that the call center was notified,
- **Notification times** of volunteers, and
- **Acceptance times and/or rejection** times.

Data (Cont.)

Primary data was complemented by information from a **survey** that was filled out by the volunteers who had been assigned a mission. It included questions about

- What they had done after they had received their task assignments and what occurred.
- Not all volunteers filled out the survey completely.

Data (Cont.)

By merging the mission data with the survey data, it was possible to calculate the required probabilities, i.e. probabilities of task compliance, noncompliance, and rejection.

- Compliance/noncompliance of volunteers were determined based on both the mission information and the surveys.
- The rejection rate could be extracted directly from the mission data.

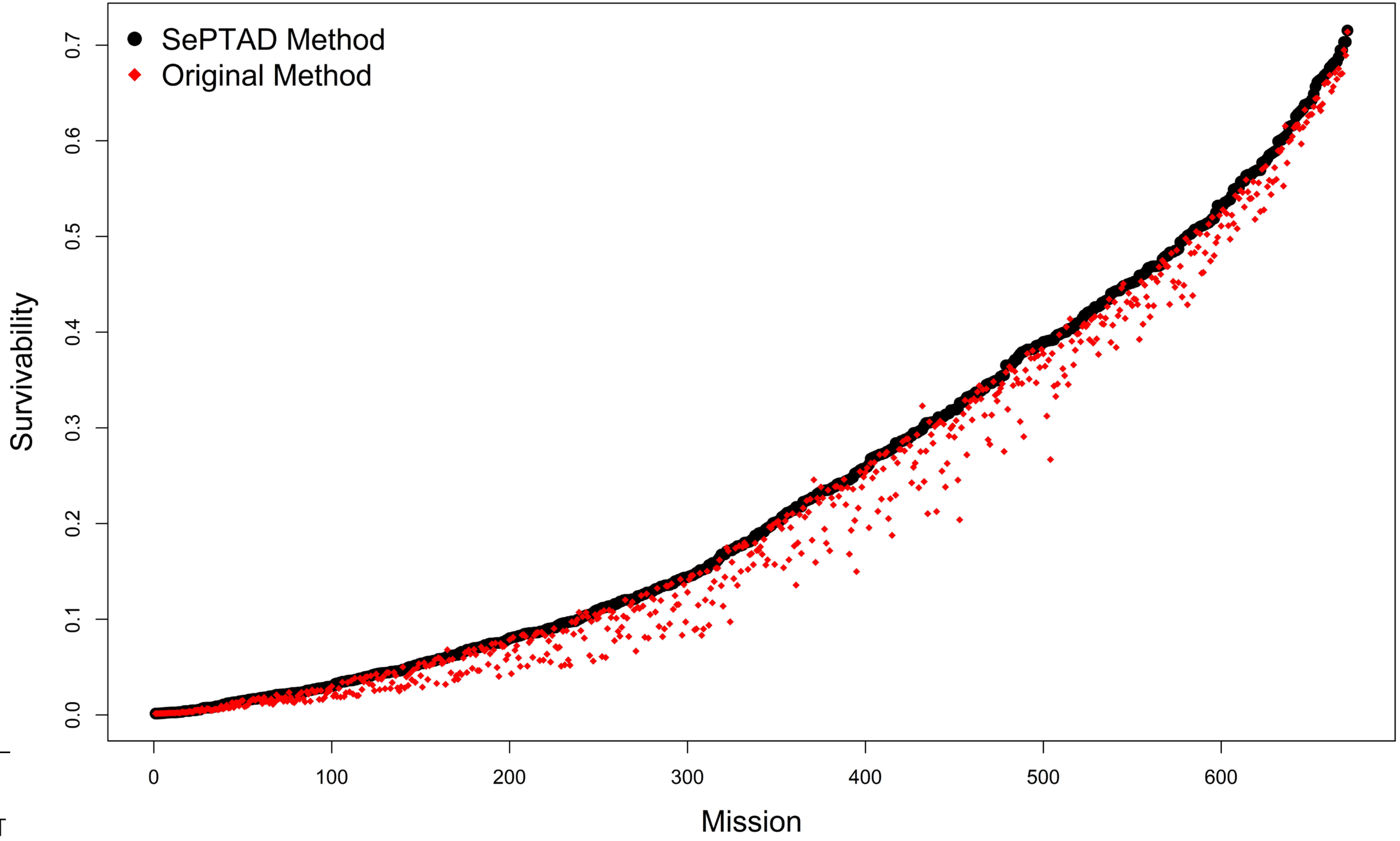
Data (Cont.)

The dataset consisted of 671 missions

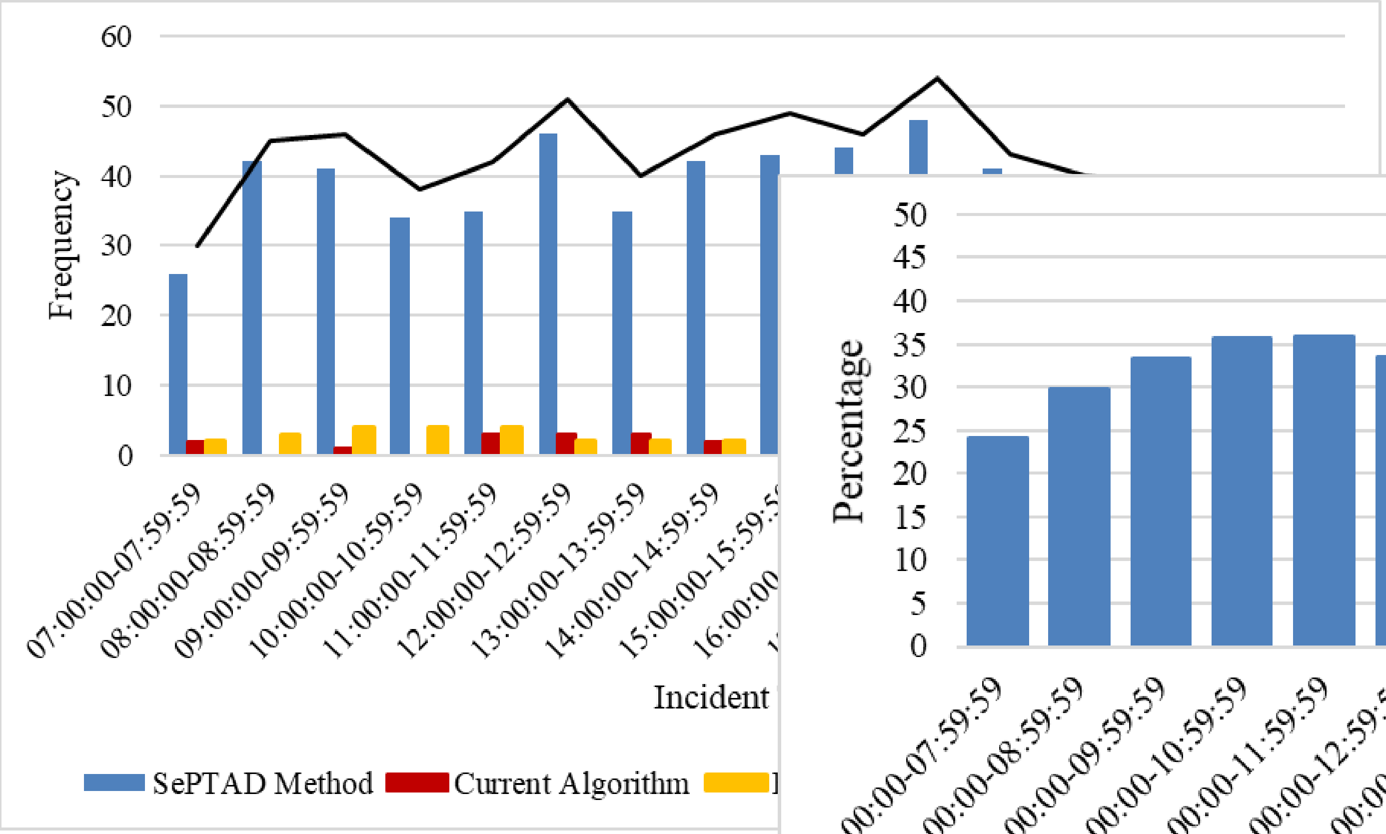
- $P(O^D|D) = 0.659$,
- $P(O^A|D) = 0.048$,
- $P(O^R|D) = 0.293$,
- $P(O^D|A) = 0.348$,
- $P(O^A|A) = 0.352$,
- $P(O^R|A) = 0.300$.

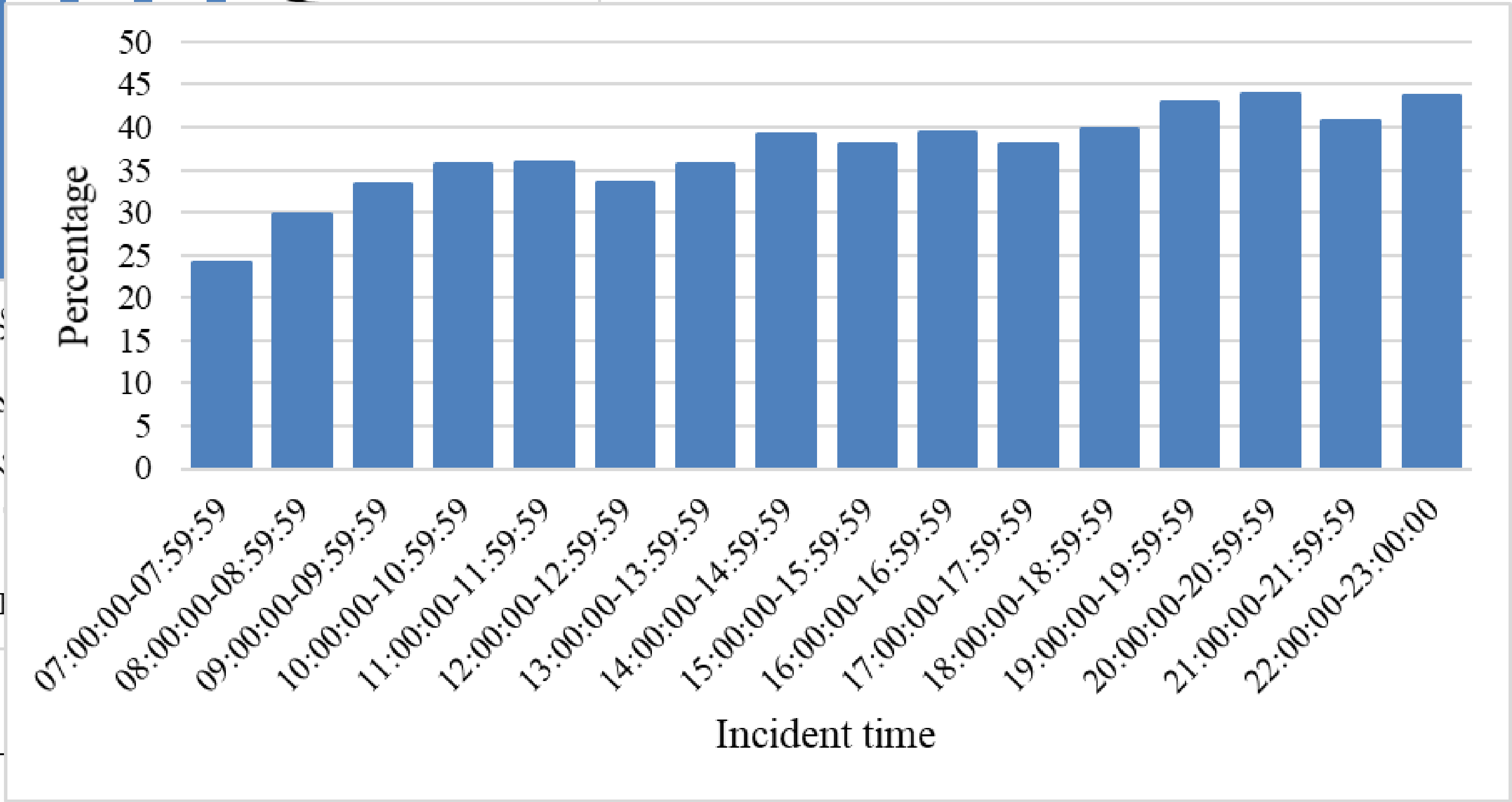
!

Results – Our model vs. Rule block



Results – Temporal Analysis





Concluding remarks

- In average there is a 1.6% increase of survivability probability when using the non-static method. This could translate to 11 people more that could have survived the OHCA incident, in the 4-month period of the data (about 30 more lives per year in Sweden).

- In 79% of dispatches, send to AED (A) is selected. There are multiple reasons that can lead to this choice of task assignment.
  - CPR time will be set equal to the AED time, i.e. $s^* = t^*$,
  - The probabilities of task compliance in AED were similar

- The time difference between the CPR and AED time influences the decision, but the relationship is not trivial

Thank you!

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