VIETNAM NATIONAL UNIVERSITY – HO CHI MINH CITY INTERNATIONAL UNIVERSITY
SCHOOL OF INDUSTRIAL ENGINEERING & MANAGEMENT

MODELING AMBULANCE SERVICE FOR HIGH-RISK EPIDEMIC PATIENTS IN HO CHI MINH DURING COVID-19

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Table of Content

I. INTRODUCTION

Motivation of the study

- Saving high-risk epidemic patients helps minimize the mortality rate of COVID-19 during the outbreaks

- The mortality rate - one of the main factors in determining the effectiveness of a healthcare system.

- Modeling the ambulance service can aid the decision making process in resource allocation, the impact of different COVID-19 scenarios and different preventive strategies in order to minimize those impact.

Problem statement & Scope of the study

Severe epidemic patients need help

Emergency Call Center 115

Dispatch Ambulance

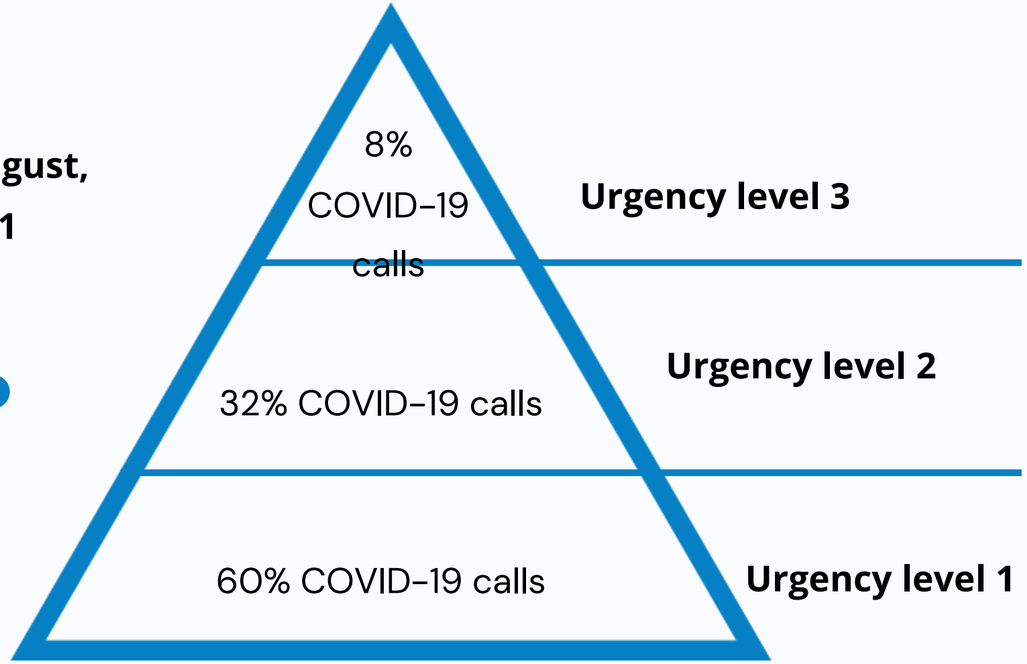
Transfer COVID-19 patients to hospital

COVID-19 patient hospitalized

27th July, 2021

28th August, 2021

Ho Chi Minh City
COVID-19 4th-wave



source: [20], [21], [40]

II. OBJECTIVES

Objectives

- Minimize high-risk epidemic patients who are not able to have access to medical assistance regarding COVID-19 and may be exposed to death if they do not receive adequate medical assistance on time

- Improve efficiency in EMS system through balancing out the emergency medical system's load in epidemic patients admission

Scope of the study

- Consider an ambulance service modeling for high-risk epidemic patients in Ho Chi Minh city during the fourth wave of COVID-19 started from June, 2021

- The following urgency levels are types high-risk patients considered:

o Urgency level 1: patients with serious conditions of COVID-19 without underlying health issues.

o Urgency level 2: patients with serious conditions of COVID-19 with underlying health issues.

o Urgency level 3: patients in critical conditions of COVID-19 who need immediate medical interventions.

III. CONSTRAINTS & MODEL ASSUMPTIONS

Logical Constraints

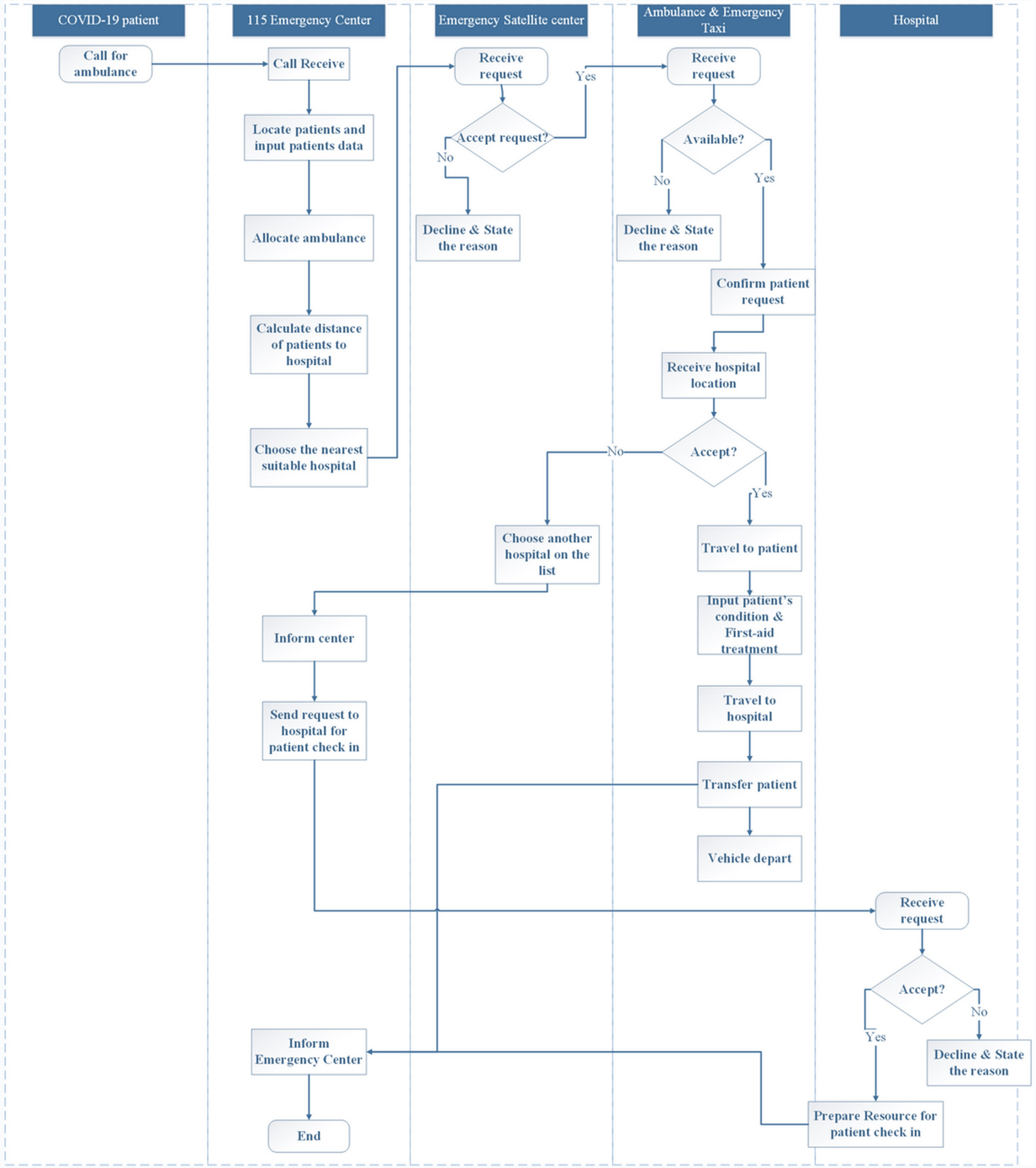
- Consider activities from receiving calls from Emergency Center 115 of Ho Chi Minh city to successfully deliver patients to their suitable hospital. The study does not consider patients from other provinces

- The vehicles used are emergency taxis provided by corporations such as Me Linh and Grab for patients' transportation and ambulances from the Emergency center 115 and other hospitals.

- Ambulances can respond to any emergency and operates 24 hours a day

- Emergency calls have parameters that are independent (e.g., location and arrival time of an emergency are independent), and these parameters do not depend on the ambulance or hospital that provides treatment

- Each emergency call requires exactly one ambulance to respond, and the call is not



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- Consider activities from receiving calls from Emergency Center 115 of Ho Chi Minh city to successfully deliver patients to their suitable hospital.

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- The vehicles used: emergency taxis provided by corporations such as Me Linh and Grab and ambulances from the Emergency center 115 and other hospitals.

- Location and arrival time of emergency calls are independent

IV. MODEL DEVELOPMENT

Structure of Ambulance Service

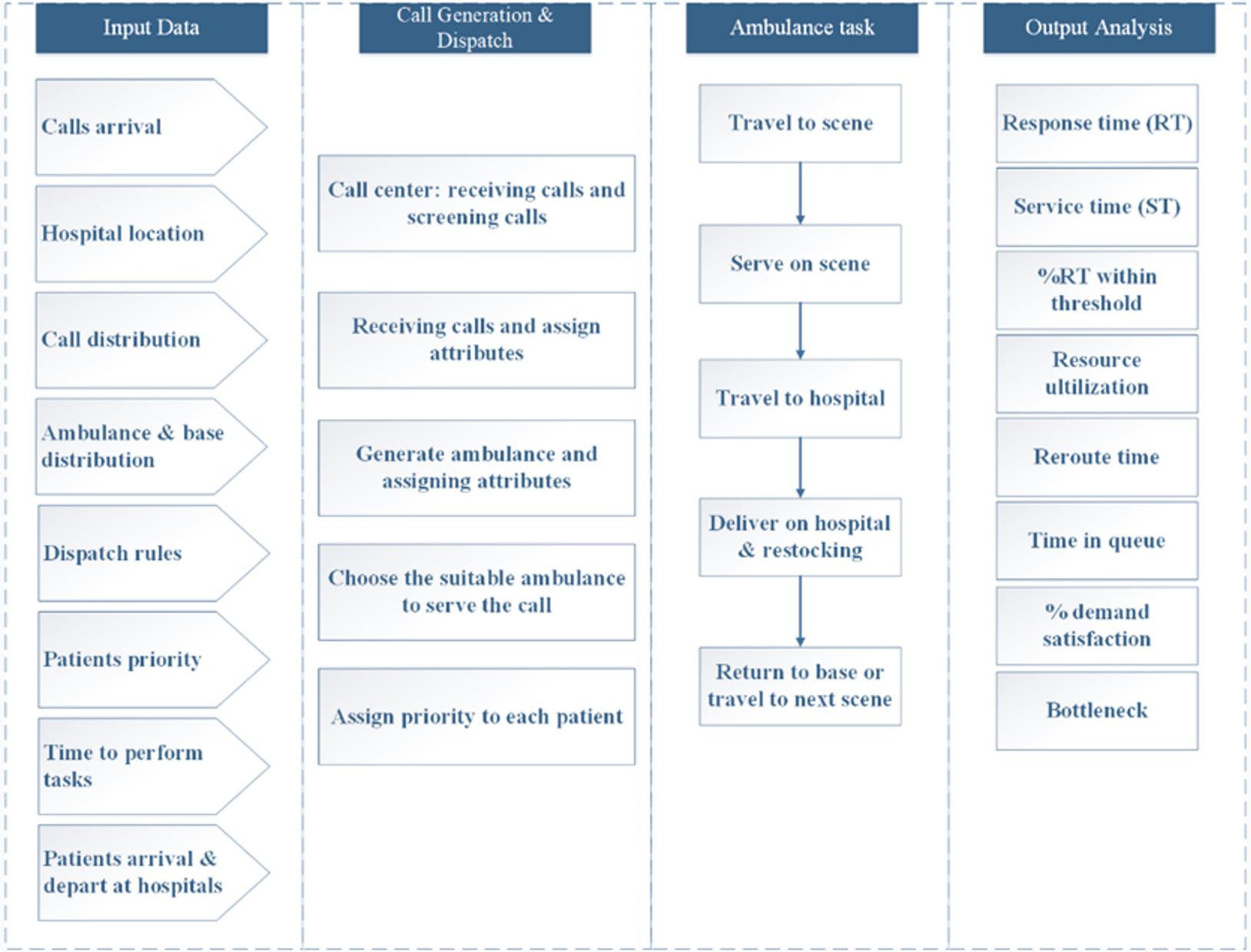


Figure 3.4: Structure of ambulance service in this study

The Ambulance Service Model

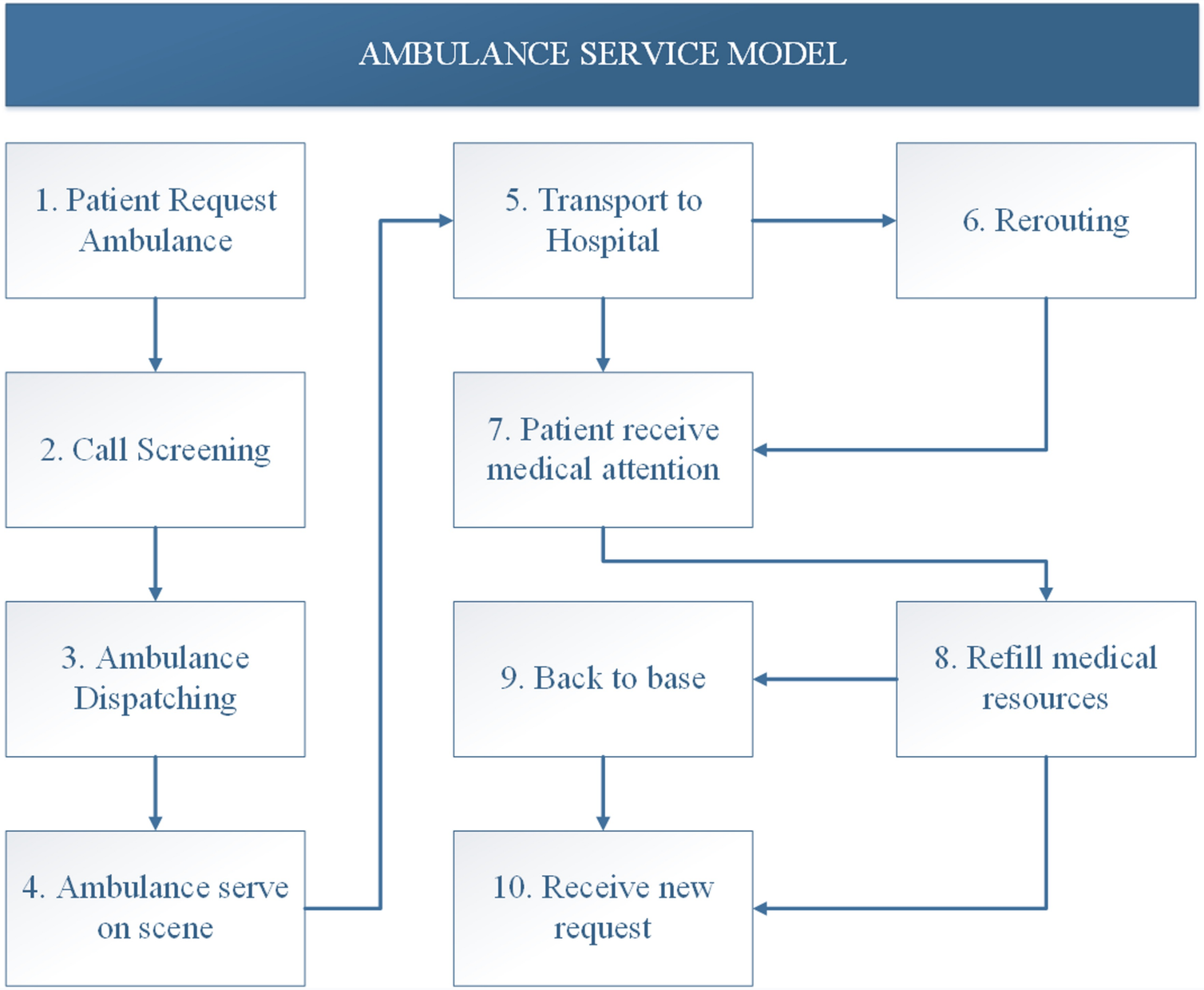


Figure 4.7. Ambulance service model summary

The EMS Call Center

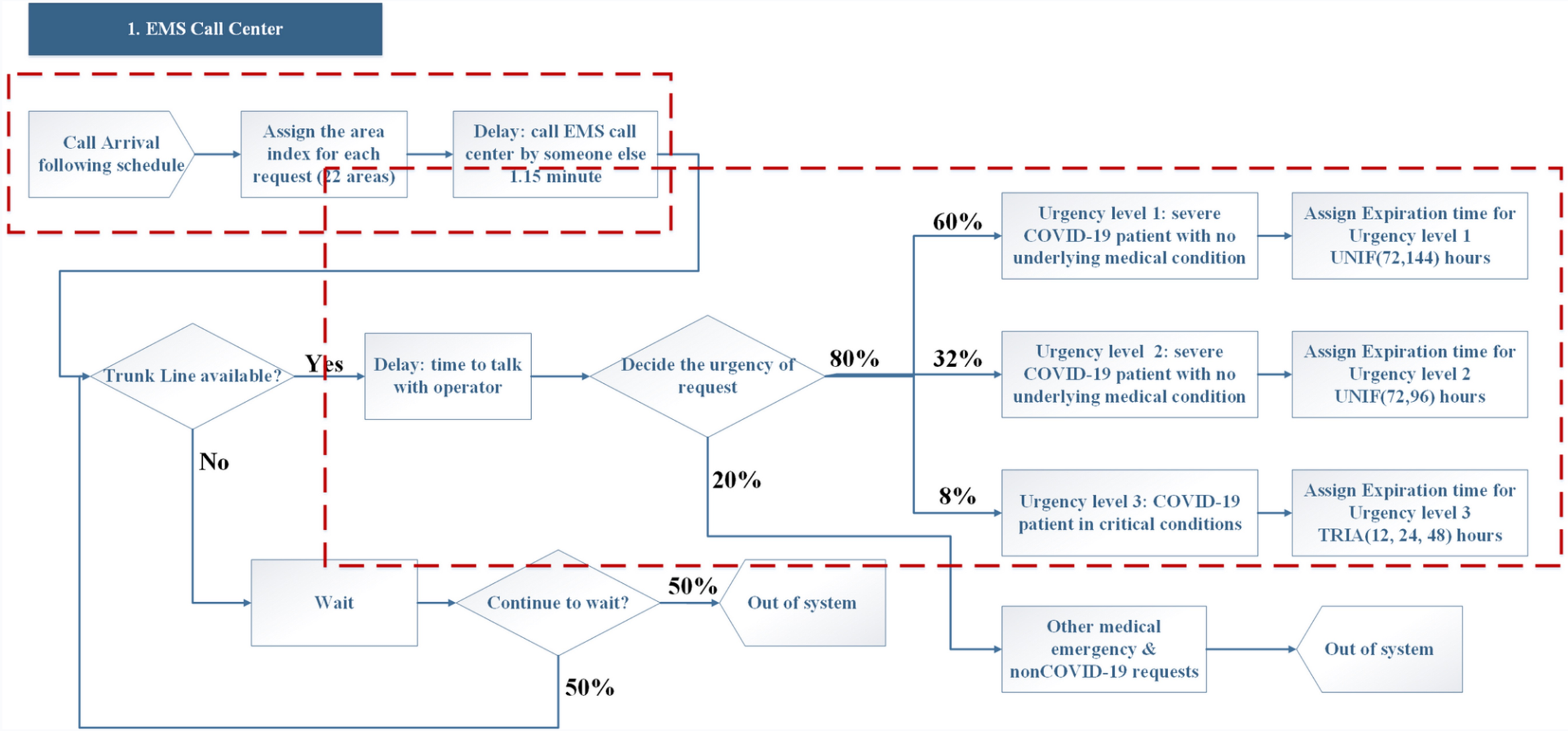


Figure 4.8. EMS call center logic for simulation

Ambulance Base for dispatch

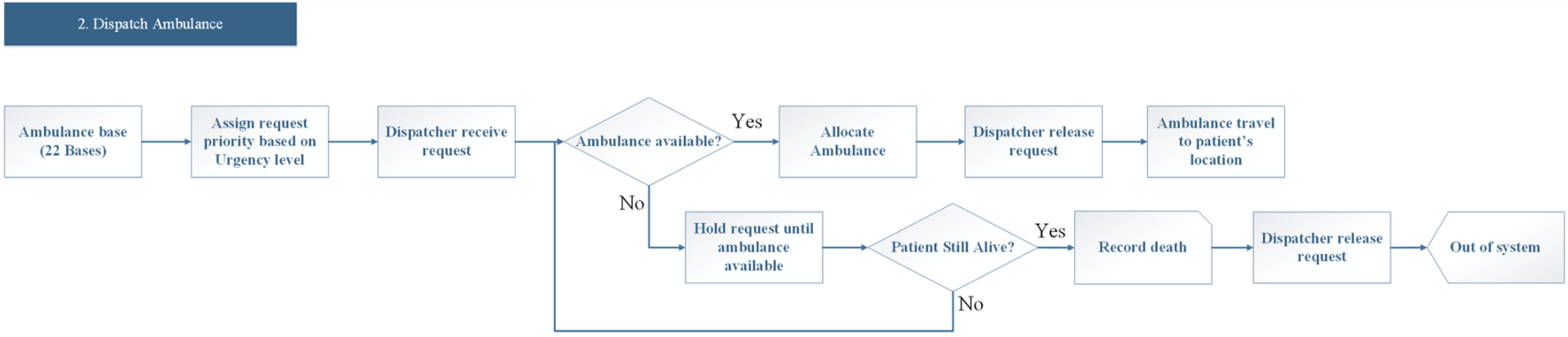


Figure 4.9. Ambulance base logic for simulation

Patient's Location (22 districts)

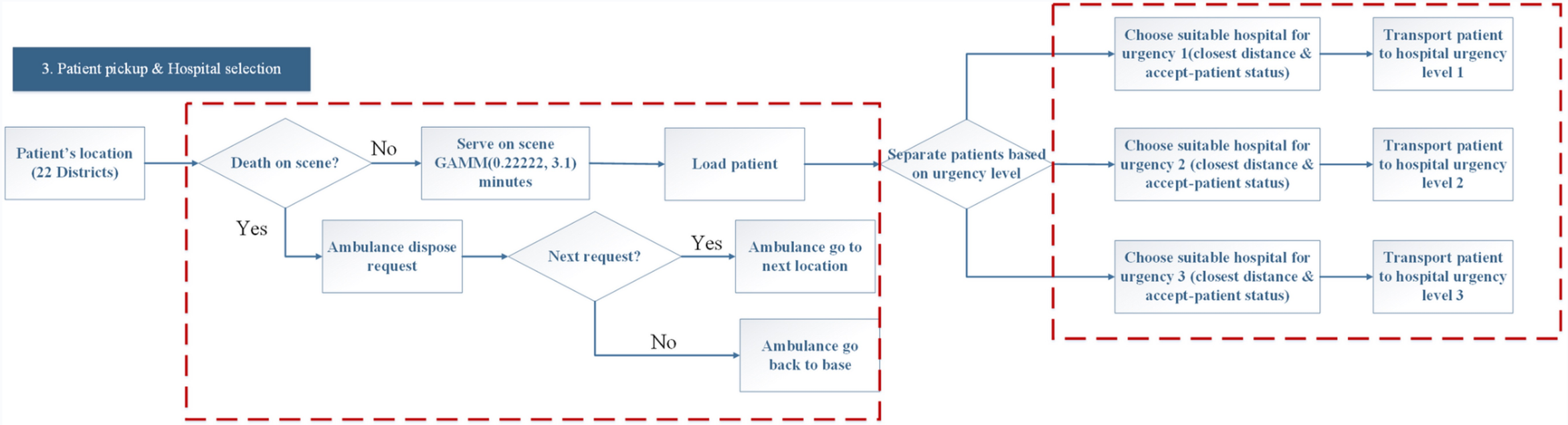


Figure 4.10. Logic for ambulance serve on scene and find suitable hospital before transporting patients

The Redirect Strategy

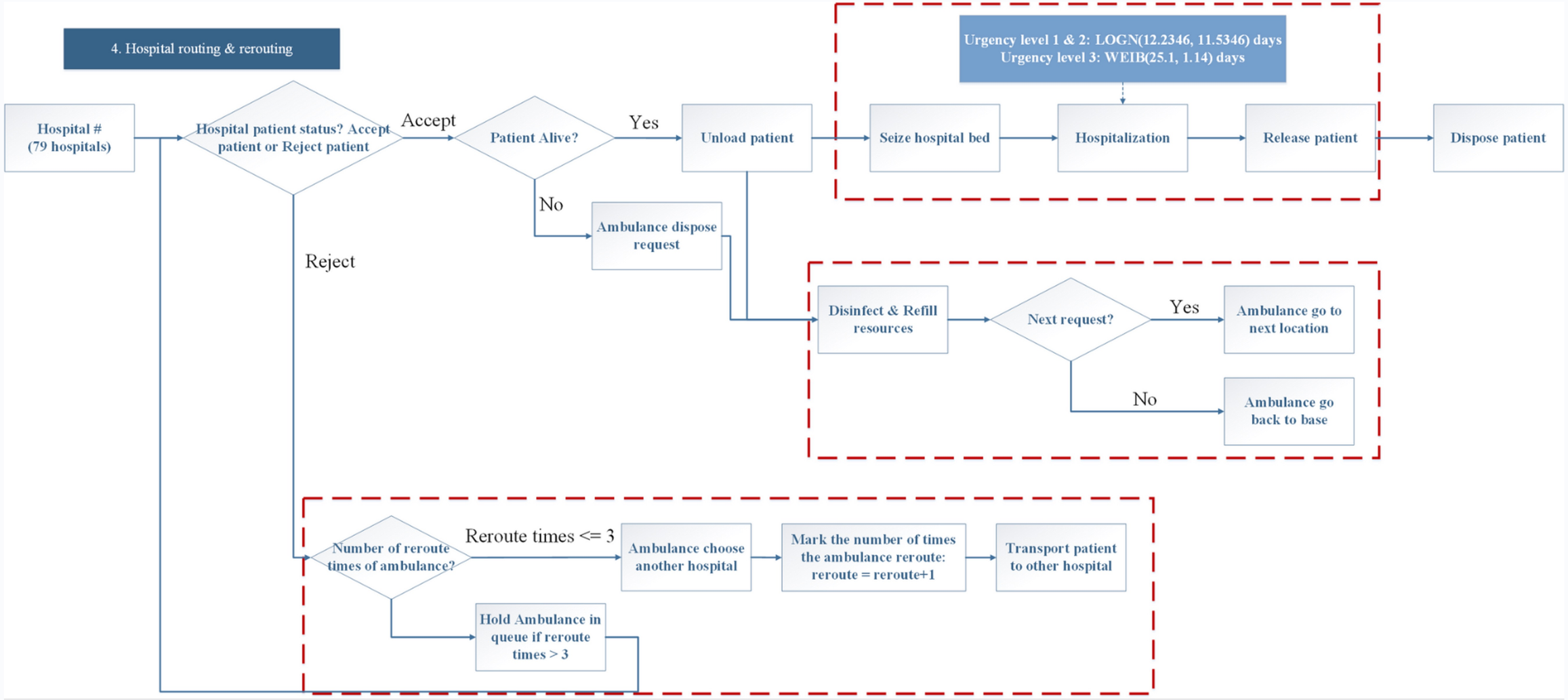


Figure 4.11. COVID-19 treatment hospital's logic for admitting patients

The Redirect Strategy (cont)

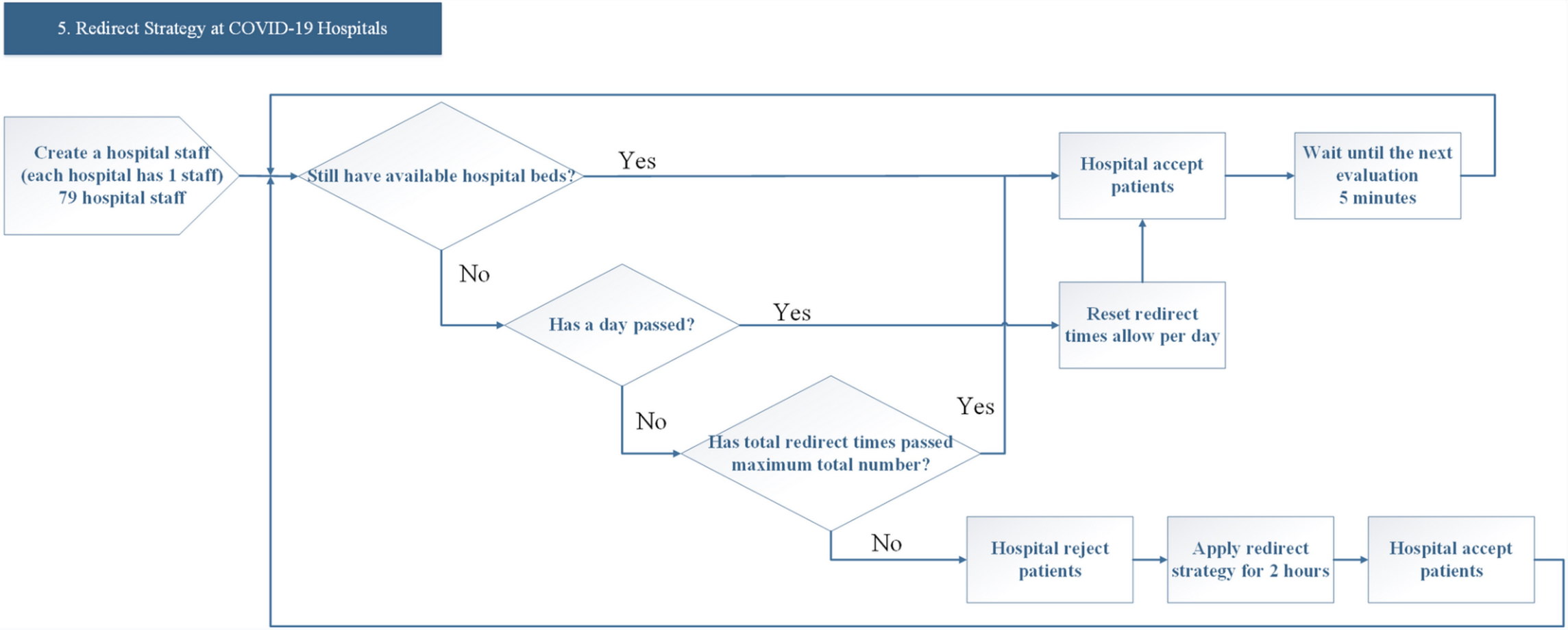


Figure 4.12. Hospital redirect strategy at COVID-19 hospitals

V. DATA COLLECTION

Daily COVID-19 call distribution

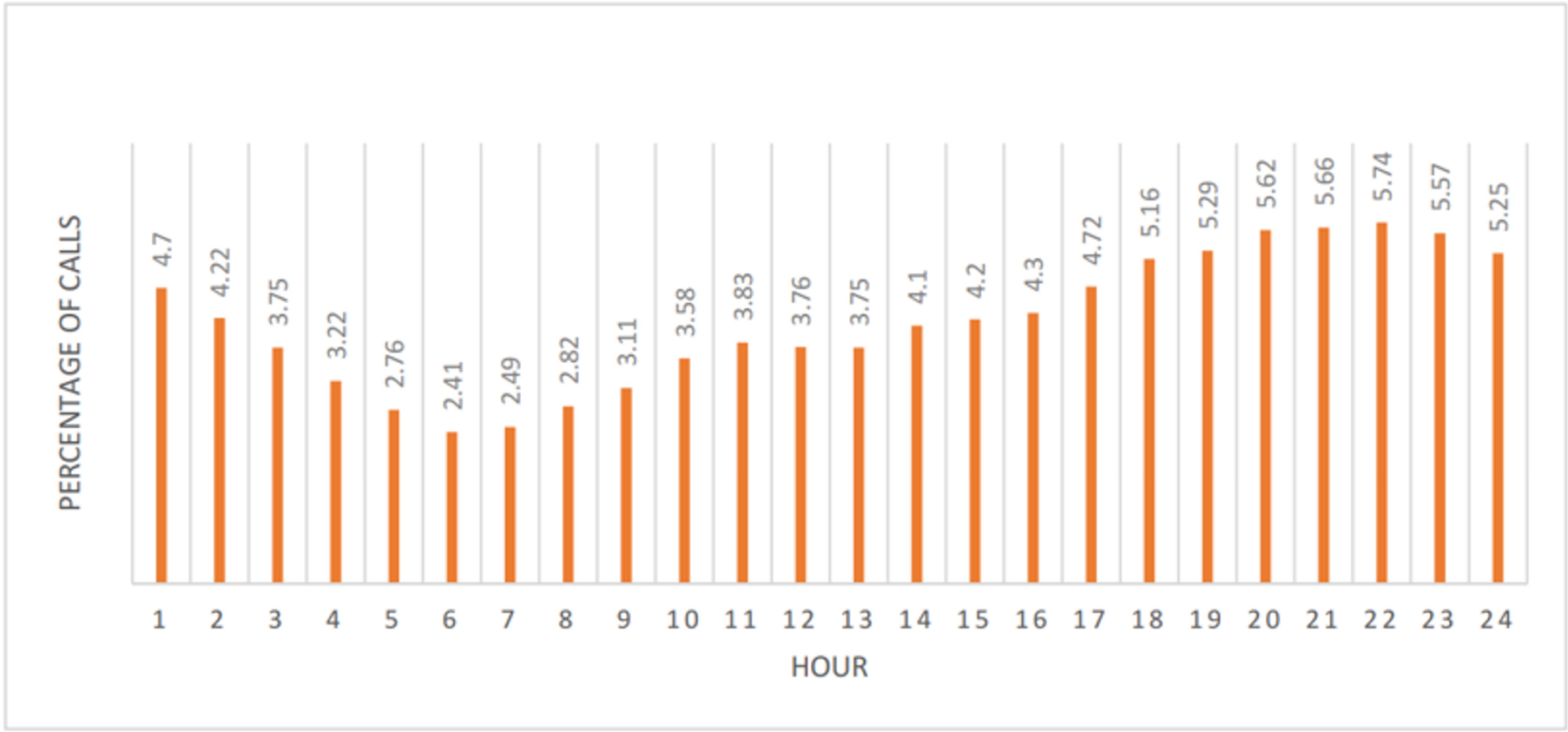


Figure 4.1. Percentage of medical services (EMS) calls during 24-hour span for entire 5-month period at Emergency Call Center according to study of Al-Wathinani (2021). Day shift corresponding to 06:00 until 18:00; night shift to 18:00 to 06:00

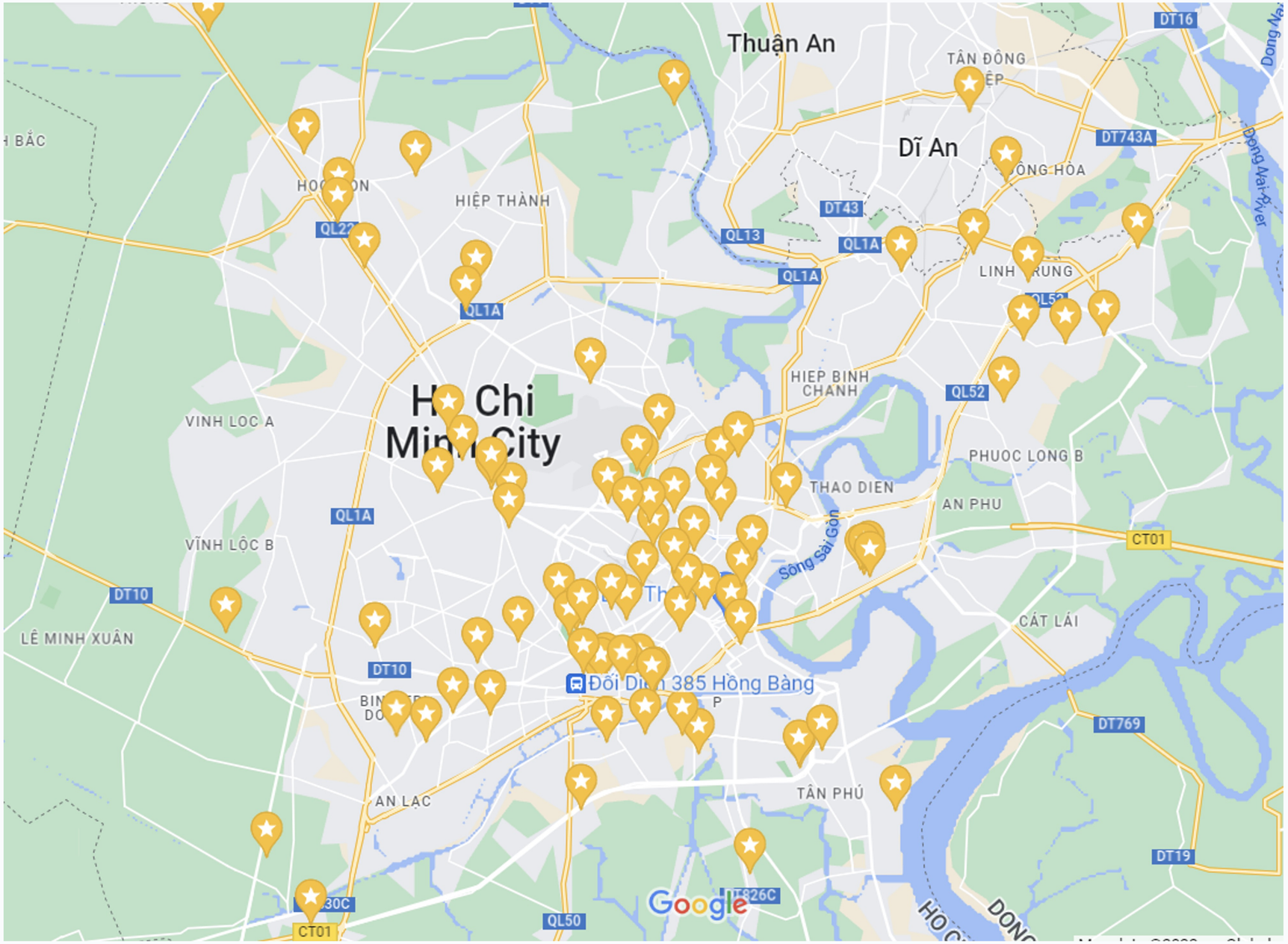
Parameter Table

Table 4.7. Parameter table for simulation of Ambulance service model

Parameters	Value	Units
Average ambulance speed (both ambulance and taxi)	50	Km/h
Number of trips restocking materials for ambulance	1	trip
Number of operators at call centre	40	People/call center
Number of resource dispatchers at ambulance base	8	People/call center
Number of urgency level 1 hospitals	57	Hospitals
Number of urgency level 2 hospitals	17	Hospitals
Number of urgency level 3 hospitals	5	Hospitals
Number of Ambulance bases	22	Bases
Expiration time for urgency level 1 patients	UNIF(72,144)	Hours
Expiration time for urgency level 2 patients	UNIF(72,96)	Hours
Expiration time for urgency level 3 patients	TRIA(12, 24, 48)	Hours
Expression for spent time by Operator for each call	TRIA(2 , 3 , 6)	minutes
Time spend prepairing at base after receiving request at ambulance [22]	4	minutes
Total number of ambulances in the city	287	ambulances
Expression for spent time to replenish first aid materials and products [3]	5.02	minutes
Average time for preparation and check resources before heading to patient's location [4]	4	minutes

Parameter Table

average time to inform the emergency call center by the patient or patient relatives [3]	1.15	minutes
The time period allowed to reject patient admission at hospitals (redirect strategy)	2	Hours
the first intervention of the ambulance authorities and the departure time of the patient for the hospital [3]	UNIF(1.08, 4.911)	minutes
Load patient onto vehicle	2.15	Minutes
Unload patient from vehicle	2.15	Minutes
Length of stay in hospital beds	LOGN(12.3, 11.6)	Days
Length of stay in ICU beds	WEIB(25.1, 1.14)	Days
Probability of patients having urgency level 1	0.6	
Probability of patients having urgency level 2	0.32	
Probability of patients having urgency level 3	0.08	



A screenshot on Google map of the 79 locations of COVID-19 hospitals during 4th-wave pandemic based on the list provided by [59].

Retrieved from: https://nld.com.vn/suc-khoe/danh-sach-136-benh-vien-cap-cuu-benh-nhan-covid-19-hoac-benh-thong-thuong-tai-tp-hcm-20210816165923915.htm

V. RESULT ANALYSIS

Emergency call center performance

Table 5.1. Call center performance across 5 replications

Indicators	Replications					System overview
	1	2	3	4	5	
Number of observations	185,343	185,537	185,241	185,483	184,936	185,308
Average time in call center	0.06107919	0.0610681	0.0611162	0.0611042	0.06107035	0.06108761
Standard deviation	0.01413081	0.0141605	0.0141735	0.0141503	0.01414749	0.01415255
Maximum time in call center	0.0999	0.0998	0.0999	0.0999	0.0999	0.0999
Minimum time in call center	0.03343774	0.0334341	0.0334207	0.0333812	0.03343087	0.03342097

The waiting time before ambulance dispatch

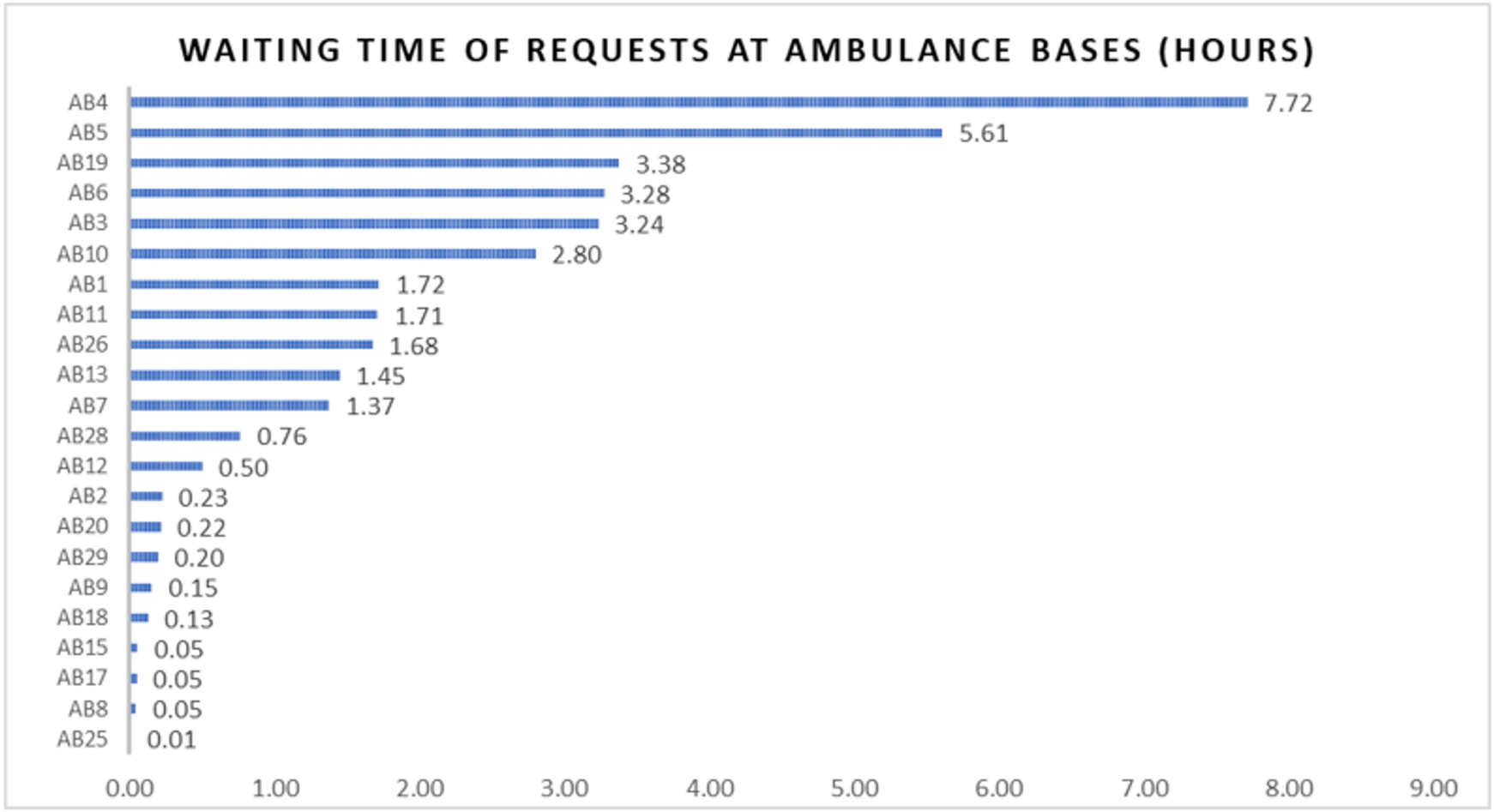
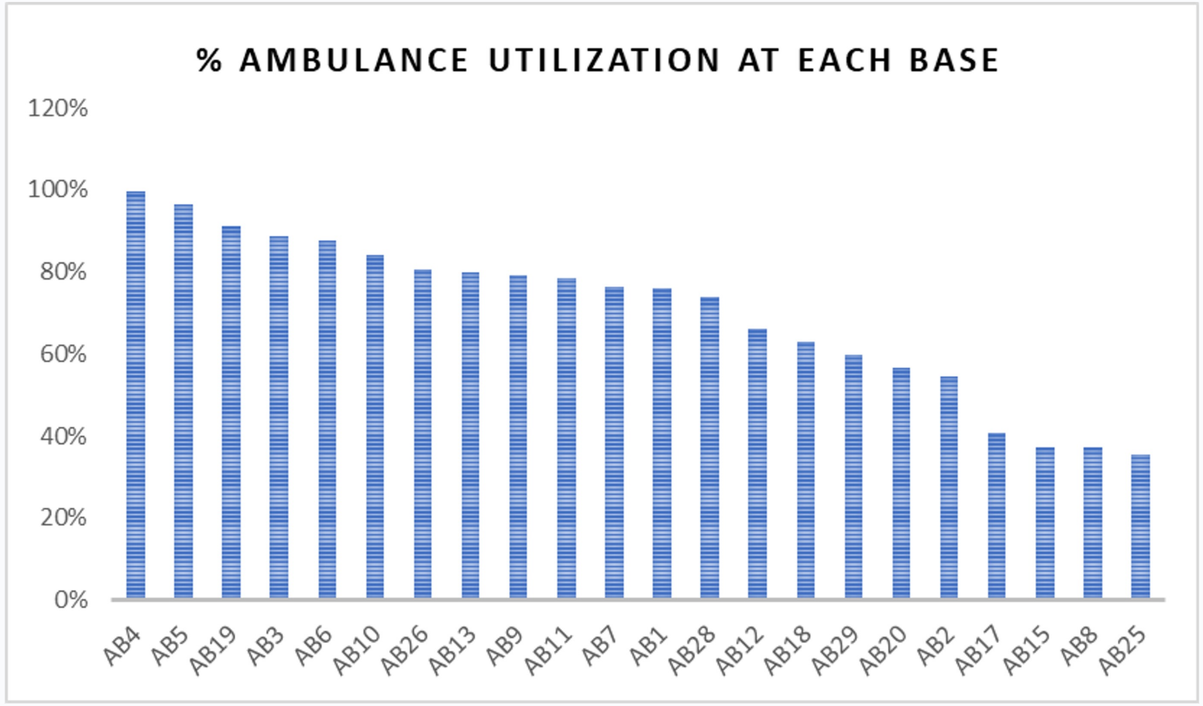
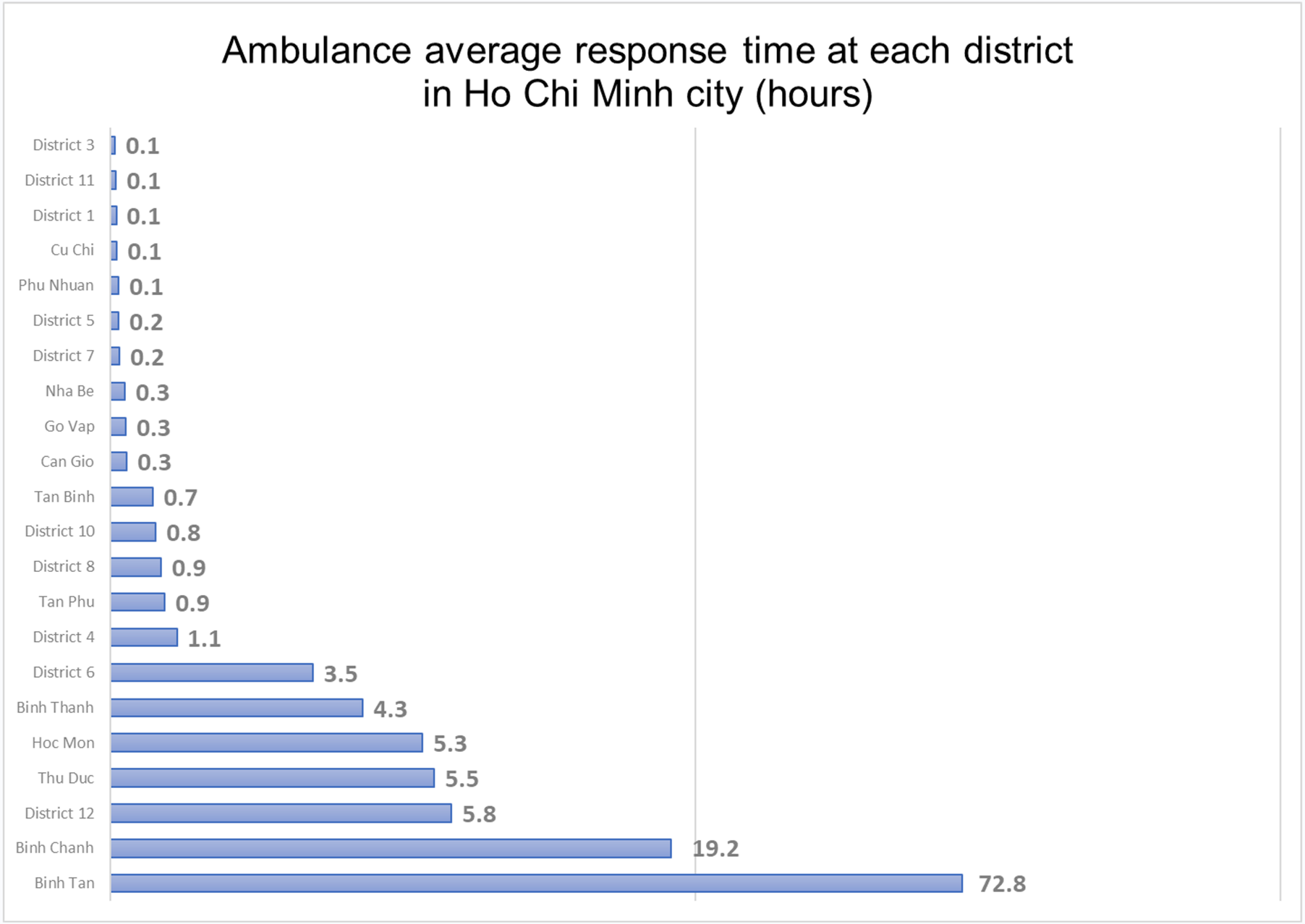


Figure 5.1. Waiting time of request across 22 ambulance bases (unit = hours)

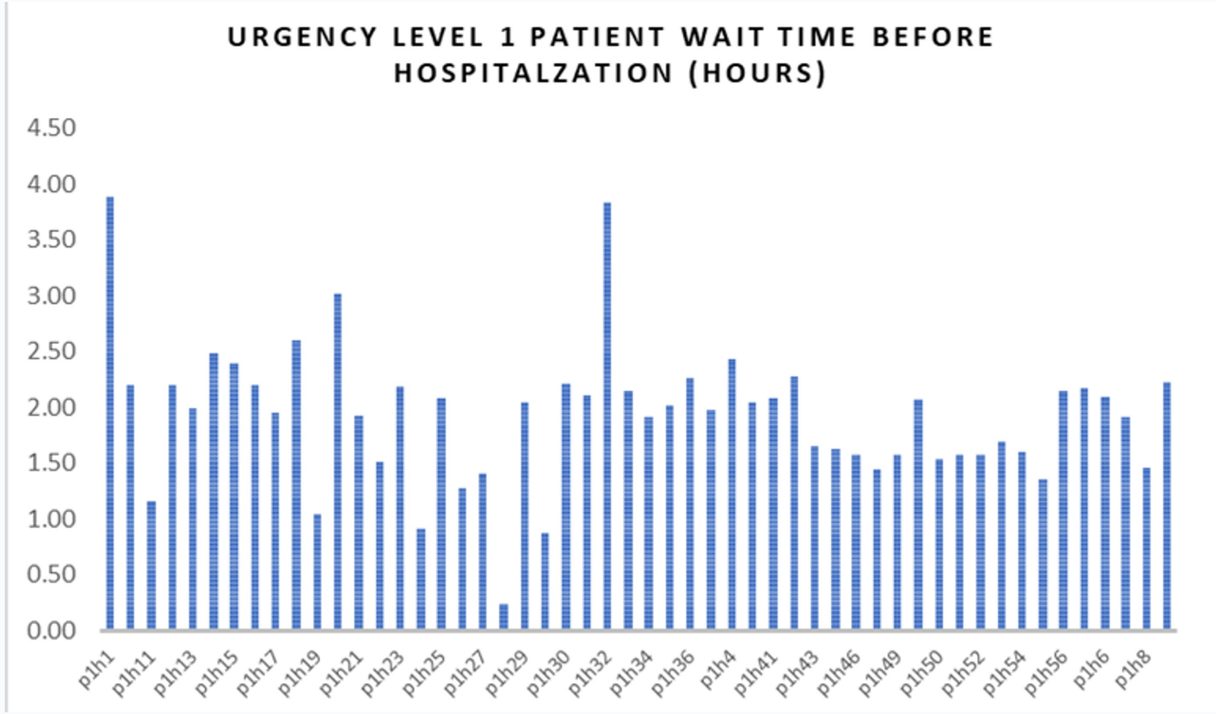
Ambulance Utilization

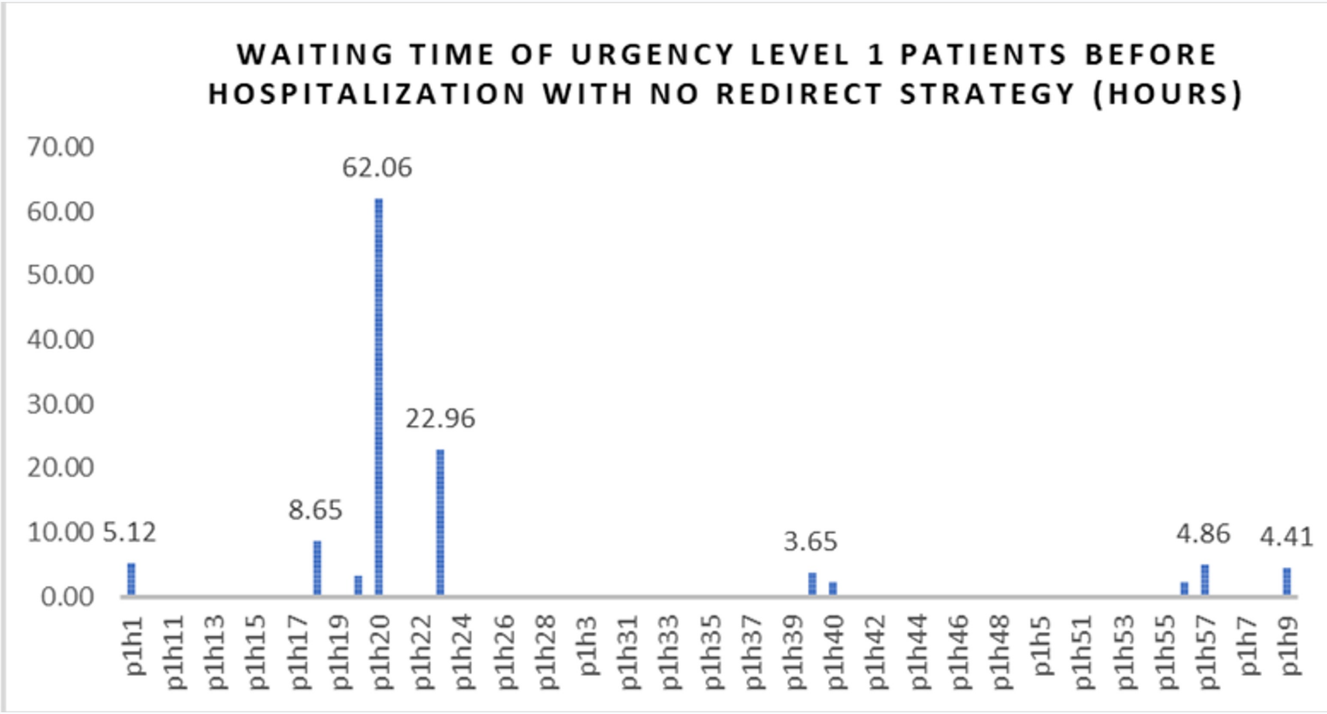


Ambulance index	% Ambulance Utilization	Current ambulance distribution	Location responsible	Infected cases distribution
AB4	99.6%	13	Binh Tan	10.75%
AB5	96.5%	13	Binh Chanh	6.57%
AB19	91.1%	13	Hoc Mon	5.29%
AB3	88.7%	13	District 12	6.87%
AB6	87.8%	13	Thu Duc	6.86%
AB10	84.1%	13	Binh Thanh	6.32%
AB26	80.6%	13	Tan Phu	5.85%
AB13	79.9%	13	District 4	4.34%
AB9	79.1%	13	District 6	4.21%
AB11	78.6%	13	District 8	5.10%
AB7	76.5%	13	Tan Binh	5.59%
AB1	76.0%	13	District 10	5.03%
AB28	73.9%	13	Nha Be	4.22%
AB12	66.2%	13	District 7	3.90%
AB18	63.1%	13	Cu Chi	2.21%
AB29	59.7%	13	Go Vap	3.02%
AB20	56.8%	13	District 5	3.07%
AB2	54.7%	13	District 11	3.57%
AB17	40.6%	13	Phu Nhuan	1.96%
AB15	37.3%	13	District 3	2.76%
AB8	37.1%	13	District 1	2.10%
AB25	35.6%	13	Can Gio	0.40%

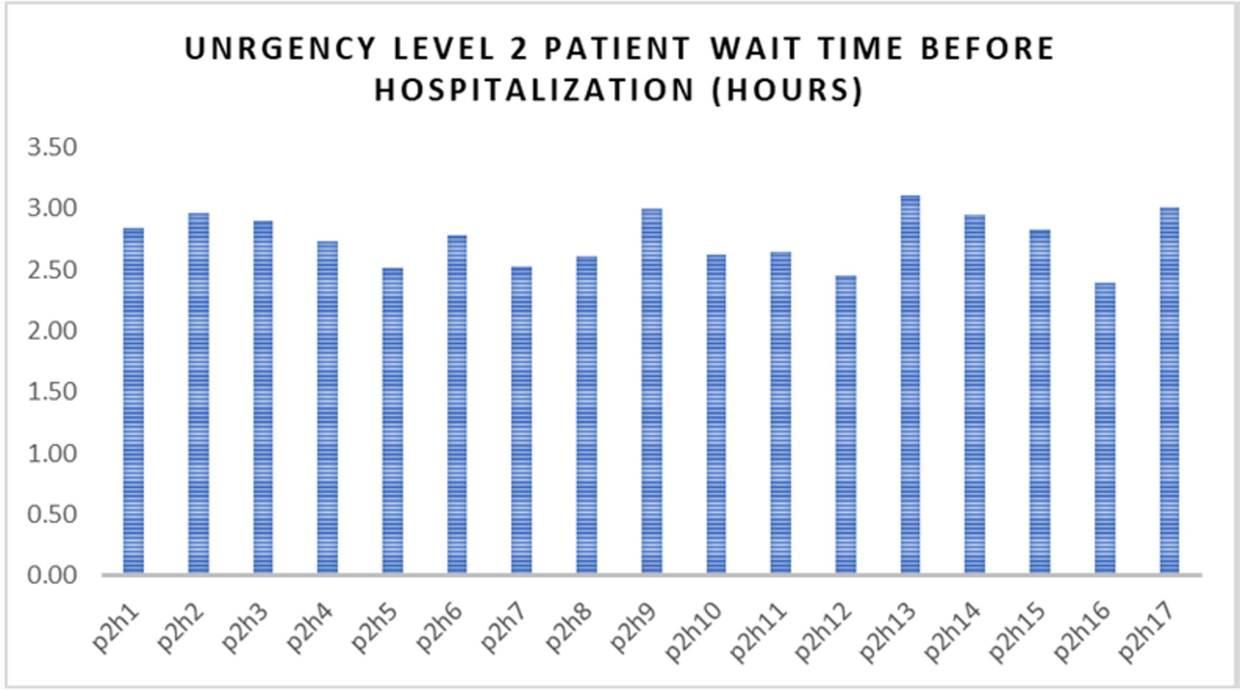

Ambulance average response time at each district in Ho Chi Minh city (hours)
District 3 0.1
District 11 0.1
District 1 0.1
Cu Chi 0.1
Phu Nhuan 0.1
District 5 0.2
District 7 0.2
Nha Be 0.3
Go Vap 0.3
Can Gio 0.3
Tan Binh 0.7
District 10 0.8
District 8 0.9
Tan Phu 0.9
District 4 1.1
District 6 3.5
Binh Thanh 4.3
Hoc Mon 5.3
Thu Duc 5.5
District 12 5.8
Binh Chanh 19.2
Binh Tan 72.8

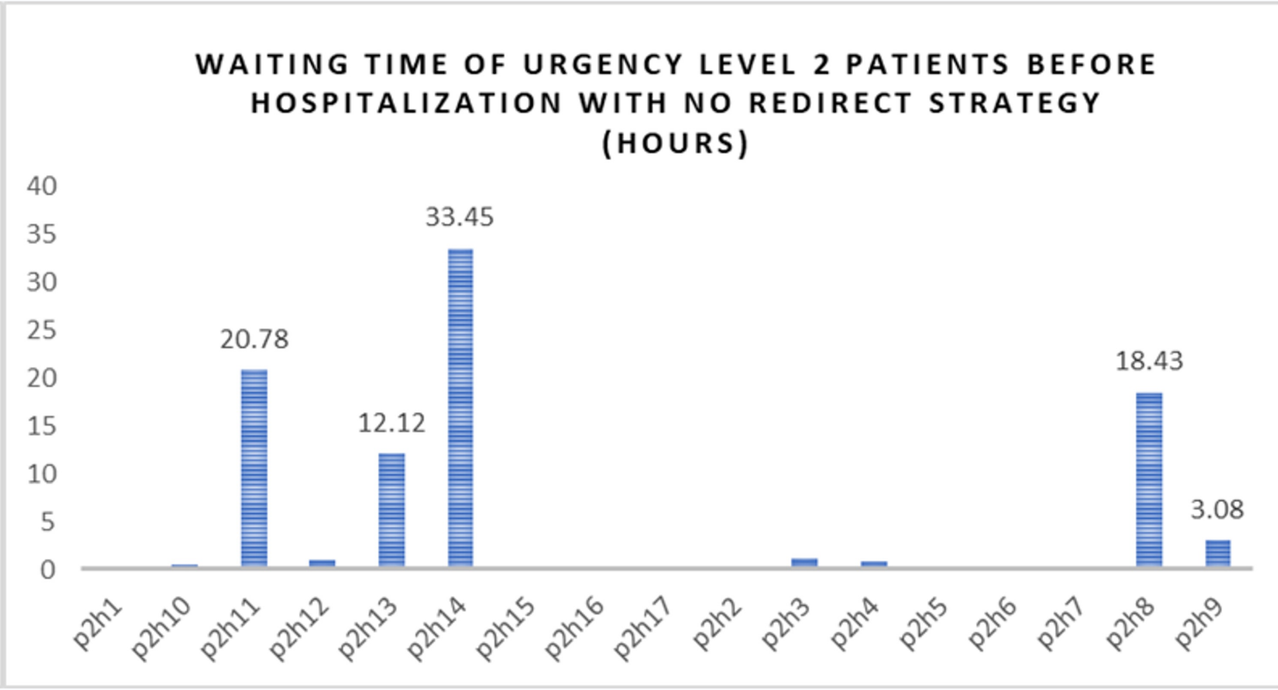
The waiting time before hospitalization



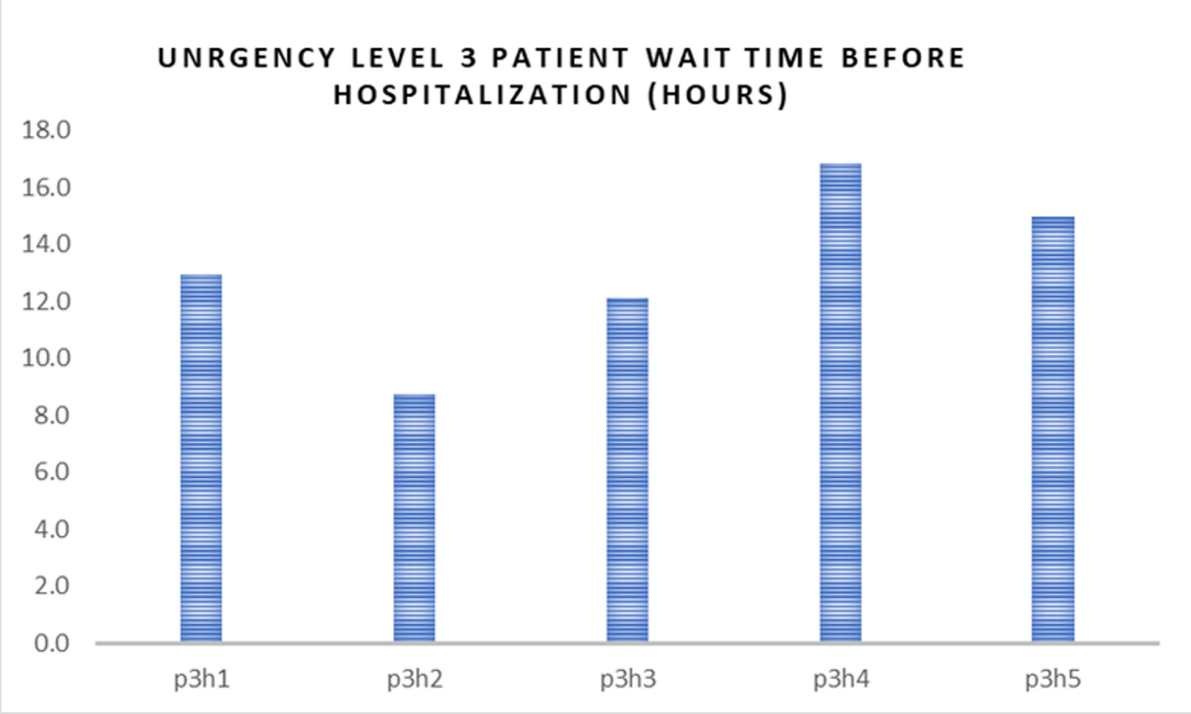


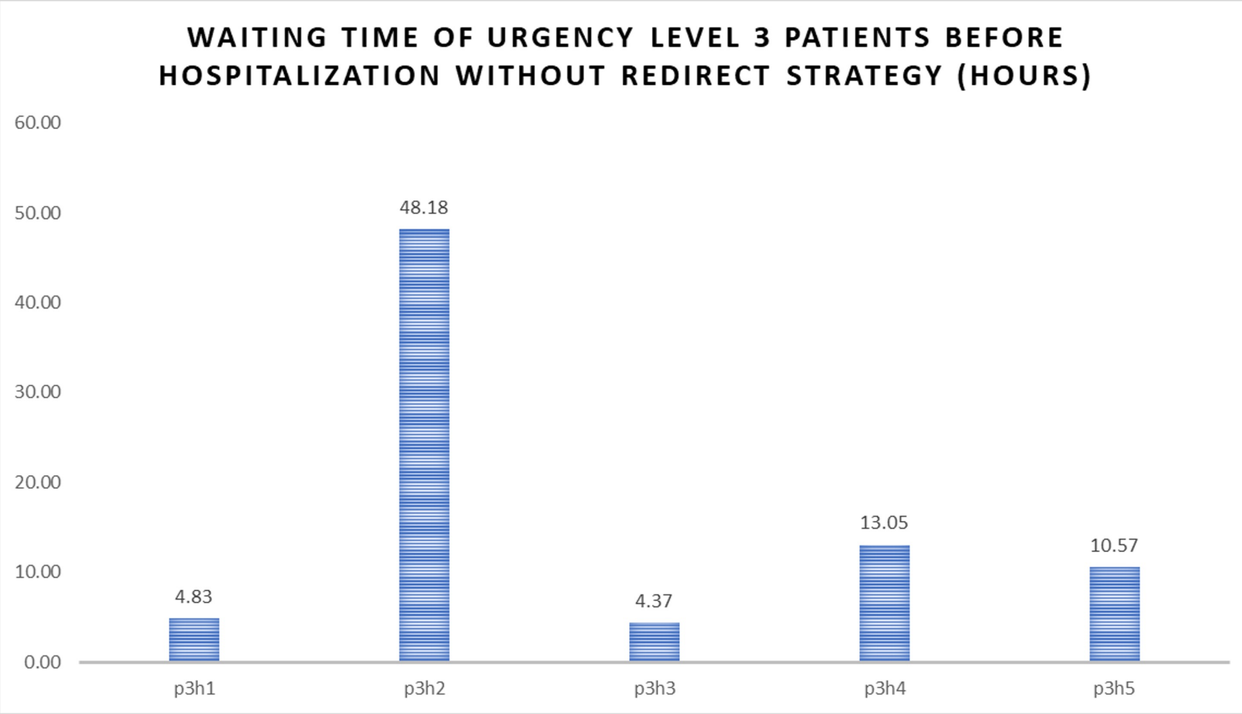
The waiting time before hospitalization





The waiting time before hospitalization





VI. MODEL IMPROVEMENT

Improvements:

- Improvement 1: Re-distribute the number of ambulances at 22 ambulance bases with respect to infected case distribution across the city

- Improvement 2: Eliminate the limitation on the number of rerouting times an ambulance can perform during 1 trip (the initial model set the limitation to maximum 3 hospitals/trip)

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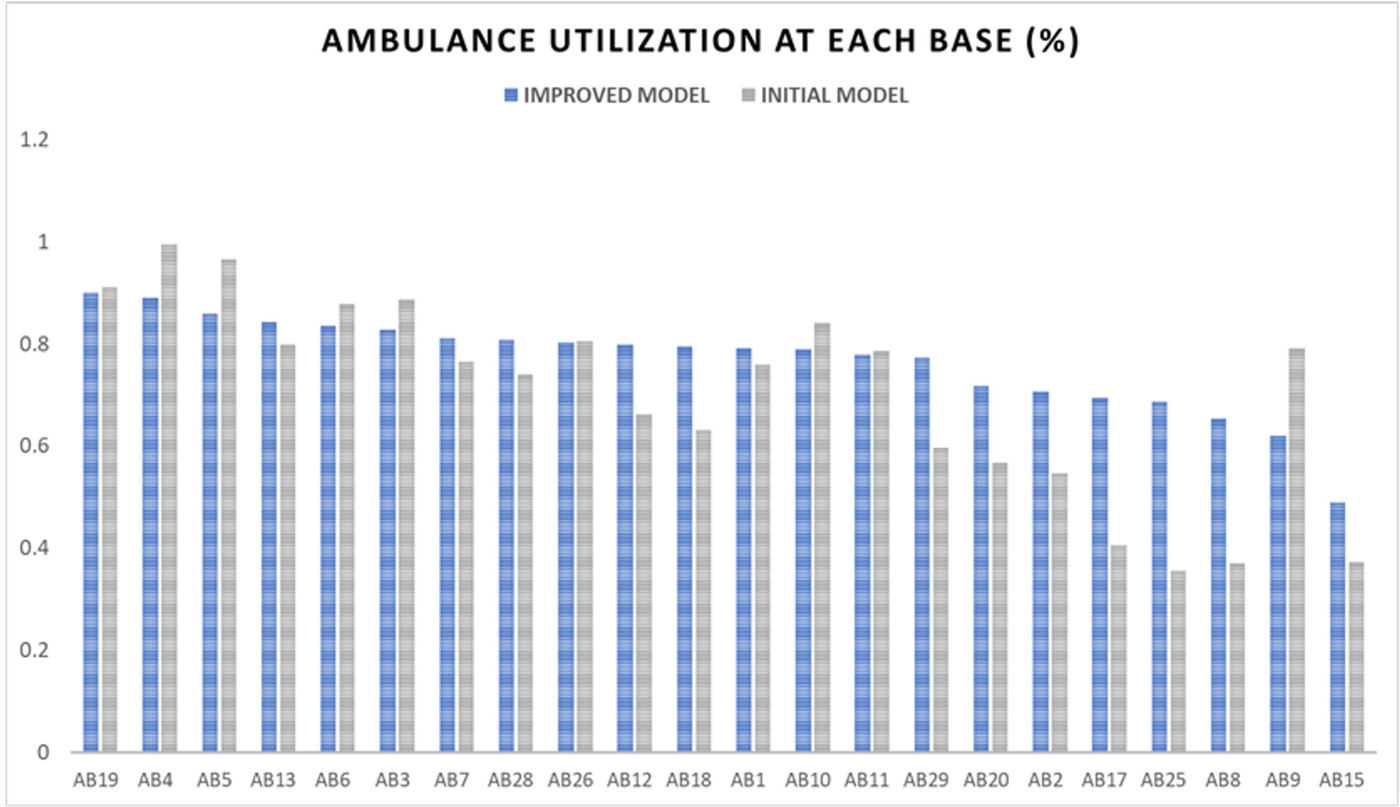
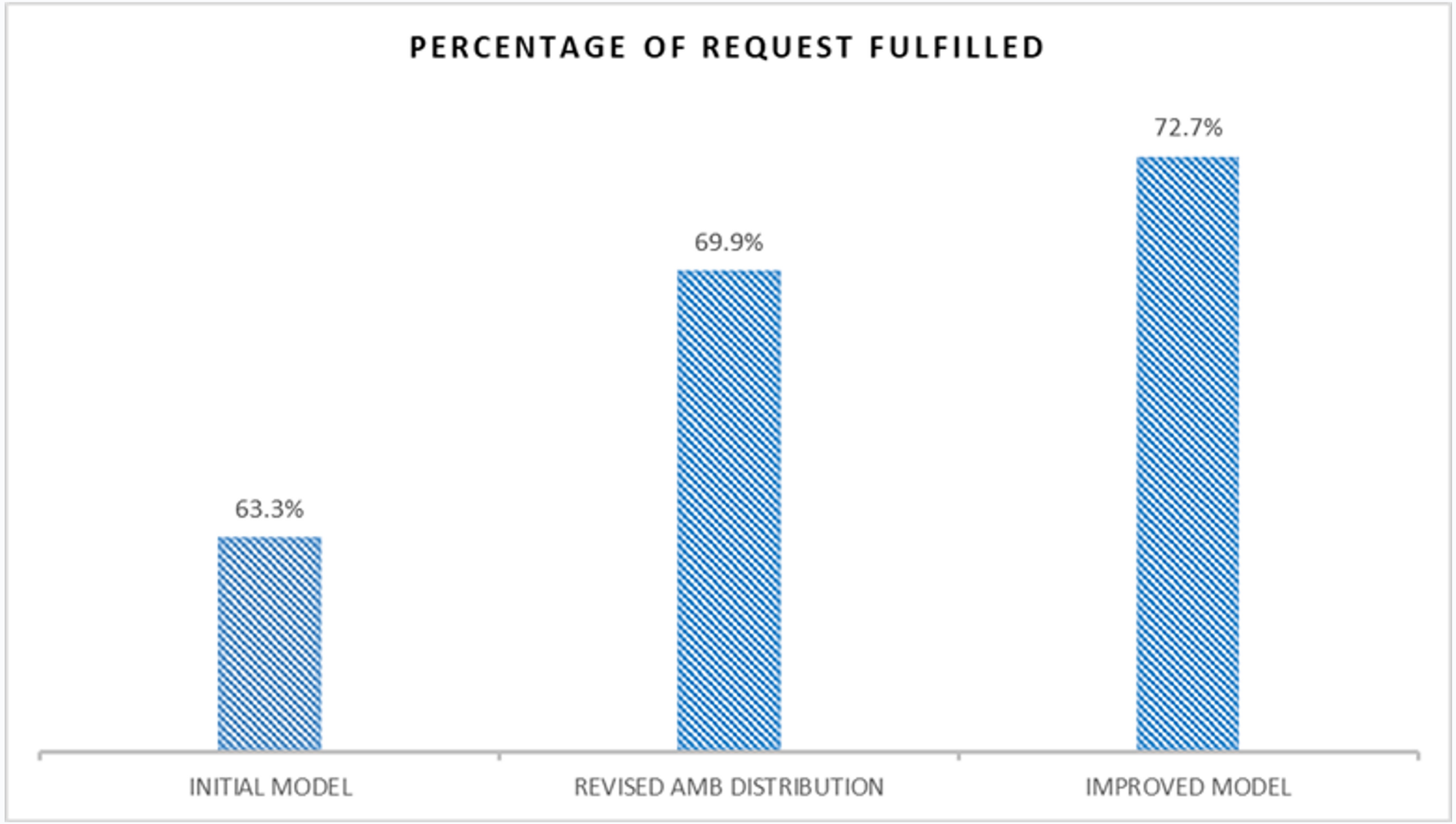
Ambulance index	Utilization	Current ambulance distribution	Location responsible	Infected cases distribution	Revised ambulance distribution
AB4	100%	13	Binh Tan	10.75%	30
AB5	97%	13	Binh Chanh	6.57%	22
AB19	91%	13	Hoc Mon	5.29%	16
AB3	89%	13	District 12	6.87%	20
AB6	88%	13	Thu Duc	6.86%	18
AB10	84%	13	Binh Thanh	6.32%	18
AB26	81%	13	Tan Phu	5.85%	15
AB13	80%	13	District 4	4.34%	12
AB9	79%	13	District 6	4.21%	12
AB11	79%	13	District 8	5.10%	15
AB7	77%	13	Tan Binh	5.59%	13
AB1	76%	13	District 10	5.03%	13
AB28	74%	13	Nha Be	4.22%	12
AB12	66%	13	District 7	3.90%	10
AB18	63%	13	Cu Chi	2.21%	9
AB29	60%	13	Go Vap	3.02%	9
AB20	57%	13	District 5	3.07%	9
AB2	55%	13	District 11	3.57%	9
AB17	41%	13	Phu Nhuan	1.96%	6
AB15	37%	13	District 3	2.76%	8
AB8	37%	13	District 1	2.10%	6
AB25	36%	13	Can Gio	0.40%	5



Improved model performance



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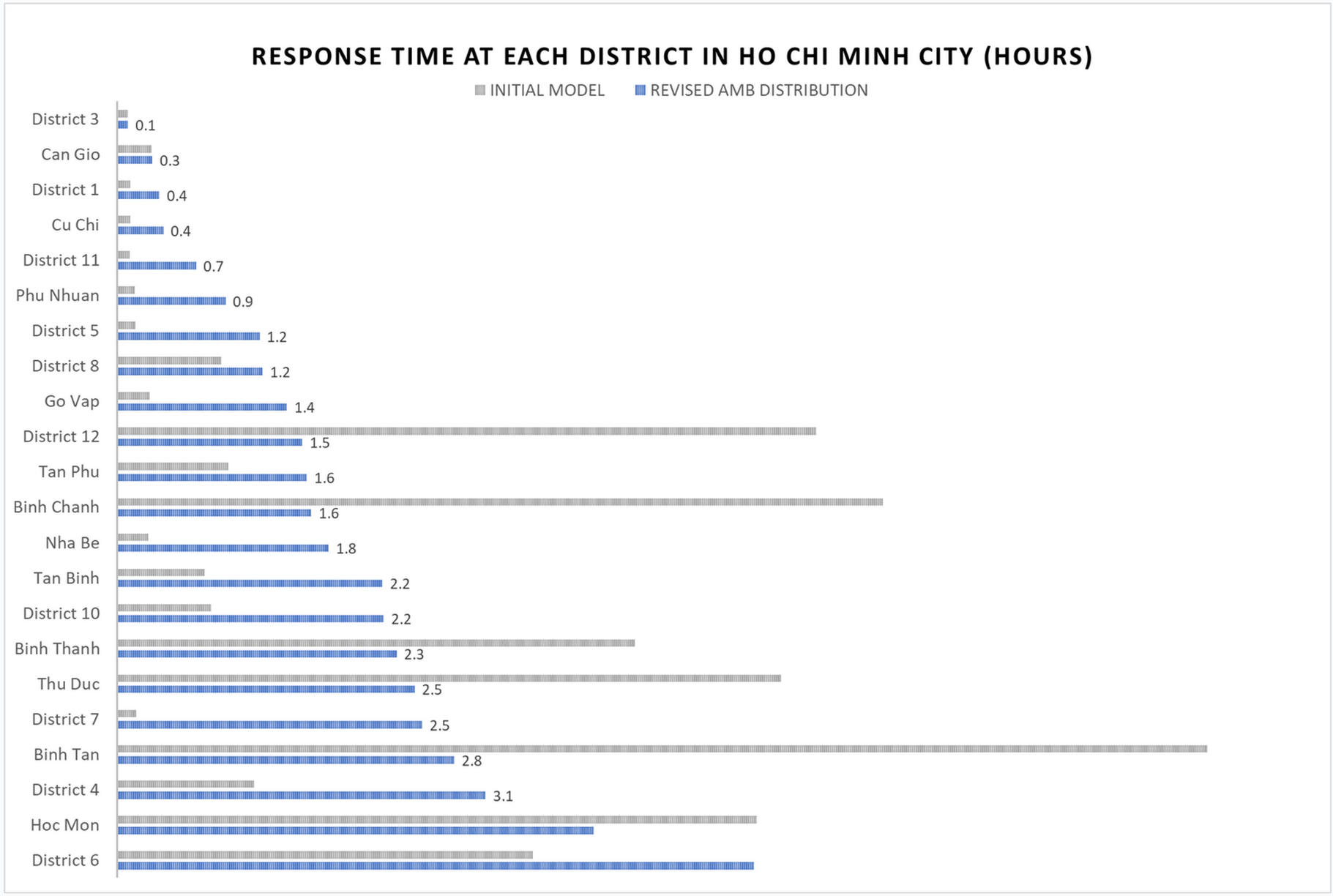
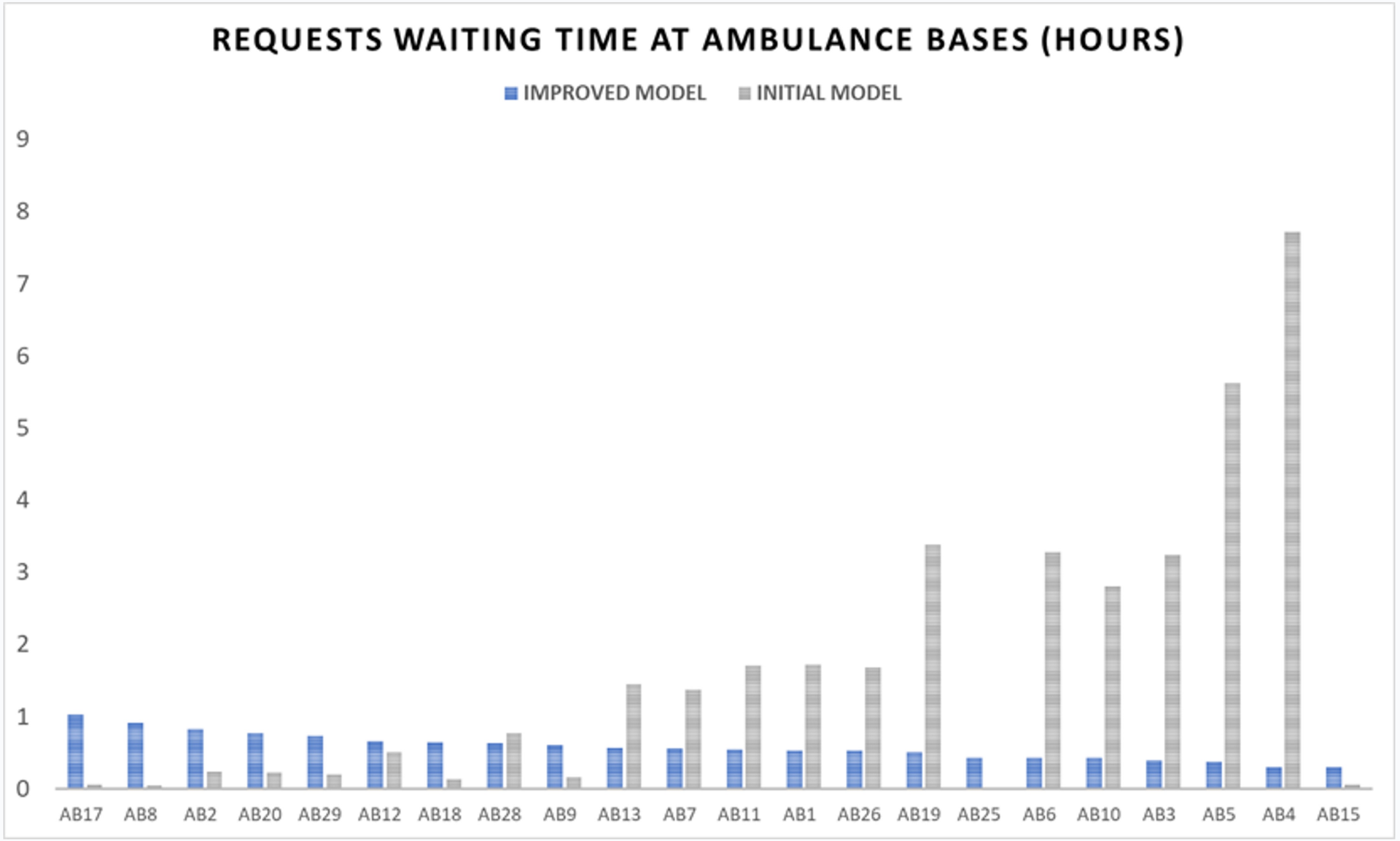


Improved model performance



VIII. CONCLUSION

Main References

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Future work

- Apply GIS (geographic information system): help individuals and organizations better understand spatial patterns and relationships of the diseases like COVID-19 and provided better information for the decision-making process

- Develop an ambulance patrol strategy. A portion of ambulances should be assigned to patrol a certain area when the outbreak starts to minimize response time

- Focus on the decision-making processes of humans during the ambulance service to fully describe the situation of emergency transportation during pandemics

- Improvement of information transfer among different parties in the EMS system