Discrete event simulation as a tool in optimization of a professional complex adaptive system.

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But the (health care) system is under pressure

Health care systems are struggling with financial limitations worldwide. The increasing demand for health care services leads to what many categorize as a health care crisis [1]. The problems were highlighted by The Institute of Medicine [2] calling for health care systems to be more efficient [3].

[1] Goldsmith JC. The new health-cost crisis. Harv Bus Rev 2001; 79(10):20-21.
[2] Kohn LT, Corrigan JM, Donaldson MS. To err is human: building a safer health system. Washington, D.C.: National Academy Press; 2000.
[3] WHO. World Report on Knowledge for Better Health - Strengthening Health Systems. 1-146. 2004. Geneva,Switzerland, World Health Organization. Report.

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Eric William's Medical Science Complex, Mt. Hope; Trinidad, W.I:

Trinidad and Tobago has a health care system of socialized medicine.

The health care system is inefficient.

Accordingly to WHO 'malfunctioning health systems are at the heart of the problem'. In addition 'countries with few resources struggle with creaking infrastructures, inadequate financing, migrating doctors and nurses, and lack of basic information on health indicators'

WHO. World Report on Knowledge for Better Health - Strengthening Health Systems. 1-146. 2004. Geneva,Switzerland, World Health Organization. Report.

Eric William's Medical Science Complex, Mt. Hope; Trinidad, W.I:

Eric William's Medical Science Complex, Mt Hope is our 'tertiary Hospital'

However the delivered health care is less than ideal.

Daily headlines emphasize shortcomings including unacceptable long waits and poor quality especially in the emergency departments (=ED).

The question is how can we improve the service within the given constraints?

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Why use modeling and simulation?

How is our decision-making processes ?

The "Think first" model

The "think first" or rational model follows a clearly defined process:

Define → Diagnose → Design → Decide.

This model represents the scientific approach and represents the core logic in medicine and thus the way medical professionals ideally make decisions. One could a little provocative say that it is the way medical professionals always argue that they make decisions

Mintzberg H, Westley F. Decision Making: It's not What You Think. MIT Sloan Management Review 2001; 42(3):89-93

The "See it" model

After realizing a problem we work on it, consciously and unconsciously, and suddenly we see the solution and we can verify it either by logic or by actually doing it.

Preparation → Incubation → illumination → verification

This is clearly a central part of vision, to see what others do not and have the confidence and the experience to recognize the sudden insight for what it is.

Mintzberg H, Westley F. Decision Making: It's not What You Think. MIT Sloan Management Review 2001; 42(3):89-93

The "Doing First" model

But what happens when one can't see it and can't think it up? Just do it. The process for "doing first", in essence this is experimentation – trying something so that you can learn, has three steps:

Enactment → Selection → Retention.

That means trying various things under various circumstances, finding out which one works, making sense of that and repeating the successful behavior and discarding the rest. Another term for it is "learning by doing".

Mintzberg H, Westley F. Decision Making: It's not What You Think. MIT Sloan Management Review 2001; 42(3):89-93

Why use modeling and simulation?

How is our decision-making processes ?

Doing first or experimenting could represent a way forward
But this approach is not reasonable in an ED

Kelton WD, Sadowski RP, Sturrock DT. Simulation with Arena. 4 ed. New York: McGraw-Hill; 2007

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Why use modeling and simulation?

How is our decision-making processes ?

Could experiments in the 'virtual world' be the solution?

Several papers from the developed world indicate that modeling and simulation could be such a tool.

Coats TJ, Michalis S. ***Mathematical modelling of patient flow through an accident and emergency department****. Emerg Med J 2001; 18(3):190-192.*
Harper PR. ***A Framework for Operational Modelling of Hospital Resources****. Health Care Management Science 2002; 5(3):165-173.*
Huang X-M. ***Decision making support in reshaping hospital medical services****. Health Care Management Science 1998; 1(2):165-173.*
Hung GR, Whitehouse SR, O'Neill C, Gray AP, Kissoon NM. ***Computer Modeling of Patient Flow in a Pediatric Emergency Department Using Discrete Event Simulation****. Pediatric Emergency Care 2007; 23(1):5-10.*
Sinreich D, Jabali O. Staggered work shifts: ***A way to downsize and restructure an emergency department workforce yet maintain current operational performance****. Health Care Management Science 2007; 10(3):293-308.*
Vissers JMH. ***Health care management modelling: a process perspective****. Health Care Management Science 1998; 1(2):77-85.*

Why use modeling and simulation?

How is our decision-making processes ?

Could experiments in the 'virtual world' be the solution?

Key elements needed?

1) A system can be identified i.e. the ED
2) There is a problem relating to the system that needs to be corrected

The modeling activity creates an object (i.e. a model) that is subsequently used as a vehicle for experimentation (i.e. simulation)

Birta LG, Arbez G. Modelling and Simulation - Exploring Dynamic System Behaviour. 1 ed. London: Springer-Verlag; 2007.

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Why use discrete event simulation?

The state of the variables (i.e. patients) only changes at a discrete set of points in time (i.e. contact with the health care staff).

Banks J, Carson II JS, Nelson BL, Nicol DM. Discrete-event system simulation. 4 ed. Pearson Education Inc; 2005.

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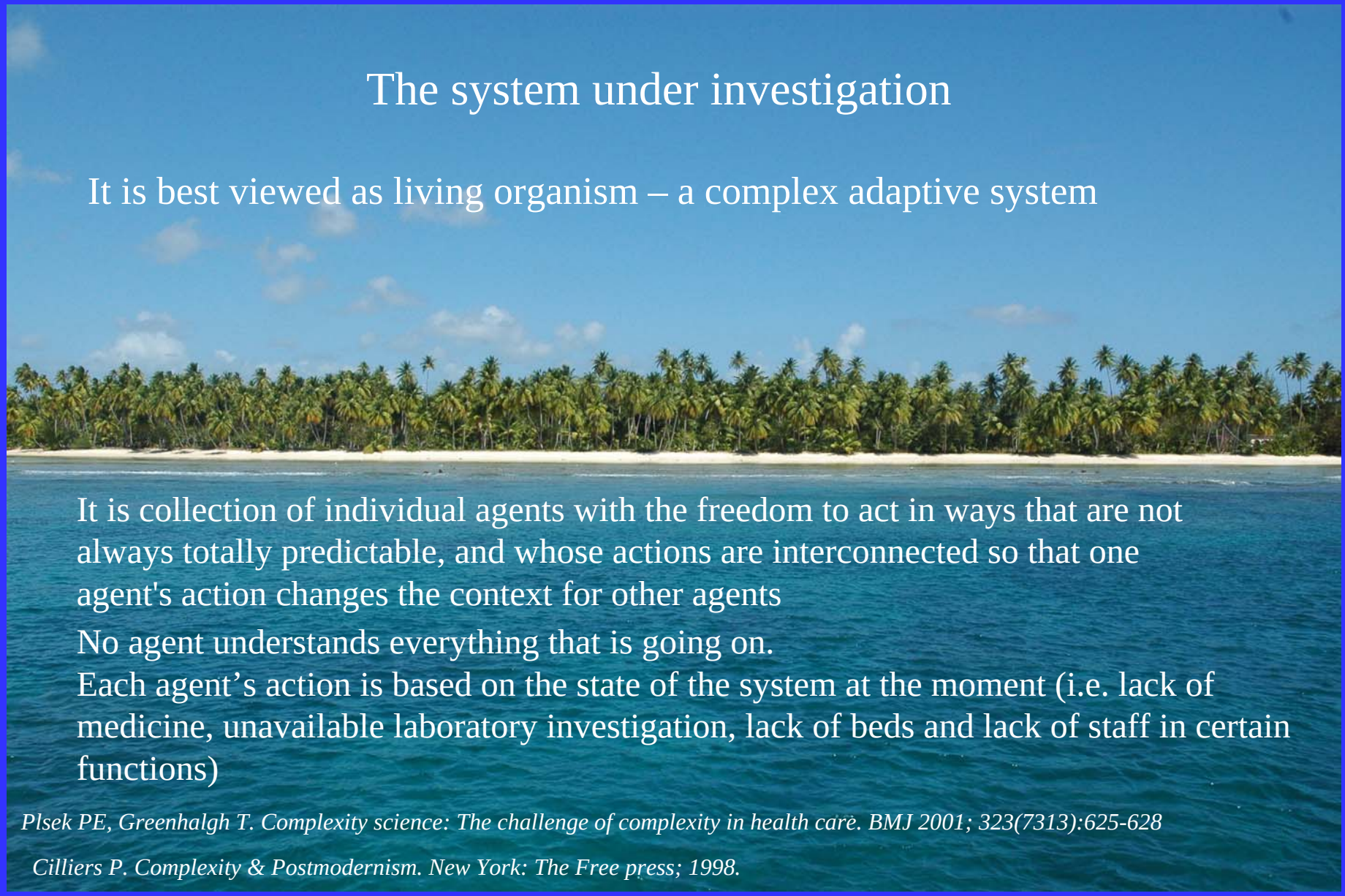
The system under investigation

It is best viewed as living organism – a complex adaptive system



It is collection of individual agents with the freedom to act in ways that are not always totally predictable, and whose actions are interconnected so that one agent's action changes the context for other agents

No agent understands everything that is going on.

Each agent’s action is based on the state of the system at the moment (i.e. lack of medicine, unavailable laboratory investigation, lack of beds and lack of staff in certain functions)

Plsek PE, Greenhalgh T. Complexity science: The challenge of complexity in health care. BMJ 2001; 323(7313):625-628

Cilliers P. Complexity & Postmodernism. New York: The Free press; 1998.

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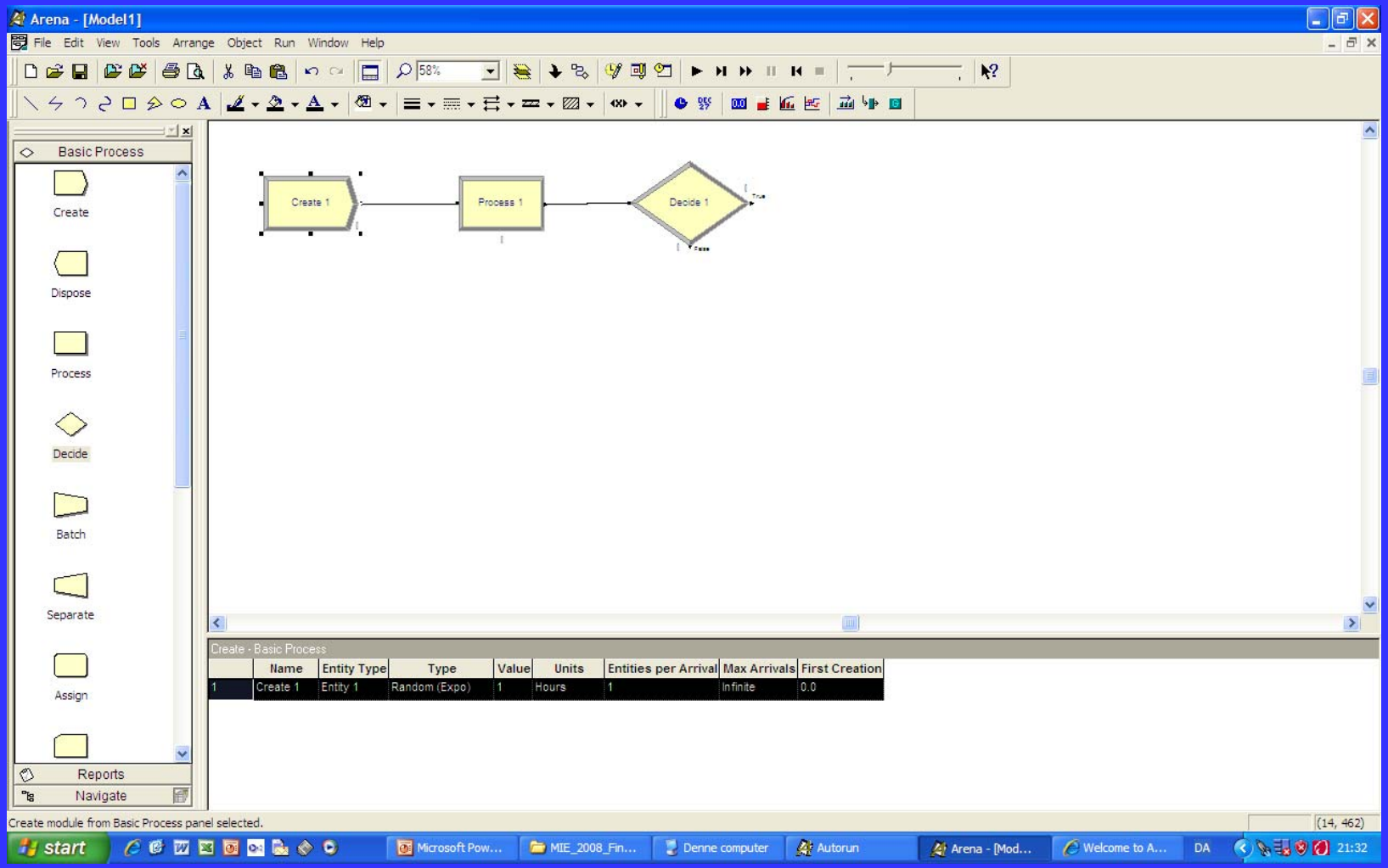
Simulation software: Arena v 10.0



NB We used the Student version provided with the book ***Kelton WD, Sadowski RP, Sturrock DT. Simulation with Arena. 4 ed. New York: McGraw-Hill; 2007***

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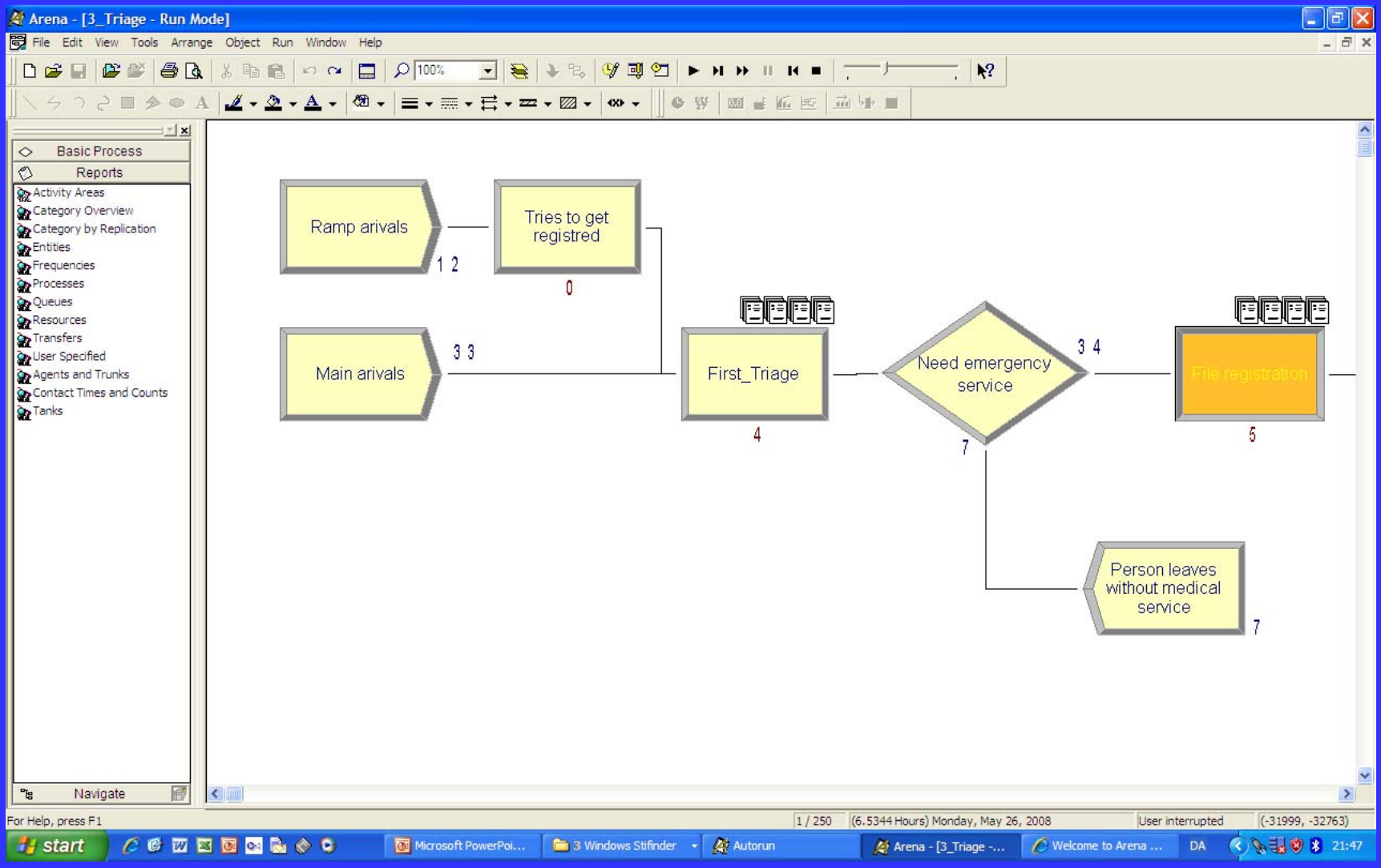
Simulation: After 6.5 hours



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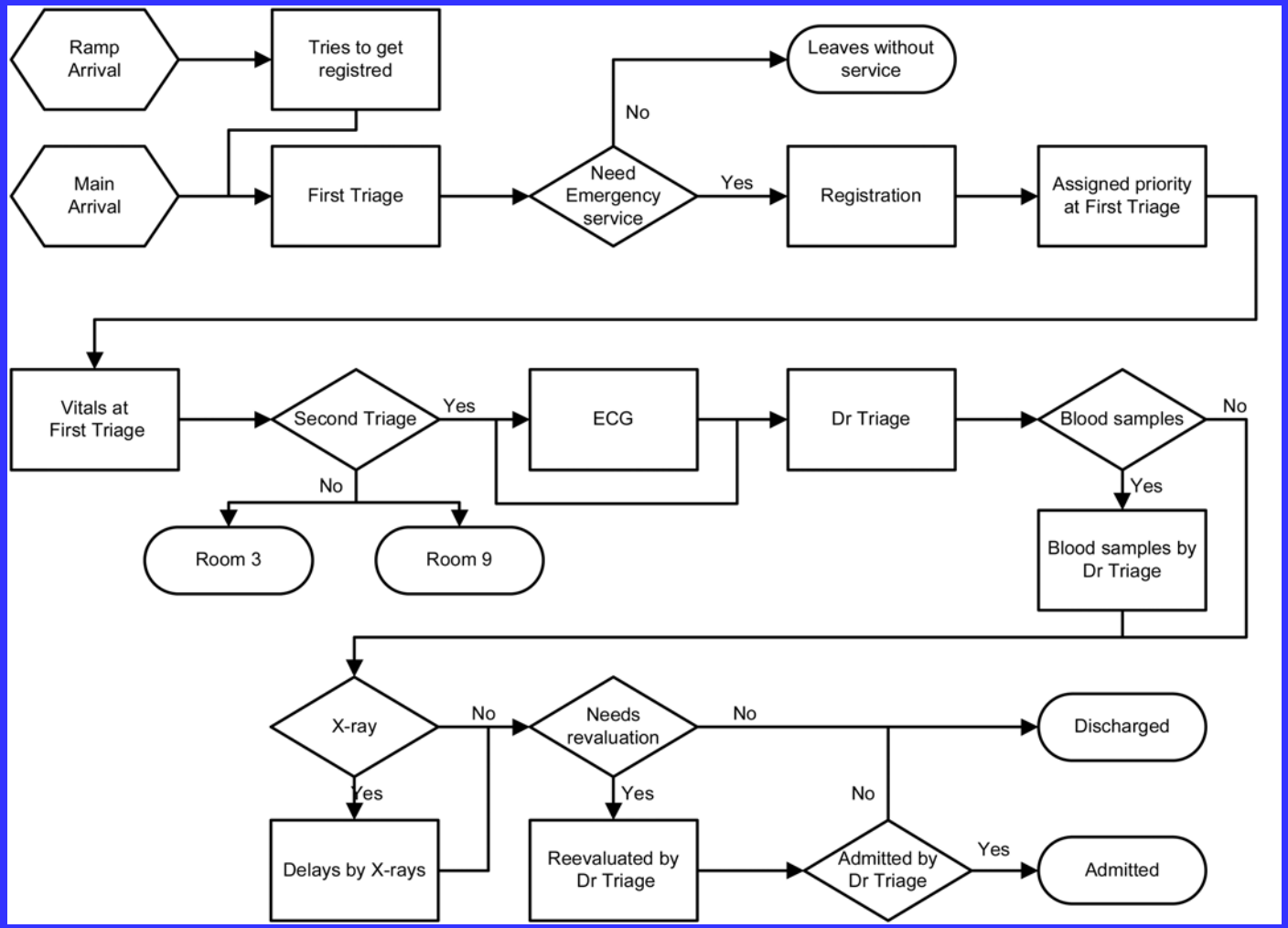
The flow- Model



We used a prototyping developing approach

Simulation:
Terminating simulation over 24 hours with 500 replications

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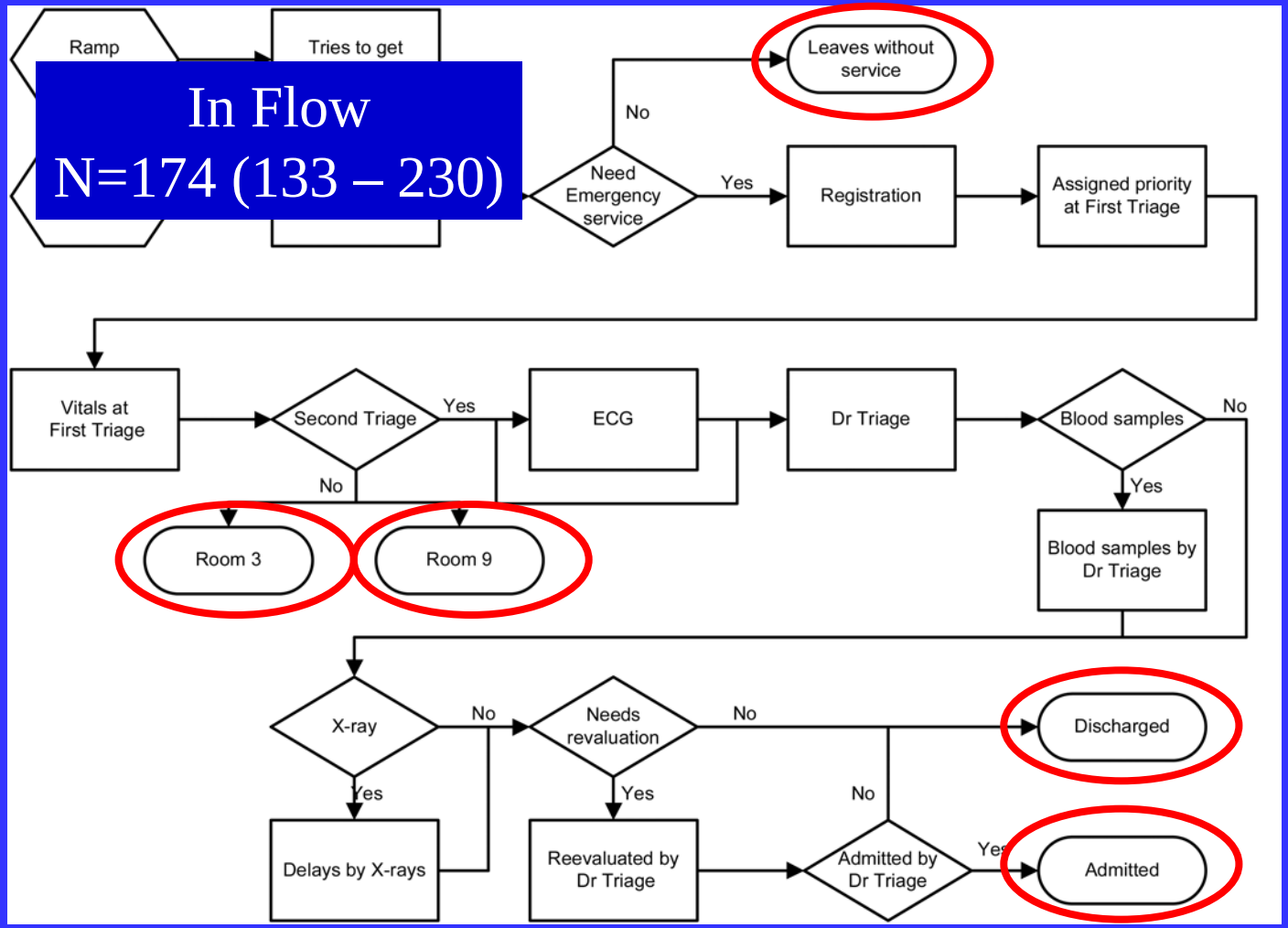
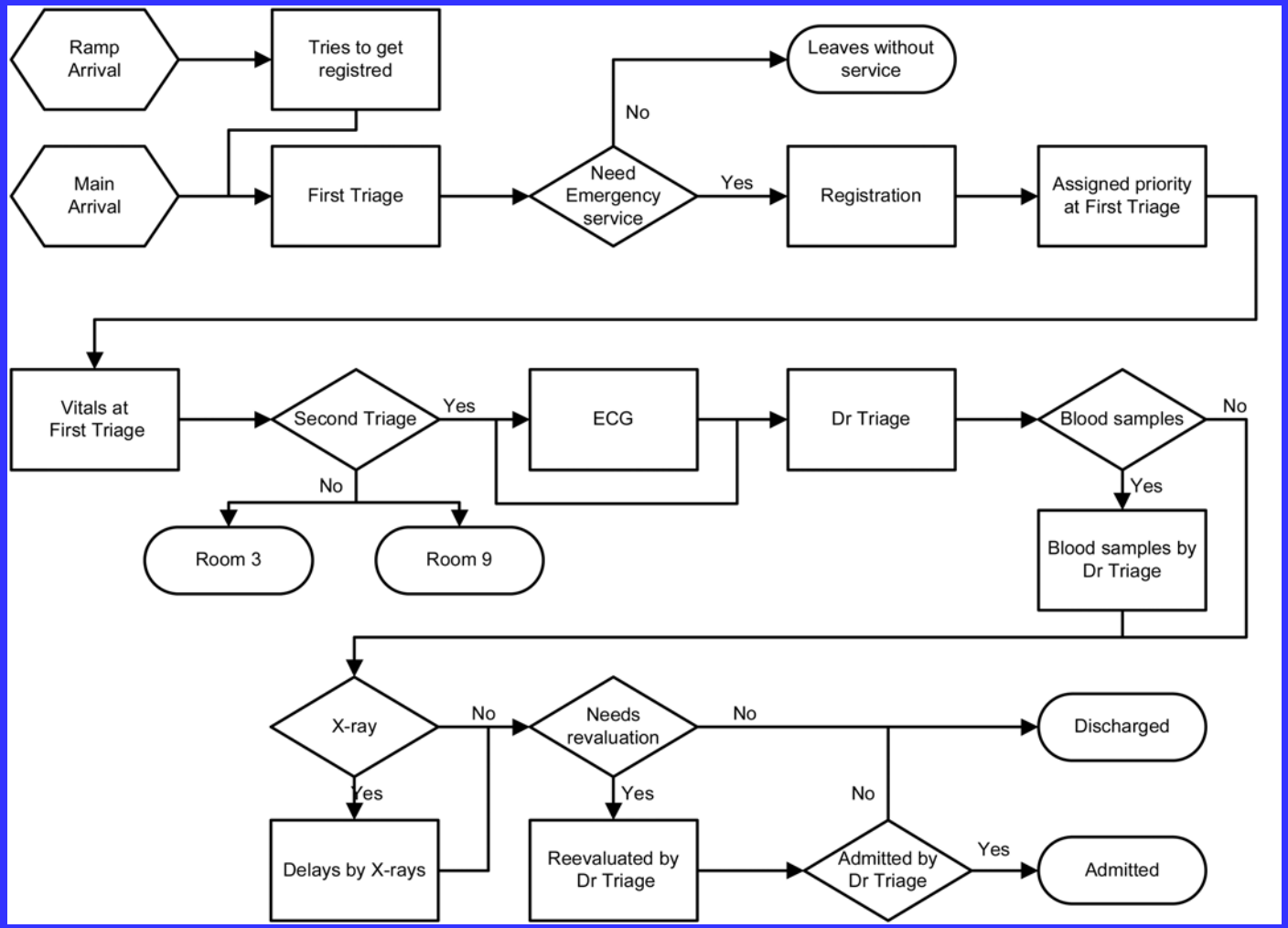
Results

Fully processed



Fully processed
N = 87 (62-115)

Results Waiting time



Fully processed
N = 87 (62-115)

Waiting time
h = 9.2 (2.4-17)

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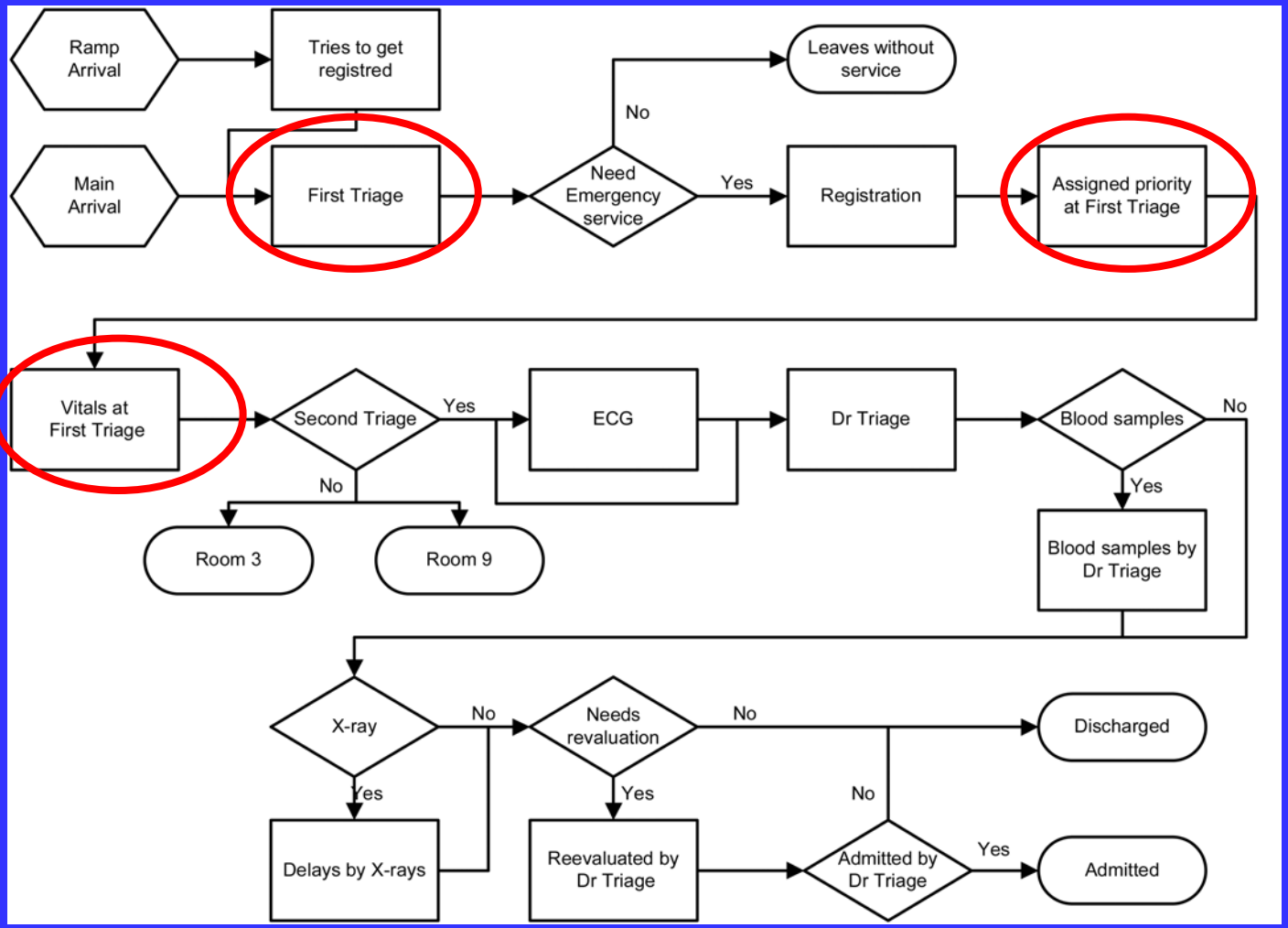
Results 1st Triage Nurse



Fully processed
N = 87 (62-115)

Waiting time
h = 9.2 (2.4-17)

1st Triage Nurse
Utiliz. = 99.5

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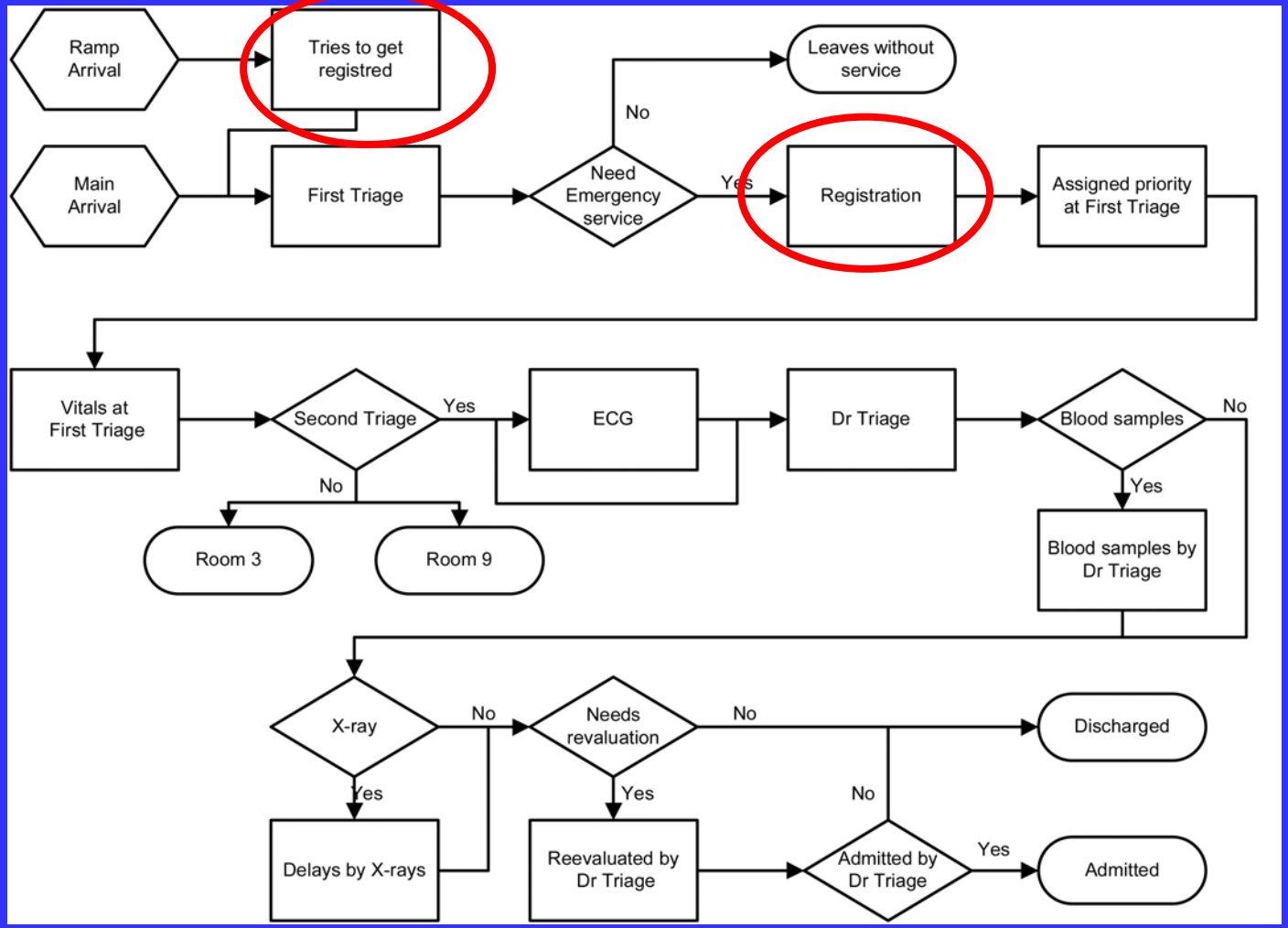
Results Clerk



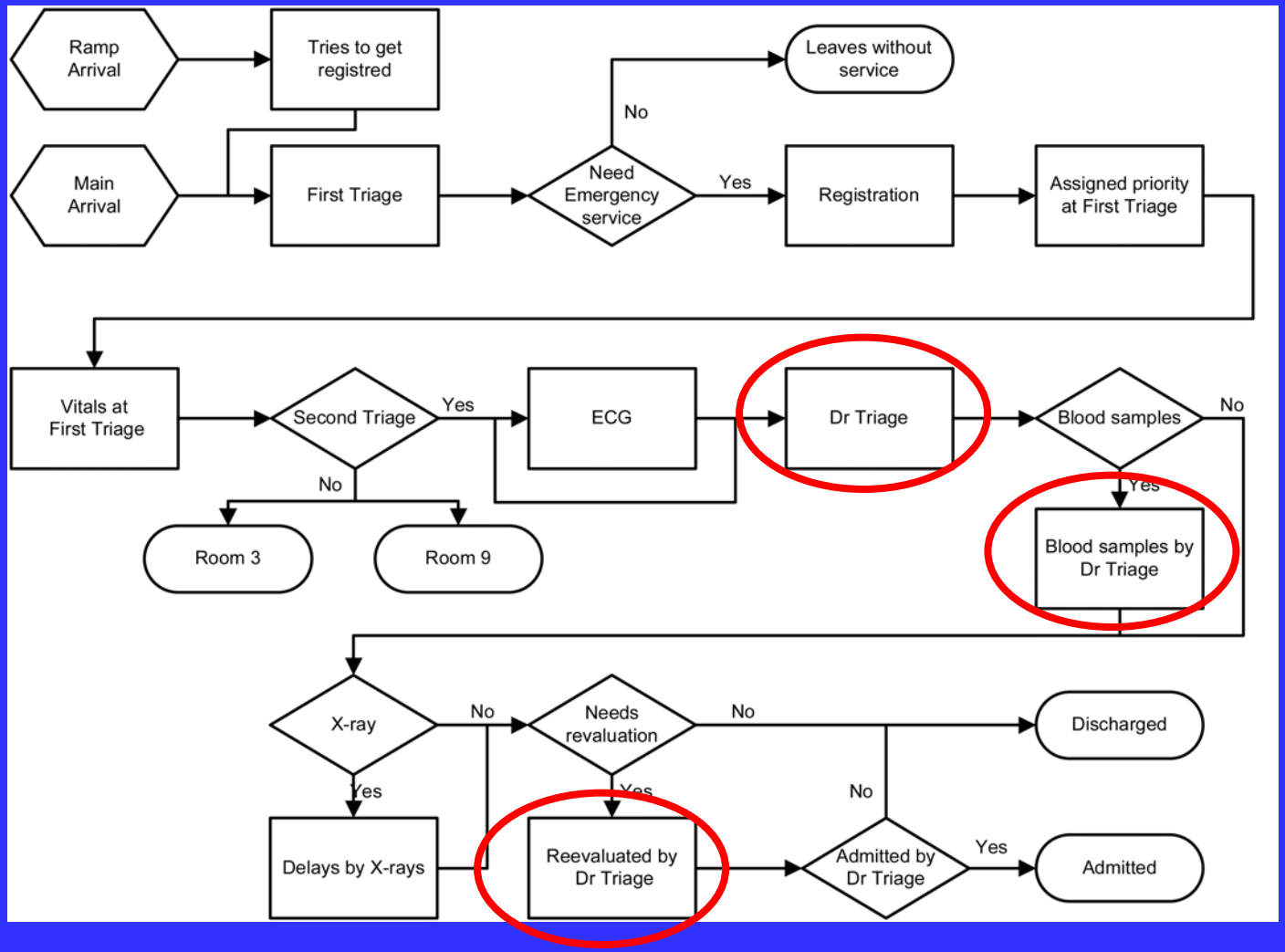
Fully processed
N = 87 (62-115)

Waiting time
h = 9.2 (2.4-17)

1st Triage Nurse
Utiliz. = 99.5

Clerk
Utiliz. = 73.9

Results ED-Doctor



Fully processed
N = 87 (62-115)

Waiting time
h = 9.2 (2.4-17)

1st Triage Nurse
Utiliz. = 99.5

Clerk
Utiliz. = 73.9

Dr.
Utiliz. = 44.3

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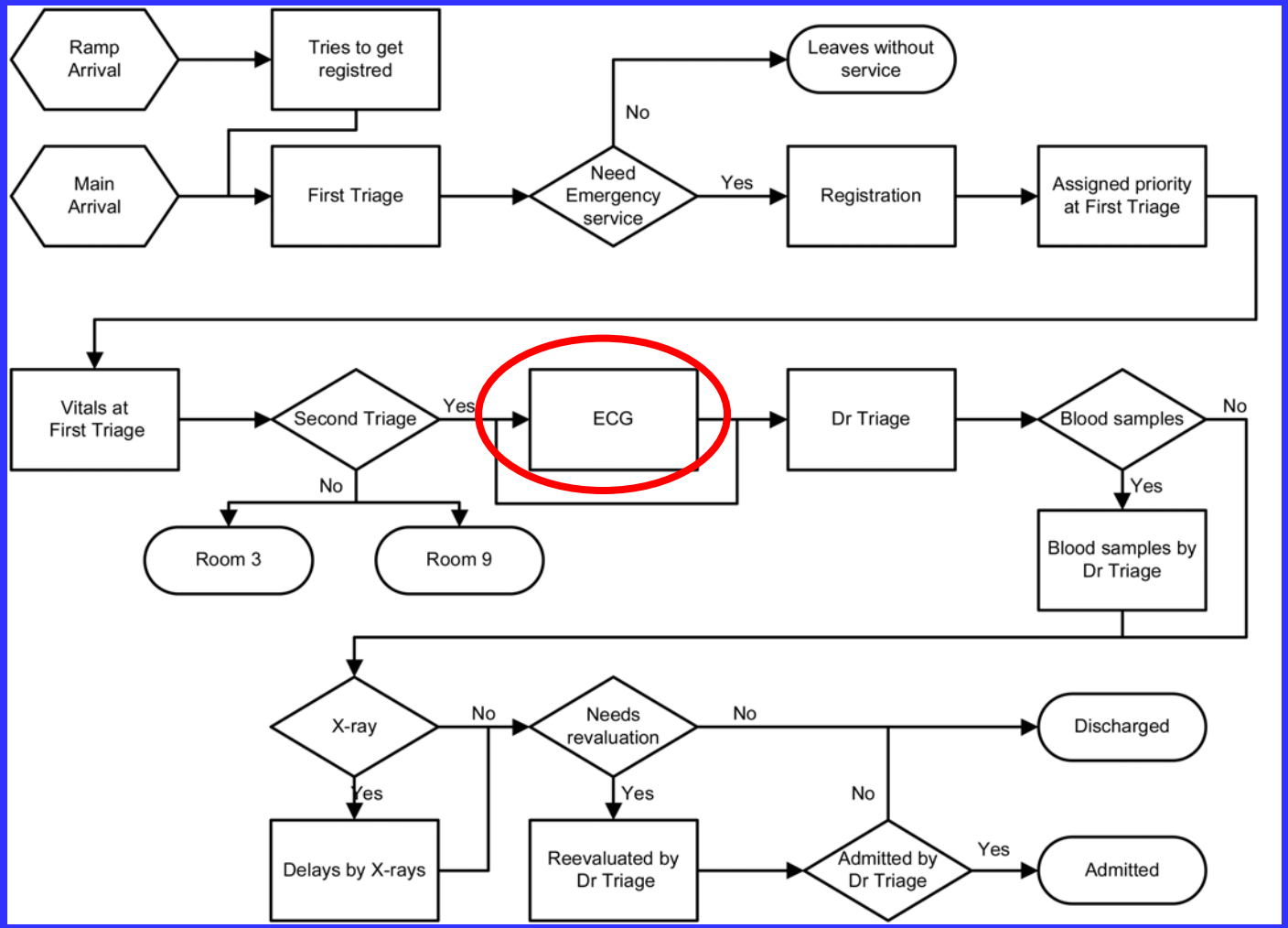
Results ECG-nurse



Fully processed
N = 87 (62-115)

Waiting time
h = 9.2 (2.4-17)

1st Triage Nurse
Utiliz. = 99.5

Clerk
Utiliz. = 73.9

Dr.
Utiliz. = 44.3

ECG-nurse
Utiliz = 6.9

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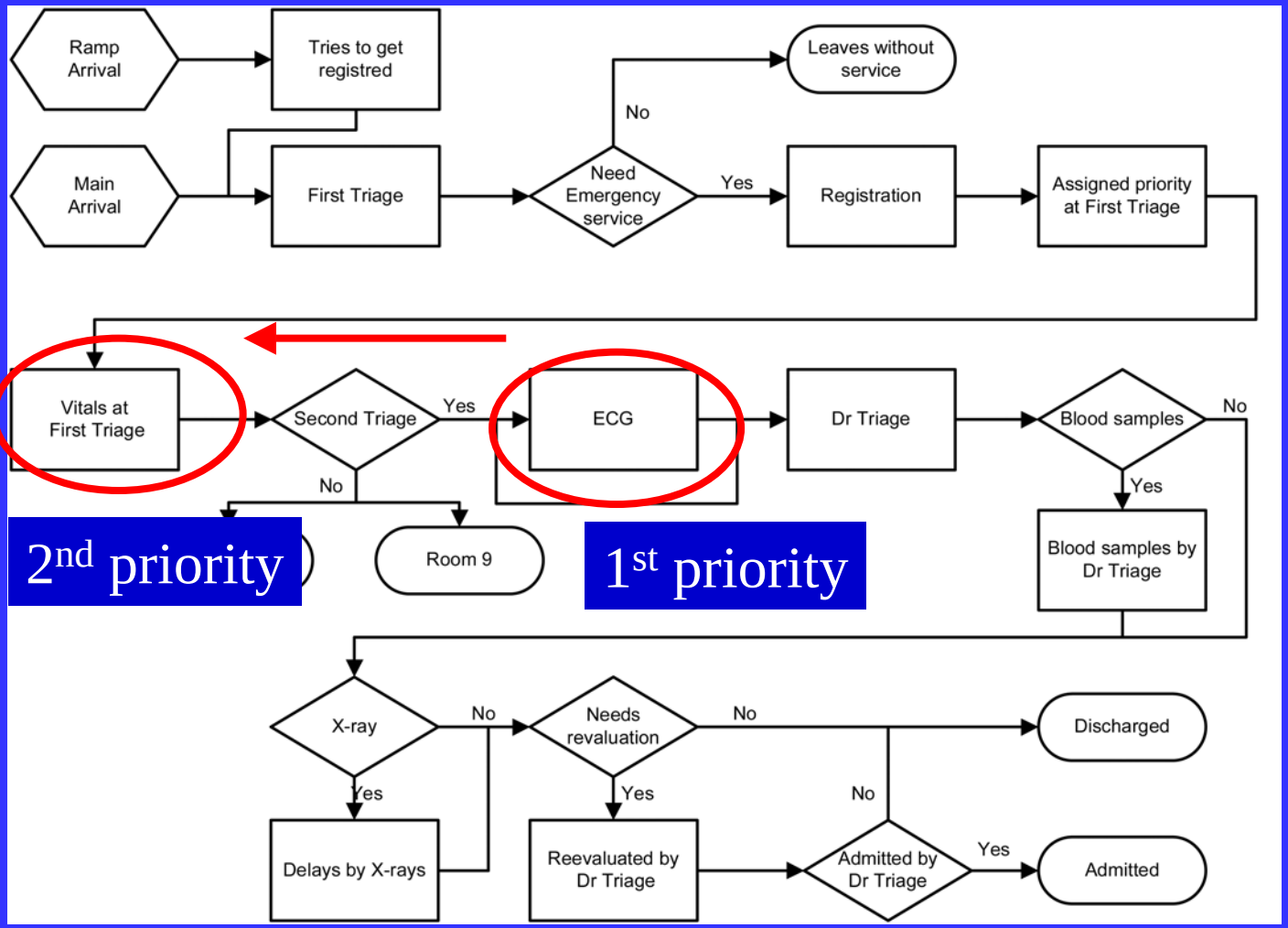
Simple rearrangement



Fully processed
N = 87 (62-115)

Waiting time
h = 9.2 (2.4-17)

1st Triage Nurse
Utiliz. = 99.5

Clerk
Utiliz. = 73.9

Dr.
Utiliz. = 44.3

ECG-nurse
Utiliz = 6.9

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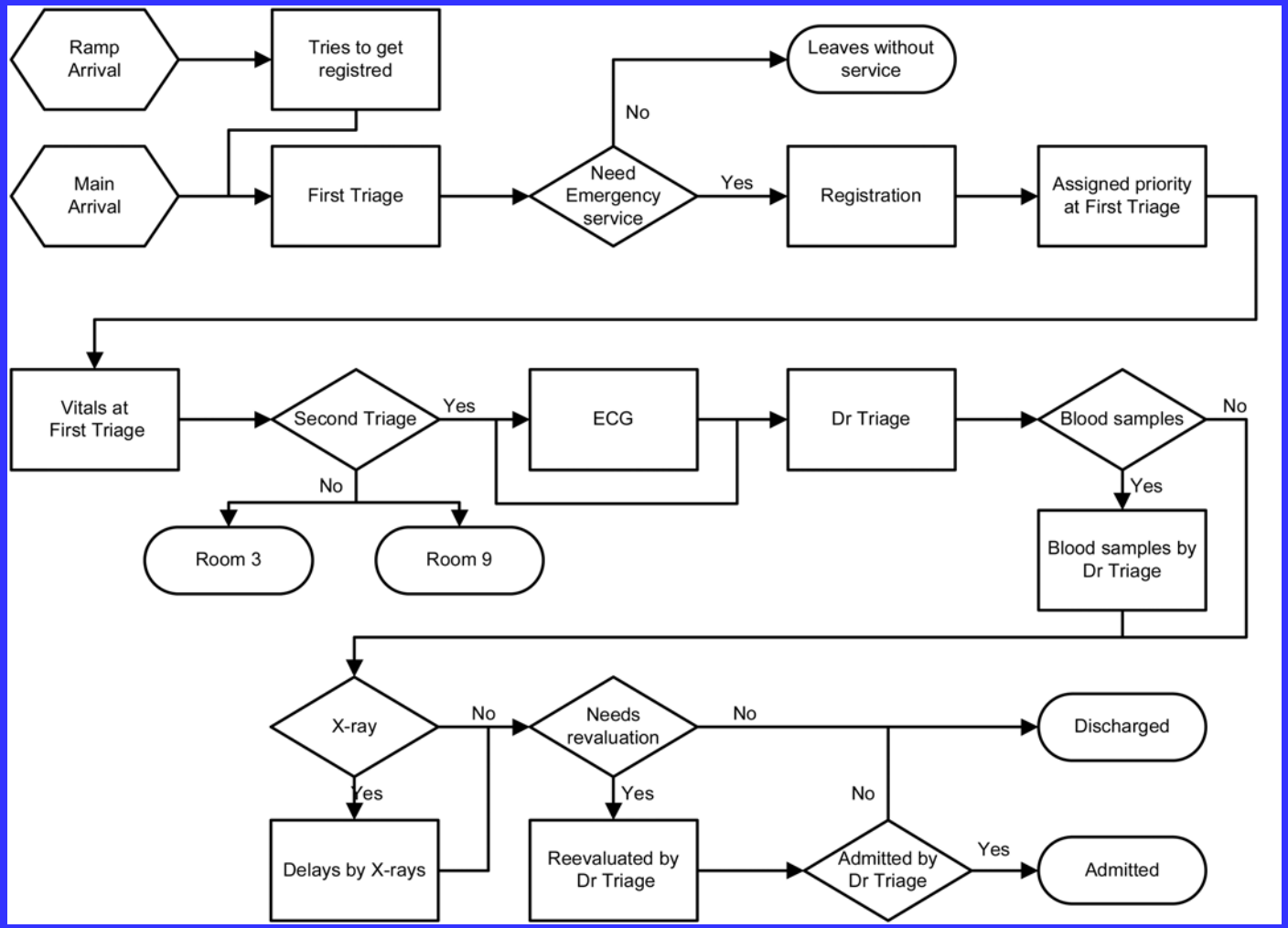
Results after



Fully processed
147 (129-135)

Waiting time
h = 5.0 (0.6-13)

1st Triage Nurse
Utiliz. = 95.8

Clerk
Utiliz. = 88.7

Dr.
Utiliz. = 87.4

ECG-nurse
Utiliz = 89.7

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Usefulness of the simulation

The evaluation of the usefulness of the simulation :
(1) evaluate the method,
(2) assess the information required to build a usable model,
(3) to determine if it was worthwhile to undertake the data collection needed to build a detailed model.

1: Evaluation of the method

The degree of process thinking in the organization has consequences for the way the models are developed. The concept of processes is not widely shared in the observed organization.

Close cooperation between modeler and manager and a profound insight into the dynamics of the area being modeled are therefore important requirements for developing a successful model

We found as our partners at UBC that one could effectively change the model and easily simulate its effects on patient flow

Hung GR, Whitehouse SR, O'Neill C, Gray AP, Kissoon NM. Computer Modeling of Patient Flow in a Pediatric Emergency Department Using Discrete Event Simulation. Pediatric Emergency Care 2007; 23(1):5-10.

2: Assess the information required to build a usable model

The time consuming analysis of the activities in the organization is needed.

No single expert fully grasp, and no set of documents fully captures, the subtle ways in which individual components are interwoven with one another.

One has to look at the ongoing activity itself.

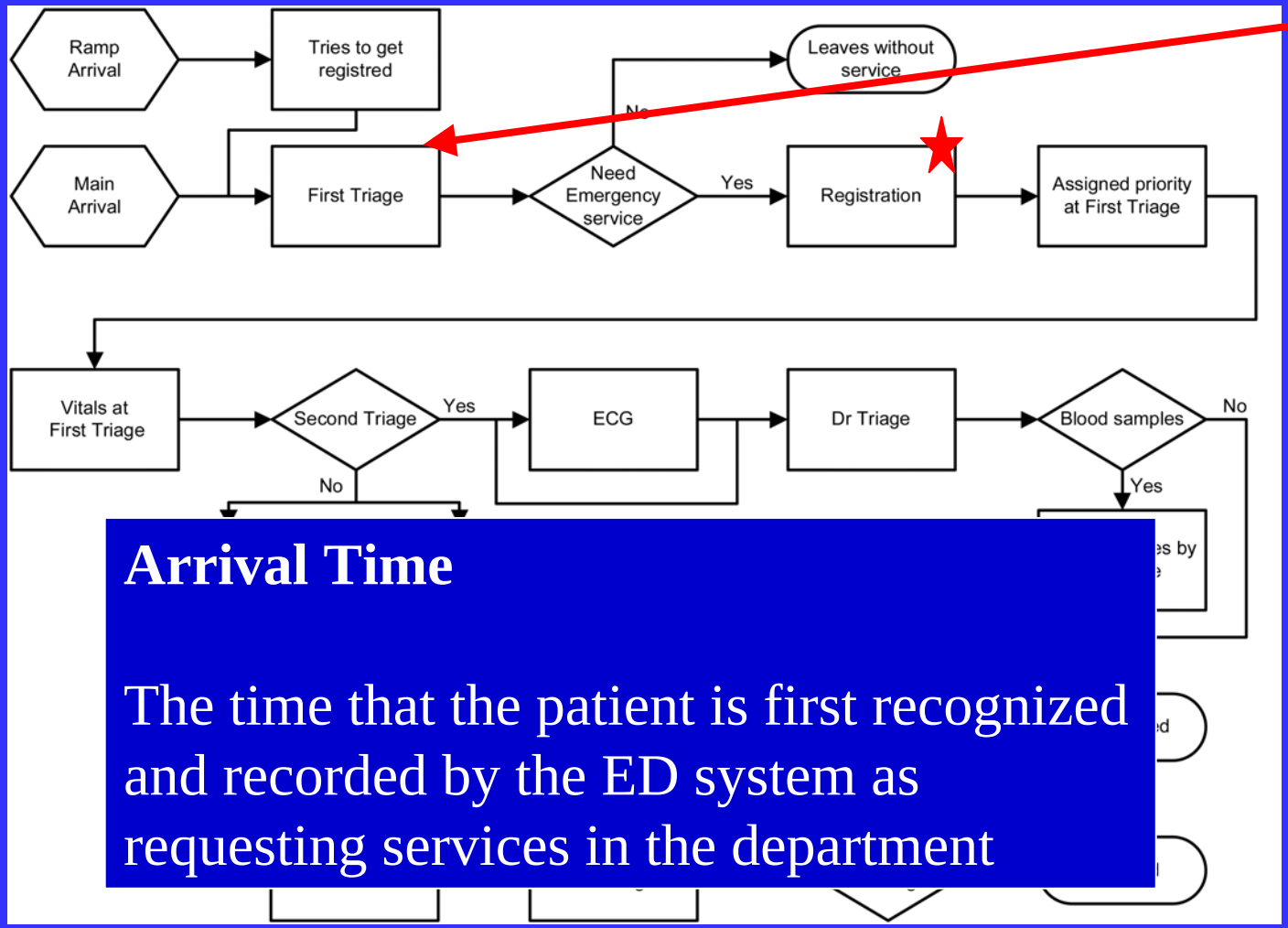
Hirschhorn L. Campaigning for Change. Harv Bus Rev 2002; 80(7):98-104.
Szulanski G, Winter S. Getting It Right the Second Time. Harv Bus Rev 2002; 80(1):62-69.
Brown JS. Research that reinvents the corporation. Harvard Business Review on Knowledge Management. Boston: Harvard Business School Press; 1998. 153-159.

3: Was it worthwhile to undertake the data collection needed to build a detailed model ?

Performance measures as defined by:
Emergency Department Performance Measures and Benchmarking Summit

Welch S, Augustine J, Camargo CA, Jr., Reese C. Emergency Department Performance Measures and Benchmarking Summit. Acad Emerg Med 2006; 13(10):1074-1080

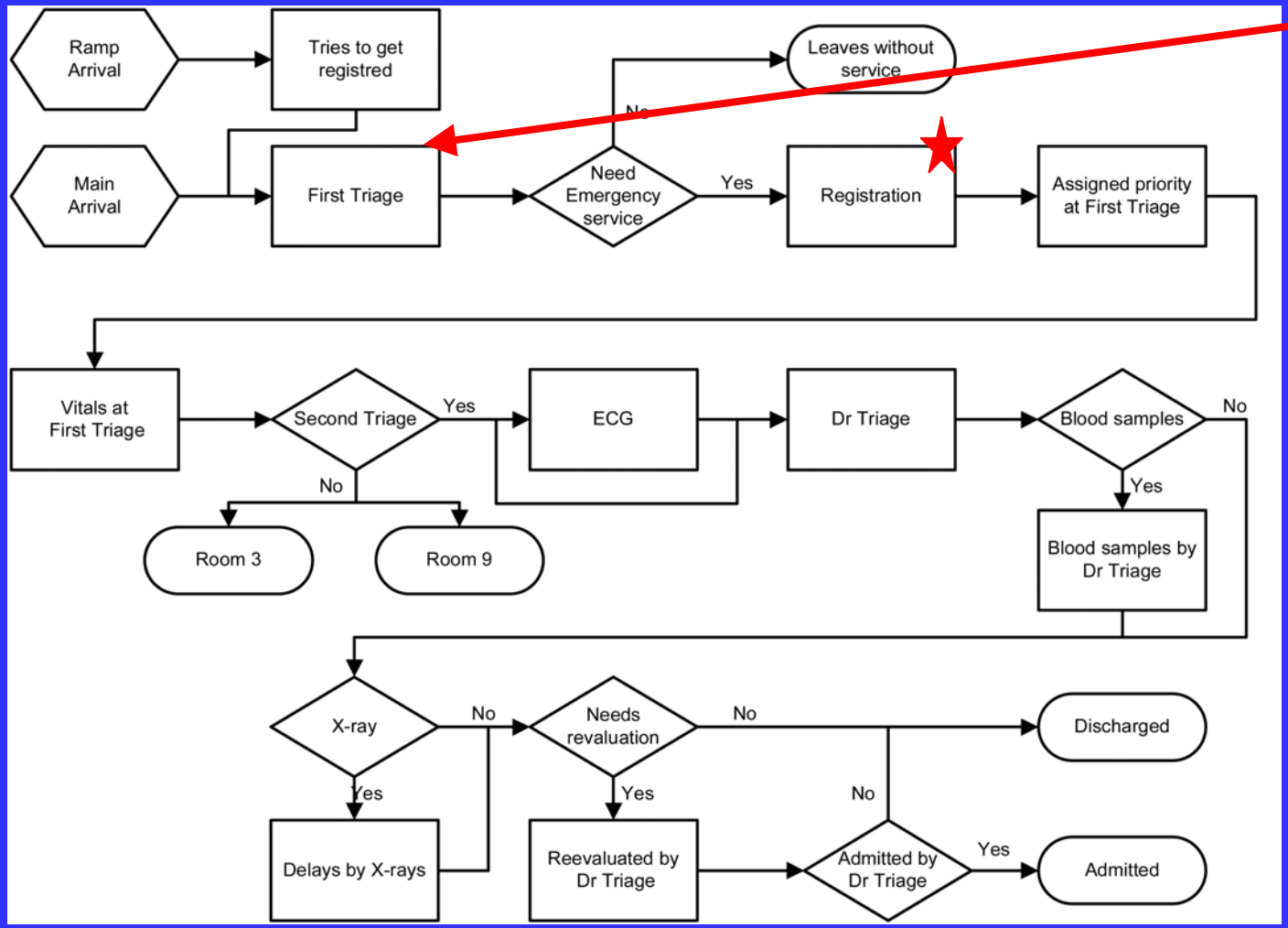
Time Definitions (Point in Time)



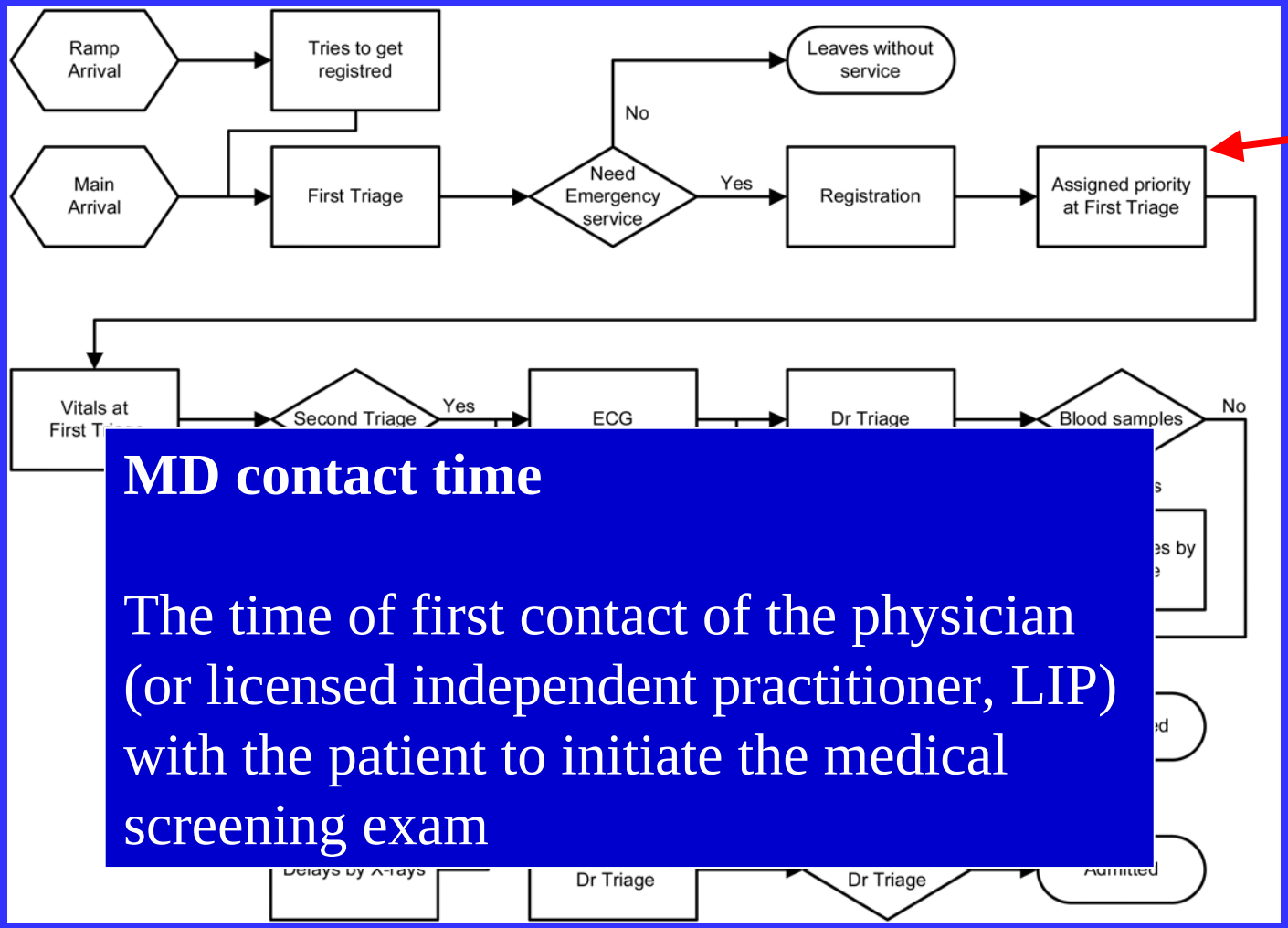
Arrival Time

The time that the patient is first recognized and recorded by the ED system as requesting services in the department

Time Definitions (Point in Time)



Time Definitions (Point in Time)



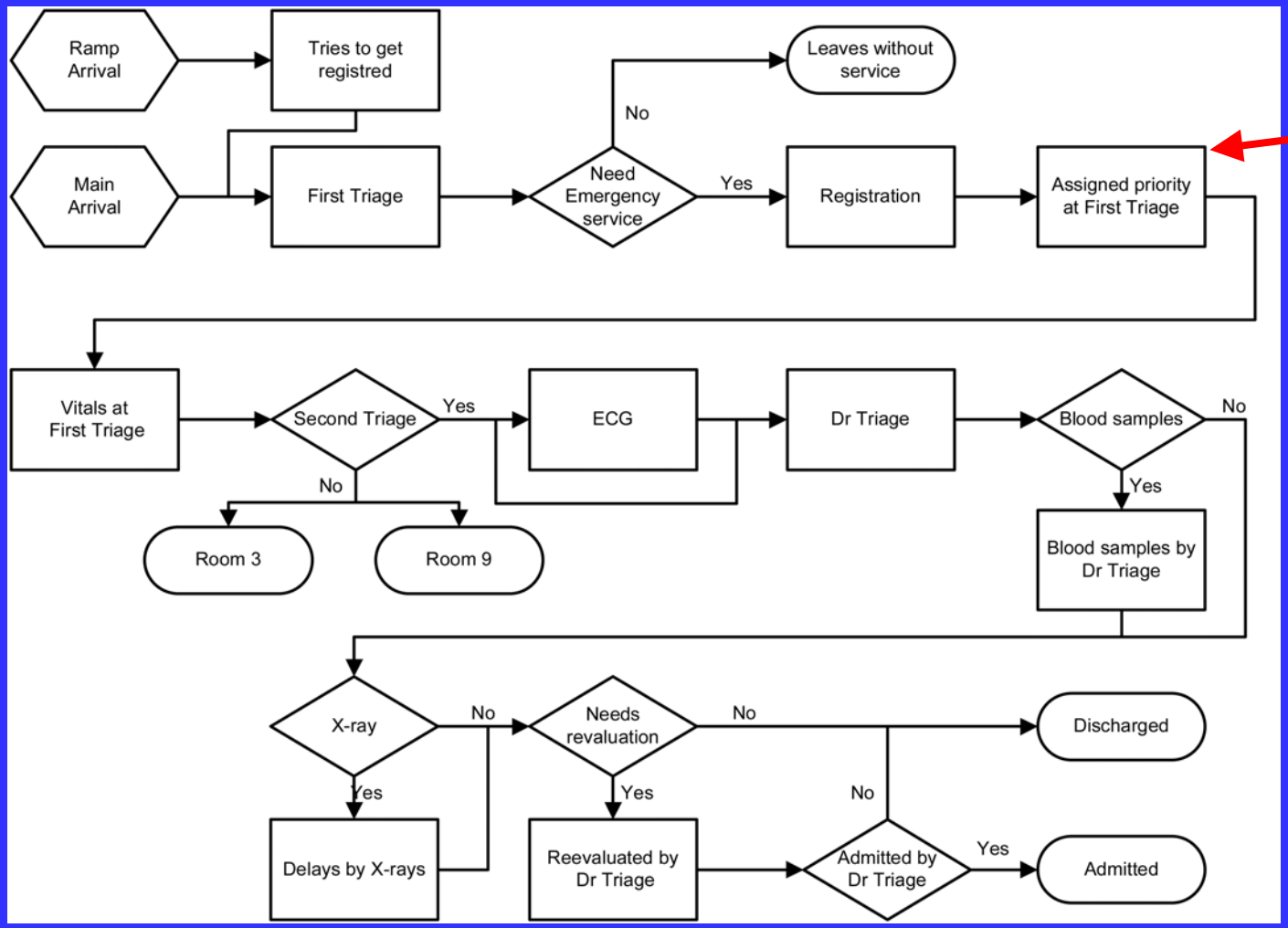
Arrival Yes

MD contact Yes

MD contact time

The time of first contact of the physician (or licensed independent practitioner, LIP) with the patient to initiate the medical screening exam

Time Definitions (Point in Time)

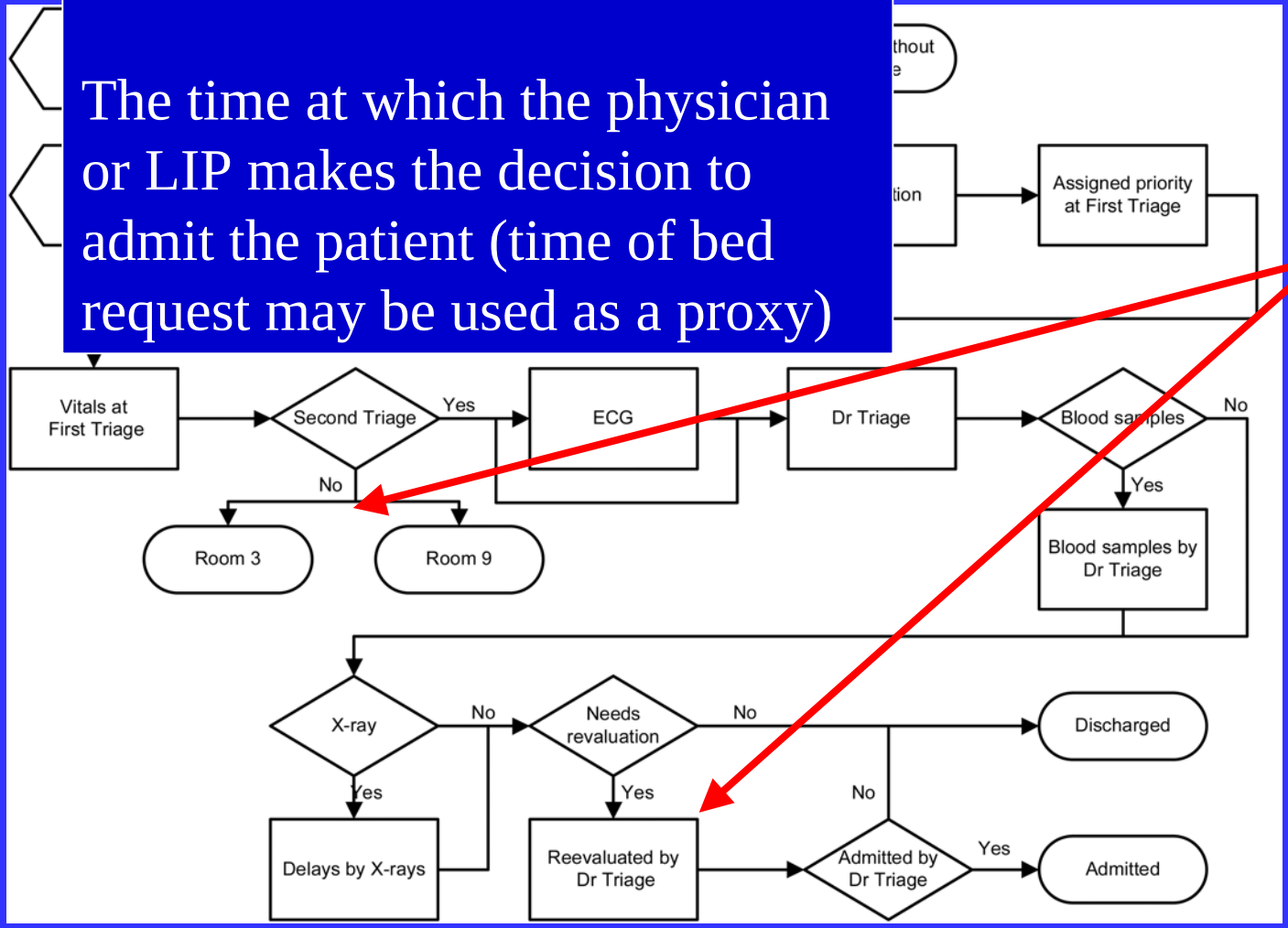


Arrival Yes

MD contact Yes

Decision to admit time

The time at which the physician or LIP makes the decision to admit the patient (time of bed request may be used as a proxy)

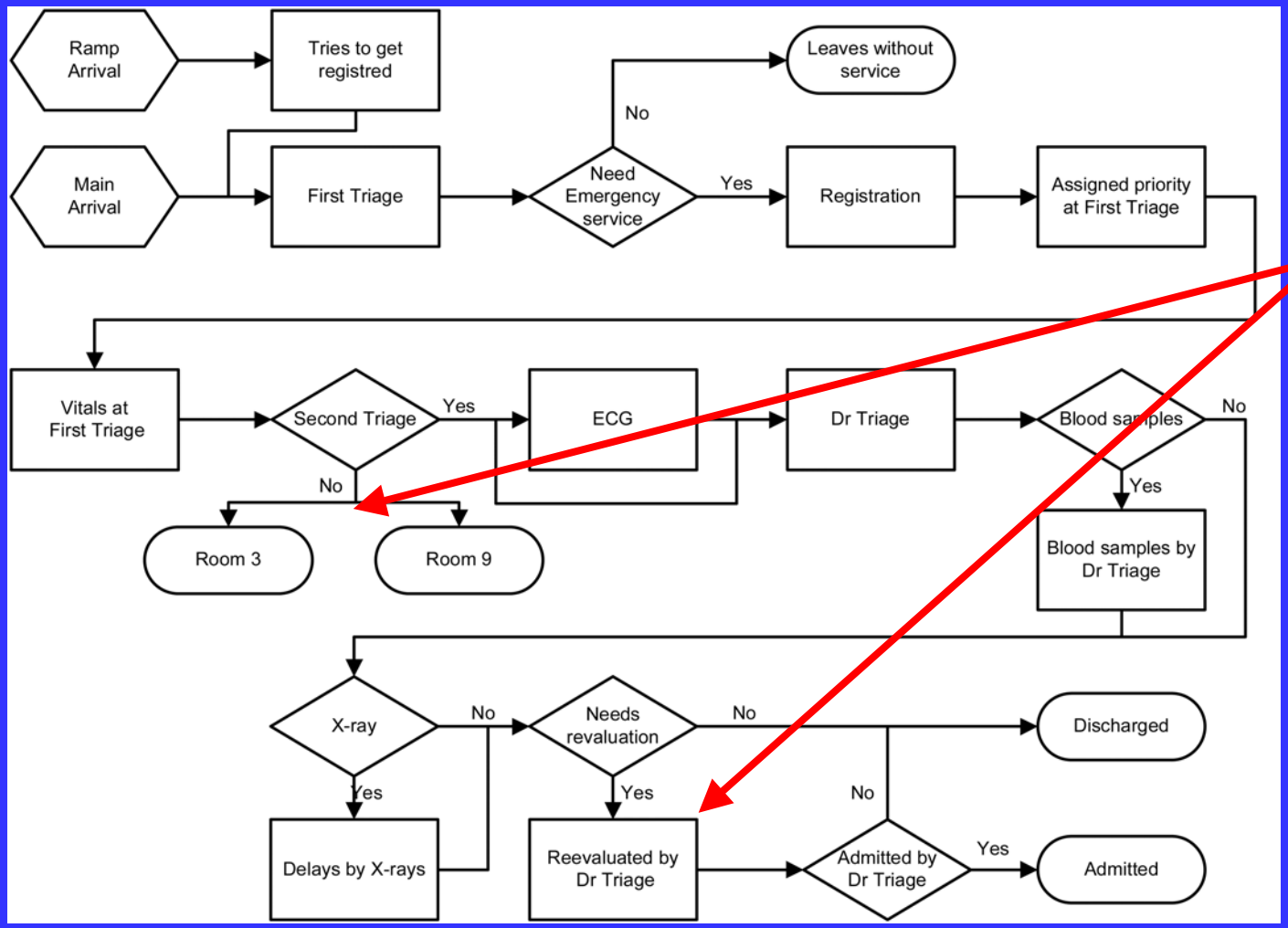


Arrival Yes

MD contact Yes

Decision to admit

Time Definitions (Point in Time)



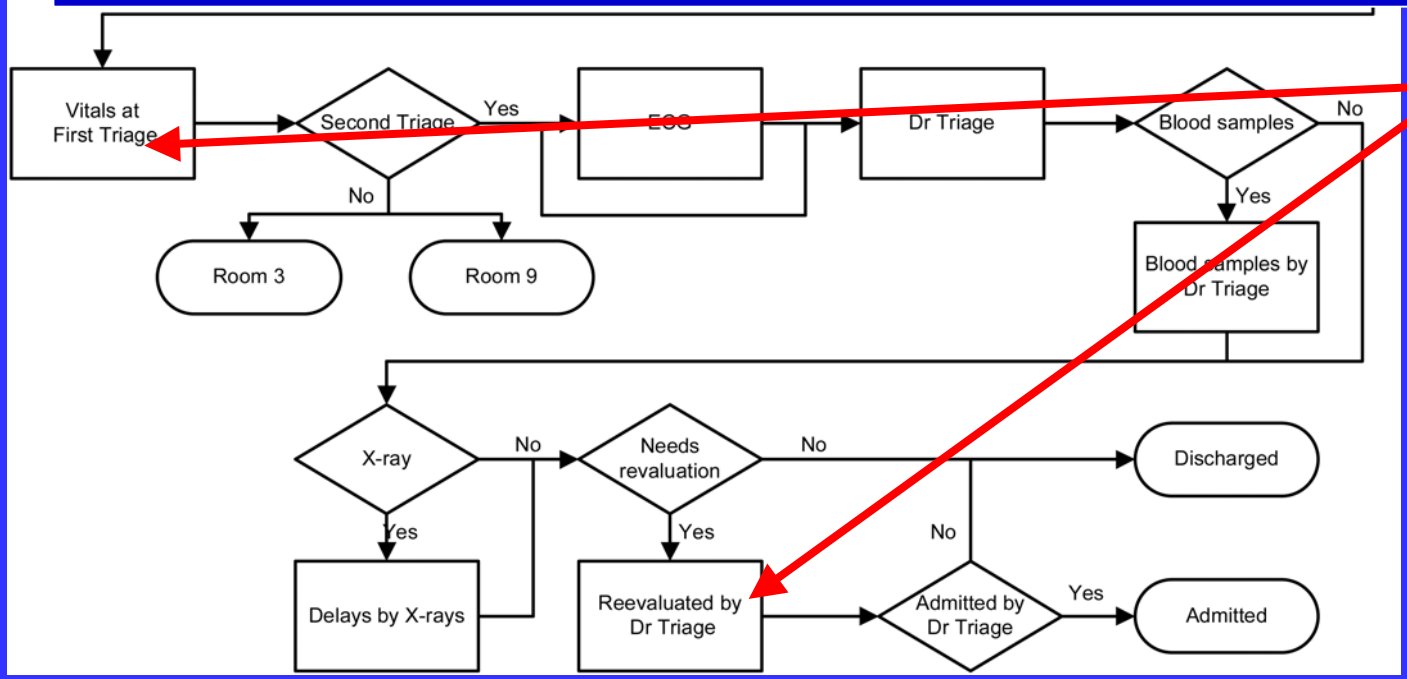
Arrival Yes

MD contact Yes

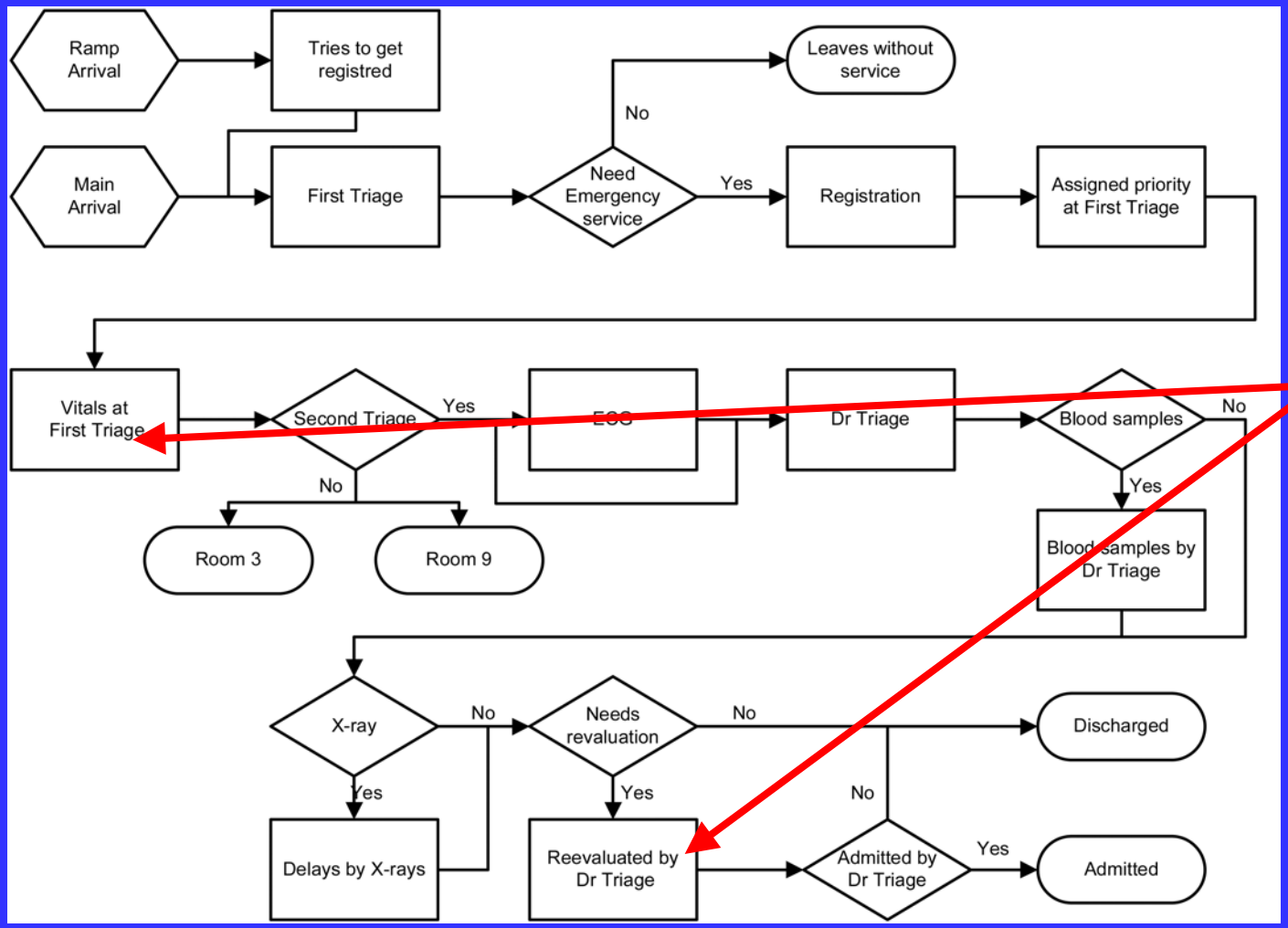
Decision to admit Yes

Conversion time

The time at which the disposition is made for a patient to be admitted to the hospital as an inpatient or observation patient, or at which a patient is designated for observation within a clinical decision area of the ED

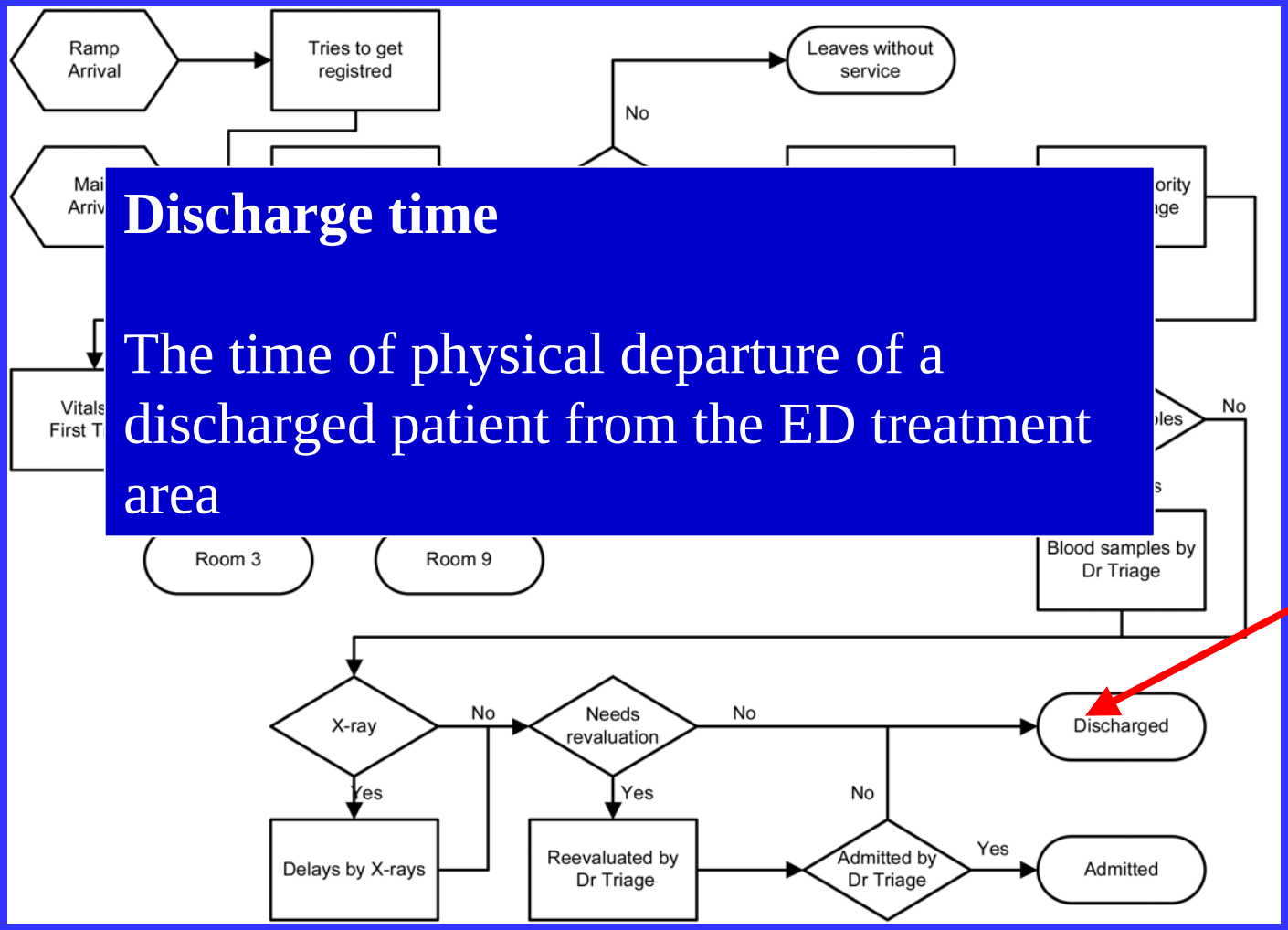


Time Definitions (Point in Time)



Arrival	Yes
MD contact	Yes
Decision to admit	Yes
Conversion	Yes

Time Definitions (Point in Time)



Discharge time

The time of physical departure of a discharged patient from the ED treatment area

Arrival	Yes
MD contact	Yes
Decision to admit	Yes
Conversion	Yes
Discharge	

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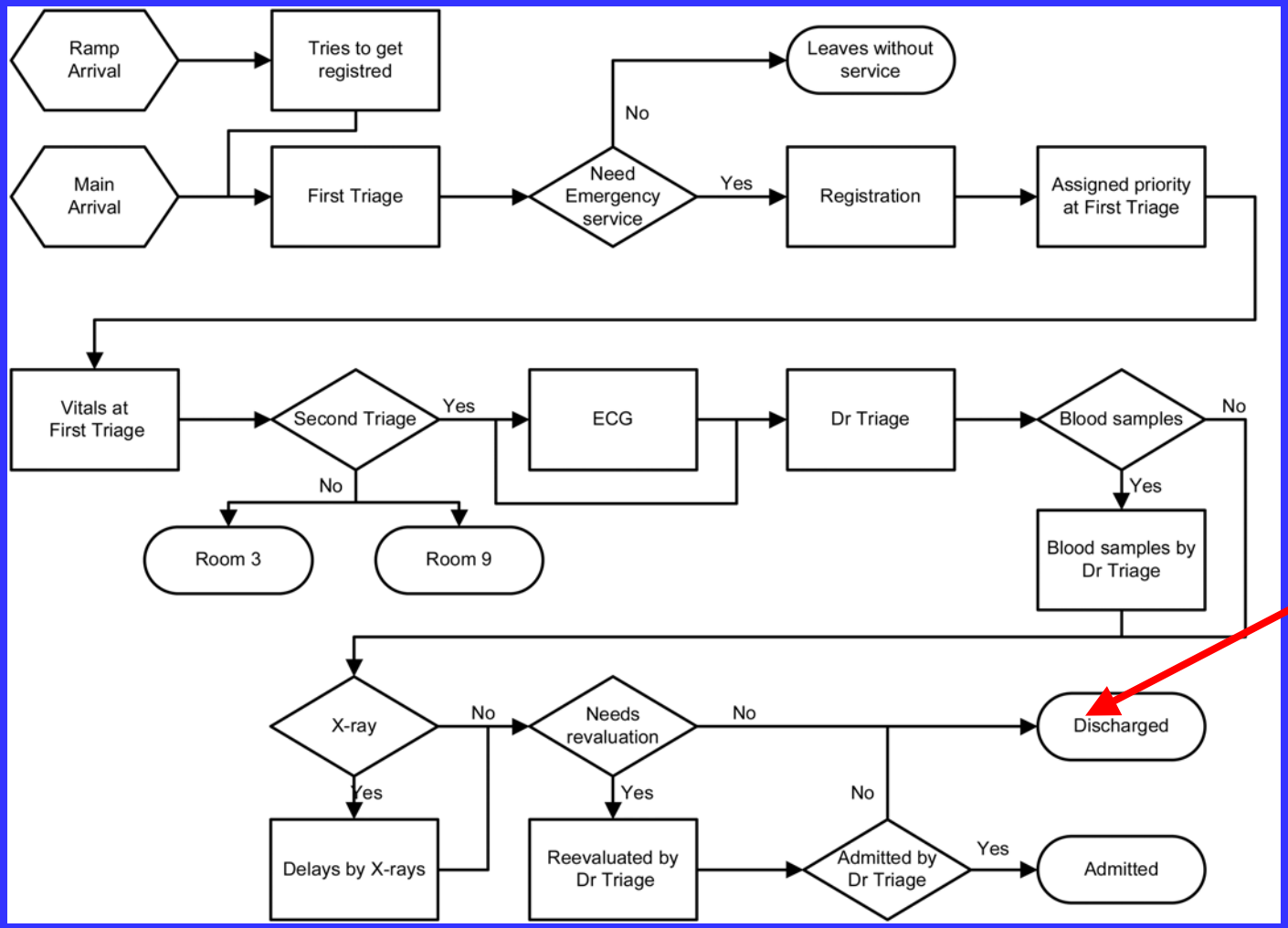
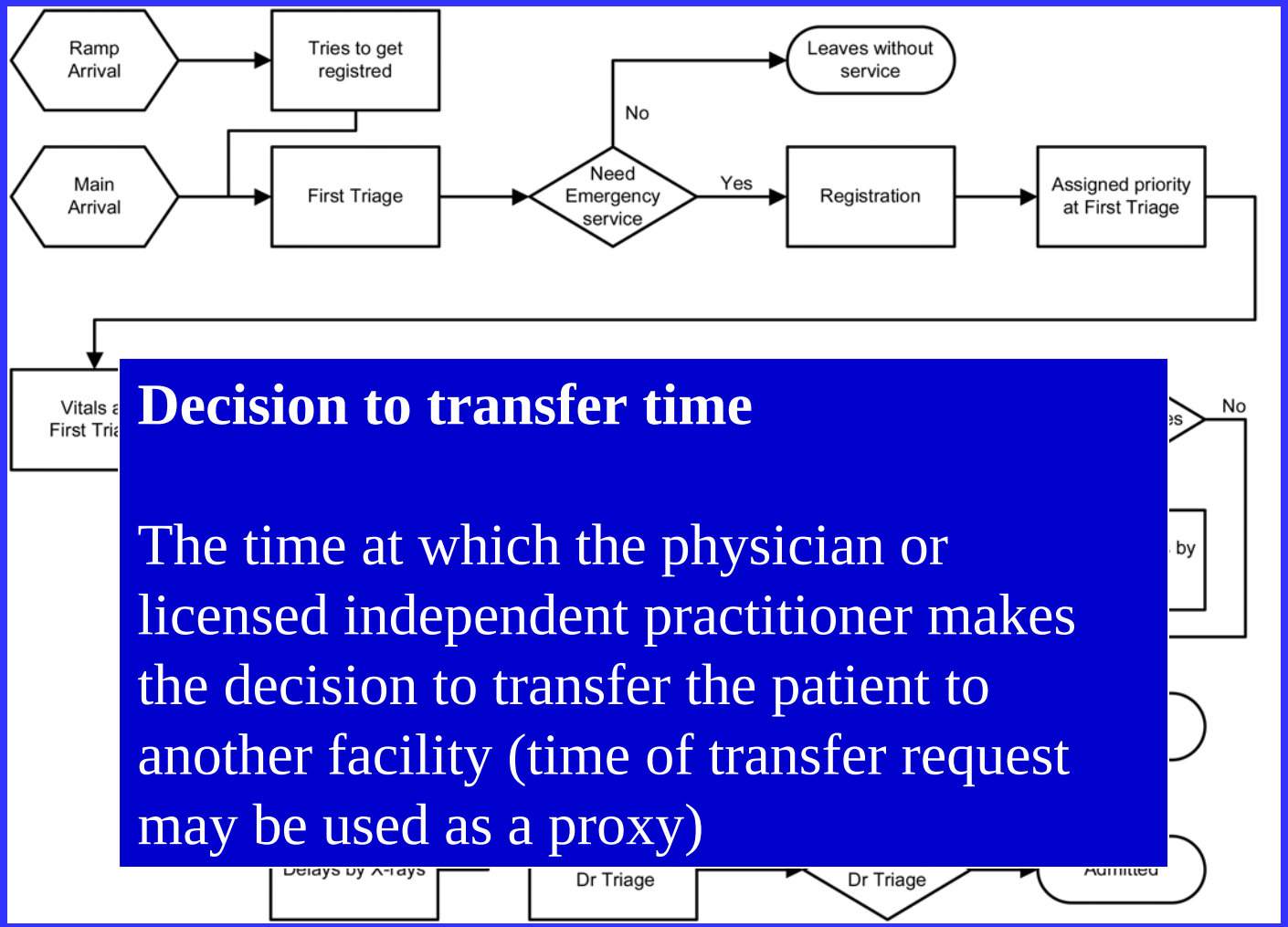
Time Definitions (Point in Time)



Arrival	Yes
MD contact	Yes
Decision to admit	Yes
Conversion	Yes
Discharge	Yes

Time Definitions (Point in Time)

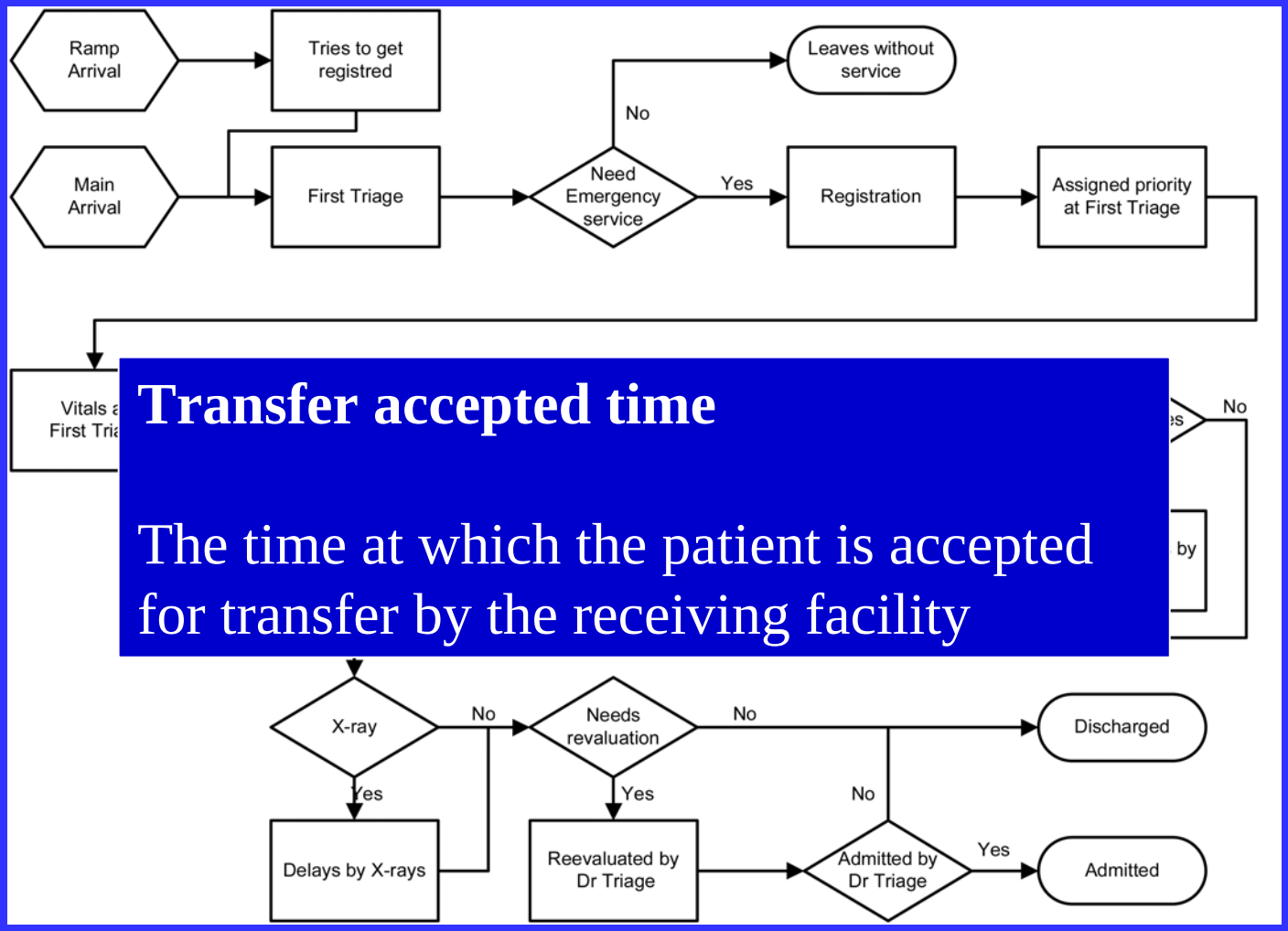


Decision to transfer time

The time at which the physician or licensed independent practitioner makes the decision to transfer the patient to another facility (time of transfer request may be used as a proxy)

Arrival	Yes
MD contact	Yes
Decision to admit	Yes
Conversion	Yes
Discharge	Yes
Decision to transfer	

Time Definitions (Point in Time)

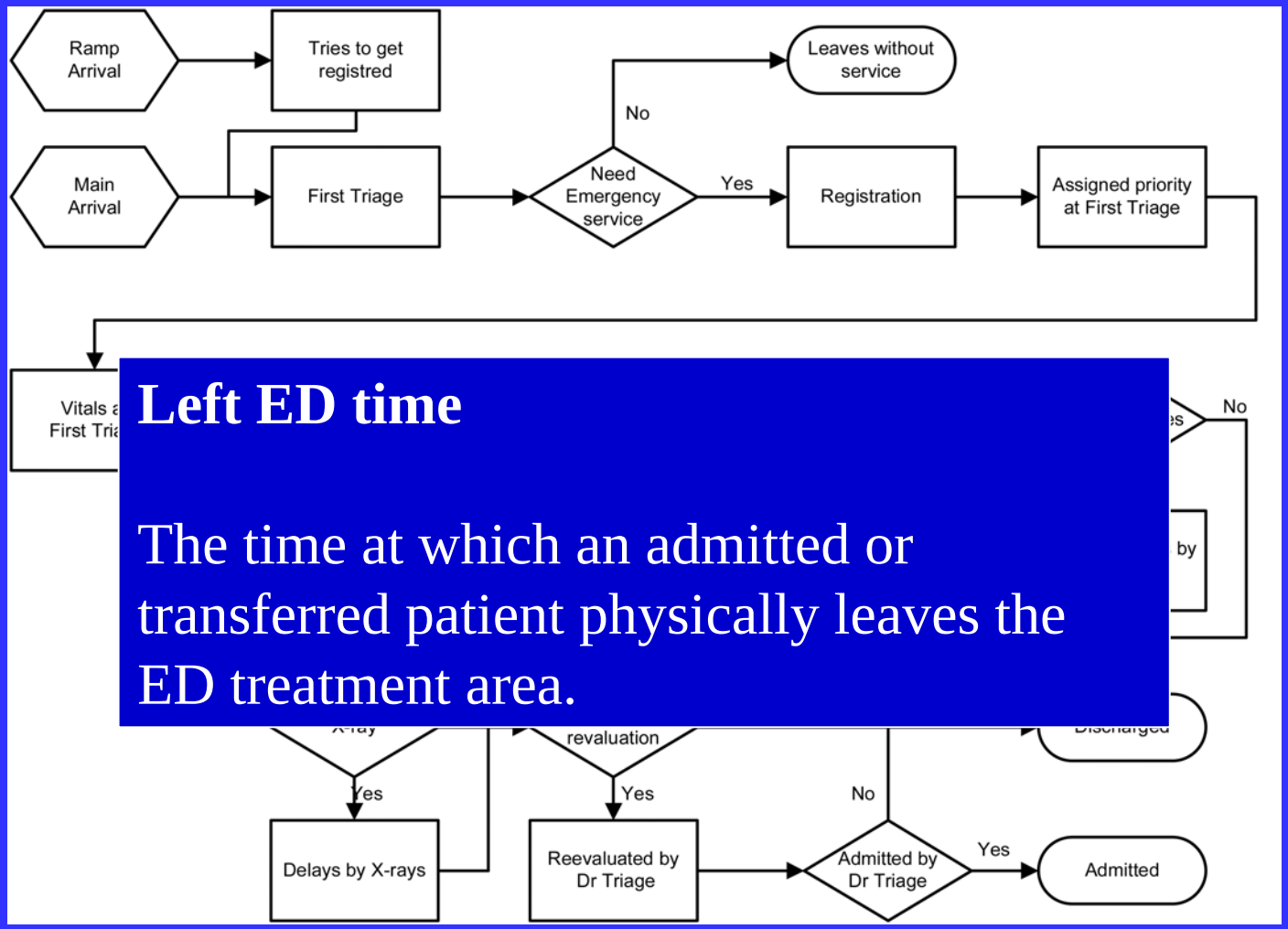


Transfer accepted time

The time at which the patient is accepted for transfer by the receiving facility

Arrival	Yes
MD contact	Yes
Decision to admit	Yes
Conversion	Yes
Discharge	Yes
~~Decision to transfer~~	
~~Transfer accepted~~	

Time Definitions (Point in Time)

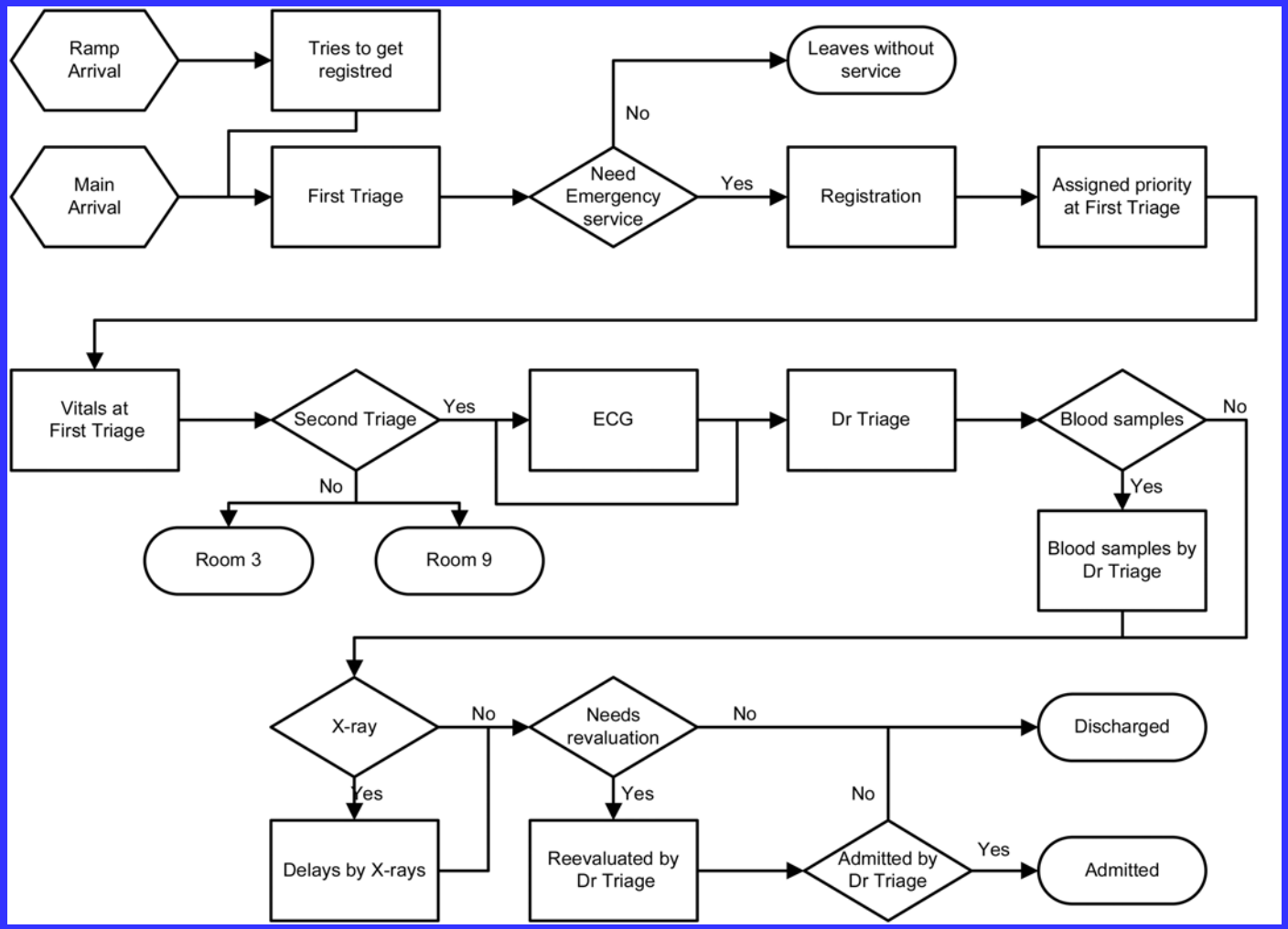


Left ED time

The time at which an admitted or transferred patient physically leaves the ED treatment area.

Arrival	Yes
MD contact	Yes
Decision to admit	Yes
Conversion	Yes
Discharge	Yes
~~Decision to transfer~~	
~~Transfer accepted~~	
Left ED time	

Time Definitions (Point in Time)



Arrival Yes

MD contact Yes

Decision to admit Yes

Conversion Yes

Discharge Yes

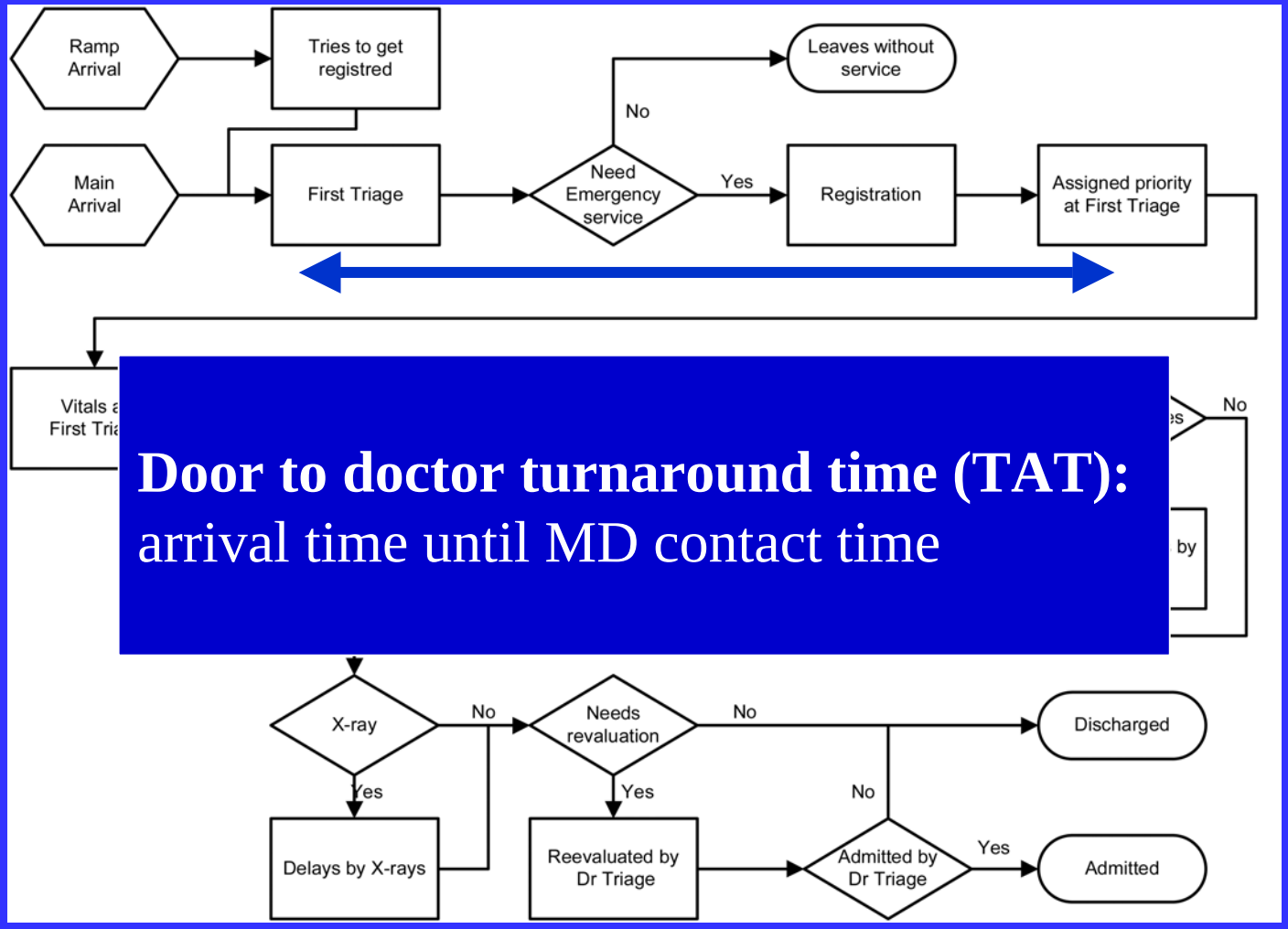
~~Decision to transfer~~

~~Transfer accepted~~

Left ED time No

Time Intervals: Turnaround Times

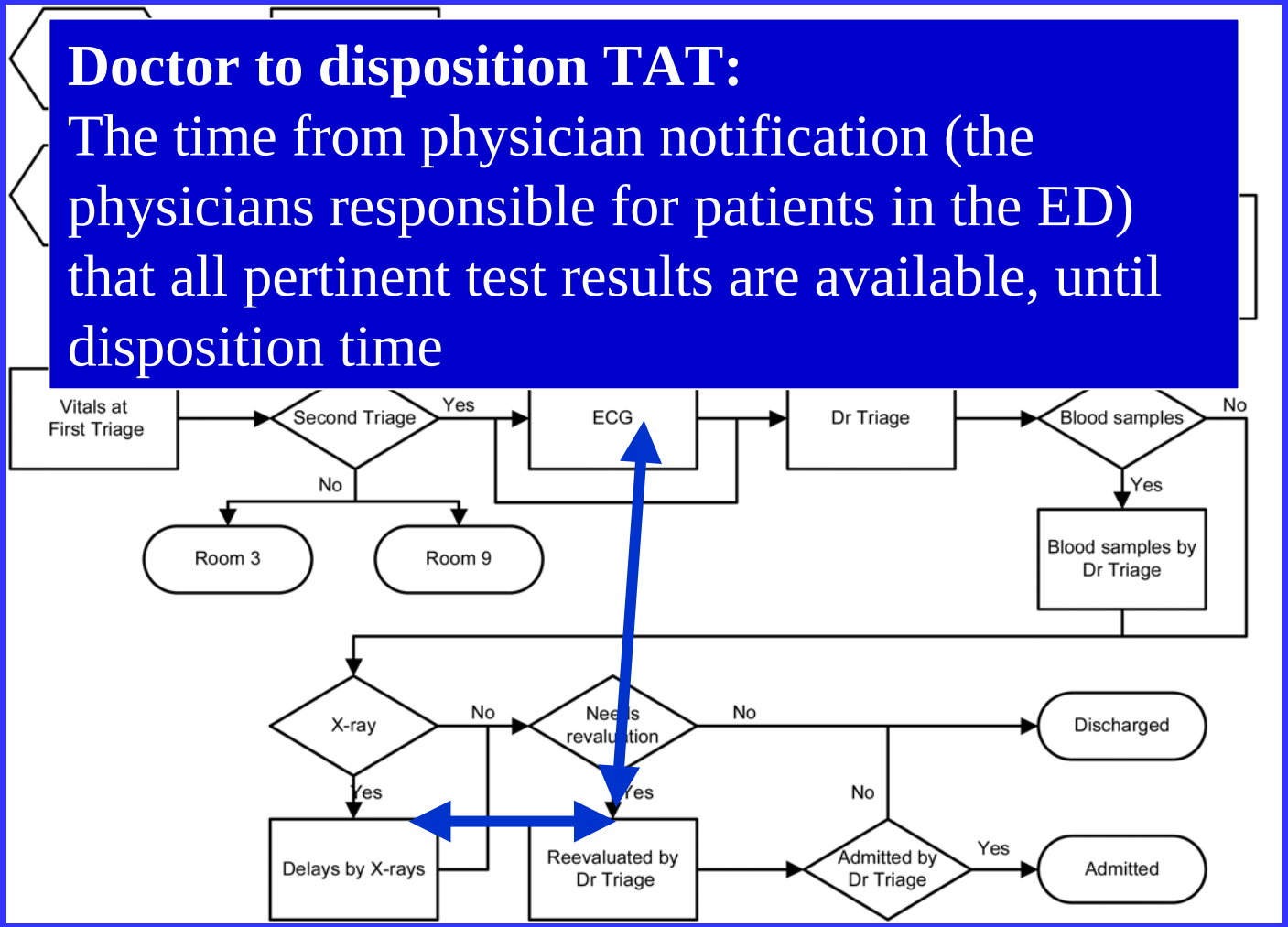
Door to Doctor Yes



Door to doctor turnaround time (TAT):
arrival time until MD contact time

Time Intervals: Turnaround Times

Doctor to disposition TAT:
The time from physician notification (the physicians responsible for patients in the ED) that all pertinent test results are available, until disposition time



Door to Doctor Yes

Dr to disposition P

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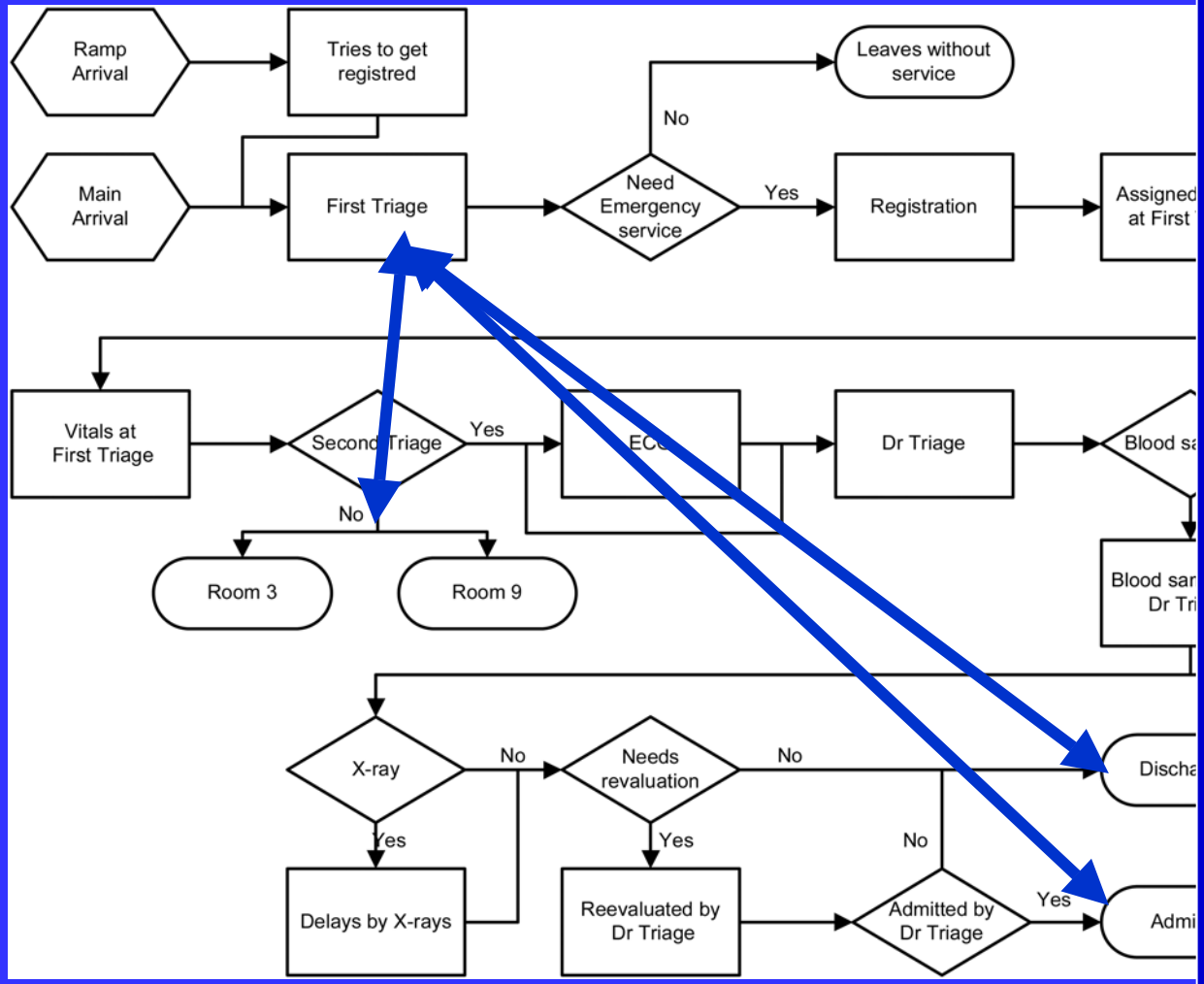
Time Intervals: Turnaround Times



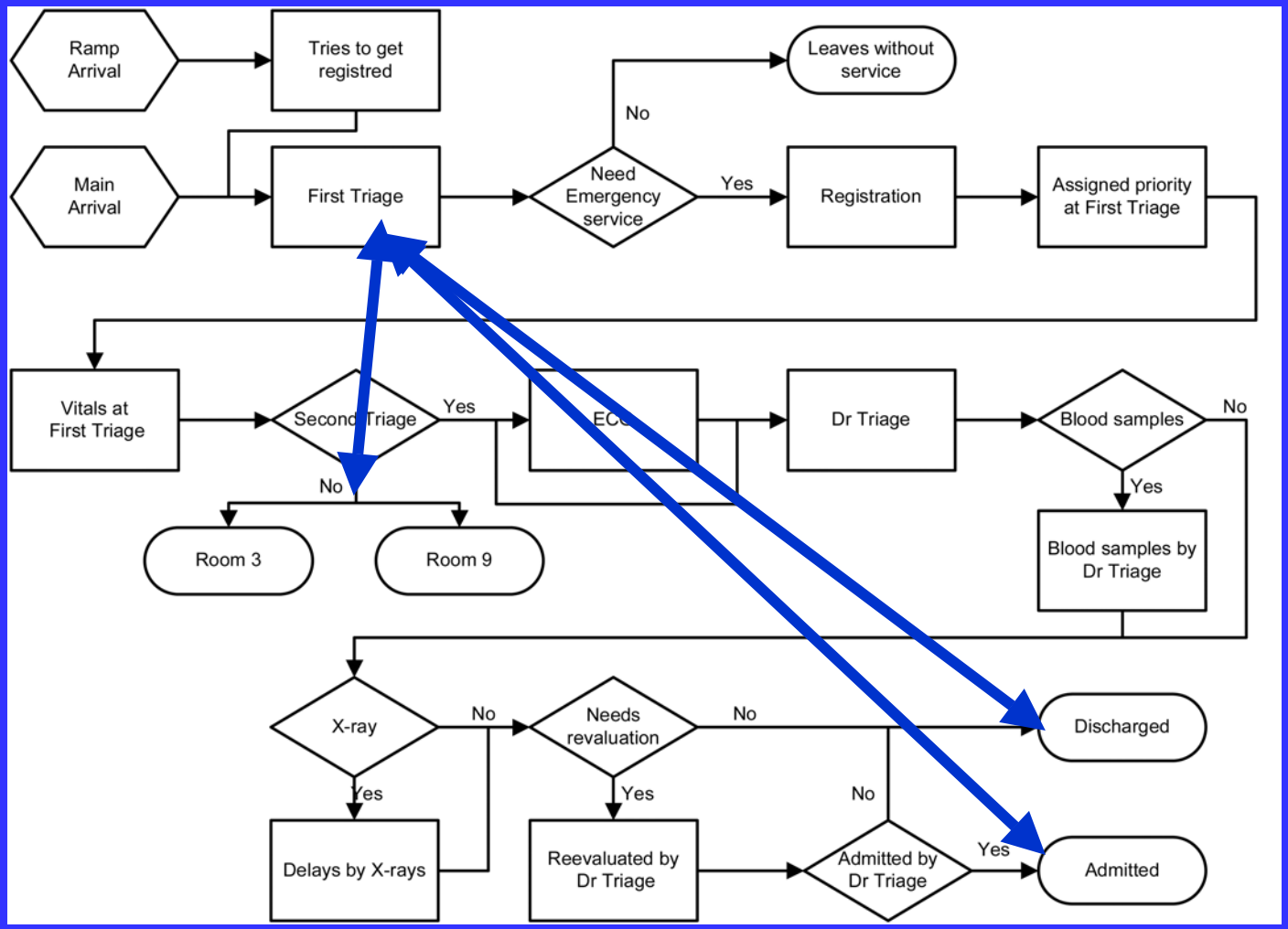
ED length of stay (LOS) or TAT the patient time in the ED with the following markers:

-Admitted patients: arrival time to conversion time

-Discharged patients: arrival time to discharge time; and

-Transferred patients: arrival time to transfer conversion time

Time Intervals: Turnaround Times



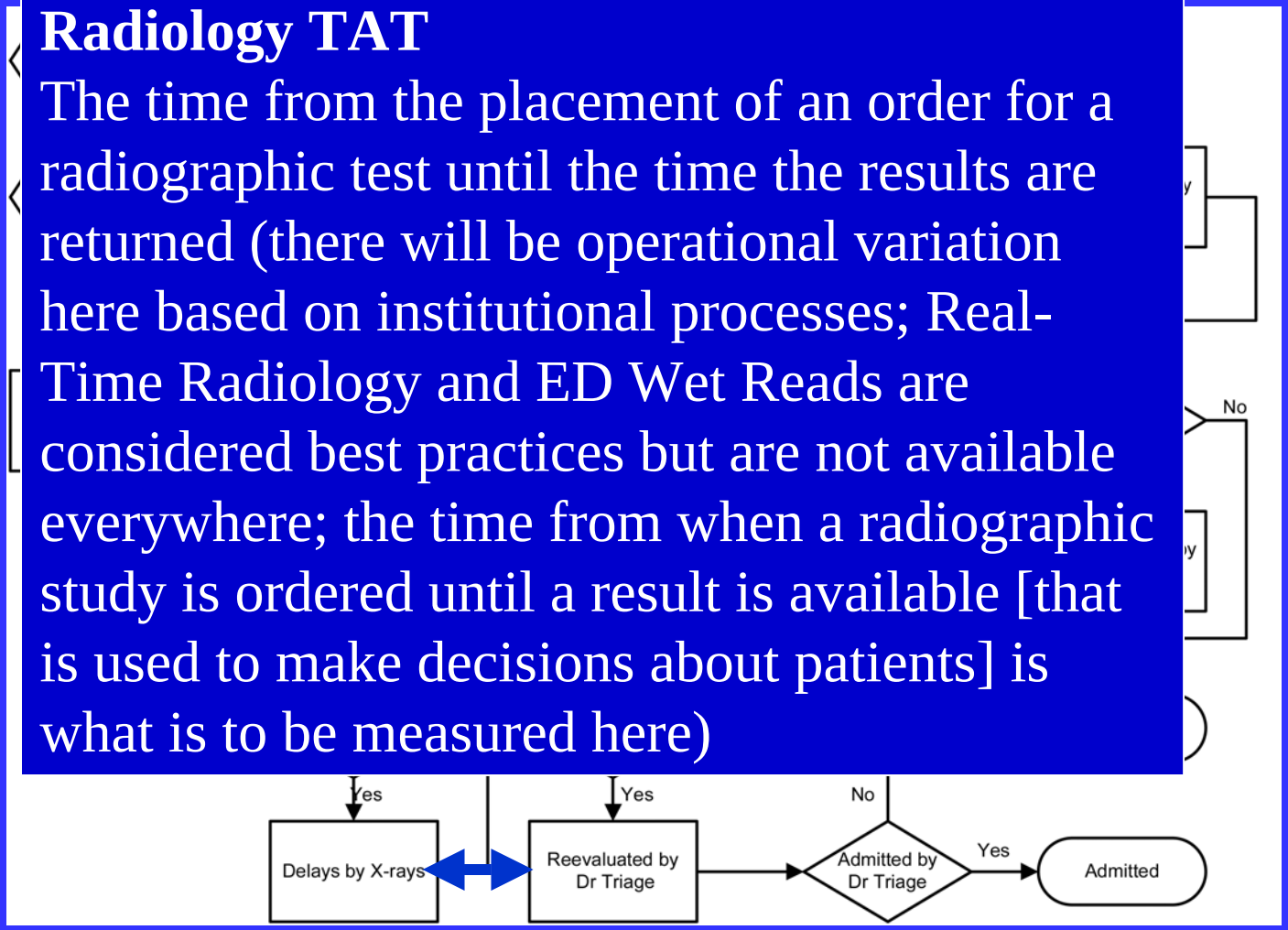
Door to Doctor Yes

Dr to disposition P

ED lenght of stay Yes

Time Intervals: Turnaround Times

Radiology TAT
The time from the placement of an order for a radiographic test until the time the results are returned (there will be operational variation here based on institutional processes; Real-Time Radiology and ED Wet Reads are considered best practices but are not available everywhere; the time from when a radiographic study is ordered until a result is available [that is used to make decisions about patients] is what is to be measured here)



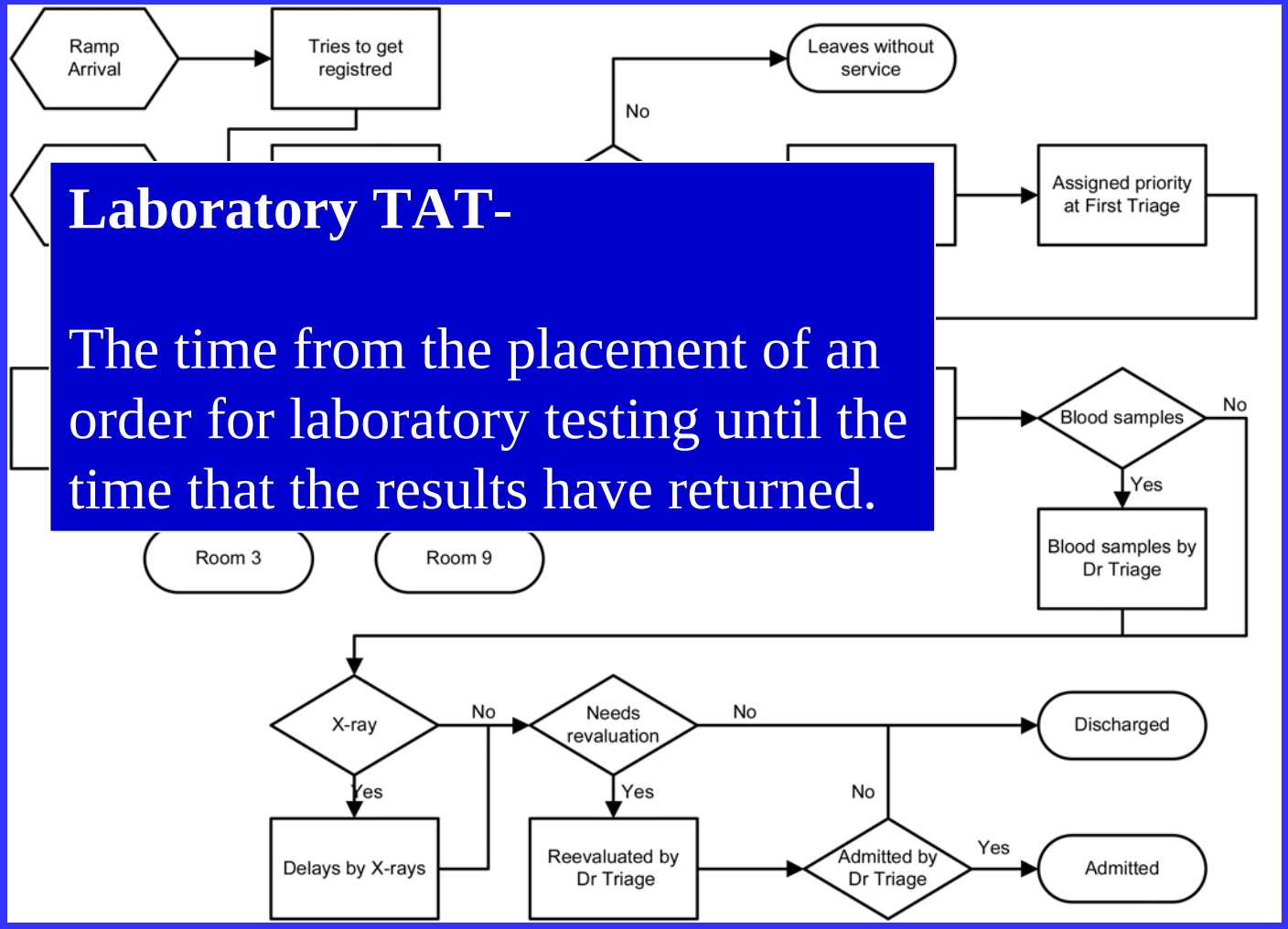
Door to Doctor Yes

Dr to disposition P

ED lenght of stay Yes

Radiology TAT Yes

Time Intervals: Turnaround Times



Laboratory TAT-

The time from the placement of an order for laboratory testing until the time that the results have returned.

Door to Doctor Yes

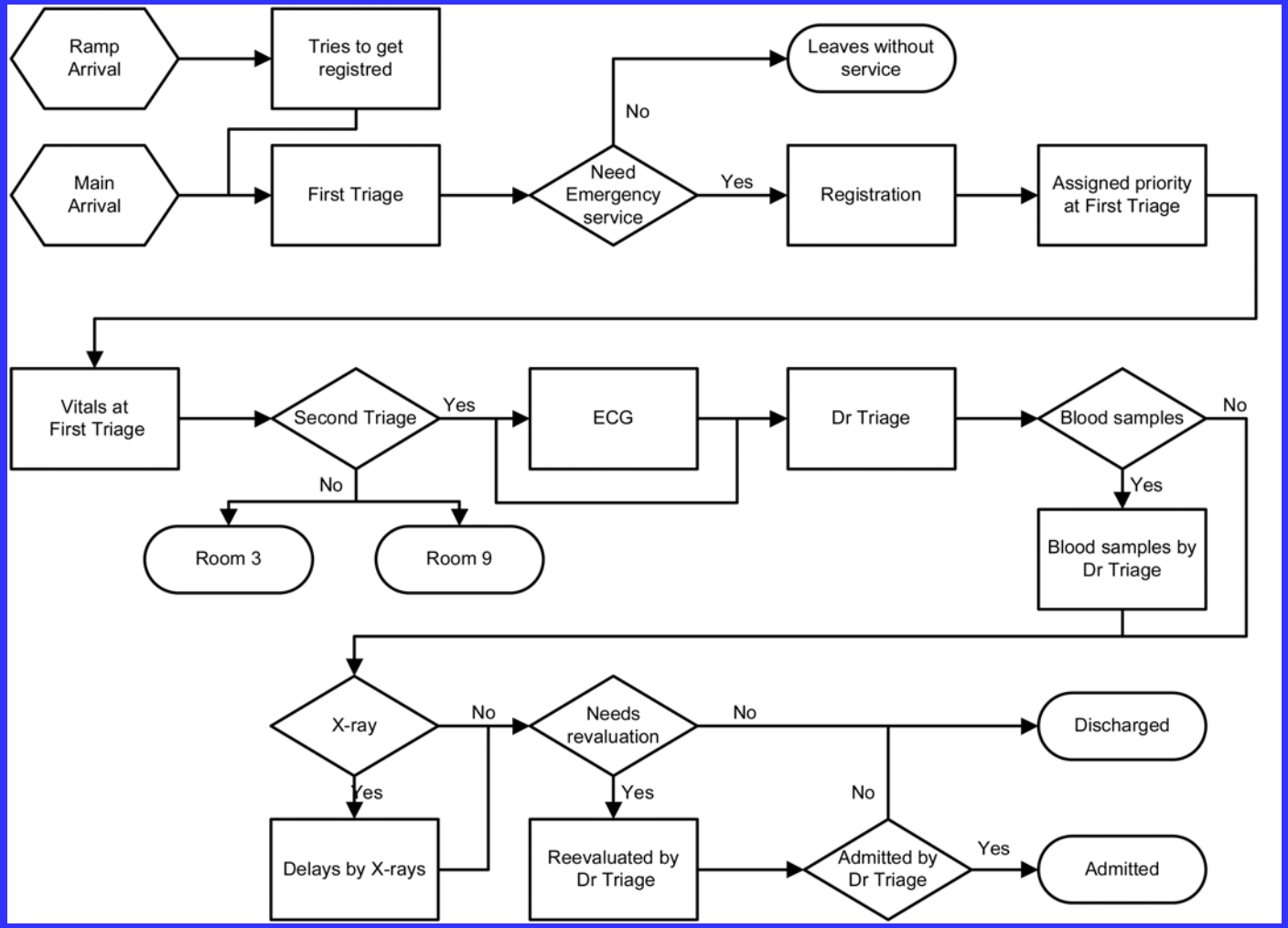
Dr to disposition P

ED lenght of stay Yes

Radiology TAT Yes

Laboratory TAT NO

Time Intervals: Turnaround Times



Door to Doctor Yes

Dr to disposition P

ED lenght of stay Yes

Radiology TAT Yes

Laboratory TAT NO

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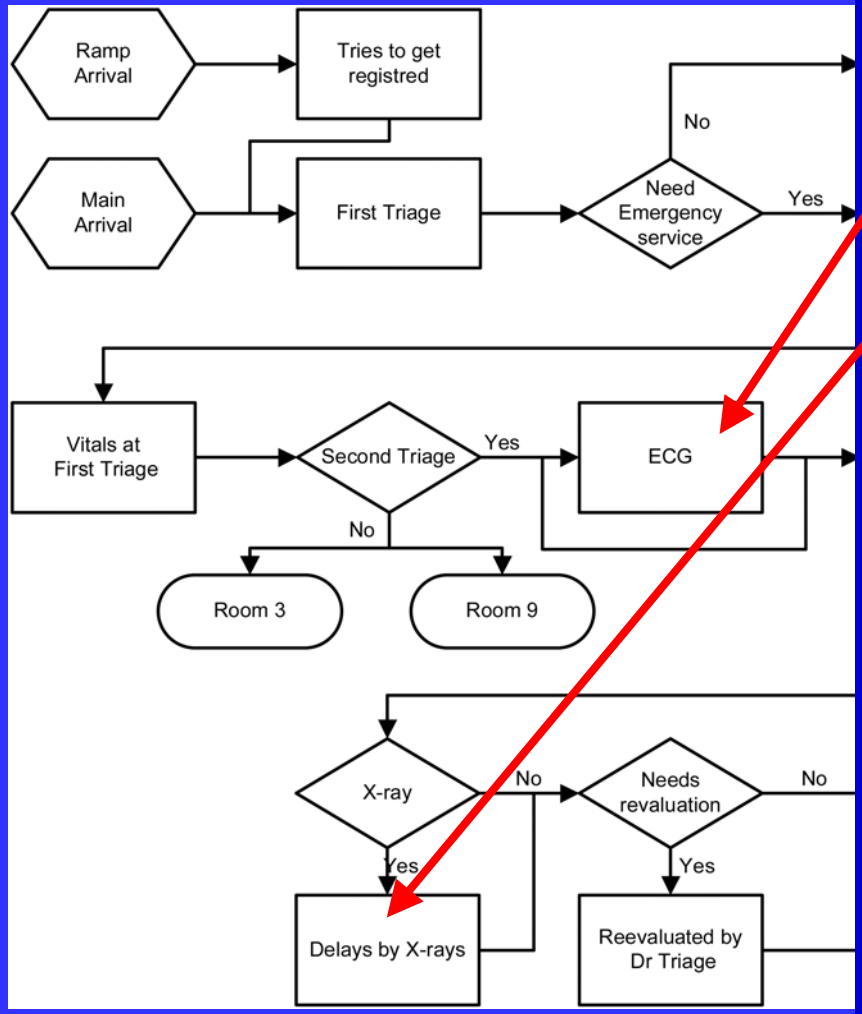
Defined Elements of Emergency Service Units



- Electrocardiograms performed per 100 patients seen;
- Simple imaging procedures performed per 100 patients seen;
- Computed tomography or magnetic resonance imaging scans performed per 100 patients seen;
- Trauma panel utilization per 100 patients seen;
- Cardiac biomarker tests performed per 100 patients seen;
- Medication doses administered per 100 patients seen (eventually stratified by type of medication);
- ED crowding, defined as the number of hours (reported as a per-day element) in which patient census exceeds designated patient-care areas.

Was it worthwhile to undertake the data collection needed to build a detailed model ?

The collected data gave us data to benchmark performance with published data on ED performance, and allowed the benchmarking of results from each simulations

We Agee with Coats and Michalis that the collection of additional data and development of more sophisticated models seem worthwile

Our conclusion is that discrete event simulation can be applied to any ED

Coats TJ, Michalis S. Mathematical modelling of patient flow through an accident and emergency department. Emerg Med J 2001; 18(3):190-192

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Is it worthwhile in a developing country

Models of integrated patient pathways is one way forward. It will have to incorporate evidence-based medicine at a high level.

Require well-defined patient flow. Simulation is a development tool

Young argues that because healthcare systems around the world are undergoing redesign and refocusing on patients, there is a strategic role for modeling and simulation to play. The creation of strategic scenarios that work according to process philosophies - as used, for instance, in manufacturing and aviation - could help to deliver high quality care to millions of people

Young T. An Agenda for Healthcare and Information Simulation. Health Care Management Science 2005; 8(3):189-196.

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Is it worthwhile in a developing country

As a secondary effect of the process

1. A picture of the real flow emerged not only the one described in the official diagrams
2. Critical aspect of the prevailing culture surfaced.

We conclude that a successful application of simulation methodology in a Third World environment was achievable and that further potentials exist