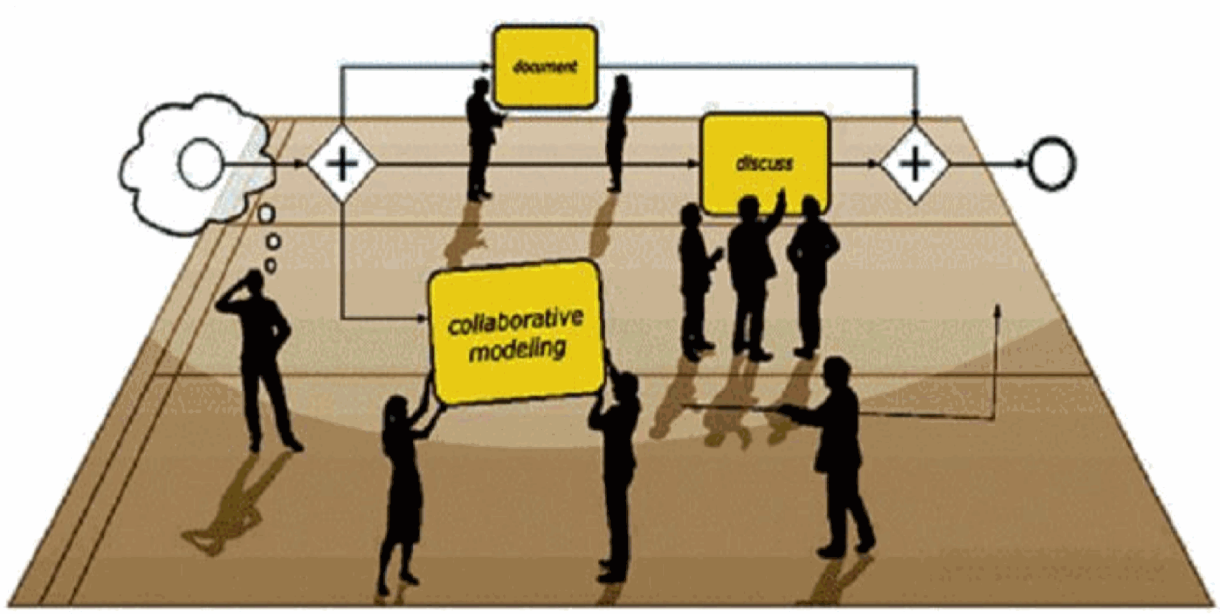
University of Pisa

MSc in Computer Engineering

Supply Chain Operation Management

"Large and complex organizations are a tangible manifestation of advanced technology, more than machinery itself." (J.K. Galbraith)

BPMN Modeling and Simulation



Lectures

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Pisa, March-May 2016, Monday 14.30-17.30, Room: ADInform2

Modeling from informal natural language: a Hospital Emergency Center

a. Consider the operation of a Hospital Emergency Center (HEC). The process begins when a patient arrives through the *acceptation* process in the Entrance Room of the HEC, and ends when a patient is either *released* from the HEC or an *arrangement* into the hospital has been established, for further treatment.

b. Patients arriving on their own, after *acceptation* go to an Administrative Room to *sign in*, and subsequently are assessed in the Triage Room in terms of their condition (*triage*).

c. Depending on their condition, patients are classified into different codes (levels): with Red Code (14.8% of all patients), patients are more critical than with Yellow and Green codes.

d. Red Code patients are taken to an Emergency Room. Once in the room, they undergo their *treatment*. Subsequently, they go to an Administrative Room to make the *registration* process and then to be formally *released* or *admitted* into the hospital.

Modeling from informal natural language: a Hospital Emergency Center

e. Yellow and Green Code patients go to an Administrative Room to make the *registration* process and then to an Emergency Room to undergo their *treatment*. Subsequently, they go to an Administrative Room to be formally *released* or *admitted* into the hospital.

f. After admission, the patient must then wait at the Entrance Room for a hospital bed to become available (*arrangement*), so as to be transferred to the hospital room.

g. Patients arriving by ambulance (5.6% of all patients) are directly classified with Red Code after *acceptation* and then immediately taken to an Emergency Room for *treatment*. Subsequently, they are then considered Red code patients.

h. Overall, 90% of all patients (regardless of the assigned code) are released from the HEC, while the remaining 10% are admitted into the hospital for further treatment.

i. In terms of resources, the *treatment* process consists of the following activities: a secondary assessment performed by a **nurse** and a **physician**; laboratory tests, performed by a **patient care technician**; the treatment itself, performed by two **nurses** and a **physician**.

Modeling from informal natural language: a Hospital Emergency Center

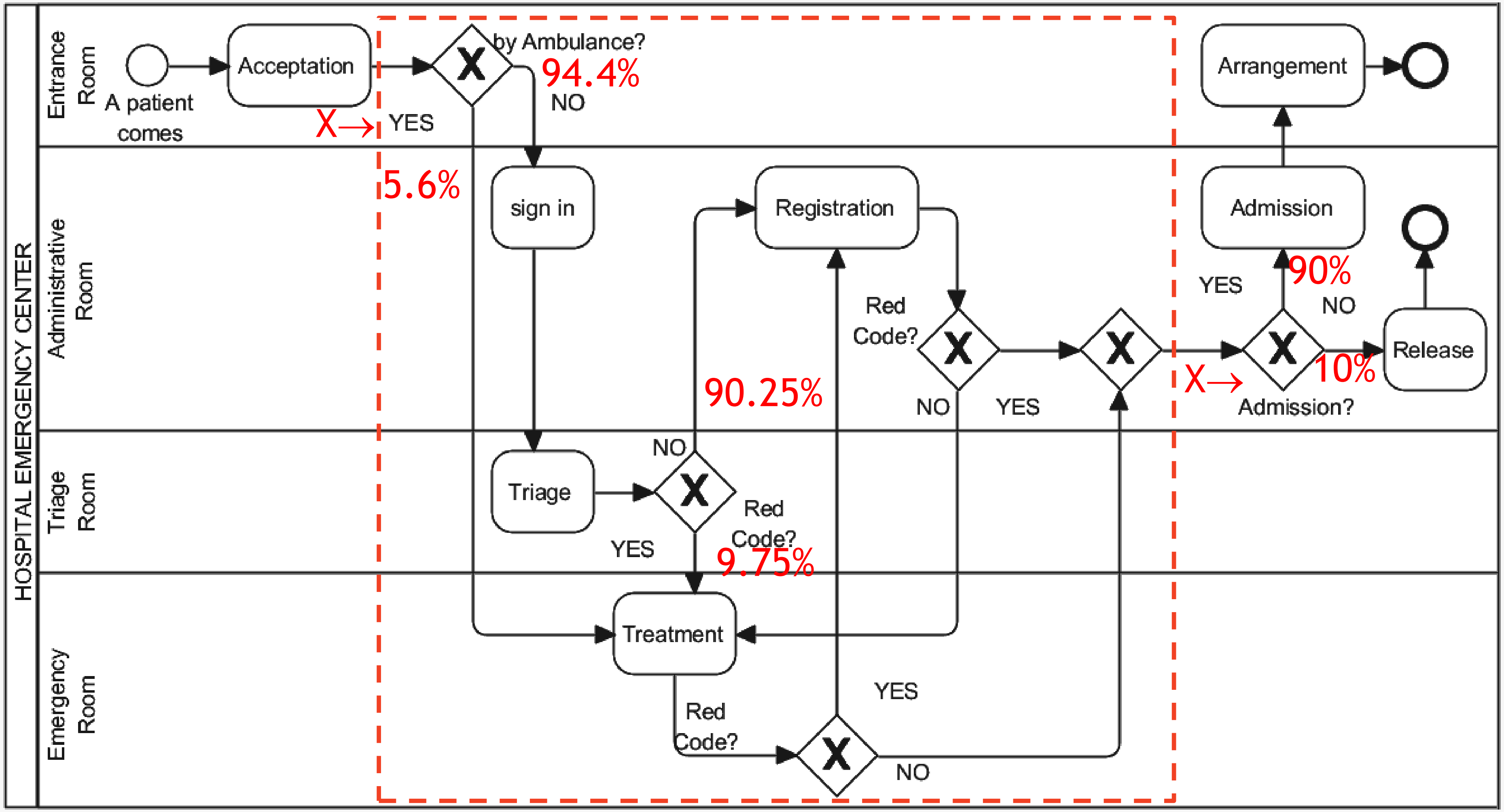
i. In terms of resources, the *registration* process consists of: a data collection activity performed by an **administrative clerk**; an additional data collection activity performed by an **administrative clerk**, in case the patient has Worker's Compensation Insurance; a printing of the patient's medical chart for future reference, performed by an **administrative clerk**.

j. The final *release / hospital admission* processes consist of: in case of *release*, an **administrative clerk** fills out the release papers; in case of *admission* into the hospital, an **administrative clerk** fills out the patient's admission papers.

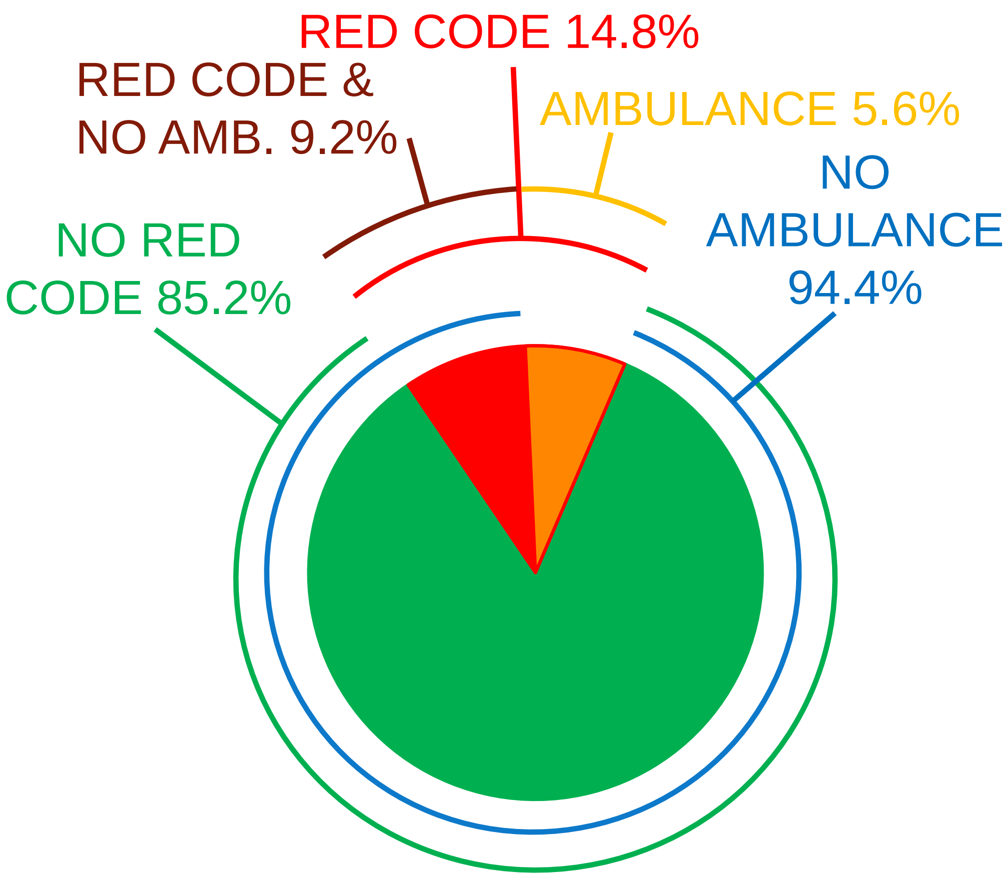
- Create a BPMN model, taking into account only items *a,b,c,d,e,f*, assigning a lane for each underlined term, a task for each italicized term. Do not consider resources (represented in boldface style).

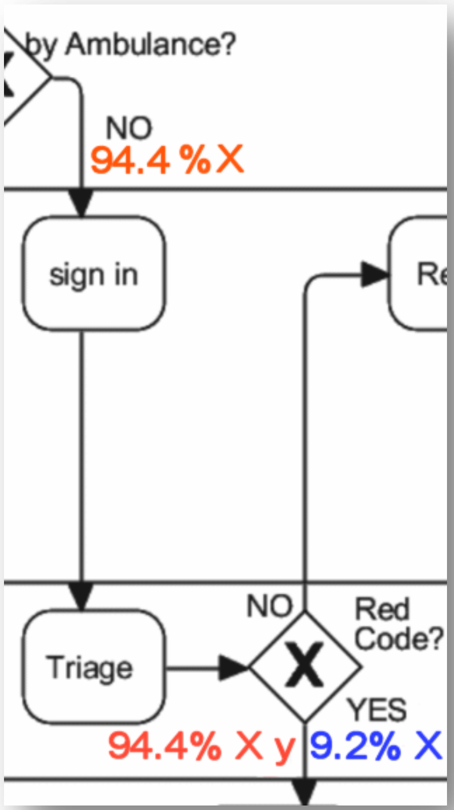
- Given 100 starting tokens, determine the number of ending tokens for each scenario (path), considering the aforementioned branching proportion (percentage of cases) for each gateway: Ambulance 5.6%, Red code 14.8%, Released 90%

- Multiple input flows at the tasks *treatment* and *registration* should be avoided by using a XOR-join (not inserted to avoid a high number of gateways).
- The number X of incoming patients is the same at the exit of the *acceptation* task and at the entry of the “Admission?” gateway, because there is a 1-entry-1-exit block.
- Relative percentages at each gateway are calculated as shown in the next slide.



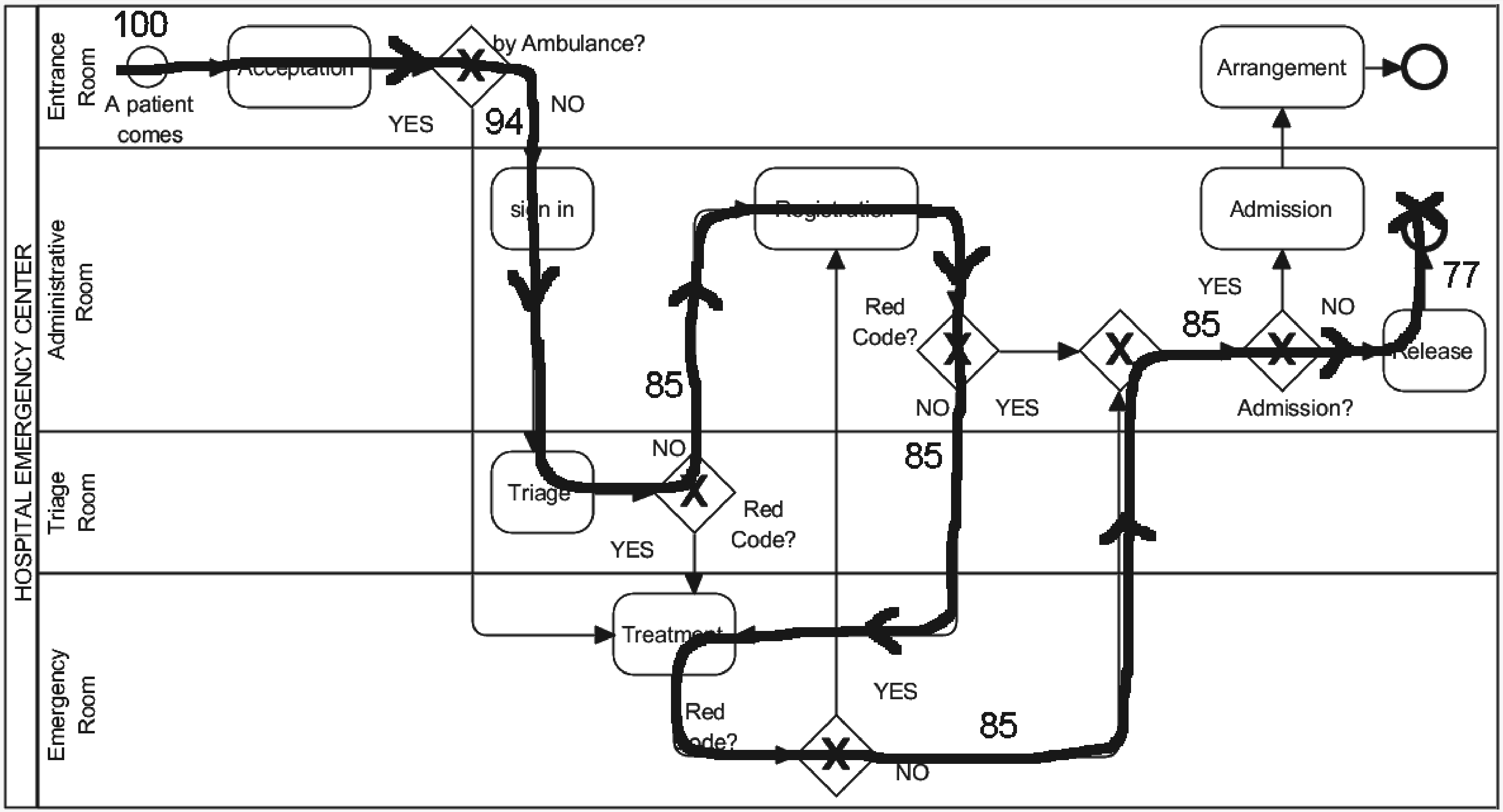
- Percentages at the first and last gateways can then be calculated with respect to all patients. **5.6%** of patients come by ambulance, and 100% - 5.6% = **94.4%** come by their own. **90%** released and **10%** admitted.
- Percentages at the second gateway should be calculated with respect to the incoming flow. The 14.8% of all patients (X) have a red code; 5.6% come by ambulance, and then 14.8-5.6 = 9.2% of X have red code but come by their own. The same number can be calculated as a percentage y of the incoming flow. The incoming flow is 94.4%·X. Thus 94.4·X·y = 9.2·X, and then y = 9.2 / 94.4 = **9.75%**





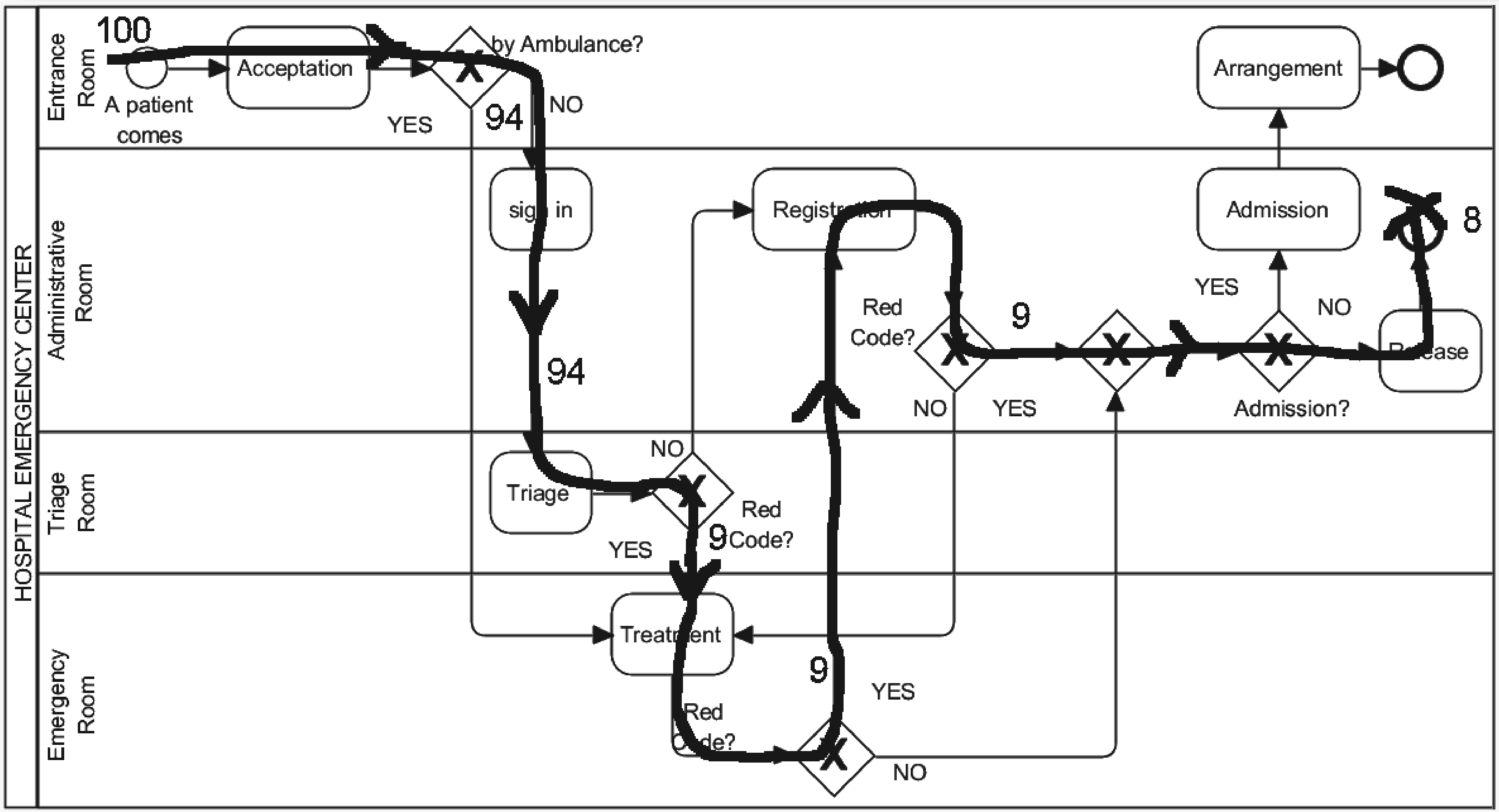
S1) NO AMBULANCE & NO RED CODE & NO ADMISSION:

100 x .944 & 94 x .9025 & 85 x .9 = 76.5 ≈ **77**.



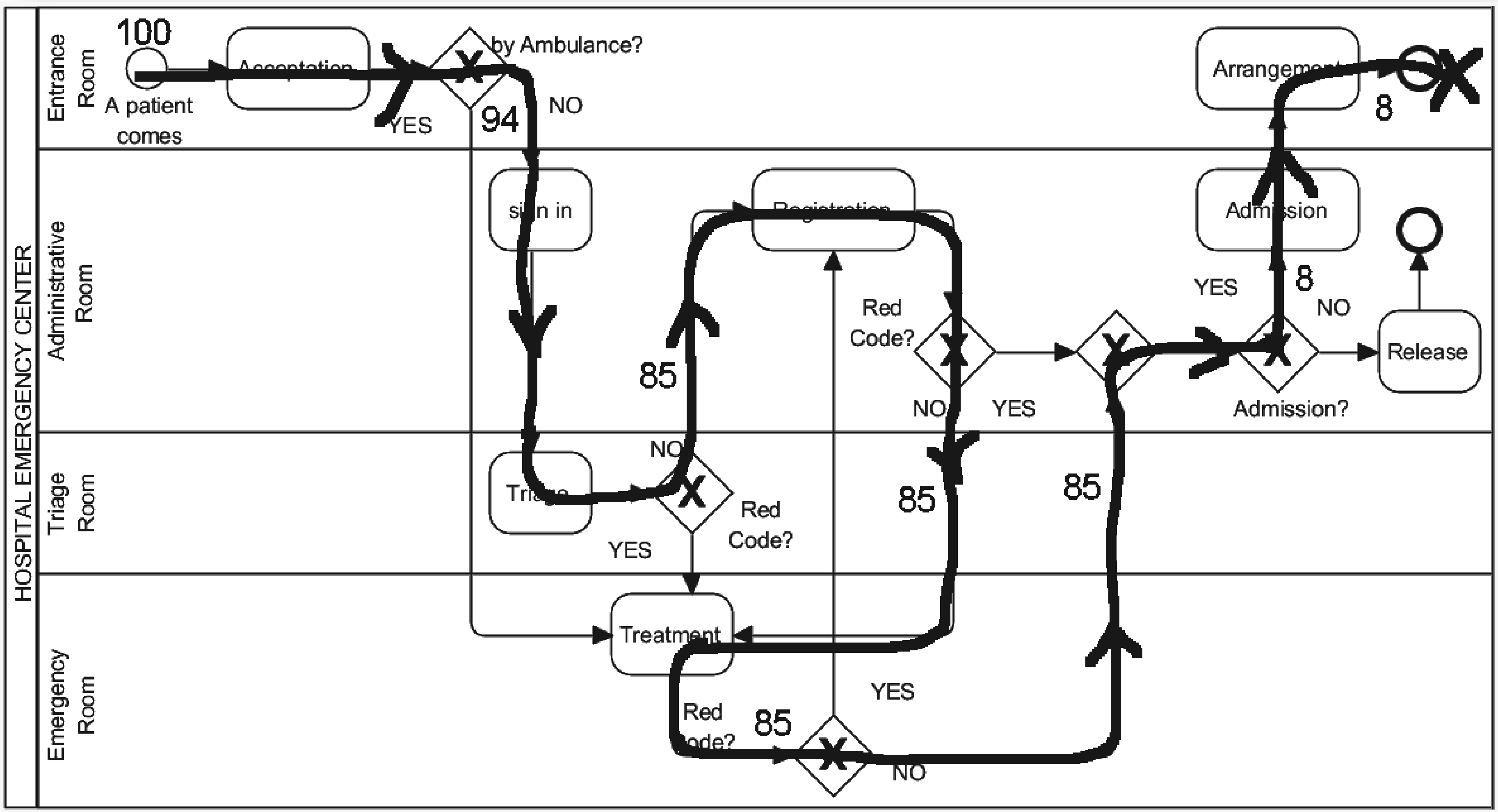
S2) NO AMBULANCE & RED CODE & NO ADMISSION:

100 x .944 & 94 x 0.0975 & 9 x .9 = **8**.



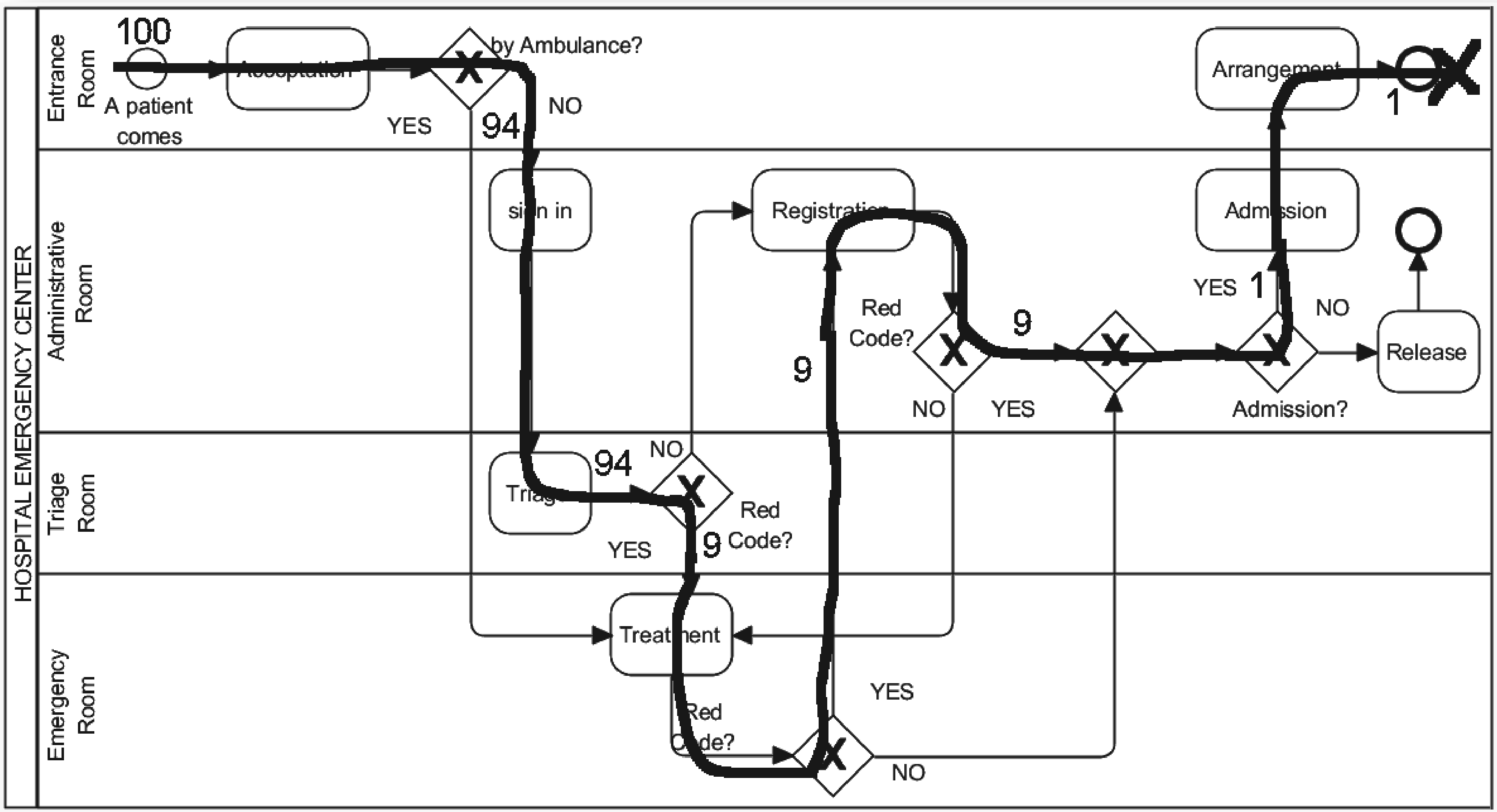
S3) NO AMBULANCE & NO RED CODE & ADMISSION:

100 x .944 & 94 x .9025 & 85 x .1 = 8.5 ≈ **8**.

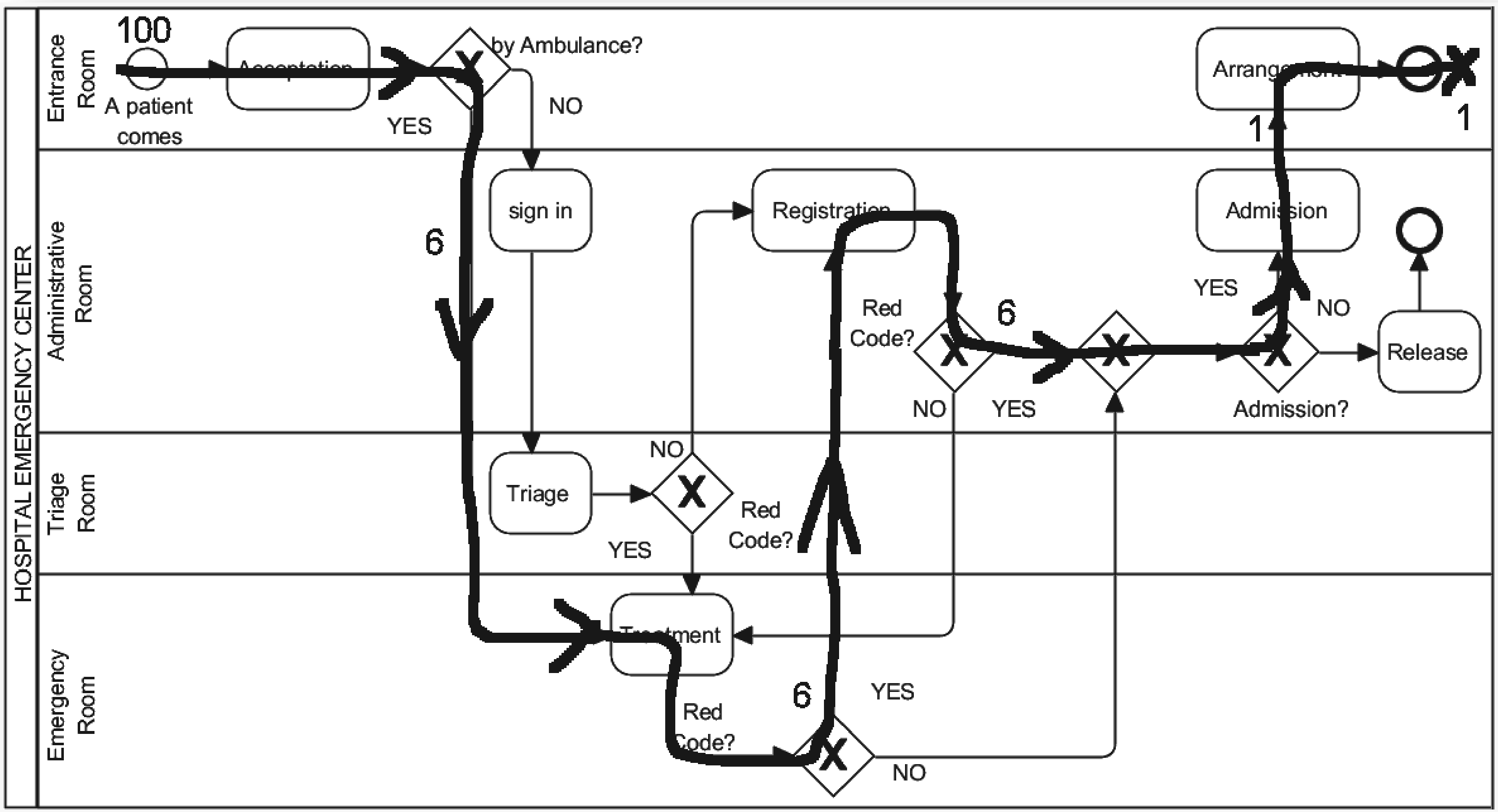


S4) NO AMBULANCE & RED CODE & ADMISSION:

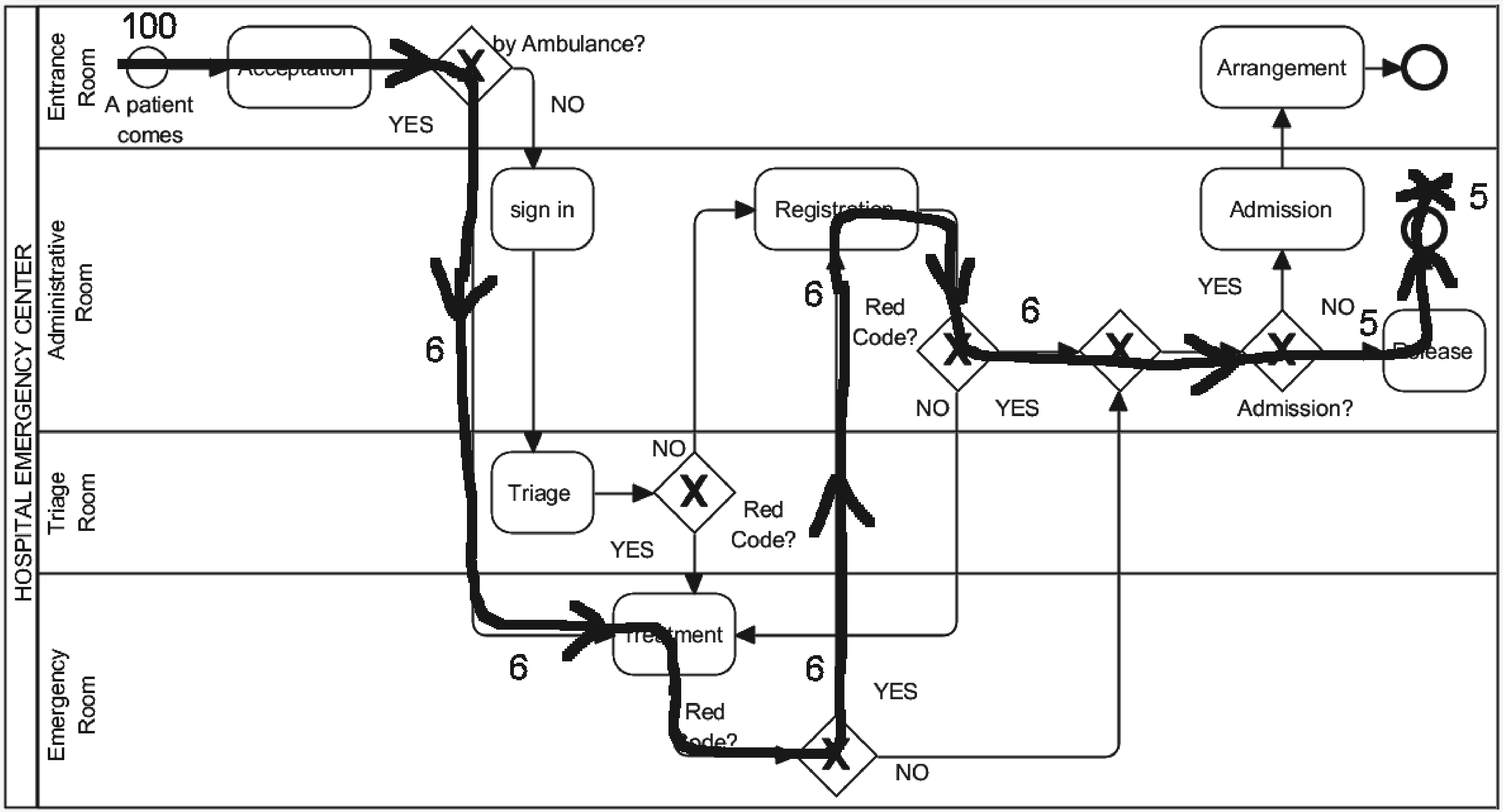
100 x .944 & 94 x 0.0975 & 9 x .1 = **1**.



S5) AMBULANCE & RED CODE & ADMISSION:
100 x .056 & 6 & 6 x .1 = **1**.



S6) AMBULANCE & RED CODE & NO ADMISSION:
100 X .056 & 6 & 6 x .9 = **5**.



S1 + S2 + S3 + S4 + S5 + S6 = 77 + 8+ 8+ 1 + 1 + 5 = **100**

Hospital Emergency Center (HEC): selecting the best configuration

• The HEC has the following resources: nurses, physicians, technicians, administrative clerks, Medical and Administrative rooms.

• Due to cost and layout considerations, hospital administrators have determined that the staffing level must not exceed 7+2 nurses, 3+1 physicians, 4 technicians, and 4+4 Administrative Clerks

• The constraint "x+χ" means "x is the maximum, but exceptionally you can add χ when special performance can be meet".

• The HEC has 7 medical rooms and 13 administrative rooms available; using fewer rooms would be beneficial, since other departments in the hospital could use the additional space more profitably.

• The hospital wants to find the configuration of the above resources that minimizes the total asset cost. The asset cost includes the staff's hourly wages and the fixed cost of each room used.

• We must also make sure that the **total cost is lower than 300K$** and that, on average, patients do **not spend more than 6 hours** in the HEC.

- Summary of parameters and constraints

Resource or Activity	Data or Constraints
Available Nurses	7+2
Available Physicians	3+1
Available Technicians	4
Available Administrative Clerks	4+4
Available rooms	7 medical rooms + 13 administrative rooms = 20 (using fewer rooms is beneficial)
Staff's hourly wages ($):	Nurse: 54.10; Physician: 78.70; Technician: 36.54; Admin: 29.03
Fixed Cost of each room used ($) Total Cost	55800 (Med. Room) 13200 (Adm. Room) Less than **300K $**
Max Average Time spent per patient	Less than or equal to **6h**
Acceptation	30s / 0.24$ (1 Admin.)
Sign in (average duration/cost)	3m 12s / 1.55$ (1 Admin.)
Triage (average duration/cost)	5m 24s / 11.95$ (1 Nurse + 1 Phys.)
Registration (average duration/cost)	9m 30s / 4.59$ (1 Admin.)
Admission (average duration/cost)	3m 42s / 1.79$ (1 Admin.)
Release (average duration/cost)	2m 12s / 1.06$ (1 Admin.)
Treatment (average duration/cost)	25m 54s / 80.69$ (2 Nurses + 1 Phys.)
Arrangement (average duration/cost)	21m 15s / 10.28$ (1 Admin.)

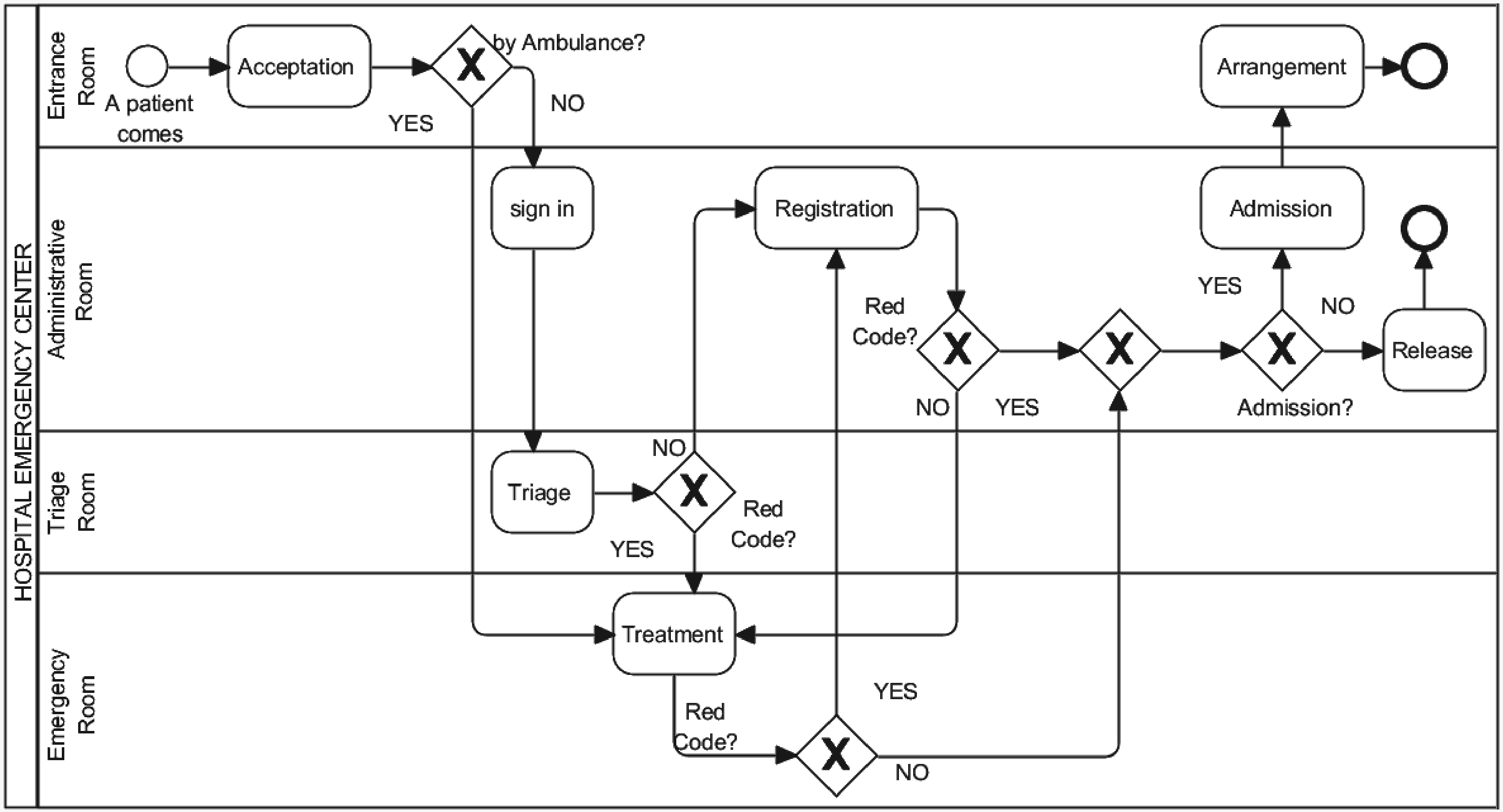
Exercise:

- Create all scenarios according to the constraints, for 100 patients.
- Try the following configuration, and compute the average patient cycle time.

N. of Lanes	Related Activities and required resources
1 Entrance Room	Acceptation, Arrangement: 1 Admin Clerk + 1 Admin Room
3 Administrative Rooms	Sign in, Registration, Admission, Release: 1 Adm Clerk + 1 Adm Room
1 Triage Room	Triage: 1 Nurse + 1 Physician + 1 Medical Room
2 Emergency Rooms	Treatment: 2 Nurses + 1 Physician + 1 Techn + 1 Med Room

- Compute the Total Asset Cost for this configuration, and discover some optimal solution that minimizes the average patient cycle time.

- First solution



- **Total Duration and Total Variable Cost: 21h 40m 12s 10037$**

- Looking at the Completion chart, it can be assumed that the completion time for each scenario is linearly increasing.

- The following completion data can be derived from the graphical interface at a glance (you can also download an excel file from the top-right icon):

Scenarios

☐ Highlight in diagram

Name	Percent	Cases
OWN & NORED & REL	77%	77
OWN & RED & REL	8%	8
OWN & NORED & ADM	8%	8
OWN & RED & ADM	1%	1
AMB & RED & ADM	1%	1
AMB & RED & REL	5%	5

Total: 100

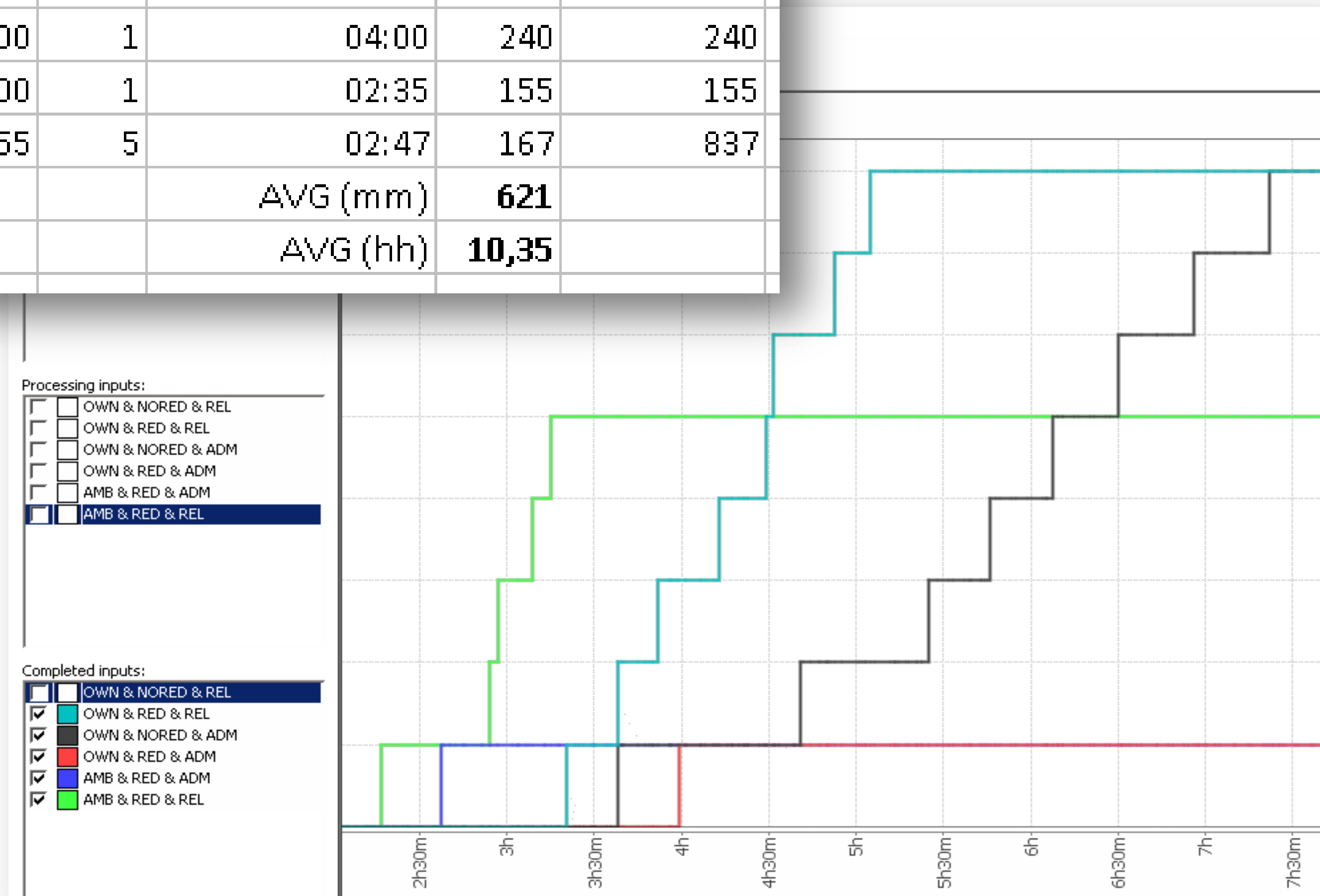
Available resources

Name	Type	Amount
Nurse	Staff	7
Physician	Staff	3
Technician	Staff	4
Administrative Clerk	Staff	4
Medical Room	Room	7
Administrative Room	Room	13

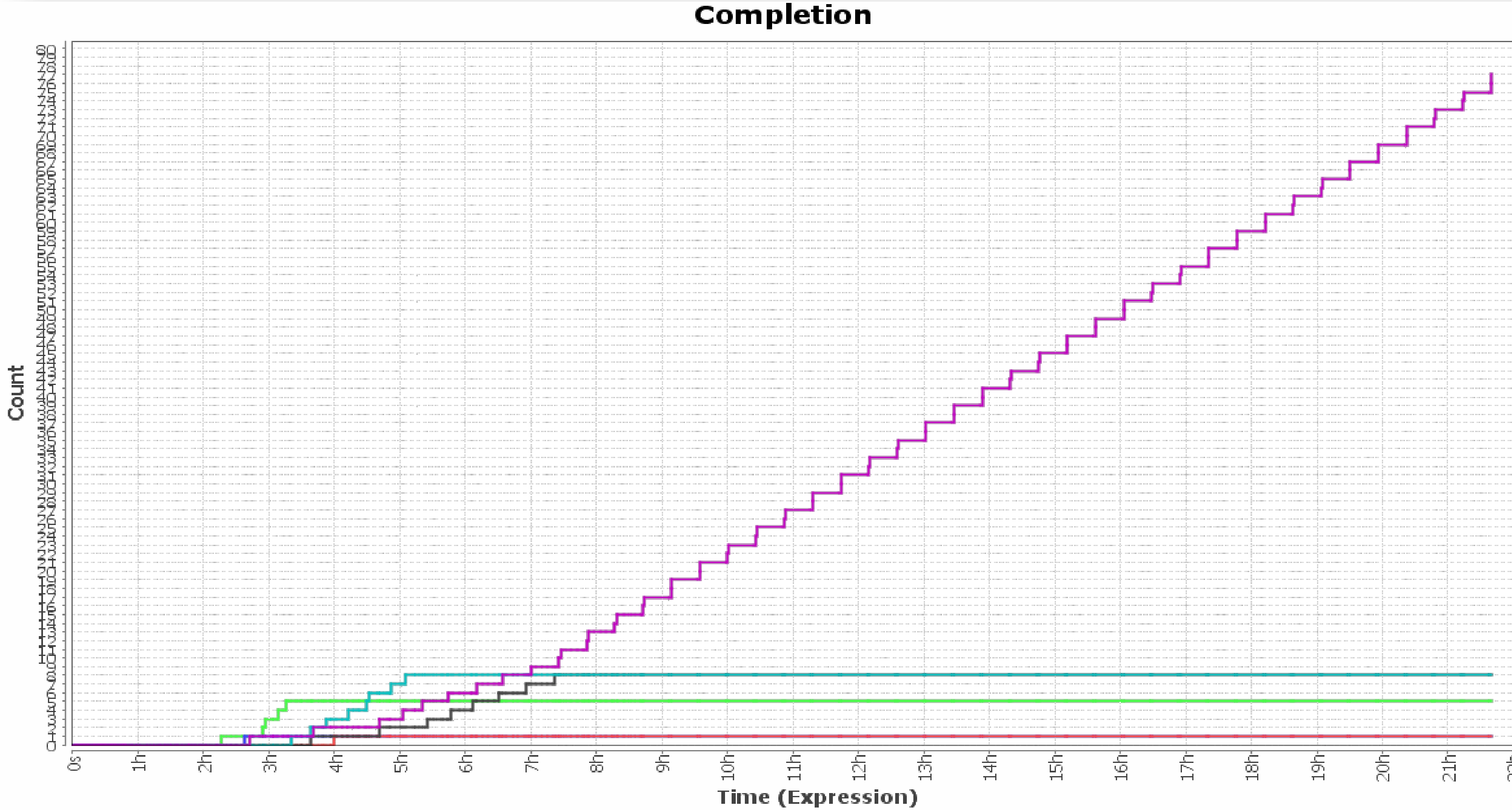
Scenario	First Token exits at	Last Token exits at	N. of Tokens	Average Completion Time
OWN & NORED & REL	2h 40m	21h 40m	77	12h 10m
OWN & RED & REL	3h 25m	5h 5m	8	4h 15m
OWN & NORED & ADM	3h 35m	7h 25m	8	5h 30m
OWN & RED & ADM	4h	4h	1	4h
AMB & RED & ADM	2h 35m	2h 35m	1	2h 35m
AMB & RED & REL	2h 20m	3h 15m	5	2h 47m
AVERAGE TIME				

- Using MS Excel, the total average time is **10.35 hours, very higher than 6!**

	A	B	C	D	E	F	G
1	START	END	END-START	NUM	(START+END)/2	mm	NUM*mm
2	02:40	21:40	19:00	77	12:10	730	56210
3	03:25	05:05	01:40	8	04:15	255	2040
4	03:35	07:25	03:50	8	05:30	330	2640
5	04:00	04:00	00:00	1	04:00	240	240
6	02:35	02:35	00:00	1	02:35	155	155
7	02:20	03:15	00:55	5	02:47	167	837
8					AVG (mm)	**621**	
9					AVG (hh)	**10,35**	

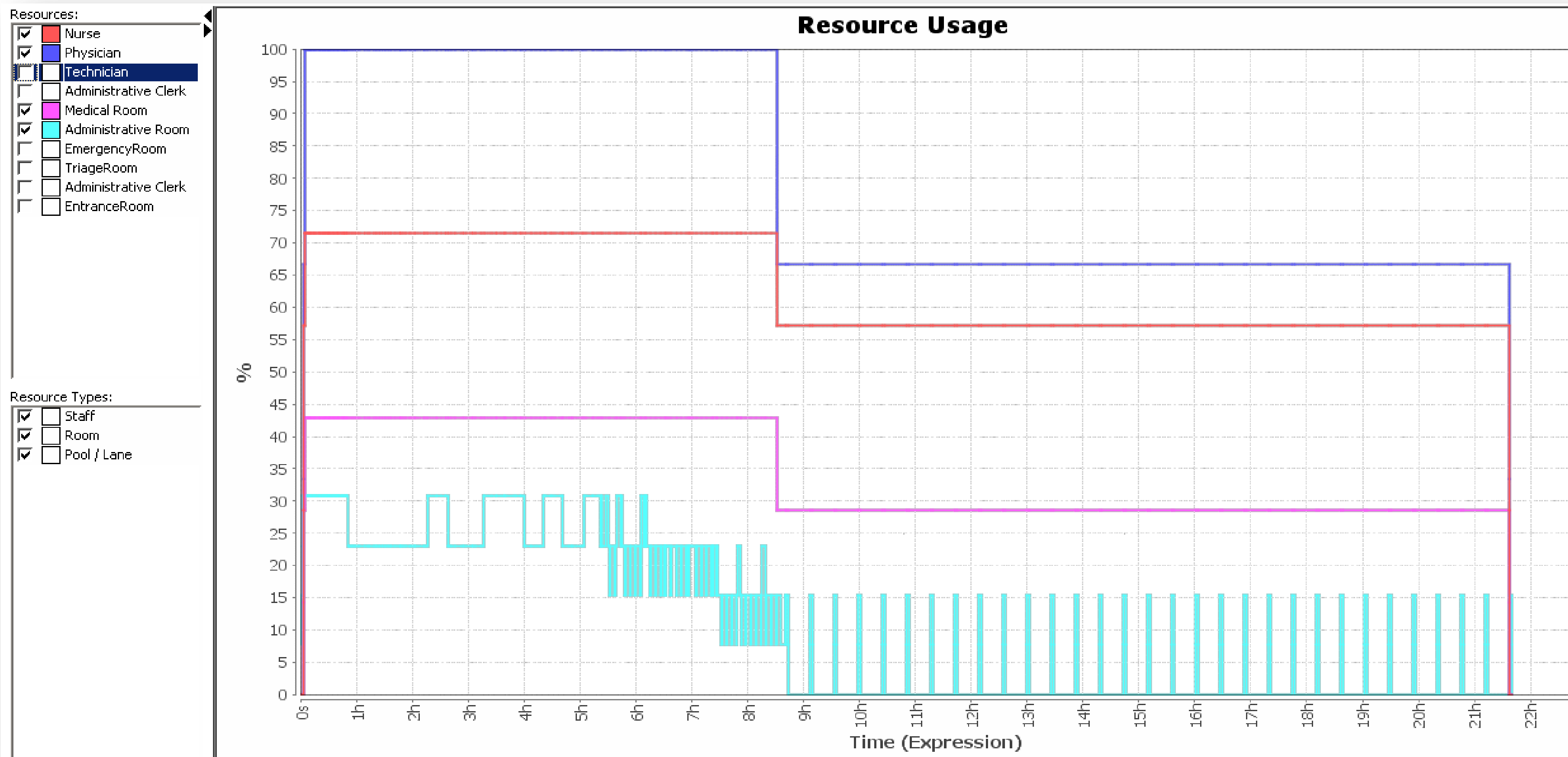


Business Process Simulation



- The maximum resource usage can be also derived. Looking at the Resource Usage diagram (expressed in percentage w.r.t. the available ones) the maximum usage per resource can be easily calculated: Nurses: 5/7; Phys: 3/3; Techn: 2/4; Adm: 4/4; Med Rooms: 3/7; Adm Rooms: 4/13;

- Total costs = Fixed costs + Costs per Input =55800*3 + 13200*4 + 10037= **230237$**

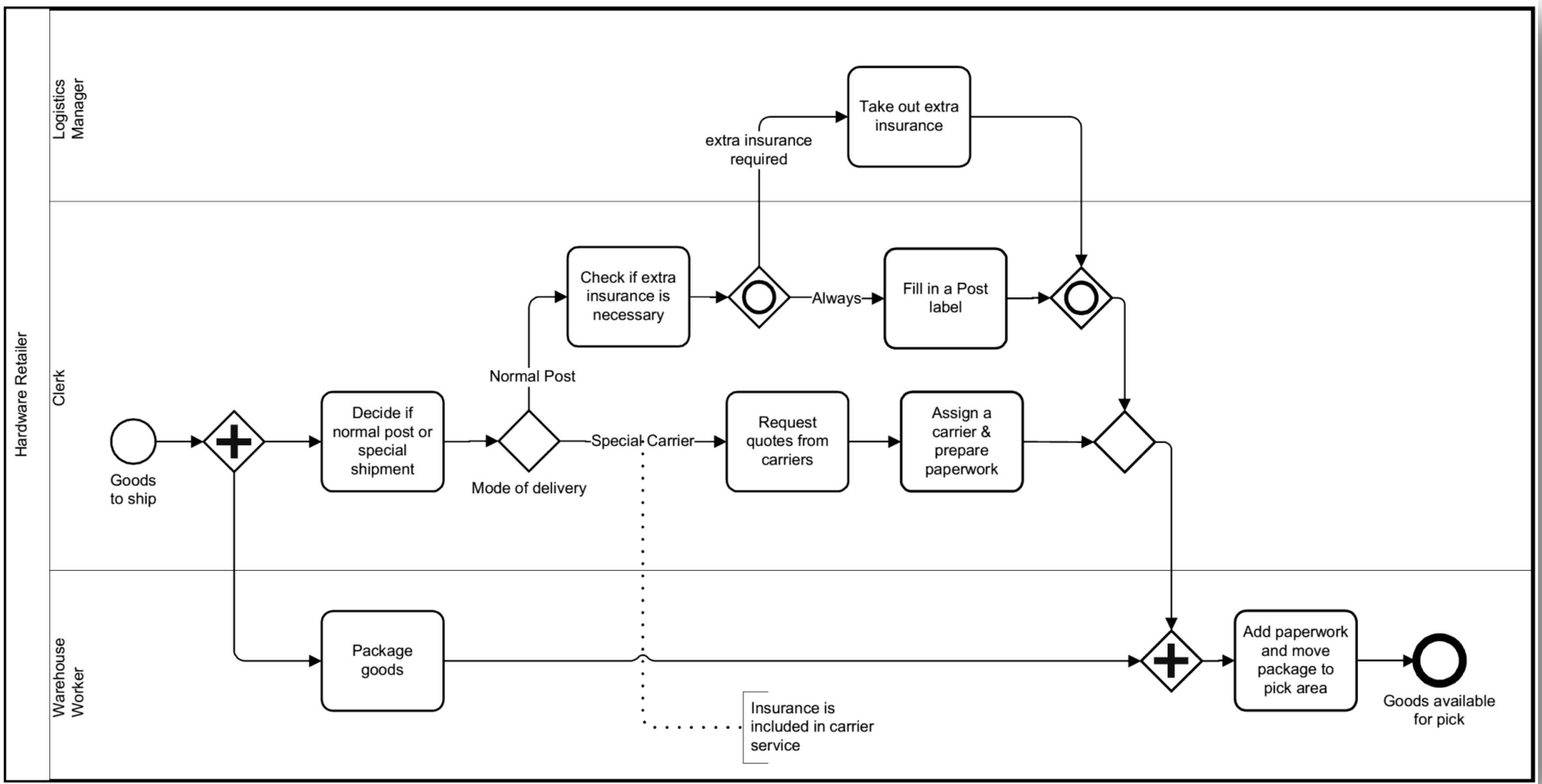


- Looking at the Queue Time, it can be seen that the bottleneck is at the Treatment activity. Let us increase the number of resource for treatment: 3 Emergency Room.
- **Total Duration and Total Variable Cost: 17h 21m 12s 10037$**
- **Total Average Time: 8.65h**

- The new queuing situation is more balanced.

Shipment Process of a Hardware Retailer

- Describe in semi-formal natural language the following shipment process, modeling the preparing steps a hardware retailer has to fulfill before the ordered goods can actually be shipped to the customer.
- Given 100 starting tokens, determine the number of ending tokens for each scenario (path), considering the following branching proportions at each gateway: normal post (90%), extra insurance required(10%).



Semi-formal notation

1. The Clerk has good to ship

2.a The Clerk decides if normal or special shipment

2.a.1 If normal post:
2.a.1.1 The Clerk checks if extra insurance is necessary
2.a.1.2.a The Clerk fills in a post label → **2.a.1.3**
2.a.1.2.b If extra insurance is required
2.a.1.2.b.1 The Logistics Manager takes out extra insurance
2.a.1.3 Clerk waits for the end of the ongoing activities in **2.a.1.2.a** and **2.a.1.2.b ->3**

2.a.2 If special carrier (insurance is included):
2.a.2.1 The Clerk requests quotes to carriers
2.a.2.2 The Clerk assigns carrier and prepare paperwork ->3

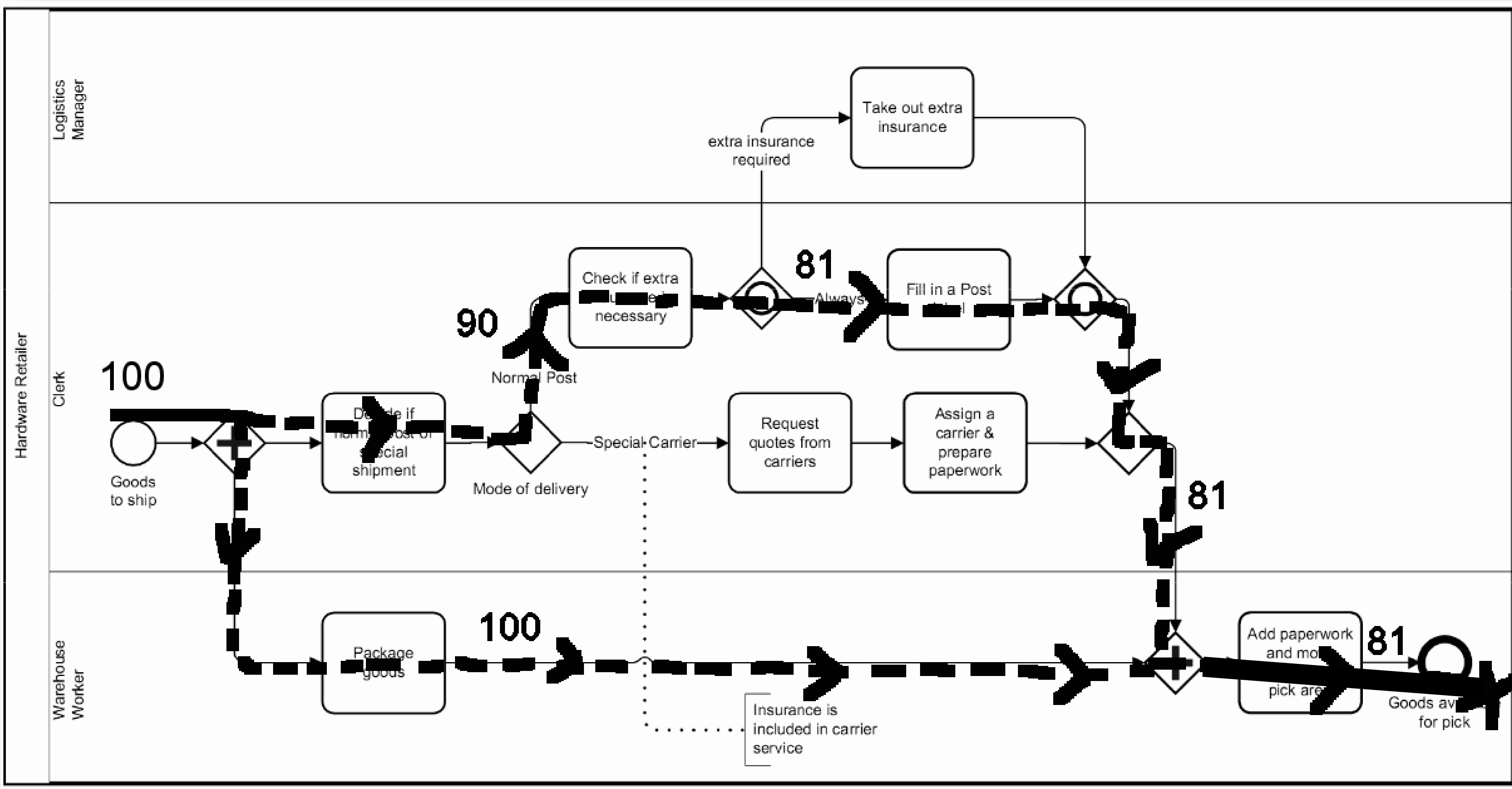
2.b The Warehouse worker packages goods

3 The Warehouse worker waits for the end of **2.a** e **2.b**

4 The Warehouse worker adds paperwork and move package to pick area
5 Goods are available for pick (End of the process).

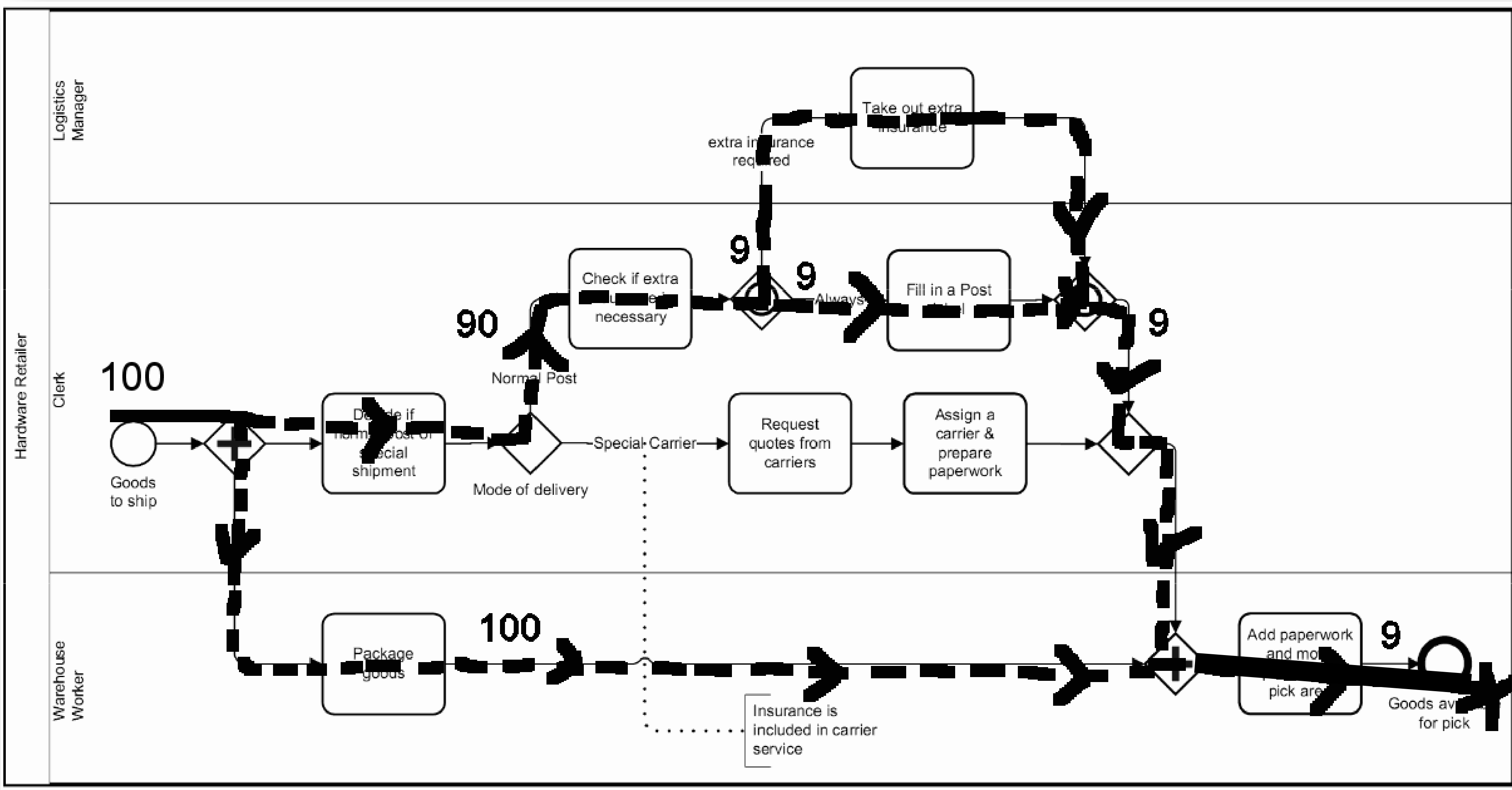
S1) NORMAL POST & NO INSURANCE: 100 x 0.9 & 90 X 0.9 = **81 (19 w)**.

- 19 “single twins” tokens (i.e., packages without labels) are still blocked at the warehouse, each waiting for their respective twin token (label).
- Only 81 process instances can end (package + label).



S2) NORMAL POST & INSURANCE: 100 x 0.9 & 90 X 0.1 = **9 (10 w)**.

- 9 of the 19 waiting single-twin tokens (packages) join the new 9 single-twins tokens (new labels), and then 9 process instances end.
- 10 single-twin tokens still wait.



S3) SPECIAL CARRIER: 100 x 0.1 = **10**.

- 10 of the 10 waiting single-twin tokens (packages) join the new 10 single-twins tokens (new labels), and then 10 process instances end.
- There are no other tokens waiting in the Pool. S1 + S2 + S3 = 81 + 9 + 10 = **100**