Quantitative Process Analysis

Departemen Informatika

Fakultas Sains dan Matematika

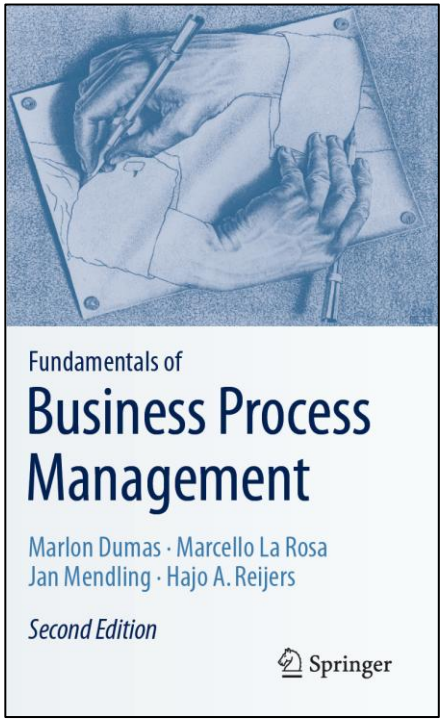
Universitas Diponegoro

Dumas · Mendling · Reijers

Fundamentals of Business Process Management

2nd Ed.

Chapter 7: Quantitative Process Analysis



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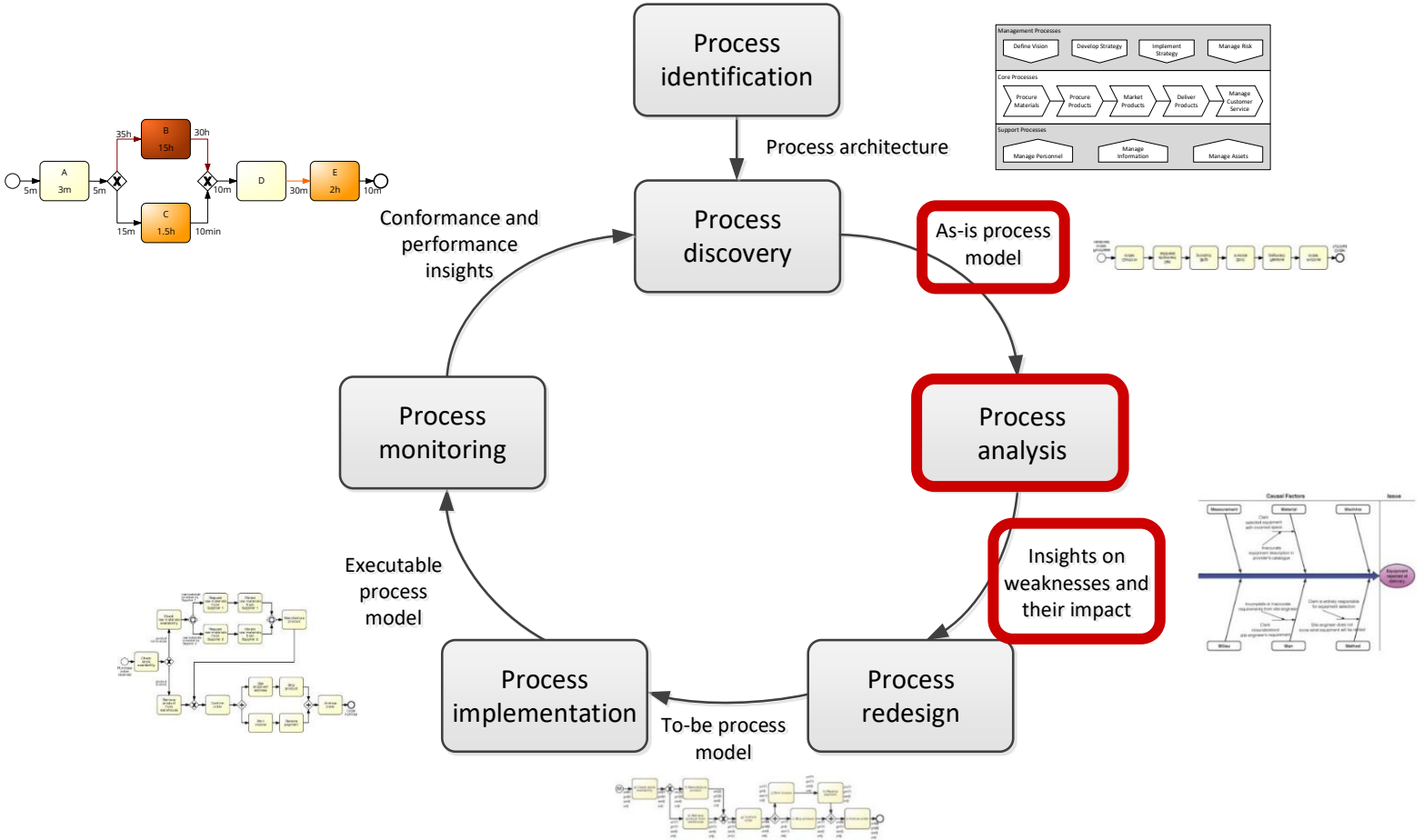
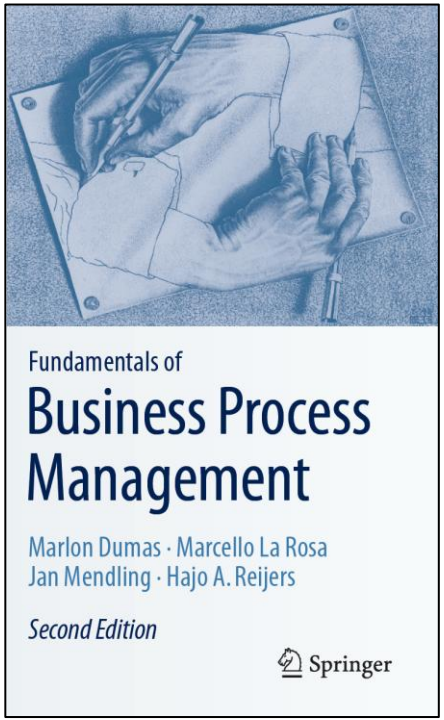
1. Flow Analysis
2. Queuing Analysis
3. Simulation
4. Recap

Process Analysis in the BPM Lifecycle



Chapter 7: Quantitative Process Analysis



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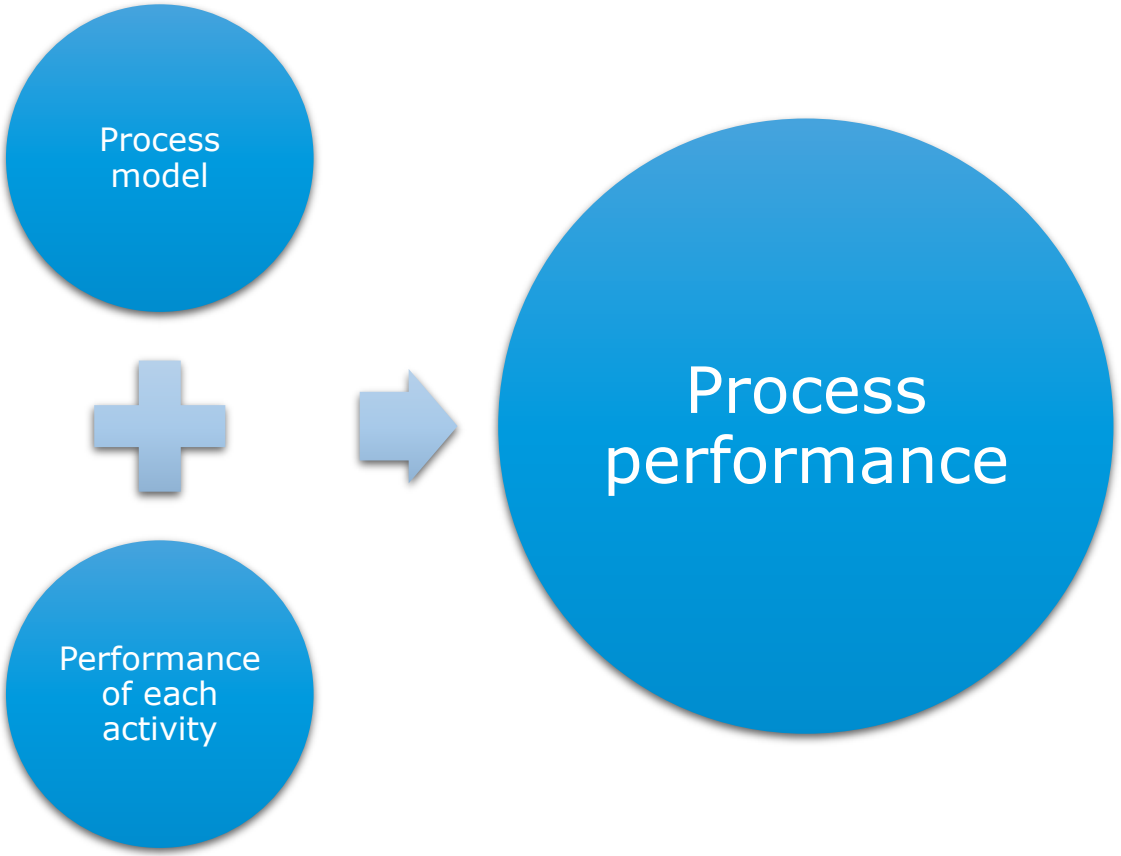
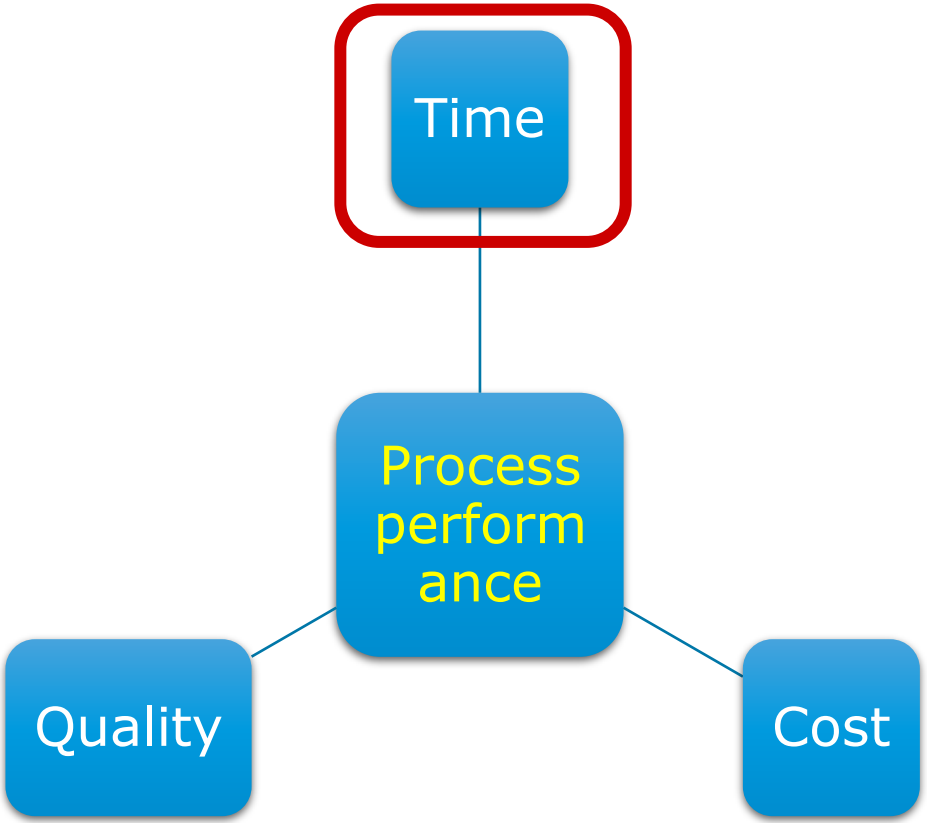
Flow analysis



Refresher: Process performance measures



Common time-related measures

Time taken by value-adding activities

Processing time

+

Waiting time

Time taken by non-value-adding activities

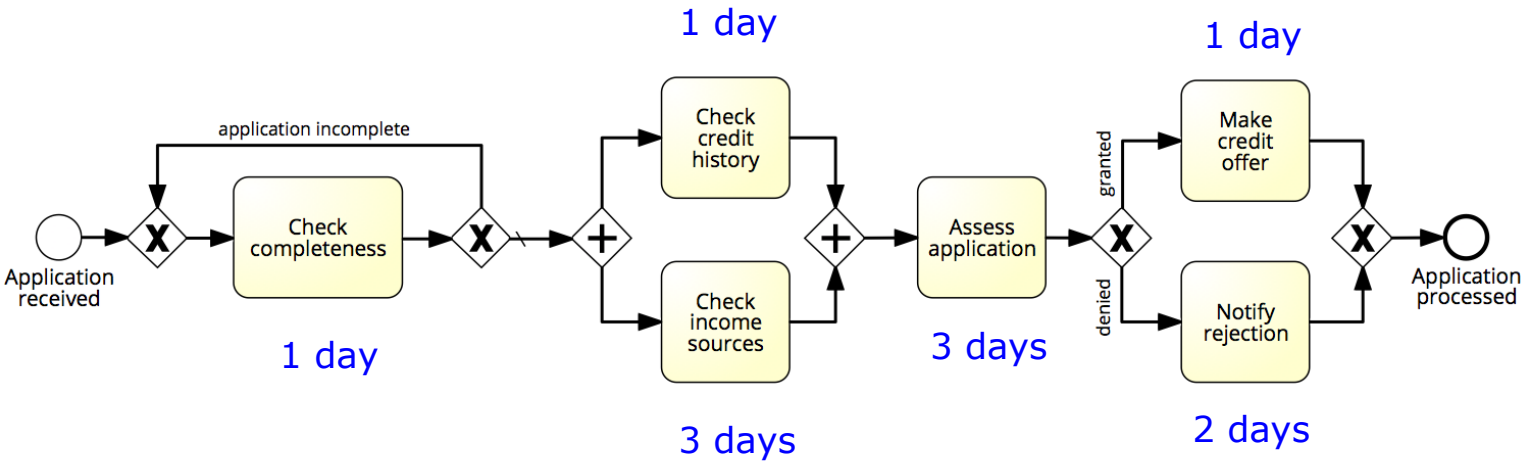
→

Cycle time

Time between start and completion of a process instance

Cycle time efficiency

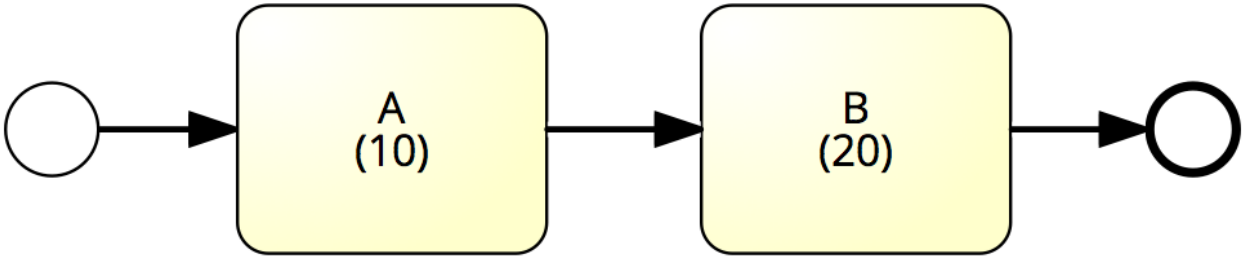
Flow analysis of cycle time



Cycle time = X days

Sequence – Example

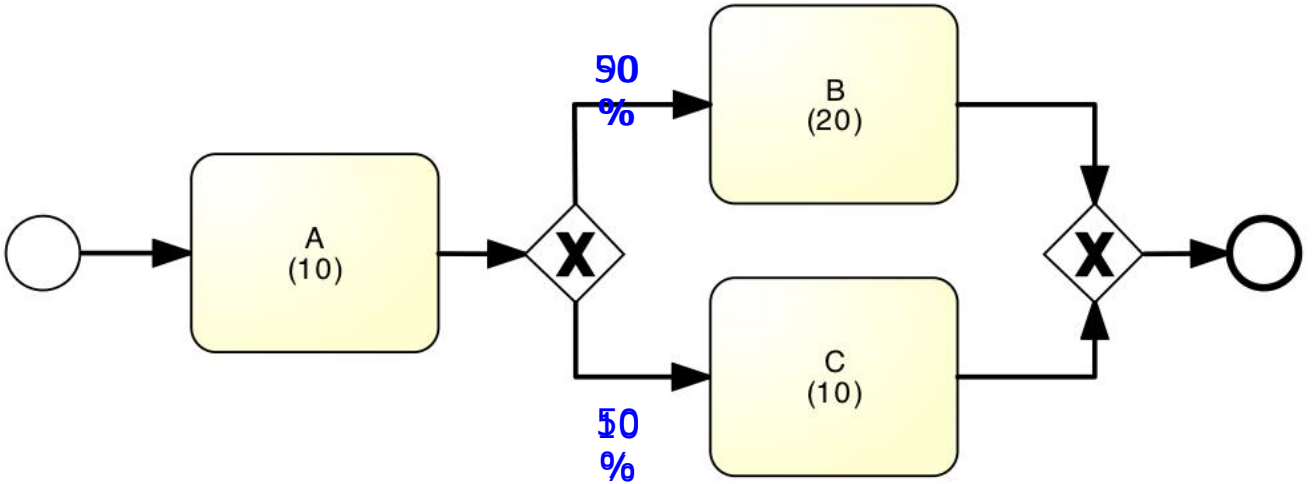
- What is the average cycle time?



Cycle time = 10 + 20 = 30

Example: Alternative Paths

- What is the average cycle time?

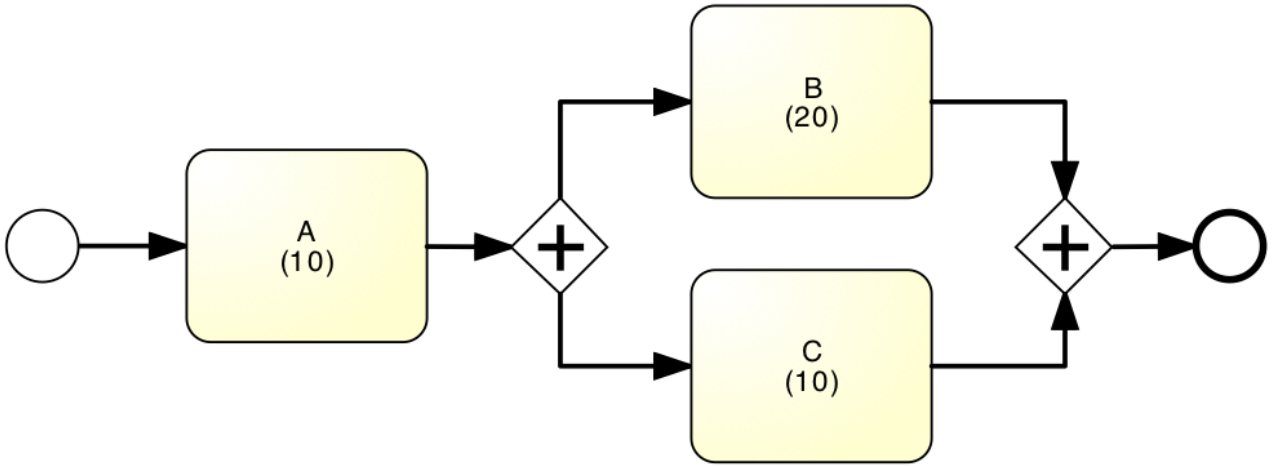


Cycle time = 10 + (20+10)/2 = 25

Cycle time = 10 + 0.9*20+0.1*10 = 29

Example: Parallel paths

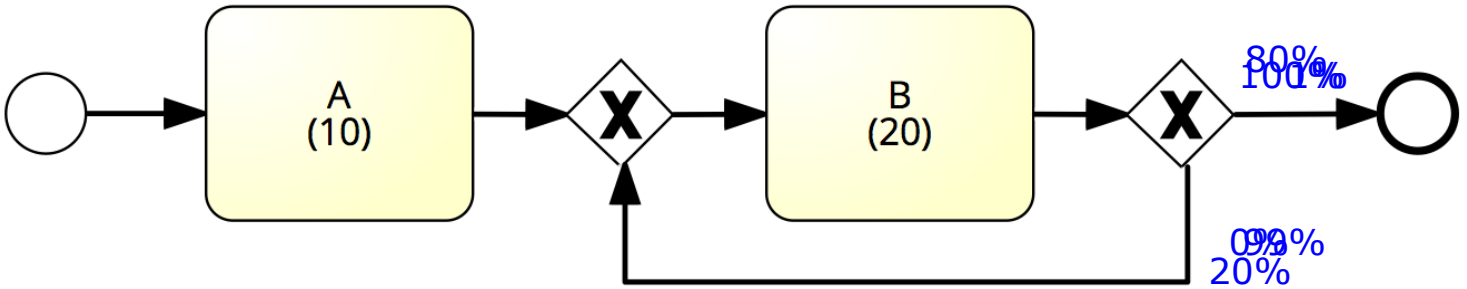
- What is the average cycle time?



Cycle time = 10 + 20 = 30

Example: Rework loop

- What is the average cycle time?

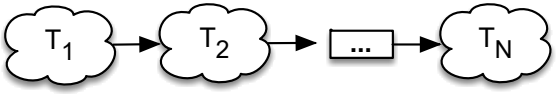


Cycle time = 10 + 20 = 30

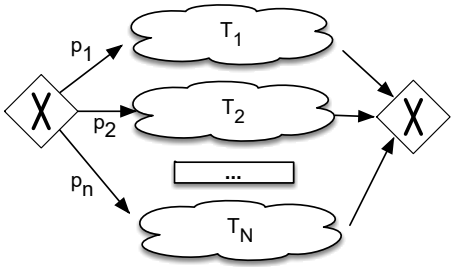
Cycle time = 10 + 20/0.01 = 2010

Cycle time = 10 + 20/0.8 = 35

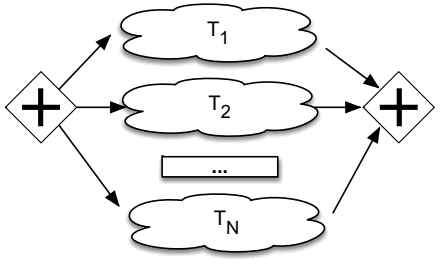
Flow analysis equations for cycle time



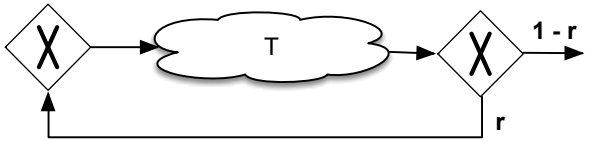
$$CT = T_1 + T_2 + \ldots + T_N$$



$$CT = p_1 * T_1 + p_2 * T_2 + \ldots + p_n * T_N$$

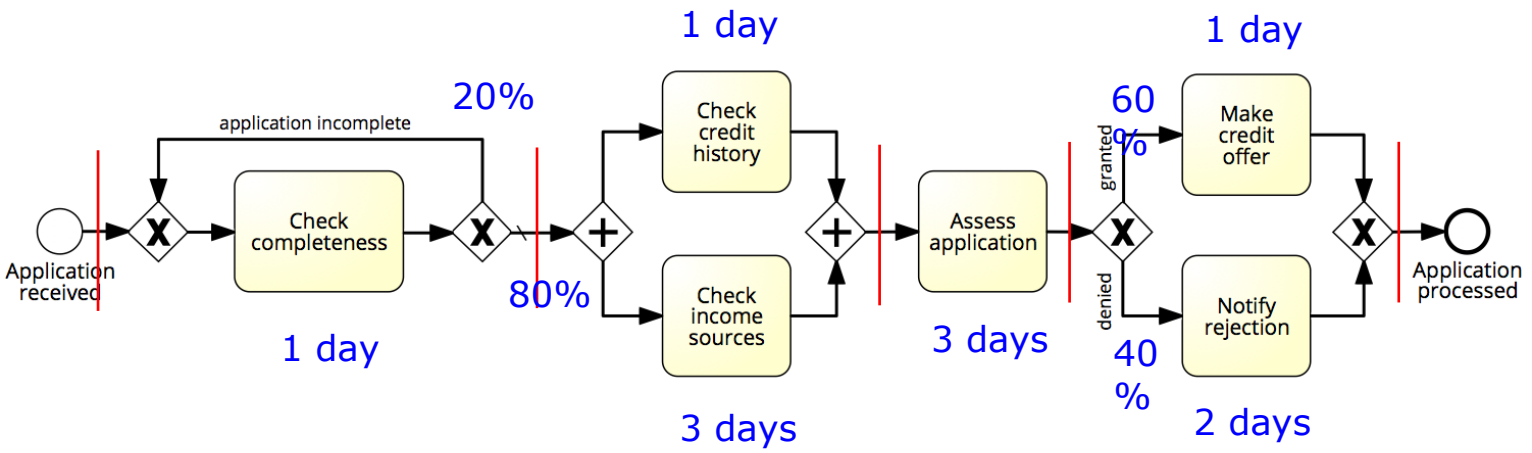


$$CT = \max(T_1, T_2, \ldots, T_N)$$



$$CT = T / (1-r)$$

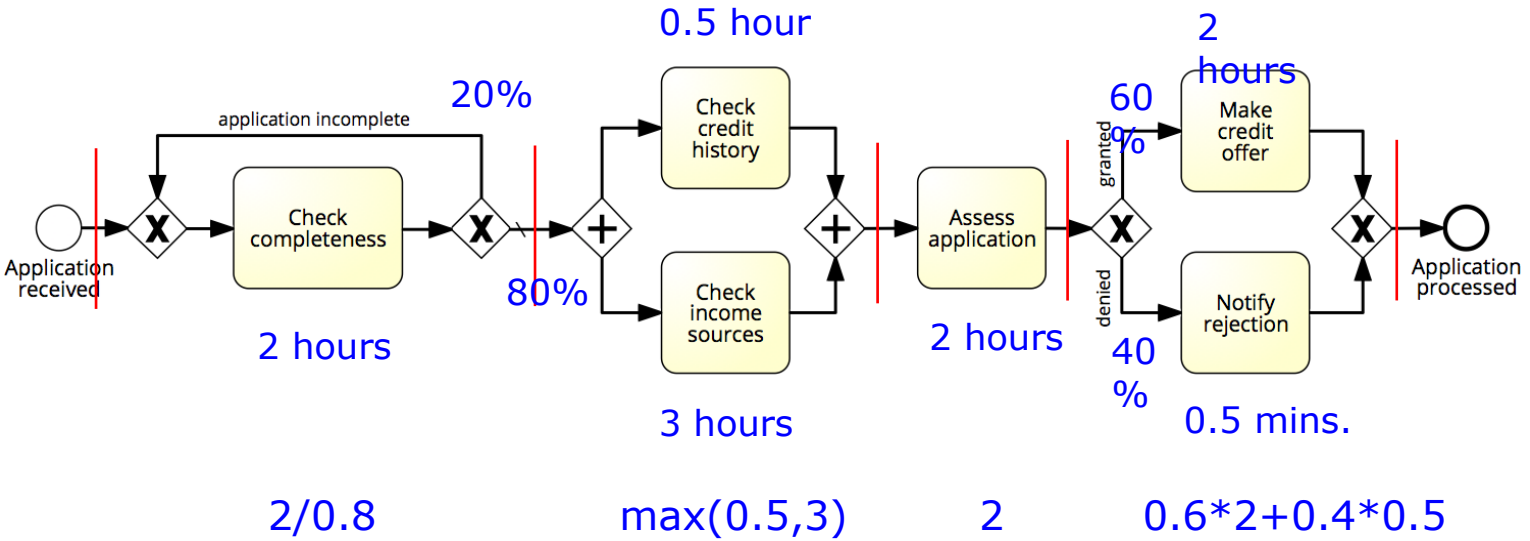
Flow analysis of cycle time



1/0.8 max(1,3) 3 0.6*1+0.4*2

Cycle time = 1.25 + 3 + 3 + 1.4 = 8.65 days

Flow analysis of processing time



Processing time = 2.5 + 3 + 2 + 1.4 = 8.9 hours

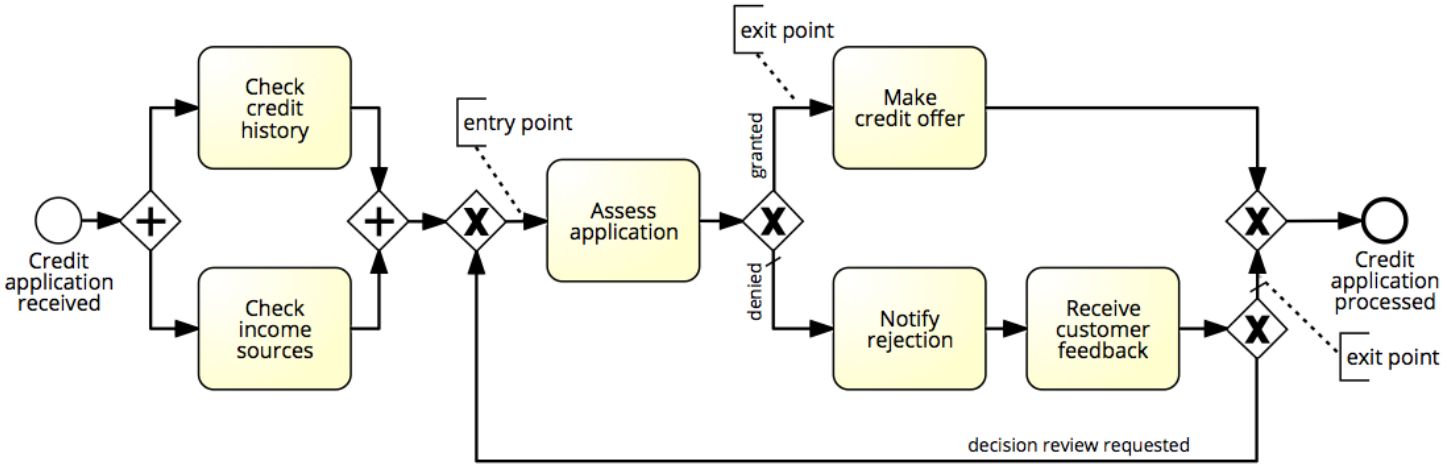
Cycle time efficiency = 8.9 hours / 8.65 days = 12.9%

Flow analysis: scope and limitations

- We have seen how to use flow analysis for processing & cycle time calculation
- Flow analysis can also be applied to calculate:
  - The average cost of process instances (assuming we know the cost of each activity)
    - Cf. Section 7.1.6
  - The number of times on average each activity is executed
    - Can be used to calculate the “unit load” of each task, the resource utilization of each resource pool, and the theoretical capacity of an “as is” process
    - Cf. Section 7.1.5

- But flow analysis has some fundamental limitations…

Limitation 1: Not all Models are Structured



Limitation 2: Fixed arrival rate capacity

- Cycle time analysis does not consider:
  - The rate at which new process instances are created (arrival rate)
  - The number of available resources
- Higher arrival rate at fixed resource capacity
  ➔ high resource contention
  ➔ higher activity waiting times (longer queues)
  ➔ higher activity cycle time
  ➔ higher overall cycle time
- The slower you are, the more people have to queue up…
  - and vice-versa

Resource utilization

Resource utilization = 60%
➔ on average resources are idle 40% of their allocated time

Resource utilization vs. waiting time

Typically, when resource utilization > 90%
➔ Waiting time increases steeply

Interlude: Cycle Time & Work-In-Progress

- WIP = (average) Work-In-Process
  - Number of cases that are running (started but not yet completed)
  - E.g. # of active and unfilled orders in an order-to-cash process
- WIP is a form of waste (cf. 7+1 sources of waste)
- Little's Formula: WIP = $\lambda \cdot$CT
  - λ = arrival rate (number of new cases per time unit)
  - CT = cycle time

Exercise

A fast-food restaurant receives on average 1200 customers per day (between 10:00 and 22:00). During peak times (12:00-15:00 and 18:00-21:00), the restaurant receives around 900 customers in total, and 90 customers can be found in the restaurant (on average) at a given point in time. At non-peak times, the restaurant receives 300 customers in total, and 30 customers can be found in the restaurant (on average) at a given point in time.

1. What is the average time that a customer spends in the restaurant during <u>peak</u> times?
2. What is the average time that a customer spends in the restaurant during <u>non-peak</u> times?

Exercise (cont.)

3. The restaurant plans to launch a marketing campaign to attract more customers. However, the restaurant's capacity is limited and becomes too full during peak times. What can the restaurant do to address this issue without investing in extending its building?

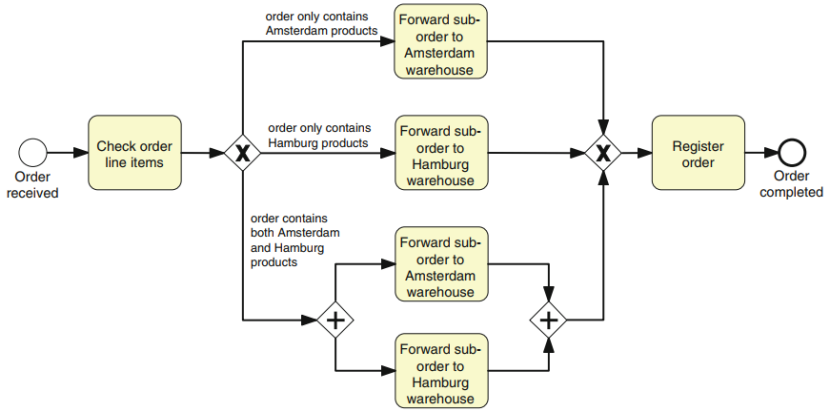


Fig. 3.8 Modeling an inclusive decision: first trial

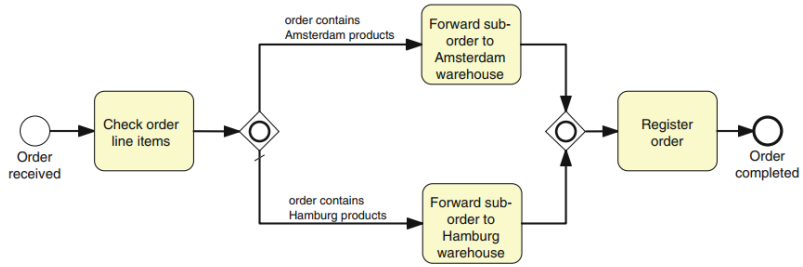


Fig. 3.10 Modeling an inclusive decision with the OR gateway

Exercise 7.1 Consider the process model given in Figure 3.8 (page 86). Calculate the cycle time under the following assumptions:

- Each task in the process takes 1 h on average.
- In 40% of the cases the order contains only Amsterdam products.
- In 40% of the cases the order contains only Hamburg products.
- In 20% of the cases the order contains products from both warehouses.

Compare the process model in Figure 3.8 (page 86) with the one in Figure 3.10 (page 88). Does this comparison give you an idea of how to calculate cycle times for process models with OR gateways?

Solution 7.1 First we observe that the cycle time of the AND-block is 1. Next, we calculate the cycle time of the XOR-block as follows: $0.4 \times 1 + 0.4 \times 1 + 0.2 \times 1$ h. The total cycle time is thus: $1 + 1 + 1 = 3$ h.

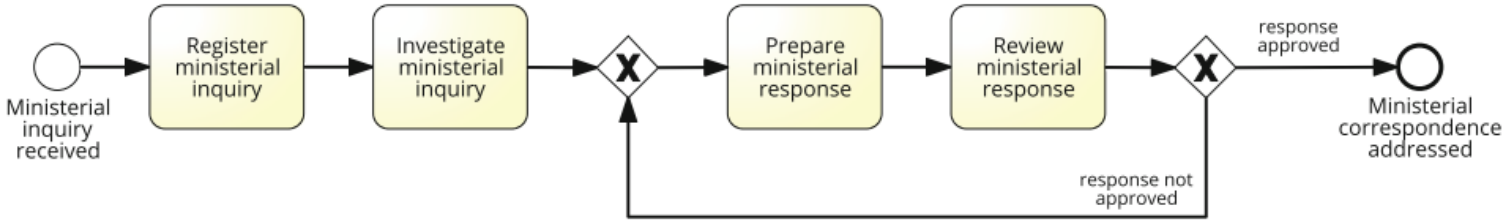


Fig. 3.13 A process model for addressing ministerial correspondence

Exercise 7.2 Calculate the overall cycle time, theoretical cycle time, and cycle time efficiency of the ministerial enquiry process introduced in Example 3.7 (page 90). Assume that the rework probability is 0.2 and the waiting times and processing times are those given in Table 7.3.

Table 7.3 Task cycle times and processing times for ministerial enquiry process

Task	Cycle time	Processing time
Register ministerial enquiry	2 days	30 min
Investigate ministerial enquiry	8 days	12 h
Prepare ministerial response	4 days	4 h
Review ministerial response	4 days	2 h

Solution 7.2 The cycle time of the process is $2 + 8 + \frac{4+4}{1-0.2} = 20$ days. Assuming 8 working hours per day, this translates to 160 working hours. The theoretical cycle time is $0.5 + 12 + \frac{4+2}{1-0.2} = 20$ h. Hence, cycle time efficiency is 12.5%.

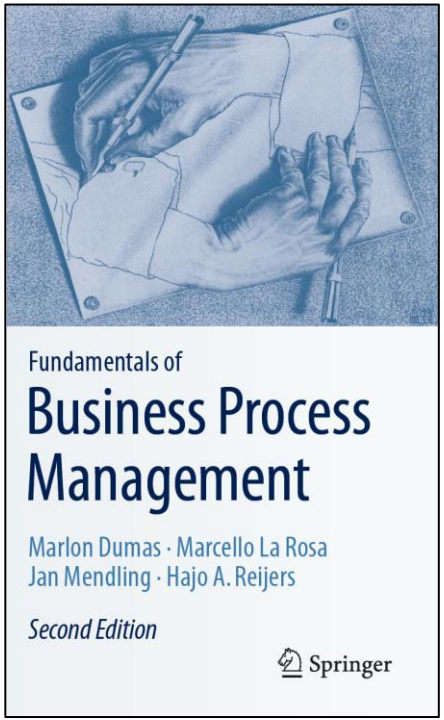
Table 7.4 Analysis of cycle times in white-collar processes [21]

Industry	Process	CT	TCT	CTE
Life Insurance	New policy application	72 h	7 min	0.16%
Consumer Packaging	New graphic design	18 days	2 h	0.14%
Commercial Bank	Consumer Loan	24 h	34 min	2.36%
Hospital	Patient Billing	10 days	3 h	3.75%
Automobile Manufacture	Financial Closing	11 days	5 h	5.60%

Exercise 7.3 The measurements reported in Table 7.4 stem from 1992. How do you expect that these measurements have changed since then? What role do information systems play in this context?

Solution 7.3 It can be expected that the average cycle times of the reported process have generally improved. Since 1992, several technological advancements have drastically improved white-collar work productivity. These relate to a better coordination and routing of tasks using information technology including office applications, enterprise systems, and Internet technology. In Chapter 9, we will discuss how Business Process Management Systems and different types of Process-Aware Information Systems have contributed to better coordination and task automation. These advancements have likely reduced waiting times in many business processes. Therefore, also cycle time efficiency should have improved since 1992.

Chapter 7: Quantitative Process Analysis



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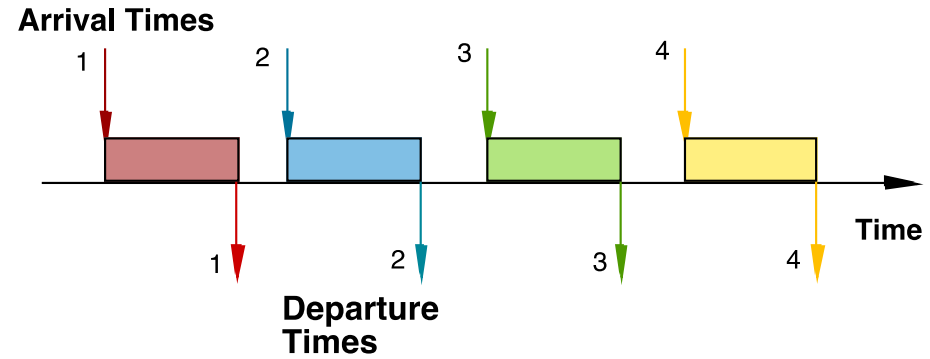
Queuing Analysis

- Capacity problems are common and a key driver of process redesign
  - Need to balance the cost of increased capacity against the gains of increased productivity and service
- Queuing and waiting time analysis is particularly important in service systems
  - Large costs of waiting and/or lost sales due to waiting
- **Example – Emergency Room (ER) at a Hospital**
  - Patients arrive by ambulance or by their own accord
  - One doctor is always on duty
  - More patients seeks help ⇒ longer waiting times
  - *Should we increase the capacity from one to two doctors?*

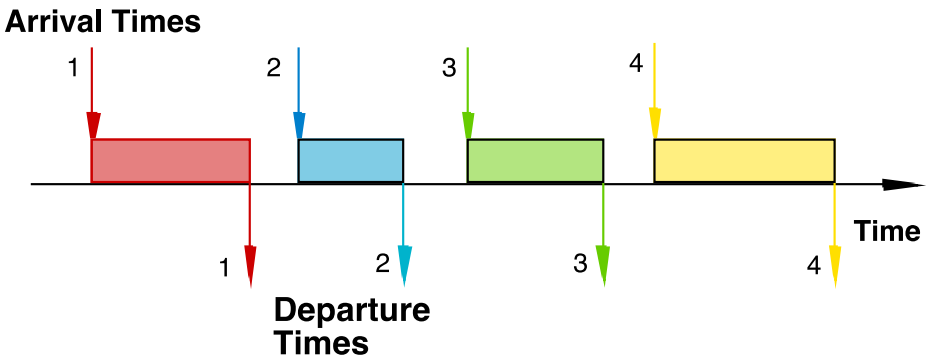
Inspired by an example by Laguna & Marklund (2004)

Delay is Caused by Job Interference

If arrivals are regular or sufficiently spaced apart, no queuing delay occurs



Deterministic traffic



Variable but spaced apart traffic

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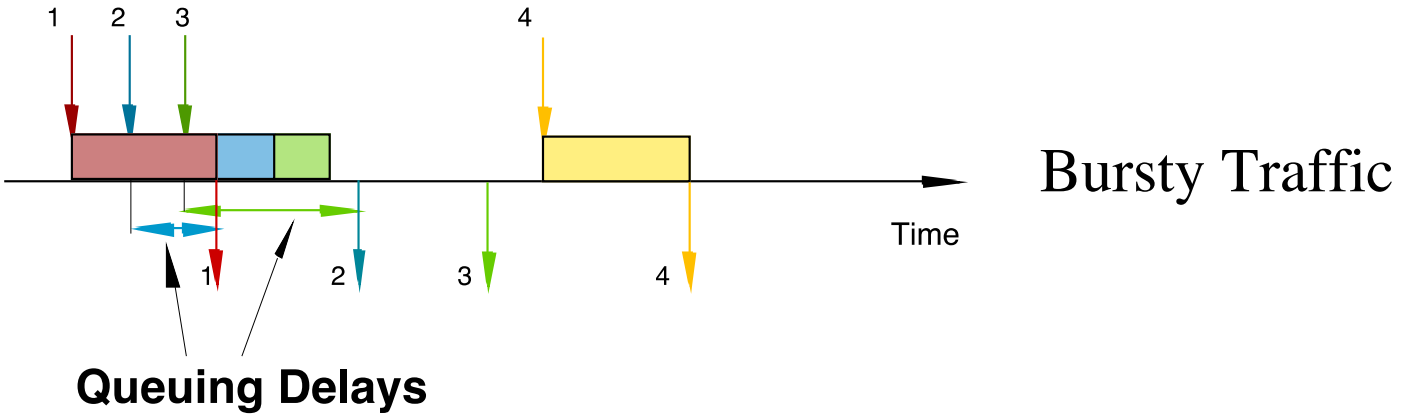
Burstiness Causes Interference

* **Queuing results from variability in <u>processing times</u> and/or <u>interarrival times</u>**



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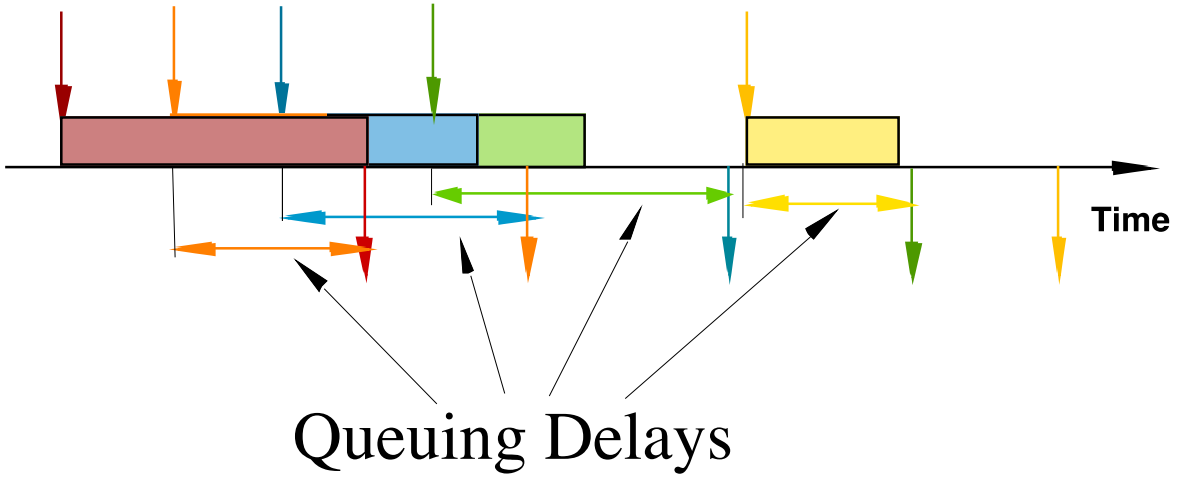
High Utilization Exacerbates Interference

- The queuing probability increases as the load increases
- Utilization close to 100% is unsustainable → too long queuing times



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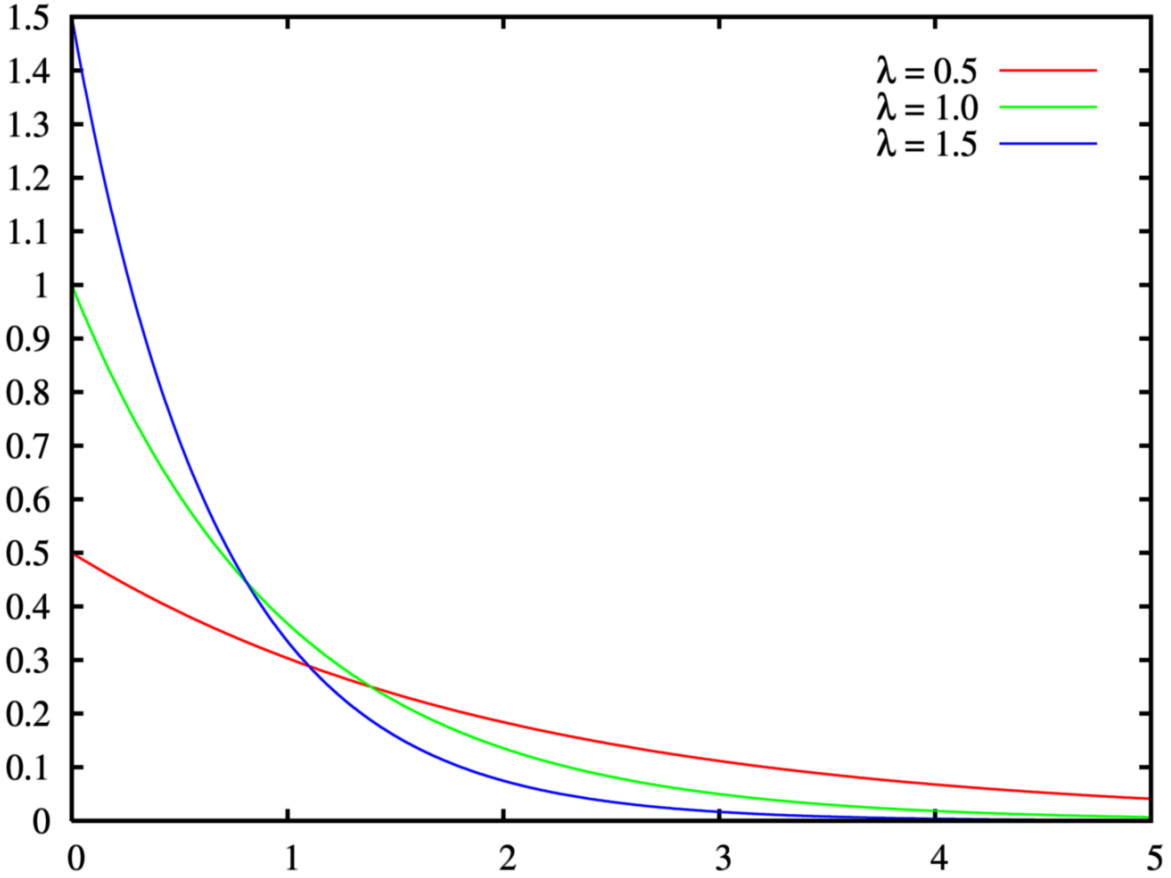
The Poisson Process

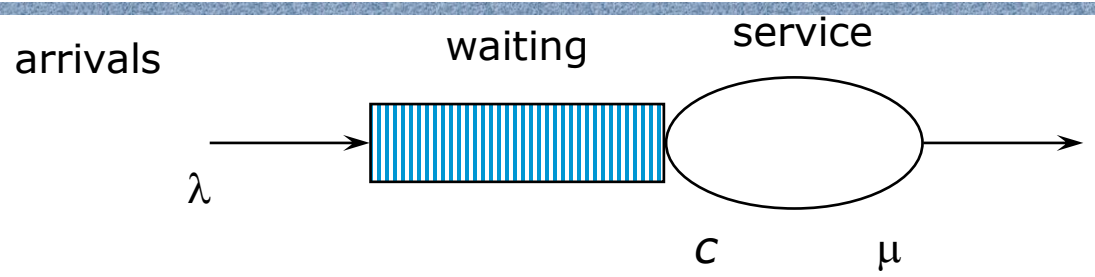
- Common arrival assumption in many queuing and simulation models
- The times between arrivals are independent, identically distributed and exponential
  - P (arrival < t) = $1 - e^{-\lambda t}$
- This distribution is applicable when the next arrival (i.e. the next creation of a case) does not depend on how long ago the previous arrival occurred
  - In other words, the creation of a case is independent of the creation of other cases.

Inspired by slide by Laguna & Marklund (2004)

Negative Exponential Distribution



Queuing theory: basic concepts



Basic characteristics:

- λ (mean arrival rate) = average number of arrivals per time unit
- μ (mean service rate) = average number of jobs that can be handled by one server per time unit:
- *c* = number of servers

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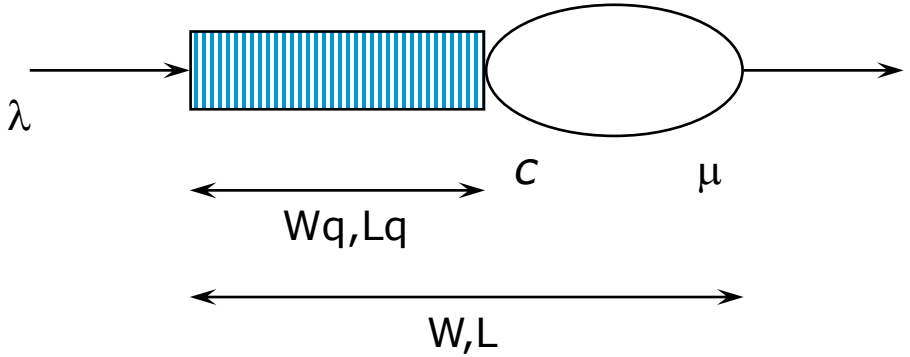
Queuing theory concepts (cont.)



Given λ , μ and c, we can calculate :

- **occupation rate: ρ**
- **Wq = average time in queue**
- **W = average system in system (i.e. cycle time)**
- **Lq = average number in queue (i.e. length of queue)**
- **L = average number in system average (i.e. Work-in-Progress)**

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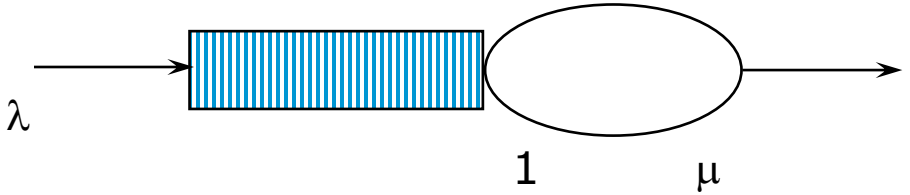
M/M/1 queue



Assumptions:

- time between arrivals and processing time follow a negative exponential distribution
- 1 server (c = 1)
- FIFO

$$\rho = \frac{\text{Capacity Demand}}{\text{Available Capacity}} = \frac{\lambda}{\mu}$$

$L = \rho/(1-\rho)$

$W = L/\lambda = 1/(\mu-\lambda)$

$L_q = \rho^2/(1-\rho) = L-\rho$

$W_q = L_q/\lambda = \lambda/(\mu(\mu-\lambda))$

Inspired by a slide by Laguna & Marklund (2004)

M/M/c queue

- Now there are c servers in parallel, so the expected capacity per time unit is then c*μ

$$\rho = \frac{\text{Capacity Demand}}{\text{Available Capacity}} = \frac{\lambda}{c * \mu}$$

Little's Formula $\Rightarrow$ $W_q = L_q/\lambda$

$W = W_q + (1/\mu)$

Little's Formula $\Rightarrow$ $L = \lambda W$

Inspired by a slide by Laguna & Marklund (2004)

Example 7.9 A company designs customized electronic hardware for a range of customers in the high-tech electronics industry. The company receives orders for designing a new circuit every 20 working days on average. It takes a team of engineers on average 10 working days to design a hardware device.

This problem can be mapped to an M/M/1 model, assuming that the arrival of designs follows a Poisson process, that the distribution of times for designing a circuit follows an exponential distribution, and that new design requests are handled in a FIFO manner. Note that even though the team includes several people, they act as a monolithic entity and therefore should be treated as a single server. Let us take the working day as a time unit. On average, 0.05 orders are received per day ($\lambda = 0.05$), and 0.1 orders are fulfilled per day ($\mu = 0.1$). Thus, the resource utilization of this system $\rho = 0.05/0.1 = 0.5$. Using the formulas for M/M/1 models, we can deduce that the average length of the queue L_q is $0.5^2/(1 - 0.5) = 0.5$ orders. From there we can conclude that the average time an order spends in the queue is $W_q = 0.5/0.05 = 10$ days. Thus, it takes on average $W = 10 + 1/0.1 = 20$ working days for an order to be fulfilled. □

Tool Support

- For M/M/c systems, the exact computation of L_q is rather complex…

$$L_q = \sum_{n=c}^{\infty}(n-c)P_n = \ldots = \frac{(\lambda/\mu)^c \rho}{c!(1-\rho)^2} P_0$$

$$P_0 = \left(\sum_{n=0}^{c-1} \frac{(\lambda/\mu)^n}{n!} + \frac{(\lambda/\mu)^c}{c!} \cdot \frac{1}{1-(\lambda/(c\mu)} \right)^{-1}$$

- Consider using a tool, e.g.
  - http://www.supositorio.com/rcalc/rcalclite.htm
  - http://queueingtoolpak.org/ (for Excel)

Example – ER at County Hospital

- Situation
  - Patients arrive according to a Poisson process with intensity λ ($\Leftrightarrow$ the time between arrivals is exp(λ) distributed.
  - The service time (the doctor's examination and treatment time of a patient) follows an exponential distribution with mean $1/\mu$ (=exp(μ) distributed)
  - $\Rightarrow$ *The ER can be modeled as an M/M/c system where c = the number of doctors*
- Data gathering
  - $\Rightarrow$ λ = 2 patients per hour
  - $\Rightarrow$ μ = 3 patients per hour
- Question
  - Should the capacity be increased from 1 to 2 doctors?

Inspired by a slide by Laguna & Marklund (2004)

Queuing Analysis – Hospital Scenario

- Interpretation
  - To be in the queue = to be in the waiting room
  - To be in the system = to be in the ER (waiting or under treatment)

Characteristic	One doctor (c=1)	Two Doctors (c=2)
ρ	2/3	1/3
L_q	4/3 patients	1/12 patients
L	2 patients	3/4 patients
W_q	2/3 h = 40 minutes	1/24 h = 2.5 minutes
W	1 h	3/8 h = 22.5 minutes

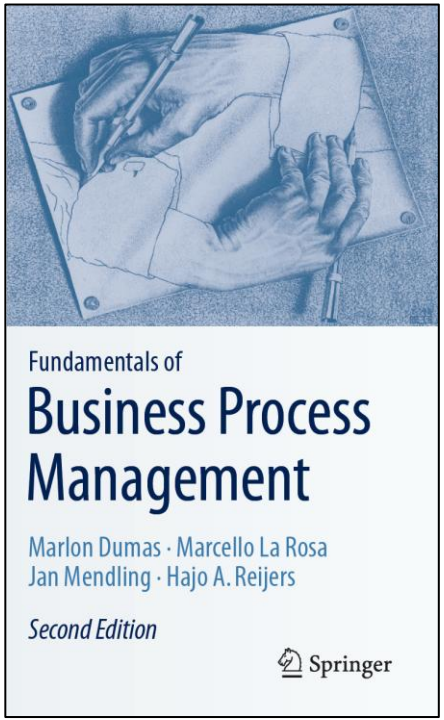
- Should we increase the capacity from one to two doctors?

Inspired by a slide by Laguna & Marklund (2004)

Limitations of basic queuing models

- Can be used to analyze waiting times (and hence cycle times), but not cost or quality measures
- Suitable for analyzing one single activity at a time, performed by one single resource pool. Not suitable for analyzing end-to-end processes consisting of multiple activities performed by multiple resource pools.
- These limitations are addressed by process simulation

Chapter 7: Quantitative Process Analysis



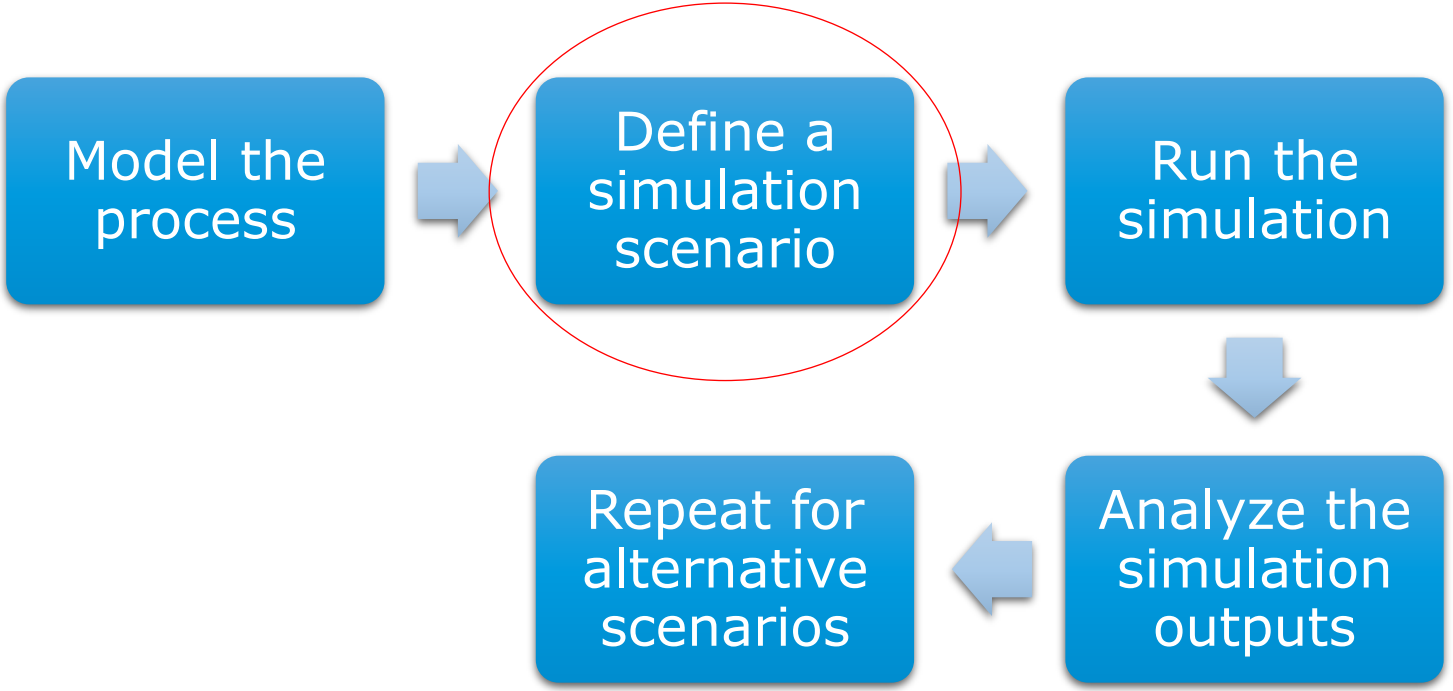
Contents

1. Value-Added Analysis
2. Queuing analysis
3. Simulation
4. Recap

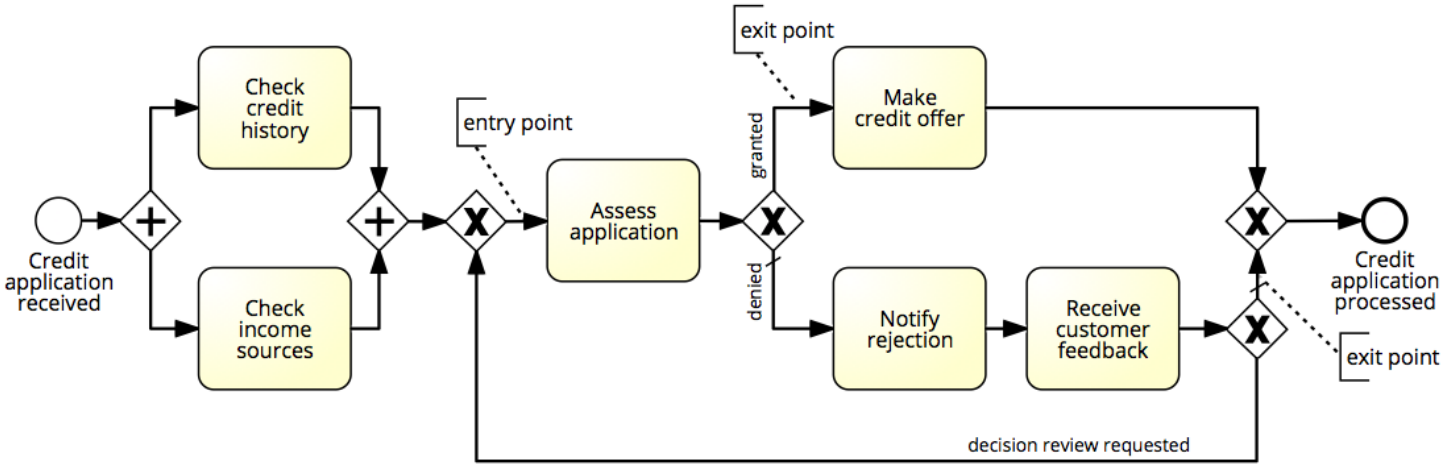
Process Simulation

- Versatile quantitative analysis method for
  - As-is analysis
  - What-if analysis
- In a nutshell:
  - Run a large number of process instances
  - Gather performance data (cost, time, resource usage)
  - Calculate statistics from the collected data

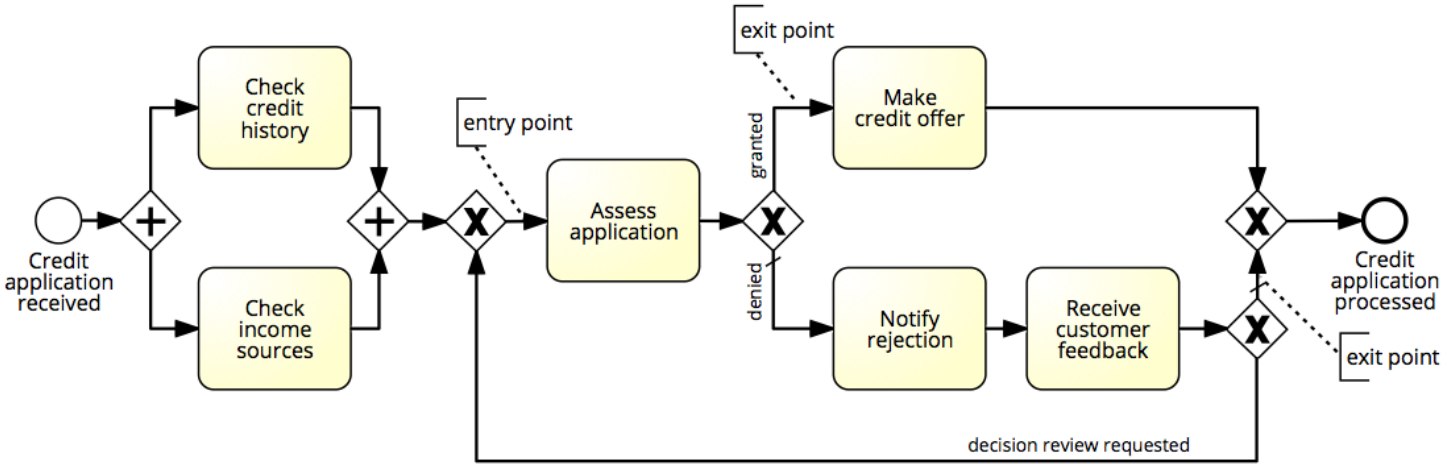
Process Simulation



Example


Credit application received
Check credit history
Check income sources
entry point
Assess application
granted
denied
exit point
Make credit offer
Notify rejection
Receive customer feedback
Credit application processed
exit point
decision review requested

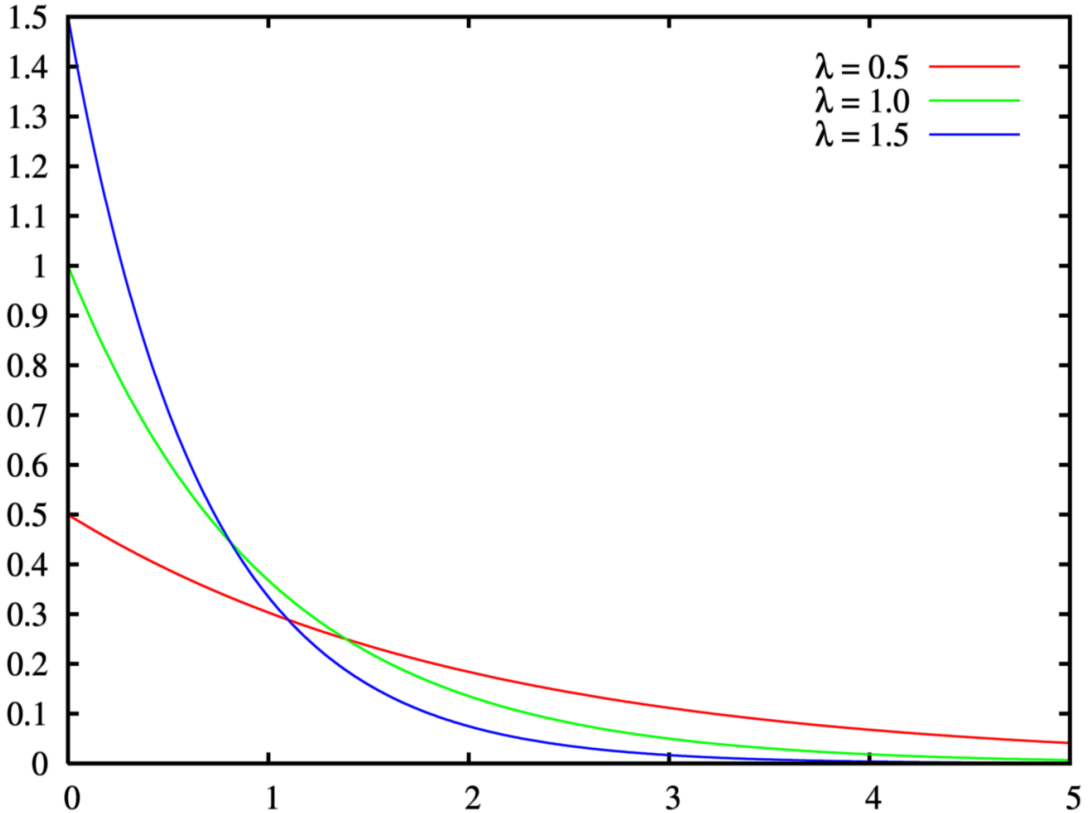
Example


Credit application received
Check credit history
Check income sources
entry point
Assess application
granted
denied
exit point
Make credit offer
Notify rejection
Receive customer feedback
Credit application processed
exit point
decision review requested

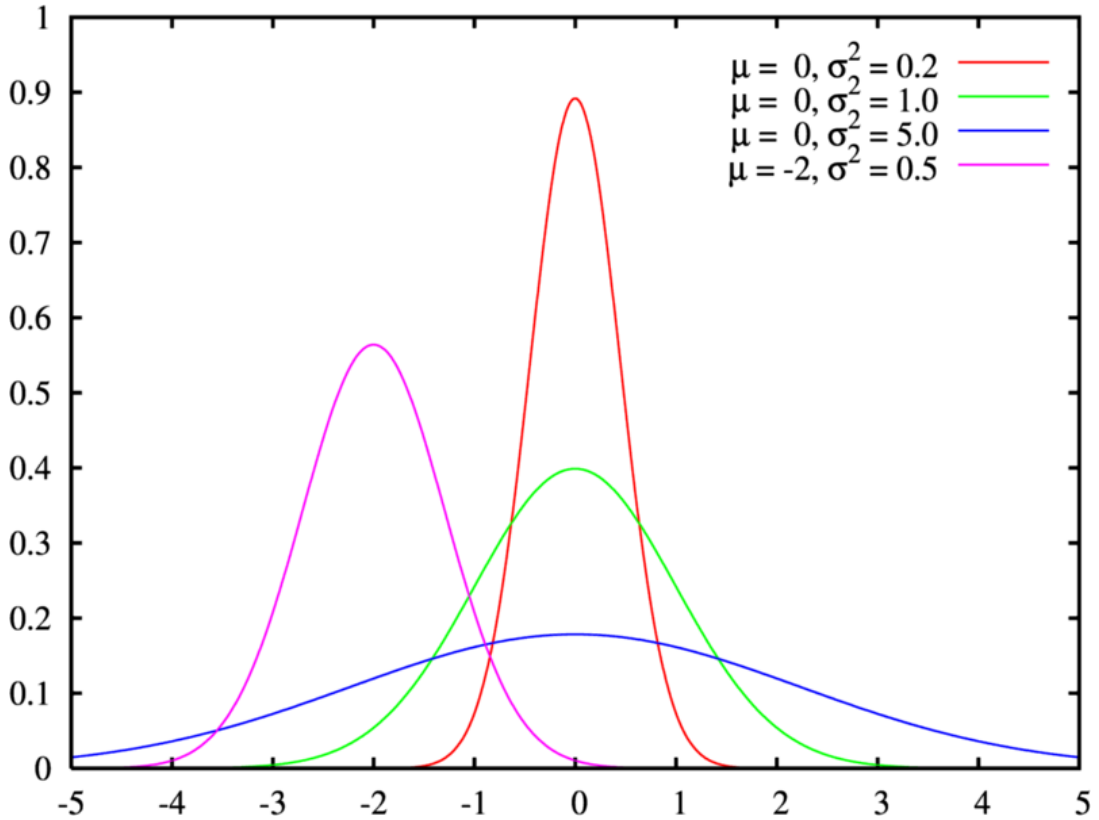
Elements of a simulation scenario

1. Processing times of activities
   - Fixed value
   - Probability distribution

Exponential Distribution



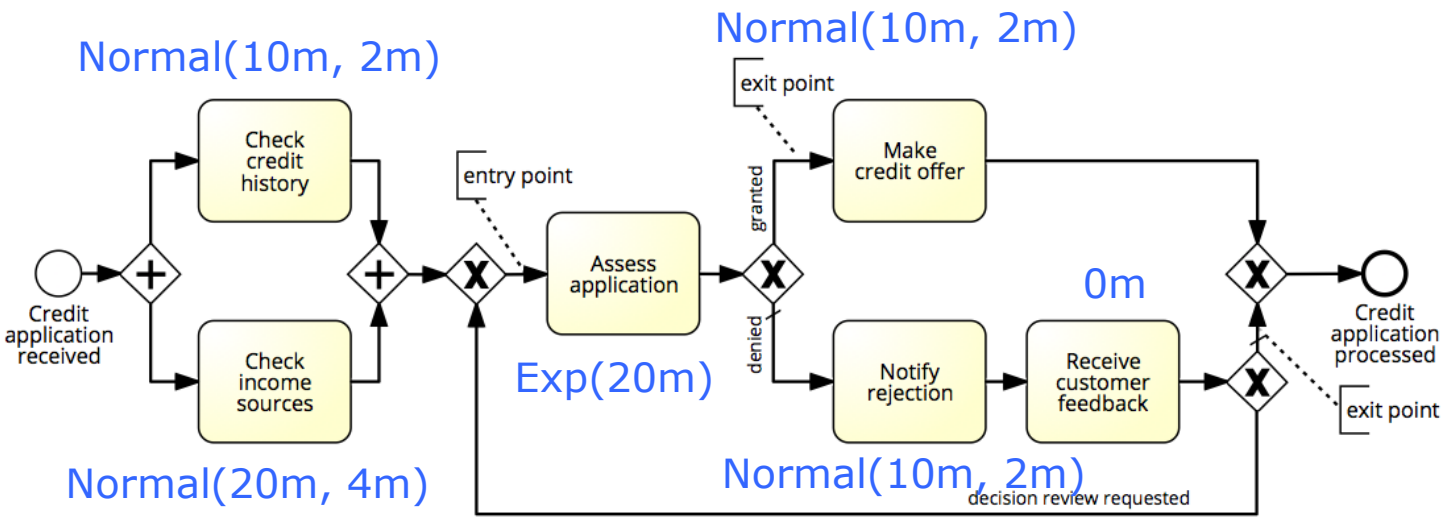
Normal Distribution



Choice of probability distribution

- Fixed
  - Rare, can be used to approximate case where the activity processing time varies very little
  - Example: a task performed by a software application
- Normal
  - Repetitive activities
  - Example: “Check completeness of an application”
- Exponential
  - Complex activities that may involve analysis or decisions
  - Example: “Assess an application”

Simulation Example

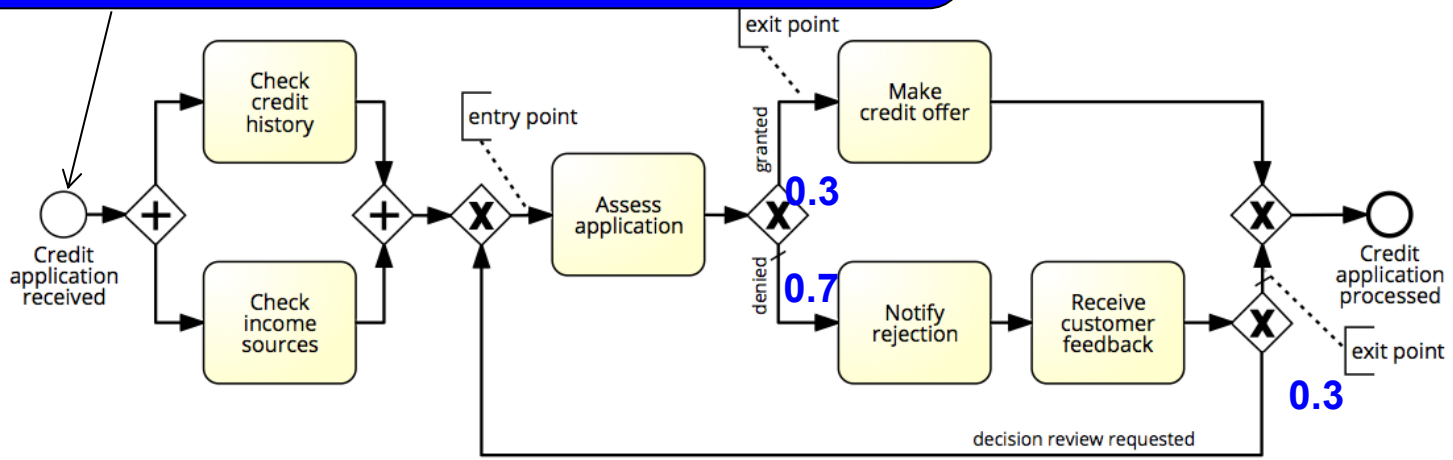


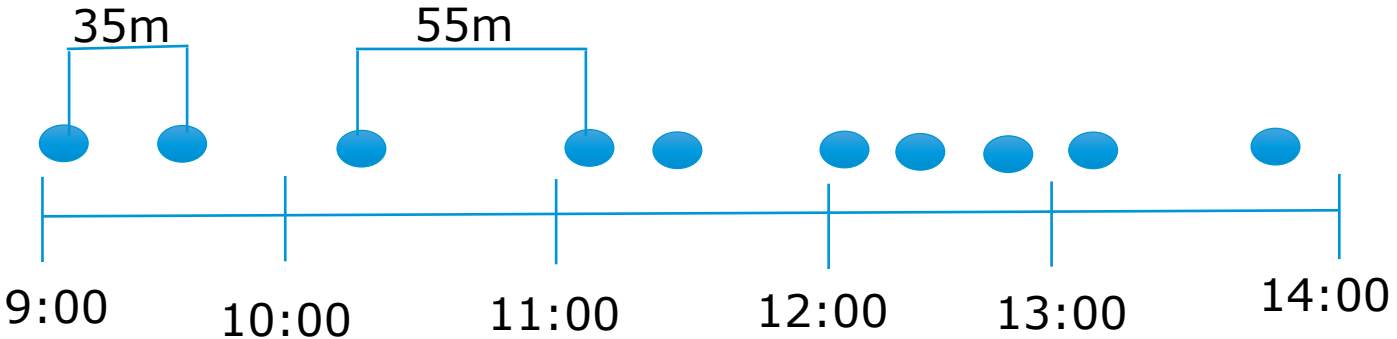
Elements of a simulation model

1. Processing times of activities
   - Fixed value
   - Probability distribution
2. Conditional branching probabilities
3. Arrival rate of process instances and probability distribution
   - Typically exponential distribution with a given mean inter-arrival time
   - Arrival calendar, e.g. Monday-Friday, 9am-5pm, or 24/7

Branching probability and arrival rate

Arrival rate = 2 applications per hour
Inter-arrival time = 0.5 hour
Negative exponential distribution
From Monday-Friday, 9am-5pm





Elements of a simulation model

1. Processing times of activities
   - Fixed value
   - Probability distribution
2. Conditional branching probabilities
3. Arrival rate of process instances
   - Typically exponential distribution with a given mean inter-arrival time
   - Arrival calendar, e.g. Monday-Friday, 9am-5pm, or 24/7
4. Resource pools

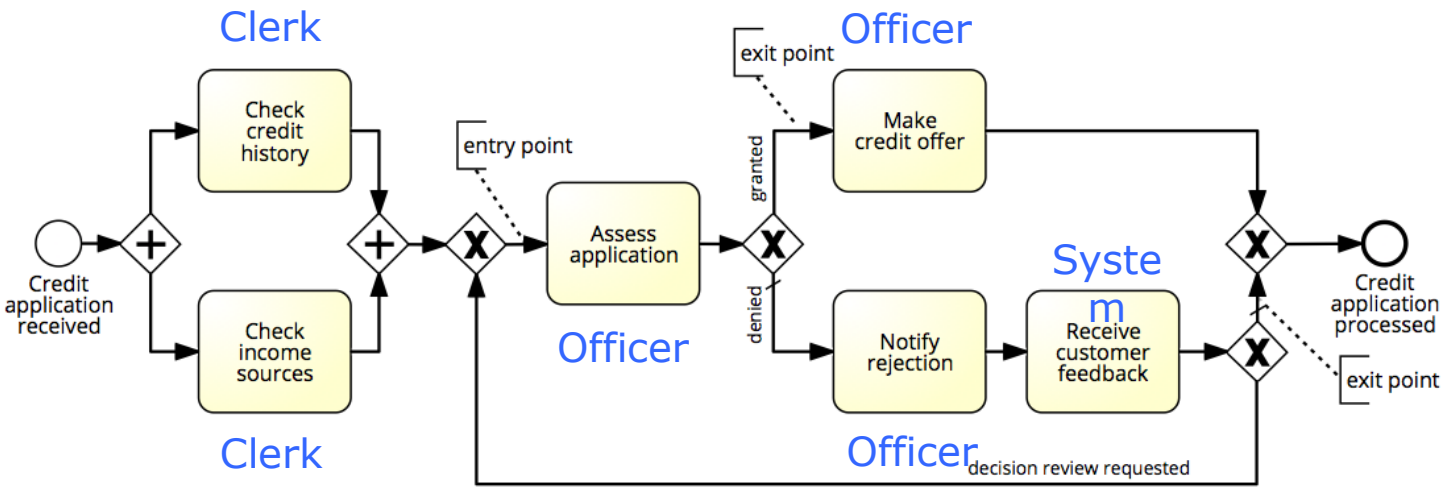
Resource pools

- Name
- Size of the resource pool
- Cost per time unit of a resource in the pool
- Availability of the pool (working calendar)
- Examples
  - Clerk — Credit Officer
  - € 25 per hour — € 25 per hour
  - Monday-Friday, 9am-5pm — Monday-Friday, 9am-5pm
- In some tools, it is possible to define cost and calendar per resource, rather than for entire resource pool

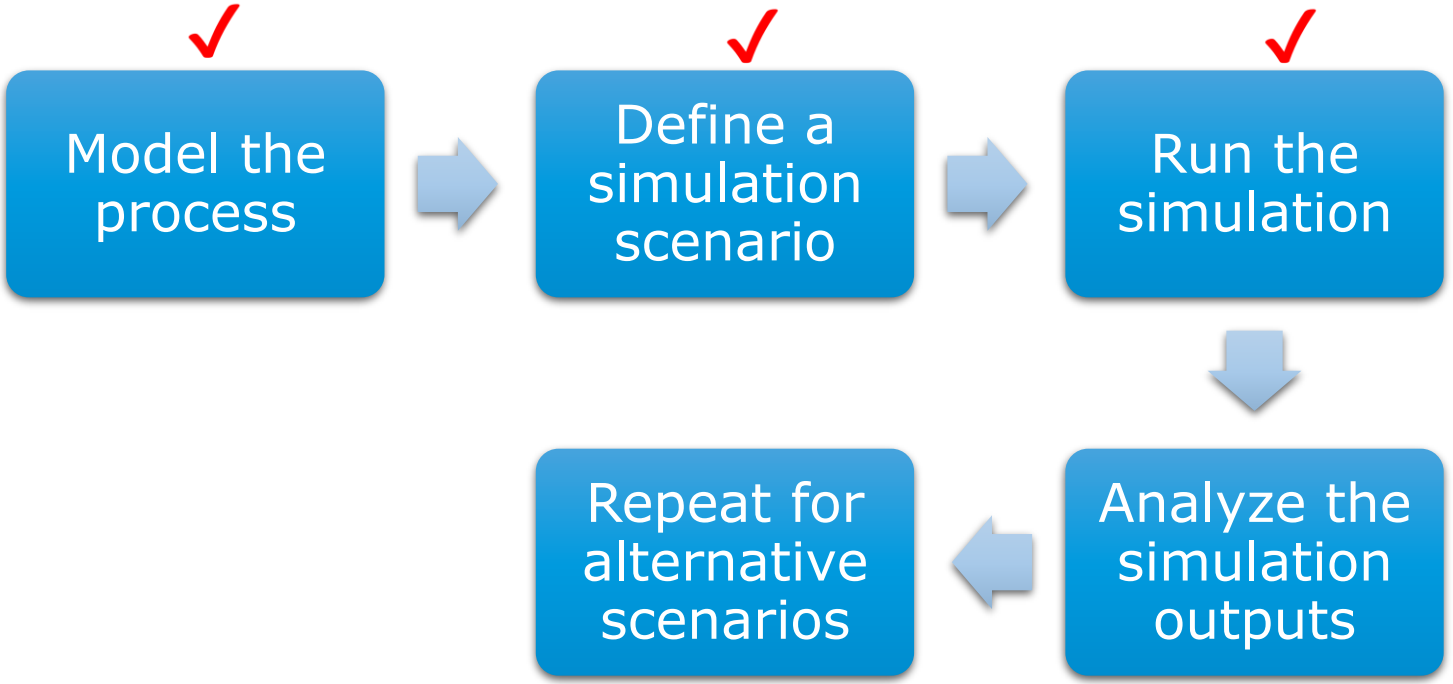
Elements of a simulation model

1. Processing times of activities
   - Fixed value
   - Probability distribution
2. Conditional branching probabilities
3. Arrival rate of process instances and probability distribution
   - Typically exponential distribution with a given mean inter-arrival time
   - Arrival calendar, e.g. Monday-Friday, 9am-5pm, or 24/7
4. Resource pools
5. Assignment of tasks to resource pools

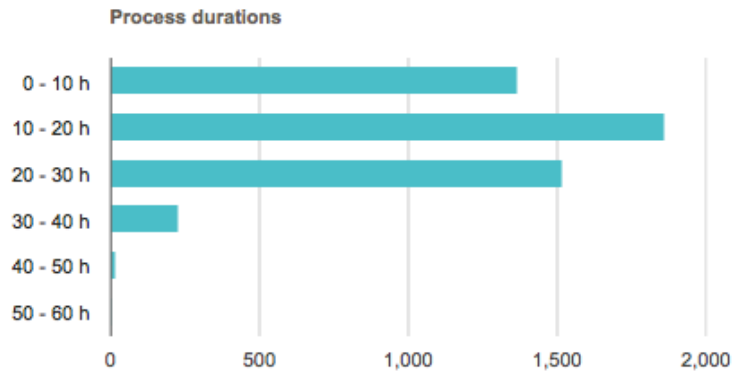
Resource pool assignment

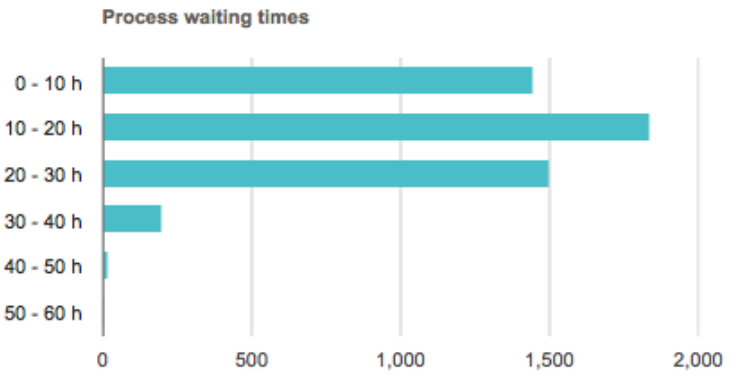


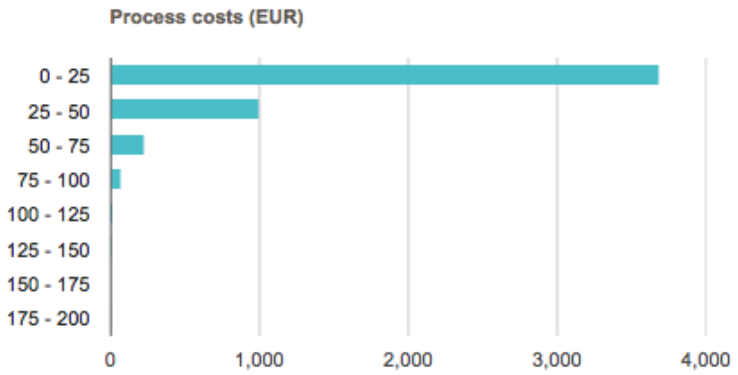
Process Simulation

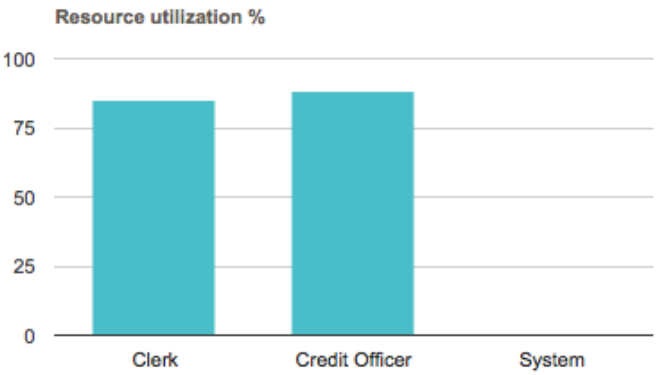


Output: Performance measures & histograms

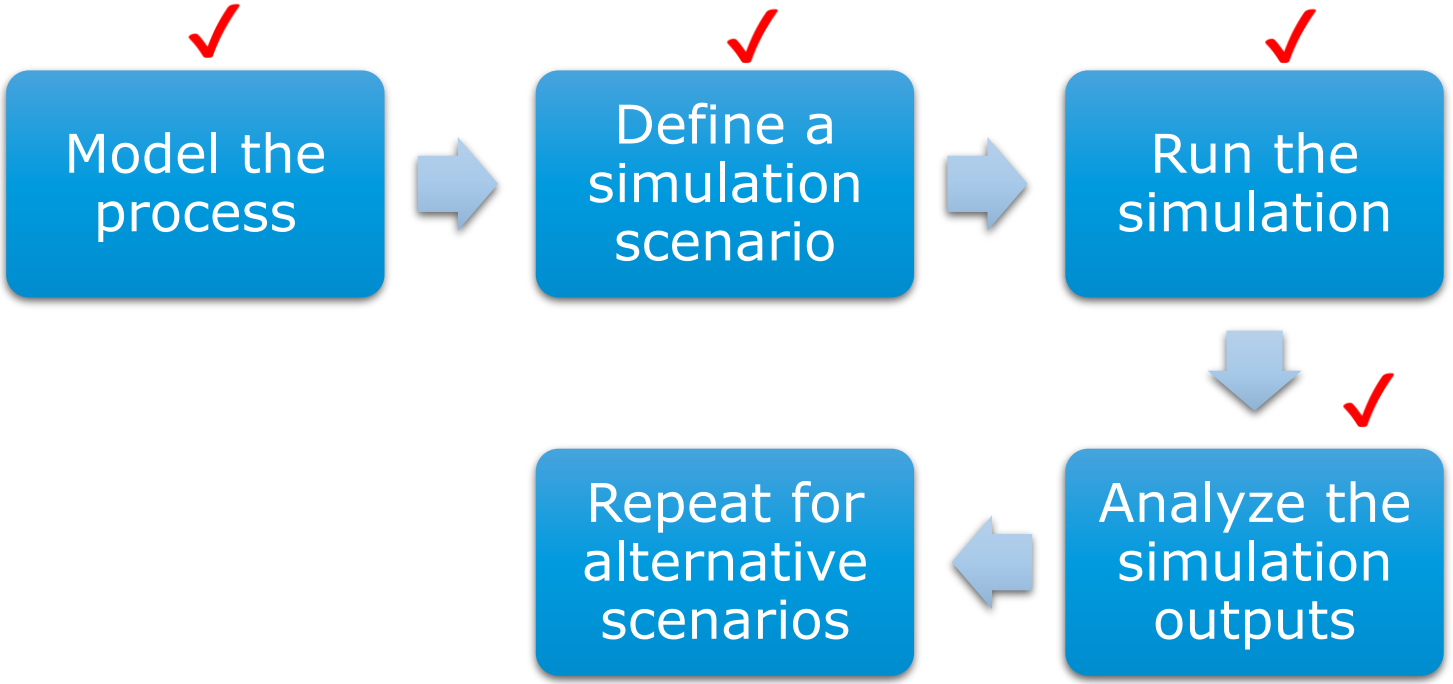








Process Simulation



Tools for Process Simulation

- ARIS
- **Bizagi Process Modeler**
- ITP Commerce Process Modeler for Visio
- Logizian
- Oracle BPA
- Progress Savvion Process Modeler
- ProSim
- Signavio + BIMP

3. BPMN SIMULATION (USING BIZAGI)

3.1 PROCESS VALIDATION

3.2 TIME ANALYSIS

3.3 RESOURCE ANALYSIS

3.4 CALENDAR ANALYSIS

Tujuan Simulasi

- Mengevaluasi performance dari model, dengan menggunakan berbagai ragam konfigurasi dan waktu
- Mengurangi kemungkinan kegagalan pemenuhan kebutuhan dan mengatasi *bottleneck* yang sulit diprediksi
- Mencegah under dan over-utilization dari resource (uang dan orang)
- Mengoptimisasi performance dari sistem

Level dan Tahapan Simulasi

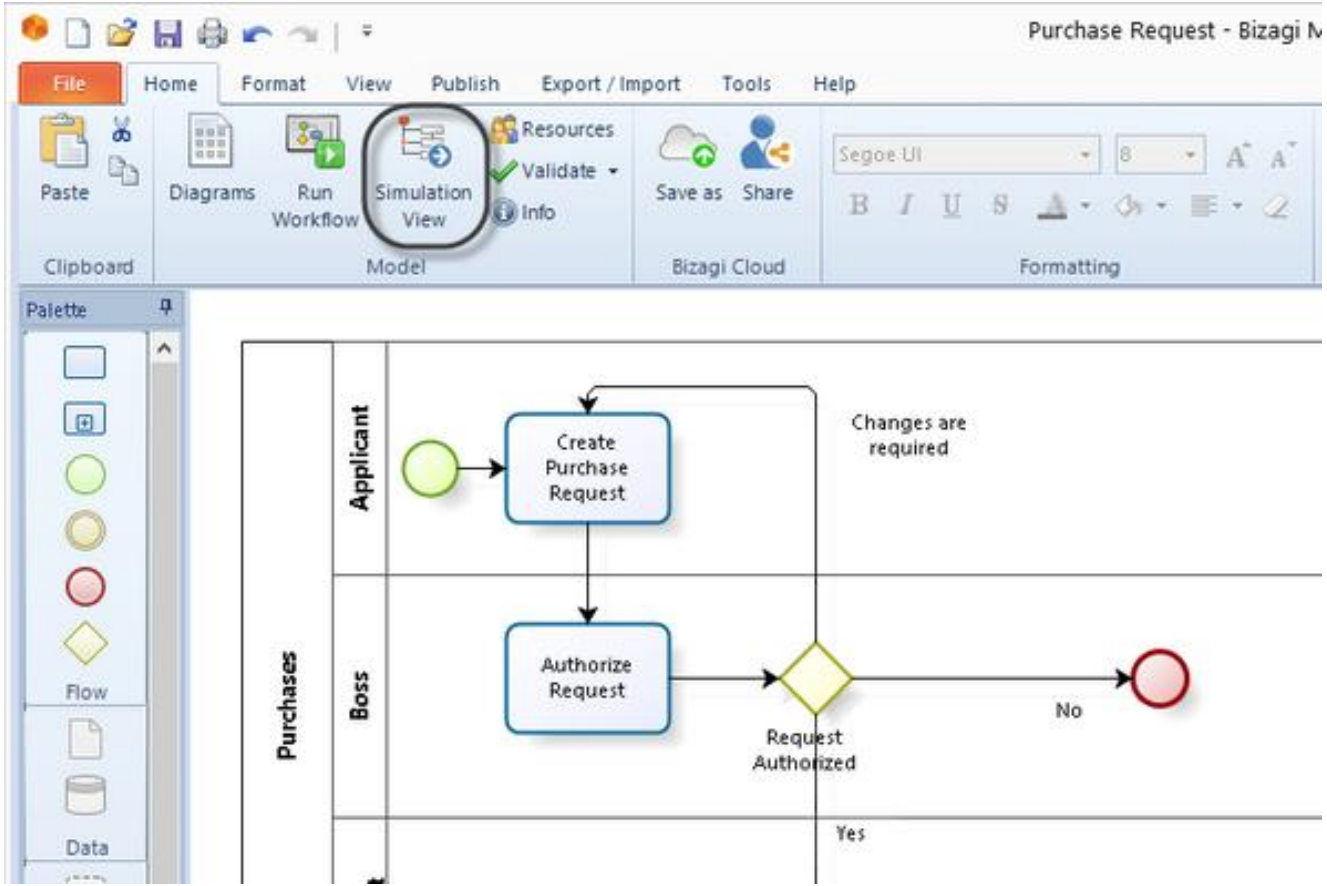
- Level dari simulasi meliputi:
  - Level 1 -Process Validation
  - Level 2- Time Analysis
  - Level 3 - Resources Analysis
  - Level 4 - Calendars Analysis

- Tahapan pada setiap proses simulasi:
  1. Kumpulkan data untuk simulasi proses
  2. Tambahkan data ke obyek yang relevan pada diagram
  3. Interpretasikan dan tampilkan hasil simulasi

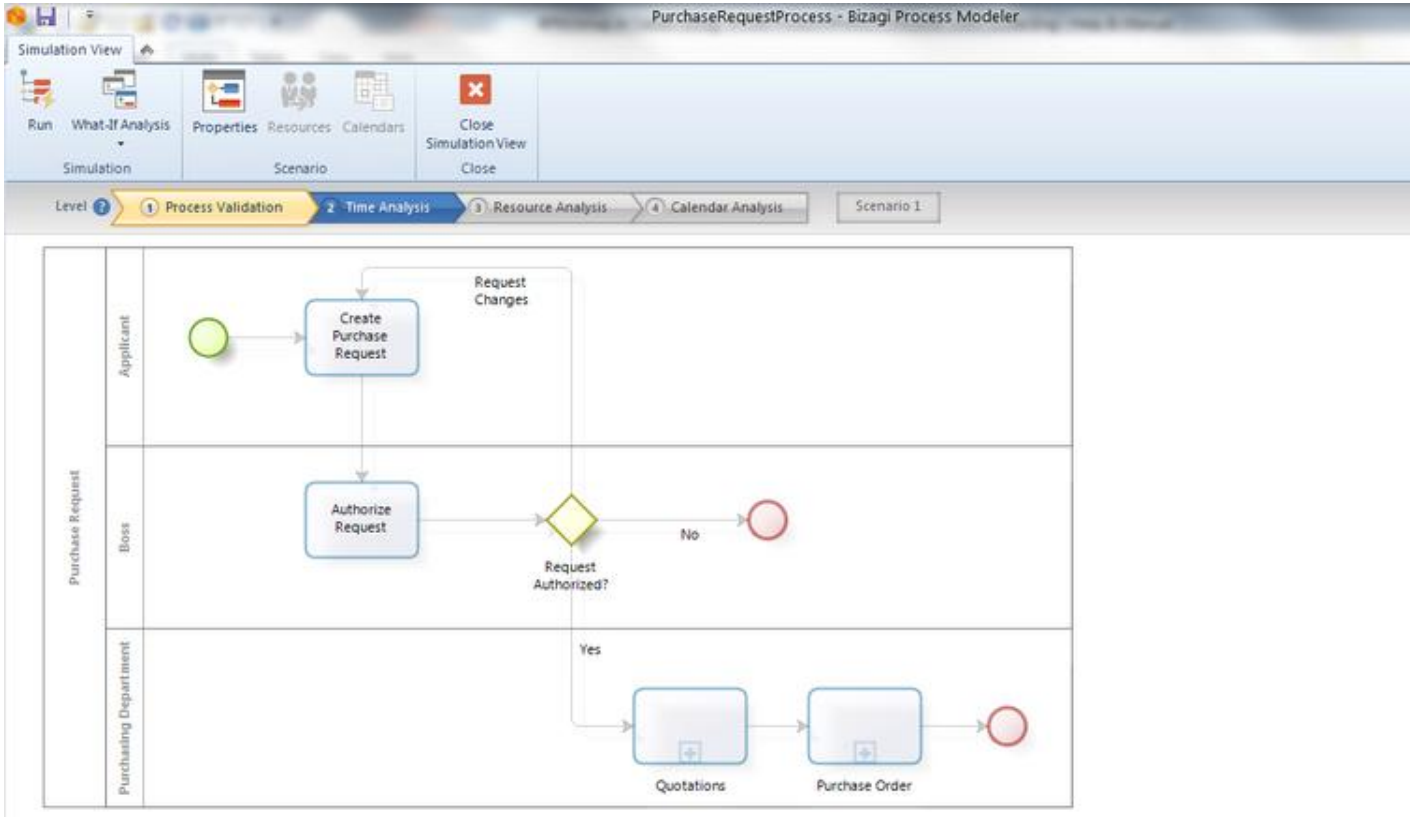
Elemen dan Notasi yang Didukung

- Elemen yang tidak didukung:
  - Multiple events
  - Complex gateways
  - Event based gateways
  - Multiple instance tasks
  - Multiple instance Sub-processes
- Notasi yang tidak didukung:
  - BPMN Choreography diagrams
  - BPMN Conversation diagrams
  - Transactional Subprocess

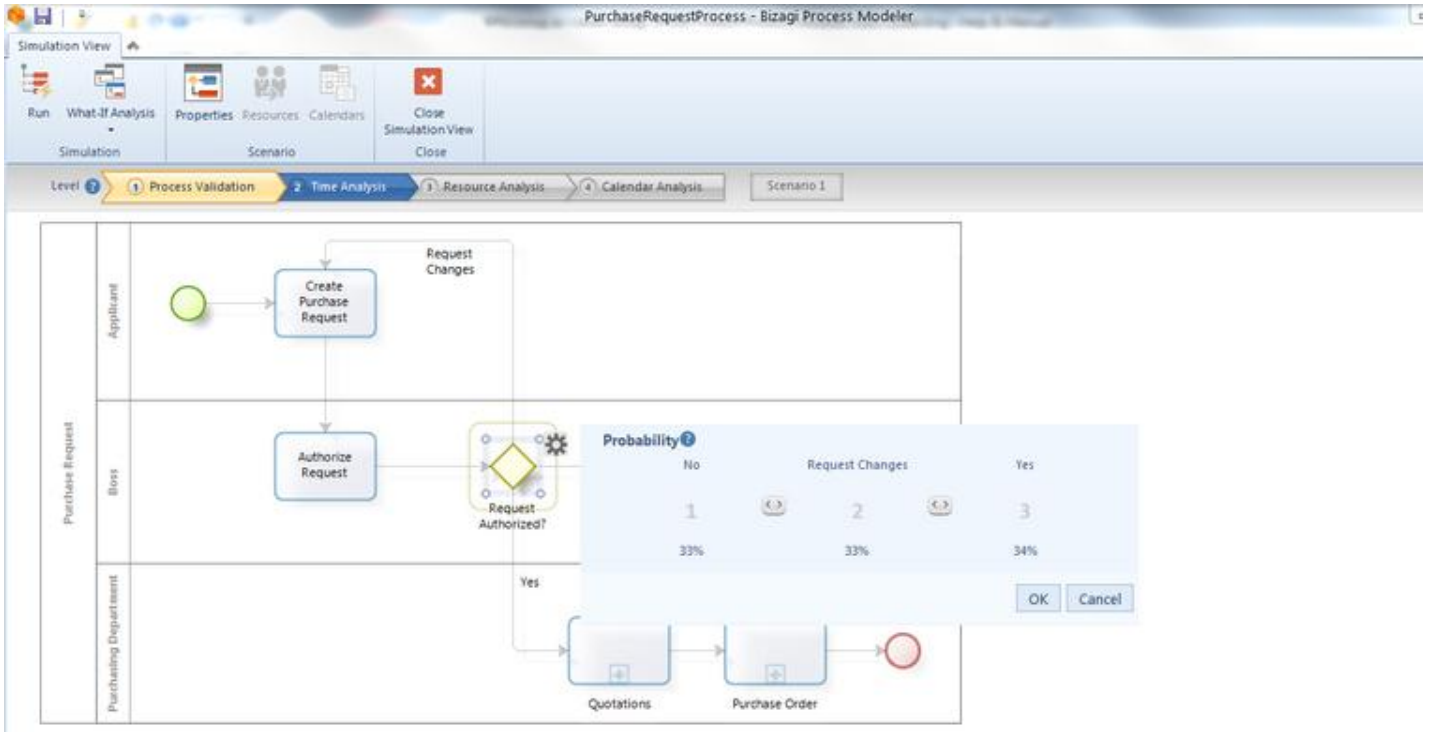
1. Klik *Simulation View*



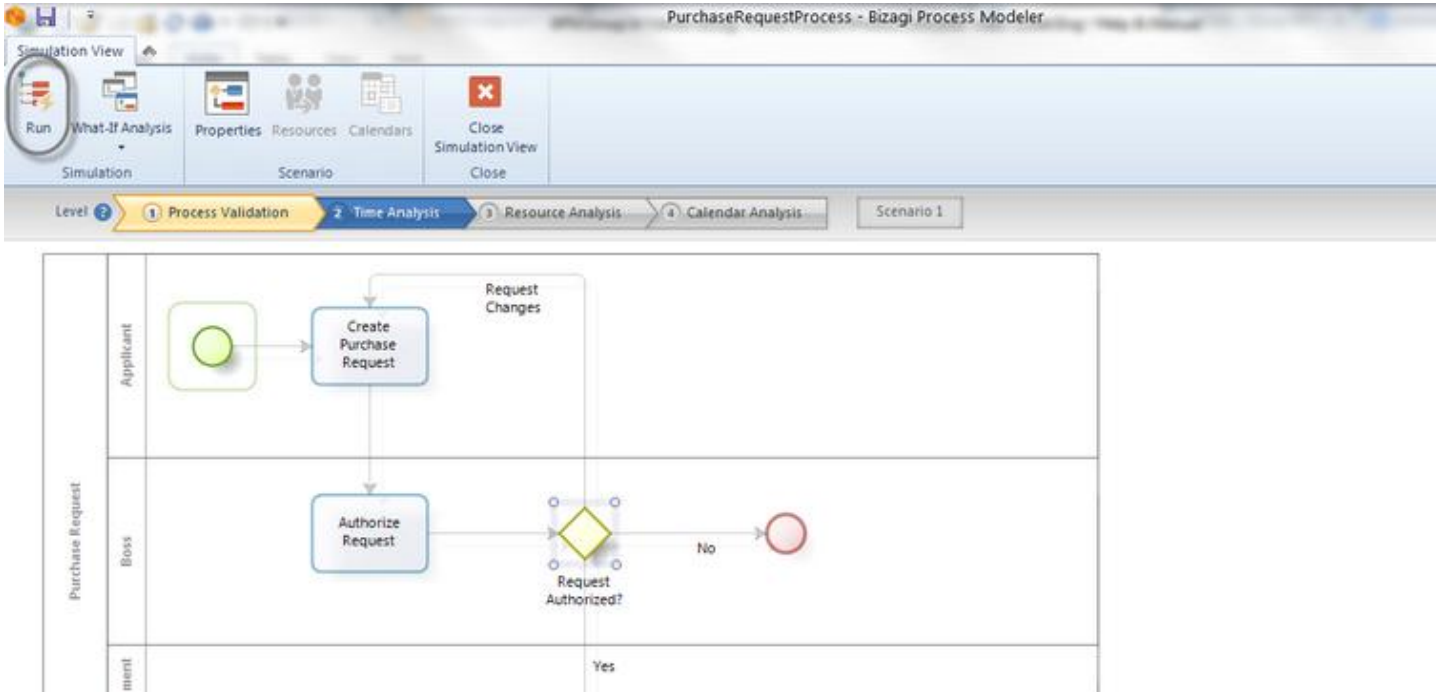
2. Obyek yang Perlu Data Berwarna Terang



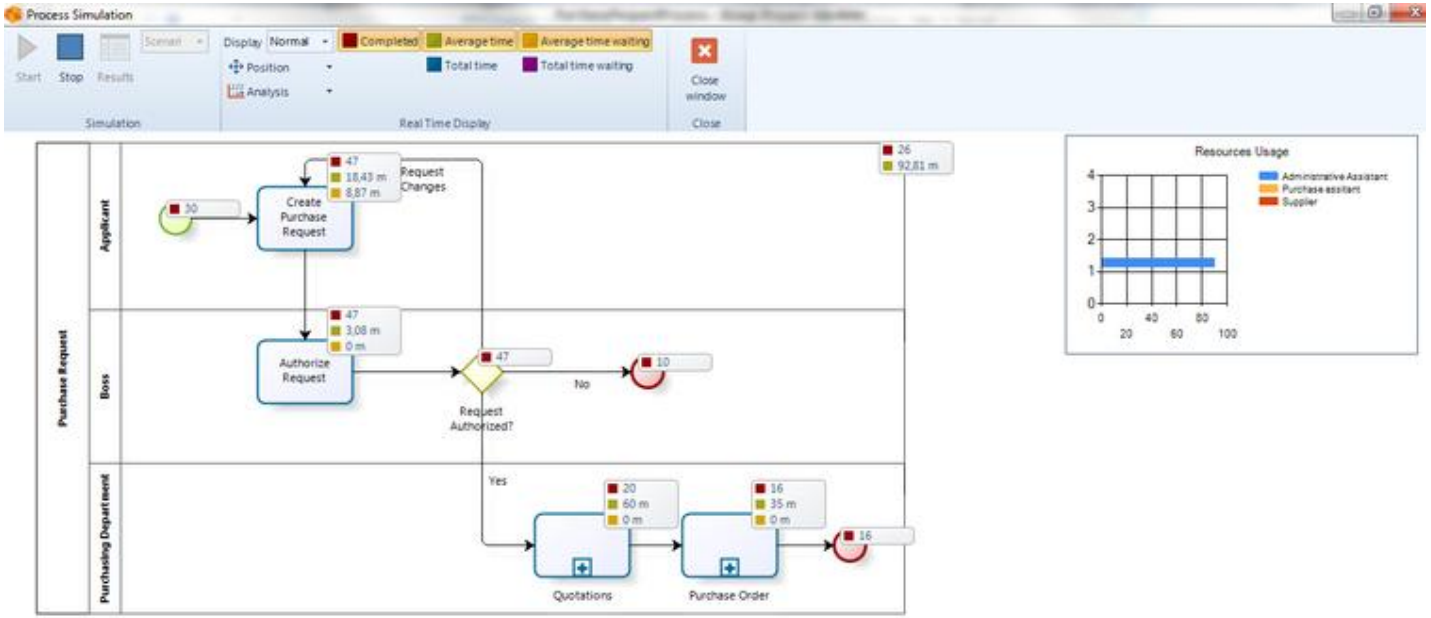
3. Pilih Obyek dan Isikan Data



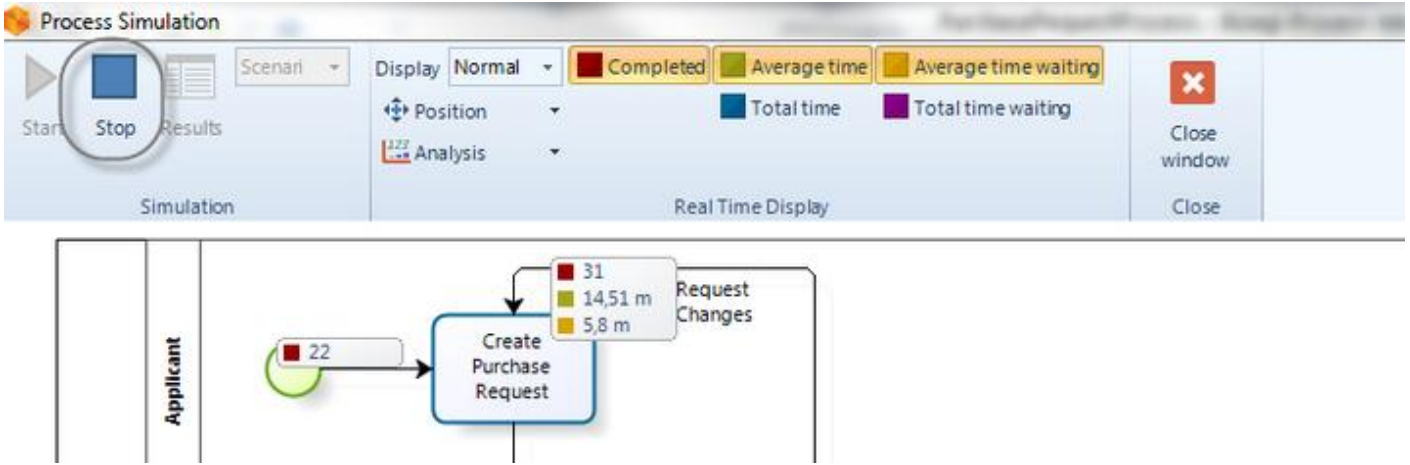
4. Klik *Run* untuk Masuk ke Simulasi



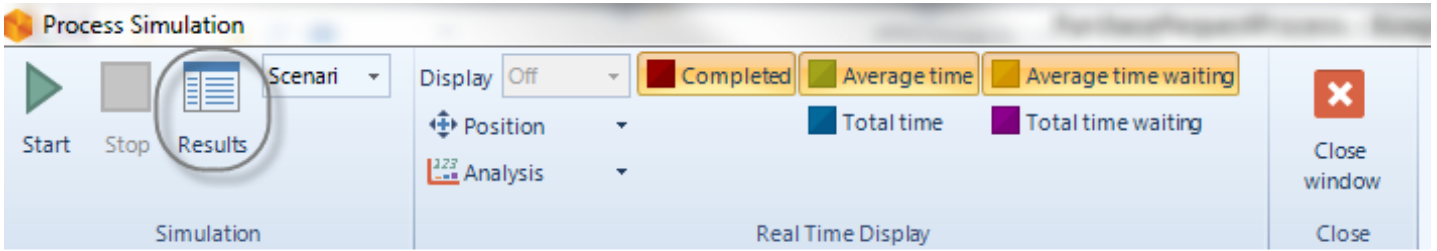
5. Klik *Start* untuk Memulai Simulasi

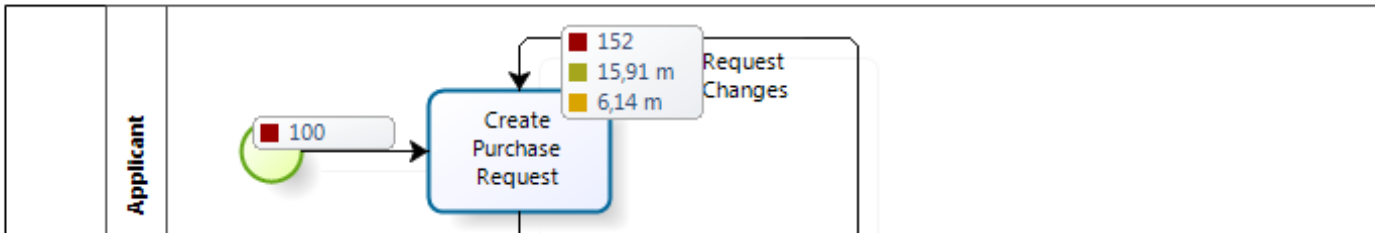


6. Klik *Stop* untuk Menghentikan Simulasi



7. Klik *Results* untuk Melihat Hasil





8. Klik *Export to Excel* untuk Menyimpan hasil

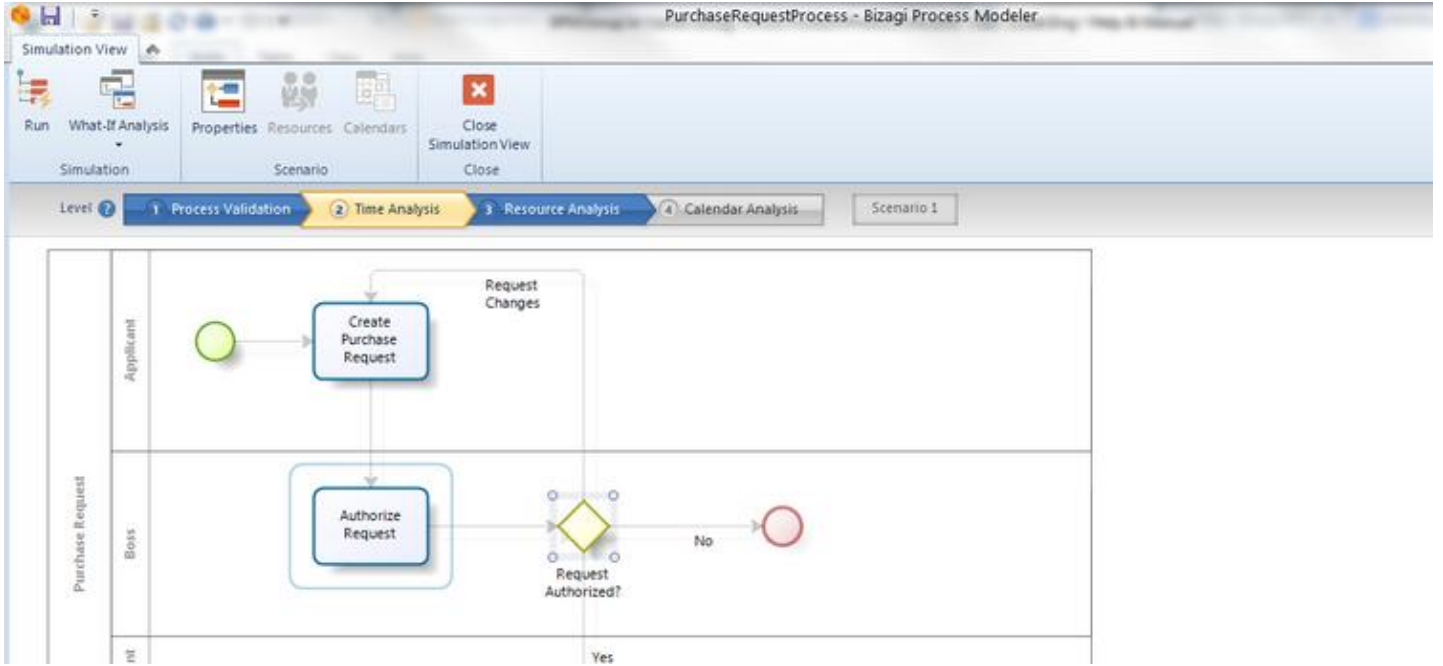
Simulation Results

Purchase Request

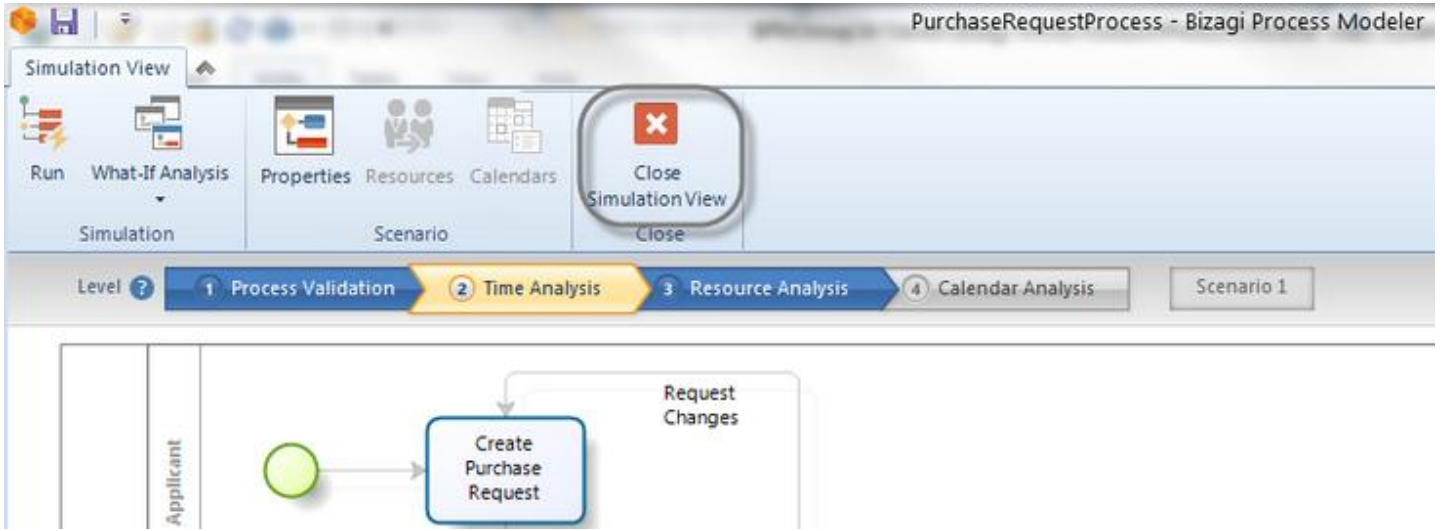
Name	Type	Tokens completed	Tokens started	Min. time	Max. time	Avg. time	Total time
Purchase Request	Process	100	100	8,39 m	169,25 m	71,77 m	7177,17 m
NoneStart	Start event	100					
Create Purchase Request	Task	153	153	4,22 m	15,59 m	9,78 m	1496,07 m
Authorize Request	Task	153	153	0,72 m	5,53 m	2,98 m	456,1 m
Request Authorized?	Gateway	153	153				
NoneEnd	End event	45					
NoneEnd	End event	55					
Purchase Order	Process	55	55	103,57 m	169,25 m	114,93 m	1925 m
Quotations	Process	55	55	68,57 m	134,25 m	79,93 m	3300 m

Export to Excel

9. Lanjutkan Simulasi ke Level Berikutnya dengan Mengulang Tahap 1-9



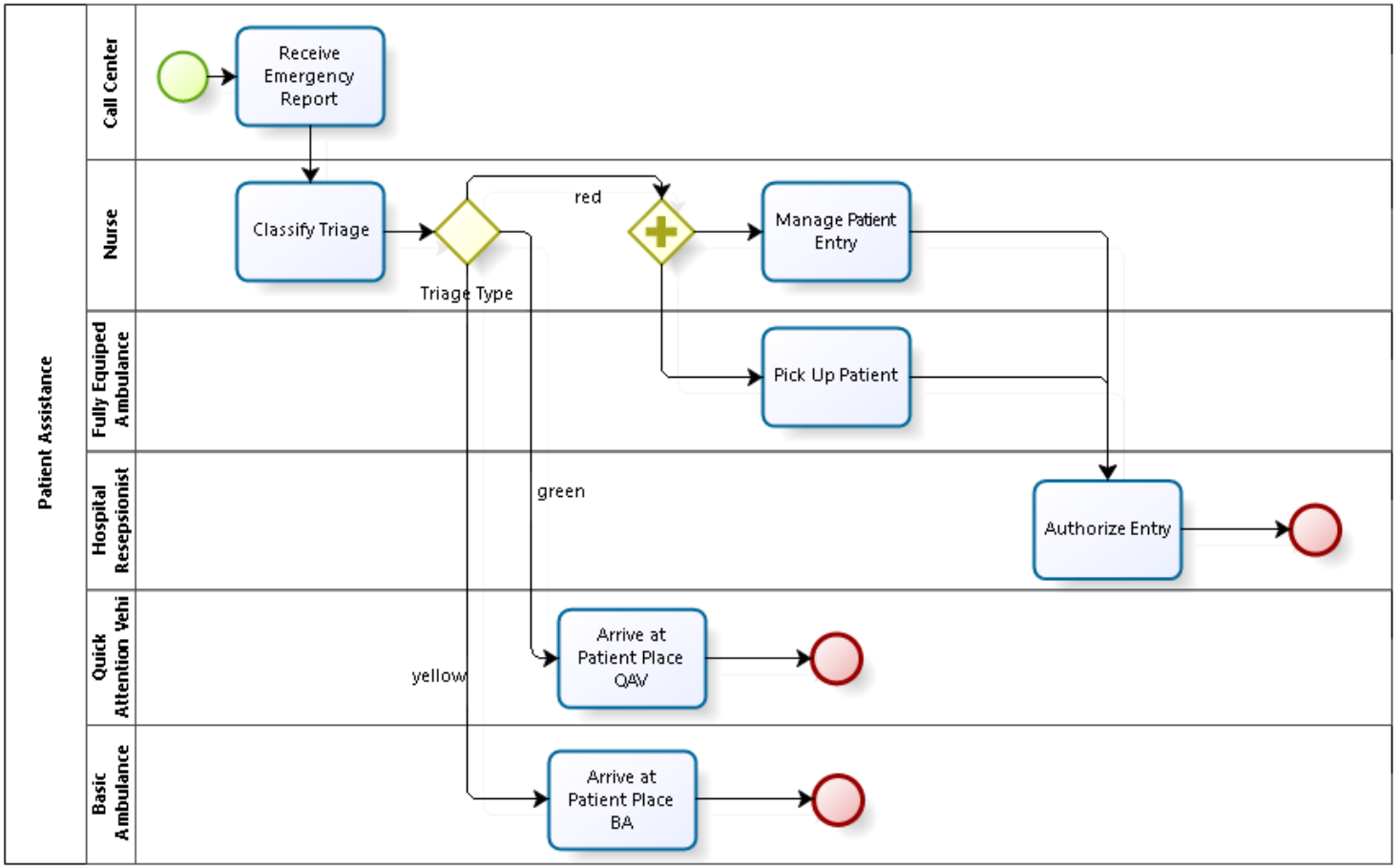
10. Klik *Close Simulation View* untuk Selesai



Case Study: Patient Assistance

- A call center receives a report of an emergency. A call center agent enters details on the person affected, the symptoms and the physical address
- A qualified nurse classifies the emergency according to its severity
  - Green: Low severity. The patient can be easily stabilized
  - Yellow: Medium severity. The patient requires special attention but can be stabilized at the place of emergency
  - Red: High severity. The patient must be collected and taken to the nearest hospital
- According to the priority assigned, the Emergency attendance department presents a different level of response
  - Green: This triage is assisted by a quick response vehicle carrying two people: a paramedic and a doctor
  - Yellow: This triage is assisted by a basic ambulance having a doctor, nurse and a paramedic on Board
  - Red: This triage is assisted by a fully equipped ambulance holding two doctors, a nurse and a paramedic
- This process must be carefully analyzed in order to reduce the time between receiving the request and providing medical assistance

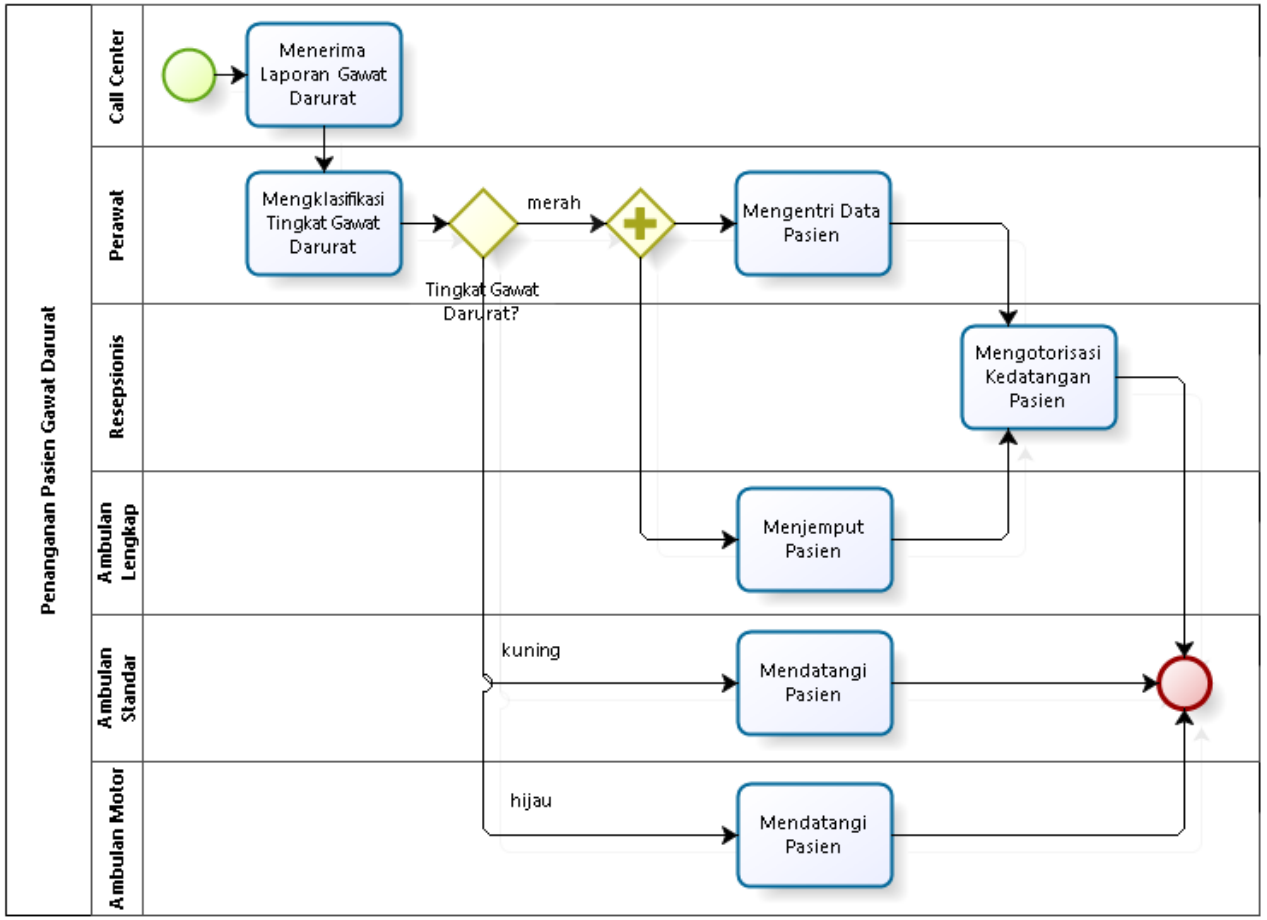
Case Study: Patient Assistance



Case Study: Penanganan Pasien Gawat Darurat

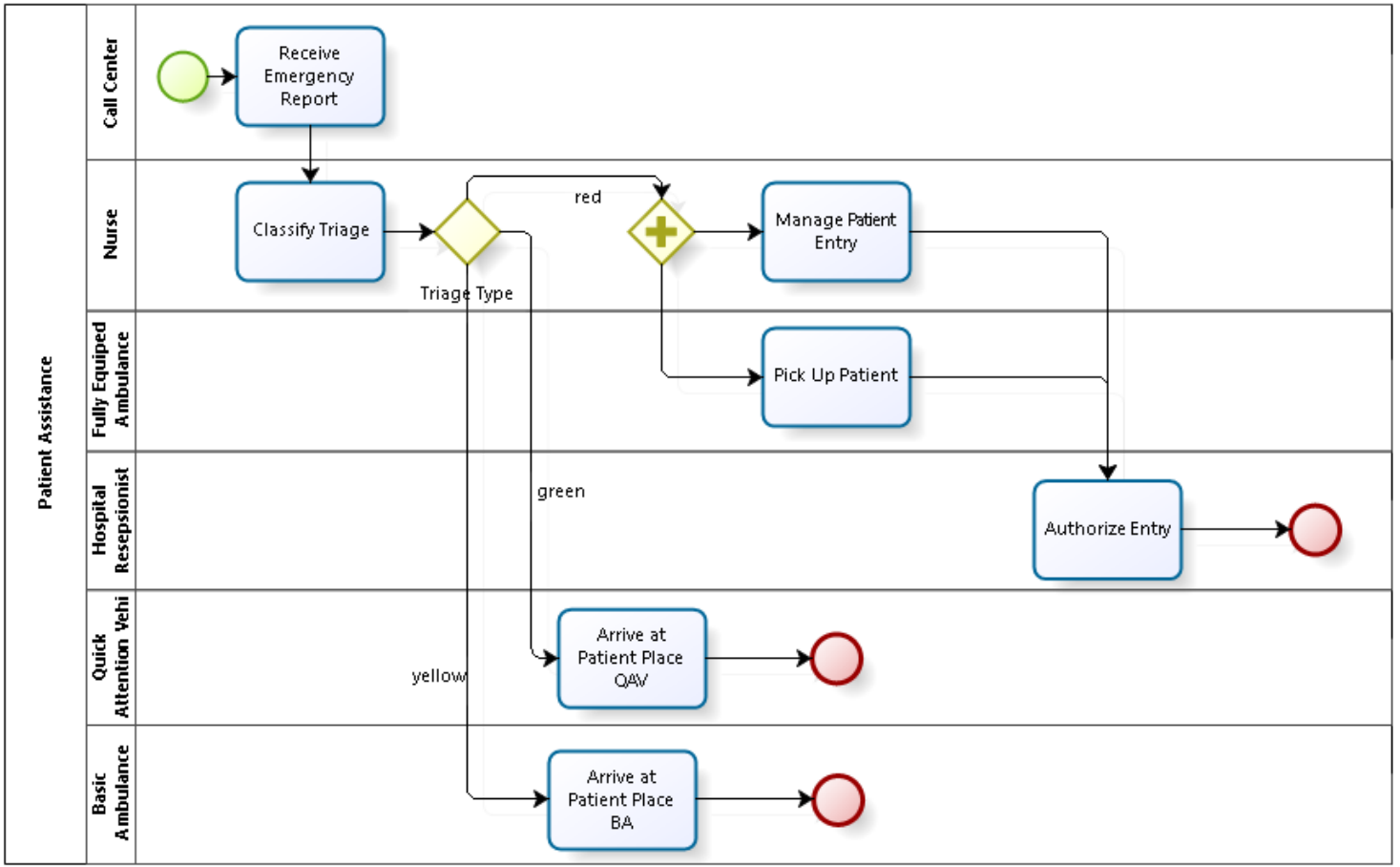
- Call Center menerima laporan gawat darurat, kemudian mencatat data gejala dan alamat lengkap pelapor
- Perawat mengklasifikasi tingkat kegawatan pelapor
  1. **Green**: Rendah
     - Bisa disembuhkan di lokasi
     - Mengirimkan ambulan motor dengan satu dokter dan satu perawat
  2. **Yellow**: Sedang
     - Perlu perhatian khusus, tapi bisa disembuhkan di lokasi
     - Mengirimkan ambulan standar dengan satu dokter, satu perawat dan satu paramedis
  3. **Red**: Tinggi
     - Perlu dijemput dan dibawa ke rumah sakit
     - Mengirimkan ambulan lengkap dengan dua dokter, satu perawat, dan satu paramedis
- Proses bisnis ini perlu dianalisis dan disimulasi untuk bisa menentukan service level agreement waktu dan jumlah penanganan pasien, dan menganalisis kebutuhan SDM yang dibutuhkan

Penanganan Pasien Gawat Darurat

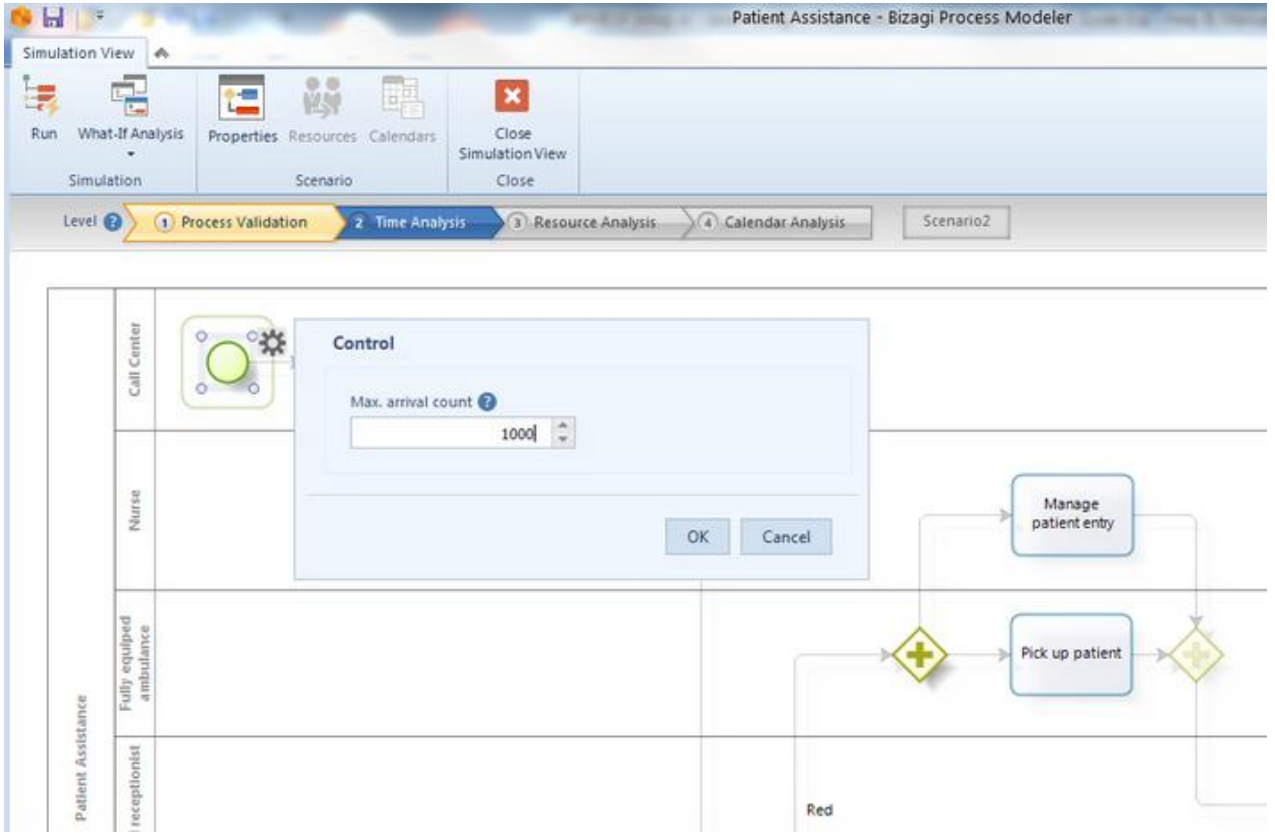


3.1 PROCESS VALIDATION

Case Study: Patient Assistance

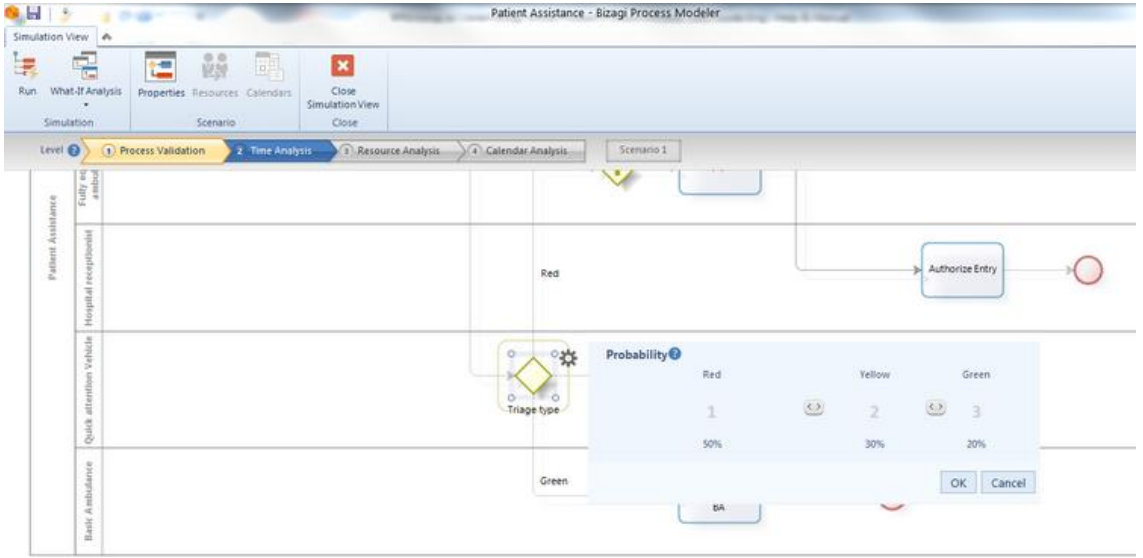


1. Set the Max. Arrival Count = 1000



2. Define the Probabilities for Gateway

- Suppose the emergency department has estimated, based on historical data, that the probabilities for the different sequence flows are:
  - Green: 20%
  - Yellow: 30%
  - Red: 50%
- Define each probability for the Gateway named Triage type



3. Click the Run and Start button

Patient Assistance - Bizagi Process Modeler

Simulation View

Run | What-If Analysis | Properties | Resources | Calendars | Close Simulation View

Simulation | Scenario | Close

Level: 1 Process Validation | 2 Time Analysis | 3 Resource Analysis | 4 Calendar Analysis | Scenario 1

Call Center | Nurse | Fully equiped ambulance | Hospital receptionist

Receive Emergency Report

Process Simulation

Start | Stop | Results | Scenari | Display Off | Completed | Position | Analysis | Close window

Simulation | Real Time Display | Close

Patient Assistance

Receive Emergency Report (1000)

Classify Triage (1000)

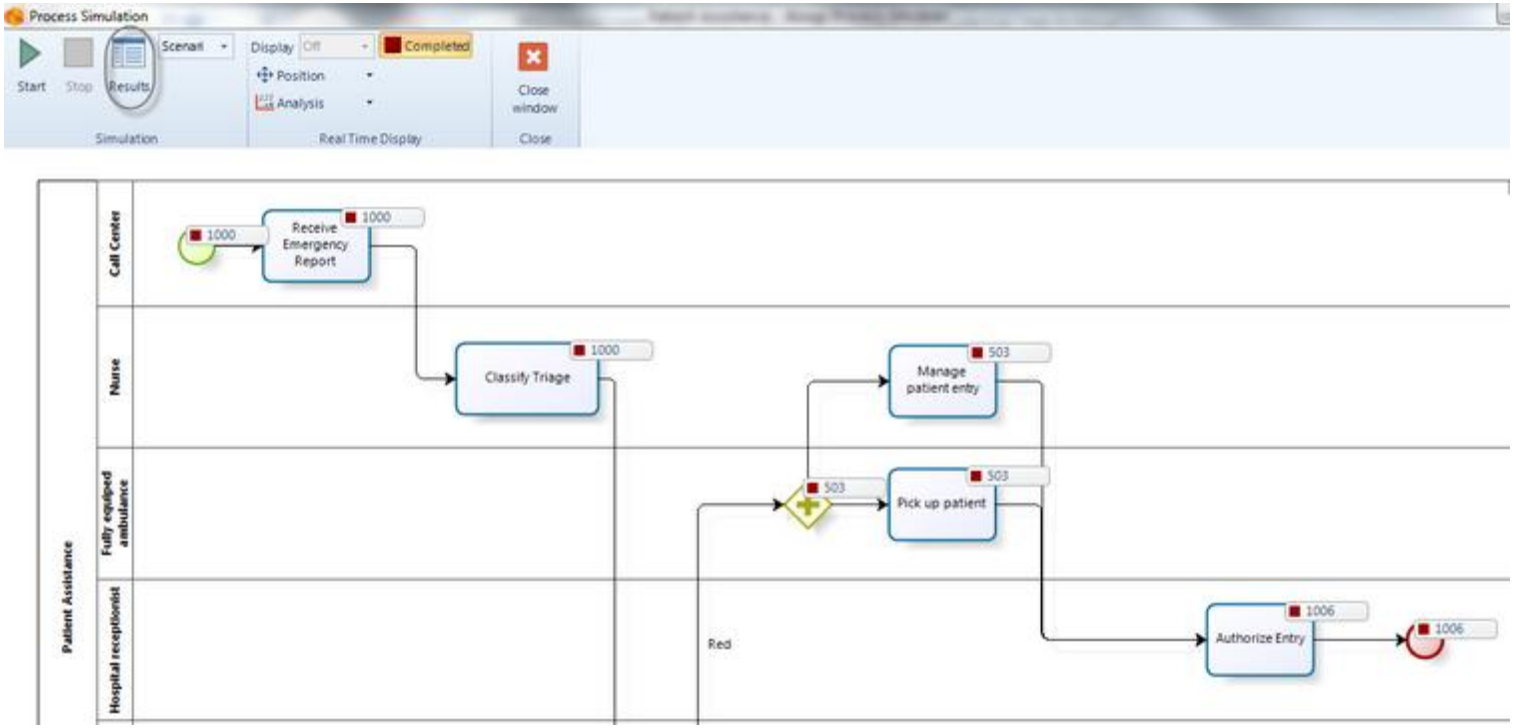
Manage patient entry (503)

Pick up patient (503)

Authorize Entry (1006)

Red

Select Results



4. Analyzing the Results

- Analyzing the results we conclude that something is wrong:
  - The number of tokens (1000) created at the Start Event of the process differs to the sum of tokens completed at the End Events (1006+311+186=1503)

- Can you identify what is wrong in the flow?

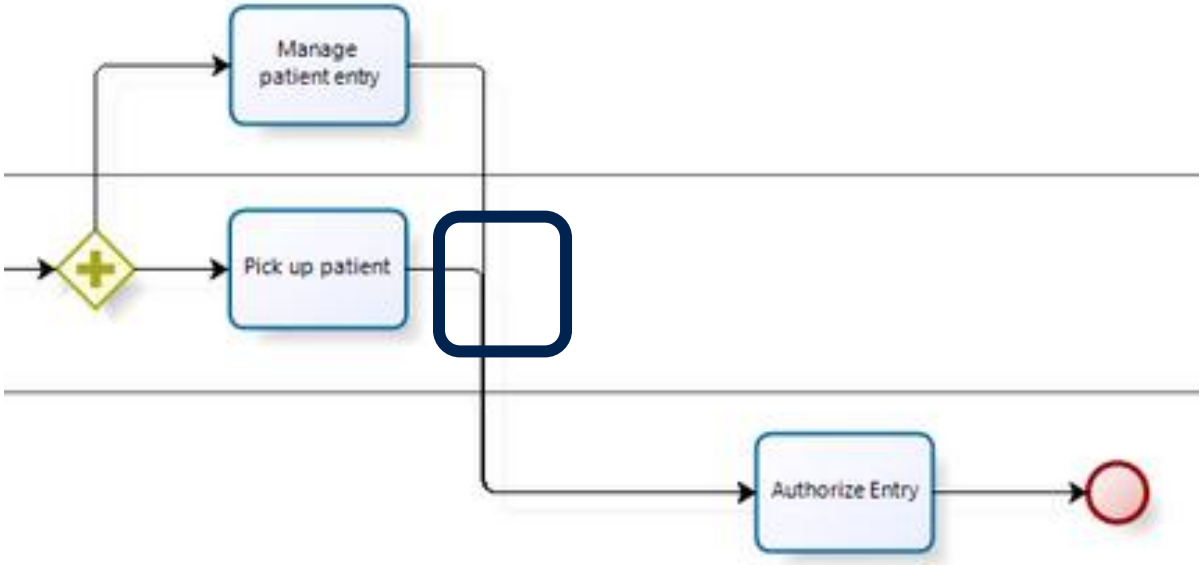
Simulation Results

Patient Assistance

Name	Type	Tokens completed
Patient Assistance	Process	1000
NoneStart	Start event	1000
Receive Emergency Report	Task	1000
Classify Triage	Task	1000
Pick up patient	Task	503
Authorize Entry	Task	1006
Red triage end	End event	1006
Arrive at patient place QAV	Task	311
Arrive at patient place BA	Task	186
Yellow triage end	End event	311
Green triage end	End event	186
Triage type	Gateway	1000
Manage patient entry	Task	503
ParallelGateway	Gateway	503

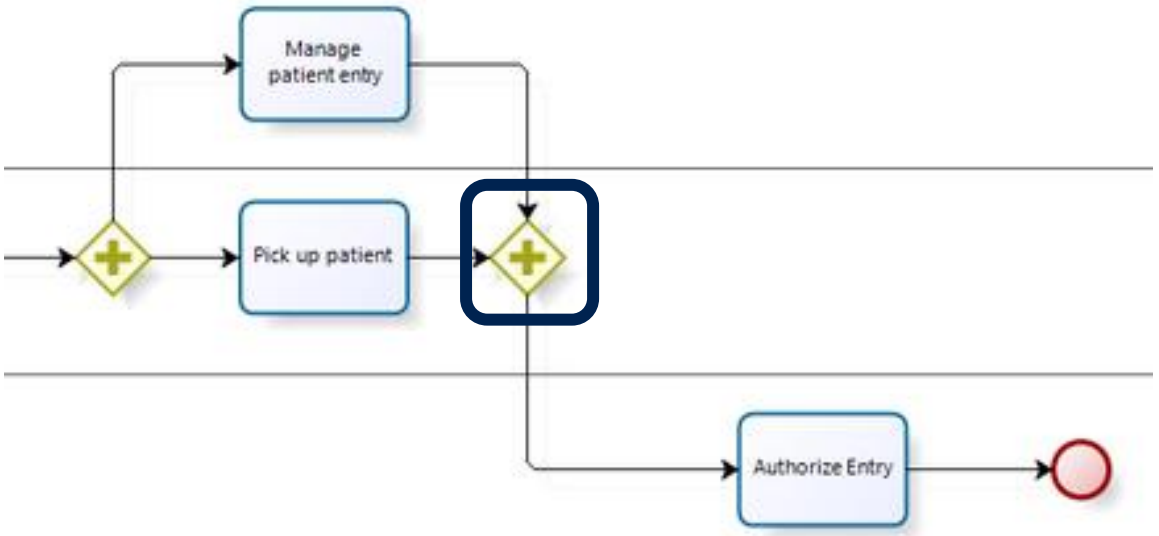
Problem

If you watch the diagram carefully, you will see there is no point of convergence, that is, no shape has been defined to synchronize the paths that



5. Solution

- It is necessary to merge the outgoing flows into a single flow before the token continues to the next activity
- To do this, include a Parallel Gateway (as a convergence element) to synchronize them



Solution

- Once the change is done, Run the simulation again
- Looking at the new results we can see that all is working as expected:
  - The number of tokens created (1000) is equal to the sum of tokens completed (483+315+202=1000)
- In addition, each token is passed correctly to the triage based on the probabilities defined

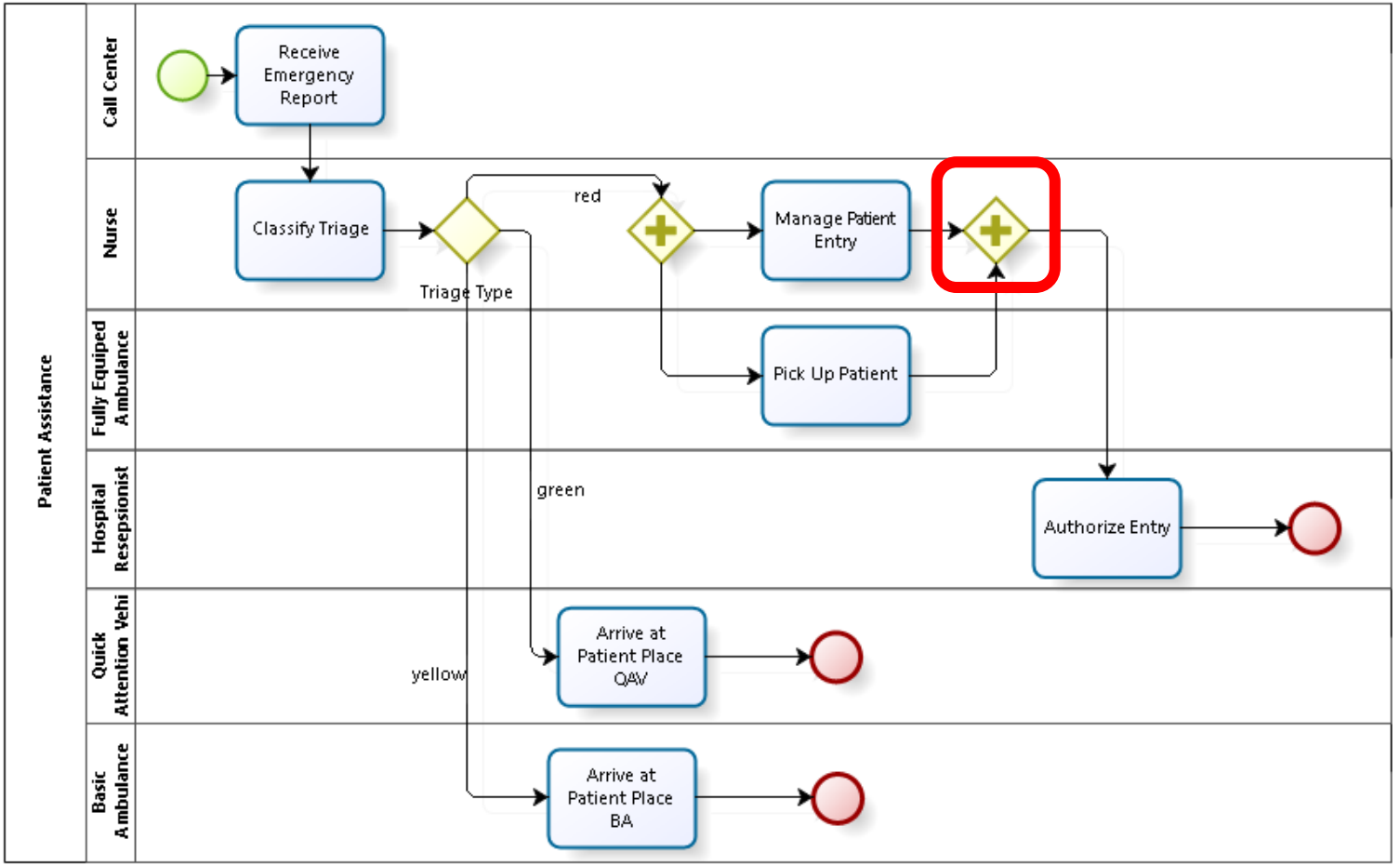
Simulation Results

Patient Assistance

Name	Type	Tokens completed
Patient Assistance	Process	1000
NoneStart	Start event	1000
Receive Emergency Report	Task	1000
Classify Triage	Task	1000
Pick up patient	Task	483
Authorize Entry	Task	483
Red triage end	End event	483
Arrive at patient place QAV	Task	315
Arrive at patient place BA	Task	202
Yellow triage end	End event	315
Green triage end	End event	202
Triage type	Gateway	1000
Manage patient entry	Task	483
ParallelGateway	Gateway	483
ParallelGateway	Gateway	483

Export to Excel

Case Study: Patient Assistance



3.2 TIME ANALYSIS

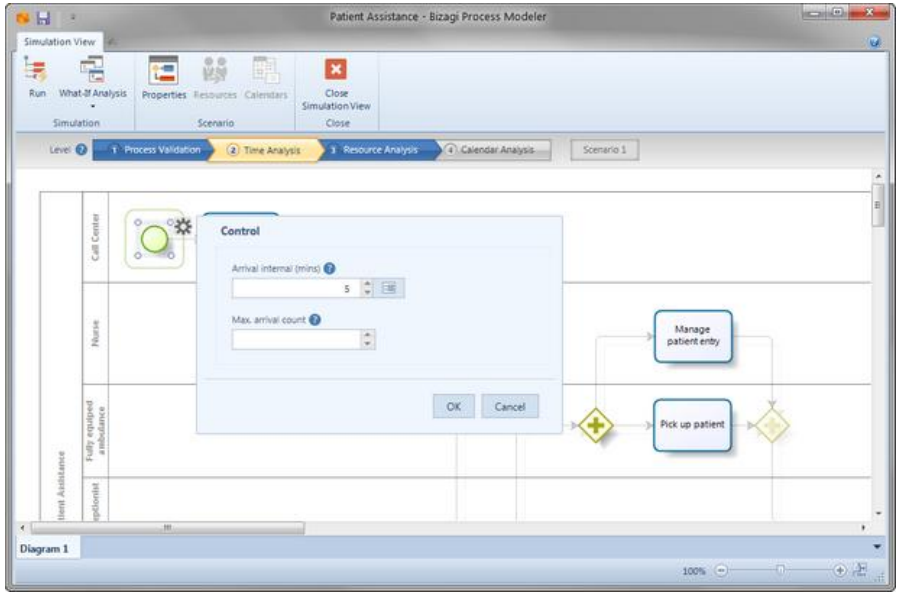
Assumptions

- Necessary resources to perform activities have infinite capacity
- The expected time between reports is 5 minutes
- The simulation will evaluate 100 patients (tokens)
- The estimated processing times for each of the activities are fixed as shown in the next table:

Activity	Processing time (min)
Receive emergency report (Menerima Laporan Gawat Darurat)	4
Classify Triage (Mengklasifikasi Tingkat Gawat Darurat)	5
Manage patient entry (Mengentri Data Pasien)	11
Pick up patient (Menjemput Pasien dg Ambulan Lengkap)	20
Arrive at patient place QAV (Mendatangi Pasien dg Ambulan Motor)	7
Arrive at patient place BA (Mendatangi Pasien dg Ambulan Standard)	10
Authorize entry (Mengotorisasi Kedatangan Pasien)	4

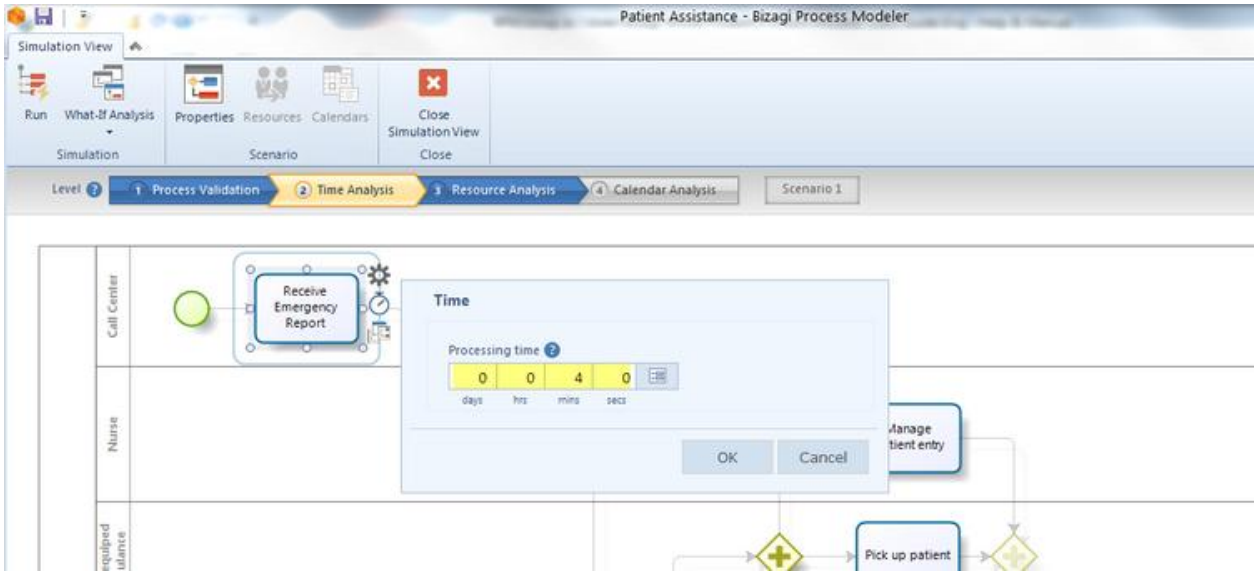
1. Define Trigger Times

- To do so, click the Start Event and then the Gear icon on the pie menu
- For this example, the expected time between reports is 5 minutes, so set the time to this value
  - Note the value entered is in minutes



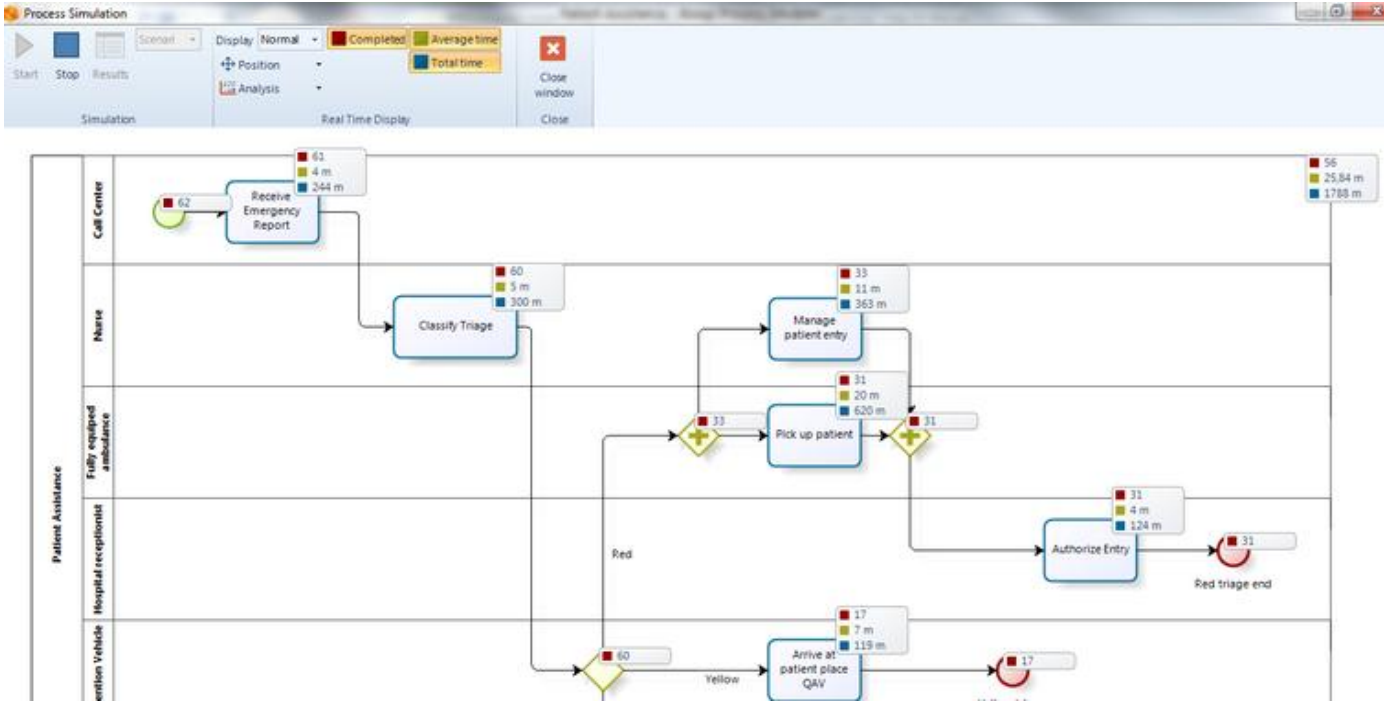
2. Define the Activities' processing times

- Click the Activity, select Clock on the pie menu and set a value for the Time control
- In the following image the processing time for the first activity is set to 4 minutes

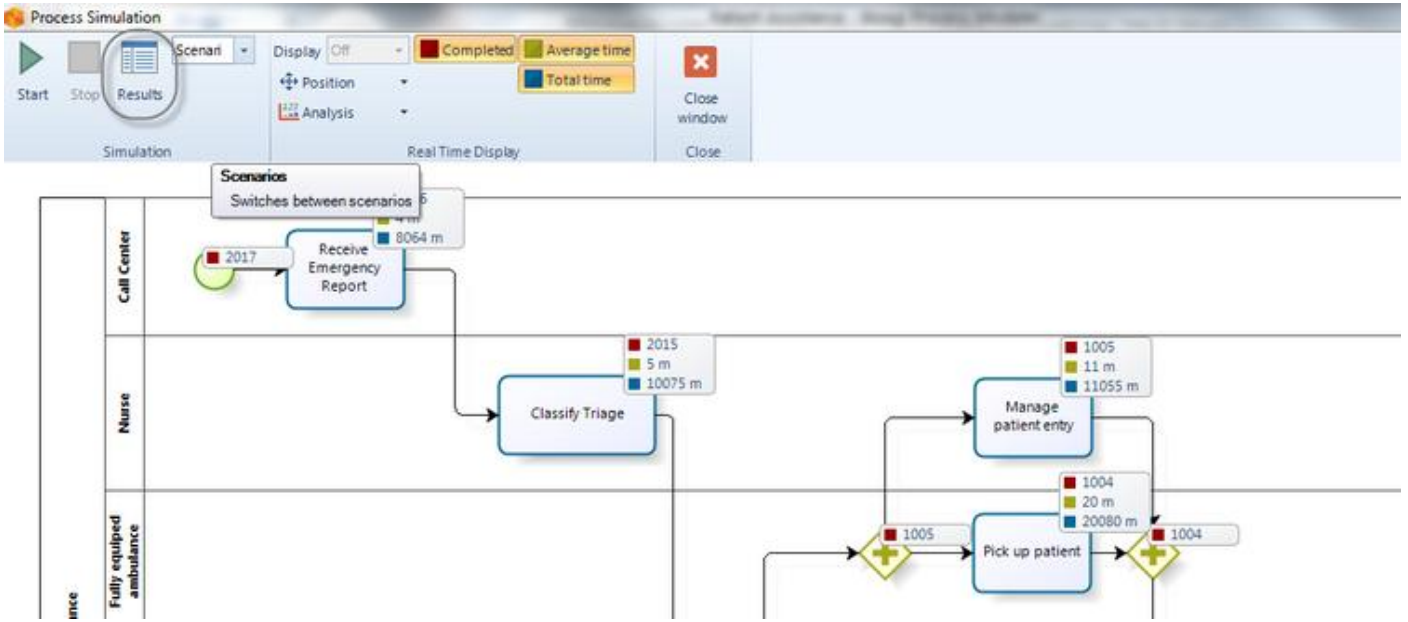


3. Run the Simulation

The simulation shows analysis findings for each shape in real time as it executes, such as average time, total processing time and the number of completed tokens



4. Select Results to View the Outcome



5. Analyzing the results

- A patient waits at least 16 minutes before receiving medical attention
- A patient waits no more than 33 minutes for medical attention
- The expected time a patient waits to receive medical attention is 25,06 minutes

Simulation Results

Patient Assistance

Name	Type	Tokens completed	Tokens started	Min. time	Max. time	Avg. time	Total time
Patient Assistance	Process	2011	2017	16 m	33 m	25,06 m	61436 m
NoneStart	Start event	2017					
Receive Emergency Report	Task	2016	2017	4 m	4 m	4 m	8064 m
Classify Triage	Task	2015	2016	5 m	5 m	5 m	10075 m
Pick up patient	Task	1004	1005	20 m	20 m	20 m	20080 m
Authorize Entry	Task	1003	1004	4 m	4 m	4 m	4012 m
Red triage end	End event	1003					
Arrive at patient place QAV	Task	616	617	7 m	7 m	7 m	4312 m
Arrive at patient place BA	Task	392	393	10 m	10 m	10 m	3920 m
Yellow triage end	End event	616					
Green triage end	End event	392					
Triage type	Gateway	2015	2015				
Manage patient entry	Task	1005	1005	11 m	11 m	11 m	11055 m
ParallelGateway	Gateway	1005	1005				
ParallelGateway	Gateway	1004	1005				

Export to Excel

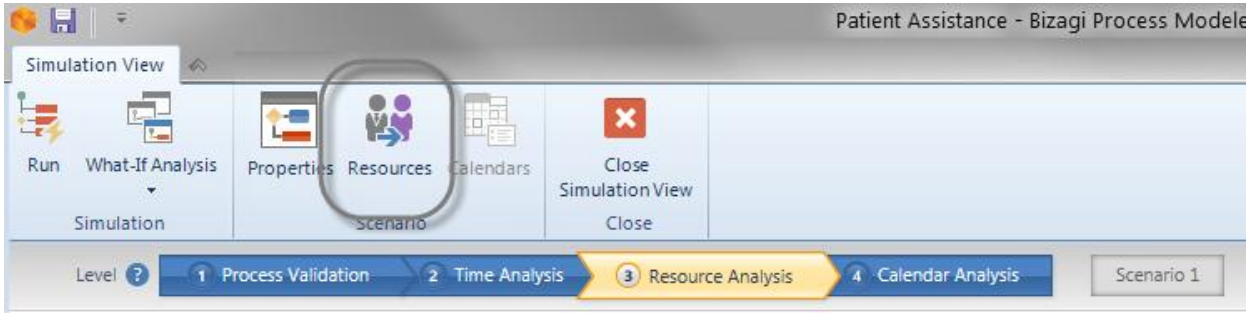
3.3 RESOURCE ANALYSIS

Assumptions

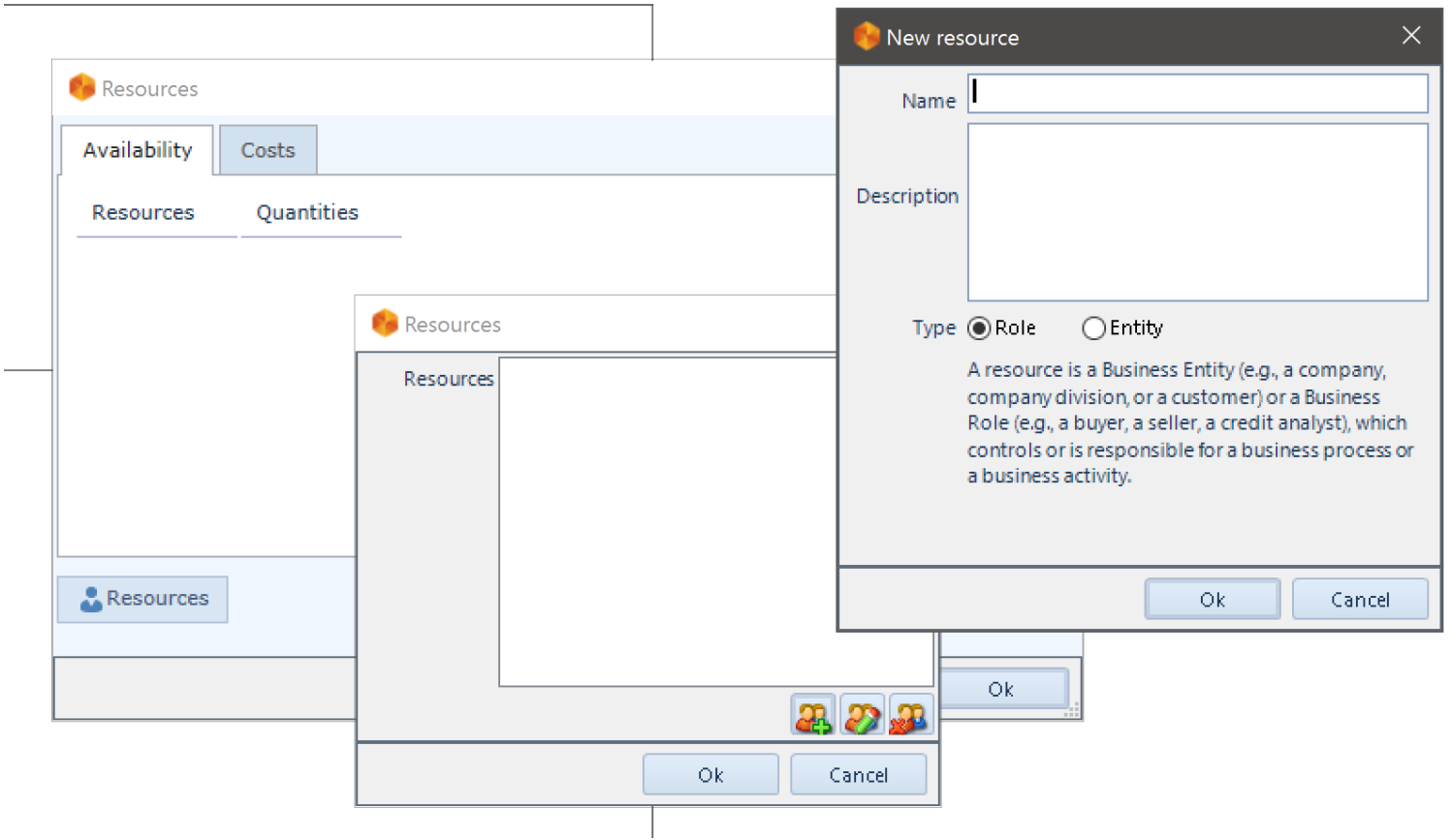
- The expected time between reports is 5 minutes
- The simulation will evaluate 100 patients (tokens)
- Resources can be shared between activities

1. Define the resources involved in the process

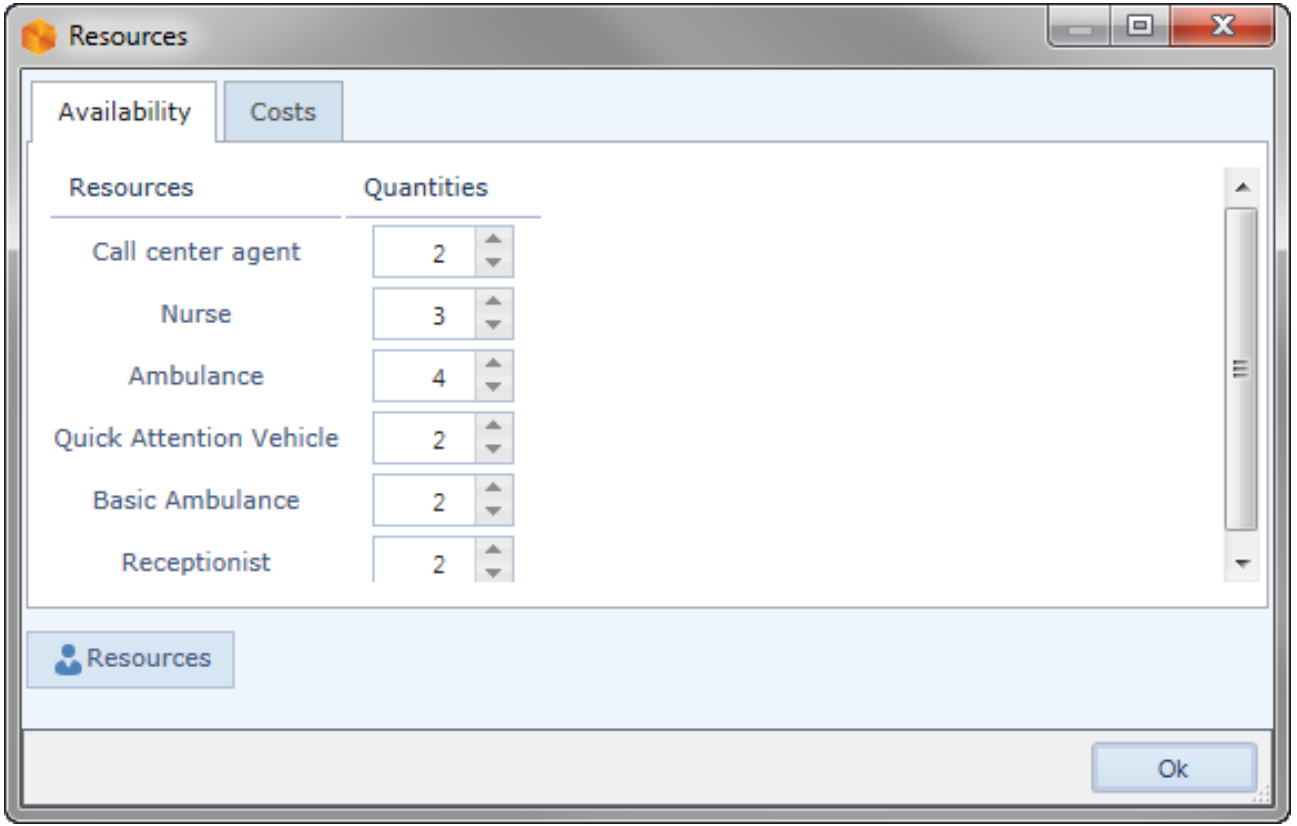
Create the necessary resources from the Resources option



Define the Resources



2. For each resource define the available quantity, fixed cost and unit cost



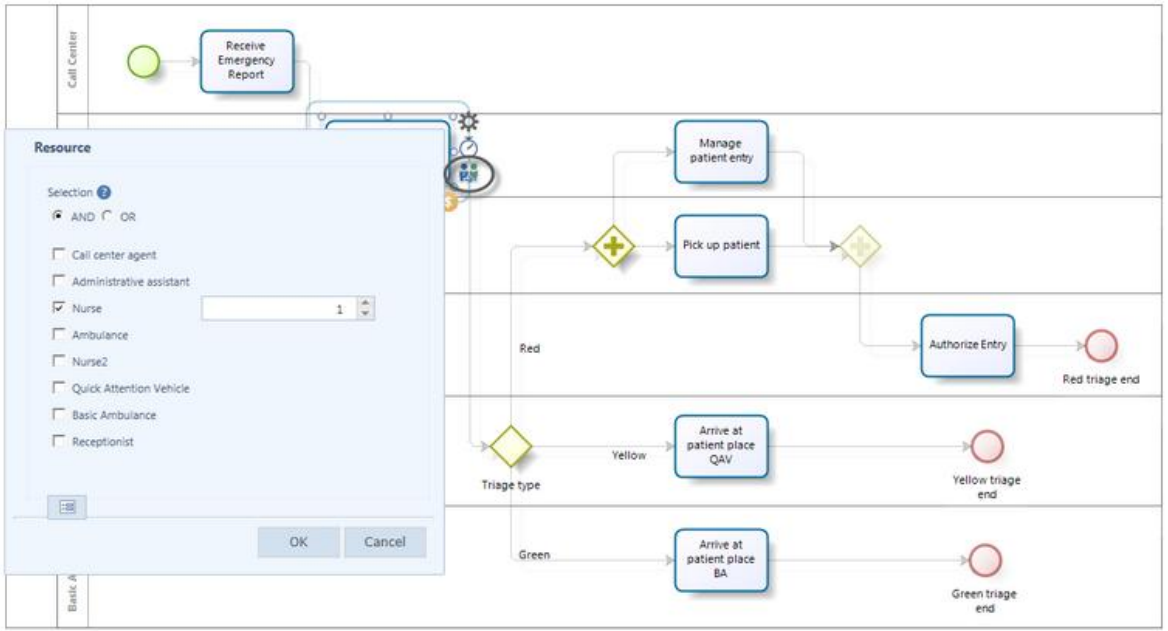
Resource, Quantity and Cost

Resource	Quantity	Fixed Cost (US)	Unit Cost (US)
Call center agent	2	3	0
Nurse	2	5	0
Fully equipped ambulance	4	30	0,4
Basic ambulance	2	25	0,3
Quick attention vehicle	2	18	0,22
Receptionist	2	3	0

- Fixed cost: This cost is generated each time a resource processes a token
- Per hour (unit) cost: This cost is generated for each hour a resource employs processing a token

3. Define the resources requirements for each activity

- Click the activities and then the Resources icon. Set the resource and number of instances to perform the activity
- For example, here we are defining that the second activity requires a nurse in order to be performed

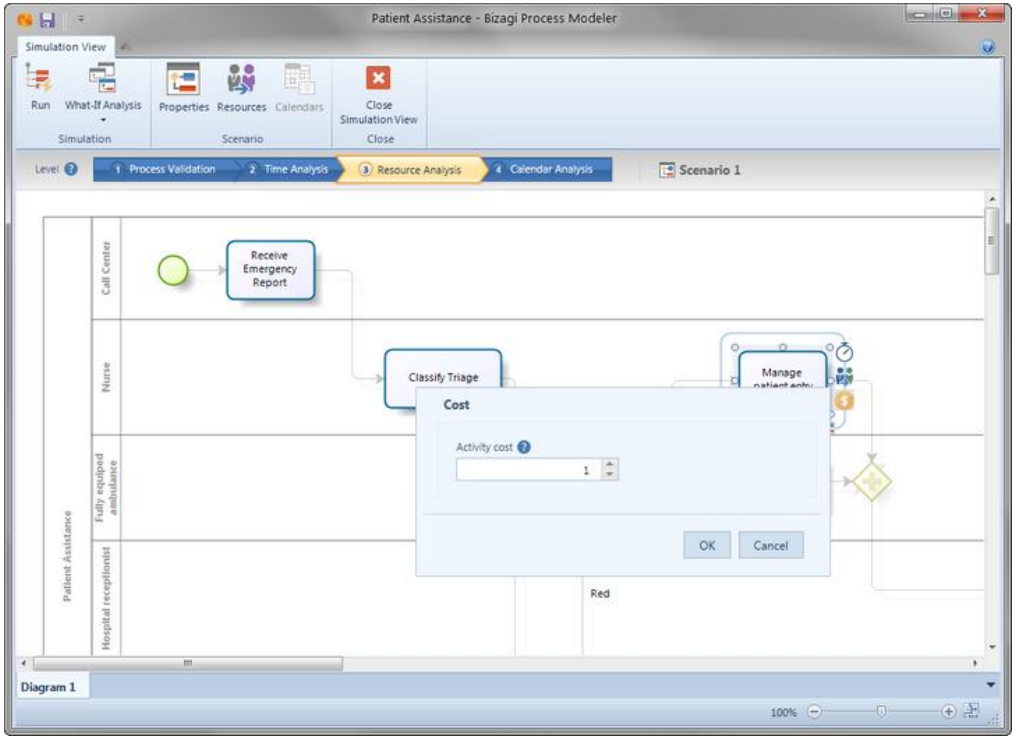


Quantity of Resources for Each Activity

Activity	Resource	Quantity
Receive emergency report	Call center agent	1
Classify Triage	Nurse	1
Manage patient entry	Nurse	1
Pick up patient	Fully equipped ambulance	1
Arrive at patient place QAV	Basic ambulance	1
Arrive at patient place BA	Quick attention vehicle	1
Authorize entry	Receptionist	1

4. Define the cost of performing each activity

- Click the activity, select Cost and enter the corresponding cost
- Here we are defining the the cost of performing the Manage patient entry activity is 1 dollar. This cost is related to paperwork and calls



Cost of the Performance of Each Activity

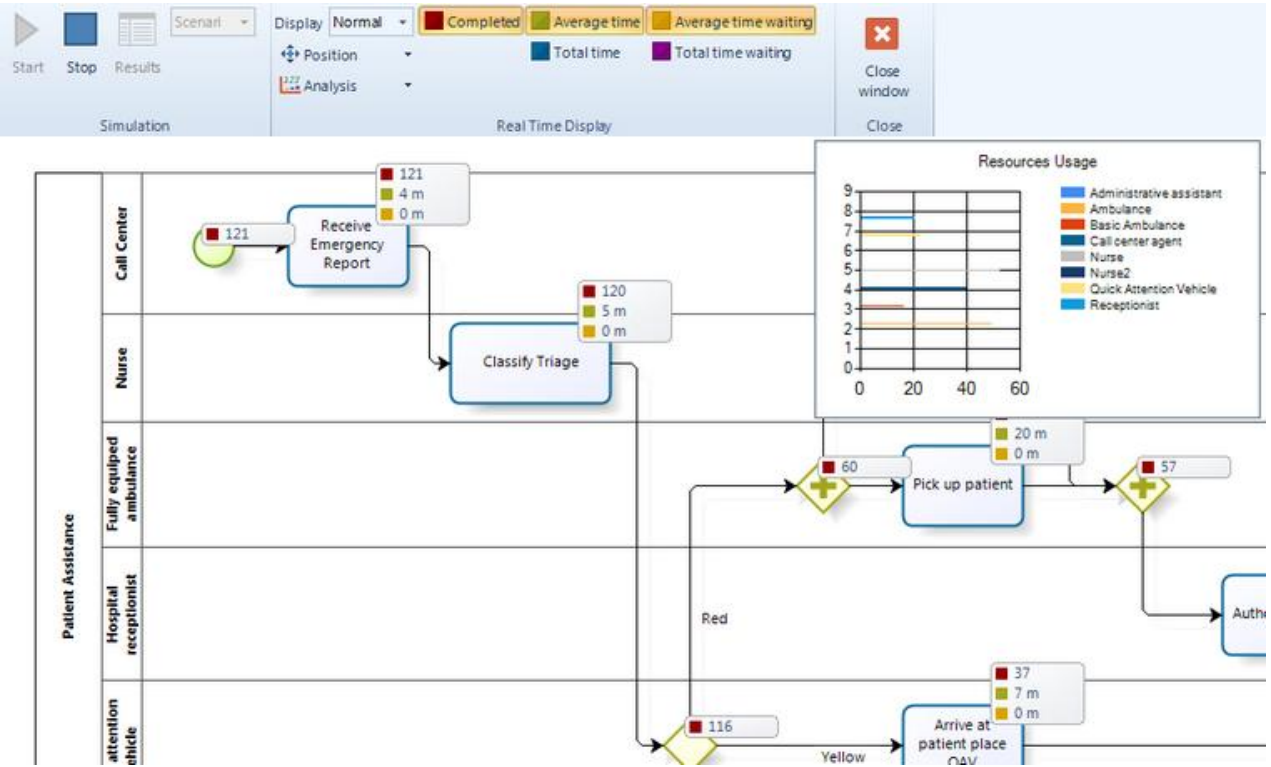
Activity	Cost (US dollars)
Receive emergency report	2
Classify Triage	1
Manage patient entry	1
Pick up patient	0
Arrive at patient place QAV	0
Arrive at patient place BA	0
Authorize entry	1

Processing Times for Each of the Activities

Activity	Processing time (min)
Receive emergency report	4
Classify Triage	5
Manage patient entry	11
Pick up patient	20
Arrive at patient place QAV	7
Arrive at patient place BA	10
Authorize entry	4

5. Click Run and Select Start

Note the number of completed Events are displayed



6. Analyzing the Results

- The results of a resource analysis give us a general insight into the cycle time of the process
- Consequently, we can identify how the cycle time is affected

Simulation Results

Resources

Patient Assistance

Name	Type	Tokens completed	Tokens started	Min. time	Max. time	Avg. time	Total time	Min. time waiting resource	Max. time waiting resource	Avg. time waiting for resource
Patient Assistance	Process	1922	2017	16 m	657 m	204,91 m	58321 m			
NoneStart	Start event	2017								
Receive Emergency Report	Task	2016	2017	4 m	4 m	4 m	8064 m	0	0	0
Classify Triage	Task	1950	1952	5 m	331 m	130,01 m	253528 m	0	326 m	125,21 m
Pick up patient	Task	970	971	20 m	30 m	20,25 m	19641 m	0	10 m	0,25 m
Authorize Entry	Task	944	944	4 m	4 m	4 m	3776 m	0	0	0
Red triage end	End event	944								
Arrive at patient place QAV	Task	599	599	7 m	11 m	7,06 m	4230 m	0	4 m	0,06 m
Arrive at patient place BA	Task	379	380	10 m	15 m	10,06 m	3811 m	0	5 m	0,06 m
Yellow triage end	End event	599								
Green triage end	End event	379								
Triage type	Gateway	1950	1950							
Manage patient entry	Task	944	944	11 m	336 m	137,2 m	129519 m	0	325 m	126,2 m
ParallelGateway	Gateway	971	971							
ParallelGateway	Gateway	944	970							

Export to Excel

Analyzing the Results

- Compared with the best case scenario achieved in the previous level, the inclusion of resources constraints has significantly increased the cycle times.
  - The minimum time remains at 16 minutes but the maximum increased to 657 minutes and now the average is 204,91 minutes
    - The previous results only had an average waiting time of 25,06 minutes
  - As is evident, the processing times for each activity have changed. Now, they reflects delays
    - The highest average processing times are recorded at Classify triage and Manage patient
    - The average waiting times confirm there is a problem in those activities. Possibly, resources used in them are not enough.

Analyzing the Results

- The usage of the resources indicates some sub and over-utilization
- For this case we confirm our hypothesis about a possible problem of resources capacity
- The nurse who performs the Classify triage and Manage patient reception has a usage of 99,91%
  - This means she is utilized at full capacity and tokens have to wait until she becomes available
  - The emergency department should consider increasing the number of triage nurses to reduce service and waiting times, and thereby reducing the cycle time

Analyzing the Results

Simulation Results

Resources

Patient Assistance

Resource	Usage	Total fixed cost	Total unit cost
Call center agent	40,00 %	6051	0
Nurse	99,91 %	14480	0
Ambulance	48,12 %	29130	7761,6
Quick Attention Vehicle	20,80 %	14975	1257,9
Basic Ambulance	18,84 %	6840	835,78
Receptionist	18,73 %	2832	0

Export to Excel

Analyzing the Results

We'll see if the situation gets better including a new nurse in the available resources. Now we would have three nurses. Click Run to simulate the new scenario

Simulation Results

Resources

Patient Assistance

Name	Type	Tokens completed	Tokens started	Min. time	Max. time	Avg. time	Total time	Min. time waiting resource	Max. time waiting resource	Avg. time waiting for resourc
Patient Assistance	Process	2011	2017	16 m	35 m	25,26 m	61436 m			
NoneStart	Start event	2017								
Receive Emergency Report	Task	2016	2017	4 m	4 m	4 m	8064 m	0	0	0
Classify Triage	Task	2015	2016	5 m	7 m	5,2 m	10474 m	0	2 m	0,2 m
Pick up patient	Task	1004	1005	20 m	20 m	20 m	20080 m	0	0	0
Authorize Entry	Task	1003	1004	4 m	4 m	4 m	4012 m	0	0	0
Red triage end	End event	1003								
Arrive at patient place QAV	Task	616	617	7 m	7 m	7 m	4312 m	0	0	0
Arrive at patient place BA	Task	392	393	10 m	11 m	10 m	3921 m	0	1 m	0
Yellow triage end	End event	616								
Green triage end	End event	392								
Triage type	Gateway	2015	2015							
Manage patient entry	Task	1005	1005	11 m	15 m	11,06 m	11113 m	0	4 m	0,06 m
ParallelGateway	Gateway	1005	1005							
ParallelGateway	Gateway	1004	1005							

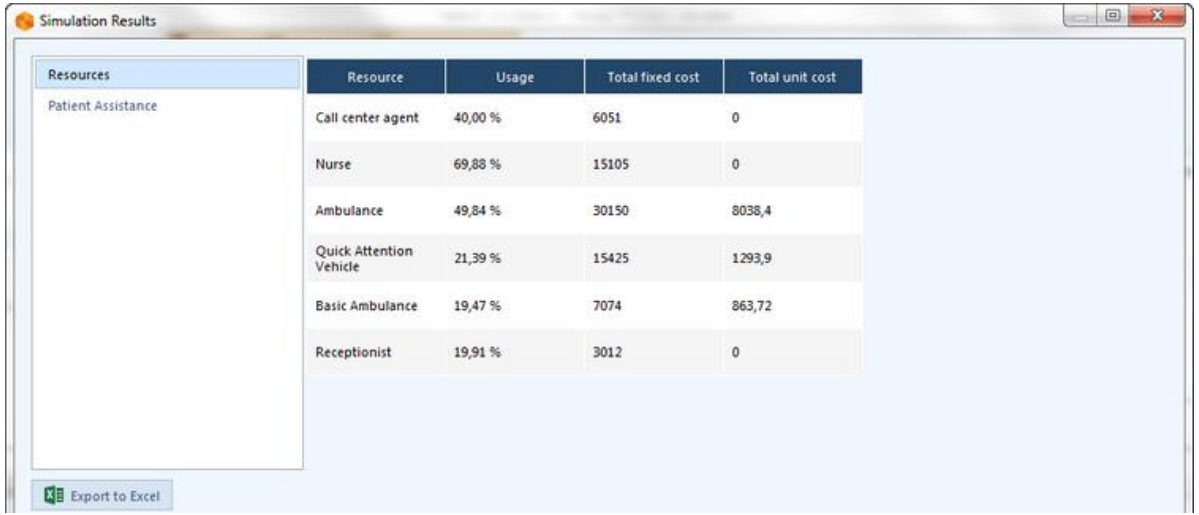
Export to Excel

Analyzing the Results

- Introducing another resource brings us closer to the best case scenario with no process delays. The minimum time remains at 16 minutes, the maximum now becomes 35 minutes and the average 25,26
- The results also show waiting times close to 0 in the activities where they exist. The current resources are sufficient to avoid critical delays

Analyzing the Results

- Usages are acceptable. Nurses now have a utilization of 69,88%
- From the resources cost perspective, there was a total cost of 84.163 US
- The new cost of 86.986 US includes the additional nurse
  - The increase of 2.823 US offsets the benefit in reducing the average waiting time to 179,5 minutes.
- There may be other ways to reduce the cost even further and to improve resource utilization, but for now we can accept the state of affairs



Simulation Results

Resources

Patient Assistance

Resource	Usage	Total fixed cost	Total unit cost
Call center agent	40,00 %	6051	0
Nurse	69,88 %	15105	0
Ambulance	49,84 %	30150	8038,4
Quick Attention Vehicle	21,39 %	15425	1293,9
Basic Ambulance	19,47 %	7074	863,72
Receptionist	19,91 %	3012	0

Export to Excel

Standard Utilisasi Resource

No	Category	Range	Actor
1	Top Manajerial	65-75%	Board of Directors (BoD)
			Chief
2	Level Manajerial	75-85%	Division Head
			Deputi
			Department Head
			Sub-Department Head
			Branch Head
			Representative Head
3	Level Officer/Staf	85-95%	Section Head
			Unit Head
			Officer
			Senior Administrator
			Administrator
			Coordinator

(John Jeston, Johan Nelis, Business Proces Management 3rd Edition, Routledge, 2013)

Fundamentals of Business Process Management
2nd Ed.

Latihan

- Masukan ke Resources: Dokter (5 orang) dan Paramedis (5 orang)
- Masukan Dokter dan Paramedis pada saat menjemput atau mendatangi pasien
- Lakukan simulasi untuk melihat utilisasi dari Dokter dan Paramedis

3.4 CALENDAR ANALYSIS

Assumptions

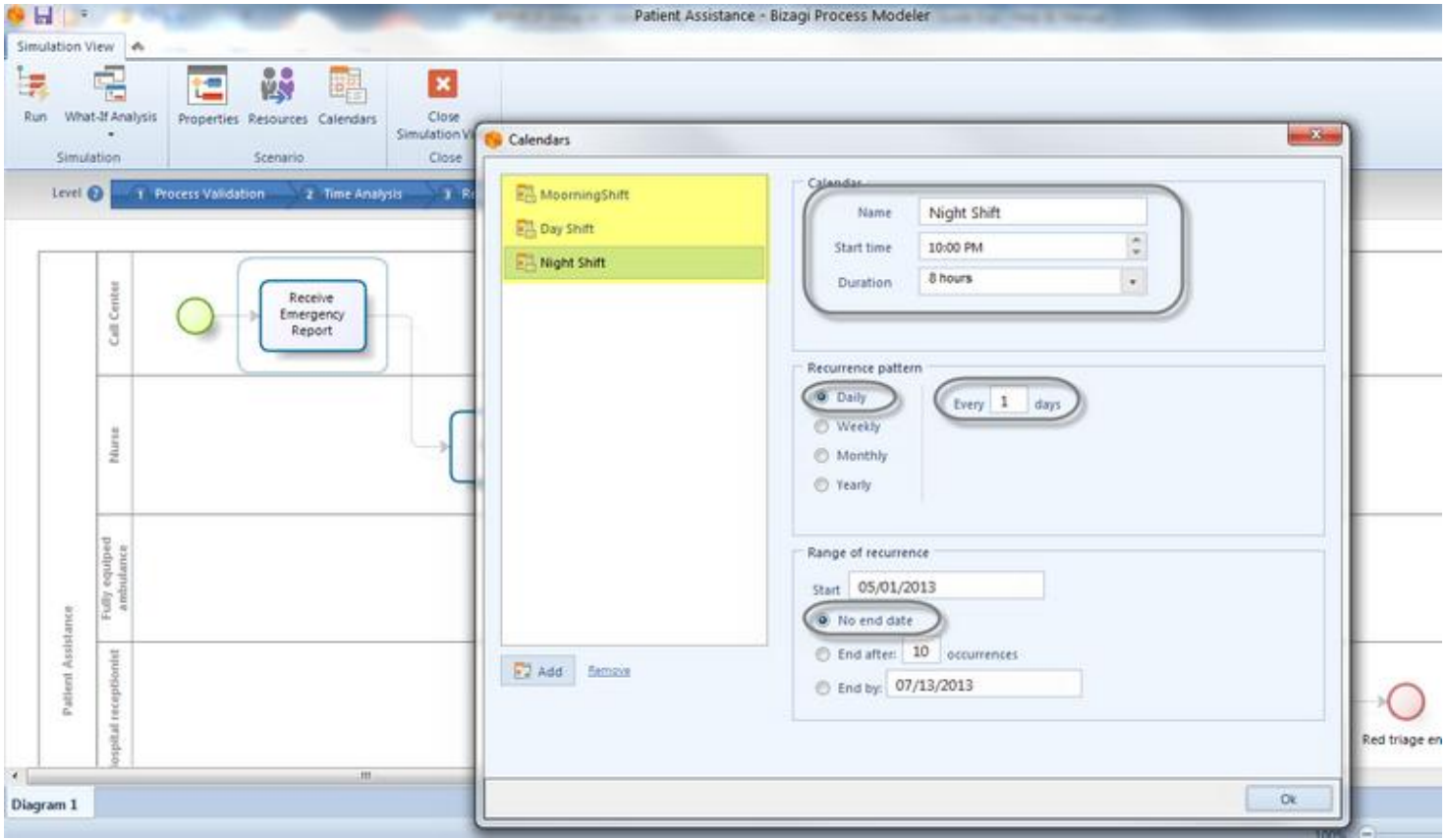
- In order to analyze the impact of calendars in the Patient Assistance, the Emergency department has decided to perform a Calendar analysis
- The shifts for the process will be as follow:

Resource	Morning shift (6:00 am - 2:00 pm)	Day shift (2:00 pm - 10:00 pm)	Night shift (10:00 pm - 6:00 am)
Call center agent	2	2	1
Nurse	3	3	3
Fully equipped ambulance	4	4	4
Basic ambulance	2	1	2
Quick attention vehicle	1	2	1
Receptionist	2	1	1

1. Create the three calendars (working shifts)

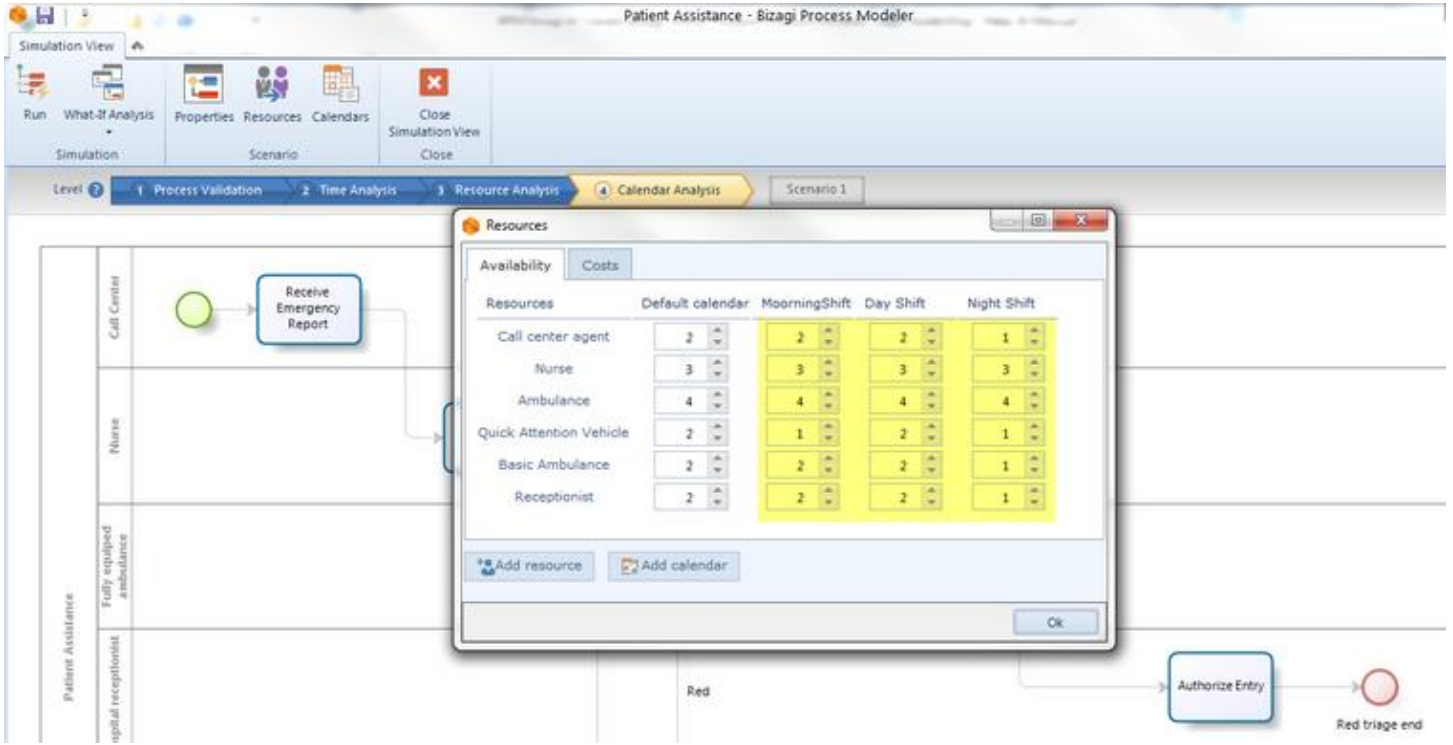
- Click the Calendars and add a new Calendar
- We are going to create the Night shift. In the Calendar configuration options enter the following information:
  - Name: Type Night Shift
  - Start Time: This calendar starts at 10:00 pm (see table above) so this is the start time
  - Duration: This calendar starts at 10:00 pm and finishes at 6:00 am so the calendar duration is 8 hours
  - Recurrence Pattern: This calendar is repeated everyday so select Daily and type 1 in the alongside field
  - Start of recurrence: This calendar applies always so the start date is the same start date of the simulation.
  - End of recurrence This calendar applies always so it has no end date.

Repeat for Morning and Day Shift Calendars

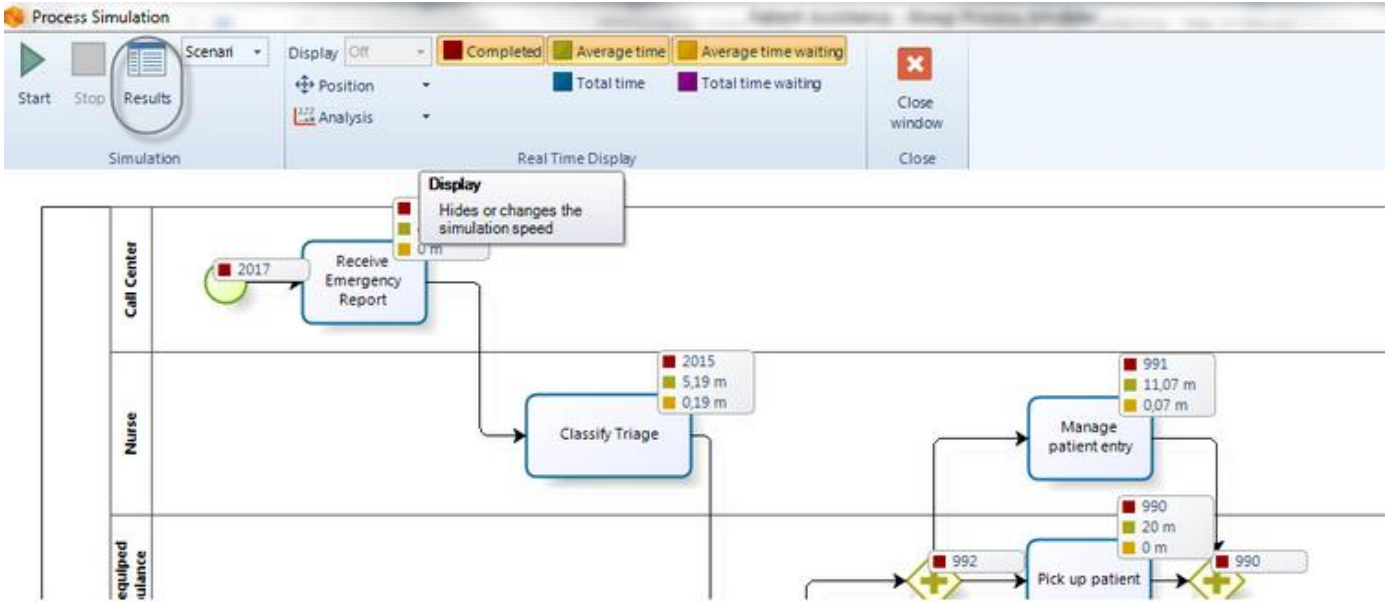


2. Through the Resources option

Set the availability of resource for each calendar created previously



3. Click the Run button



4. Analyzing the results

- Recall that incorporating ever changing conditions in the resource availability gives us a better understanding of true process performance
- The results of the calender analysis will reflect this change. Let us analyze them

Analyzing the results

Simulation Results

Resources

Patient Assistance

Name	Type	Tokens completed	Tokens started	Min. time	Max. time	Avg. time	Total time	Min. time waiting resource	Max. time waiting resource	Avg. time waiting for resource
Patient Assistance	Process	2011	2017	16 m	39 m	25,48 m	61077 m			
NoneStart	Start event	2017								
Receive Emergency Report	Task	2016	2017	4 m	4 m	4 m	8064 m	0	0	0
Classify Triage	Task	2015	2016	5 m	7 m	5,19 m	10449 m	0	2 m	0,19 m
Pick up patient	Task	990	992	20 m	21 m	20 m	19802 m	0	1 m	0
Authorize Entry	Task	989	990	4 m	4 m	4 m	3956 m	0	0	0
Red triage end	End event	989								
Arrive at patient place QAV	Task	619	620	7 m	15 m	7,59 m	4695,58 m	0	8 m	0,58 m
Arrive at patient place BA	Task	403	403	10 m	30 m	10,74 m	4327,58 m	0	20 m	0,74 m
Yellow triage end	End event	619								
Green triage end	End event	403								
Triage type	Gateway	2015	2015							
Manage patient entry	Task	991	992	11 m	14 m	11,07 m	10974 m	0	3 m	0,07 m
ParallelGateway	Gateway	992	992							
ParallelGateway	Gateway	990	991							

Export to Excel

Analyzing the Results

- The average time a patient waits for assistance suffered a little increase from 25,06 minutes to 25,48 minutes
  - This is not significant
- The increase from 35 to 39 minutes in the maximum time can be explained by the existing waiting times in some of the activities of the process that were not present in the previous level
- The Arrive at patient place BA task has a maximum waiting time of 20 min. It could be critical for a patient, however the average waiting time is 0,74 min
  - It is clear that high waiting times in this task are rare
- Despite the presence of waiting times, they are not regarded critical

Analyzing the Results

- The highest usage is for the Nurse. Remember that this resource performs two activities in the process: Classify triage and Manage patient entry.
- From the Process results we can conclude that the usage of nurses is not at full capacity since the waiting times of the associated activities are not significant
- Assigning shifts and resources did not overtly affect the process in general; therefore, we can conclude that the allocation is adequate for our purpose

Simulation Results

Resources

Patient Assistance

Resource	Usage	Total fixed cost	Total unit cost
Call center agent	48,00 %	6051	0
Nurse	69,39 %	15040	0
Ambulance	49,16 %	29760	7928,8
Quick Attention Vehicle	32,25 %	15500	1300,2
Basic Ambulance	23,99 %	7254	886,6
Receptionist	23,55 %	2970	0

Latihan

- Buat BPMN untuk peta proses bisnis di unit kerja anda
- Peta proses bisnis dikembangkan berdasarkan kajian peraturan Tata Kelola, Perencanaan Strategis organisasi, Tugas Pokok dan Fungsi
- Keluarkan ide baru dan kreatifitas untuk mendesain peta proses bisnis dari organisasi anda
- Mulai membuat peta proses bisnis dari level atas. Beri contoh minimal satu level satu diagram:
  1. Level 0 (Kementerian/Dirut/CEO/Rektor)
  2. Level 1 (Dirjen/Director/WakilRektor)
  3. Level 2 (Eselon 2/SVP/Direktur/Kabiro)
  4. Level 3 (Eselon 3/VP/Kabag)
  5. Level 4 (Eselon 4/Manajer)
- Lakukan simulasi dari Process Validation, Time Analysis dan Resource Analysis

Pitfalls of simulation

- Stochasticity
- Data quality pitfalls
- Simplifying assumptions

Stochasticity

- Simulation results may differ from one run to another
- Make the simulation time frame long enough to cover weekly and seasonal variability, where applicable
- Use multiple simulation runs
- Average results of multiple runs, compute confidence intervals

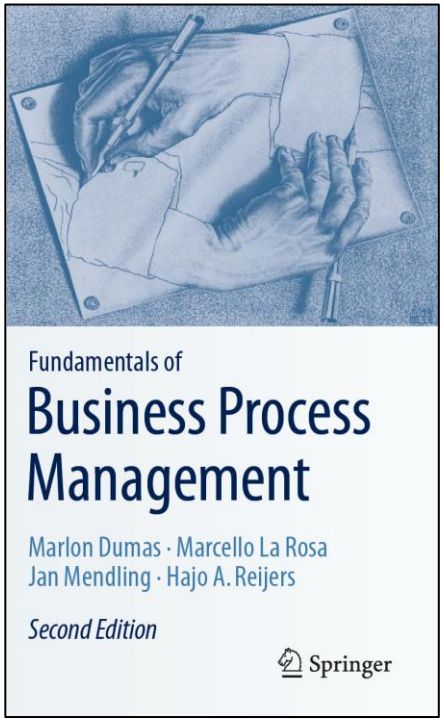
Data quality pitfalls

- Simulation results are only as trustworthy as the input data
- Rely as little as possible on “guesstimates”
- Use input analysis
  - Deriver simulation scenario parameters from numbers in the scenario
  - Use statistical tools to check fit the probability distributions
- Simulate the “as is” scenario and cross-check results against actual observations

Simulation assumptions

- That the process model is always followed to the letter
  - No deviations
  - No workarounds
- That there is no multi-tasking (the same resource performs multiple tasks concurrently) nor batching (tasks being accumulated and performed in a single go)
- That resources work constantly and non-stop
  - Every day is the same!
  - No tiredness effects
  - No distractions beyond “stochastic” ones

Chapter 7: Quantitative Process Analysis



Contents

1. Value-Added Analysis
2. Queuing analysis
3. Simulation
4. Recap

Recap

- Assuming we have performance measures for each activity in a process, flow analysis allows us to calculate the following performance measures for an "as is" process:
  - Cycle time, processing times, cycle time efficiency of a process
  - Average cost per process instance
- It can also be used to calculate the theoretical capacity of an "as is" process and the resource utilization of resource pools
- But it is not suitable for "what if" analysis
- Queing analysis is a suitable technique for "what if" analysis of waiting times and cycle times, suitable for analyzing individual activities performed by one resource pool
- Simulation is a versatile technique for "what if" analysis of entire processes, covering waiting times, cycle times, and costs.
  - Particularly useful for identifying bottlenecks