Sterilisation centre

‘’A.O. Curiamo Tutti”

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Theory link

- The queuing theory is necessary for companies in order take better business decisions in terms of resources
- Companies can better manage their resources and understanding which is the need of farther resources in order to provide a service.
- It studies the waiting times of customers/products

Key messages from the lesson

- Focus on a network of systems
- Understanding in practical terms how to apply the queuing theory
  - How to map a complex system
  - How to manage different types of customers/products
  - How to map/understand/evaluate the customers/products paths

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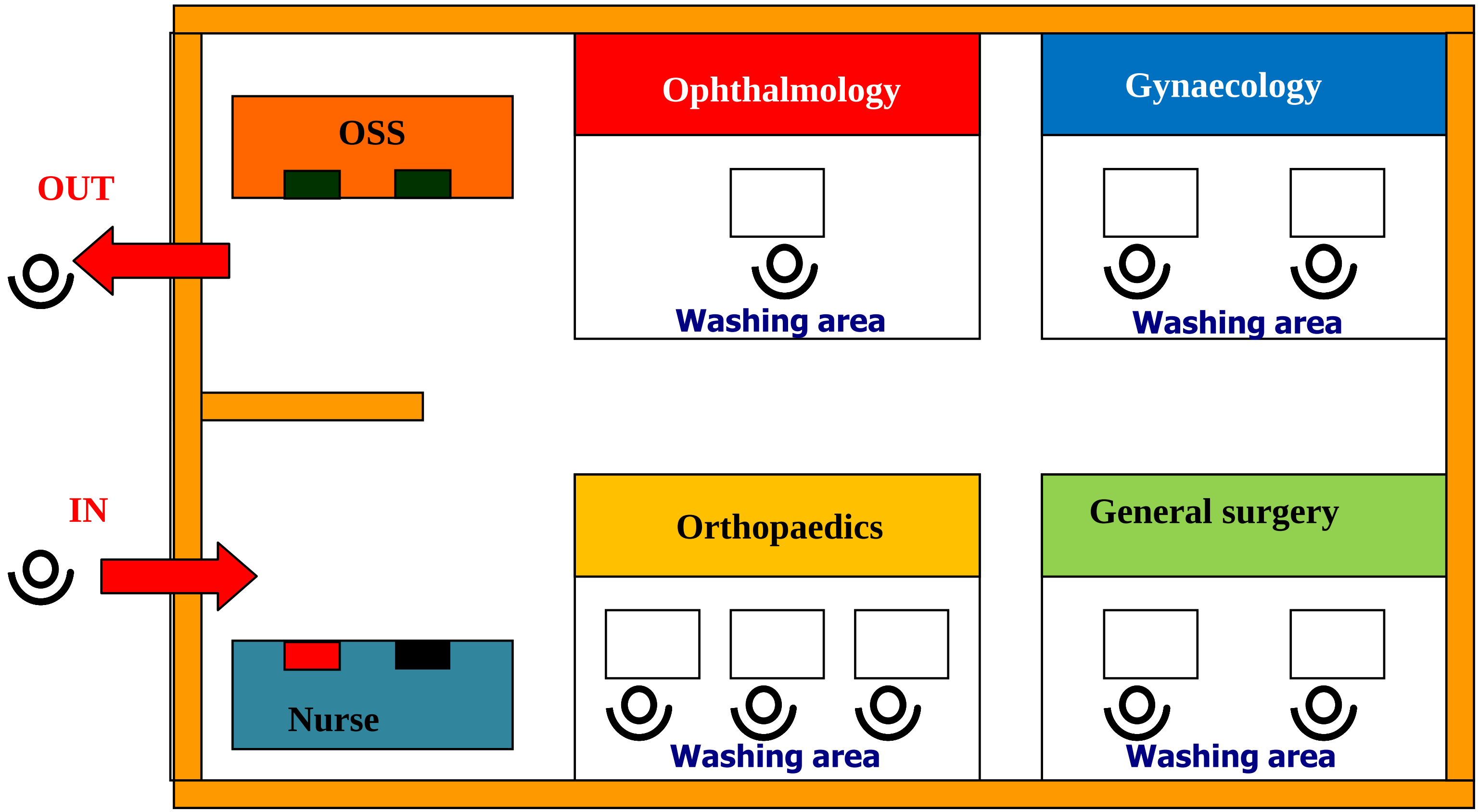


Sterilisation centre

Framework to solve the problem:

1. Shape the system and define the main parameters (μ,λ, queue's types, …)
2. Understand different kinds of ''customers'' and their paths
3. Compute the occurrences of the paths
4. Calculate throughput times
5. Decide the strategic actions to improve the system

The two surgery blocks (S.B.) of the hospital "A.O. Curiamo Tutti" don't have a cleaning instruments zone. The surgery instruments kits are directly sent to the sterilisation centre, once used by different specialised departments.

In order to improve service level offered to "A.O Curiamo Tutti", Eng. Smith is in charge of studying the sterilization system during the rush hours, when all the 12 operating theatres of the hospital work simultaneously.

The specialised departments are as follow:

- Orthopaedics
- General Surgery
- Gynaecology
- Ophthalmology

The sterilisation centre is located on the same floor of S.B. At sterilisation centre entrance, a nurse receives all the surgery instruments kits. She is in charge of recognizing and categorizing all the instruments kit, and of sending them in the right dedicated area.

In each area (in particular there are 4 areas dedicated to the specialised departments: Orthopaedics ,General Surgery, Gynaecology and Ophthalmology) there are specialized nurses that are in charge of the cleaning phase. The instruments kits are allocated to each nurse according to the single queue configuration.

Once the cleaning phase ended, instruments kit are sent to 2 specialized operators that are in charge of preparing the material before putting that onto the sterilizations machines. The two operators work in parallel, according to the multiple queue configuration.

Eng. Smith collected the following data:

- During rush hours, two different types of surgery kit arrive, some classified as "*urgent*" and some others as "*not urgent*" . The arrival rate of the urgent kit is 5 kits/hour, and they have pre-emptive priority on the not urgent kits. In particular, not urgent kits have an arrival rate of 10 kits/hour. The nurse is able to recognize and categorize one kit each 2 minutes. Only in this stage there is a distinction between urgent kit and not urgent kit; after this stage they are characterized by the same priority.
- The 30% of the whole amount of kit in entrance goes to the Orthopaedics cleaning area, the 20% of the whole amount of kit in entrance goes to the General Surgery cleaning area, the 30% of the whole amount of kit in entrance goes to the Gynaecology cleaning area, the 20% of the whole amount of kit in entrance goes to the Ophthalmology cleaning area.
- The instruments kit that arrive at the Ophthalmology cleaning area are categorized as "*normal*"(40% on the total amount in entrance at the Ophthalmology cleaning area) or "special" (60% on the total amount in entrance at the Ophthalmology cleaning area) . The special ones have a non pre-emptive priority on the normal ones.

Another data, collected by Eng. Smith, is that the 15% of the instruments kit cleaned in the Orthopaedics cleaning area, once cleaned in this area, is sent in the General Surgery cleaning area, where will be cleaned another time.

Service rate and number of operators involved in the flow are depicted in the following table:

Operators	Service time/operator
Orthopaedics (3 nurses)	2 kit every 30 minutes
General Surgery (2 nurses)	1 kit every 20 minutes
Gynaecology (2 nurses)	1 kit every 12 minutes
Ophthalmology (1 nurse)	1 kit every 12 minutes
Categorization (1 nurse)	5 kit every 10 minutes
Preparing phase (2 Operators)	2 kit every 10 minutes

Service rates and arrival rates are distributed according a negative exponential. Queues are managed with a FCFS rule.

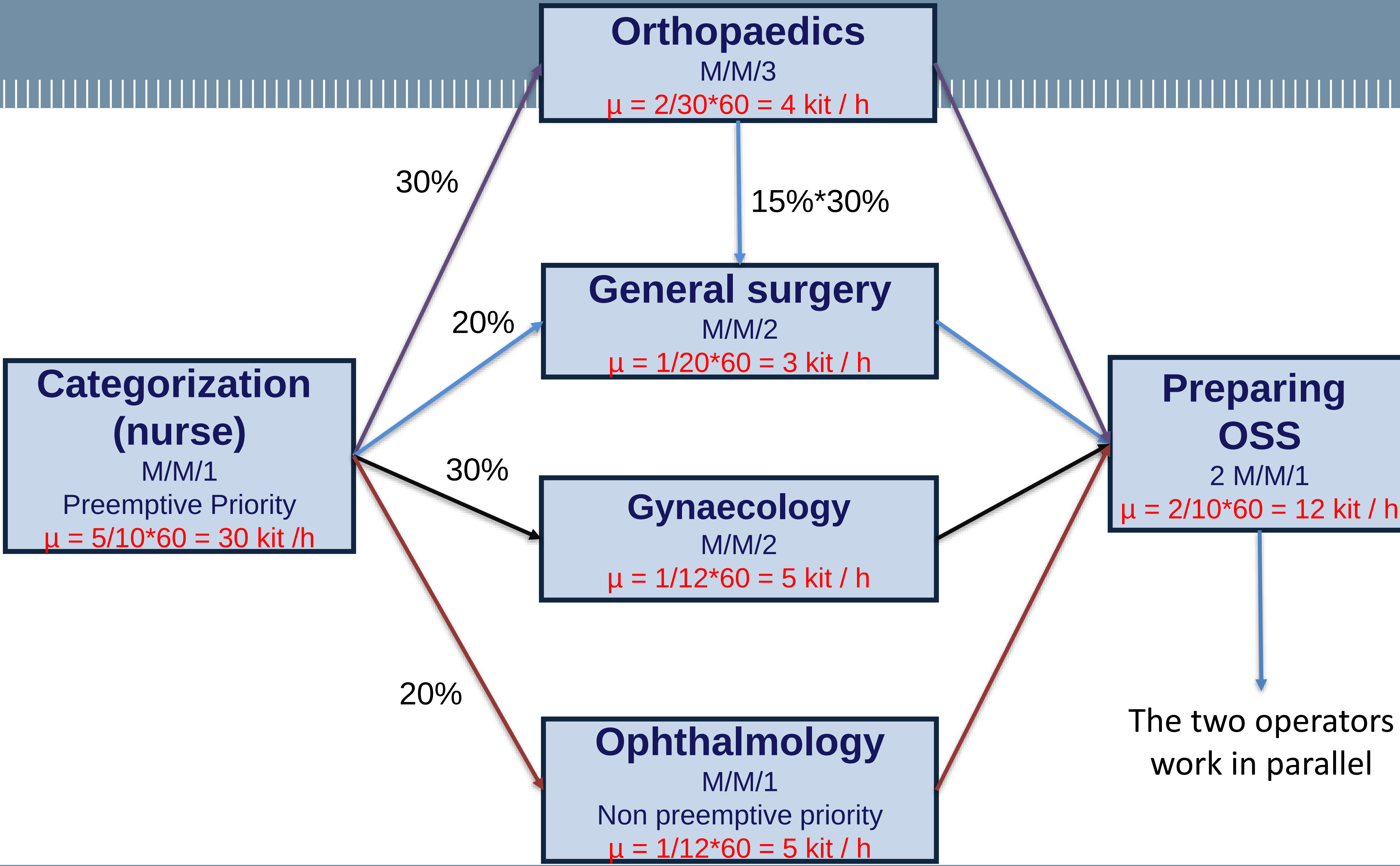
You are required to:

a) Mapping the system in a detailed and precise way, putting all the important parameters.

b) Calculating the average time between an instruments kit enter in the sterilization centre, until it is ready to be put into the sterilisation machines.

c) ***Which kind of improvements you would like to propose in order to improve the whole system? (examples: decreasing cost without increasing queues, reducing queues without increasing resources etc.). You are required to motivate each proposed improvement.***

Design actual configuration



Actual state

	Catergorization (nurse) (set/h)	Ophthalmology (set/h)	Orthopaedics (set/h)	Gynaecology (set/h)	General surgery (set/h)	Preparing (OSS) (set/h)
λ	Urg.= 5 Not urg.=10 Total = 15	20%*15 = 3 Spec.=60%*3 = 1,8 Norm.=40%*3= 1,2	30%*15 = 4.5	30%*15 = 4.5	20%*15 + 15%*30%*15 = 3.675	15/2 (half demand to each server!)
μ	30	5	4	5	3	12
	M/M/1	M/M/1	M/M/3	M/M/2	M/M/2	2 M/M/1

Single queue configuration

Multiple queue configuration (work in parallel)

λ arrival rate

μ serice rate of a single operator

Customers' typologies

- **A total of 12 typologies of "customers" (12 kinds of products)**
  - 2 kinds of kits (urgent / not urgent)
    - Nurse urgent kit
    - Nurse not urgent kit
  - 6 different paths
    - Nurse → Ophthalmology (special)→ OSS
    - Nurse → Ophthalmology (normal)→ OSS
    - Nurse → Orthopaedics → OSS
    - Nurse → Orthopaedics → surgery→ OSS
    - Nurse → surgery → OSS
    - Nurse → Gynaecology → OSS

Paths' occurrences

Products distribution according to their path.

	nurse		Orthop.	General surgery	Gyneac.	Opthal.		OSS	Frequency
	Urgent	Not urgent				Special	Normal		
1	X		X					X	8.5%
2	X		X	X				X	1.5%
3	X			X				X	6.67%
4	X				X			X	10.0%
5	X					X		X	4.0%
6	X						X	X	2.67%
7		X	X					X	17.0%
8		X	X	X				X	3.0%
9		X		X				X	13.33%
10		X			X			X	20.0%
11		X				X		X	8.0%
12		X					X	X	5.33%
								Total	1

Occurences_Urgent

1) Urgent- Othop –OSS = $\underbrace{5/15}_{\%Urgent} * \underbrace{(30\% - 15\% * 30\%)}_{\%Orthop\ without\ Gen\ Surgery} = 8{,}5\%$

2) Urgent –Orthop –Gen Surgery –OSS= $\underbrace{5/15}_{\%Urgent} * \underbrace{(15\% * 30\%)}_{\%Orthop\ with\ Gen\ Surgery} = 1{,}5\%$

3) Urgent- Gen Surgery –OSS= $\underbrace{5/15}_{\%Urgent} * \underbrace{(20\%)}_{\%Only\ Gen\ Surgery} = 6{,}67\%$

4) Urgent- Gyneac-OSS = $\underbrace{5/15}_{\%Urgent} * \underbrace{(30\%)}_{\%\ Gyneac} = 10\%$

5) Urgent – Ophtal Spec –OSS = $\underbrace{5/15}_{\%Urgent} * \underbrace{(20\% * 60\%)}_{\%Ophtal\ *\ \%Spec} = 4\%$

6) Urgent – Ophtal Spec –OSS = $\underbrace{5/15}_{\%Urgent} * \underbrace{(20\% * 40\%)}_{\%Ophtal\ *\ \%Normal} = 2{,}67\%$

Occurences

7) Non Urgent- Othop –OSS = 10/15* (30%-15%*30%)=17%

%Non Urgent %Orthop without Gen Surgery

8) Non Urgent –Orthop –Gen Surgery –OSS= 10/15 * (15%*30%)= 3%

%Non Urgent %Orthop with Gen Surgery

9) Non Urgent- Gen Surgery –OSS= 10/15*(20%)=13,33%

%Non Urgent %Only Gen Surgery

10) Non Urgent- Gyneac-OSS = 10/15*(30%) = 20%

%Non Urgent % Gyneac

11) Non Urgent – Ophtal Spec –OSS = 10/15*(20%*60%)= 8%

%Non Urgent %Ophtal * %Spec

12) Non Urgent – Ophtal Spec –OSS = 10/15*(20%*40%)= 5,33%

%Non Urgent %Ophtal * %Normal

Throughput time- nurse

Ws with preemptive priority **(M/M/1)**

$E(S1) = (1/\mu) / (1 - \rho 1)$

$E(S2) = (1/\mu) / ((1 - \rho 1) * (1 - \rho 1 - \rho 2))$

Nurse (preemptive priority)	Urgent kit	ρ_1 = 5/30= 0,17	$E(S_1)$= 2,4 min
	Not urgent kit	ρ_2 = 10/30 = 0,333	$E(S_2)$ = 4,8 min

Throughput time- ophthalmology

Ws with not preemptive priority (M/M/1)

$E(S1) = ((1 + \rho 2) / \mu) / (1 - \rho 1)$

$E(S2) = ((1 - \rho 1 * (1 - \rho 1 - \rho 2))/ \mu) / ((1 - \rho 1) * (1 - \rho 1 - \rho 2))$

Ophthalmology (NOT preemptive)	Special kit	$\rho_1 = 1{,}8 / 5 = 0{,}36$	$E(S_1) = 23{,}25$ min
	Normal kit	$\rho_2 = 1{,}2 / 5 = 0{,}24$	$E(S_2) = 40{,}125$ min

Throughput time-orthopaedics

Queue system, M/M/3 type

$\rho = 4{,}5 / 4 = 1{,}125$

$L_q(1{,}125; c=3) = 0{,}073 \rightarrow$ SEE NEXT SLIDE !

$W_s = L_q/\lambda + 1/\mu = 0{,}073/4{,}5 + 1/4 = 15{,}97$ min

Lq results of model M/M/c

λ/μ	c=1	c=2	c=3	c=4	c=5	c=6	c=7	c=8
0,15	0,026	0,001						
0,20	0,050	0,002						
0,25	0,083	0,004						
0,30	0,129	0,007						
0,35	0,188	0,011						
0,40	0,267	0,017						
0,45	0,368	0,024	0,002					
0,50	0,500	0,033	0,003					
0,55	0,672	0,045	0,004					
0,60	0,900	0,059	0,006					
0,65	1,207	0,077	0,008					
0,70	1,633	0,098	0,011					
0,75	2,250	0,123	0,015					
0,80	3,200	0,152	0,019					
0,85	4,817	0,187	0,024	0,003				
0,90	8,100	0,229	0,030	0,004				
0,95	18,050	0,277	0,037	0,005				
1,0		0,333	0,045	0,007				
1,1		0,477	0,066	0,011				
1,2		0,675	0,094	0,016	0,003			
1,3		0,951	0,130	0,023	0,004			
1,4		1,345	0,177	0,032	0,006			
1,5		1,929	0,237	0,045	0,009			
1,6		2,844	0,313	0,060	0,012			
1,7		4,426	0,409	0,080	0,017			
1,8		7,674	0,532	0,105	0,023			
1,9		17,587	0,688	0,136	0,030	0,007		
2,0			0,889	0,174	0,040	0,009		
2,1			1,149	0,220	0,052	0,012		
2,2			1,491	0,277	0,066	0,016		
2,3			1,951	0,346	0,084	0,021		
2,4			2,589	0,431	0,105	0,027	0,007	
2,5			3,511	0,533	0,130	0,034	0,009	
2,6			4,933	0,658	0,161	0,043	0,011	
2,7			7,354	0,811	0,198	0,053	0,014	
2,8			12,273	1,000	0,241	0,066	0,018	
2,9			27,193	1,234	0,293	0,081	0,023	
3,0				1,528	0,354	0,099	0,028	0,008
3,1				1,902	0,427	0,120	0,035	0,010
3,2				2,386	0,513	0,145	0,043	0,012
3,3				3,027	0,615	0,174	0,052	0,015
3,4				3,906	0,737	0,209	0,063	0,019
3,5				5,165	0,882	0,248	0,076	0,023
3,6				7,090	1,055	0,295	0,091	0,028

Let's do the interpolation!

$$\frac{y - 0{,}066}{0{,}094 - 0{,}066} = \frac{1{,}125 - 1{,}1}{1{,}2 - 1{,}1}$$

Throughput time- general surgery

Queue system, M/M/2 type

ρ = 3,675 / 3 = 1,225

Lq (1,225; c=2) = 0,744 (Interpolation as before)

Ws= Lq/λ + 1/μ = 0,744/3,675 + 1/3 = 32,15 min

Throughput time- Gynaecology

Queue system, M/M/2 type

$\rho = 4{,}5 / 5 = 0{,}9$

$L_q (0{,}9; c=2) = 0{,}229$

$W_s = L_q/\lambda + 1/\mu = 0{,}229/4{,}5 + 1/5 = 15{,}053$ min

Throughput time-OSS

2 queue systems, M/M/1 type

For each queue:

$\lambda = \lambda_{Oss} / 2 = 7{,}5$

$Ws = 1/(\mu - \lambda) = 1/(12 – 7{,}5) = 13{,}33$ min

Mean Ws for the whole system

	Nurse	Orthop.	General surgery	Gyneac.	Opthal.	OSS	Occurrence	Weig. time
1	2,4	15,97	-	-	-	13,33	0,085	2,69
2	2,4	15,97	32,15	-	-	13,33	0,015	0,96
3	2,4	-	32,15	-	-	13,33	0,0667	3,19
4	2,4	-	-	15,05	-	13,33	0,1	3,08
5	2,4	-	-	-	23,25	13,33	0,04	1,56
6	2,4	-	-	-	40,125	13,33	0,0267	1,49
7	4,8	15,97	-	-	-	13,33	0,17	5,80
8	4,8	15,97	32,15	-	-	13,33	0,03	1,99
9	4,8		32,15	-	-	13,33	0,1333	6,70
10	4,8	-	-	15,05	-	13,33	0,2	6,64
11	4,8	-	-	-	23,25	13,33	0,08	3,31
12	4,8	-	-	-	40,125	13,33	0,0533	3,10
							TOTAL (min)	40,51

Which actions to improve system performances?

1. Single queue system for OSS (40% Ws reduction for OSS stage)
2. Understand the main causes of second working for kits processed in orthopaedics
   1. Ad hoc process or tools to avoid second working
   2. More training for orthopaedics' operators
3. Improve service process in orthopaedics: 2 kits in 25 minutes instead of 30 minutes. Ws is still about 16 minutes (16,1 minutes in front of 15,93 minutes) but it cuold move one operator to other areas.
4. …………

Few messages about the use of queueing theory

The analysis let us to understand:

- Where were the problems and the inefficiences;
- The possible impacts of changes in the system.

Some examples – How to shape the following systems?

1. In a supermarket, there are different areas devoted to different product type: vegetables and fruits department, meat department, dairy products department etc... Each person entering the supermarket has different needs thus will do different paths. Map some of the possible paths.

2. Imagine to be at “Fiera dell’artigianato” where there are different pavilions. Map some possible path.

3. Imagine to be at IKEA where there are different departments divided per product type. You might do not need to visit the entire store. Map some possible path.

Take aways

1. Different customers/products have different paths

2. Map the system enables to really understand where the inefficiencies are

3. Always consider the occurrenes where calculating the expected throughput time

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