AN APPOINTMENT ORDER OUTPATIENT SCHEDULING SYSTEM THAT IMPROVES OUTPATIENT EXPERIENCE

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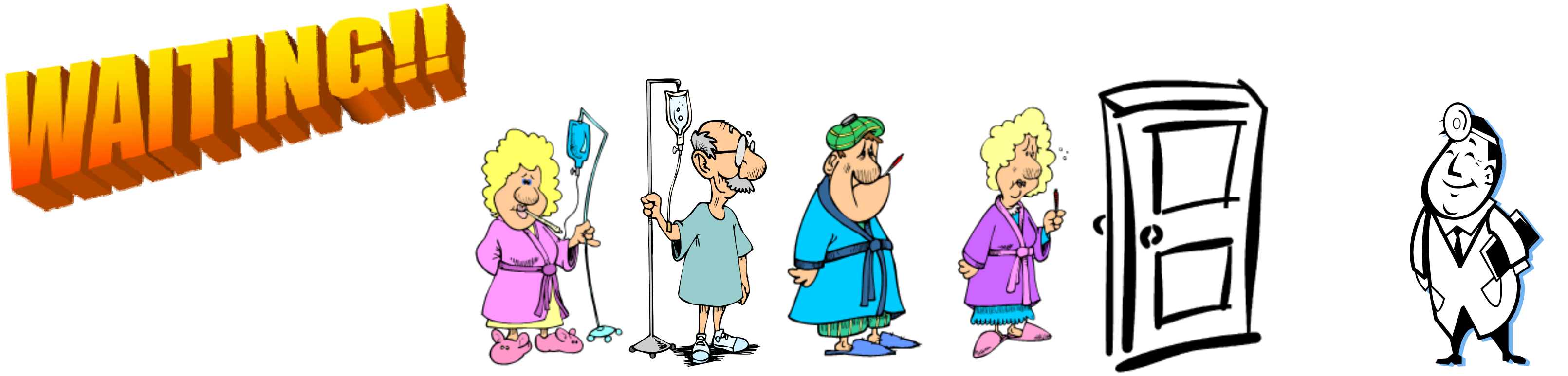
Learning Objectives

1. Understand the fundamental reasons and shortcomings of the current scheduling systems.
2. Define an effective patient central scheduling model that meets the clinic policies.
3. Develop and extend the proposed model considering ancillary services.
4. Learn and evaluate the implementation of the proposed model.
5. Develop a overbooking policy to reduce the negative impact of no-shows.

Introduction



- Shift inpatient care to outpatient facilities to reduce cost
- Competition increases
- Currently focus more on the efficiency of provider time
- Lack of implemented model

Learning Objective 1

Unrealistic Estimations of Treatment Time

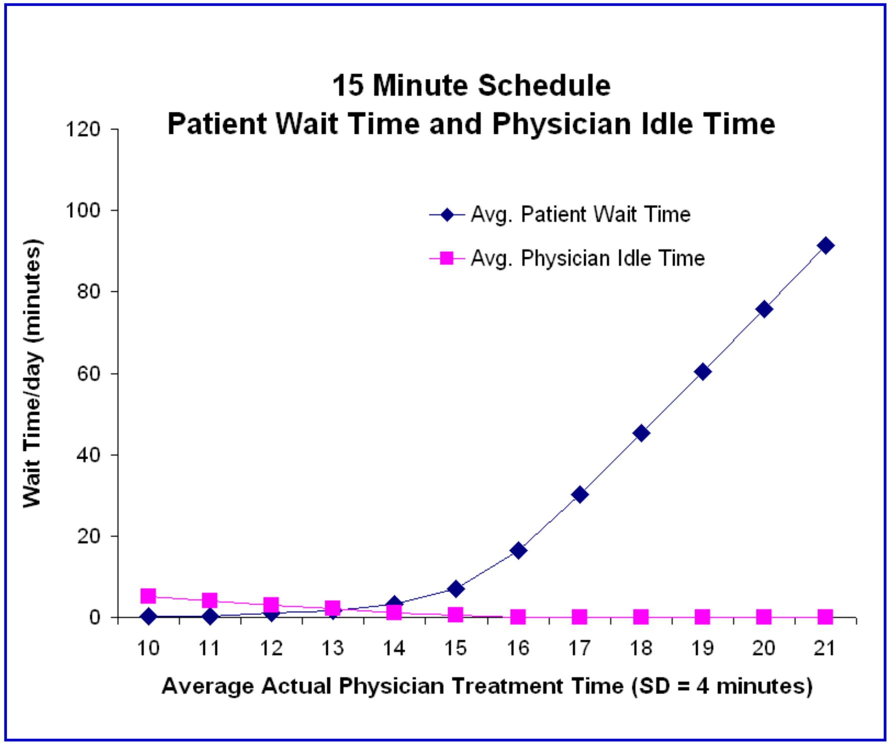
- Physician centric solution to the problem of wait time
  - Underestimating visit times
  - Overbooking or double booking
- Physician’s perception

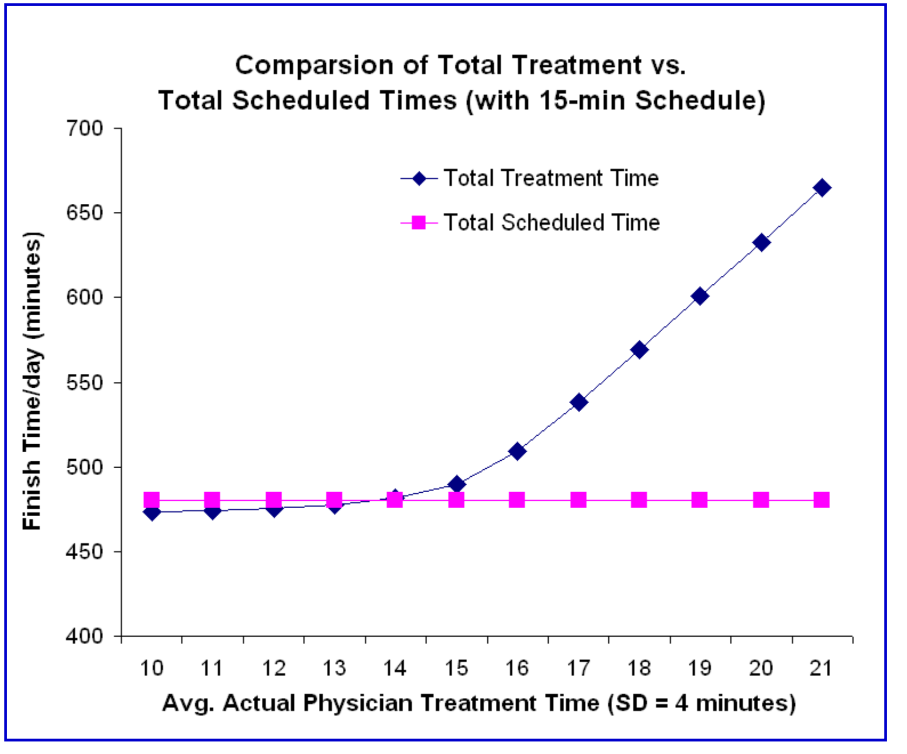
Patient Arrival Time vs. Patient Appointment Time

- Often blurred in practice
- Physician idling may compounds patient wait time

Learning Objective 1

Impact of Inaccurate Estimated of Treatment Time





Even *“One Minute”* on average will make a significant difference.

Learning Objective 1

Literature Limitation

- Most studies are either *theoretical* or *case-specific.*
- Appointment rules have not been adopted and implemented successfully in reality due to the *lack of understanding* and *cooperation* of the medical staff.
- *No real case study* supports these appointment rules.

Learning Objective 1

Literature Limitation

- The *variability* of the physician treatment time has not been addressed from the patients' standpoint.

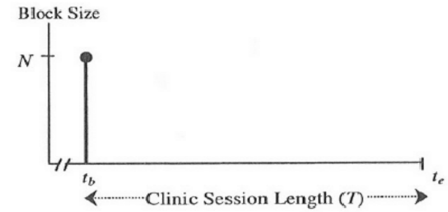
Major Problem ⇨ $\min.\ \overline{W} \times c_W + \overline{P} \times c_P$ *(cost ratio)*

- The *probability of a patient delay* at any given time has never been studied to the point that the patients of each type should be treated equally at any given time in the pre-determined template (slots).

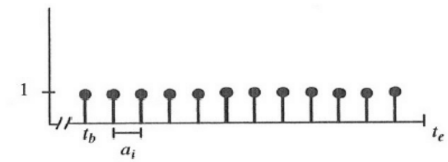
- There isn't a clear distinguish between the *physician's schedule* and the *patients' schedule*.

Appointment Rules

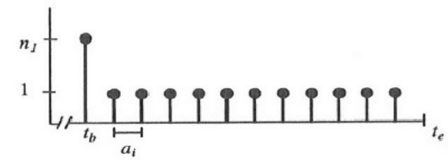
1. **Single-block**
   $n_1 = N$
   no a_i



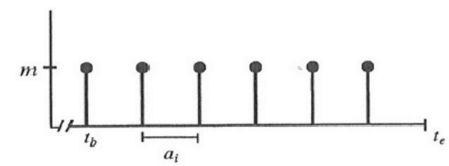
2. **Individual-block/Fixed-interval**
   $n_i = 1$ for all $i = 1, 2, 3, \ldots, N$
   a_i constant



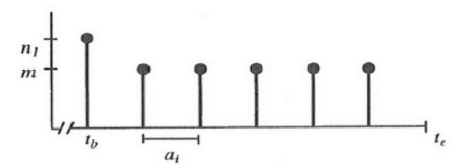
3. **Individual-block/Fixed-interval with an initial block**
   $n_1 > 1$; $n_i = 1$ for all $i = 1, 2, 3, \ldots, N$
   a_i constant



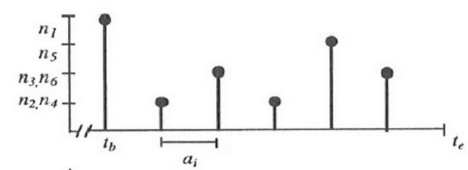
4. **Multiple-block/Fixed-interval (m-at-a-time)**
   $n_i = m > 1$ for all $i = 1, 2, 3, \ldots, N$
   a_i constant



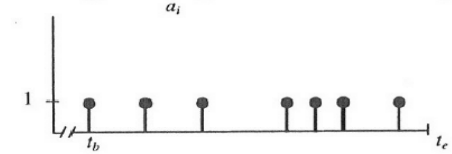
5. **Multiple-block/Fixed-interval with an initial block**
   $n_1 > m$; $n_i = m > 1$ for $i = 2, 3, \ldots, N$
   a_i constant



6. **Variable-block/Fixed-interval**
   n_i variable for $i = 1, 2, 3, \ldots, N$
   a_i constant



7. **Individual-block/Variable-interval**
   $n_i = 1$ for all $i = 1, 2, 3, \ldots, N$
   a_i variable



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a_i= appointment interval, t_b= time begin session, t_e= time end session, n_i= block size for i^{th} block, n_1= initial block

General Modeling

Definitions and Formulations

T_i = Physician's service time to treat patient *i* where *i* = 1, 2, 3, …, *n, and* $T_i \sim D(\mu, \sigma^2)$

n = The number of patients scheduled per session

X = The scheduled time interval for a patient in minutes

S_i = The scheduled time to start patient *i* where *i* = 1, 2, 3, …, *n,* $S_1 = 0$ *and* $S_i = S_{i-1} + X = (i-1)X$

F_i = The finish time for patient *i* where *i* = 1, 2, 3, …, *n*

General Modeling

Definitions and Formulations

A_i = The actual time to start patient *i* where *i* = 1, 2, 3, …, *n*

$$F_i = A_i + T_i \qquad A_i = \begin{cases} S_i & if \quad F_{i-1} < S_i \\ F_{i-1} & Otherwise \end{cases}$$

W_i = The wait time for patient *i* in minutes where *i* = 1, 2, 3, …, *n*

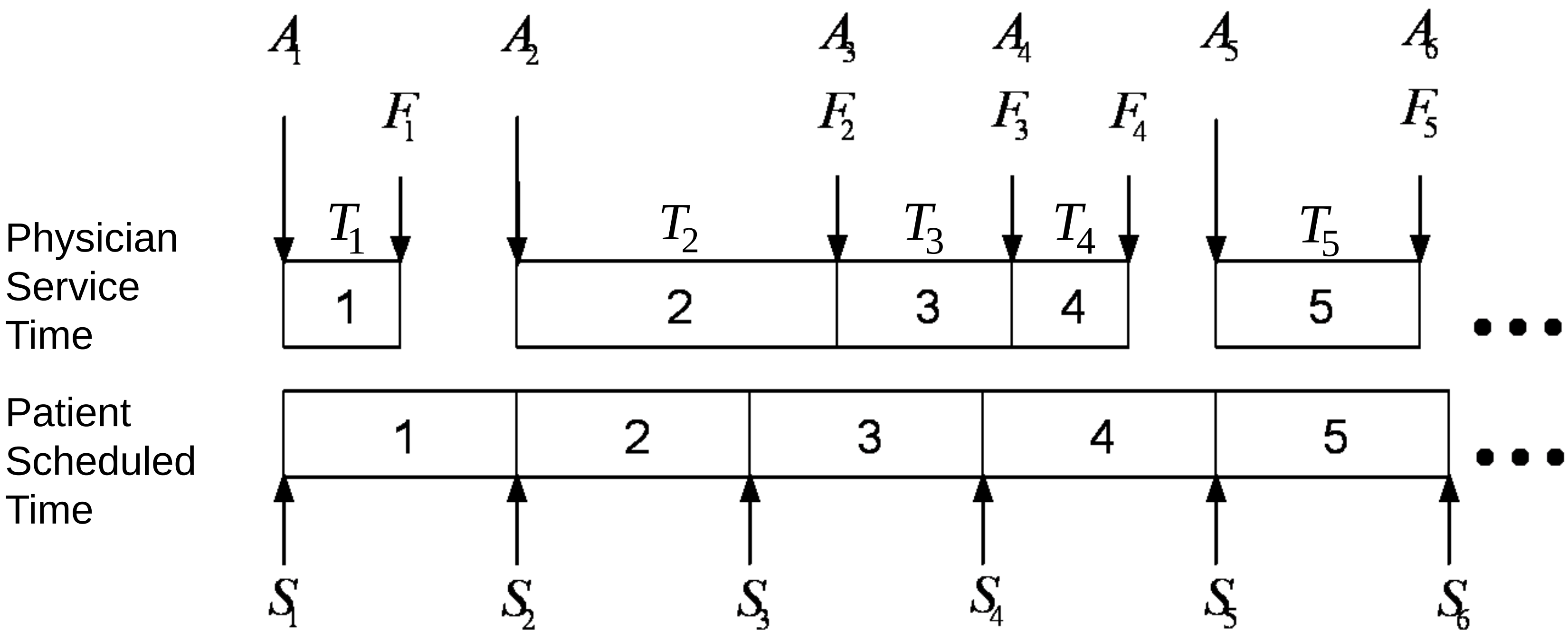
$$W_i = A_i - S_i$$

P_i = The physician idle time waiting for patient *i* where *i* = 1, 2, 3, …, *n*

$$P_i = A_i - F_{i-1}$$

General Modeling

Definitions and Formulations



$W_1 = A_1 - S_1 = 0$ $W_2 = A_2 - S_2 = 0$ $W_3 = A_3 - S_3$ $W_4 = A_4 - S_4$ $W_5 = A_5 - S_5 = 0$

$P_1 = A_1 = 0$ $P_2 = A_2 - F_1$ $P_3 = A_3 - F_2 = 0$ $P_4 = A_4 - F_3 = 0$ $P_5 = A_5 - F_4$

General Modeling

Definitions and Formulations

$\overline{W} =$ The average patient wait time

$$\overline{W} = \frac{\sum_{i=1}^{n} W_i}{n}$$

$\overline{P} =$ The average physician idle time

$$\overline{P} = \frac{\sum_{i=1}^{n} P_i}{n}$$

Learning Objective 2

Wait Ratio

$d =$ Number of standard deviation away from μ

$$X = \mu + d\sigma$$

$R =$ The wait ratio, which is the degree to which patient wait time exceeds *R* physician idle time

$$\frac{\overline{W}}{\overline{P}} = R \Rightarrow \overline{P} \times R = \overline{W} \rightarrow d^* \rightarrow X^* = \mu + d^*\sigma$$

Learning Objective 2

Wait Ratio

Example:

$$T_i \sim Gamma\left(\mu = 15,\ \sigma = 4\right)$$

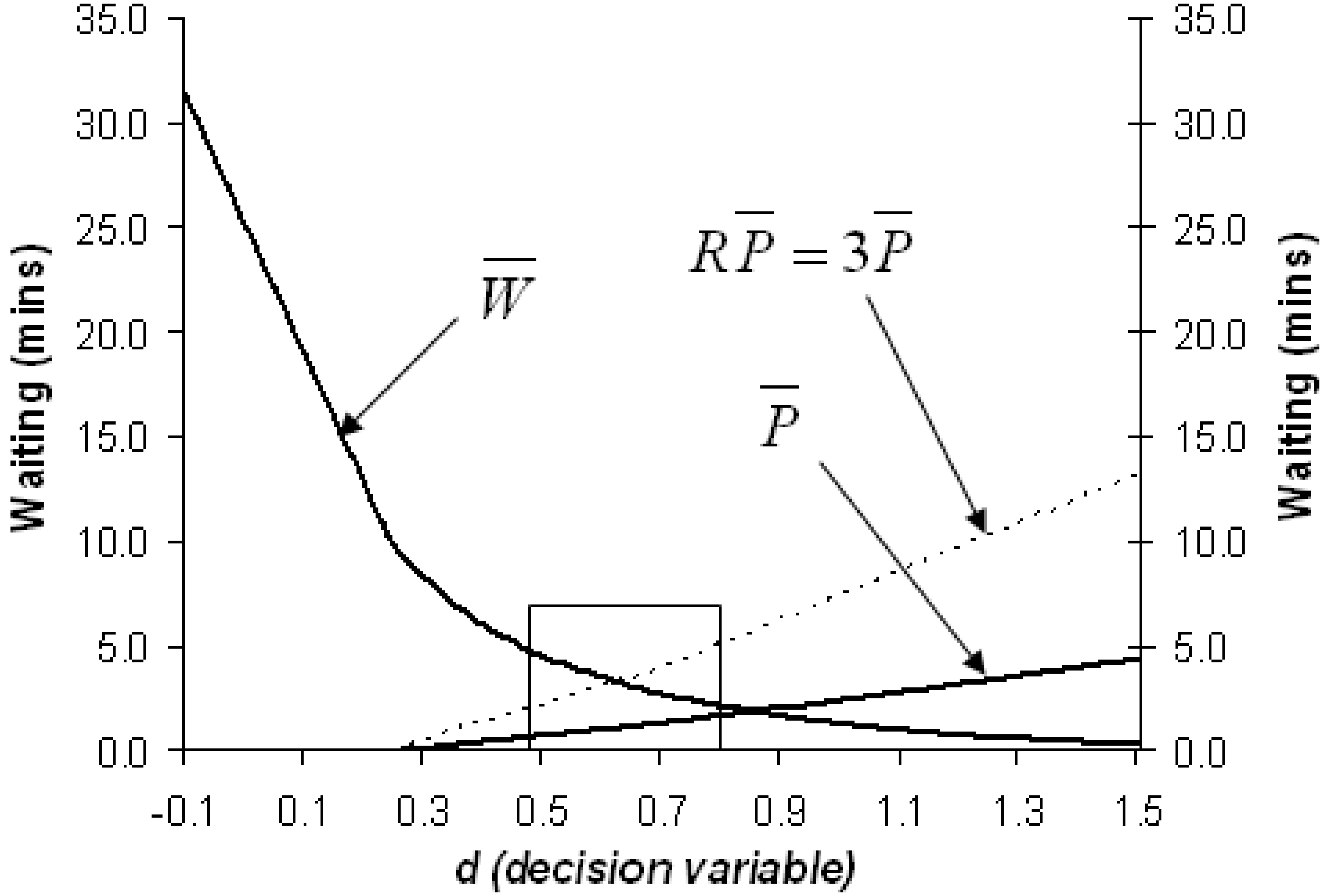
for Return Visit patients, a simulation run.

$n = 32$, 32 patients a day

$R = 3$, Wait Ratio is equal to 3

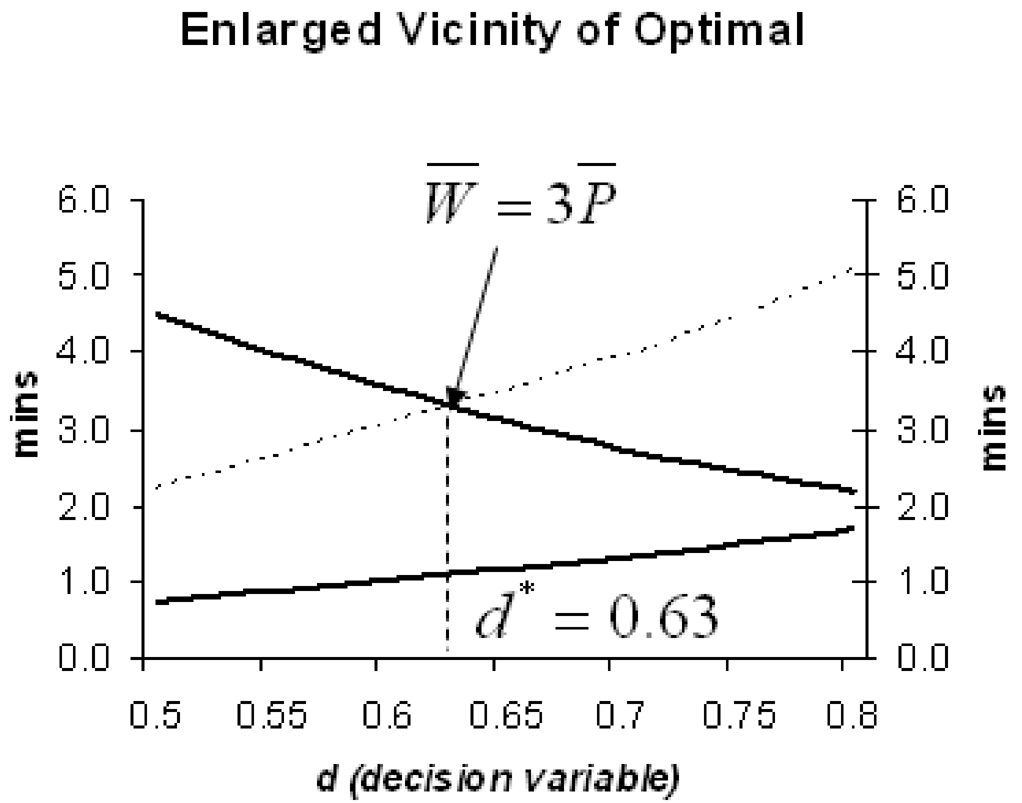
Learning Objective 2

Wait Ratio Example



Learning Objective 2

Wait Ratio Example



The simulation found $d^* = 0.63$. Therefore, the X^* is calculated as:

$$X^* = \mu + d^*\sigma = 15 + 0.63 \times 4 = 17.5\,\text{min}$$

Learning Objective 2

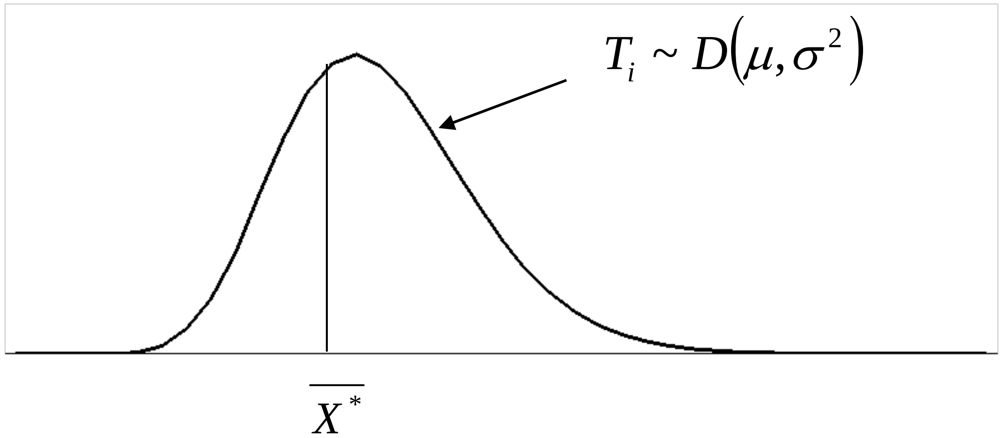
Determine the best wait ratio - Underlying Constraints

Let X be the Scheduled Time Interval, the *i* th patient wait time "in general" is:

$$W_i \ \ consists \ \ of \ \ W_{i-1} \ \ and \ \ \left(T_{i-1} - X\right)$$

In order not to generate additional waiting, the $\left(T_{i-1} - X\right)$ term is preferred to be less than *"0"*. Therefore, given $T_i \sim D\left(\mu, \sigma^2\right)$ and best time interval $\overline{X^*}$, we can only hope:

$$\Pr\left(T_i \le \overline{X^*}\right) \ge 0.5$$



Learning Objective 2

Determine the best wait ratio - Clinical Constraints

- Clinic or session finish time
- Time of last appointment
- Number of patients to be seen in a given session
- Average patient wait time
- Maximum patient wait time
- Average physician Idle time
- Maximum physician Idle time

Learning Objective 2

Example – Orthopedic Surgery Clinic

Patient Type	Average	Standard Deviation
NP	10.6	4.5
FU	7.3	4.0
XR	5.5	3.4

Unit: minutes

NP: new patients

FU: follow-up patients

XR: patients need x-ray before being seen

Learning Objective 2

Orthopedic Surgery Clinic

Wait Ratio	Best Scheduled Time Interval		
	FU	NP	XR
1:1	9.2	12.7	6.8
2:1	8.6	12.1	6.4
3:1	8.4	11.8	6.1
4:1	8.2	11.5	6.0
5:1	8.0	11.4	5.9
6:1	7.9	11.3	5.8
7:1	7.8	11.2	5.7
8:1	7.8	11.1	5.7
9:1	7.7	11.0	5.6
10:1	7.6	11.0	5.6
11:1	7.6	10.9	5.5
12:1	7.6	10.8	5.5
13:1	7.5	10.8	5.4
14:1	7.5	10.8	5.4
15:1	7.4	10.7	5.4
16:1	7.4	10.7	5.4
17:1	7.4	10.7	5.3
18:1	7.4	10.6	5.3
19:1	7.3	10.6	5.3
20:1	7.3	10.6	5.3

Learning Objective 2

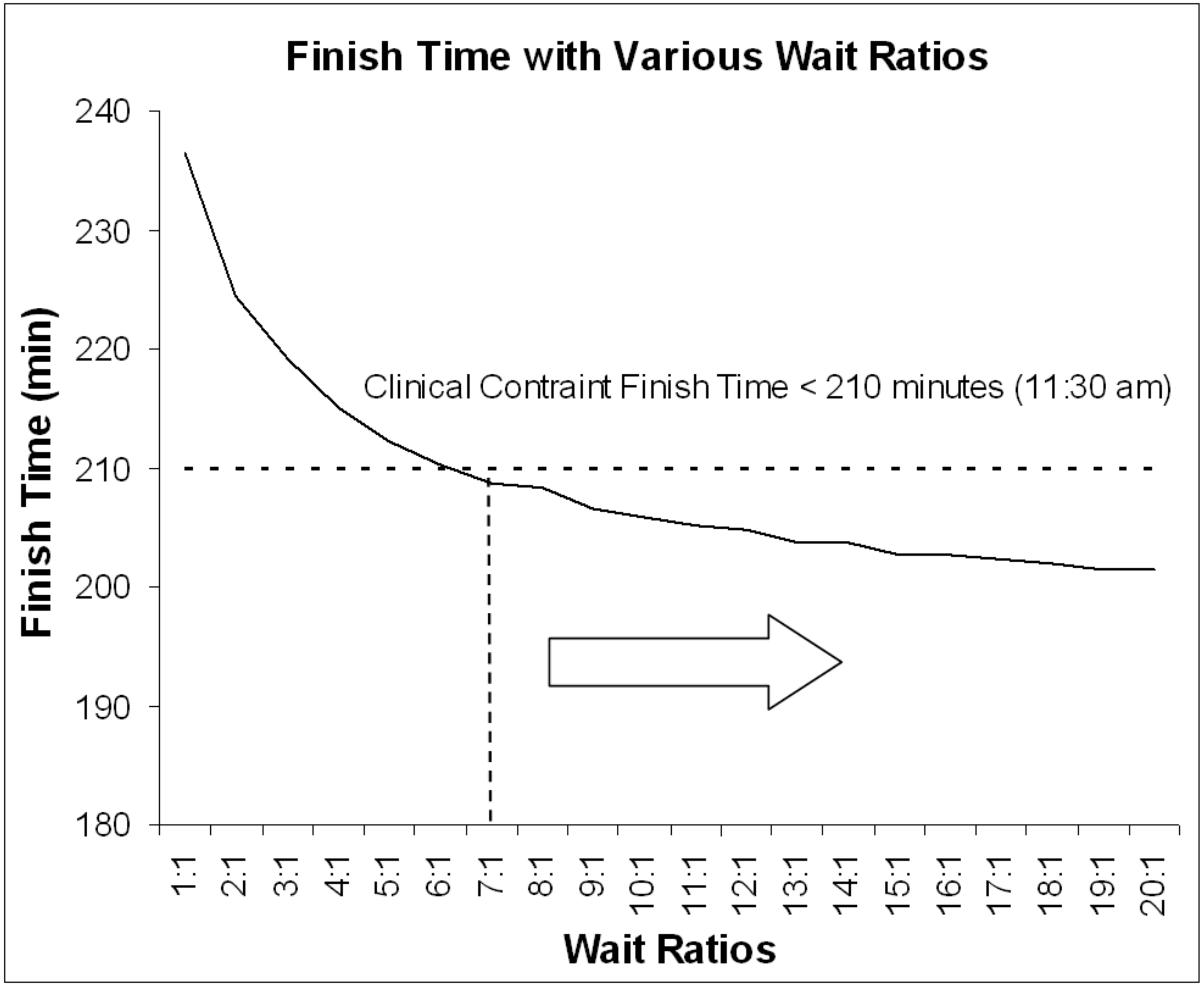
Example – Orthopedic Surgery Clinic

Clinic constraints:

- Session finished by 11:30 a.m. (210 min)
- Last patient scheduled by 11:00 a.m. (180 min)
- 25 patients in a session

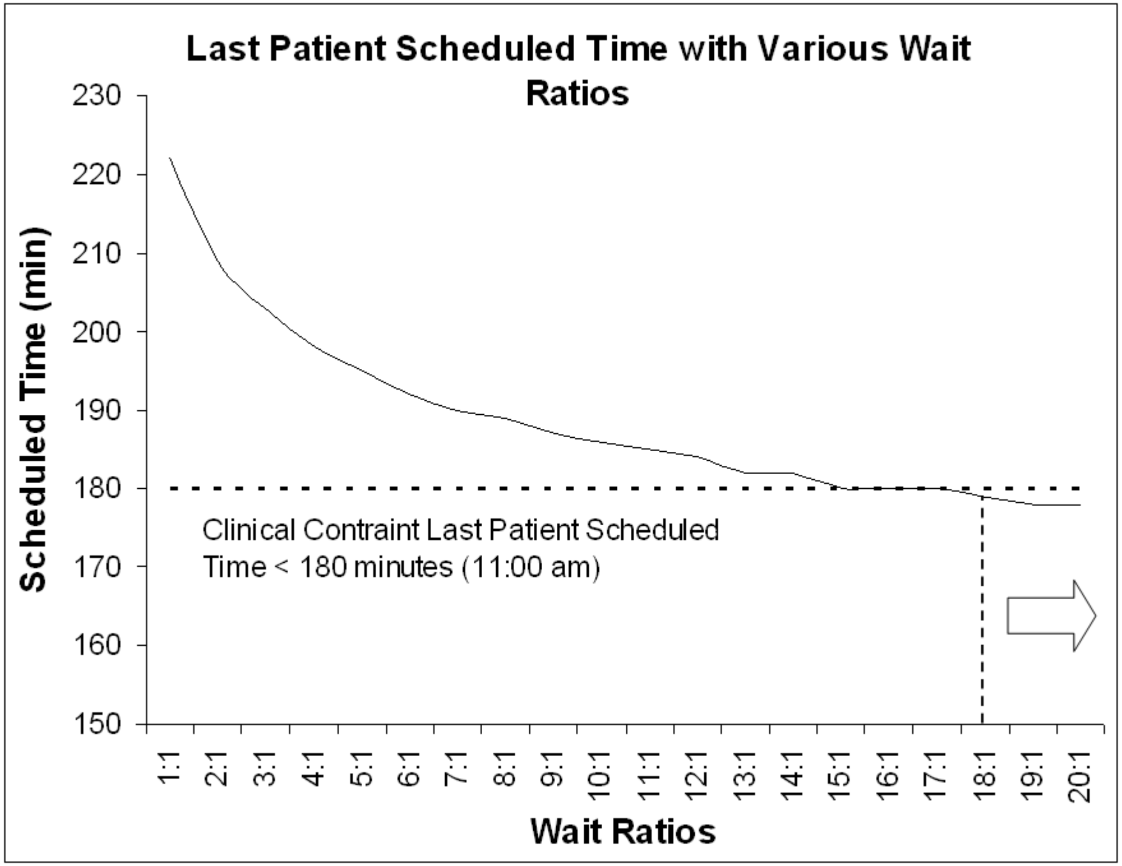
Learning Objective 2

Example – Orthopedic Surgery Clinic



Learning Objective 2

Example – Orthopedic Surgery Clinic



The wait ratio that satisfies both constraints is ***<u>18:1</u>***, which

$$\Pr\left(T_i \leq \overline{X^*}\right) \cong 57\%$$

Learning Objective 2

Provider Schedule – Orthopedic Surgery Clinic

<u>Provider Schedule</u>: Once best treatment time intervals for each visit type are determined, the schedule can be set up accordingly. For example: assuming start time is at 8:00 a.m.

Visit Type	Best Time Interval (min.)
FU	7.4
NP	10.6
XR	5.3

Visit Type	Physician Schedule
FU	8:00
XR	8:07
NP	8:13
FU	8:23
XR	8:31
NP	8:36
⋮	⋮

Learning Objective 3

Patient Arrival Schedule

Patient Arrival Schedule: Once the provider schedule is set up, then patients' arrival is scheduled accordingly. The determination of "Enough Time" includes:

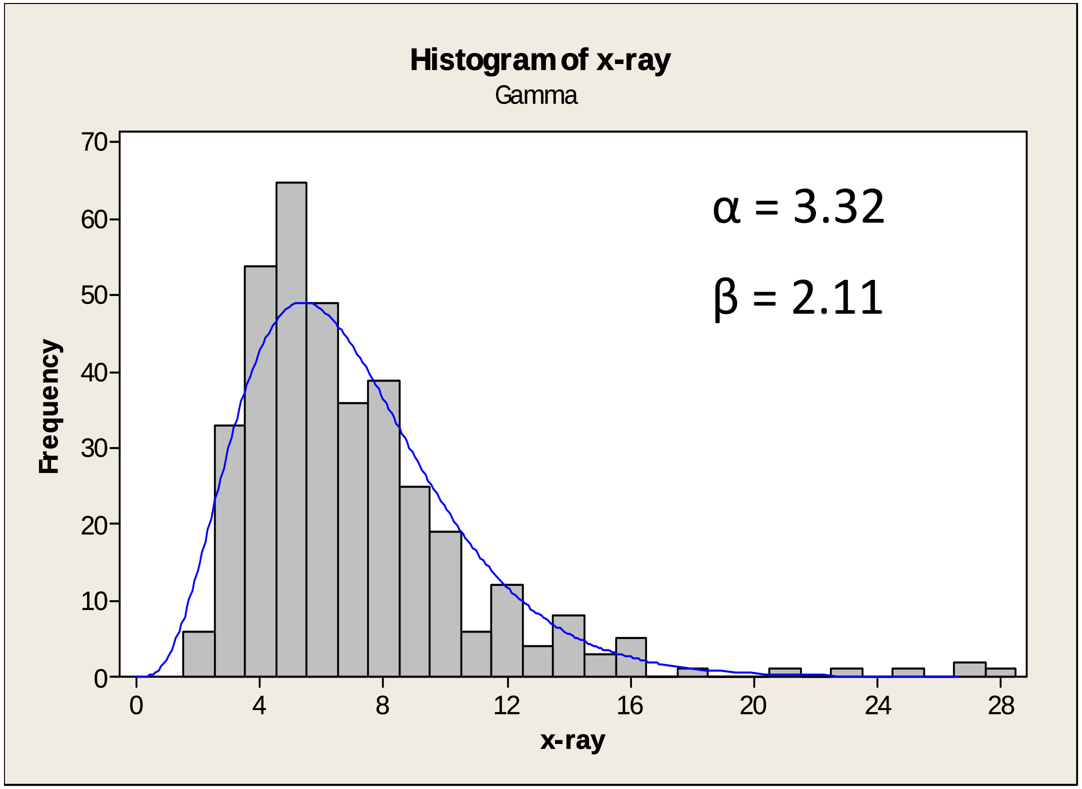
- Signing in
- Filling out paperwork
- Having vital or x-ray taken
- Moving from room to room
- Being seen by Medical Assistance or Nurse
- Providing a specimen……..

Goal *is to minimize average patient wait time.*

Learning Objective 3

Patient Arrival Schedule – Orthopedic Surgery Clinic

X-ray is the main ancillary service that is focused on.

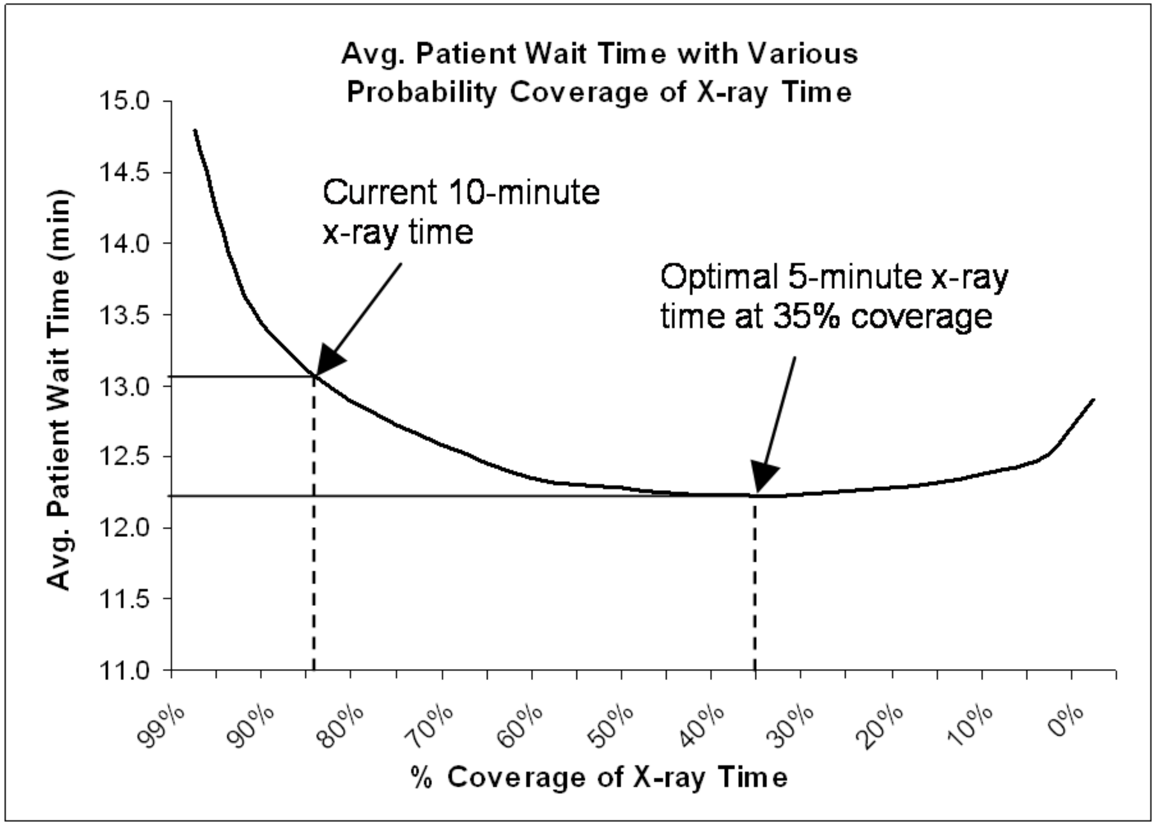


Learning Objective 3

Patient Arrival Schedule – Orthopedic Surgery Clinic

Let *Y* be the scheduled time interval of ancillary service

$$X-ray \sim Gamma\left(6.3, 3.7^2\right) \rightarrow \Pr\left(X-ray \leq Y^*\right) = 0.35 \Rightarrow Y^* = 5 \text{ min}.$$



Learning Objective 3

Patient Arrival Schedule – Orthopedic Surgery Clinic

10 minutes for all pre-visit activities and 5 minutes for taking x-ray for XR patients. (Arrival times are rounded to the nearest 5-minute increment)

Visit Type	Physician Schedule	Patient Arrival Schedule
FU	8:00	7:50 (0 – 10)
XR	8:07	7:50 (7.4 - 15)
NP	8:13	8:00 (12.7 - 10)
FU	8:23	8:15 (23.3 – 10)
XR	8:31	8:15 (30.7 – 15)
NP	8:36	8:25 (36 – 10)
⋮	⋮	⋮

Learning Objective 3

Patient Arrival Schedule – Orthopedic Surgery Clinic

23% of NP and 21% of FU needs X-ray before seeing physician and are most likely determined by RN or MA.

Existing Rules:

- Patients who have had joint replacement will need to have x-rays at post operation, 3 month check, and 1year check scheduled under FU patient slots. After a year, if a patient call in and complain of "pain", they would be scheduled as FU and have an x-ray.
- Patients who have had bone displacement or fracture that was manipulated or operated on in the hospital will need an x-ray and are scheduled as FU.

Learning Objective 3

Patient Arrival Schedule – Orthopedic Surgery Clinic

Existing Rules:

- All new patients will need x-rays if they have not had one done elsewhere. A special case is new patients with an indication of arthritis in their knee; if their x-ray only has two views, then they will need to have x-ray for two additional views.
- Patients who are 60+ years old will need x-rays.

Learning Objective 4

Case Study General Problems

- Patient wait time is very sensitive to the average treatment time yet most clinics collects no data on average treatment times.

- Clinics usually have 15 or 30 minute slots regardless the difference on the practice of individual physician which generates additional wait time either on the patients or the physician.

Learning Objective 4

Case Study General Problems

- There isn't a clear distinguish between physician schedule and patient arrival schedule. No ancillary services being considered.

- Many clinic schedules are designed to overbook appointments to prevent idle time for physician, which creates unnecessary patient wait time.

Learning Objective 4

Case Study – Orthopedic Surgery Clinic

Original (Morning)	
Patient Type	Patient Arrival
XR	8:00
FU	8:00
NP	8:05
FU	8:15
XR	8:15
NP	8:20
XR	8:25
FU	8:30
FU	8:30
NP	8:45
FU	8:55
FU	9:00
FX	9:00
FU	9:15
XR	9:15
NP	9:20
FX	9:30
XR	9:30
FU	9:45
NP	9:45
FX	10:00
XR	10:00
NP	10:15
FU	10:20
FU	10:30

Proposed (Morning)		
Patient Type	Physician Schedule	Patient Arrival
FU	8:00	7:50
XR	8:07	7:50
NP	8:13	8:00
FU	8:23	8:15
XR	8:31	8:15
NP	8:36	8:25
FU	8:47	8:35
XR	8:54	8:40
FU	8:59	8:50
NP	9:07	8:55
FU	9:17	9:05
XR	9:25	9:10
FU	9:30	9:20
NP	9:37	9:25
FU	9:48	9:40
XR	9:55	9:40
FU	10:01	9:50
FU	10:08	10:00
NP	10:16	10:05
XR	10:26	10:10
FU	10:31	10:20
FU	10:39	10:30
NP	10:46	10:35
FU	10:57	10:45
FU	11:04	10:55

Learning Objective 4

Case Study Summary

Case 1 (Orthopedic Surgery):

	Current		Proposed	
Visit Type	Scheduled Time (min)	Wait Ratio	Scheduled Time (min)	Wait Ratio
NP	10	58:1	10.6	18:1
FU	5	$\infty:1$	7.4	18:1
XR	none	$\infty:1$	5.3	18:1

Results:	Avg. Patient Wait Time (min)	Est. Avg. Physician Idle Time (min)
Before	27.8	0.2
After	13.1	0.8
% Reduction	53%	

Learning Objective 4

Case Study Summary

Case 2 (Plastic Surgery):

	Current		Proposed	
Visit Type	Scheduled Time (min)	Wait Ratio	Scheduled Time (min)	Wait Ratio
NP	30	25:1	33.3	3:1
RV	15	33:1	17.5	3:1
POP	15	53:1	17.4	3:1
HP	15	$\infty:1$	20.4	3:1

Results:

	Avg. Patient Wait Time (min)	Est. Avg. Physician Idle Time (min)
Before	15.0	5.4
After	7.5	5.3
% Reduction	50%	

Learning Objective 4

Case Study Summary

Case 3 (Vascular Surgery):

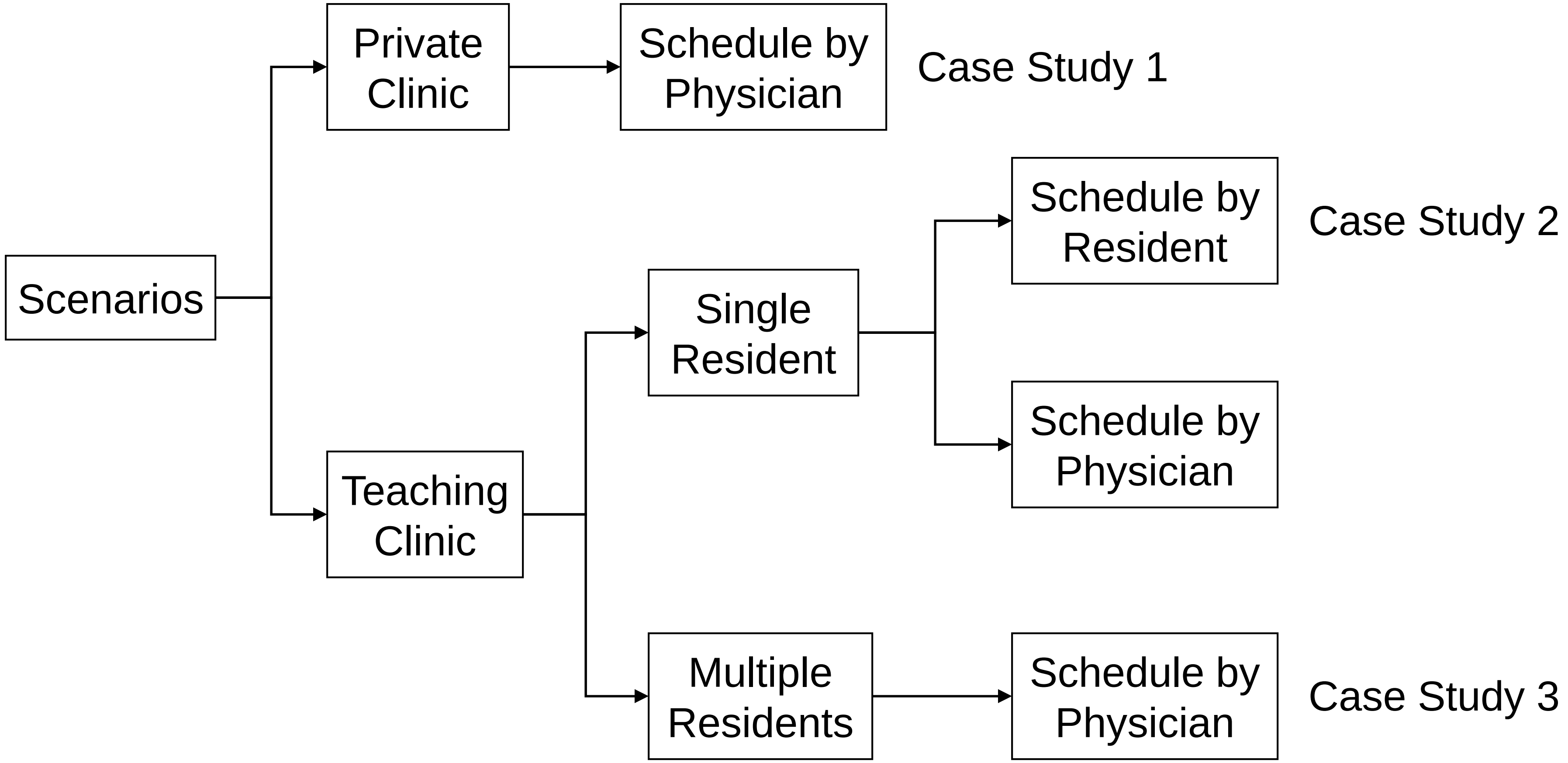
	Current		Proposed	
Visit Type	Scheduled Time (min)	Wait Ratio	Scheduled Time (min)	Wait Ratio
NP	30	1:9	20.7	9:1
RV	15	6:1	14.6	9:1

Results:

	Avg. Patient Wait Time (min)	Est. Avg. Physician Idle Time (min)
Before	27.8	2.0
After	12.4	1.1
% Reduction	56%	

Learning Objective 4

Case Study Summary



Learning Objective 5

Introduction to No-show

- Some of the negative consequences of patient no show are:
  - They create disturbances in the system
  - Reduced provider productivity and clinic efficiency
  - Increased healthcare costs
  - Limited patient access to care

Learning Objective 5

Introduction to No-show

- Issue with Open Access
  - “Doing today’s work today”
  - Burden patients in attempting to get appointments
    - Patients and profit loss
  - Allow overtime to complete
  - High patient wait time

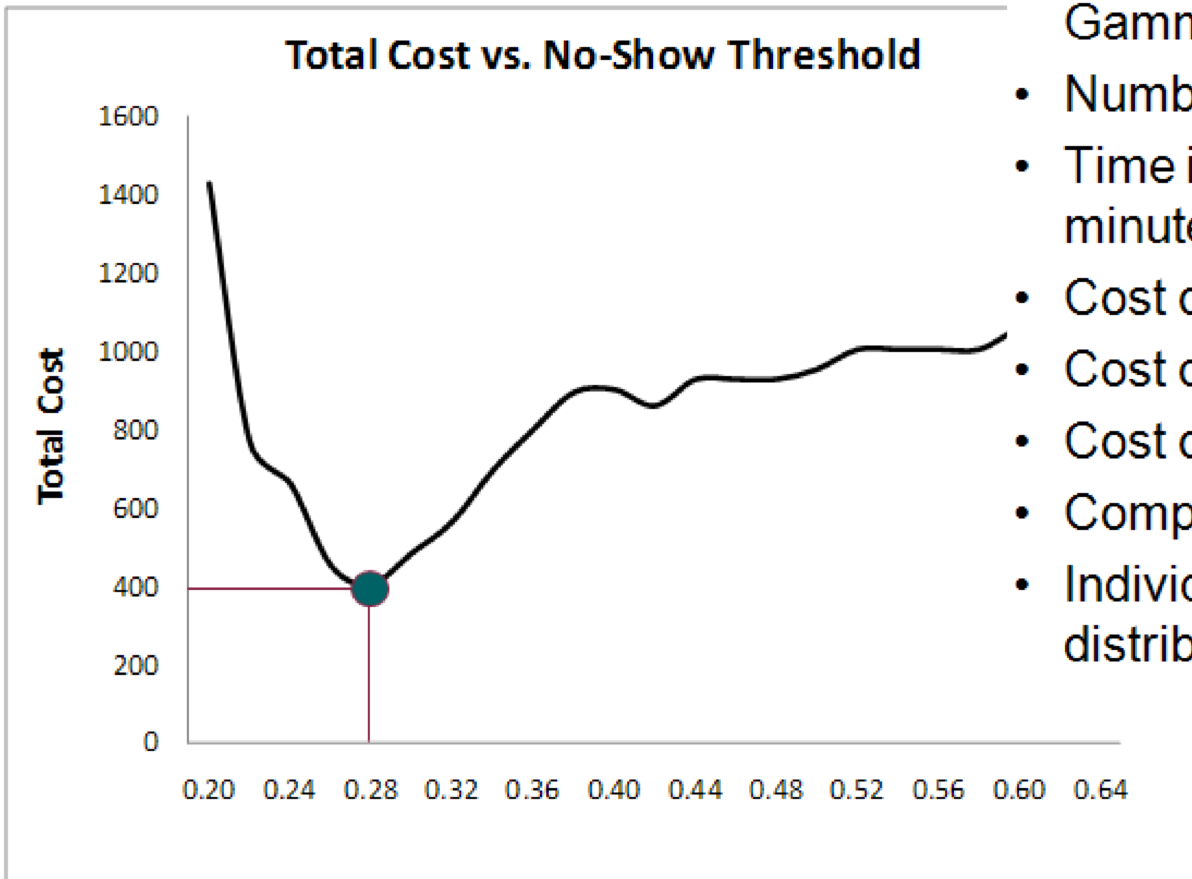
Learning Objective 5

Proposed Overbooking Policy

- Basic steps:
  1. Use a predictive no-show model to estimate individual no-show probabilities
  2. Find the optimal no-show threshold that minimizes the total costs (patient wait time, physician idle time, and overtime)
  3. Overbook slots where the patient’s no-show probability is greater than the threshold
     - Slots can be overbooked more than once if the combined no-show rate of patients in any given slot exceeds the threshold

Learning Objective 5

Proposed Overbooking Policy



- Physician service time distribution: Gamma (15, 10^2)
- Number of slots = 32
- Time interval between slots = 15 minutes
- Cost of patient wait time c_w = 0.25
- Cost of physician idle time c_p = 5
- Cost of clinic overtime c_o = 7.5
- Completion time = 480 minutes
- Individual no-show probability distribution: Gamma (0.3, 0.1^2)

Learning Objective 5

Proposed Overbooking Policy

Given p* = 0.28, $p_{i,j}$ is the predicted no-show rate for patient *j* at slot *i*

i	Scheduled time slots	j=1 First booked patient 1=Yes 2=No	$p_{i,1}$	j=2 first overbooked patient if $p_{i,1} \geq p^*$	$p_{i,2}$	$p_{i,1} \times p_{i,2}$	j=3 second overbooked patient if $p_{i,1} \times p_{i,2} \geq p^*$	Total overbooked (j=2) +(j=3)	Total booked
1	8:00	1	0.14	0					1
2	8:15	1	0.37	1	0.38	0.14	0	1	2
3	8:30	1	0.21	0					1
4	8:45	1	0.55	1	0.42	0.21	0	1	2
5	9:00	1	0.22	0					1
6	9:15	1	0.37	1	0.16	0.06	0	1	2
7	9:30	1	0.59	1	0.38	0.22	0	1	2
8	9:45	1	0.21	0					1
9	10:00	1	0.24	0					1
10	10:15	1	0.36	1	0.32	0.12	0	1	2

Implementation Steps and Outcomes

Overview

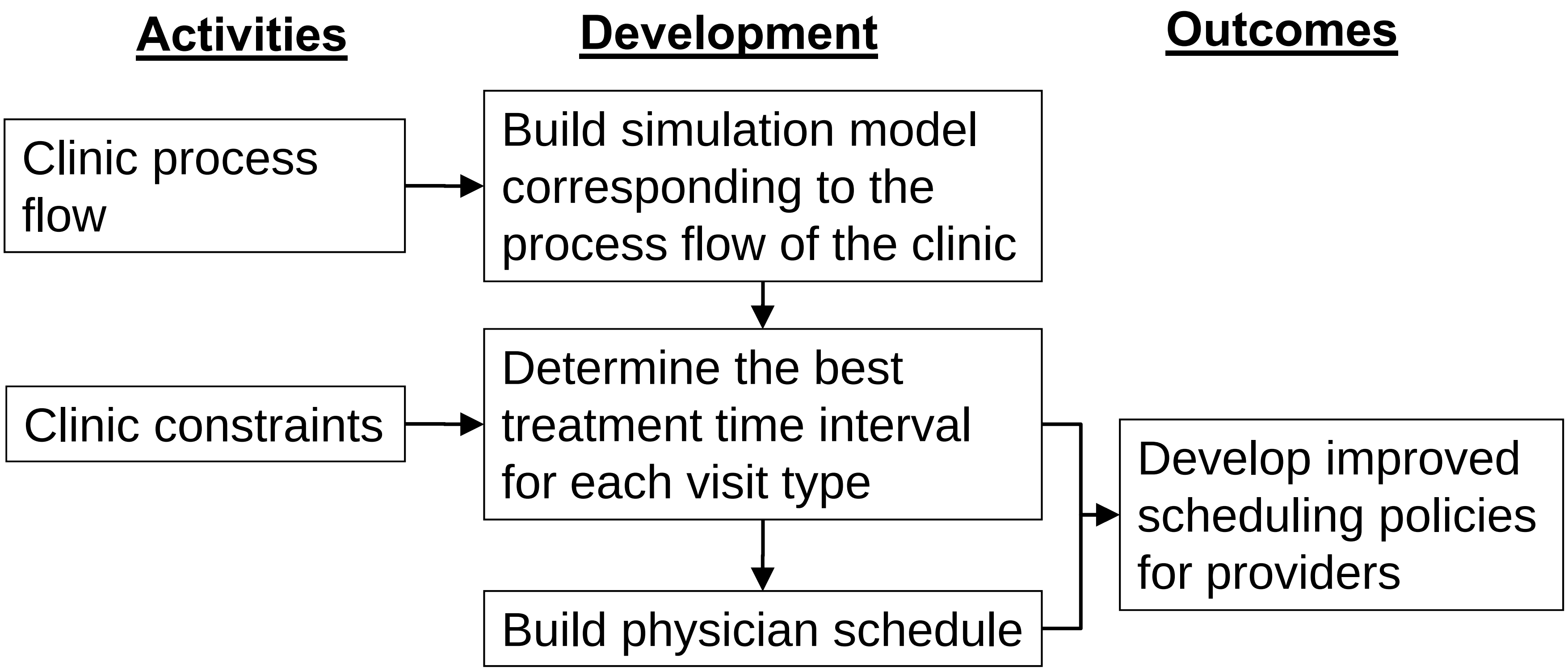
Step 1:

Activities	**Development**	**Outcomes**
Data for physician and medical staff treatment time Data for patient and physician wait time	Understand patient visit time and its variability	Improve physician and staff understanding of time required for different patient types

Implementation Steps and Outcomes

Overview

Step 2:



Implementation Steps and Outcomes

Overview

Step 3:

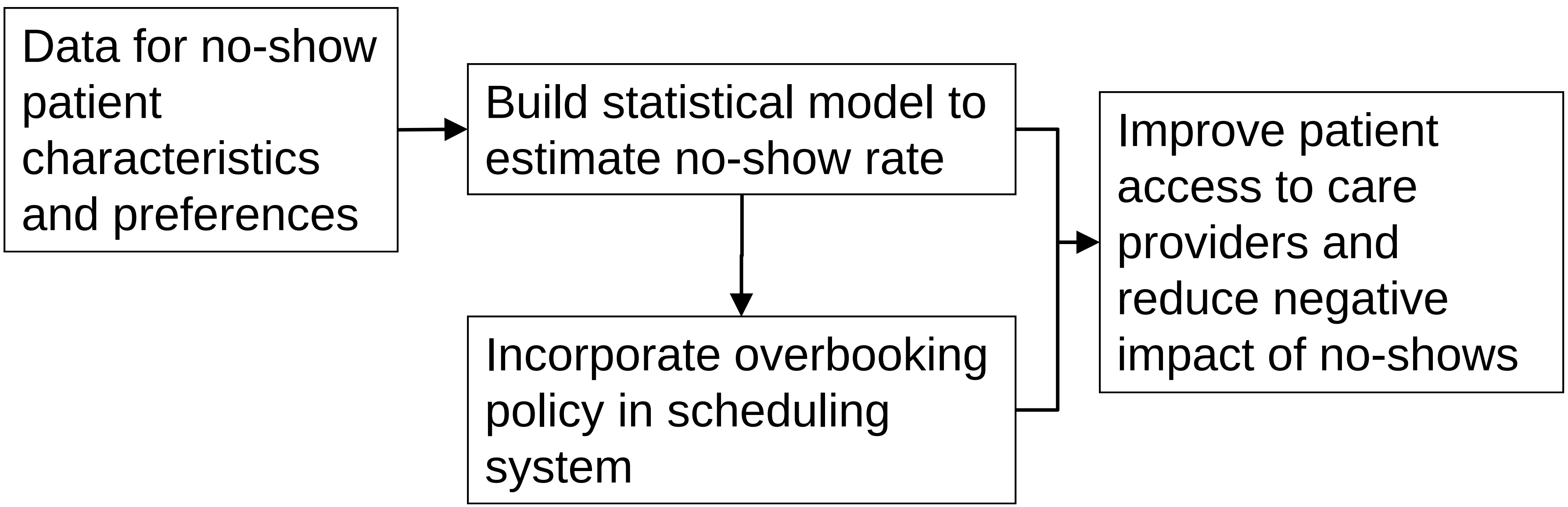
Activities		**Development**		**Outcomes**
Date for treatment time of ancillary services	→	Build patient arrival schedule	→	Develop improved scheduling practices for patient arrival

Implementation Steps and Outcomes

Overview

Step 4:

Activities | **Development** | **Outcomes**



Implementation Steps and Outcomes

Overview

Step 5:

Activities	**Development**	**Outcomes**
Date for patient and physician wait time after implementation →	Approach implementation in clinics →	Enhance patient satisfaction and quality of care

Conclusion

Contributions

- Present the impact where the scheduled treatment times are not based on the actual data.
- Understand the benefit and difference of wait ratio concept to the traditional cost ratio.
- Provide step-by-step approach to develop physician and patient arrival schedules.
- Implement the proposed solution for three clinics to further demonstrate the effectiveness and the simplicity of the approach.

5. Conclusion

Contributions

- A cost-effective overbooking policy that accounts for individual patient’s no-show rate.
- Change patients’ perception of long wait in a physician office.
- Provide a better quality service in terms of patients’ waiting.
- Create a much less stressful working environment for the medical staff.

Questions?

Please contact...

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