

# Reducing Variability in Anesthesia Work Hours by Good Decision-Making on the Day of Surgery

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# Reducing Variability in Anesthesia Work Hours by Good Decision-Making on the Day of Surgery

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# Financial Disclosure

- I am employed by the University of Iowa, in part, to consult and analyze data for hospitals, anesthesia groups, and companies
- Department of Anesthesia bills for my time, and the income is used to fund our research
  - I receive no funds personally other than my salary and allowable expense reimbursements from the University of Iowa, and have tenure with no incentive program
  - I own no healthcare stocks (other than indirectly through mutual funds)

# Topics of Talk on Reducing Variability

- Review of principles in calculating allocated OR time for use in reducing over-utilized time
- Decision-making on the day of surgery to reduce over-utilized time
- Review of why use displays to guide decision-making on the day of surgery
- Monitoring reduced variability in work hours



# Topics of Talk on Reducing Variability

- Dexter F, Wachtel RE, Epstein RH. Decreasing the hours that anesthesiologist and nurse anesthetists work late by making decisions to reduce the hours of over-utilized operating room time. *Anesthesia & Analgesia* 122: 831-842, 2016



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- Review of principles in calculating allocated OR time for use in reducing over-utilized time
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# Example of *Under-Utilized OR Time*

- Allocated time is from 7:15 AM to 3:30 PM
  - These are hours into which cases are scheduled
- An OR's last case of the day ends at 1:30 PM
- There are 2 hours of under-utilized OR time
  - Under-utilized time is from 1:30 PM to 3:30 PM

McIntosh C et al. Anesth Analg 2006

Dexter F, Epstein RH. Periop Care Oper Room Manag 2024



# Example of *Over-Utilized OR Time*

- Allocated time is from 7 AM to 4 PM
- OR's last case of the day ends at 6 PM
- There are 2 hours of *over-utilized OR time*
  - Over-utilized OR time is from 4 PM to 6 PM





# Precise Meaning of “Maximize OR Efficiency”

Inefficiency of use of OR time (\$) =  
(Cost per hour of under-utilized OR time)  
× (hours of under-utilized OR time)  
+ (Cost per hour of over-utilized OR time)  
× (hours of over-utilized OR time)

Strum DP et al. J Med Syst 1997

Dexter F, Epstein RH. Periop Care Oper Room Manag 2024

# Calculating Allocated OR Time

- On Mondays, hospital currently plans 3 ORs for orthopedics, each OR for 10 hr
  - $3 \text{ ORs} \times 10 \text{ hr} = 30 \text{ hr}$
- On Mondays, total hours of orthopedic cases including turnovers follows a normal distribution with a mean of 30 hr
- Relative cost of 1 hr over-utilized OR time =  $2.0 \times$  that of 1 hr under-utilized OR time

McIntosh C et al. Anesth Analg 2006

Pandit JJ, Dexter F. Anesth Analg 2009

Dexter F, Epstein RH. Periop Care Oper Room Manag 2024

# Calculating Allocated OR Time

- Consider standard deviation of orthopedics' workload on Mondays = 5 hr, a typical value
- Since workload follows a normal distribution, need inverse of normal distribution function
  - Ratio of 2.0:1.0 over-utilized: under-utilized
  - Excel "= NORMINV( 2/3, 30, 5 )"
- The 66<sup>th</sup> percentile of the normal distribution function with mean 30 hr and standard deviation 5 hr equals **32 hr**



# Calculating Allocated OR Time

- Consider standard deviation of orthopedics' workload on Mondays = 5 hr, a typical value
- Using the mean of 30 hr, what OR allocation maximizes efficiency of use of OR time?
  - 1) 3 ORs : 2 × 8 hr, 1 × 10 hr
  - 2) 3 ORs : 1 × 8 hr, 2 × 10 hr
  - 3) 3 ORs : 0 × 8 hr, 3 × 10 hr
  - 4) 4 ORs : 4 × 8 hr, 0 × 10 hr
  - 5) 4 ORs : 3 × 8 hr, 1 × 10 hr
  - 6) 4 ORs : 2 × 8 hr, 2 × 10 hr

# Calculating Allocated OR Time

- Consider standard deviation of orthopedics' workload on Mondays = 5 hr, a typical value
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  - 5) 4 ORs : 3 × 8 hr, 1 × 10 hr
  - 6) 4 ORs : 2 × 8 hr, 2 × 10 hr

# Calculating Allocated OR Time

- Consider standard deviation of orthopedics' workload on Mondays = **10** hr, a large value
- Since workload follows a normal distribution, need inverse of normal distribution function
  - Ratio of 2.0:1.0 over-utilized: under-utilized
  - Excel "= NORMINV( 2/3, 30, **10** )"
- The 66<sup>th</sup> percentile of the normal distribution function with mean 30 hr and standard deviation **10** hr equals **34 hr**





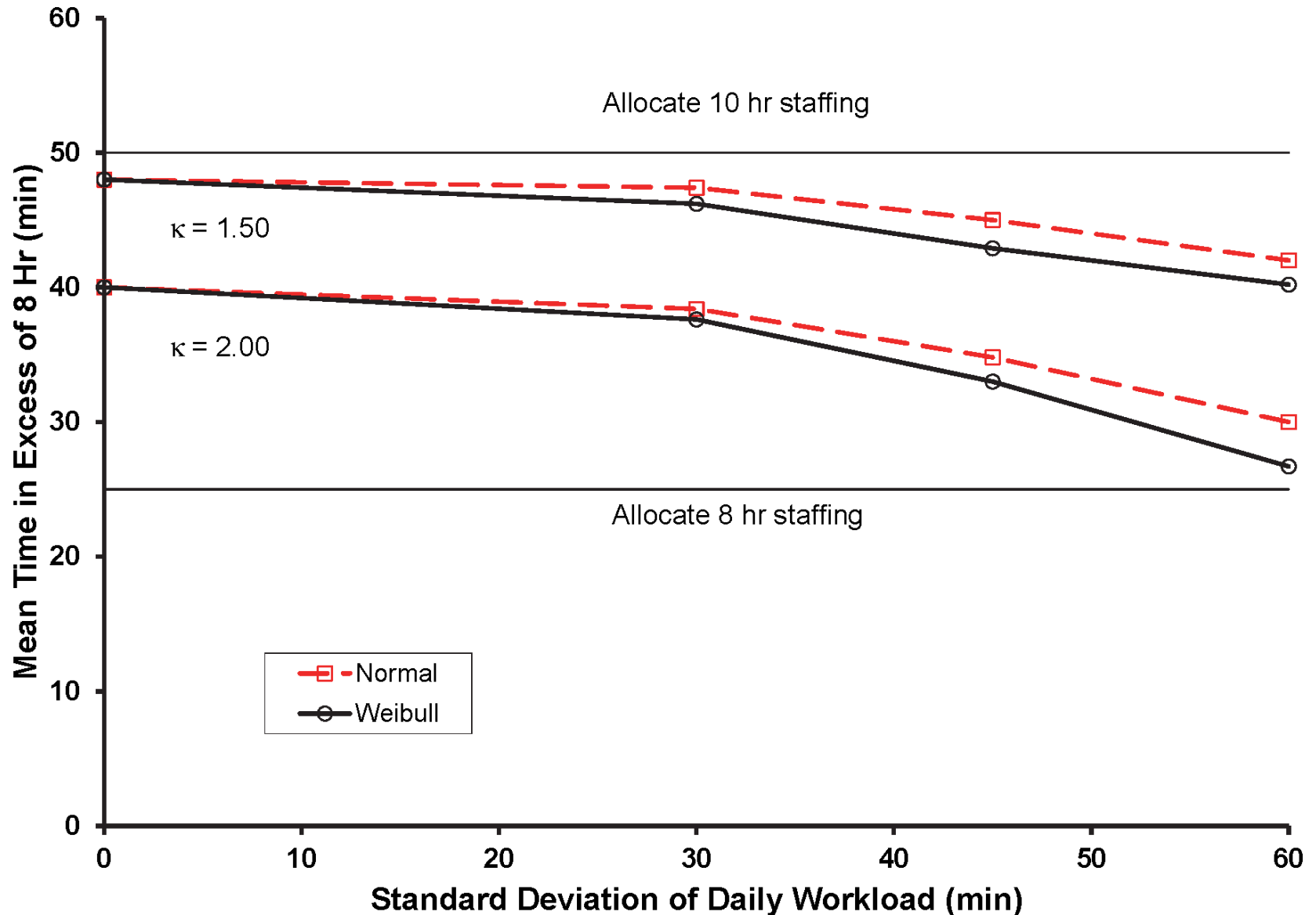
# Calculating Allocated OR Time

- Consider standard deviation of orthopedics' workload on Mondays = 10 hr, a large value
- Using the mean of 30 hr, what OR allocation maximizes efficiency of use of OR time?
  - 1) 3 ORs : 2 × 8 hr, 1 × 10 hr
  - 2) 3 ORs : 1 × 8 hr, 2 × 10 hr
  - 3) 3 ORs : 0 × 8 hr, 3 × 10 hr
  - 4) 4 ORs : 4 × 8 hr, 0 × 10 hr
  - 5) 4 ORs : 3 × 8 hr, 1 × 10 hr
  - 6) 4 ORs : 2 × 8 hr, 2 × 10 hr

# Calculating Allocated OR Time

- Consider standard deviation of orthopedics' workload on Mondays = 10 hr, a large value
- Using the mean of 30 hr, what OR allocation maximizes efficiency of use of OR time?
  - 1) 3 ORs : 2 × 8 hr, 1 × 10 hr
  - 2) 3 ORs : 1 × 8 hr, 2 × 10 hr
  - 3) 3 ORs : 0 × 8 hr, 3 × 10 hr
  - 4) 4 ORs : 4 × 8 hr, 0 × 10 hr
  - 5) 4 ORs : 3 × 8 hr, 1 × 10 hr
  - 6) 4 ORs : 2 × 8 hr, 2 × 10 hr

# Allocated Times for Single ORs From Pandit & Dexter 2009



# Allocated Times for Single ORs From Pandit & Dexter 2009

- Suppose normal distribution, mean workload 30 hours, standard deviation 5 hours, relative cost ratio of 2.00, and 10 hours allocated time
- Inefficiency of use of OR time proportional to:

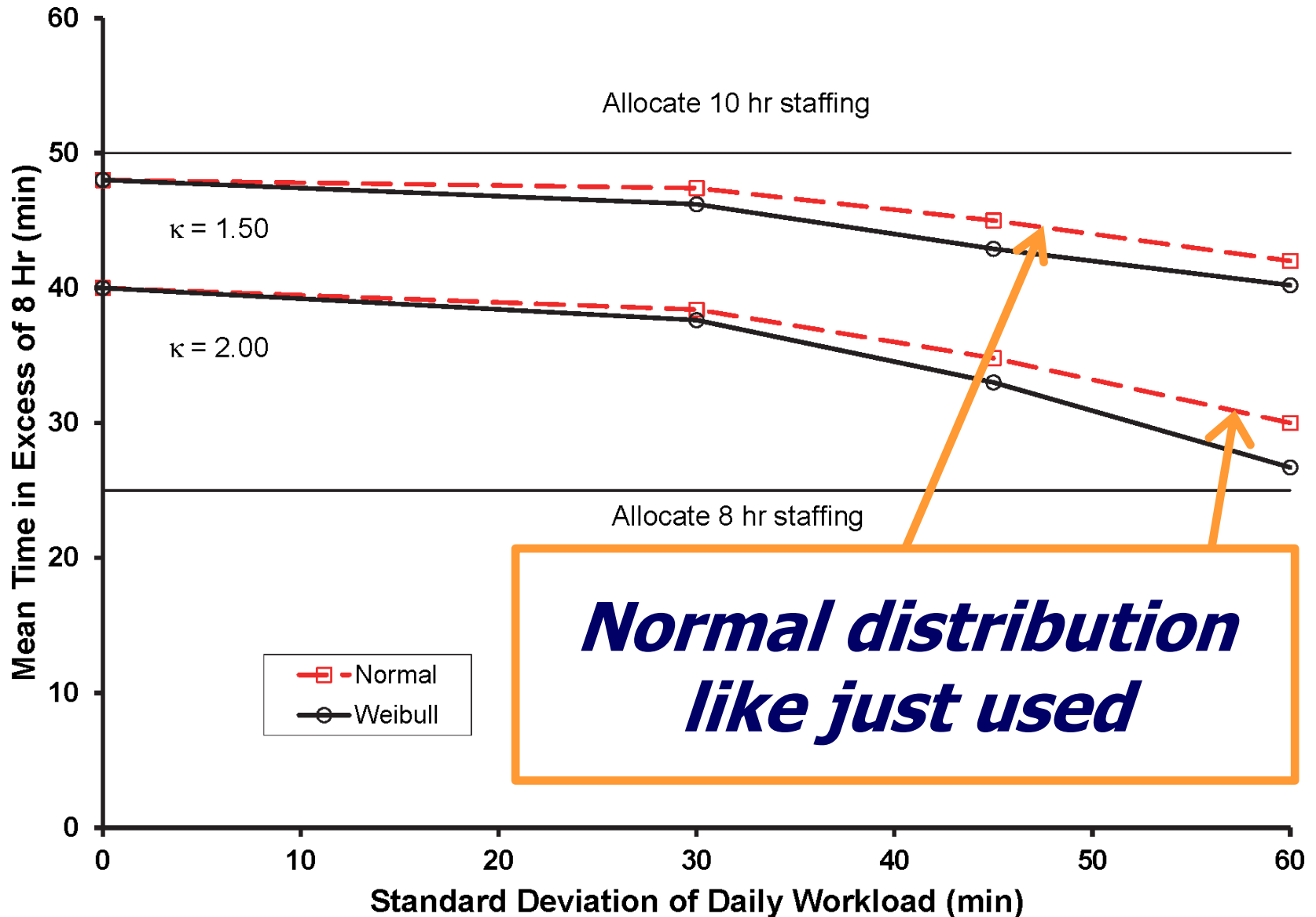
```
= AVERAGE ( LET ( X,  
                NORM.INV ( RANDARRAY (1000000), 30, 5 ),  
                IF ( X < 10, 10 - X, 2.0 * ( X - 10 ) )))
```

Dexter F, Epstein RH. JVS Vasc Insights 2024

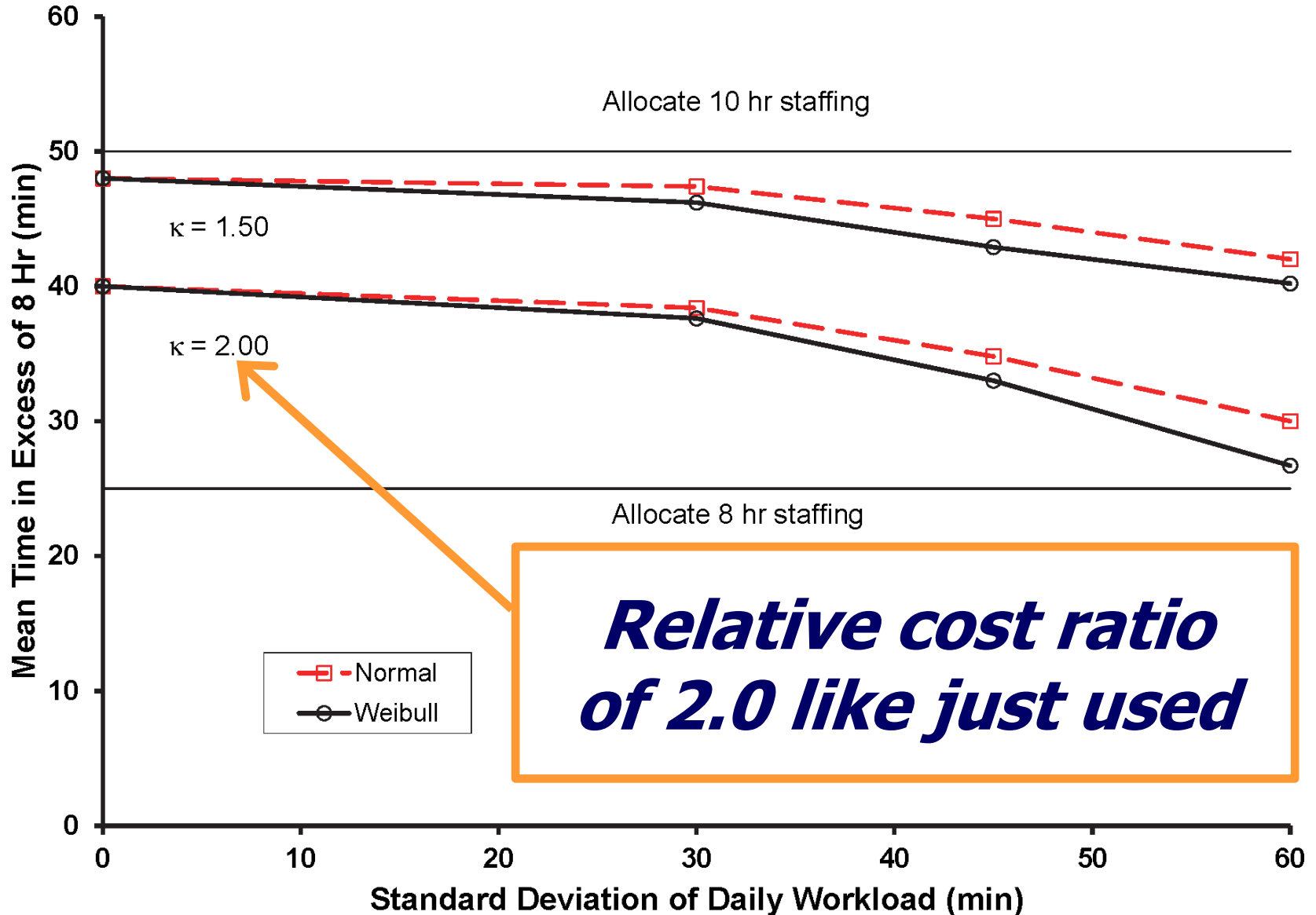
Dexter F et al. Am J Vet Res 2024



# Allocated Times for Single ORs From Pandit & Dexter 2009

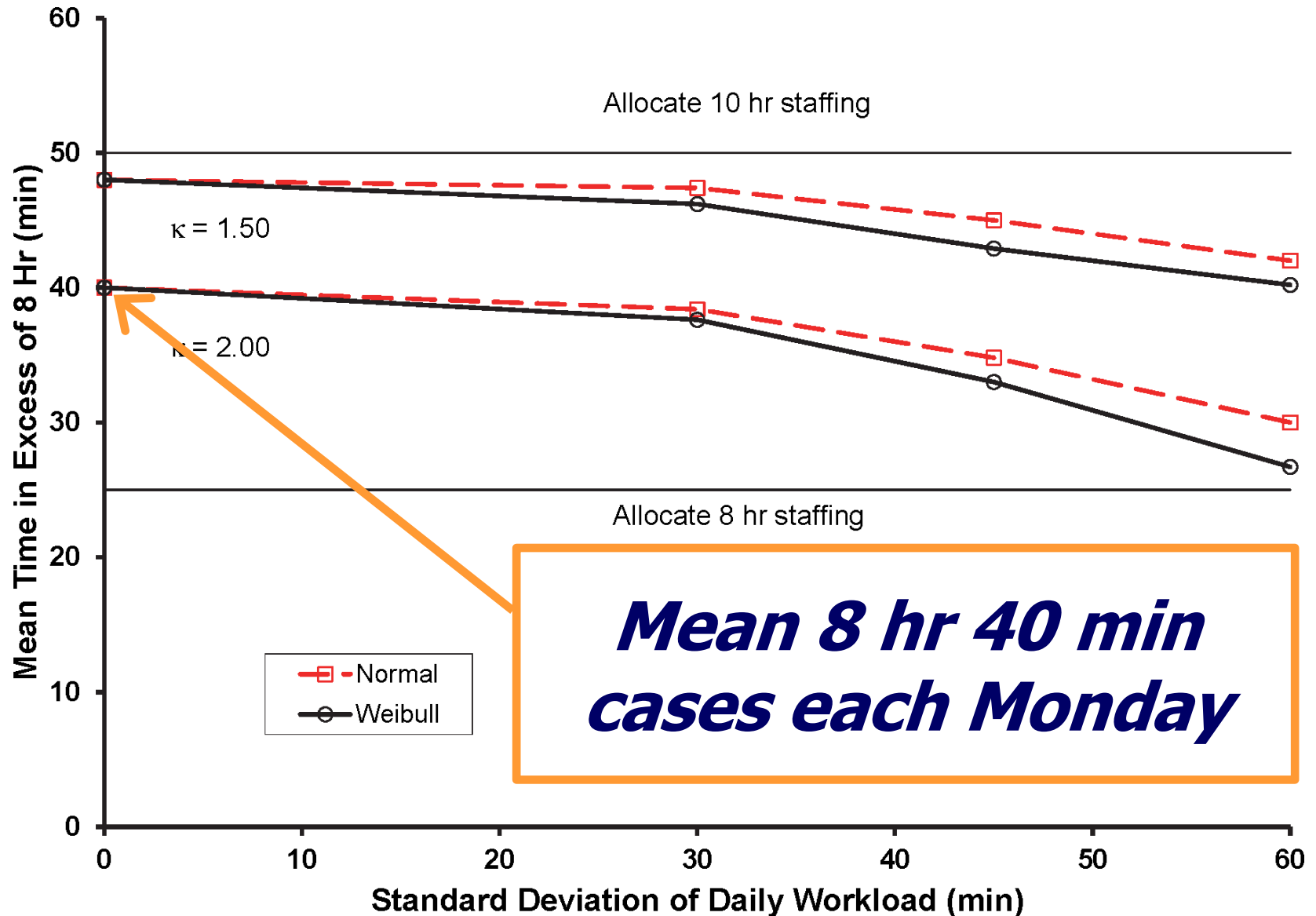


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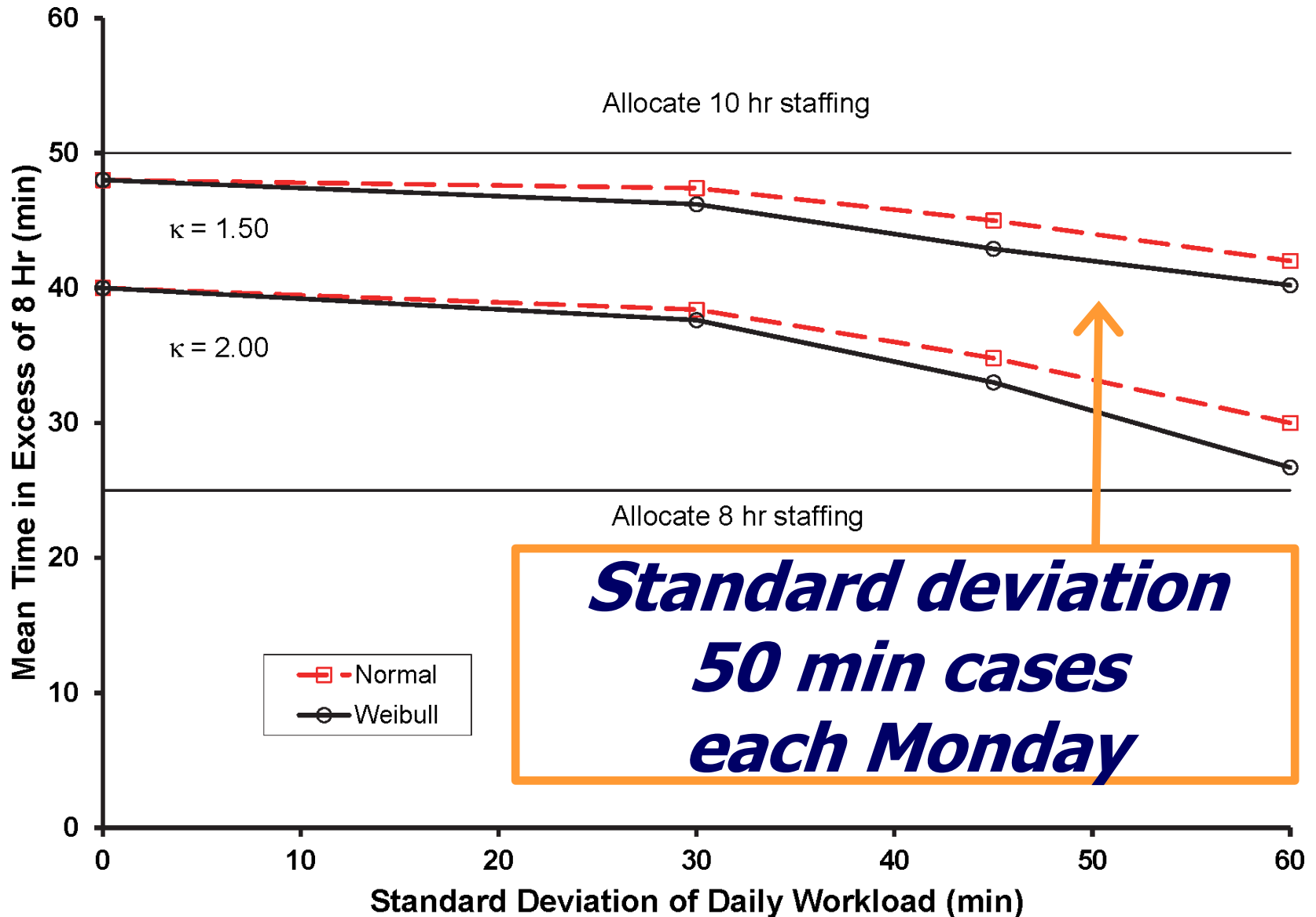




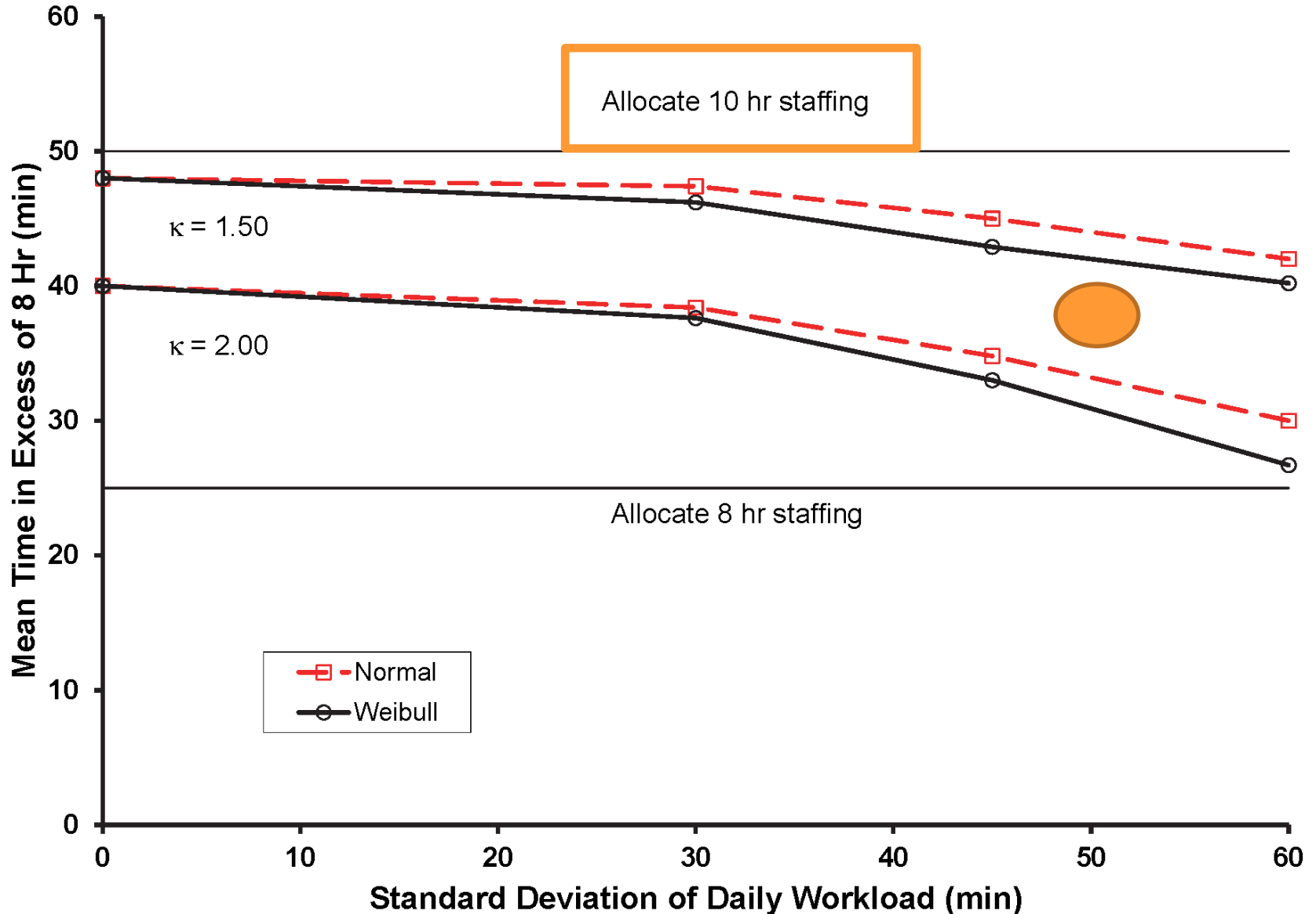
# Allocated Times for Single ORs From Pandit & Dexter 2009



# Allocated Times for Single ORs From Pandit & Dexter 2009



# Allocated Times for Single ORs From Pandit & Dexter 2009



# Reducing Variability

- Vertical axis relates to mean
  - Commonly used to report adjusted utilization
- Horizontal axis relates to standard deviation



# Reducing Variability

- Vertical axis relates to mean
  - Commonly used to report adjusted utilization
- Horizontal axis relates to standard deviation
- Since objective is to reduce ***variability*** in work hours, focus includes both mean and the standard deviation, principally the latter



# Topics of Talk on Reducing Variability

- Review of principles in calculating allocated OR time for use in reducing over-utilized time
- Decision-making on the day of surgery to reduce over-utilized time
- Review of why use displays to guide decision-making on the day of surgery
- Monitoring reduced variability in work hours





# Scenario 1 – Can Working Fast Increase OR Efficiency?

- OR nurses, nurse anesthetists, and anesthesiologists are full-time employees
- Allocated time is from 8 AM to 3:30 PM
- There are estimated to be 8.5 hr of cases
- Turnover and extubation times are brief
- OR finishes at 3:30 PM, instead of 4:30 PM
- Has OR efficiency been increased?



# Scenario 1 – Can Working Fast Increase OR Efficiency?

- OR nurses, nurse anesthetists, and anesthesiologists are full-time employees
- On the day of surgery, the cost of an hour of under-utilized OR time is negligible relative to the cost of an hour of over-utilized OR time



# Meaning of Maximizing OR Efficiency on Day of Surgery

Inefficiency of use of OR time (\$)  $\cong$   
~~(Cost per hour of under-utilized OR time)~~  
× (hours of under-utilized OR time)  
+ (Cost per hour of over-utilized OR time)  
× (hours of over-utilized OR time)

Dexter F, Traub RD. Anesth Analg 2002

Dexter F et al. Anesthesiology 2004



# Meaning of Maximizing OR Efficiency on Day of Surgery

Inefficiency of use of OR time (\$)  $\cong$   
(Cost per hour of over-utilized OR time)  
 $\times$  (hours of over-utilized OR time)



# Meaning of Maximizing OR Efficiency on Day of Surgery

Inefficiency of use of OR time (\$)  $\cong$   
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 $\times$  (hours of over-utilized OR time)

***Constant***



# Meaning of Maximizing OR Efficiency on Day of Surgery

Inefficiency of use of OR time (\$)  $\cong$   
~~(Cost per hour of over-utilized OR time)~~  
 $\times$  (hours of over-utilized OR time)

***Constant***

- Implication
  - Maximize OR efficiency on the day of surgery by minimizing hours of over-utilized OR time





# Meaning of Maximizing OR Efficiency on Day of Surgery

Inefficiency of use of OR time (\$)  $\cong$   
~~(Cost per hour of over-utilized OR time)~~  
 $\times$  (hours of over-utilized OR time)

***Constant***

- Implication
  - Maximize OR efficiency ***on the day of surgery*** by minimizing hours of over-utilized OR time





# Scenario 1 – Can Working Fast Increase OR Efficiency?

- Scenario
  - Allocated time was from 8 AM to 3:30 PM, which is 7.5 hr
  - Reducing turnover and extubation times resulted in cases finished in 7.5 hr instead of in the expected 8.5 hr
    - Finished at 3:30 PM instead of at 4:30 PM
    - Had 0 hours of over-utilized time instead of 1 hour of over-utilized time



# Scenario 1 – Can Working Fast Increase OR Efficiency?

- Scenario
  - Allocated time was from 8 AM to 3:30 PM, which is 7.5 hr
  - Reducing turnover and extubation times resulted in cases finished in 7.5 hr instead of in the expected 8.5 hr
    - Finished at 3:30 PM instead of at 4:30 PM
    - Had 0 hours of over-utilized time instead of 1 hour of over-utilized time
  - Increased efficiency of use of OR time by preventing 1 hr of over-utilized OR time

# Scenario 1 – Can Working Fast Increase OR Efficiency?

- OR nurses, nurse anesthetists, and anesthesiologists are full-time employees
- Allocated time is from 8 AM to ~~3:30~~ **6** PM
- There are estimated to be 8.5 hr of cases
- Turnover and extubation times are brief
- OR finishes at 3:30 PM, instead of 4:30 PM
- Has OR efficiency been increased?



# Scenario 1 – Can Working Fast Increase OR Efficiency?

- Scenario
  - Allocated time is from 8 AM to ~~3:30~~ **6** PM
  - Reducing turnover and extubation times resulted in cases finished in 7.5 hr instead of in the expected 8.5 hr
  - No increase in OR efficiency



# Scenario 1 – Can Working Fast Increase OR Efficiency?

- Scenario

- Allocated time is from 8 AM to ~~3:30~~ **6** PM
- Reducing turnover and extubation times resulted in cases finished in 7.5 hr instead of in the expected 8.5 hr
- No increase in OR efficiency

Good OR management operational decision-making is highly sensitive to the OR allocations, which is why those values used on the day of surgery need to be calculated appropriately



# Scenario 2 – Anesthesiologist Reduces Turnover Times

- Allocated time is from 7:15 AM to 3:30 PM
- Anesthesiologist is assigned to supervise resident physicians in OR 3 and OR 4
- These ORs have just finished their first cases
- The second and last case of the day in OR 3 is expected to be finished at 2:30 PM
- The second and last case of the day in OR 4 is expected to be finished at 4:30 PM
- Which OR should anesthesiologist start next?



# Scenario 2 – Anesthesiologist Reduces Turnover Times

- The cases will be performed safely regardless of the decision, thus not influencing decision
- *OR efficiency*
  - OR 3 expected 0 hr of over-utilized OR time
    - Finish 2:30 PM, but allocated time to 3:30 PM
  - OR 4 expected 1 hr of over-utilized OR time
    - Finish 4:30 PM, but allocated time to 3:30 PM
- If the patient for OR 4 is ready, the anesthesiologist should start OR 4 first





# Scenario 2 – Anesthesiologist Reduces Turnover Times

- Allocated time is from 7:15 AM to ~~3:30~~ **6** PM
- Anesthesiologist is assigned to supervise resident physicians in OR 3 and OR 4
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- The second and last case of the day in OR 3 is expected to be finished at 2:30 PM
- The second and last case of the day in OR 4 is expected to be finished at 4:30 PM
- Which OR should anesthesiologist start next?



# Scenario 2 – Anesthesiologist Reduces Turnover Times

- *OR efficiency* is unaffected by the decision
  - OR 3 expected 0 over-utilized hours
  - OR 4 expected ~~1~~ 0 over-utilized hours
- *Patient waiting* is unaffected by the decision
  - Last case of the day in both ORs
- *Personal satisfaction* may be affected
  - Whichever anesthesiologist thinks best



# Scenario 2 – Anesthesiologist Reduces Turnover Times

- Moral
  - To make good (rational) OR management operational decisions, you need to know the allocated time planned for each OR
    - Calculated based on minimizing the inefficiency of use of OR time



# Scenario 3 – Which OR Should Housekeeper Clean First?

- Right when two ORs are finishing their first cases of the day on time, only one person is free to clean the two ORs
- Last case of the day in OR 12 is expected to end at 2 PM
- Last case of the day in OR 14 is expected to end at 4:30 PM
- Allocated hours are from 7 AM to 3:30 PM
- Which OR should housekeeper clean first?
  - Follow the ordered priorities



# Scenario 3 – Which OR Should Housekeeper Clean First?

- Safely performing the cases today will not be affected by the decision
- *OR efficiency* is affected by the decision
  - OR 12 expected 0 hr of over-utilized OR time
    - Finish 2 PM, but allocated time to 3:30 PM
  - OR 14 expected 1 hr of over-utilized OR time
    - Finish 4:30 PM, but allocated time to 3:30 PM
- Cleaning OR 14 first is likely to increase OR efficiency





# Scenario 3 – Which OR Should Housekeeper Clean First?

- Right when two ORs are finishing their first cases of the day on time, only one person is free to clean the two ORs
- Last case of the day in OR 12 is expected to end at 2 PM
- Last case of the day in OR 14 is expected to end at 4:30 PM
- Allocated time is from 7 AM to ~~3:30~~ **6** PM
- Which OR should housekeeper clean first?



# Scenario 3 – Which OR Should Housekeeper Clean First?

- *OR efficiency* is unaffected by the decision
  - OR 12 expected 0 over-utilized hours
  - OR 14 expected ~~1.5~~ **0** over-utilized hours
- *Patient waiting* is unaffected by the decision
  - Last case of the day in each OR
- *Personal satisfaction* is basis for decision





# Scenario 4 – Calling For the Next Patient

- Two ORs call for their next cases, but only one person is free to prepare the patients
- Both ORs are 10 min behind schedule
- The four remaining cases in OR-A are estimated to end at 2 PM
- The one remaining case in OR-B is estimated to end at 4 PM
- Allocated time is from 7 AM to 6 PM
- Prepare which patient first?



# Scenario 4 – Calling For the Next Patient

- Safely performing all of these cases today will not be affected by the decision
- *OR efficiency* is unaffected by the decision
  - OR-A expected 0 over-utilized hours
  - OR-B expected 0 over-utilized hours
- *Patient waiting* is affected by decision
  - OR-A expected total tardiness is 40 min
  - OR-B expected total tardiness is 10 min
- Prepare the patient for OR-A first



# Scenario 4 – Calling For the Next Patient

- Two ORs call for their next cases, but only one person is free to prepare the patients
- Both ORs are currently on schedule
- The four remaining cases in OR-A are estimated to end at 2 PM
- The one remaining case in OR-B is estimated to end at 4 PM
- Allocated time is from 7 AM to ~~6 PM~~ **3 PM**
- Prepare which patient first?



# Scenario 4 – Calling For the Next Patient

- *OR efficiency* is affected by the decision
  - OR-A expected 0 over-utilized hours
  - OR-B expected 1 over-utilized hours
- Prepare the patient for OR-B first



# Scenario 4 – Calling For the Next Patient

- *OR efficiency* is affected by the decision
  - OR-A expected 0 over-utilized hours
  - OR-B expected 1 over-utilized hours
- Prepare the patient for OR-B first

Good (rational) OR management operational decision-making is highly sensitive to the allocated time in each OR, and requires knowing the allocated time for each OR



# Topics of Talk on Reducing Variability

- Review of principles in calculating allocated OR time for use in reducing over-utilized time
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- Review of why use displays to guide decision-making on the day of surgery
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# Many Decisions Made on Day of Surgery (or Night Before)

- Add-on cases per OR per day,  $0.247 \pm 0.052$
- OR date combinations with at least one add-on case,  $24.1\% \pm 0.3\%$
- Change in a case  $0.59 \pm 0.02$  events per hour per 10 first case start locations
- OR date combinations with at least one change at private UK hospital,  $37.3\%$

Dexter F et al. Anesthesiology 1999

Dexter F et al. Anesth Analg 2012

Epstein RH et al. Anesth Analg 2015

Walmsley T et al. J Perioper Pract 2018





# Managerial Behavior on the Day of Surgery

- Common behavior is to keep each provider busy during her assigned hours
  - Same as optimal behavior for decisions involving single ORs
  - Not same as optimal behavior for decisions involving multiple ORs, especially when allocated hours differ among ORs

Dexter F et al. Anesth Analg 2007

Stepaniak PS et al. Anesth Analg 2009

Wang J et al. Anesth Analg 2013



# Managerial Behavior on the Day of Surgery

- For scenarios involving pairs of ORs, decisions made without electronic recommendations (displays) less accurate than random chance ( $37\% < 50\%$ ,  $P = 0.011$ )
- Displays with recommendations increase the accuracy of decisions ( $P < 0.0001$ )
- Displays with information on over-utilized time but without recommendations do not increase accuracy ( $P = 0.40$ )



# Managerial Behavior Before the Day of Surgery

- Choice of OR allocations used in the display calculations also are not typically made well
  - Reason is cognitive biases
    - Not politics, culture, lack of buy in, personalities, or organizational inertia
  - Simply, stochastic optimization is not intuitive and what seems intuitive is sub-optimal

Wachtel RE, Dexter F. Anesth Analg 2010



# Managerial Behavior Before the Day of Surgery

- Implications
  - Provide electronic displays with evidence-based recommendations
    - Include OR allocations calculated based on maximizing efficiency of use of OR time
  - Provide education, the value of which is increased trust in the recommendations

Dexter F et al. Anesth Analg 2007

Wachtel RE, Dexter F. J Grad Med Educ 2010

# Managerial Behavior Before the Day of Surgery

- When monitoring managers' performance, good criterion is use by their facility of either:
  - Displays providing recommendations
  - Displays providing information and checklists for how to use the information

Stepaniak PS, Dexter F. Anesth Analg 2013





# Managerial Behavior Before the Day of Surgery

- When monitoring managers' performance, good criterion is use by their facility of either:
  - Displays providing recommendations
  - Displays providing information and checklists for how to use the information
- Use anesthesia group – facility agreement to codify the performance criteria

Dexter F, Epstein RH. Anesth Analg 2008

Dexter F, Epstein RH. Anesth Analg 2015





# Topics of Talk on Reducing Variability

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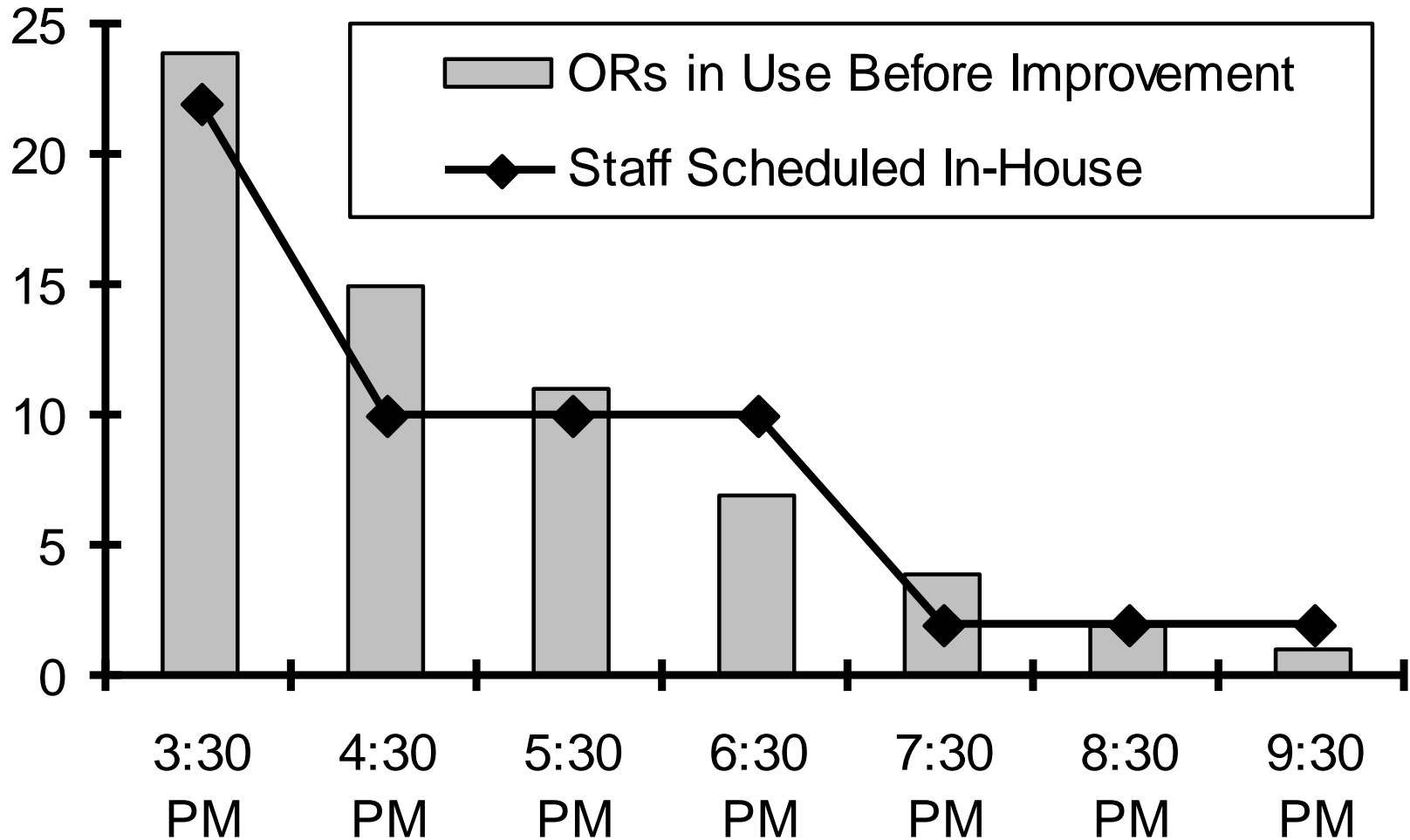


# Reducing Variability Reduces the Variability

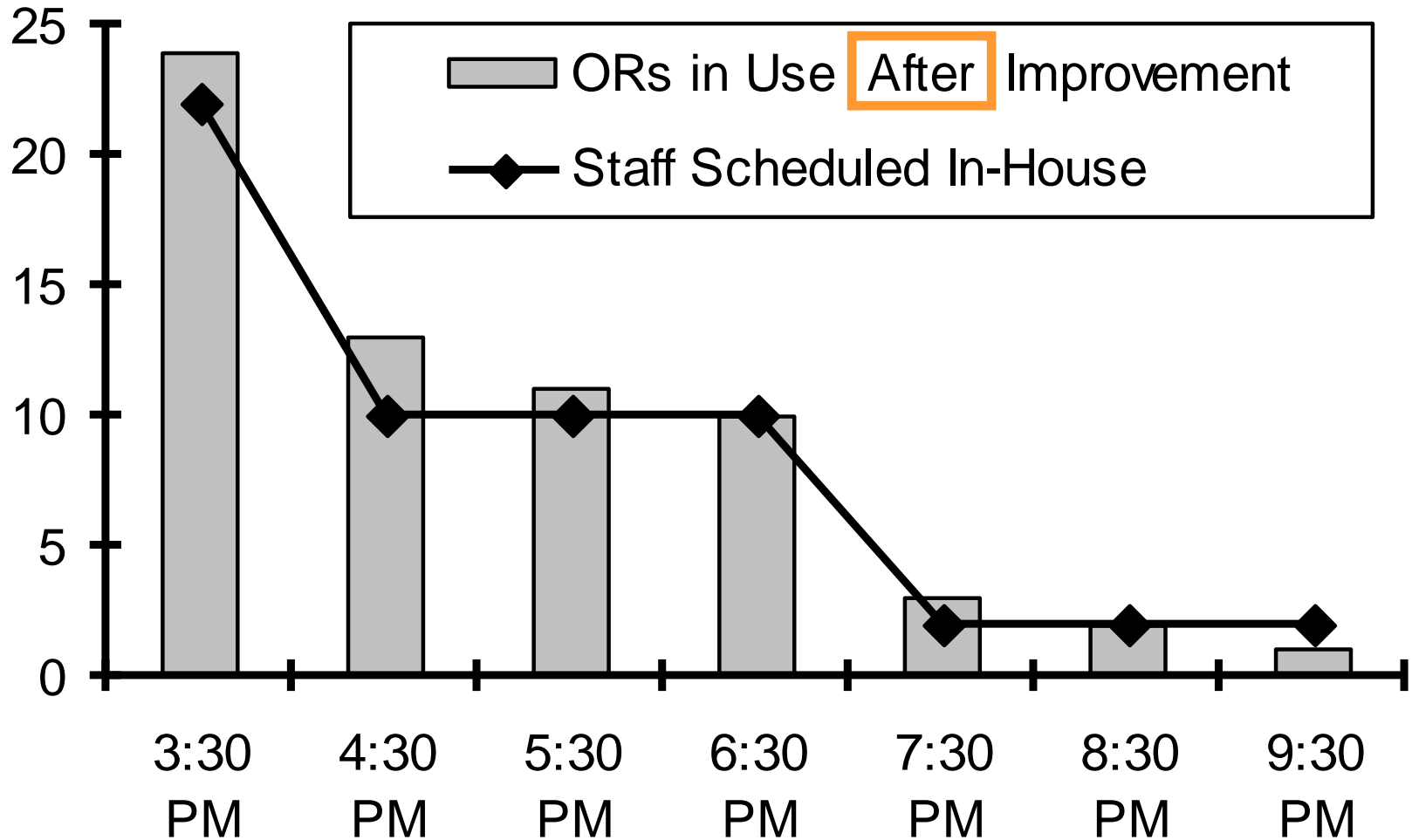
- Reducing total hours of cases including turnovers while performing all of the cases
  - May be good economically, or not
  - May be good clinically, or not
  - Regardless, finishing the day earlier on average is a different topic



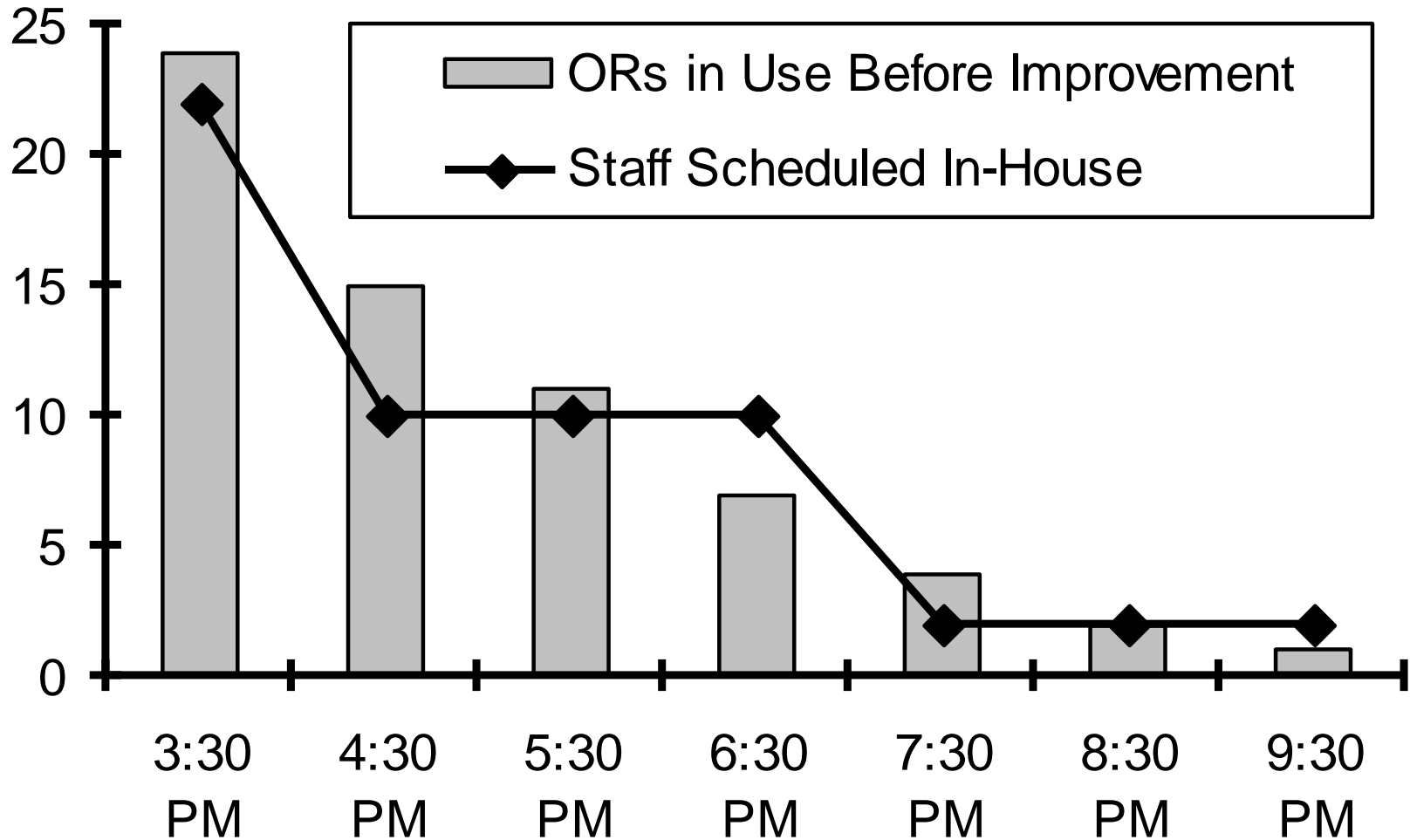
# Example of Reduced Variability



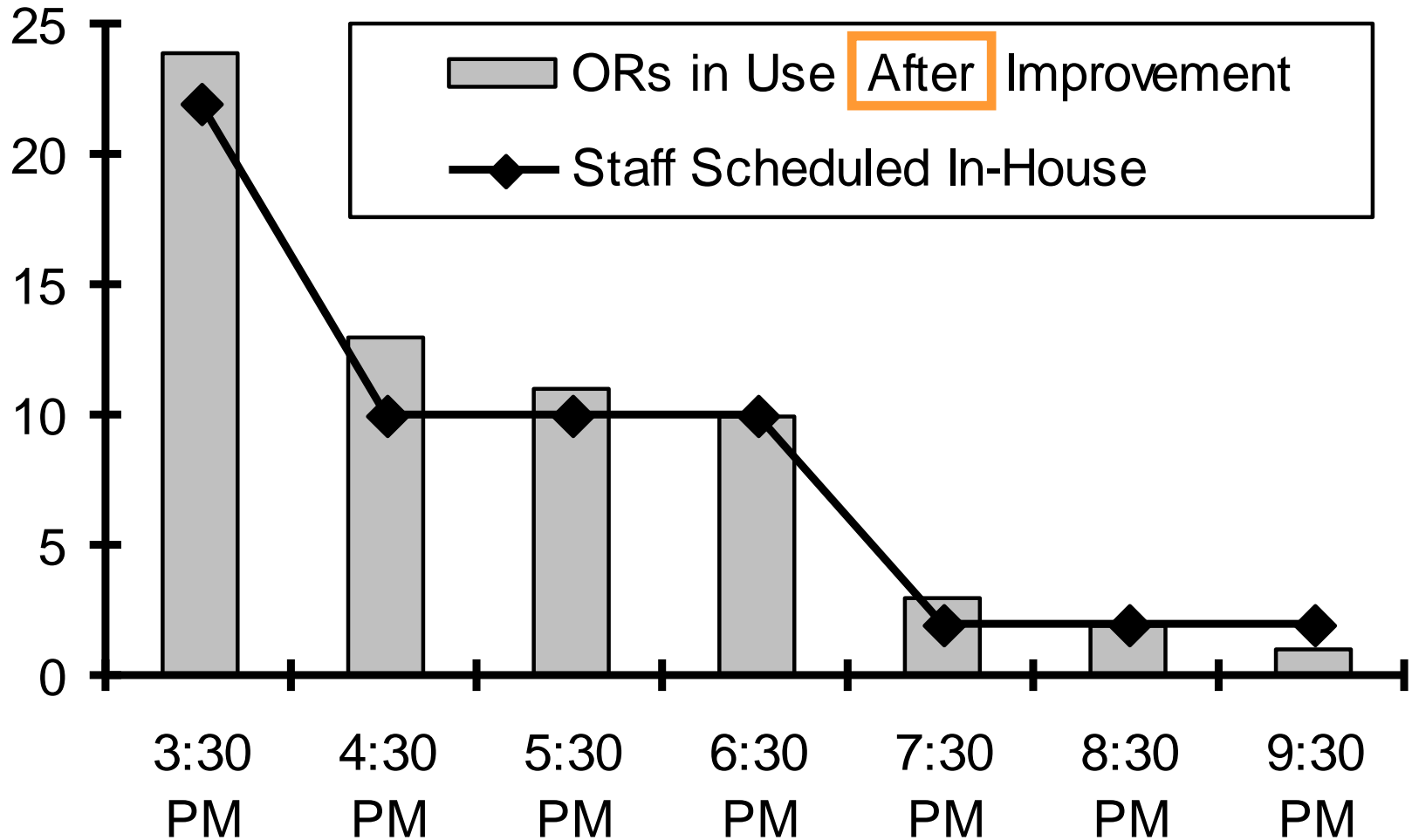
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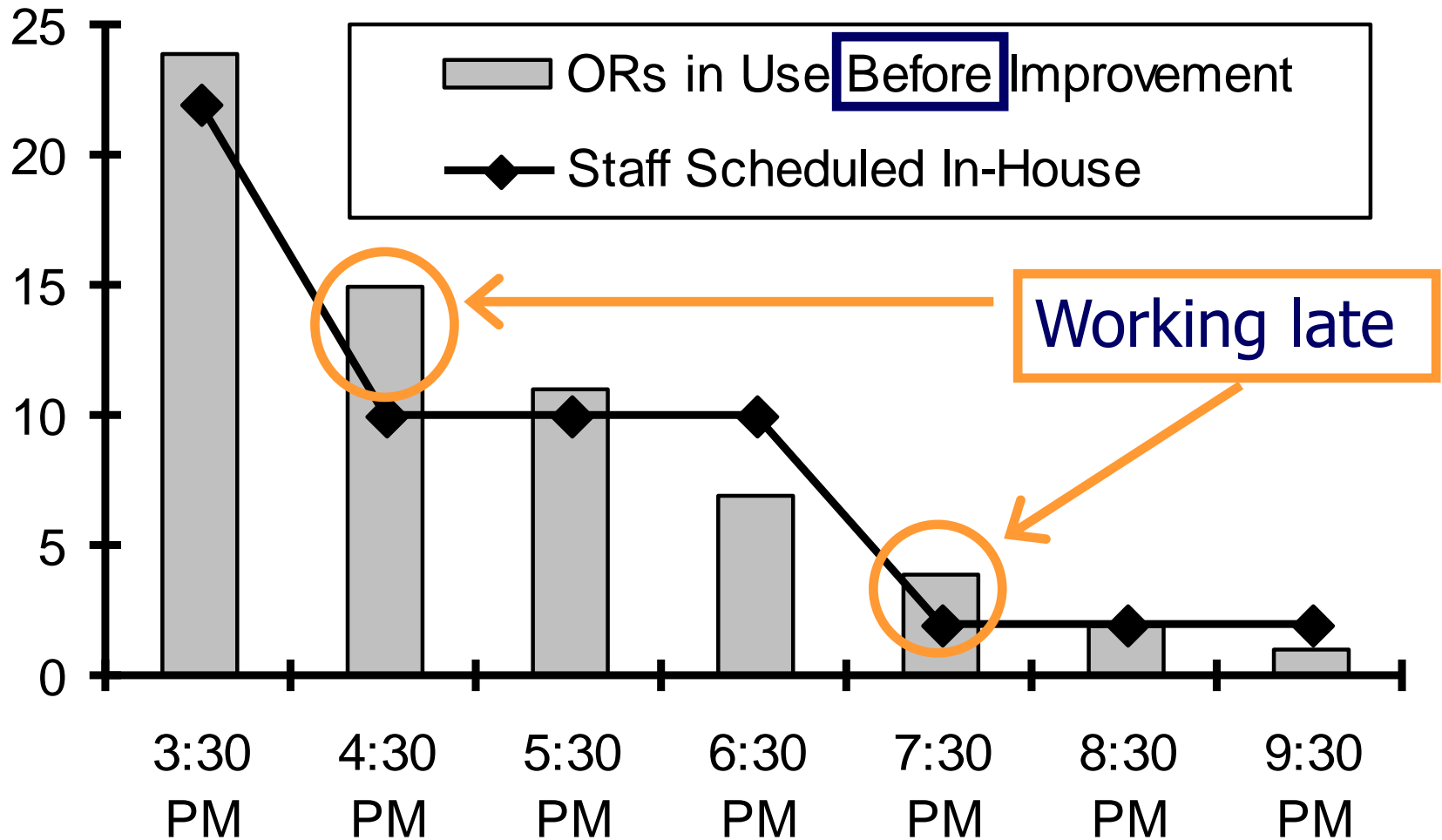


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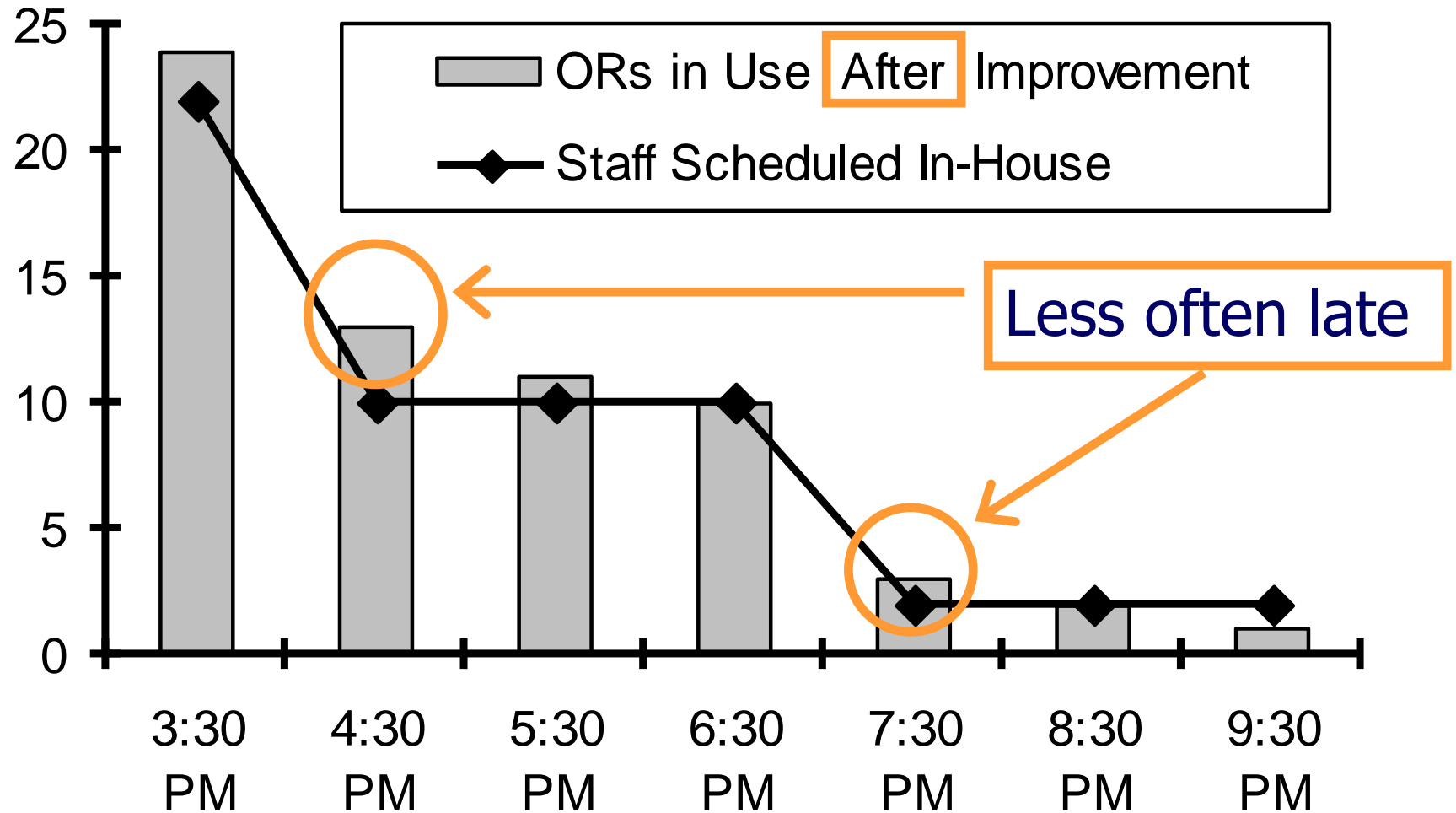




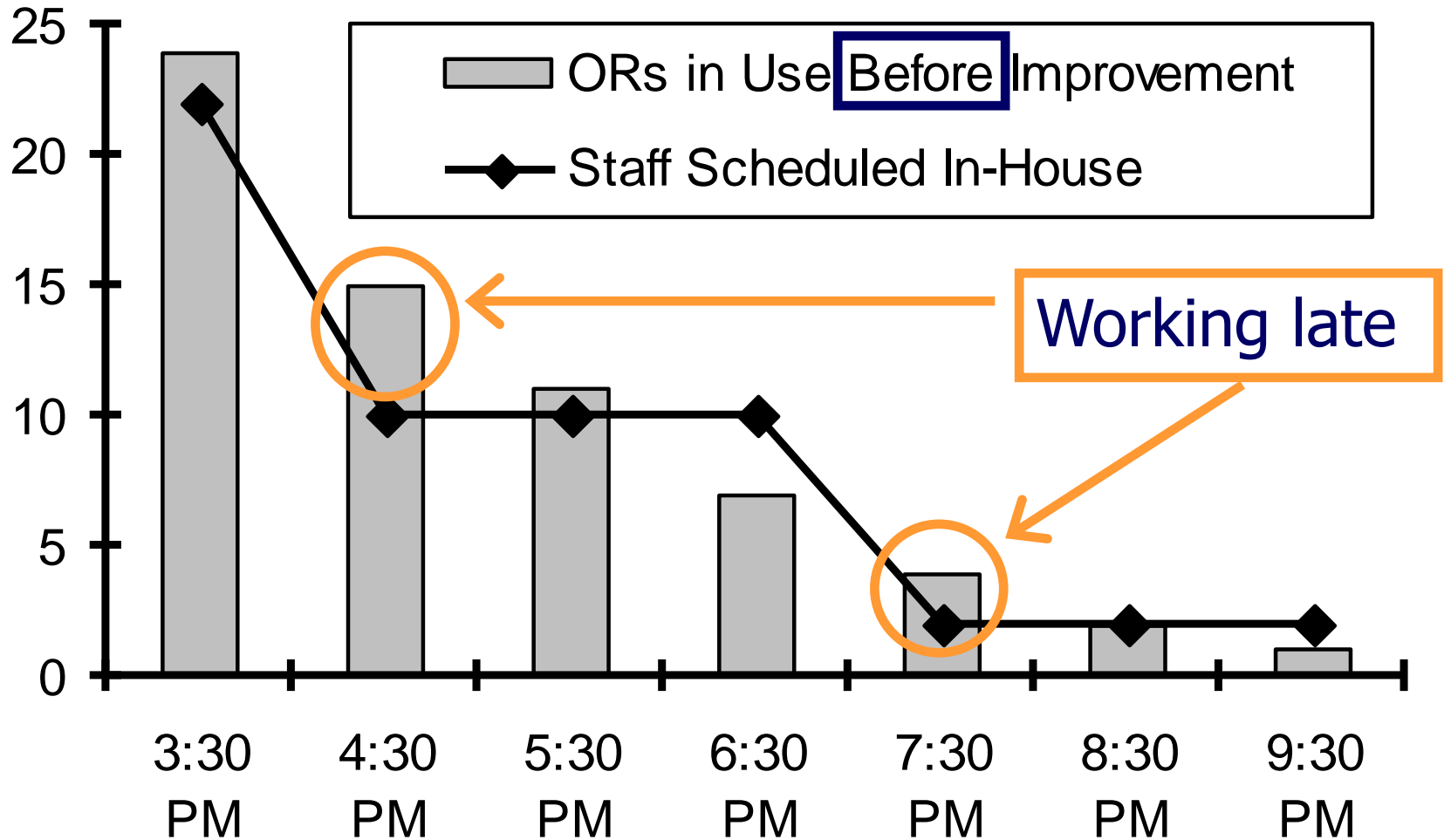
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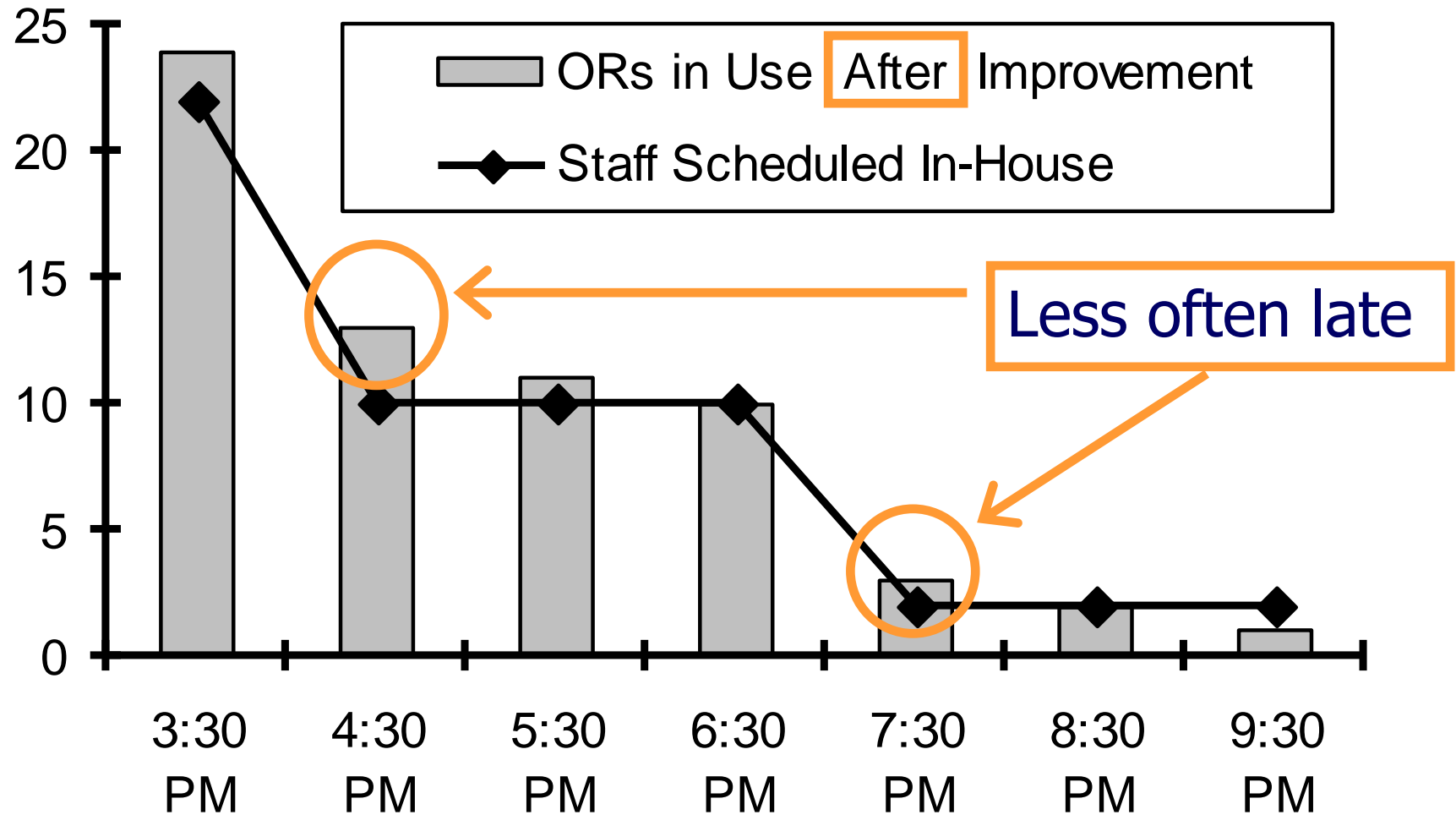
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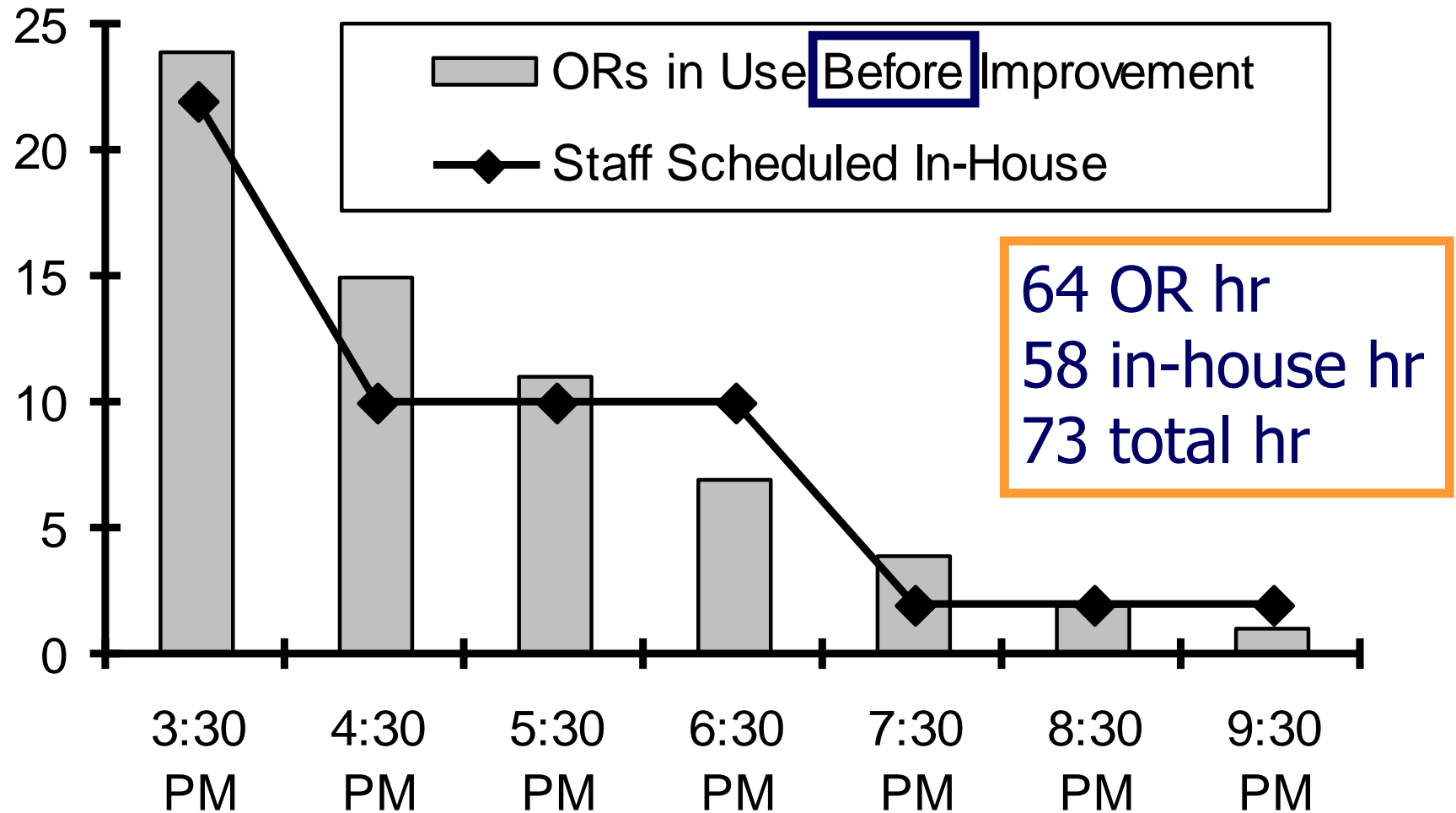
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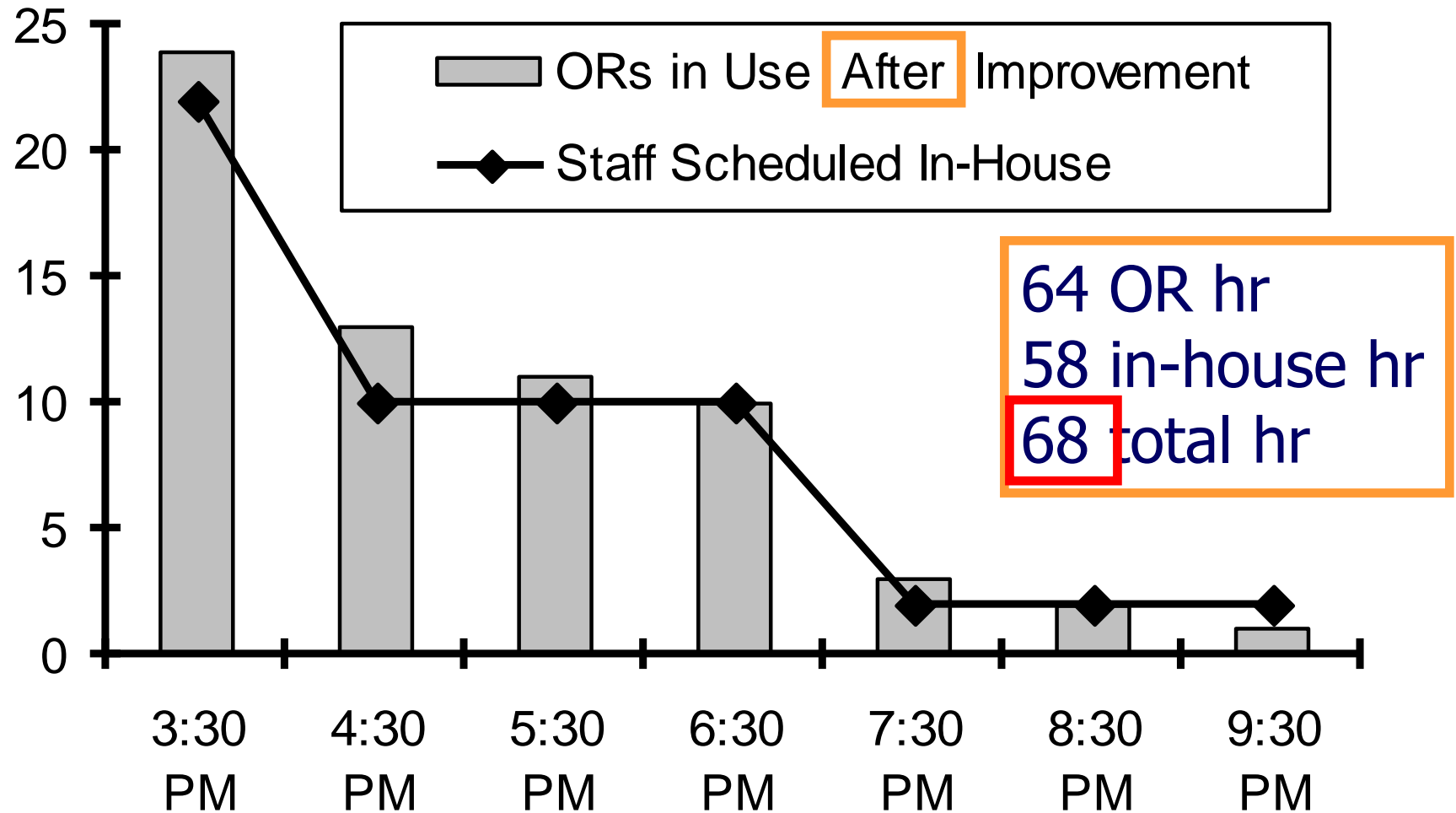
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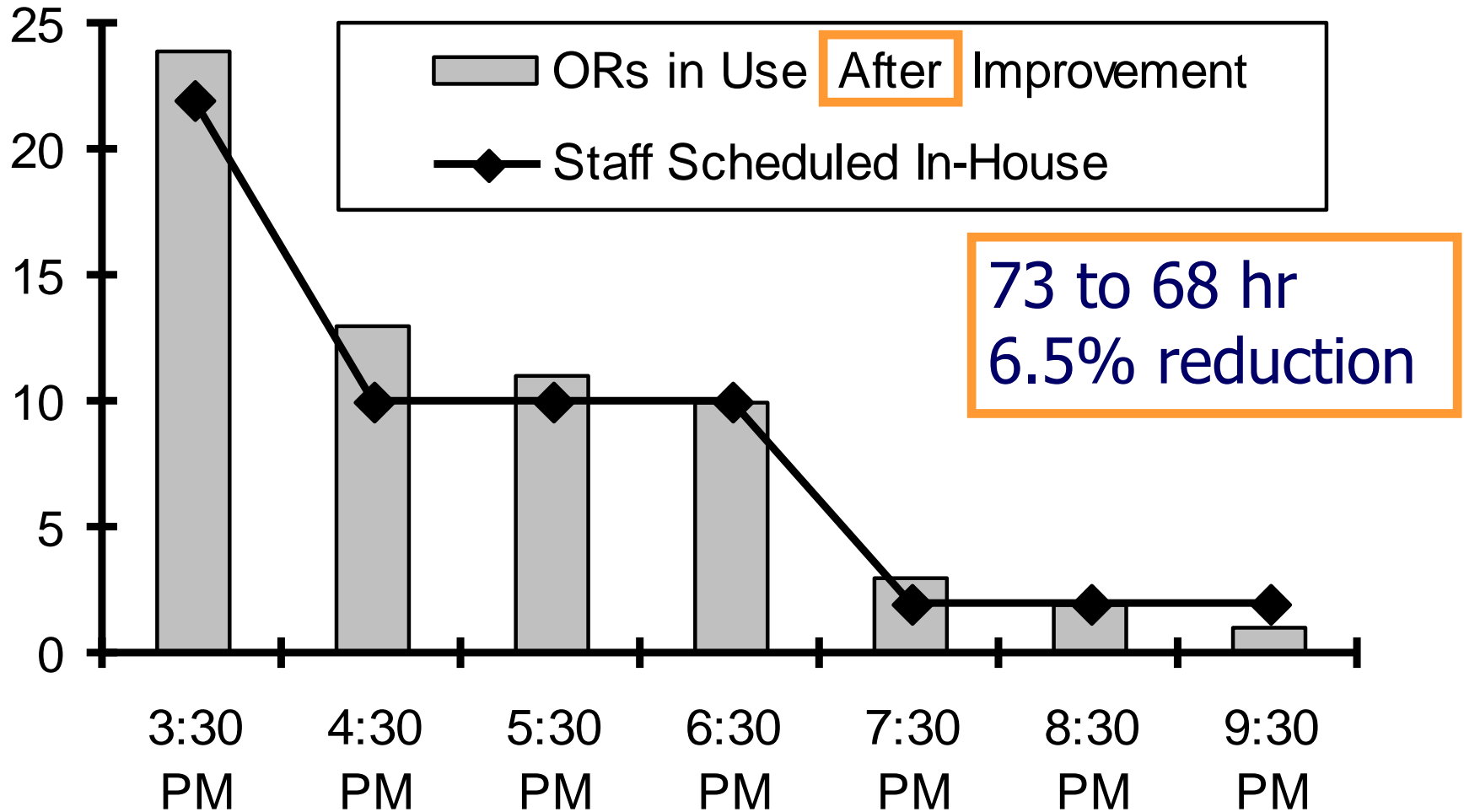


# Example of Reduced Variability





# Example of Reduced Variability



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# Additional Information on Operating Room Management

- [www.FranklinDexter.net/education.htm](http://www.FranklinDexter.net/education.htm)
  - Full course (e.g., medical directors and analysts)
  - Lectures on day of surgery decision making, case duration prediction, allocating OR time, increasing anesthesia productivity, financial analysis, and strategic decision-making
- [www.FranklinDexter.net](http://www.FranklinDexter.net)
  - Comprehensive bibliography of peer reviewed articles in operating room and anesthesia group management
    - Sign-up for notifications of new articles

# Pretest Question #1

- OR time is allocated at a surgical suite either for 8 hours or 10 hours
- A service on Tuesdays has a mean of 8 hr 40 min with a standard deviation of 50 min
- Allocate 8 hr or 10 hr and why?



# Pretest Question #2

- Two healthy patients arrive for elective (scheduled) surgery
- Each of their ORs likely will be ready for the patients in 30 minutes, but having both ready so soon will be hard to accomplish
- How decide which of the two patients should be ready soonest?



# Pretest Question #3

- OR managers make decisions on scheduling add-on cases and moving cases among ORs using electronic displays
- One group gets displays that include calculation of expected hours of over-utilized OR time in each OR and one group does not
- Are the quality of the decisions made better with the calculated information provided?





# Pretest Question #4

- A facility achieved a 5% reduction in labor costs by reducing variability in work hours in afternoons after 3:00 PM
- The mean hours of cases being performed after 3:00 PM likely changed approximately how much?



# Answers to Pretest Questions

1. 10 hr maximizes efficiency of use of OR time
2. Prepare patient for whichever OR has the most (if any) hours of over-utilized OR time
3. No, information alone does not significantly improve the quality of decisions
4. 0% reduction in mean hours, because it is reduction in variability in those hours that has been accomplished, the same amount of surgery is being done

