

RFID-ENABLED ANALYSIS OF SERVICE DELIVERY AND PROCESS VISIBILITY IN AMBULATORY CARE: *Preliminary Analysis*

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Collaborators

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Outline

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- Motivation
- Research Questions
- Context
- Methodologies
- Results
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Motivation

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- Ambulatory care setting handles most of the healthcare delivery in the U.S. and worldwide
- Work flow efficiency and effectiveness impact outcomes, cost, quality of care, and patient satisfaction
- Manual time and motion approaches are labor intensive, obtrusive, imprecise and impractical in this setting
- RFID technology collects detailed movement and location data precisely and unobtrusively

Why Study In-process Visibility?

- Given existing appointment scheduling policy:
 - For patients: monitor wait times, arrival rates of scheduled and unscheduled patients, service time and service quality received
 - For clinicians: monitor utilization rates, ability to maintain schedule, service time and service quality delivered
 - For practice: monitor bottleneck activities, congestion levels, capacity utilization

- RFID-based system as enabler for data collection

Research Questions

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- Analyze patient flow process in ambulatory care to improve operational efficiency and process visibility
 - How efficient is the current operation?
 - What are the most efficient care delivery patterns?
 - What are the bottlenecks that prevent the delivery of care from being efficient?
 - How can efficiency be improved through process interventions?
 - How can we generalize this methodology to other patient care settings?

Literature Review

- A. Hendrich, M. Chow, B.A. Skierczynski, Z. Lu, 2008
RFID is used to track nurses' movement. They have identified three main targets for improving the efficiency of nursing care, and one of them is care coordination.
- N.M. Potisek, R.M. Malone, B.B. Shilliday, T.J. Ives, P.R. Chelminski, D.A. DeWalt, M.P. Pignone, 2007
Forms filled out by clinicians are used to track patient flow. They successfully improve the efficiency by relocating one care station, increasing nursing support, and changing the flow of the patient visit.
- R. Hall, D. Belson, P. Murali, M. Dessouky, 2007
They present process charting and performance measurement approaches and apply these tools to a case study. They conclude that clinicians can form collaboratives to reduce health care delays.
- L.V. Green, S. Savin, B. Wang, 2006
They focus on designing the outpatient appointment schedule and establishing dynamic priority rules for admitting patients into service. By constructing and optimizing a discrete-time Markov chain, they are able to develop insights of the optimal policies to the various parameters.
- F.R. Lin, S.C. Chou, S.M. Pan, Y.M. Chen, 2000
They develop an algorithm for mining time dependency patterns in clinical pathways.
- J. Li, Y. Zhou, F. Ishino, 2008
They use simulation to reduce waiting time by 38% by changing the distribution of the number of appointments.

Study Site and Data Collection

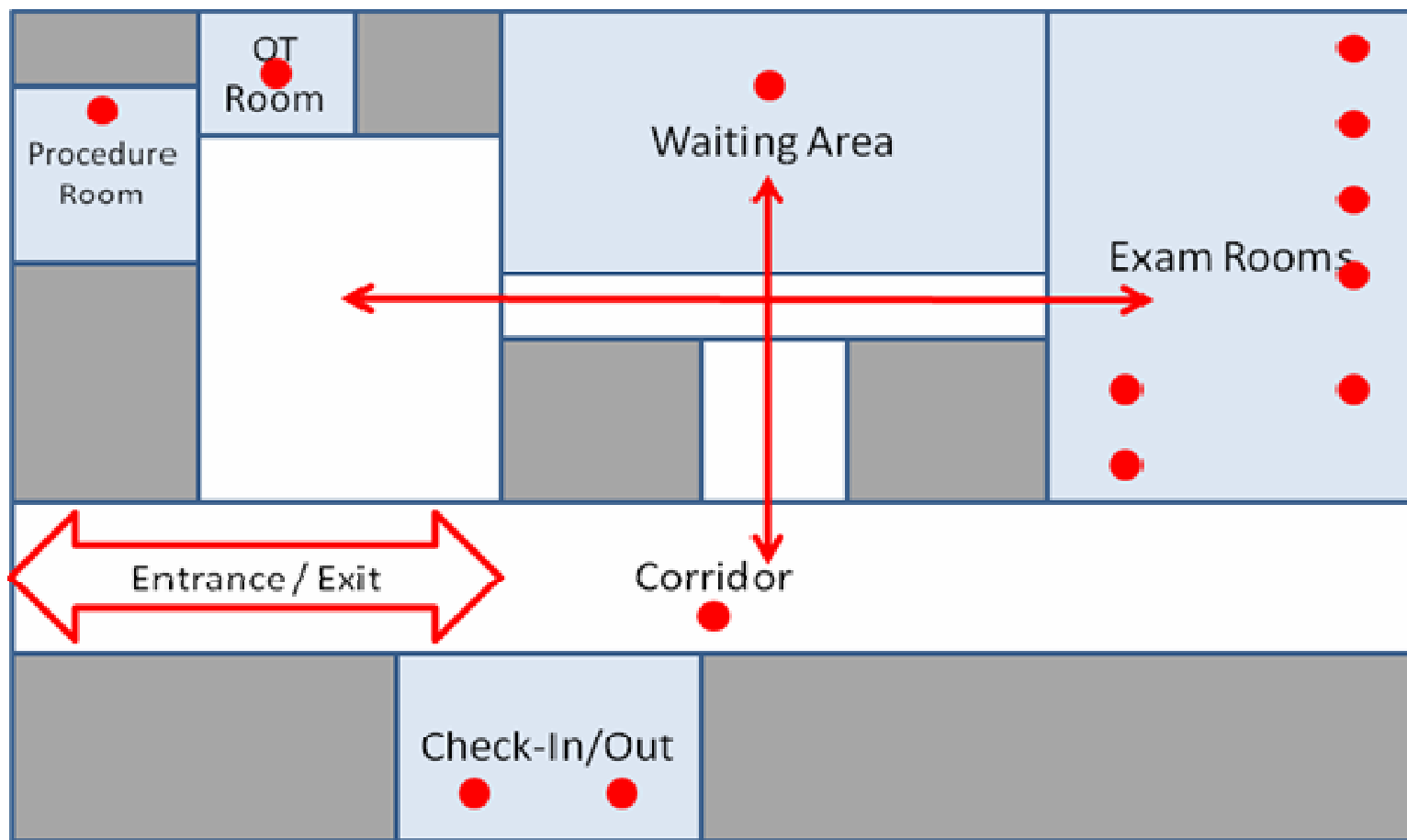
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Study Site: Plastic and Reconstructive Surgery clinic (an outpatient clinic affiliated with UPMC)

- Radio Frequency Identification (RFID) Technology
 - Monitors are deployed in each room in the clinic to provide time and location information.
 - Tags are worn by patients and clinicians to identify each individual with unique ID as each visit is completed.
 - Communication between RFID monitors and tags generate time and location stamped data every few seconds.
- Data analyzed: 499 patient visits are recorded from 5/5/08 to 7/16/08.
- Observations in the clinic

RFID Monitors and Deployment

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Data Description

- Data duration: 5/5~7/16
- Total number of records (visits): 500
- Total number of unique patients: 394
- Total number of business days: 26
- Visits that include encounter: 479/499* (95.99%)
- Visits that include occupational therapy: 33/499 (6.61%)
- Visits that include procedure: 4/499 (0.80%)

* 1 record was removed due to ambiguity in room identification

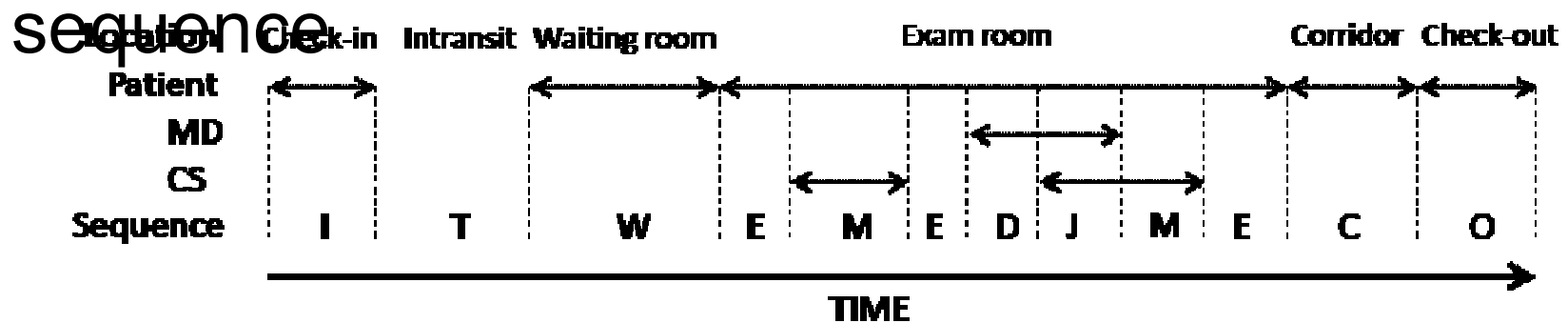
Data Processing

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- Before: time stamped data for each individual

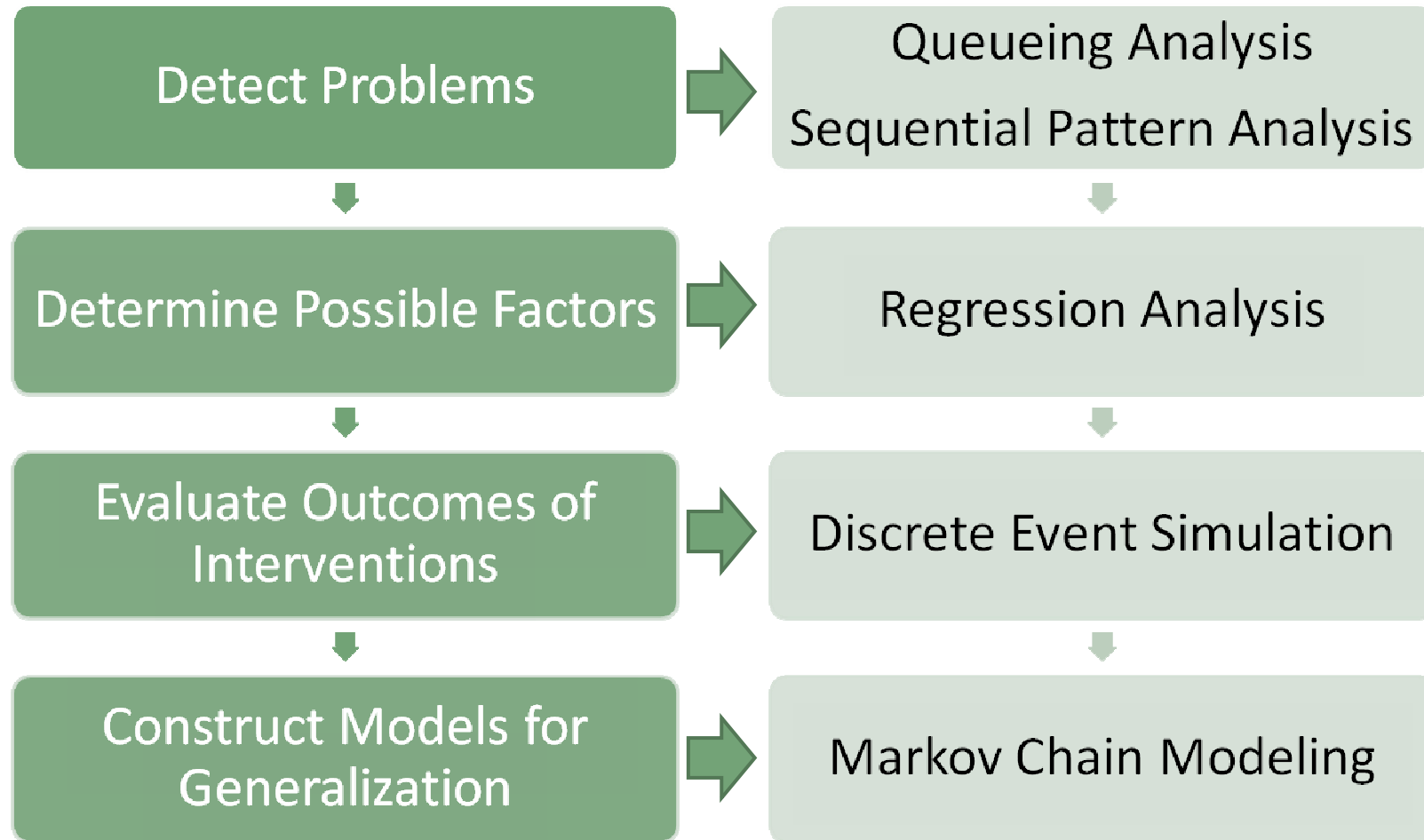
| Date | Staff | Patient | ApptTime | TagId | Room | Staff/Patient | EnteredTime | ExitedTime | TimeSpent |
|---------------------------|--------|---------|---------------------------------|-------|------|---------------|-------------|------------|-----------|
| Physician : M.D. A | | | Total Patients Seen : 10 | | | | | | |
| 10/22/2007 | M.D. A | 0798 | 10:20 AM | 139 | 13 | 0798 | 9:57 AM | 10:25 AM | 28 |
| 10/22/2007 | M.D. A | 0798 | 10:20 AM | 139 | 25 | 0798 | 10:26 AM | 11:13 AM | 47 |
| 10/22/2007 | M.D. A | 0798 | 10:20 AM | 28 | 25 | M.D. A | 10:44 AM | 10:58 AM | 14 |

- After: combining individual data into a single



Analysis Objective and Methodology

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Problems detected by preliminary Queueing Analysis

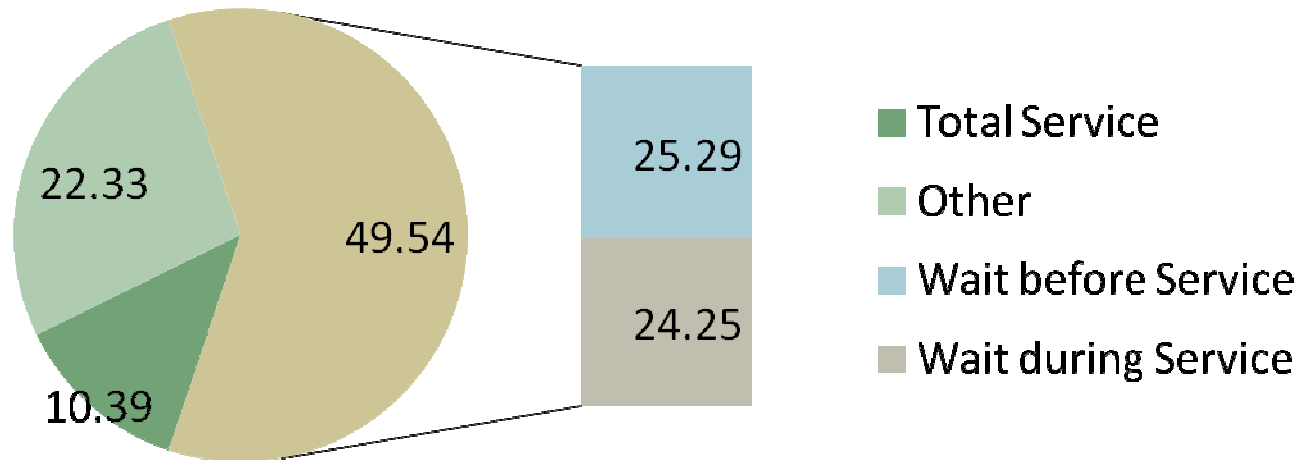
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- **Long waiting time**

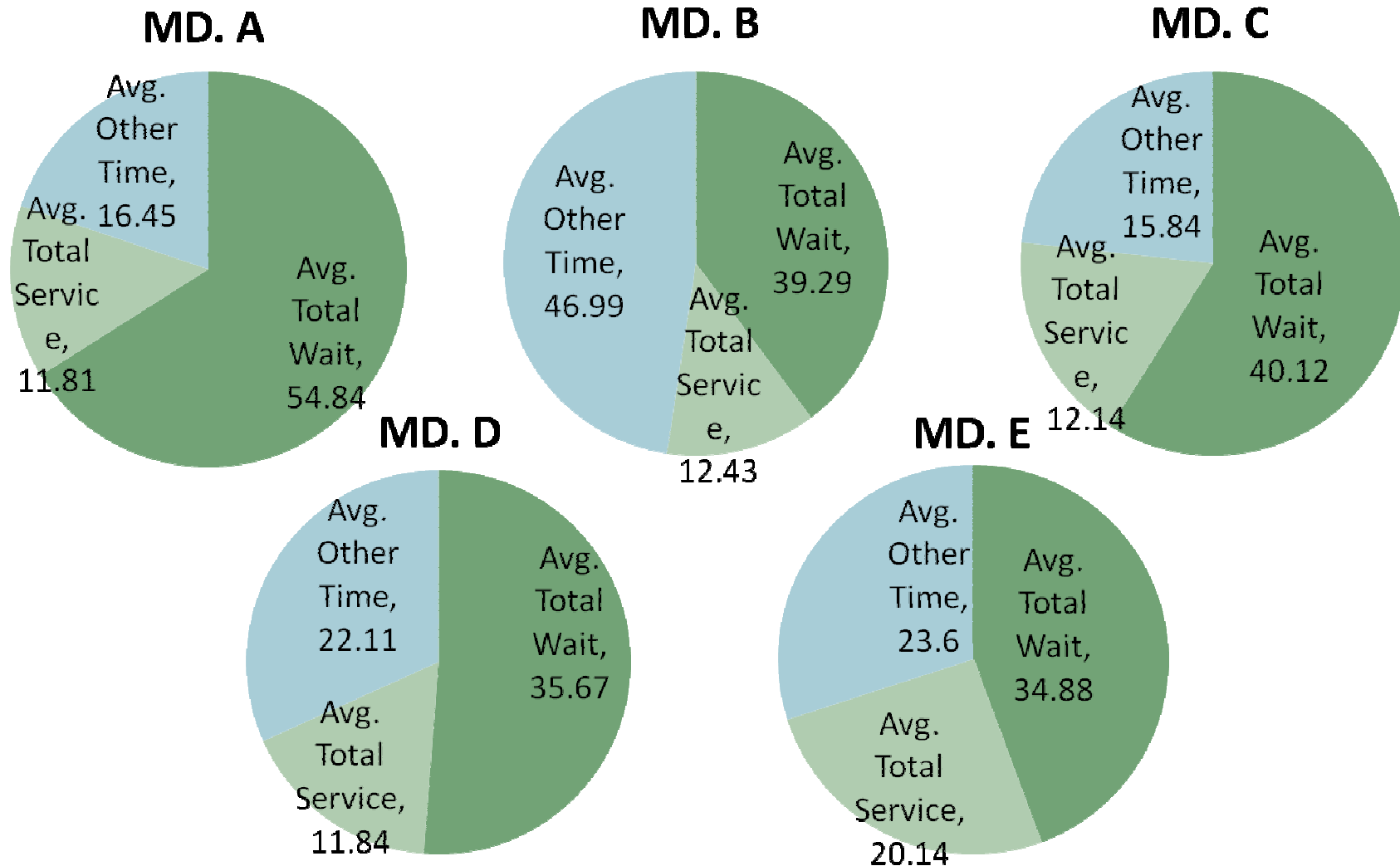
Total waiting time accounts for about 60% of total time in the clinic

- **Long waiting time “during” service as well**

Patients wait for 30 minutes on average before service and another 30 minutes on average during the encounter



Distribution of Patient Visit Time by Physician



Sequential Pattern Analysis



Discovers recurring sequential patterns in event sequences

- Sequential Pattern: an event sequence that satisfies a certain minimum support threshold
- Support threshold: The support for a sequence p is the fraction of total sequences that include p
- Maximal Sequential Pattern: The largest length sequential pattern that is not part of any other pattern

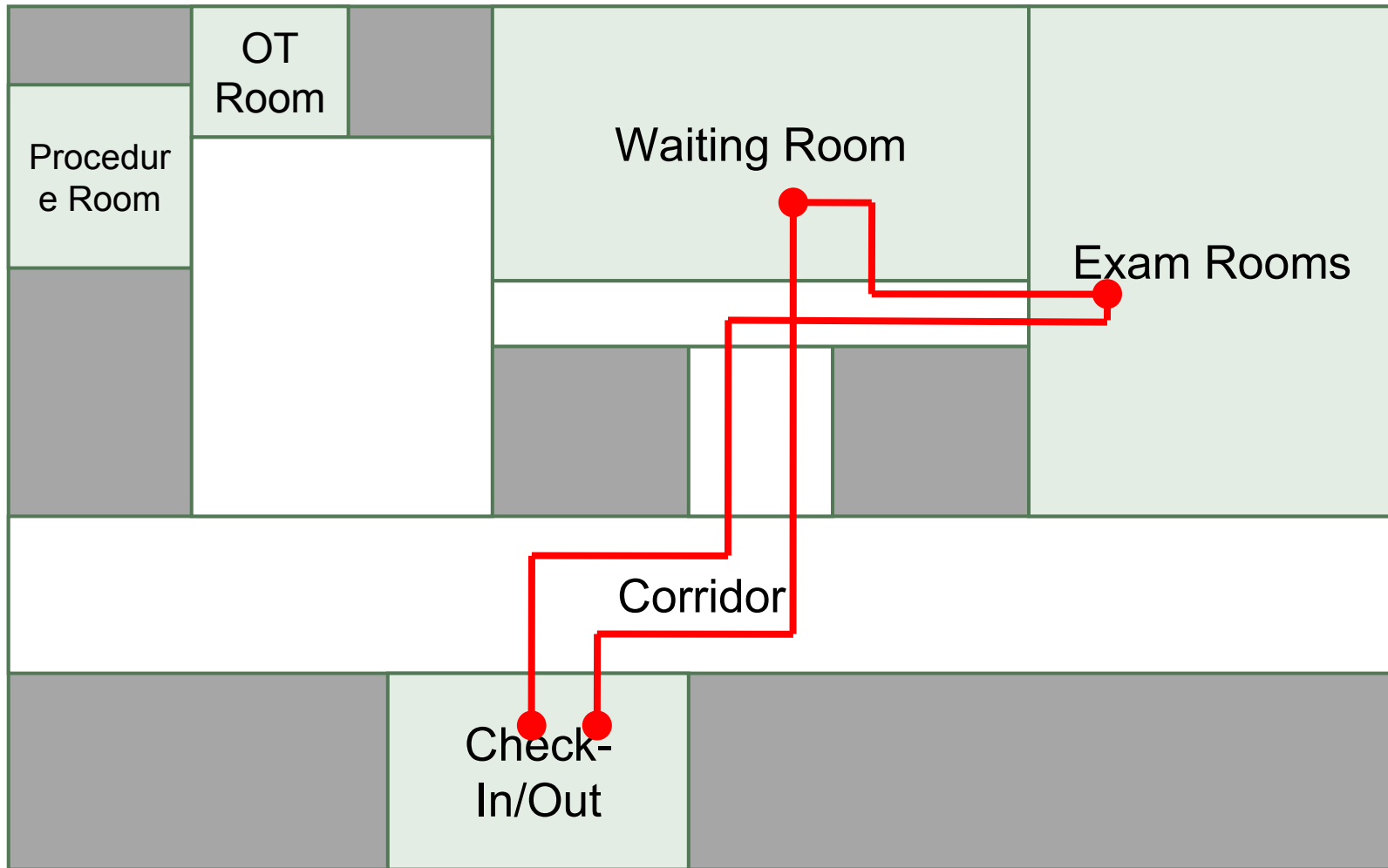
Sequential Pattern Analysis



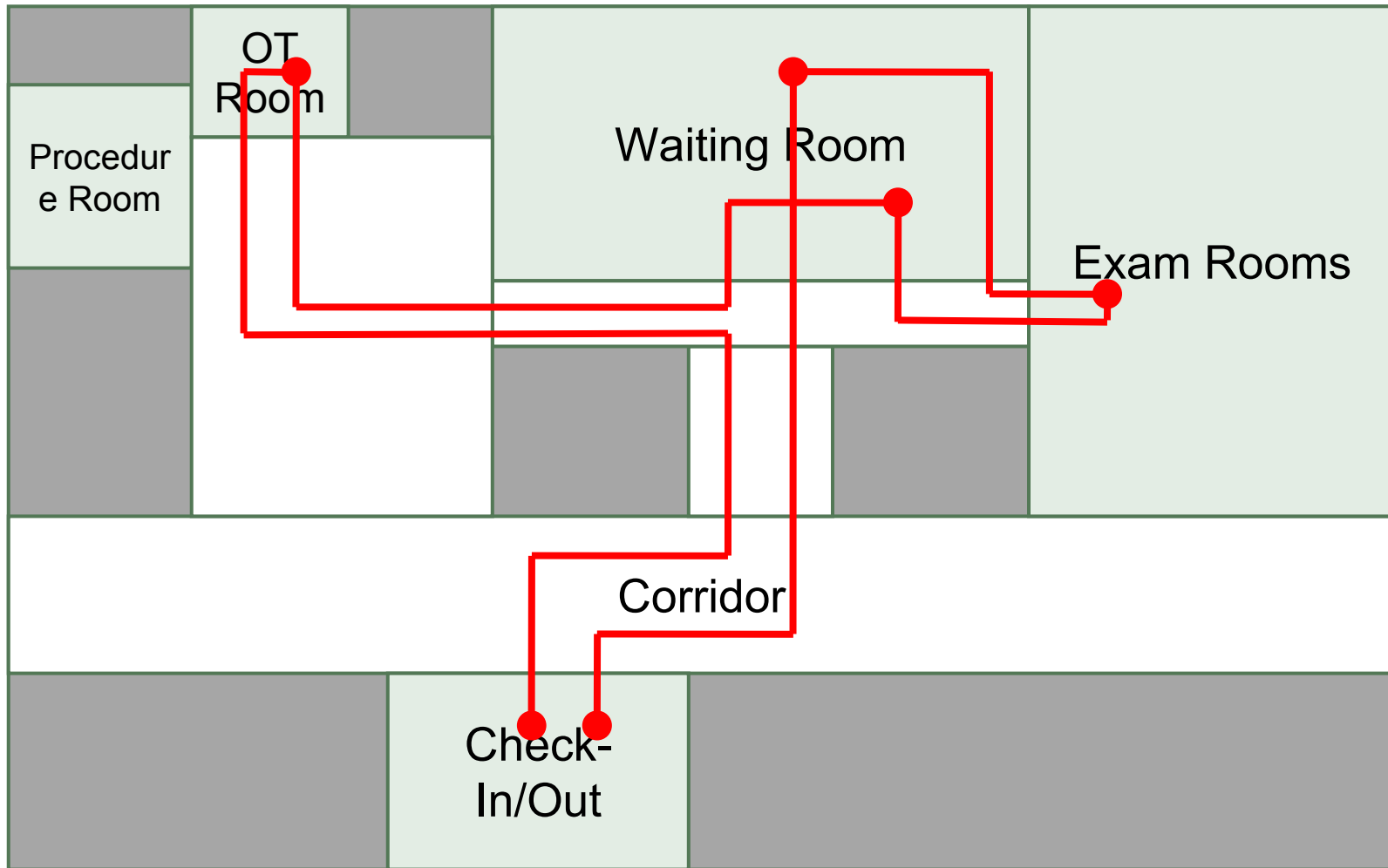
Discovers recurring sequential patterns in event sequences

1. An iterative sequential pattern algorithm is employed to analyze the event sequences identified
2. Such patterns represent frequent patient flow components occurring next to each other and in a given sequential order
3. The objective of the sequential pattern analysis is to find all Maximal Sequential Patterns

Example Flow 1: IWEO (269 visits)



Example Flow 2: IWEWE70 (9 Visits)



Problems detected by Sequential Pattern Analysis

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□ High Variability

167 unique clinic patterns and 116 unique encounter patterns are found among the 499 patient visits!

□ Inefficiency

Visit efficiency is less than 0.30 even though the selected flows have the shortest total time among all patient visits

| Clinic Flow | Total Time | Wait Time | Ideal Flow | Effective Time | Visit Efficiency |
|-------------|------------|-----------|------------|----------------|------------------|
| IWTEDTO | 38.2 | 26.0 | IDO | 10.2 | 0.27 |
| IWTEDO | 43.0 | 32.4 | IDO | 9.0 | 0.21 |
| IWMEDO | 43.8 | 36.6 | IMDO | 7.2 | 0.16 |

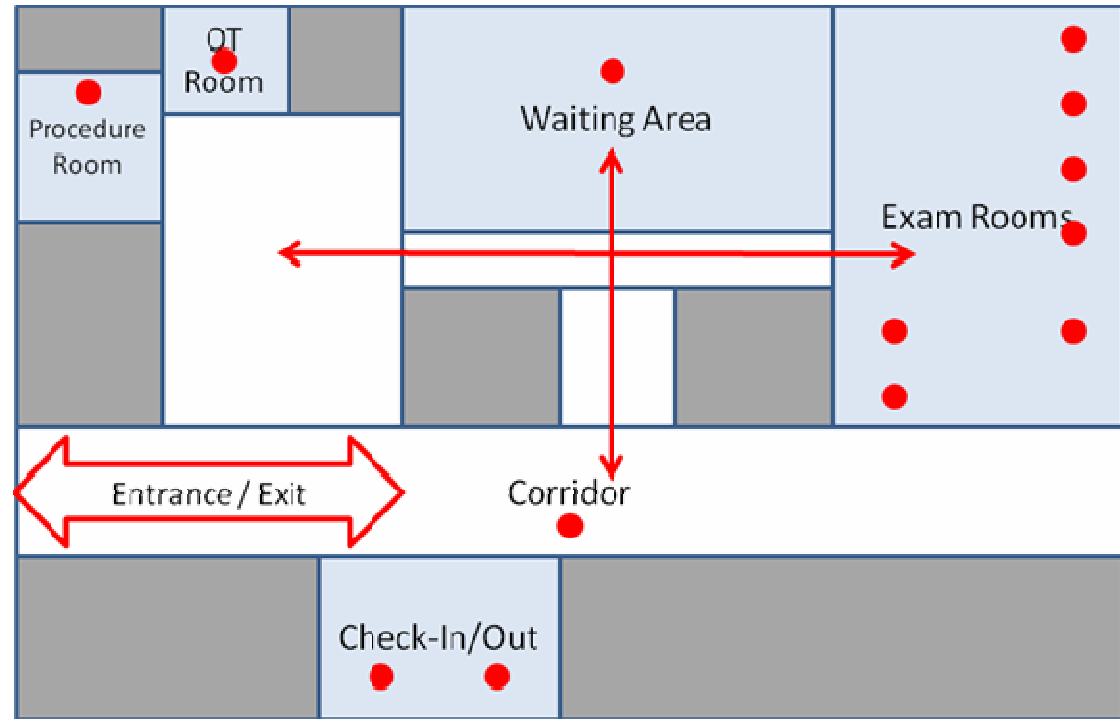
Summary for Patient-Flow Patterns

- There is a large variability in the sequencing of visit activities. Both within-encounter flows and outside-encounter flows contribute to this variation.
- The insights from within-encounter flow can help to understand the coordination of clinician activities, while outside-encounter flow can help to reengineer the non-clinical tasks.

Data Used for Simulation Analysis

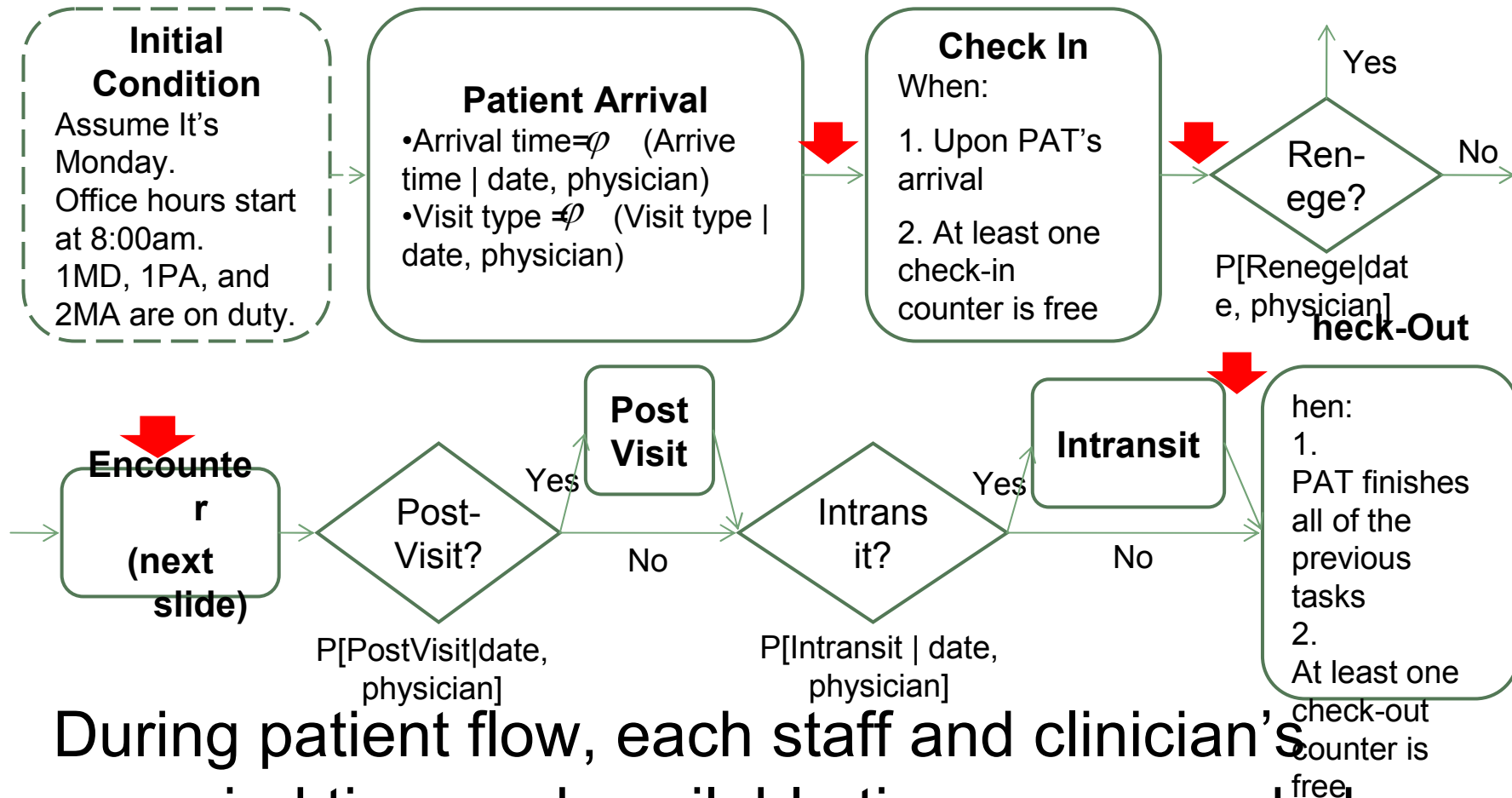
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- Dates
 - Mondays: 5/5, 12, 19, 6/2, 9, 16, 7/14
 - Tuesdays: 5/20, 27
 - Wednesdays: 6/11, 7/9, 16
 - Thursdays: 5/15, 6/5, 19
- Number of patient visits: 350



Simulation Schema

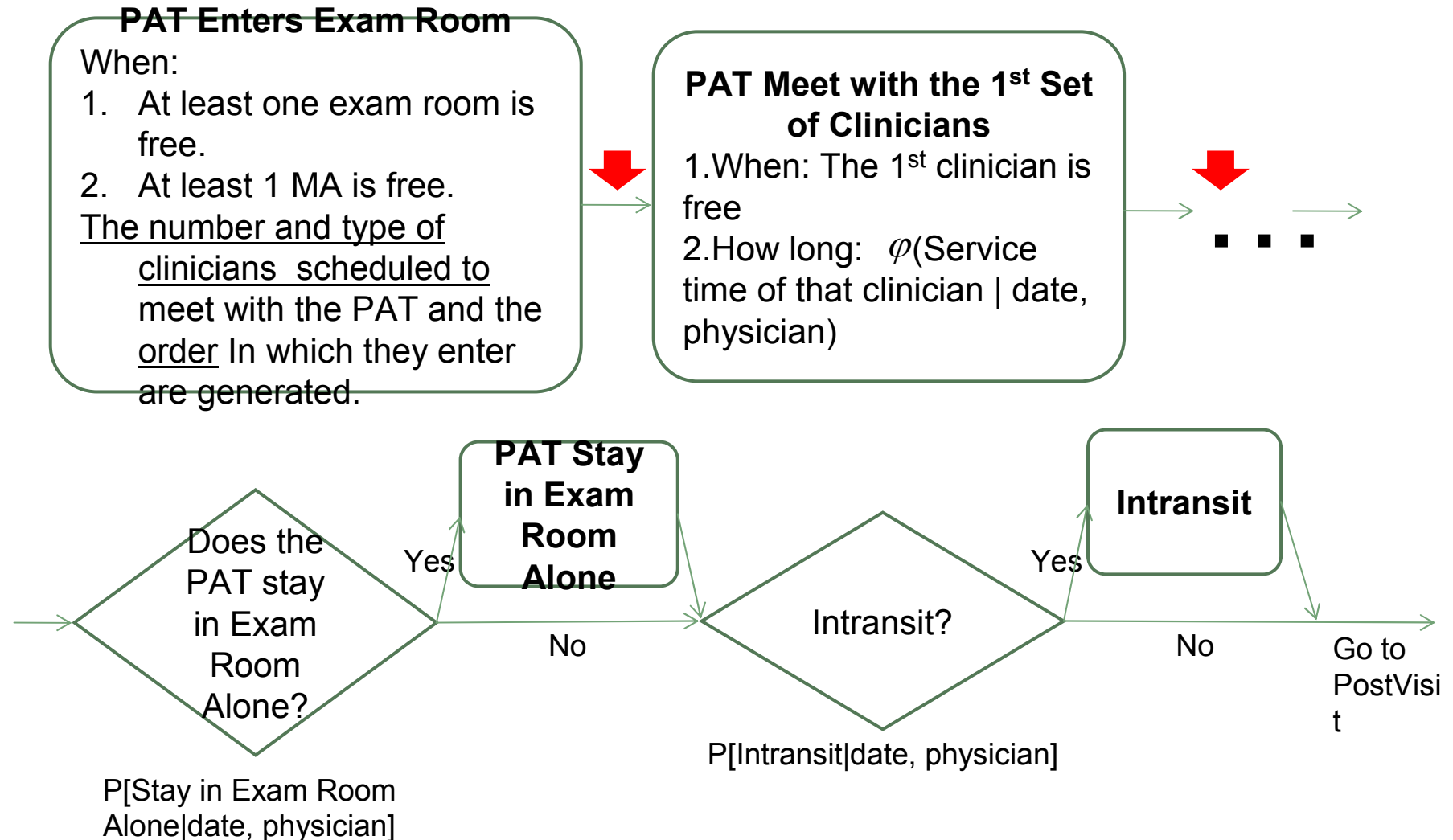
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During patient flow, each staff and clinician's occupied time and available time are recorded.

Encounter Schema in Exam Room

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Simulated Results vs. Observed Data

(Average Values)

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| Time Measures (minutes) | MD. A (M) | MD. B (M) | MD. C (T) | MD. D (W) | MD. E (R) |
|-------------------------|-----------|-----------|-----------|-----------|-----------|
| Sim. Total Wait | 56.22 | 37.93 | 37.50 | 34.59 | 34.97 |
| Obs. Total Wait | 54.84 | 39.29 | 40.12 | 35.67 | 34.88 |
| Sim. Total Service | 8.47 | 11.21 | 11.41 | 10.08 | 17.82 |
| Obs. Total Service | 11.81 | 12.43 | 12.14 | 11.84 | 20.14 |
| Sim. Total Visit | 82.55 | 94.05 | 65.65 | 66.10 | 77.28 |
| Obs. Total Visit | 83.10 | 98.71 | 68.10 | 69.62 | 78.62 |

Test Results of Some Interventions

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- Equal appointment intervals
- Increase number of Medical Assistants by 1
- Decrease number of Medical Assistants by 1
- Increase availability of exam rooms by 1

Equal Appt. Interval Reduces Waiting Time by about 43% on Average

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| Time Measures (minutes) | MD. A (M) | MD. B (M) | MD. C (T) | MD. D (W) | MD. E (R) |
|----------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Total Wait (Base Line) | 56.22 | 37.93 | 37.50 | 34.59 | 34.97 |
| Total Wait (Equal Int.) | 30.77 (↓25.45) | 19.17 (↓18.76) | 21.15 (↓16.35) | 23.51 (↓11.08) | 18.69 (↓16.28) |
| Total Service (Base Line) | 8.47 | 11.21 | 11.41 | 10.08 | 17.82 |
| Total Service (Equal Int.) | 8.57 | 11.19 | 11.20 | 10.00 | 18.25 |
| Total Visit (Base Line) | 82.55 | 94.05 | 65.65 | 66.10 | 77.28 |
| Total Visit (Equal Int.) | 54.22 | 66.70 | 45.94 | 53.37 | 54.55 |

Summary of Simulation Analysis

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- The current allocation of MA resources seems to be optimal.
- The number of exam rooms is not a constraint with the current patient volume.
- Appointment intervals impact waiting time significantly! By evenly spreading appointments across office hours, waiting time can be reduced considerably.
- Is there an optimal interval for each physician?
- Are there other feasible interventions to be tested?

Conclusions

Suggested Directions for Changes

- Scheduling
 - The duration of each appointment
 - Number of appointments per day
- Service policy
 - Managing arrival types
- Utilization
 - The optimal scheduling of clinician availability
 - Potential reorganization of facility