A Systems Approach to Improving Patient Flow at UVA Cancer Center Using Real-Time Locating System

Authors: Anna Ewing, Jordan Rogus, Prathibha Chintagunta, Logan Kraus, and Morgan Sabol
Advisor: Hyojung Kang, PhD

Introduction

Background & Motivation: The Emily Couric Clinical Cancer Center (ECCCC) at the University of Virginia, a multi-clinic facility, has experienced a 30% growth in patients in the past 3 years. Management ultimately wants to reduce patient wait times, but first they want to understand where and with what frequency problems are occurring and who they are affecting.

Technology: In May 2016, the ECCCC implemented Ekahau, a Real-Time Locating System (RTLS). RTLS uses beacon technology in conjunction with wearable sensors to communicate data through radio frequencies or Wi-Fi. The ECCCC provides these sensors to its doctors and patients. RTLS tracks entities at all times throughout a facility providing timestamps and information relating to an entity's location every couple of seconds.

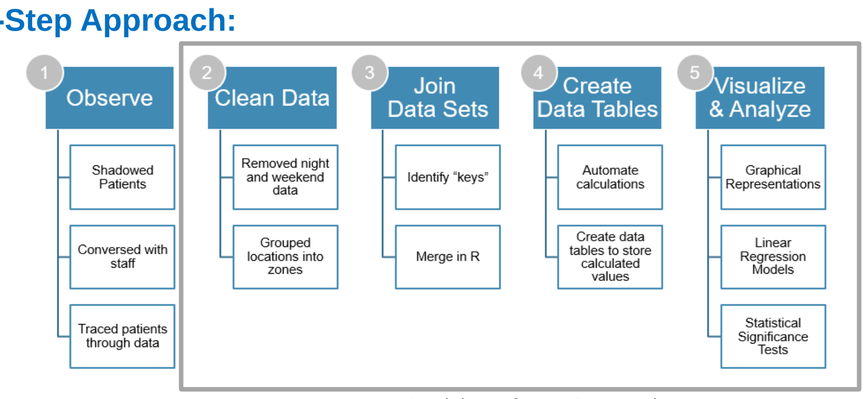
Wearable Sensor

Data: The ECCCC provided four data sets that are described below. A2K3 and Epic data are independent of the RTLS.

	Ekahau (RTLS) Patient	Ekahau (RTLS) Care Provider	A2k3 (Scheduling)	Epic (Appointment Info)
Collection Dates	Aug 2016- Dec 2016	Nov 2016 – Dec 2016	Nov 2016 – Dec 2016	Nov 2016 – Dec 2016
Summary	- Time of encounter - Date - Dwell time - Location name - Patient ID	- Time of encounter - Date - Dwell time - Location name - Provider Name	- Appointment Date - Appointment Time - Patient ID - Provider Name	- Appointment Date - Appointment Cancellations - Type of encounter - Provider Name - Patient ID
Size of data set	3,012,721 rows	1,190,236 rows	70,798 rows	92,823 rows

Methods

Five-Step Approach:

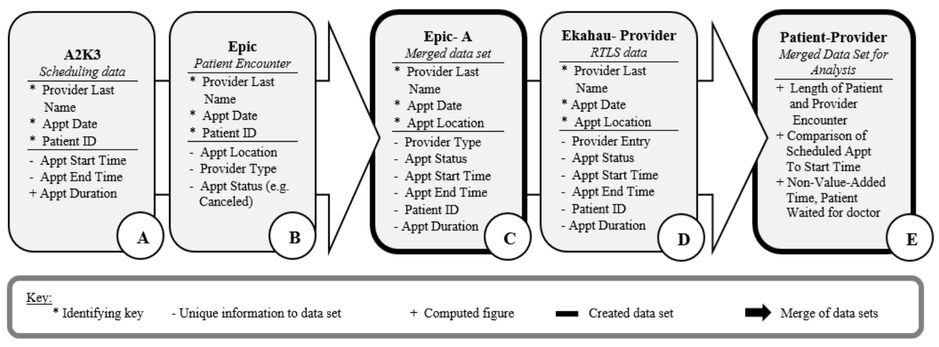


Used the software R to analyze

1. Observations: Observations and time-motion studies were conducted in the ECCCC to enhance understanding of the system. Researchers were paired with a patient and followed him or her throughout the center for the entirety of the patient's visit, collecting data on the patients arrival time, dwell time, and location.

2. Cleaning: In Ekahau RTLS Data, instances between 9 p.m. and 5:59 a.m. were removed, as well as those on weekends. Dwell times greater than 8 hours in one location were removed. Inconsistencies in data formatting within data sets and across data sets had to be detected and reformatted in order to merge data sets. Beacon inaccuracies produced rapid movements of one badge between two locations (jumps) that did not represent human movement. Jumps were accounted for by grouping individual locations into zones.

3. Joining Data Sets: In order to gain insight into patient-provider interactions, data sets were joined from different information sources. An example of which is below.



4. Creating Data Tables: Calculations on the original data sets were automated and new values were stored in 3 new data tables.

Patient Locations Data Table
- A patient's arrival time to cancer center
- Cumulative time spent in each room
- Total Time at cancer center
- Number of locations (waiting and not) visited
- Percent time spent in wait rooms

Daily Patient Experience Data Set
- Dwell Time in each location (collapsed adjacent rows)

Patient-Provider Interaction Data Set
- Duration of appointment
- Length of patient-provider interaction
- Difference of scheduled appointment start time and actual start time

5. Visualizations and Analysis: The new data tables were analyzed using graphical visualization, linear regression, Bayes theorem, and statistical significance tests to determine factors affecting patient wait times and bottlenecks.

Analysis and Discussion

1. Patient: Patient flow was analyzed by comparing the dwell times and the count of patients in each location. Linear regression models revealed insights into day of week, arrival time, and locations visited.

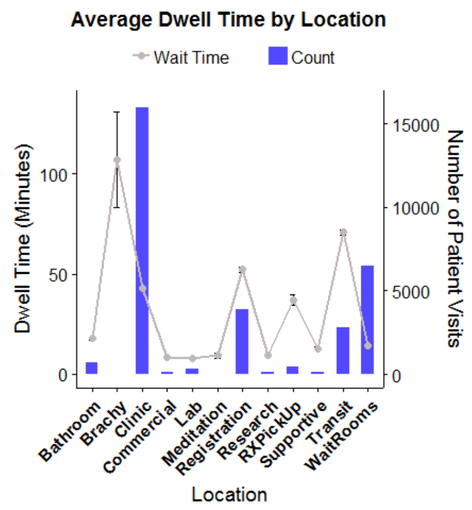


Figure I reveals that patients spend more time in Clinic rooms than waiting rooms.

- Average length of stay (LOS) was 3 hours and 15 minutes (SD 2 hours and 20 minutes).
- 39% of patients visited for 0-2 hours, 23% for 2-4 hours, and 48% for 4-8 hours.
- On average, patients spent 9.4% of his or her time in a waiting room during their visit.
- There is a significant difference in wait times across waiting areas. The first floor Waiting area had the maximum average wait time of about 20 minutes 30 seconds while Women's Waiting had the minimum at about 11 minutes and 30 seconds.
- According to Bayes Theorem, Lab/Imaging Waiting had the minimum likelihood of waiting more than 30 minutes at 3.87% whereas the first floor Waiting had the maximum likelihood of 14.02%.

Table I: Linear Regression: Patients Total LOS
Results of full interaction model (adj. R^2 = 0.3386)

	Coefficient	P-value
(Intercept)	60.40	< 0.01
# Locations Visited	4.31	< 0.01
Monday	-4.09	0.68
Thursday	-2.11	0.79
Tuesday	0.88	0.92
Wednesday	12.05	0.13
Mid-Morn	73.89	< 0.01
Afternoon	-8.29	0.50
Evening	-105.97	0.04
# Locations Visited*Tuesday	-2.74	0.01
Estimate	-2.61	0.01
# Locations Visited*Mid-Morn	8.76	< 0.01
# Locations Visited*Afternoon	13.79	< 0.01
Thursday*Evening	155.21	0.04

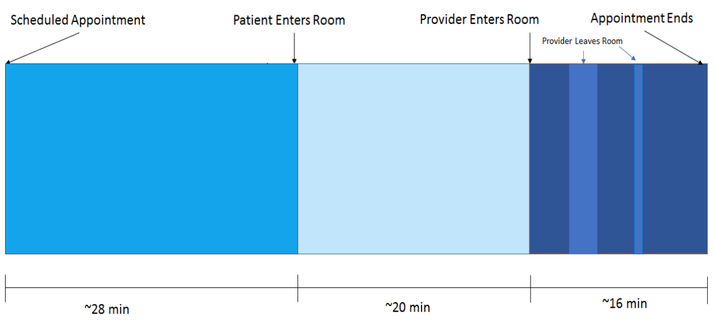
Insights for ECCCC:
- Hasten transit and reduce registration by increasing staff number or improve the human factors of registration forms to reduce time spent in "Other" locations.
- Investigate staffing and resource allocation in the bottleneck locations, East Waiting and Waiting Areas.
- Tailoring appointment lengths may prevent afternoon back-up of appointments.
- Inform patients of potential waiting times in different locations

2. Patient-Provider: Joining the three data sets provided insight into the interaction between the patient and provider in the exam room.

Timeliness: 86% of Providers arrived an average of 48±1.8 minutes after the appointment was scheduled to begin.

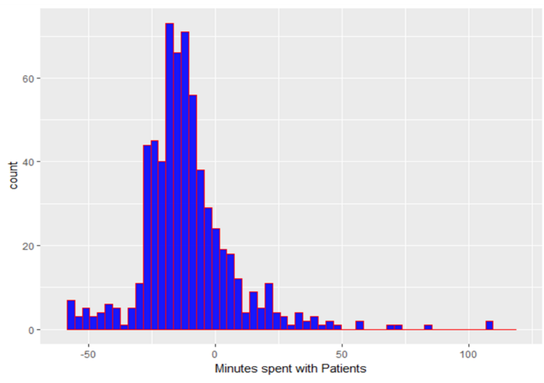
Non-value added Time (Time spent in exam room before provider arrived for the first time): 75% of patients waited an average of 20.2±0.8 minutes in an exam room before his or her provider arrived. The longest 10% of wait times averaged 1 hour.

Figure II: The Average Patient-Provider Interaction Exam Experience



Overage (Compared the time a provider spent in a room for an appointment, "their duration," to the scheduled duration of an appointment): On average, providers spent 11.2 minutes less time with the patient then designated by the appointment length.

Figure III: Scheduled Provider Interactions vs. Actual Interactions



Insights for ECCCC:
The ECCCC management team should investigate how providers time is spent in and out of the exam room during an appointment. Considerations should be made for appointment time schedules.

3. Room Utilization: Exam Room Utilization is defined as the sum of patient dwell time in a given room divided by the total time that room is available. In general, utilization was greater in the morning than the afternoons, and less in consulting and procedure rooms.

Insights for ECCCC:
The ECCCC management team associates specific exam rooms with individual providers to understand differences in providers habits and schedules

Limitations

1. **Badge Acceptance**: lower physcian buy-in limits insights into overall clinic flow
2. **Badge Return**: loss of badges
3. **Beacon Inaccuracy**
4. **Data inaccuracies** and mismatching/typos
5. **Unable to analyze interactions in Infusion Clinic:** multiple patients and physicians in the same room
6. **Assumptions of provider non-value-added time:** Cannot tell what a provider is doing out of an exam room during an appointment

Future Work

1. Study impact of patient arriving early
2. Investigate room utilization with respect to specific providers
3. Simulation of individual clinics and their waiting rooms to provide insights that allow for recommendations such as rescource and employee allocation
4. Simulation of the entire multi-clinic facility to reveal interactions between clinics more clearly

Conclusion

The East and first floor waiting areas are bottlenecks. Processes such as registration, transit and RXPick Up have long patient dwell times. Healthcare providers arrive on average 48 minutes after appointments are scheduled to begin. Providers also spend on average 11 minutes less with a patient than the duration of the scheduled appointment. Finally, about 75% of patients wait on average 20 minutes in an exam room before their provider arrives for the first time.

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