Improving Accuracy of Appointment Capacity Forecasting Utilizing Predictive Modeling

J. B. HUNT ®

UNIVERSITY OF ARKANSAS

Industry Partners: Brent Wiles, Logistics Engineer & Emily May, Associate Logistics Engineer

Team Members: Brittany Watts, Project Manager; Amanda Beard, Seth Briley & Matt Turner

Faculty Advisor: Dr. Ashlea Milburn

Current Delivery Capacity Forecast Method

| Market	Day of Week	Stop Date	Week	Delivery Stops	Pickup Stops	Total Stops
DA	Friday	7/21/17	29	571	374	945
DA	Friday	4/7/17	14	520	417	937
DA	Friday	9/8/17	36	420	411	831
DA	Friday	9/22/17	38	476	306	782
DA	Friday	5/12/17	19	380	384	764
DA	Friday	6/16/17	24	439	305	744
DA	Friday	8/18/17	33	236	170	406
DA	Friday	7/28/17	29	154	108	262

The method starts by finding the 5 highest volume days for each weekday in the chosen market for the past 6 months

Market	Day of Week	Stop Date	Hour	Delivery Stops
DA	Friday	7/21/17	0	7
DA	Friday	7/21/17	1	8
DA	Friday	7/21/17	2	8
DA	Friday	7/21/17	3	7
DA	Friday	7/21/17	4	15
DA	Friday	7/21/17	5	21
DA	Friday	7/21/17	6	22
DA	Friday	7/21/17	7	31
DA	Friday	7/21/17	8	40

Next, partition each day into its hourly **delivery** stops

Market	Day of Week	Hour	7/21/17 Delivery Stops	4/7/17 Delivery Stops	9/8/17 Delivery Stops	9/22/17 Delivery Stops	5/12/17 Delivery Stops	Average Delivery Stops
DA	Friday	0	7	6	4	3	5	5
DA	Friday	1	8	13	10	15	9	11
DA	Friday	2	8	8	9	11	10	9
DA	Friday	3	7	9	16	15	9	11
DA	Friday	4	15	11	17	14	18	15
DA	Friday	5	21	20	18	22	22	21
DA	Friday	6	22	19	26	22	26	23
DA	Friday	7	31	30	32	30	34	31
DA	Friday	8	40	39	25	31	30	33

Lastly, average the five days hourly **delivery** stops
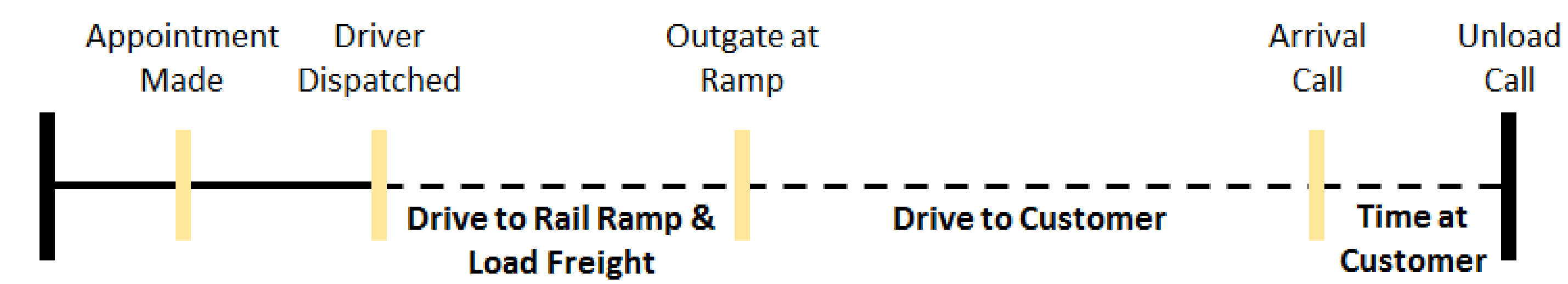
Average Total Time for Customers
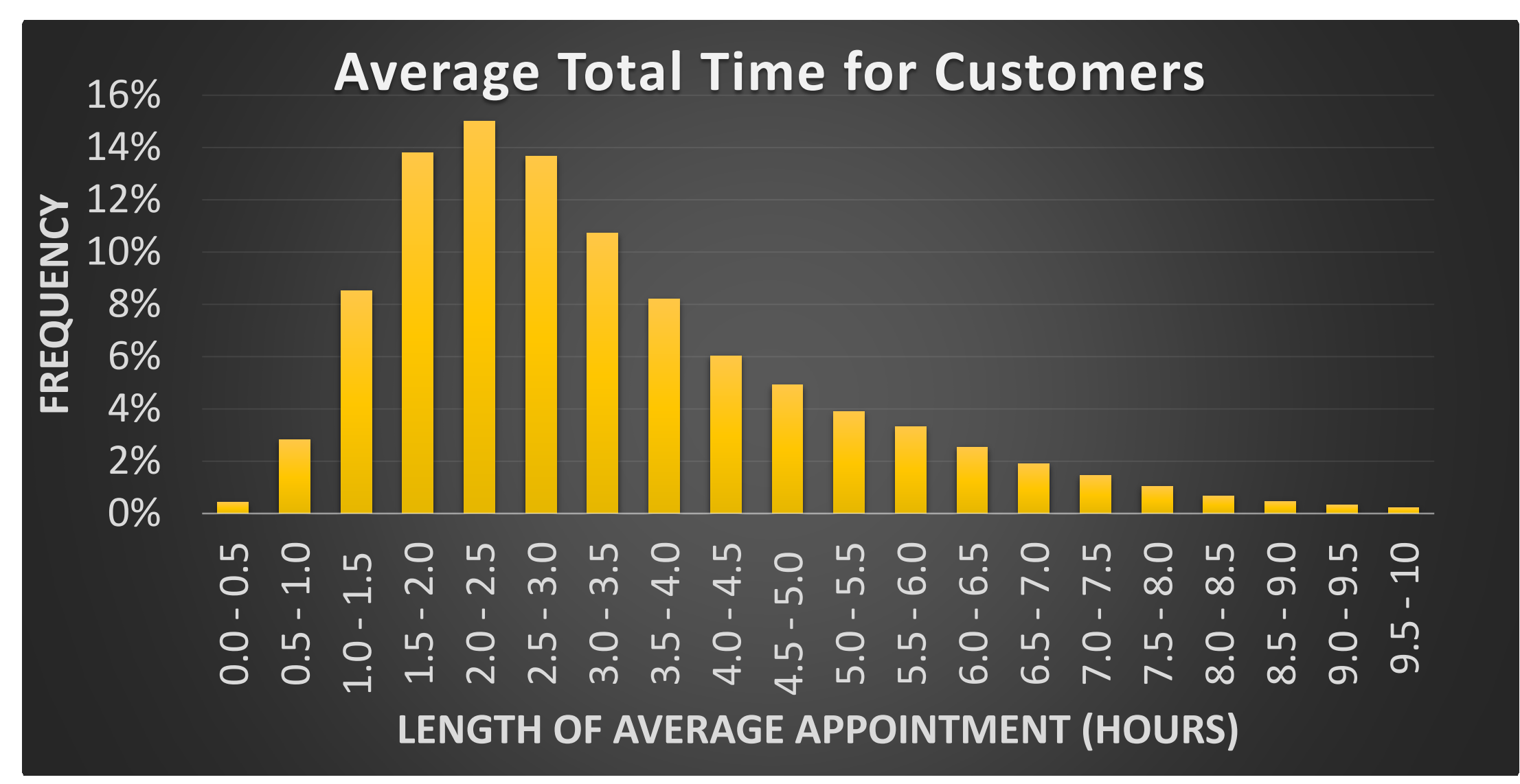
The histogram highlights the variance in customer appointment length, illustrating all appointments should not be treated equally, as currently assumed.
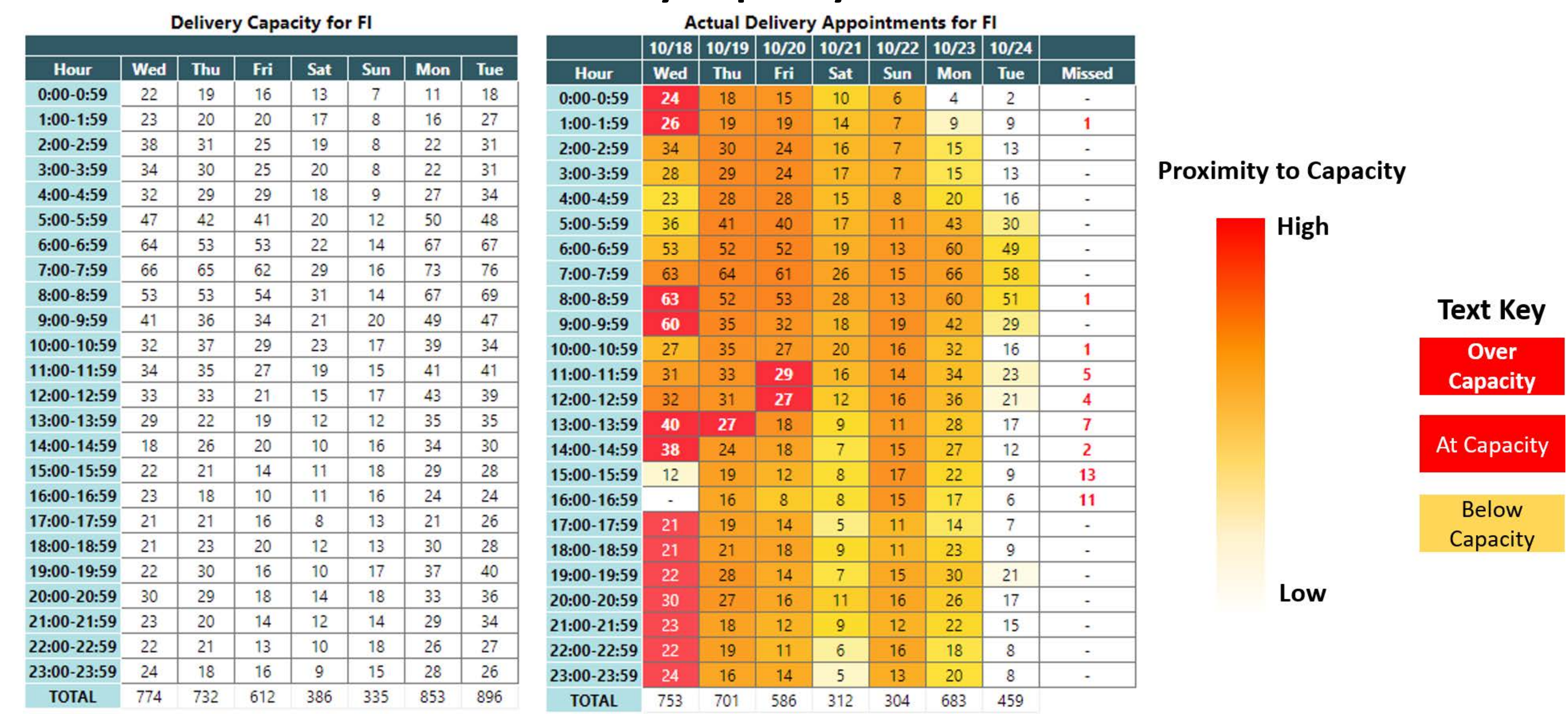
Opportunities for Improvement

- **The current metric is lagging:** Using the top producing days from the last six months causes the metric to lag and not take fluctuations of resources into account
- **All stops are not created equal:** The current methodology does not take into account the unique lengths of individual appointments.

Delivery Stop Timeline

Delivery Capacity Forecast

Delivery Capacity for FI

Hour	Wed	Thu	Fri	Sat	Sun	Mon	Tue
0:00-0:59	22	19	16	13	7	11	18
1:00-1:59	23	20	20	17	8	16	27
2:00-2:59	38	31	25	19	8	22	31
3:00-3:59	34	30	25	20	8	22	31
4:00-4:59	39	29	29	18	9	27	34
5:00-5:59	47	42	41	20	12	50	48
6:00-6:59	53	52	53	22	14	67	67
7:00-7:59	66	65	62	29	16	73	76
8:00-8:59	63	53	54	31	14	67	69
9:00-9:59	41	36	34	21	20	49	47
10:00-10:59	27	35	27	20	16	32	16
11:00-11:59	34	35	27	19	15	41	41
12:00-12:59	33	33	21	15	17	43	39
13:00-13:59	29	22	19	12	12	35	35
14:00-14:59	26	20	10	16	34	34	24
15:00-15:59	22	21	14	11	18	29	28
16:00-16:59	23	18	10	11	16	24	24
17:00-17:59	21	21	16	8	11	21	26
18:00-18:59	21	23	20	12	13	30	28
19:00-19:59	22	30	16	10	17	37	40
20:00-20:59	24	29	18	14	18	33	36
21:00-21:59	23	20	14	12	14	29	34
22:00-22:59	22	21	13	10	18	26	27
23:00-23:59	24	18	16	9	15	28	26
TOTAL	774	732	612	386	335	853	896

Actual Delivery Appointments for FI

Hour	10/18 Wed	10/19 Thu	10/20 Fri	10/21 Sat	10/22 Sun	10/23 Mon	10/24 Tue	Missed
0:00-0:59	24	18	15	10	6	4	2	-
1:00-1:59	26	19	19	14	7	9	9	1
2:00-2:59	34	30	24	16	7	15	13	-
3:00-3:59	28	29	24	17	7	15	13	-
4:00-4:59	23	28	28	15	8	20	16	-
5:00-5:59	36	41	40	17	11	43	30	-
6:00-6:59	53	52	52	19	13	60	49	-
7:00-7:59	63	64	61	26	15	66	58	-
8:00-8:59	63	52	53	28	13	60	51	1
9:00-9:59	60	35	32	18	19	42	29	-
10:00-10:59	27	35	27	20	16	32	16	1
11:00-11:59	31	33	29	16	14	34	23	5
12:00-12:59	32	31	27	12	16	36	21	4
13:00-13:59	40	27	18	9	11	20	17	7
14:00-14:59	38	24	18	7	15	27	12	2
15:00-15:59	12	19	12	8	17	22	9	13
16:00-16:59	-	16	8	8	15	17	6	11
17:00-17:59	21	19	14	5	11	14	7	-
18:00-18:59	21	21	18	9	11	23	9	-
19:00-19:59	22	18	14	7	15	30	21	-
20:00-20:59	30	27	16	11	16	26	17	-
21:00-21:59	23	18	12	9	12	22	15	-
22:00-22:59	22	19	11	6	16	18	9	-
23:00-23:59	24	16	14	5	13	20	7	-
TOTAL	753	701	586	312	304	683	459	

Proximity to Capacity — High / Low

Text Key
- Over Capacity
- At Capacity
- Below Capacity

Our Initial Estimation Model

t_{avg} = average appointment duration for that market on that day

$$\text{\# drivers available for fleet} \times \frac{10 \text{ hours}}{\text{driver}} = T_{fleet}$$
determines total time available for a fleet

$$T_{total} = \sum_i (T_{fleet} \times \% \text{ fleet services market})_i$$
determines total time available for that day

$$\frac{T_{total}}{t_{avg}} \times \%F \text{ stops} = A$$
determines estimated number of appointments available that day

Fleet Name	Driver Minutes Avail. (T)	Fleet %	Day of Week	Drivers Available
JBI MMICL	600	100%	Sunday	1
JBI MMICL	4800	95%	Monday	8
JBI MMICL	6600	93%	Tuesday	11
JBI MMICL	6600	92%	Wednesday	11
JBI MMICL	6600	94%	Thursday	11
JBI MMICL	6000	94%	Friday	10
JBI MMICL	2400	86%	Saturday	4
JBI MMLA	11400	83%	Sunday	19
JBI MMLA	31800	92%	Monday	53
JBI MMLA	36000	92%	Tuesday	60
JBI MMLA	36000	91%	Wednesday	60
JBI MMLA	39600	90%	Thursday	66
JBI MMLA	34800	90%	Friday	58
JBI MMLA	16200	83%	Saturday	27

Raw Est. Appts.	Day of Week	t_{avg}	% F Stops	F Est. Appts
77	Sunday	133	0.36	28
229	Monday	157	0.51	120
255	Tuesday	166	0.43	113
240	Wednesday	171	0.38	95
243	Thursday	182	0.30	78
216	Friday	182	0.32	74
114	Saturday	144	0.32	36

$$Raw \; Est \; Appts = \frac{T_{total}}{t_{avg}}$$

The column F Est Appts is the estimation of **delivery** capacity, including outsource.

$$F \; Est \; Appts = (\; Raw \; Est \; Appts \times \%F \; Stops) + ((\; Raw \; Est \; Appts \times \%F \; Stops) \times Outsource \%)$$

Day of Week	Hour of Day	%	Appts
Sunday	0	2.12%	0.59
Sunday	1	1.57%	0.44
Sunday	2	1.18%	0.33
Sunday	3	1.18%	0.33
Sunday	4	1.49%	0.42
Sunday	5	1.73%	0.48
Sunday	6	2.44%	0.68
Sunday	7	3.77%	1.05
Sunday	8	4.87%	1.36

The Delivery Capacity Forecast is required to be hourly. The day's estimate is distributed hourly by the % of stops historically done on that hour

Update Methodology

Variables
t_k = average appointment of customer k
t_b = time before appointment = drive time
t_a = time after appointment = time at customer + drive time
L = time to be reallocated, when $t_k \neq t_{avg}$
L_b = time to be reallocated before appointment
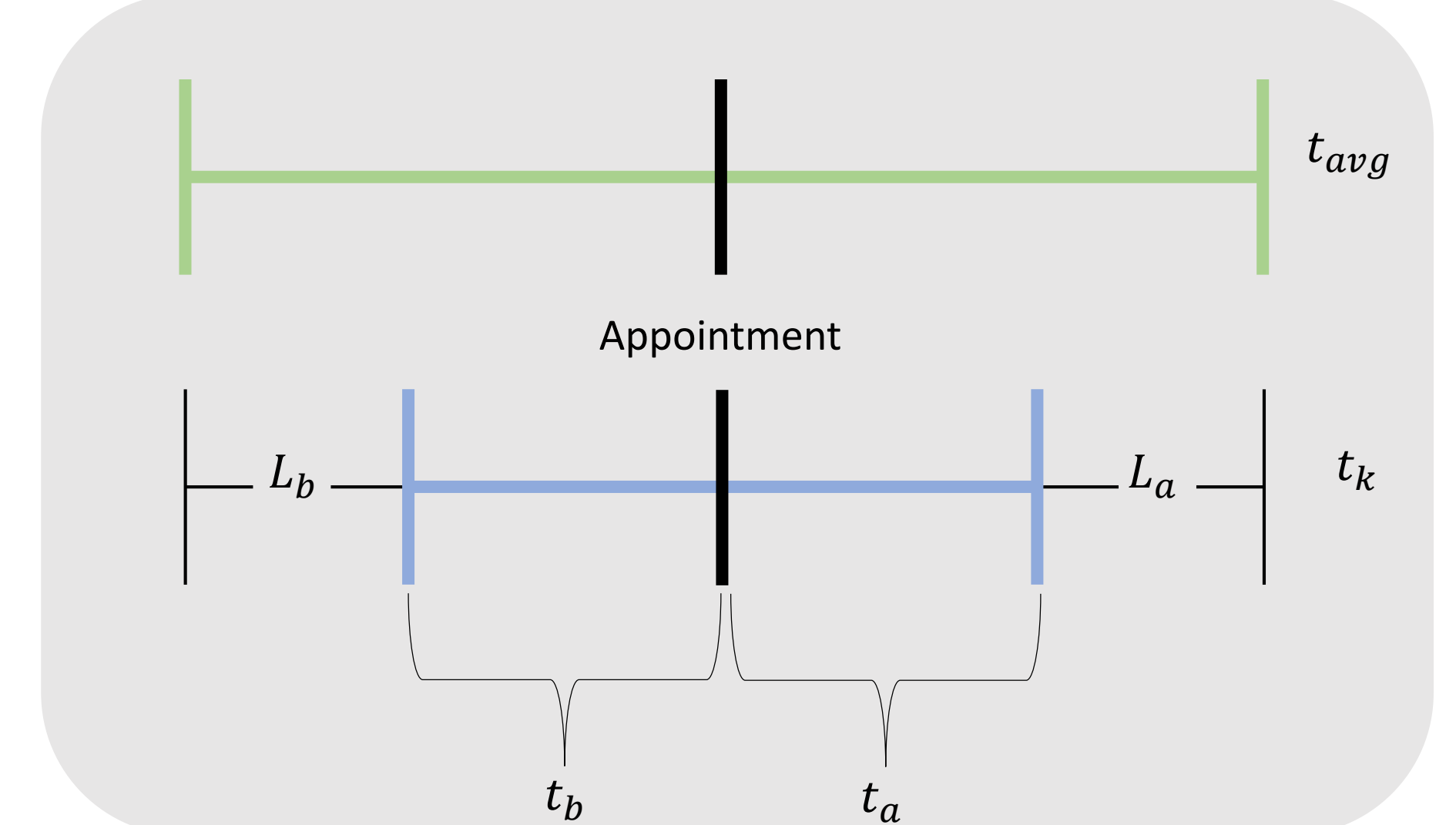L_a = time to be reallocated after appointment

Equations
$$L = |t_{avg} - t_k|$$
$$L = L_a + L_b$$
$$L_b = L \times \frac{t_b}{t_k}$$
$$L_a = L \times \frac{t_a}{t_k}$$

If a customer's average appointment is less than the market's average appointment, time is added back to the surrounding hours.

If the opposite is true, then time is subtracted from the surrounding hours.

Results

Two 2 sample t-test with $H_1: \mu_{Team} < \mu_{Cap}$ on calculated errors and calculated absolute error between JBI's Capacity Estimate & actual appointments and our team's initial estimate & actual appointments were conducted.

Results of Calculated Absolute Errors

Market Set	μ_{Cap} Error	μ_{Team} Error	P-value	CI Upper Bound
DV	2.167	2.012	0.141	0.083
HO	1.393	1.619	0.994	0.375
LC	2.905	6.654	1.000	4.547
SV	0.904	0.701	0.002	-0.09
WB	0.81	0.72	0.146	0.05
VF	1.22	0.643	0.000	-0.432

- According to the P-value, only in 2 of the 6 markets tested the team's estimate proved statistically to be significantly less than the current estimate
- The team's large error in market LC is believed to be due to some model assumptions needing adjusted for higher volume markets

Results of Calculated Errors

Market Set	μ_{Cap} Error	μ_{Team} Error	P-value	CI Upper Bound
Test*	0.285	-0.617	0.000	-0.815
DV	0.905	-0.095	0.000	-0.759
HO	-0.012	-0.226	0.014	-0.054
LC	-0.036	-5.548	0.000	-4.477
SV	0.21	-0.521	0.000	-0.648
WB	0.31	-0.696	0.000	-0.916
VF	0.875	-0.226	0.000	-0.987

Removing the absolute value requirement from the errors gives operational insight. The costs associated with underestimating capacity is more favorable than costs associated with overestimating capacity. **Therefore, operationally our estimate's error is preferred.**

*represents 18 markets chosen for testing