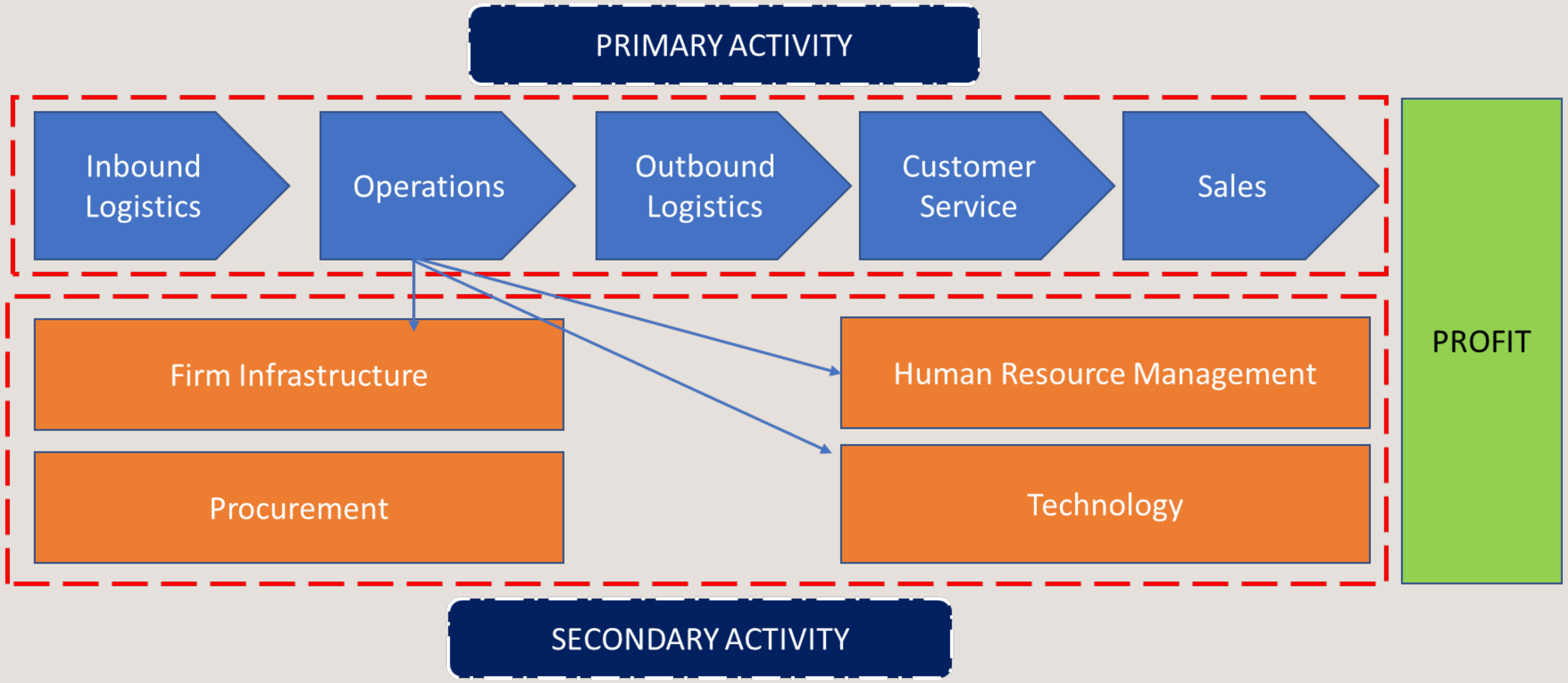
Gaps in Literature

Gaps in Literature

- WMS was a system which was adopted in 1970's by the retail industry and even in 2017, large applicability has been within the retail sector.

- WMS is an expensive proposition, it takes companies several budgetary approvals to make a credible investment in a WMS, hence time value of money of companies who executed WMS is unknown.

- From a value chain perspective, shifting costs from primary activities within the operations side of the business to the secondary side into the technology, firm infrastructure.



Gaps in Literature

- There are after costs associated with implementing a WMS:
  - Training employees to use a new portal/system
  - Software engineers and programmers
  - Consultants to constantly seek improvements to the current system

- In the returns process,
  - Process flow plays a vital role
  - Understanding of whether a Kaizen for a process made the difference or
  - Implementing a WMS which forced the process to change is hard to determine
  - Returns policy has a corresponding impact based on whether the customer is an OE or an Aftermarket

- In the Dock to Stock process,
  - Large part of the literature focused on hardware technologies
  - To implemented these hardware interventions a company need not have a WMS to capture the data

Gaps in Literature

- In the warehouse space utilization process,
  - Capabilities of a WMS are defined by the organization
  - We are not sure if organizations group complement goods near their finished good to reduce the travel time between the shelves.
  - Organizations often implement large IT based changes in phases
  - Literatures do not capture the inferences organizations draw upon their Phase I implementation, which may have an impact on the scope of a project
  - Effects of proper/improper training for employees
  - The fact that a WMS is interchangeably used as an LMS does not provide a clear enough picture to understand the leverage a LMS will have over a WMS
  - All of these assumptions affect the layout, design and method of process flow within a organization

Methodology

A

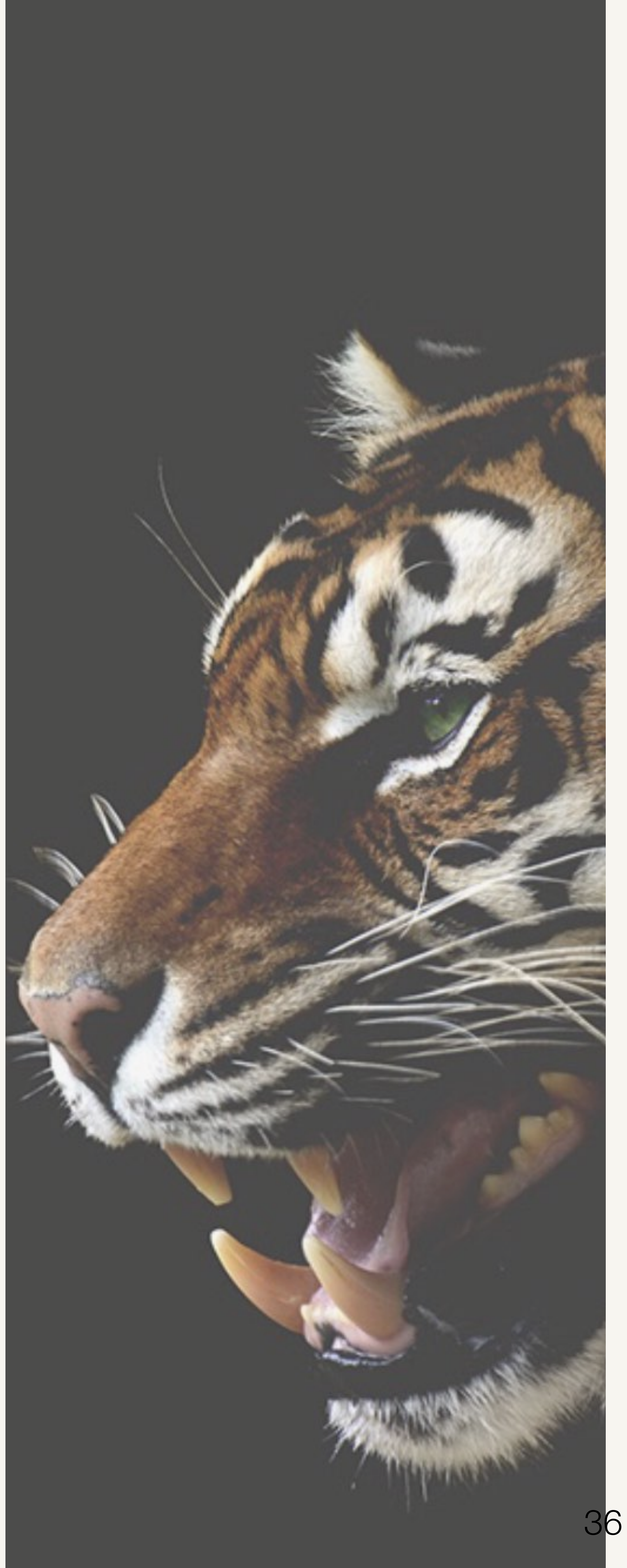
Returns process: using an Arena based simulation to see the changes in returns process

B

Dock to stock process: using a simple t-test to see the changes within the time taken

C

Warehouse space utilization: using a forecasting method and a regression analysis based on the combination of two-data set to identify the utilization



- Company A provided a data set of the product "Radiators".
  - An automobile radiator is used for cooling the internal combustion engine.
  - Experiencing large returns and high-volume movement.
  - There were over 200-part numbers within radiators which made each radiator unique.
  - Radiators had the need to ensure warehouse space was effectively utilized is critical.
  - The most challenging products among the array of other components to receive and stock.
  - Company A is in preparation to launch more part numbers under the radiator paradigm.

- Data collection:
  - Personal interview with Company A warehouse manager
  - Data from specific teams handling radiators or tasks alike

01 Return Goods Process

02 Dock to Stock Process

03 Warehouse Space Utilization

Data Analysis

PART 01

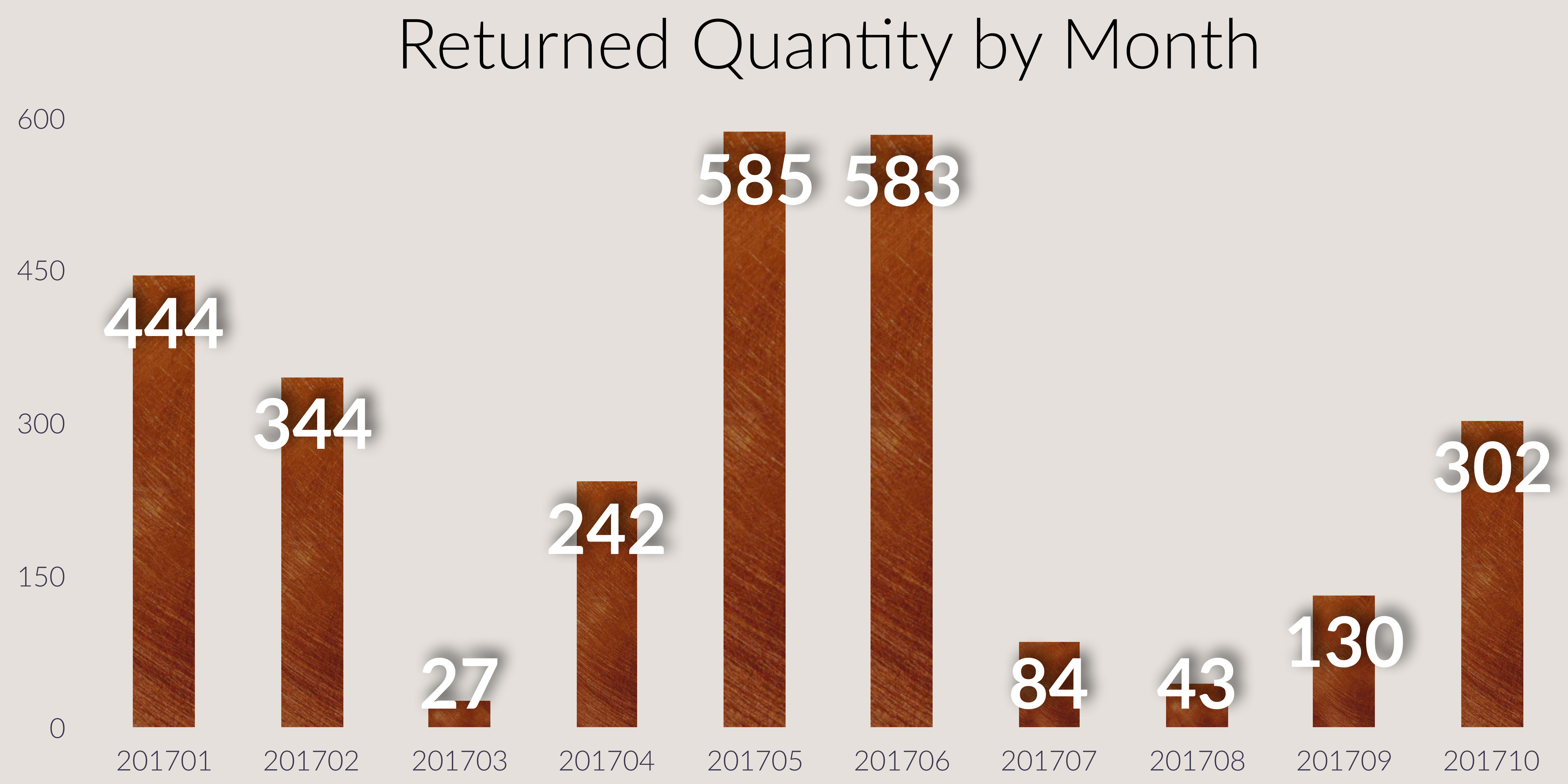
Return Goods Process

Data Analysis

Return Goods Process

Findings in Current Data of Returns

- Relatively, returns had very high volumes in both May and June.
- The quantity of returns had a seasonal fluctuation.

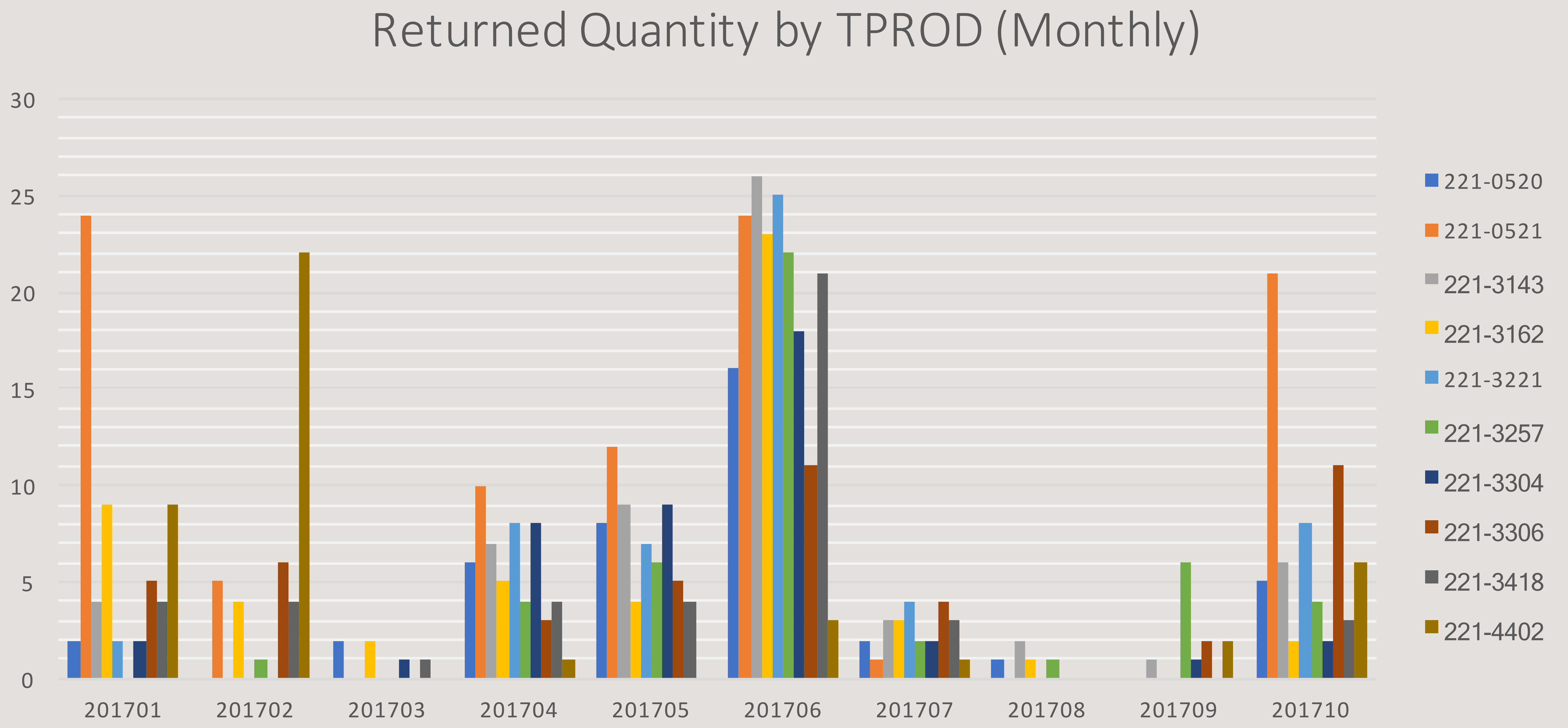


Data Analysis

Return Goods Process

Findings in Current Data of Returns

- Top 10 types of radiators that have the most volumes of returns.
- Six reasons for returns that have the most possibilities (picked out from 17 reasons):
  - Annual Return
  - Damage in Transit
  - Damage Internal
  - Duplicate Shipment
  - Entry Error
  - Inaccurate Info (e.g. packing slip)

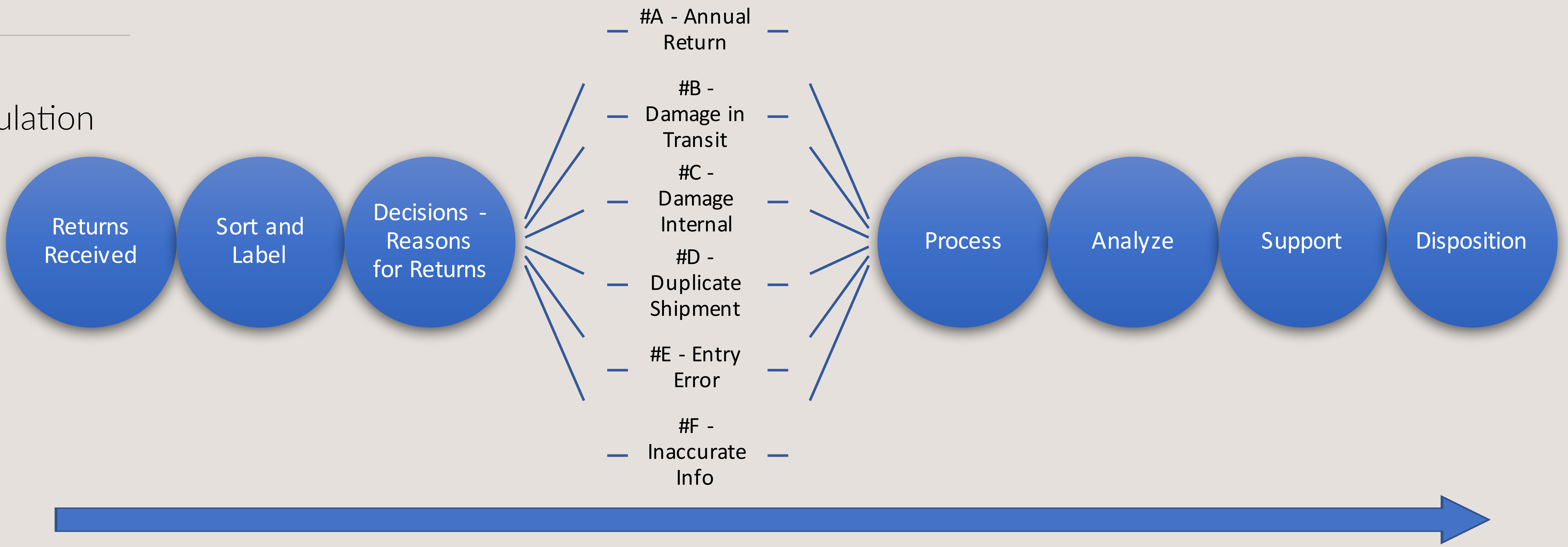


Data Analysis

Return Goods Process

Arena Simulation

- Returns process used in the simulation



Data Analysis

Return Goods Process

Assumptions in Simulation - Model 1

- There are 4 to 6 employees who work on each returns process.
- Fixed capacities: 2 workers for sorting, 3 workers for processing, 4 workers for analyzing, and 3 workers for supporting.
- Adjusted arrival rates due to the maximum of 150 entities in our student-version Arena.
  - Time between arrivals: 3 hours
- In both stages of processing and analyzing, delay types follow the triangular rule. In stage of supporting, delay type is uniform.
- Each worker has 8 working hours per day. And the replication length of simulation is 220 days.
- There is only one entity in each arrival.

Month	Total Quantity	Working Days	Arrival Rate (Returned products per day)	Adjusted Arrival Rate (Returned products per day)
201701	444	22	20	10
201702	344	20	17	9
201703	27	23	1	1
201704	242	22	11	6
201705	585	23	25	13
201706	583	22	27	13
201707	84	21	4	2
201708	43	22	2	1
201709	130	23	6	3
201710	302	22	14	7

Reason Codes	Possibility of Happening	Number of Workers Needed			
		Sort and Label	Process	Analyze	Support
#A - Annual Return	35%	1	1	2	2
#B - Damage in Transit	20%	1	1	2	2
#C - Damage Internal	11%	1	1	2	2
#D - Duplicate Shipment	15%	1	1	1	1
#E - Entry Error	9%	1	1	1	1
#F - Inaccurate Info	10%	1	1	1	1

Reason Codes	Time Duration of Processing Returns (Days)	Delay Time in Processing Stage (Days)			Delay Time in Analyzing Stage (Days)			Delay Time in Supporting Stage (Hours)	
		Min	Most	Max	Min	Most	Max	Min	Max
#A	3 or 4	1	1.5	1.7	1	1.5	1.8	1	1.5
#B	2 or 3	0.5	0.7	1	0.8	1	1.2	1	1.5
#C	3 or 4	0.6	1	1.4	1	1.3	1.5	1	1.5
#D	2 or 3	0.4	0.8	1.2	0.4	0.8	1	0.5	1
#E	2 or 3	0.3	0.7	1	0.3	0.7	0.9	0.5	1
#F	2 or 3	0.4	1	1.4	0.4	0.7	1	0.5	1

Number of products in each return	1	2	3	4	5	6	7	8	10	13	14	17
Count of frequencies	2397	56	16	6	7	5	8	1	3	1	1	1
Possibility	0.958	0.022	0.006	0.002	0.003	0.002	0.003	0.000	0.001	0.000	0.000	0.000

Data Analysis

Return Goods Process

Changed Assumptions due to Implementing a WMS - Model 2

- Delay time in stages of processing and analyzing can be decreased by 0.2 days.
- Delay time in stage of supporting can be decreased by 0.4 hours.
- The number of returned products from reasons #D, #E and #F can be decreased by two third.
- Time between arrivals: 4 hours

Month	Original Total Quantity	New Total Quantity	Original Adjusted Arrival Rate (Returned products per day)	New Adjusted Arrival Rate (Returned products per day)
201701	444	343	10	8
201702	344	266	9	7
201703	27	21	1	1
201704	242	187	6	4
201705	585	452	13	10
201706	583	451	13	10
201707	84	65	2	2
201708	43	33	1	1
201709	130	101	3	2
201710	302	234	7	5

Data Analysis

Return Goods Process

Results of **Model 1**

Reasons Code		#A	#B	#C	#D	#E	#F
Queue – Average Waiting Time (Days)	Process	0.12	0.1	0.11	0.14	0.07	0.12
	Analyze	24.92	24.53	27.2	11.58	11.25	10.08
	Support	0.01	0.01	0.01	0	0	0
Queue – Average Waiting Number	Analyze	22	12	9	5	3	3
Entity – Wait Time (Days)	19.56						
	Sorting Worker	Processing Worker	Analyzing Worker	Supporting Worker			
Resource – Average Usage	4.17%	89.76%	98.49%	16.09%			

Results of **Model 2**

Reasons Code		#A	#B	#C	#D	#E	#F
Queue – Average Waiting Time (Days)	Process	0	0	0	0	0	0
	Analyze	0.27	0.41	0.37	0.31	0.27	0.15
	Support	0.004	0.006	0.002	0	0	0
Queue – Average Waiting Number	Analyze	0.19	0.16	0.07	0.09	0.07	0.03
Entity – Wait Time (Days)	0.31						
	Sorting Worker	Processing Worker	Analyzing Worker	Supporting Worker			
Resource – Average Usage	3.13%	53.44%	77.89%	10.04%			

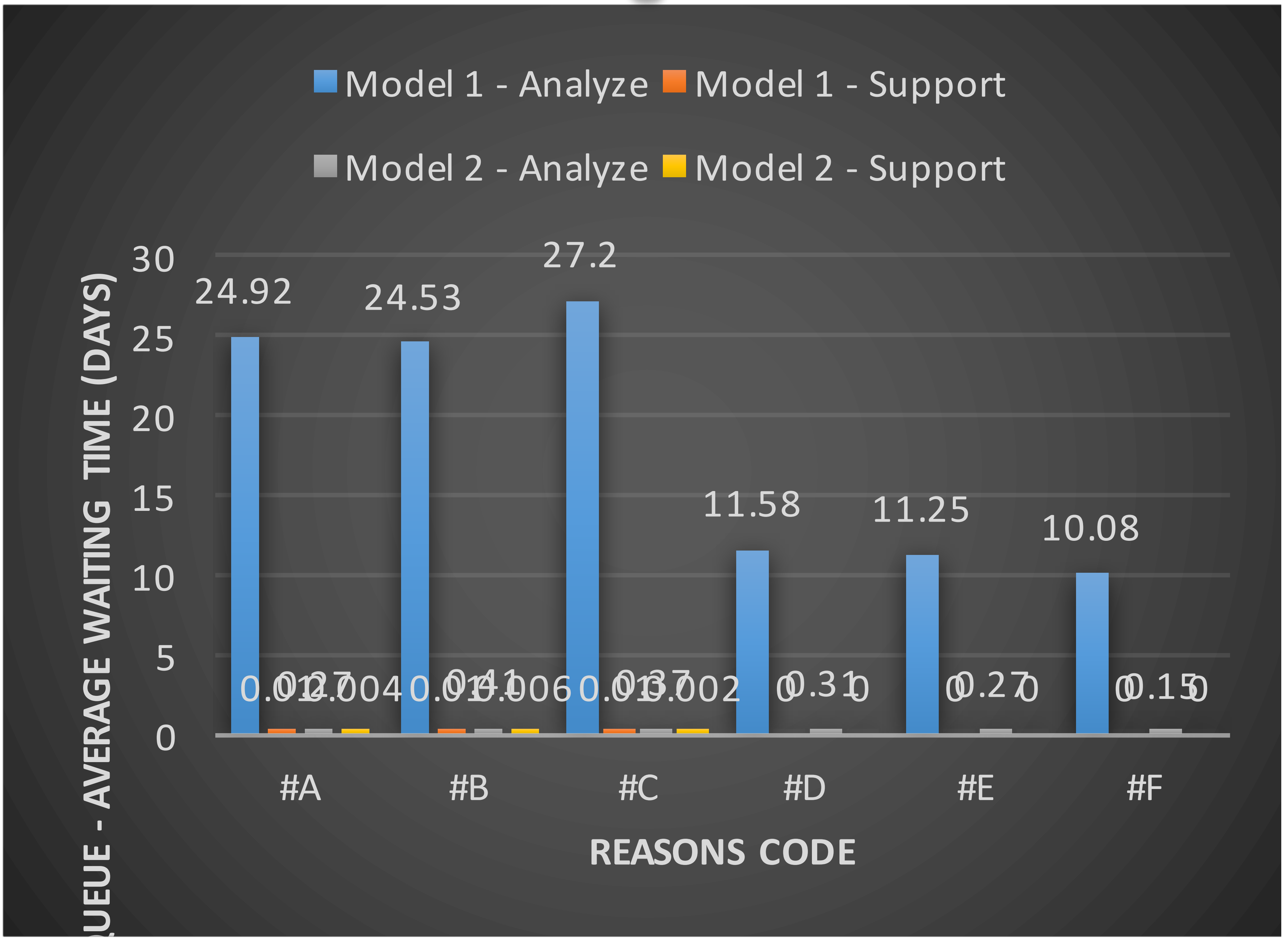
Data Analysis

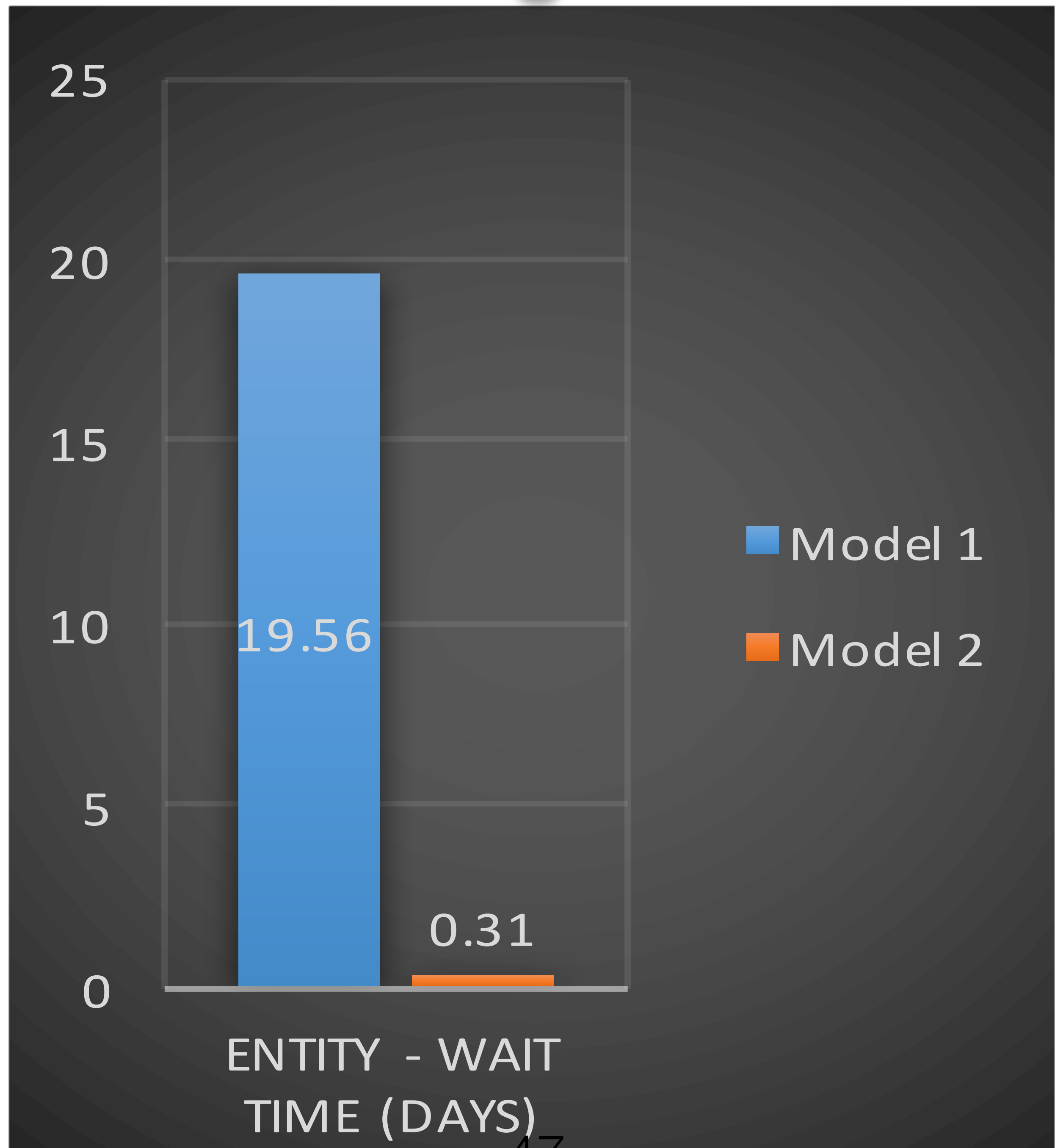
Return Goods Process

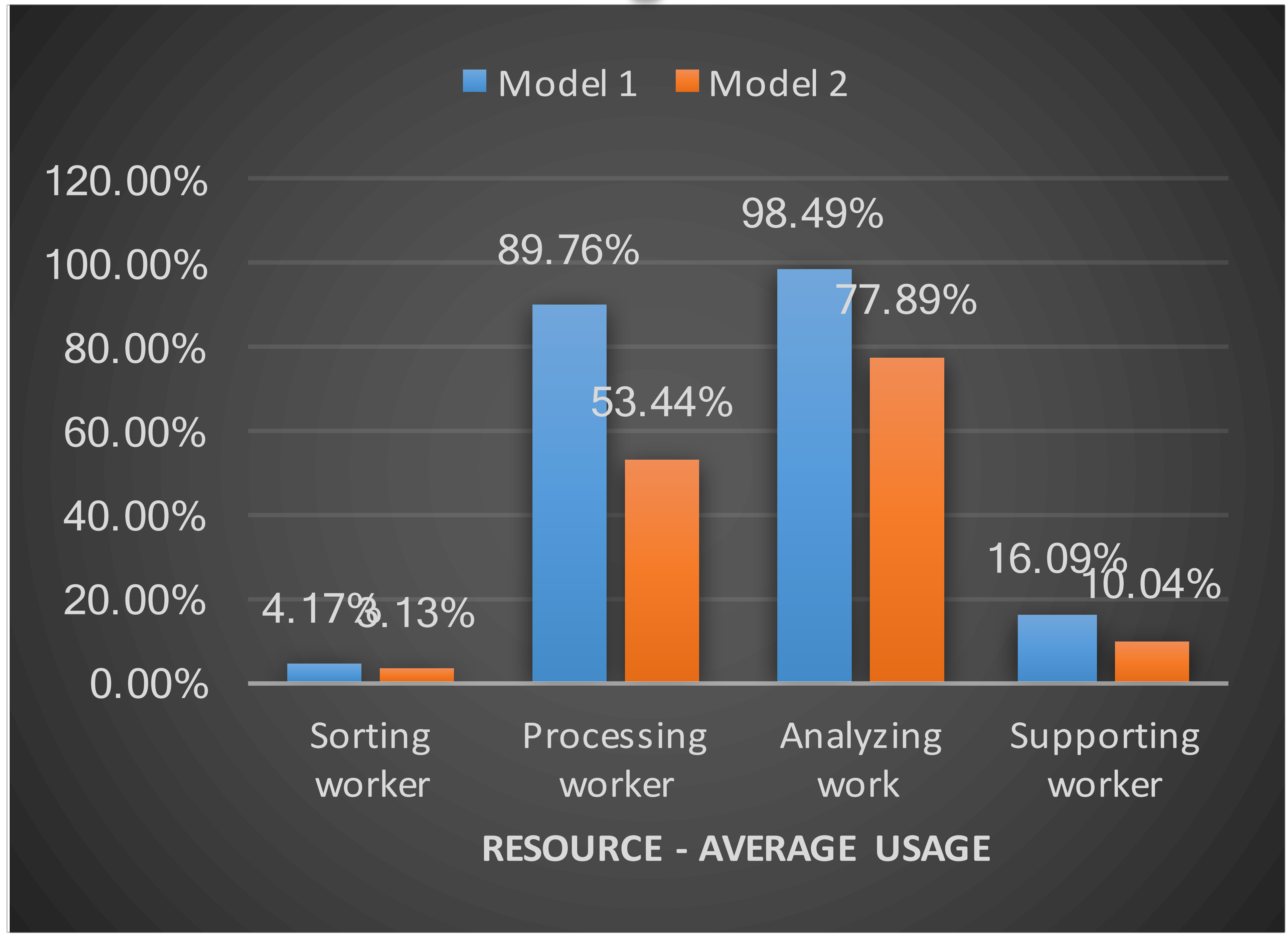
Comparisons in Graphs

Reductions:
- Average waiting time in queue (days): 98% in stage of analyzing
- Waiting time for entity (days): 61%
- Average utilization of workers:
  - 40% for processing worker
  - 21% for analyzing worker
  - 38% for supporting worker

Originally fixed capacities:
- 2 workers for sorting
- 3 workers for processing
- 4 workers for analyzing
- 3 workers for supporting







Data Analysis

Return Goods Process

Reports from Model 3

Reduced fixed capacities:
- 1 worker for sorting
- 2 workers for processing
- 4 workers for analyzing (not changed)
- 2 workers for supporting

Reasons Code		#A	#B	#C	#D	#E	#F
Queue – Average Waiting Time (Days)	Process	0.05	0.08	0.05	0.06	0.11	0.08
	Analyze	0.18	0.24	0.25	0.18	0.19	0.19
	Support	0.006	0.004	0.002	0.009	0.004	0.006
Queue – Average Waiting Number	Analyze	0.12	0.1	0.05	0.06	0.04	0.04
Entity – Wait Time (Days)	0.27						
	Sorting Worker	Processing Worker	Analyzing Worker	Supporting Worker			
Resource – Average Usage	6.25%	80.48%	75.69%	14.96%			

Data Analysis

Return Goods Process

Conclusions

- Returned products can wait for less time to be processed.
  - In stage of analyzing, average waiting time can be reduced by around 98%.

- The average utilizations of workers can be reduced.
  - Company A can hire and train less workers for sorting, processing, and supporting.

- Cost on labors, training, and processing returns because of #D, #E, #F can be reduced.

PART 02

Dock to Stock Process

Data Analysis

Dock to Stock Process

$H_0 = \mu = 2$ (Best in class range)
$H_1 = \mu <= 2$ (This is what we want to achieve)

- **T test statistic**:
  - Mean = 3.02 hrs (Unloading time per person) + 3 hrs (Put away per person) = 6.02 hours
  - Standard deviation = 0.03 hrs (Unloading time) + 0.02 hrs (put away) = 0.05 hrs
  - $\mu = 2$
  - n = 41
  - T Test statistic = $\bar{x} - \mu$/ Standard Deviation/ Square root of n
  - Therefore, test statistic is 6.02-2/0.05/Square root of 41= 541

- **T critical statistic**:
  - V degrees of freedom = n-1 = 41-1 = 40
  - At 95% confidence level, $t_{0.05, 40} = 1.68$

Data Analysis

Dock to Stock Process

$H_0 = \mu = 2$ (Best in class range)
$H_1 = \mu <= 2$ (This is what we want to achieve)

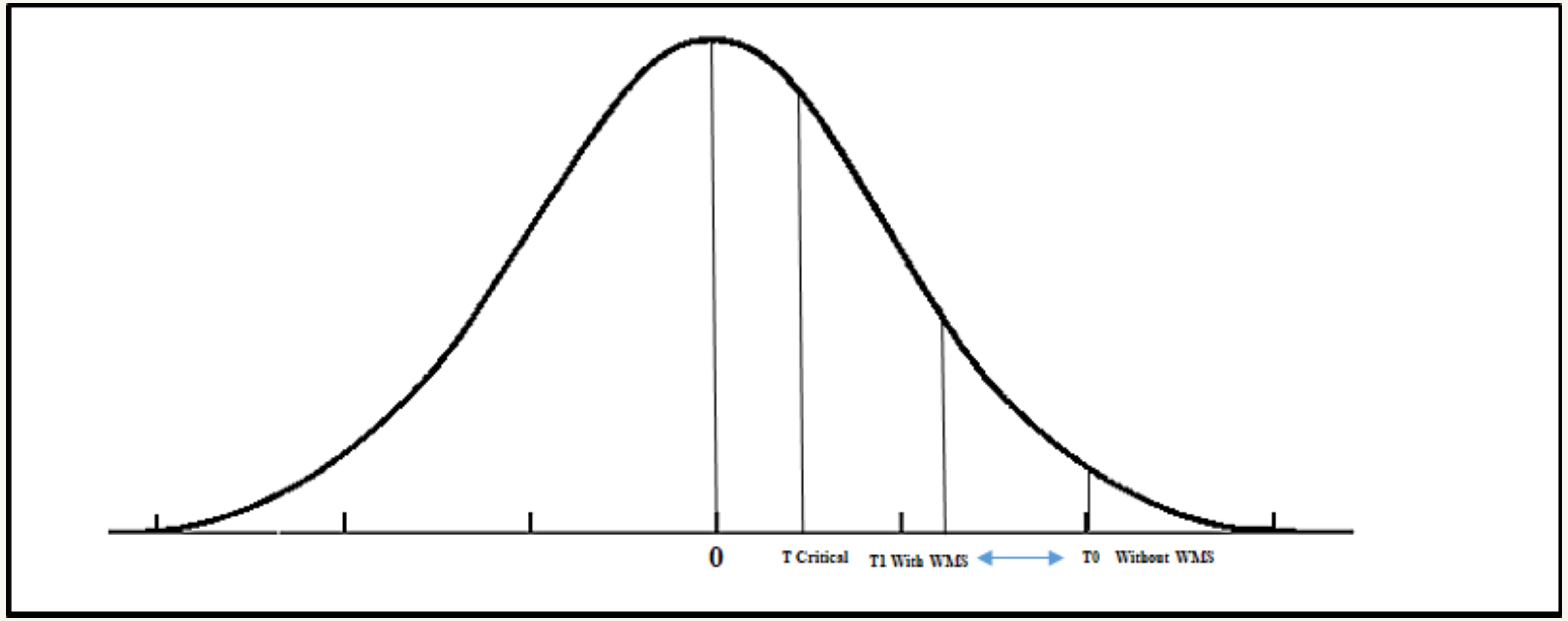
- Test statistic is much larger than critical statistic,
  - Hence we fail to reject the null hypothesis. i.e there is not enough evidence to prove that dock to stock time is less than 2 hours (Best in class)

- Having identified a potential reduction through technology and smooth flow of information through the WMS, we may be able to assume a sample mean of 4 hours for the dock tot stock process. Hence in that case,
  - T test statistic
    - Mean = 4 hours
    - Standard deviation = 0.03 hrs (Unloading time) + 0.02 hrs (put away) = 0.05 hrs
    - $\mu = 2$
    - n = 41

Data Analysis

Dock to Stock Process

$H_0 = \mu = 2$ (Best in class range)
$H_1 = \mu <= 2$ (This is what we want to achieve)



- Therefore, test statistic is
  - 4-2/0.05/Square root of 41 = 256.1
- T critical stat
  - V degrees of freedom = n-1 = 41-1 = 40
  - At 95% confidence level, $t_{0.05, 40} = 1.68$
- Therefore, we still fail to reject the null hypothesis. i.e there is not enough evidence to prove that dock to stock time is less than 2 hours (Best in class)
- But the deviation between 6 hours and 4 hours has nearly halved and the trend is moving towards the best in class.

PART 03

Warehouse Space Utilization

Data Analysis

Warehouse Space Utilization

Basic Information

- Dimension.
- Product - radiator.

Company A Warehouse Space (Radiator)			
Total Part Number	635		
Average DIMS%WHT			
Length (inch)	33	=2.75	ft
Width (inch)	8	=0.67	ft
Height (inch)	23	=1.92	ft
Usable Space in Long Beach	178500	sqft	
Maxium Storage Height			
On the floor	8	ft	
In the rack	12	ft	
Pallet for Radiator			
Length	4	ft	
Width	3.3	ft	
Area	13.2	sqft	

Data Analysis

Warehouse Space Utilization

Assumptions

- All the radiators that stored in two warehouses will be combined to be stored at Long Beach warehouse.
- If the total number of each type of radiator is larger than 400, keep the goods on the floor, or keep the goods in the rack.
- Each package can be packed 10 radiators.
- Stack 2 boxes per pallet on the floor, 3 boxes per pallet in the rack.

Data Analysis

Warehouse Space Utilization

Equations

- Number of package = (Total monthly end inventory)/10
- Storage space = (Number of package)/(Number of box per pallet)
- Space utilization = (Storage space)/(Total warehouse usable space)

Data Analysis

Warehouse Space Utilization

Monthly Radiator Space Utilization

	Original Data											
	20160930	20161031	20161130	20161231	20170131	20170228	20170331	20170430	20170531	20170630	20170731	20170831
End Inventory of each month	41333	49291	46725	43244	44176	45471	45094	43345	38761	37106	36327	31332
Large volume	12063	16226	10694	5970	9327	9829	12024	12033	8465	6355	7888	5869
Percentage	29%	33%	23%	14%	21%	22%	27%	28%	22%	17%	22%	19%
Small volume	29270	33065	36031	37274	34849	35642	33070	31312	30296	30751	28439	25463
Number of packages (10 per box)												
Large volume	1206	1623	1069	597	933	983	1202	1203	847	636	789	587
Small volume	2927	3307	3603	3727	3485	3564	3307	3131	3030	3075	2844	2546
Storage Space												
Large volume (2 boxes per pallet)	7962	10709	7058	3940	6156	6487	7936	7942	5587	4194	5206	3874
Small volume (3 boxes per pallet)	12879	14549	15854	16401	15334	15682	14551	13777	13330	13530	12513	11204
Total Space used	20840	25258	22912	20341	21489	22170	22487	21719	18917	17725	17719	15077
Space utilization												
Large volume	4.46%	6.00%	3.95%	2.21%	3.45%	3.63%	4.45%	4.45%	3.13%	2.35%	2.92%	2.17%
Small volume	7.22%	8.15%	8.88%	9.19%	8.59%	8.79%	8.15%	7.72%	7.47%	7.58%	7.01%	6.28%
Total	11.68%	14.15%	12.84%	11.40%	12.04%	12.42%	12.60%	12.17%	10.60%	9.93%	9.93%	8.45%

Data Analysis

Warehouse Space Utilization

Forecasting Data

	Forecasting Data					
	20170930	20171031	20171130	20171231	20180131	20180228
End Inventory of each month	34922	34194	33482	34199	33958	33880
Large volume	8013	7846	7683	7848	7792	7774
Percentage	23%	23%	23%	23%	23%	23%
Small volume	26908	26347	25799	26352	26166	26106
Number of packages (10 per box)						
Large volume	801	785	768	785	779	777
Small volume	2691	2635	2580	2635	2617	2611
Storage Space						
Large volume (2 boxes per pallet)	5289	5179	5071	5179	5143	5131
Small volume (3 boxes per pallet)	11840	11593	11352	11595	11513	11486
Total Space used	17128	16771	16423	16774	16656	16618
Space utilization						
Large volume	2.96%	2.90%	2.84%	2.90%	2.88%	2.87%
Small volume	6.63%	6.49%	6.36%	6.50%	6.45%	6.43%
Total	9.60%	9.40%	9.20%	9.40%	9.33%	9.31%

Data Analysis

Warehouse Space Utilization

Regression Analysis

- Variables:
  - Dependent variable: End Inventory (EI)
  - Independent variables:
    - Dock to Stock Time (D-S-T): monthly total time on dock to stock process
    - Dock to Stock Labor Arrangement (D-S-P): the number of labor working on the process
    - Return Goods Time (R-G-T): processing time on each return good
    - Return Goods Labor Arrangement (R-G-P): the number of labor working on the process.
- Equation:

EI=10933+(2*D-S-T)-(2652*D-S-P)+(4*R-P-T)+(3589*R-P-P)

Data Analysis

Warehouse Space Utilization

Summary Output in Regression

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.729
R Square	0.531
Adjusted R Square	0.387
Standard Error	4357.656
Observations	18

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	280000550.9	70000137.72	3.686	0.032
Residual	13	246859139	18989164.54		
Total	17	526859689.9			

	Coefficients	*Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	10933	24522.910	0.446	0.663	-42045.659	63911.394
D-S-T	2	1.862	1.129	0.279	-1.921	6.125
D-S-P	-2652	815.390	-3.252	0.006	-4413.403	-890.315
R-P-T	4	3.094	1.154	0.269	-3.114	10.253
R-P-P	3589	1775.895	2.021	0.064	-247.288	7425.888

Data Analysis

Warehouse Space Utilization

Time and Labor Used for 2 Processes **without a WMS**

Dock to stock time (22 days)	360-480	mins/day
Dock to stock labor	2-7	persons/day
Return goods time (22 days)	30-90	mins/day
Return goods labor	4-6	persons/day

Time and Labor Used for 2 Processes **with a WMS**

Dock to stock time (22 days)	210-270	mins/day
Dock to stock labor	0-5	persons/day
Return goods time (22 days)	6-36	mins/day
Return goods labor	2-4	persons/day

Assumptions when simulating a WMS:

- Standardize the type of package, increase 10 to 12 radiators per package.
- System can integrate all vacant storage locations, one more level is available to store the goods, thus, 3 boxes per pallet, two levels available, total 6 boxes per two pallets stacked together.

Data Analysis

Warehouse Space Utilization

Without WMS	MAX	MIN
End Inventory of each month	42943	38465
Large volume	9854	8826
Small volume	33089	29639
Number of packages (10 per box)		
Large volume	985	883
Small volume	3309	2964
Storage Space		
Large volume (2 boxes per pallet)	6504	5825
Small volume (3 boxes per pallet)	14559	13041
Total Space used	21063	18866
Total Space utilization	12%	11%

Comparison

With WMS	MAX	MIN
End Inventory of each month	27879	27077
Large volume	6397	6213
Small volume	21482	20864
Number of packages (1 p2er box)		
Large volume	533	518
Small volume	1790	1739
Storage Space		
Large volume (2 boxes per pallet)	3519	3417
Small volume (3 boxes per pallet, 2 levels)	3938	3825
Total Space used	7457	7242
Total Space utilization	4.18%	4.06%

Data Analysis

Warehouse Space Utilization

Conclusions

- Product's storage space depends on its daily and monthly end inventory. Furthermore, we can see that end inventory depends on the whole processes operation, from upstream to the down stream.

- All four factors have impact on product storage space utilization by influencing its end inventory. Improvement on Dock to stock and Return goods processes while using WMS show obvious influence on product's end inventory.

- In terms of storage space, based on the implementation of WMS, standardizing package and rearranging storage method also help to reduce product's space utilization by about 8%, thus, it is possible and positive to improve warehouse space by introducing WMS.

Conclusions

Conclusions

- A WMS is an obvious trajectory for Company A considering they are looking for seamless clarity into their operations.
- The data suggests that a WMS does have a significant impact on the overall space with respect to better time utilization, labor utilization and days taken.
- The WMS does realign company strategies on a real time. This helps utilize inventory, space and people with purpose and for the right purpose.
- Although, we see that a WMS does have its positive side, literature also suggests that auxiliary technology such as RFID play a important role in creating value for the business and raising the standard of operation visibility.
- The pathway to achieving operational excellence is moving to a synergic model which fits the strategy of Company A with its parent firm.

Conclusions

- A WMS as an investment tool shall enhance their customer satisfaction capability and improve the overall customer experience.
- There is no denying that majority of the literature within the WMS paradigm were part of the retail and consumer goods section of the market and the applicability to a auto components business is still very nascent.
- Global benchmarks in fulfillment operations such as Amazon and Alibaba embrace advance technological interventions such as robotics and artificial intelligence. It would be time that Company A adopt at least algorithm based smart picking, processing and shipping techniques to begin with.
- Competition from other automotive makers and smart technology developers are creating a disrupter effect on the parts sector and this would push Company A to add value to the end customer.
- In conclusion, a WMS is certainly a step up considering the current operations, with smarter analytics, decision making and visibility are the foundation of a trusted company.

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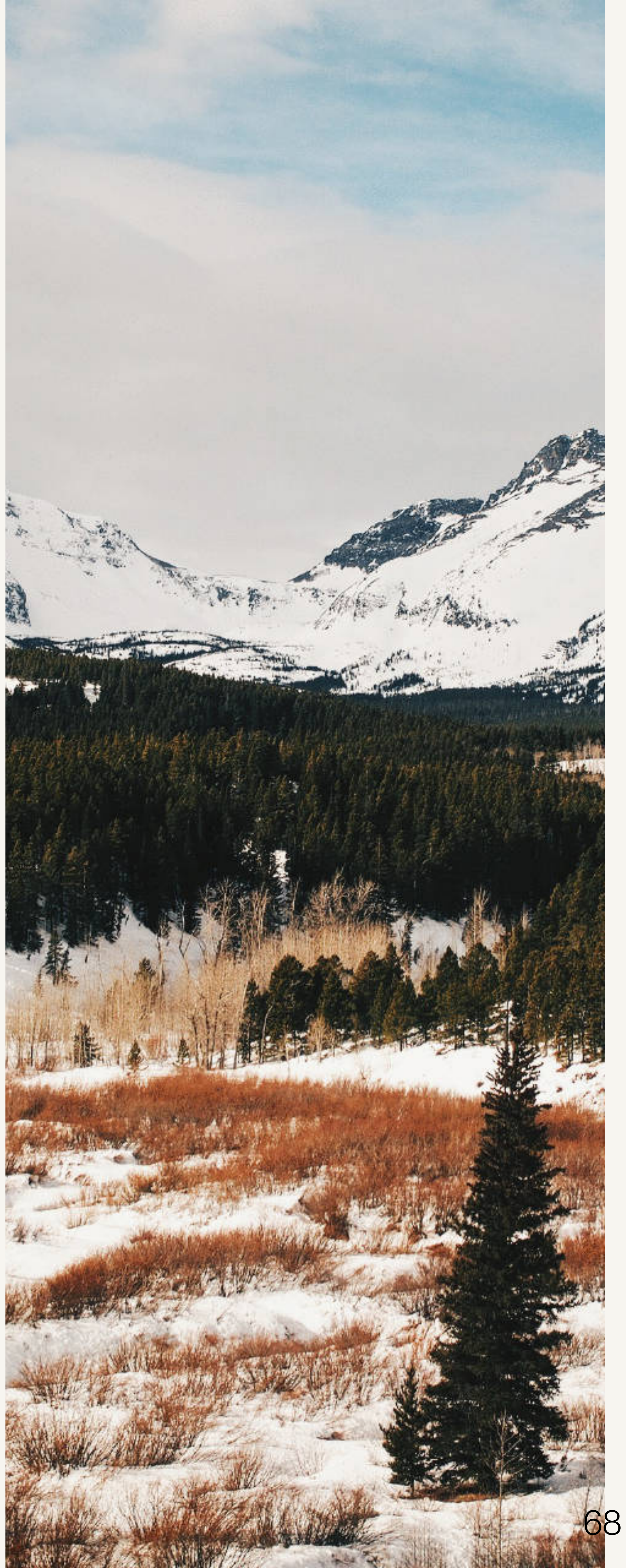

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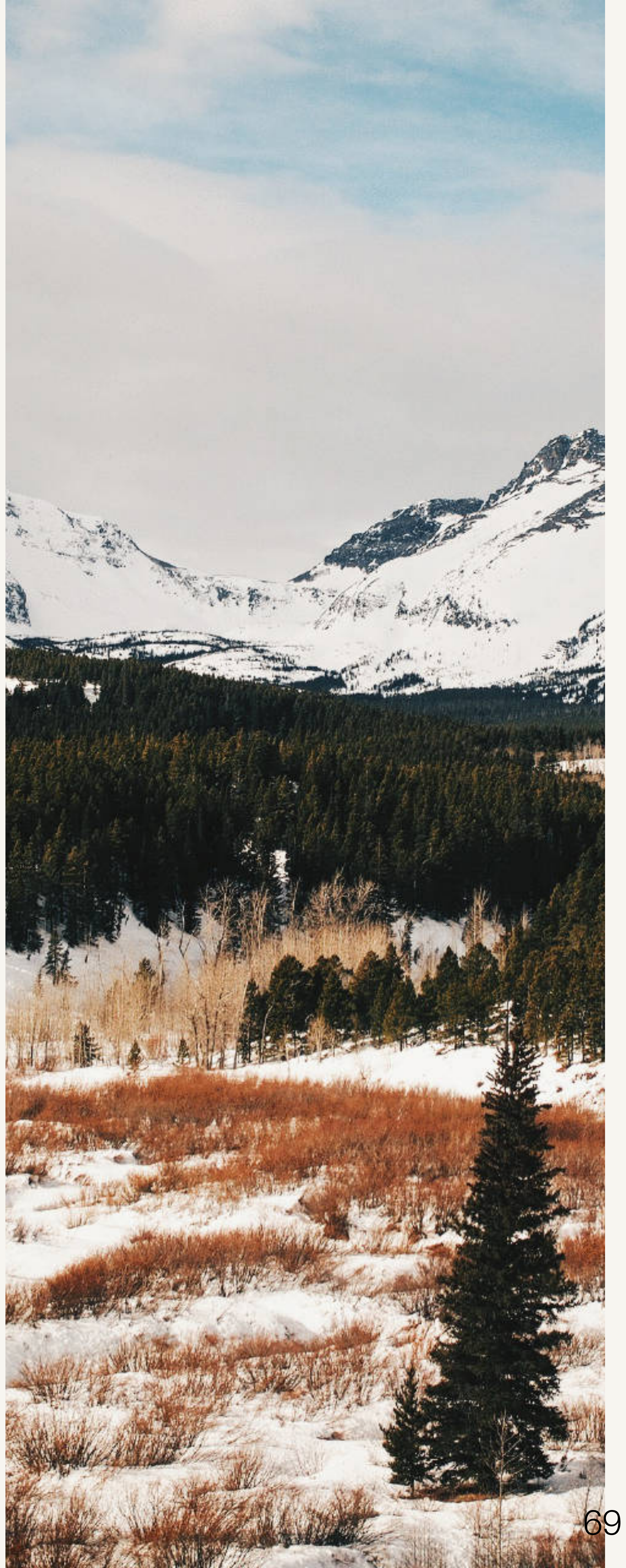

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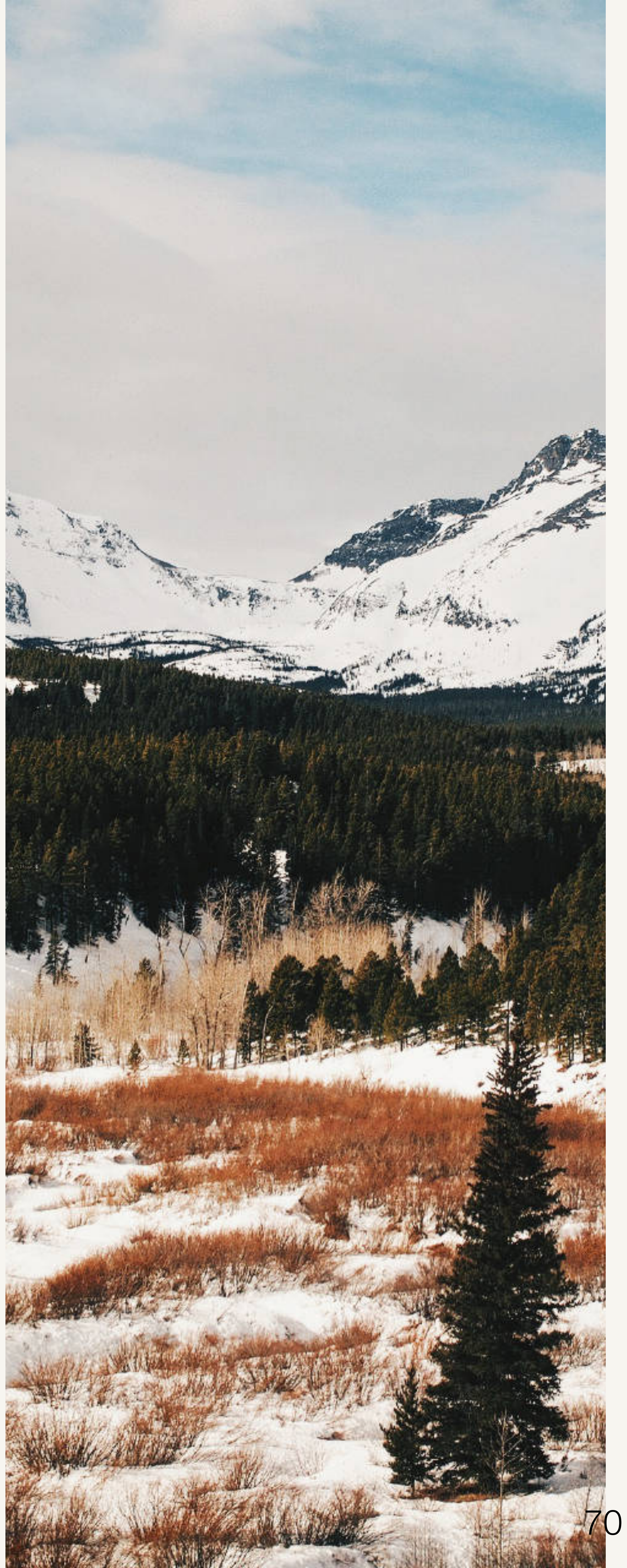

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THANKS

ANY QUESTIONS?