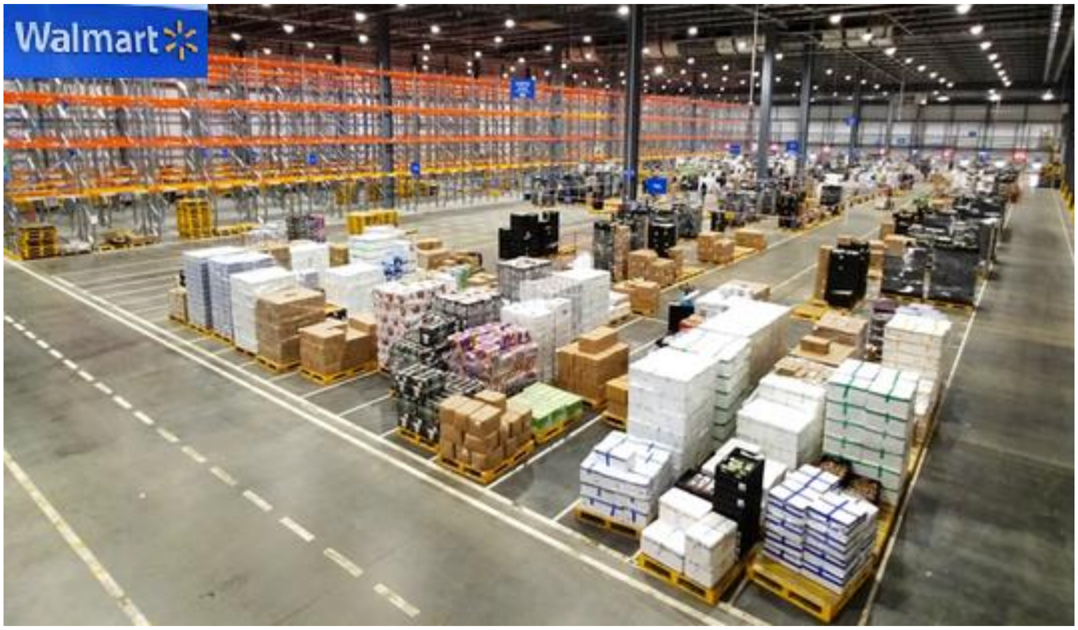
DAT561: Midterm Project:

Smart Logistic Warehouse System in Walmart

Walmart Inc. is an American multinational retail corporation that operates a chain of hypermarkets, discount department stores, and grocery stores from the United States, headquartered in Bentonville, Arkansas. Walmart warehouses are located throughout the country to ship out products and provide on-time delivery for customers.



Example of one Walmart warehouse (Received from Walmart Corporate)

Recently, Walmart is planning a 21-day countdown promotion for Christmas, and Marlon Brown, a manager of Walmart Company, must make sure that the stored products in each warehouse are proper and sufficient. After consideration, Marlon breaks this project into 2 parts:

1. Selecting products for each warehouse before the promotion starts
2. Simulating cross-warehouse-transshipment solution for possible product shortage problem for a random warehouse after the promotion starts

Working as a consulting team, you would provide your analysis to Marlon, and all the data you need is available in the "Product.csv".

Here is some information about this dataset:

Each column contains the weight and value of each product, and there are totally 50 available product options (Product No.0 - Product No.49) that can be selected into one warehouse.

Every two rows contain all product information in one warehouse, and there are 300 warehouses (Warehouse No.0 - Warehouse No.299) in total.

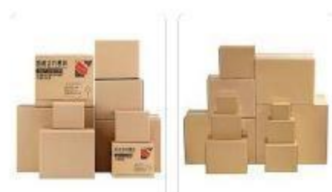
	Product 0	Product 1	Product 2	Product 3									
Weight	112	100	108	66	95	91	35	49	27	91	99		
Value	66	170.66	130	67.32	65.48	27.08	65	17.23	44.05	34.92	121.4	4	Warehouse1
	96	105	117	4	107	109	66	56	112	9	65		
	110.69	68.57	67.5	3.61	145.38	83.47	47.31	101.94	116.52	3.89	58.08	111	Warehouse2
	115	95	93	22	8	118	100	112	41	111	104		
	169.25	8.86	102.68	28.33	3.75	115.61	76.61	220.79	89.65	83.28	185.95	51	Warehouse3
	31	113	47	42	97	32	85	67	32	69	97		
	28.41	88.38	14.79	22.01	33.86	55.25	77.54	15.51	19.66	97.02	78.43	40	

For each warehouse, there are 4 variables:

1. *n* - total number of products chosen to be stored in the warehouse
2. *C* - total weight capacity of the warehouse
3. V_i - the value of available product *i*
4. W_i - the weight of available product *i*

Specifically, for each warehouse, there is a weight capacity (***C***) of 650, which means that the total weight of **n** products that are selected to be stored in a warehouse should be less than or equal to 650. Each available product *i* has its own weight ($\boldsymbol{W_i}$) and value ($\boldsymbol{V_i}$). Besides, the product information for each warehouse is different.

Warehouses can store all boxes within **Capacity C**.



There are **n** products available for selection.

Each product i: **Value Vi** and **Weight Wi**

$$C \geq \sum W_{i(stored)}$$

Problem 1: The Estimated Value for Each Warehouse

In this part, Marlon wants to select products for each warehouse. He will choose products that have the top “Value_Weight Ratios” as many as possible before reaching the capacity of each warehouse (650).

$$Value\_Weight\ Ratio = \frac{Value\ of\ a\ Product}{Weight\ of\ a\ Product}$$

That is, he will first choose the product with the highest "Value_Weight Ratio" to store in the warehouse, and then choose the product with the second-highest "Value_Weight Ratio" to store, and so on until the warehouse reaches its capacity.

Here is a simplified example for one warehouse, assuming the capacity of it is 265, and there are 10 products that could be selected. Weights and values of these products are listed below:

Package No	0	1	2	3	4	5	6	7	8	9
Weight	112	67	94	58	47	9	98	31	81	12
Value	195.71	62.59	105.44	57.15	64.21	8.79	71.14	11.19	62.89	1.64

First of all, calculate the Value_Weight Ratio for each product.

Package No	0	1	2	3	4	5	6	7	8	9
Value/Weight	0.5723	1.0705	0.8915	1.0149	0.732	1.0239	1.3776	2.7703	1.288	7.3171

Secondly, sort the products based on the Value_Weight Ratio in descending order.

Thirdly, start to select products, and in the meantime, look at the accumulated weight of products to make sure the accumulated weight does not exceed the warehouse weight capacity. With the capacity of this warehouse (265), after we select products 0, 4, 2, the accumulated weight approaches 253, and only 12 are left for the next product. When we choose the fourth product, we select product 5 rather than product 3 because the weight of product 3 (58), is larger than the remaining capacity (12). Moreover, there is no more space to contain extra products in this warehouse. As a result, we finally have products 0,2,4,5 stored in this warehouse.

Lastly, calculate the corresponding estimated value of the warehouse, and in this case, it is 374.15.

	Weight	Value	Ratio	cum_weight	cum_value
0	**112**	**195.71**	**1.7474**	**112**	**195.71**
4	**47**	**64.21**	**1.3662**	**159**	**259.9**
2	**94**	**105.44**	**1.1217**	**253**	**365.3**
3	58	57.15	0.9853	253	365.3
5	**9**	**8.79**	**0.9767**	**262**	**374.15**
1	67	62.59	0.9342	262	374.15
8	81	62.89	0.7764	262	374.15
6	98	71.14	0.7259	262	374.15
7	31	11.19	0.361	262	374.15
9	12	1.64	0.1367	262	374.15

You should perform this step with python codes!

Now you would try to help Marlon with his product selection problem for those 300 warehouses (capacity of each is 650) with the dataset "Product.csv". Calculating the estimated total value and accumulated weight of each 300 warehouses will be helpful for the later decision of cross-warehouse-transshipment solution.

Notes:

1. Please do not use other packages to read the CSV file.
2. You should perform all the steps above with python codes rather than spreadsheet
3. Sometimes when the warehouse is nearly full, the next product with the next highest ratio cannot be put in the warehouse, but there are still chances that one or more following products can be put in the warehouse. Make sure you take every product into consideration; otherwise, you may have the risk of missing products.
4. You are NOT allowed to use dynamic programming in this problem, otherwise you may get 0.

Problem 2: Top Alternative Selections

Thank you for your great job helping Marlon with the warehouse storage arrangement! In this part, he would like to simulate the situation when a random warehouse is out-of-stock during the promotion period.

It is common that a warehouse would run out of all the products during promotion, and in order to keep the promotion activities and make sure on-time delivery in one region, cross-region shipment from other warehouses (let's call them "Helpers") is necessary. More specifically, among the 300 warehouses, 1 is out-of-stock, then the rest 299 would all be Helpers.

Before seeking help from those Helpers, Marlon needs to figure out which Helpers he could choose. For Helpers selection, Marlon would choose those Helpers with the top 10 highest "Value_per_Weight" ratios. It's acceptable to recommend more than 10 Helpers because two or more Helpers may have the same "Value_per_Weight" ratio.

$$Value\_per\_Weight = \frac{Total\_Value}{Total\_Weight} - Distance \times Transportation\_Cost$$

1. *Total_Value: total value of the stored products in one warehouse*
2. *Total_Weight: total weight of the stored products in one warehouse*
3. *Distance: the distance, generated by you, between the out-of-stock warehouse and the Helpers*
4. *Transportation_Cost:* 0.015 per distance

Cross-warehouse-transshipment starts with the warehouse that is out-of-stock (total number of stored products is 0), and this warehouse would contact Helper to see if help is available. Once the Helper agrees to do the Cross-warehouse-transshipment, it will transport all products in its warehouse. In this case, Marlon assumes that Helpers have not sold any products since the selection process in Part 1. In other words, the total number of stored products in each Helper remains the same as it was before the promotion started. Since the distances between this product-shortage warehouse and the Helpers are different, the transportation fee will be correspondingly different. By using "Value_per_Weight" calculation, Marlon could find Helpers with the top 10 highest "Value_per_Weight" after considering transportation costs (The cost of a one-way trip from the Helper to the product-shortage warehouse).

Step 1: Let's generate a distance matrix among the 300 warehouses first. Each of the distances can be generated by using a normal distribution with a mean of 500 and a standard deviation of 300. (Please make sure that each generated distance is positive). Below is an example of a 10*10 distance matrix.

	0	1	2	3	4	5	6	7	8	9
0	0	992	855	423	803	521	723	465	510	434
1	992	0	276	538	553	947	122	428	55	708
2	855	276	0	217	561	373	758	825	847	1024
3	423	538	217	0	262	240	447	543	510	576
4	803	553	561	262	0	912	642	1082	627	554
5	321	947	37	240	12	0	513	51	77	249
6	723	122	758	447	642	513	0	668	782	486
7	465	428	825	543	1082	901	668	0	374	541
8	510	55	847	510	627	1377	782	374	0	629
9	434	708	1024	576	554	549	486	541	629	0

Now create your own distance matrix with a size of 300*300. Be careful, all the distances generated should be positive numbers and should be rounded to integer using round(). After successfully generating the distance matrix, please write it to a new CSV file called "Distances.csv".

Notes:

1. Please do not use any packages to write the CSV file.
2. For better understanding, we included the warehouse index in the screenshot, but the distance matrix you generated does not need to include the index.

Step 2: Now you could calculate the "Value_per_Weight" and help Marlon decide the Helpers with the top 10 highest "Value_per_Weight".

First of all, Marlon would randomly choose a warehouse (from Warehouse No.0 to Warehouse No.299) and assume it would face out-of-stock problems in this simulation.

Secondly, based on the warehouse he picks, you need to find the corresponding distance between this warehouse and each of the other Helpers from the distance matrix you generated in Step 1. Besides, you also need to find the corresponding total value and total weight of all products stored in each Helper (you have calculated these numbers in Problem 1).

Thirdly, calculate the "Value_per_Weight" ratio for each Helper, sort the ratio in descending order, and choose top helpers with 10 highest "Value_per_Weight" ratios. Recall this formula:

$$Value\_per\_Weight = \frac{Total\_Value}{Total\_Weight} - Distance \times Transportation\_Cost$$

1. *Total_Value: total value of the stored products in one warehouse*
2. *Total_Weight: total weight of the stored products in one warehouse*
3. *Distance: the distance, generated by you, between the out-of-stock warehouse and the Helpers*
4. *Transportation_Cost:* 0.015 per distance unit

Here is a simplified example, suppose now there are 10 warehouses in total and Marlon needs Helpers with top 3 “Value_per_Weight” ratios. He assumes warehouse No.5 is out-of-stock and as a result, the total number of products in it becomes 0, while the rest of the warehouses (Helpers) remain with the same amount of product as you generated in Problem 1. The corresponding distance data is located in the 6th row of the distance matrix you have generated in Step 1 (the row starts with index 5 highlighted by the red rectangle below).

	0	1	2	3	4	5	6	7	8	9
0	0	992	855	423	803	521	723	465	510	434
1	992	0	276	538	553	947	122	428	55	708
2	855	276	0	217	561	373	758	825	847	1024
3	423	538	217	0	262	240	447	543	510	576
4	803	553	561	262	0	912	642	1082	627	554
5	321	947	37	240	12	0	513	51	77	249
6	723	122	758	447	642	513	0	668	782	486
7	465	428	825	543	1082	901	668	0	374	541
8	510	55	847	510	627	1377	782	374	0	629
9	434	708	1024	576	554	549	486	541	629	0

Finding the corresponding distance

After calculating the “Value_per_Weight” ratio for each helper, you would sort those Helpers and return the top 3 “Value_per_Weight” and the corresponding index of the Helpers. (It is important you show the corresponding relationship between the “Value-per-Weight” and the index of the Helpers!)

E2 =C2/B2-H$2*D2

	A	B	C	D	E	F	G	H
1		Total_Weight	Total_Value	Distance	Value_per_Weight			
2	0	649	1035.59	321	-3.21933		Transpotation_Cost	0.015
3	1	650	1195.74	947	-12.3654			
4	2	648	1389.8	37	1.589753			
5	3	646	1387.96	240	-1.45146			
6	4	648	1673.86	12	2.403117			
7	5			0				
8	6	642	1171.695	513	-5.86993			
9	7	645	1229.38	51	1.141016			
10	8	650	996.915	77	0.378715			
11	9	645	1455.8	249	-1.47795			

You should perform this step with python codes!

The logic of how you calculate the “Value_per_Weight”

	Value_per_Weight
4	2.403117
2	1.589753
7	1.141016
8	0.378715
3	-1.45146
9	-1.47795
0	-3.21933
6	-5.86993
1	-12.3654
5	

You should perform this step with python codes!

Sorted result

(You should use the code to show this logic instead of Excel, you do not need to generate a file here.)

Notes:

1. You are NOT allowed to use dynamic programming in this problem, otherwise you may get 0.

2. In this problem, there is a chance that the “Value_per_Weight” of the two warehouses are the same. Return the top 10 Value_per_Weight, and if multiple warehouses have the same Value_per_Weight, determine those warehouses in the output.

Submission of the Project

Your final submission will contain two files:

1. The first would be the " Fall21_Mid_Walmart ipynb" notebook. You need to provide code for your answers as well as your answers. We strongly recommend you provide explanations for key steps in the code so that we can know what you intended to do when something goes wrong.
2. The second is the “Distances.csv” file.

Note: Please submit all files (Distances.csv, and Fall21_Mid_Walmart.ipynb files) as one zip file on Canvas. Please add SIDs of all teammates on the name of zip file. For example, 14325_34672_12345.zip.

Grading

Total - 27 points

5 points - towards how good your solution is – we will rank all projects and will give the grade based on the project preparation.

- Top 10% (among all groups across sessions) – 5 points
- Rest of top 30% - 4 points
- Middle 30% - 3 points
- Bottom 30% - 2 point

22 points:

The Estimated Value for Each Warehouse – 8 points

The 300*300 distance matrix generated – 7 points

Top 10 Warehouses Chosen for Help - 7 points

- Your code needs to pass the auto-grader and we need to see it works.
- We will look at your logic and whether your code is working.
- We will look at whether you submitted all files correctly.
- We will look at how effectively you solved the problems.

Instructors and TAs for help

Please feel free to reach out for help, we are ready to help you!

Professor: Salih Tutun

Email: salihtutun@wustl.edu

Office Hour: Sunday and Wednesday, 07:00 pm – 08:00 pm

Link: https://wustl.zoom.us/j/93938486334?pwd=aHp5UnhpRGJQUXc0Sm9YQXVPbndEQT09

Professor: Esmat (Yasi) Sangari

Email: dat561.sangari@gmail.com

Office Hour: Wednesday, 7:45 pm - 9:45pm

Link: https://wustl.zoom.us/j/94284993182?pwd=OGJpaVJsNm9IeksrbjBpUnlVeUp6UT09

Professor: Gerald Onwujekwe

Email: geraldo@wustl.edu

Office Hour: Monday (4:30pm-5:30pm) and Tuesday (9am-10am)

Link: https://wustl.zoom.us/j/7249235404?pwd=Rk0wSlcwQmNkSHJ3VEQ2Z1Y5TUl2QT09

Professor: Mahsa Mardikoraem

Email: mahsa@wustl.edu

Office Hour: Wednesday, 4:00 pm - 6:00 pm

Link: https://wustl.zoom.us/j/92470652434?pwd=VlhKaGIvYThQZVVyYnB3TE0vbTJsUT09

TAs for help

Email: c.zhijie@wustl.edu(Zhijie Chen), h.yixian@wustl.edu(Yixian He), j.zhang1@wustl.edu (Jie Zhang)

Extra Office Hour (during the fall break): Tuesday, Friday 07:00 pm – 08:00 pm (other time by appointment)

Office Hour (from October 18): Monday, Tuesday, Thursday, Friday, Saturday, Sunday 07:00 pm – 08:00 pm

Link: https://wustl.zoom.us/j/97560073414?pwd=eTRsRG5wcTBYMWtzT0hTK3d3czVEZz09

Good Luck!