Georgia Tech College of Engineering
H. Milton Stewart School of
Industrial and Systems Engineering

ISyE 6202 Supply Chain Facilities

EasyNode Smart Locker Bank

Casework 4.1

Fall 2024

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- *The casework is meant to be realized in self-organized teams of up to 4 students, yet may be realized solo, with the number of students in the team having no influence on the grading.*
- *The casework deliverables are due at the latest on November 17th at 23h59.*
- *The casework is shaped around a set of mandatory tasks, each having a significant grading weight, purposefully not revealed to the class.*
- *For each task, you must rigorously describe your methodology, present your results, analyze them, and discuss them relative to the current task and, when pertinent, relative to previous tasks.*
- *For computational algorithms and simulations, exploitation of Python and linked tools is preferred. Using spreadsheets such as Microsoft Excel/VBA is tolerated. All developed codes are to be provided.*
- *For simulations, preferred is exploitation of Python (including SimPy) as well as packages such AnyLogic, FlexSim, and Simio. All files are required.*
- *The casework is built around a fictitious enterprise and using a realistic yet simplified synthetic dataset, assuming that the current date is April 11th, 2024.*

EasyNode is a company that implements and operates networks of smart locker banks that can be used by any retailer, logistics service provider, and customer at any time. EasyNode's smart lockers are equipped with the latest digital interface, recognition, and security technologies. The locations where EayNode installs its banks are very rigorously selected, notably based on their convenience and safety.

Overall, AnyNode user experience ratings are excellent, except on one key criterion: a significant and growing number of users complain that too often there is no locker available at their required size. When only smaller sizes are available, they have to use a bank that is farther and less convenient. When only larger sizes are available, they will use them as EasyNode offer them at same price (for customer, the price is normally paid by the retailer), yet they dislike the waste of space this generate, which they perceive as bad for the natural and constructed environment.

EasyNode has embarqued in gathering information to better understand why this situation occurs repeatedly and how to avoid it so as to offer at least a 99% service level with sufficiently large lockers available when users arrive and to offer as best a size fit as possible, while not having to dramatically expand the overall size of its deployed locker banks.

EasyNode has requested your service to provide rigorous analysis, seeking design, planning, and operation recommendations. The company has opted for a focused deep-dive mandate and decided to provide you specific information gathered on a representative smart locker bank instead of swamping you with tons of information from many of its implemented banks.

Here follows the information provided by the analytics team of EasyNode.

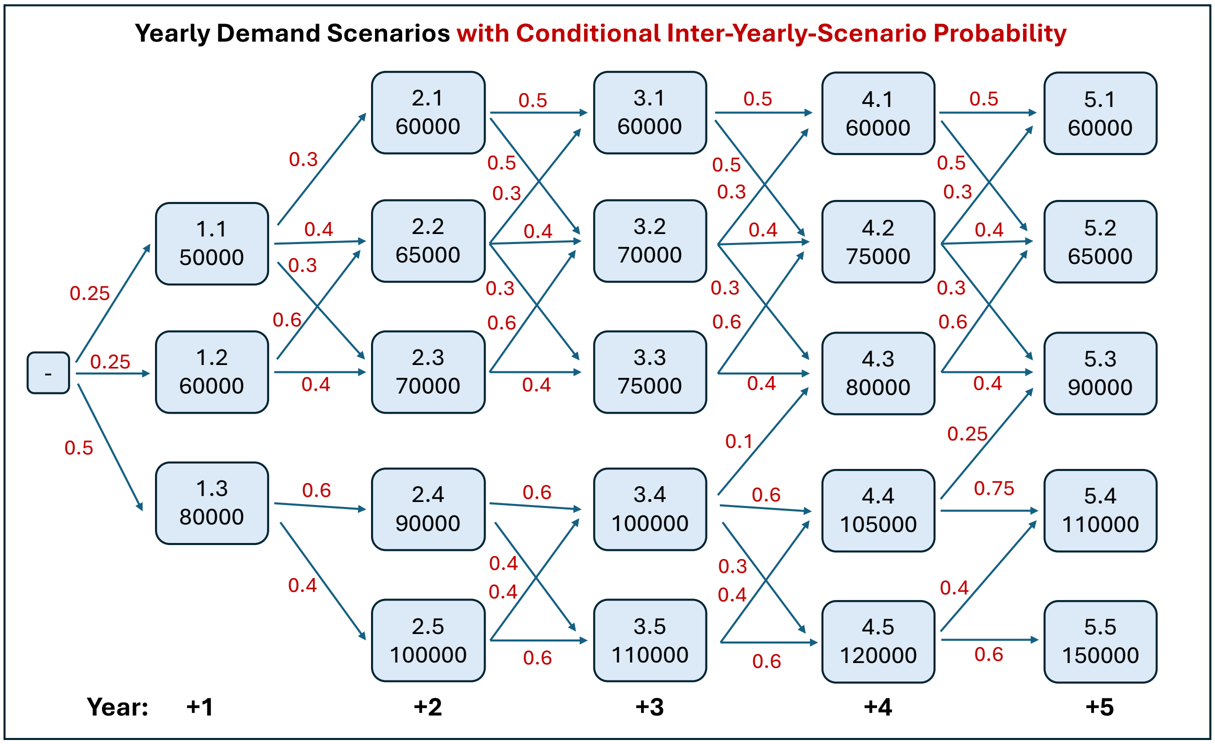
Relative to space requirements, you are provided in the Tabble below with the probability that the package (or set of packages) for a customer delivery or return requires a space of at least f cubic feet, where f ranges from 1 to 18.

	Probability that a Customer Delivery Minimally Requires a Specific Space																		
Space (ft3):	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
Probability:	0.08	0.12	0.15	0.12	0.08	0.06	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	1.00

Daily demand for customer deliveries + returns in the smart locker bank is expected to behave according to a Normal distribution with a mean and standard deviation subject to the following estimates:

4-week period:	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Demand share:	0.06	0.05	0.06	0.07	0.09	0.06	0.04	0.10	0.10	0.06	0.08	0.10	0.13	1.00
Coefficient of variation:	*0.3*	*for each 4-week period, subject to annual sum equals to 1*												
Day-of-week:	Su	Mo	Tu	We	Th	Fr	Sa	Total						
Demand share:	0.05	0.10	0.15	0.15	0.18	0.22	0.15	1.00						
Coefficient of variation:	*0.2*	*for each 4-week period, subject to annual sum equals to 1*												

Based on current history, facts gathered through discussions with retailers and logistic service providers, as well as demographic evolution and economic development data, EasyNode has projected that future demand over the next five years for this smart lockker bank is best forecast through the above set of scenarios. For each year, EasyNode has provided a set of alternative demand scenarios. For adjacent years, it has provided the probability of a specific scenario s in year y given that scenario s' has occurred in year y-1. For example, in year +3 scenario 3.5 with demand of 110000 has a probability of occurrence of 0.4 and 0.6 dependent on whether scenarios 2.4 or 2.5 has occurred in year +2. The scenarios are depicted on the following page and provided in the casework spreadsheet.



Based on data from past transactions with customers and users, the duration-of-stay distribution from deposit in the bank locker to pickup out of the locker is expected to be according to the Table below. In that Table, each row is a deposit hour of day, labeled d, and each column is a pickup hour of day, labeled p, and the entry in the cell at the intersection of a row d and a column p provides the probability that a content is deposited in hour d and picked up in hour p, according to a rolloing horizon where hour 23 is followed by hour 0 of the following day. The last column provides the daily deposit time distribution while the last row provides the daily pickup distribution.

Probability (X10,000) That a Given Parcel is Deposited In Hour d and Then Picked Up by the Customer in Hour p

Pickup Time p

Deposit Time d

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
0	30	20	4	4	4	10	20	24	32	20	12	12	8	0	0	0	0	0	0	0	0	0	0	0	200
1	0	24	12	6	4	10	20	24	32	20	16	12	12	8	0	0	0	0	0	0	0	0	0	0	200
2	0	0	12	6	3	5	10	12	16	10	8	6	6	4	2	0	0	0	0	0	0	0	0	0	100
3	0	0	0	12	6	3	10	12	16	10	8	6	6	4	4	3	0	0	0	0	0	0	0	0	100
4	0	0	0	0	36	24	30	36	48	30	24	18	18	15	12	9	0	0	0	0	0	0	0	0	300
5	0	0	0	0	0	36	45	45	48	30	24	18	18	15	12	9	0	0	0	0	0	0	0	0	300
6	0	0	0	0	0	0	60	60	72	44	32	24	24	20	16	16	20	12	0	0	0	0	0	0	400
7	0	0	0	0	0	0	0	72	100	48	32	24	24	20	16	16	20	16	12	0	0	0	0	0	400
8	0	0	0	0	0	0	0	0	150	120	60	48	48	36	24	24	30	24	18	18	0	0	0	0	600
9	0	0	0	0	0	0	0	0	0	120	96	90	60	36	24	24	36	42	30	18	12	12	0	0	600
10	0	0	0	0	0	0	0	0	0	0	90	108	108	90	30	24	36	42	30	18	12	12	0	0	600
11	0	0	0	0	0	0	0	0	0	0	0	120	138	90	48	36	36	48	30	18	12	12	12	0	600
12	0	0	0	0	0	0	0	0	0	0	0	0	80	100	40	32	32	40	40	12	8	8	4	4	400
13	0	0	0	0	0	0	0	0	0	0	0	0	0	120	108	60	48	60	60	60	36	24	18	6	600
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	144	112	112	80	80	48	32	24	8	800
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	120	120	90	66	36	24	18	6	600
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	150	120	90	48	36	24	12	600
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	180	120	84	60	24	12	600
18	0	0	0	0	0	0	10	40	20	10	0	0	0	0	0	0	0	0	100	120	100	70	20	10	500
19	5	0	0	0	0	0	15	50	40	15	0	0	0	0	0	0	0	0	0	100	150	75	35	15	500
20	8	0	0	0	0	0	20	60	40	12	8	8	4	0	0	0	0	0	0	0	80	100	40	20	400
21	10	4	0	0	0	0	12	36	30	8	4	4	2	0	0	0	0	0	0	0	0	30	40	20	200
22	20	10	4	0	0	0	12	36	30	8	4	4	2	0	0	0	0	0	0	0	0	0	30	40	200
23	30	14	6	0	0	0	16	40	36	16	6	4	2	0	0	0	0	0	0	0	0	0	0	30	200
Total	103	72	38	28	53	88	280	547	710	521	424	506	560	558	496	517	610	786	790	720	626	495	289	183	10000

You are to assume to simplify your work that actual arrival and pickup times are known at the beginning of the hour prior to the action time.

The target is for the smart locker bank to be able to accommodate 99% of the demand every day across the five-year horizon, and to achieve this at minimal cost, using the same technical and financial parameters as in Faugere and Montreuil (2020).

EasyNode currently designs, have made, and implement smart locker banks so they can sustain five years of demand without requiring them to be altered. Then, toward the end of the five-year period, EasyNode's team either repairs and extends the current locker bank or it removes it and replaces it by a new one, based on the physical state of the bank, and difference between the repair-and-extend cost and the remove-and-replace cost. To simplify your work, you are to assume that decision has already been made to replace the current one by a new one well fit for the next five years.

EasyNode also wants you to explore more innovative types of locker banks, such as ones leveraging modular towers and modular lockers.

Task 1

Given the information above, propose a new *baseline* fixed-configuration locker bank design for the next five years. The design must include:

1. Overall size of the locker bank
2. Set of locker sizes
3. Number of lockers of each size
4. Layout of the locker bank

This baseline design is meant to be simple to explain, easy to implement, probably quite myopic and not so smart (yet not merely stupid). So you are not to aim for it to be superbly perrforming, which will be aimed for in later tasks. In fact it is to become your design to beat. It may even happen that it will prove to be incapable of achieving the target service level or to be a gross overkill.

Therefore it is absolutely vital for you not to use any of the outcomes of subsequent tasks to help generate and improve the baseline design.

Task 2

As AnyNode did not provide information on arrival patterns of packages during a given hour, discuss what you believe could be representative patterns given that packages will either be brought to the locker by a logistic service provider for customer pickup purpose or by a customer for return purpose.

Given that N packages are to arrive in a given hour, propose based on the above a method to generate scenarios of arrival time for each of the N packages during that hour. Implement your method and demonstrate its valid operation given your hypotheses.

Task 3

Develop a simulator that generates instances of dynamic demand across the five-year horizon according to the information above relative to the projected demand patterns and scenarios. A simulated instance has to specify for each demand the desired deposit time and pickup time, and the minimal locker size requirement. Provide documentation describing your simulator.

Task 4

Dynamic locker assignment heuristics are to be used at the beginning of each hour to accept or reject an arrival request, and if accepted to assign a locker to each specific client, so as to maximize performance of the locker bank and satisfaction of clients (to who pay) and users (those who deposit and/or pickup package-s), given current realized and projected demand as well as the actual availability state of the locker bank as designed.

Conceive the overall logic, delvelop the algorithm, and implement the software code for two dynamic locker assignment heuristics. The two heuristics required are as follows:

a. *Strawman* heuristic: simple to explain, easy to implement, probably quite myopic and not so smart;
b. *Smarter* heuristic: best you can imagine, conceived, develop, and code within the casework timeframe.

Task 5

Extend your simulator capability to model a fixed-configuration locker bank.

This requires to embed in a decision agent your dynamic locker assignment heuristics (so you may test them alternatively); to model demand acceptance and rejection; to model sojourns in the lockers; to compute daily, annual, and global service level performance, locker bank utilization performance, as well as revenue, cost, and profit performance; and to contrast such performance over multiple simulation instances. The simulator should be able to display the layout of the locker bank and its dynamic utilization through a scenario instance if so desired. Provide documentation describing your extension.

Task 6

Assess the dynamic performance of your baseline fixed-configuration locker bank using your simulator. Provide plots, diagrams, and/or screenshots to support your assessment.

Task 7

Use a heuristic approach leveraging your simulator to develop your recommended fixed-configuration locker bank design, aiming to significantly outperform your baseline design.

The heuristic approach should start in phase 1 with generating a first design based on well-thought reasoning about all available information and performance targets. In phase 2, the current 'best' design is tested through simulation, thoroughly evaluated in terms of financial and service performance, and analyzed to identify potent improvement avenues. In phase 3, given the simulation-based assessment, the current design is systematically altered toward generating, if possible, what is perceived as an improved design. At the end of phase 3, if a new design has been generated, there is return to phase 2 to evaluate it, otherwise the heuristic is completed.

Your overall heuristic and its phase specific algorithms should be rigorously defined and justified.

Systematically contrast the expected performance of your baseline and recommended fixed-configuration locker bank designs.

Task 8

In order to initiate exploration of switching to modular-tower-based locker bank design, heuristically propose a set of up to six locker tower modules that would jointly enable, according to you, to dynamically adapt at the beginning of each four-week period the design of a modular tower based locker bank so as to accommodate the expected forthcoming demand.

These tower modules should be thought as usable in many distinct locker banks within a territory. Here assume for simplicity that all all locker banks have similar characteristics as provided by EasyNode for the studied locker bank, yet with different parameters within the min-max spectrums.

Task 9

Develop a heuristic to initially determine the size of the modular-tower-based locker bank slab foundation upon which modular towers are to be dynamically secured during the planning horizon. Demonstrate and justify the pertinence of your proposed heuristic.

Develop a heuristic that is to adjust on a rolling horizon the configuration of the modular-tower-based locker bank by adding and/or removing locker tower modules, to be applied at the beginning of each 4-week period. Demonstrate and justify the pertinence of your proposed heuristic.

Task 10

Extend your simulator capabilities so as to model adequately the usage of locker tower modules and modular tower based locker banks, and to embed in an agent the heuristic you developed in task 9. Provide documentation describing your extension.

Task 11

Assess the dynamic performance of using a modular tower based locker bank dynamically redesigned each month using your heuristic of task 9, using your simulator. Contrast with the performance of your preferred fixed-configuration locker bank from task 7.

Task 12

Provide EasyNode an Executive Summary highlighting your overall assessments, insights, and recommendations, in a up to two pages format and including compelling Figures and/or Tables.

Task 13

Synthesize your team's key learnings from performing this casework.

Note: *This casework revisits smart locker bank design with some distinct input information as contrasted with the methodology examined in class that was proposed in the paper by Faugère L. & B. Montreuil (2020). Smart Locker Bank Design Optimization for Urban Omnichannel Logistics: Assessing Monolithic vs. Modular Configurations, Computers & Industrial Engineering Journal, 139, 105544, 1-14 p.*