

Casework 1.1

BotWorld's Dedicated European Supply Chain Design

ISYE 6339 Physical Internet Engineering

Professor Benoit Montreuil

To be realized solo or in teams of up to three students
Grading does not account for the number of students

20 Points

Due on February 9, 2025

For each task and subtask, it is important to identify the team members having actively contributed to its realization, as this is to be used for individual student grading, except if all team members explicitly and unanimously indicate that they prefer an identical grade for all team members. See course syllabus for details.

Building on its huge success in North America and Asia, the BotWorld¹ company plans to launch its consumer centric MyBot robotic product line in the European Union and the United Kingdom, its strategic market deployment roadmap is currently planned to be as follows in terms of countries:

- 2026: France, Germany
- 2027: Austria, Belgium, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Switzerland, United Kingdom
- 2028: Denmark, Estonia, Finland, Latvia, Lithuania, Norway, Poland, Sweden
- 2029: Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Greece, Hungary, Malta, Romania, Slovakia, Slovenia

The MyBot products are to be sold exclusively online to consumers through leading e-commerce sites and apps. Consumers are to be promised delivery the next day in each country's capital and metropolis, as well as in each of the top 50 European metropolitan areas. Consumers from other regions are to be promised delivery within 72 hours after ordering.

The MyBot product line is to include six categories: F – Floor Care, K – Kitchen Help, L – Leisure, S – Safety & Security, W - Wall and Window Care, X – Exterior Care. MyBot Products are to be distinguished in terms of four capability levels, respectively 10, 20,

¹ Fictitious company created by Professor Montreuil for the sole purpose of developing an academic casework

30 and 50. Model focused market studies lead BotWorld to set target prices and demand expectations as follows:

Model	Demand Share			Target Market Price (Euros)
	Minimum	Most probable	Maximum	
F10	10%	17%	20%	360
K10	5%	13%	18%	360
S10	5%	10%	15%	360
W10	5%	9%	15%	360
F20	4%	8%	12%	480
K20	3%	6%	10%	480
L20	3%	5%	10%	480
S20	2%	5%	10%	480
W20	2%	4%	8%	480
X20	2%	4%	8%	480
F30	2%	3%	8%	600
K30	1%	3%	6%	600
S30	1%	3%	6%	600
W30	1%	2%	6%	600
F50	0.50%	2%	6%	720
K50	0.50%	2%	4%	720
L50	0.50%	1%	4%	720
S50	0.50%	1%	4%	720
W50	0.50%	1%	4%	720
X50	0.50%	1%	4%	720
All Models		100%		

Based on BotWorld's successful progression in America and Asia, and its European marketing studies, the company expects demand for its MyBot products in each of its targeted markets to be evolving as follows, assessed in units per year expressed as the percentage of the population in the targeted market (absolute for first year, then yearly marginal increments):

Year	Optimistic (99%)	Most Probable	Pessimistic (99%)
1	0.05%	0.025%	0.02%
2	+0.025%	+0.02%	+0.01%
3	+0.02%	+0.01%	+0.005%
4+ (yearly)	+0.01%	+0.005%	-0.002%

Consumers are expected to order any day of the week, with the following probability: Mo 5%, Tu 10%, We 15%, Th 20%, Fr 25%, Sa 15% and Su 10%. This said, the demand for MyBot products is forecast to be subject to seasonal fluctuations. The average four-week period demand share is expected to be respectively about 0.04; 0.06; 0.06;

0.08; 0.10; 0.14; 0.14; 0.10; 0.08; 0.06; 0.05; 0.05; 0.04. The first period starts on the first full week in January of the year. BotWorld estimates demand shares to be Normally distributed around the period specific average with a coefficient of variation of 20%, with the total periodic shares constrained to equal 100%. Beyond the four-week demand shares estimated above, the demand for MyBot products is to be boosted by peak sales in the Black Friday to Cyber Monday period which is expected to account for 18% of the yearly demand by itself². This peak-day demand boost is to be in terms of product units, yet prices are expected to be lowered in these days by about 15% to attract buyers.

Task 1: Market Demand Forecast & Scenario Generation

- 1. Based on statistics and forecasts publicly available on Internet, estimate the 2026-2033 population of targeted countries and capitals, metropolitan areas.*
- 2. In line with the targeted market deployment roadmap, forecast the expected annual demand for the entire product line and for each product, in each targeted territory, in units and in euros.*
- 3. Expand the annual forecasts from task 1.2 into more granular weekly and daily global and model-specific demand over the 2026-2033 horizon.*
- 4. Develop a daily demand simulator for BotWorld's expansion in Europe, in line with the uncertain forecasts from task 1.3. Use it to generate at least 1000 alternative scenarios of daily demand for the 2026-2033 with instances of daily demand for each model. Contrast this set of scenarios with expected demand estimates, notably leveraging revealing heatmaps and time-series plots (e.g. boxplots).*
- 5. Synthesize the key facts and insights to BotWorld derived from your analysis of market demand forecasts.*

BotWorld plans to open and operate a single factory for assembling, packaging, and packing its products for all of Europe. It is targeting to locate the factory near Georgia Tech Lorraine in Metz, France, and to start operations in November 2025. As the factory is to be highly automated and equipment intensive, BotWorld plans to operate it every day of the year, except during France's official holidays, and to size its daily capacity based on a production level as smoothed as possible across the worked days. This means that it is to build up inventory prior to the top-demand months. Furthermore, BotWorld targets to have at minimum four weeks of stock as safety buffer for autonomy purposes.

Assembly of MyBots is to be done using lines combining robots and automation. Each line is to have capacity of 100 MyBots daily. BotWorld has financially estimated for planning purposes that a line capable of assembling a single category of MyBots is to cost 10,000 and 15,000 Euros per day, independent of the number of MyBots

² The expected demand shares for the 4-week periods spanning the Black Friday to Cyber Monday period do not include the demand shares of peaks days.

assembled during the day, respectively for categories {Floor Care, Kitchen Help, Leisure} and categories {Safety & Security, Wall & Window Care, and Exterior Care}. Lines capable of assembling MyBots from multiple categories are to cost respectively 15,000, 20,000, and 25,000 Euros for categories {Floor Care, Kitchen Help, Leisure}, categories {Safety & Security, Wall & Window Care, and Exterior Care}, and all categories. These costs are all inclusive (notably equipment, space, implementation, energy, software, maintenance, and overhead).

Once assembled, BotWorld factory is to pack its MyBots in packages, and then over-protect them by packing them in shipping boxes. The volumetric dimensions of the packages and boxes are listed below for each MyBot, as well as their total weight including the product and packaging material. The packages and boxes are not planned to be reusable, yet they are to be recyclable.

CityBot		Packaged dimensions				Shipping box dimensions			
Category	Model	Length (cm)	Width (cm)	Height (cm)	Weight (kg)	Length (cm)	Width (cm)	Height (cm)	Weight (kg)
Floor Care	F10	40	40	30	15	55	55	50	19
	F20	40	40	30	15	55	55	50	19
	F30	48	40	30	20	65	55	50	25
	F50	53	44	30	25	70	60	50	32
Kitchen Help	K10	32	25	28	8	50	40	50	12
	K20	32	25	28	8	50	40	50	12
	K30	36	28	28	10	55	45	50	15
	K50	42	30	28	12	60	45	50	18
Leisure	L20	45	23	30	12	60	40	50	18
	L50	45	33	30	16	60	50	50	20
Safety & Security	S10	56	26	33	18	70	40	55	22
	S20	56	26	33	18	70	40	55	22
	S30	56	32	33	20	70	45	55	25
	S50	56	38	33	23	70	55	55	29
Wall & Window Care	W10	30	30	25	8	45	45	45	12
	W20	30	30	25	8	45	45	45	12
	W30	40	30	25	9	55	45	45	14
	W50	40	40	25	11	55	55	45	16
Exterior Care	X20	50	55	40	35	65	70	60	43
	X50	60	65	45	50	75	80	65	60

Once packed, the MyBot boxes are to be placed two-high max on single-MyBot-model pallets of one of the two following ISO-standard sizes:

- Wooden pallet – 3 runner L:1200 x W:1200 x H:154 mm³
- Perimeter wooden pallet L:1200 x W:1000 x H:154 mm³

BotWorld plans to implement a main European distribution center (DC) beside the factory to house most of the stock generated from its stable production strategy and overall target autonomy policy. This DC is to receive pallets of boxed MyBots directly from the adjacent factory. The DC is to have eight-pallet-high racks to store these incoming pallets in shared storage mode. In each rack, higher bays are considered

reserve bays, with picking being performed on lower bays, pallets being transferred from reserve to picking as necessary.

BotWorld also plans to implement a fulfillment center (FC) near each of its target urban market areas to serve the demand for next-day delivery from these target markets and three-day deliveries to markets for which it is the nearest fulfillment center. Nearness is adequate when the fulfillment center location enables to deliver within a maximum of five hours to the hub of the local delivery provider selected for each urban area for which the fulfillment center is assigned to be the preferred one.

Each fulfillment center is meant to be capacitated for storing two robust weeks of stock of MyBot, for receiving and placing inbound pallets, and for picking, palletizing, and shipping orders. All FCs are to use up to three-pallet-high racks to store single-MyBot-model pallets in shared storage mode. In each rack, higher bays are considered reserve bays, with picking being performed on lower bays, pallets being transferred from reserve to picking as necessary.

BotWorld plans to ship pallets of boxed MyBots to each FC once a week to maintain the FC stock of each MyBot model so that for the next week it will be at least to meet two robust weeks of demand. When picking orders from FCs at the DC, mixed-model pallets can be created to be shipped to a specific FC.

Orders received from consumers in a territory preferably served by a given FC in any given day are to be picked into city-specific pallets and loaded within 12 hours into trucks for shipment.

BotWorld aims to rely on three FC design configurations: small, medium, and large.

From the supply side, production requires parts and materials from multiple suppliers. In average, these are twice denser than the final product. Currently, 60% of the supply input in kg is planned to come from European suppliers and 40% from Chinese suppliers. The Chinese supply is to be consolidated in Shenzhen and brought in containers by ships arriving at the Port of Rotterdam. The European suppliers are based in the Haut-de-France in France, the Upper Austria region of Austria, the Pomerania region of Poland and the Andalusia region of Spain, with basically a fourth of the flow from each country.

BotWorld plans to establish a policy of (1) maintaining in a supply warehouse adjacent to the factory a supply inventory of respectively two and four weeks of production at all times for its European and Chinese supplies; (2) ordering supplies from China on a weekly basis, yet to always consolidate full containers in China prior to transportation by ship to Europe; and (3) ordering in pallet loads from suppliers and consolidating by country in full truck loads prior shipping them to the factory.

BotWorld is planning to acquire and operate a fleet of freight transport vehicles to perform all its European based transportation activities: Chinese-inbound supplies from Port of Rotterdam to the factory, European-supplies from their region to the factory, packed MyBots from DC to FCs, and from FCs to delivery service provider

hubs. BotWorld currently ponders acquiring a smart combination of semi-trailer trucks, heavy rigid trucks, light rigid trucks, and light commercial vehicles, all with combustion engines. Cargo capacity of each type can be readily found in websites.

Task 2: Dedicated Network and Operations Design and Estimation

1. *Propose a European fulfillment network with minimized number of fulfillment centers to meet adequate nearness, with the fulfillment centers (FCs) located so as minimize travel distance from/to the European DC. Make sure to make explicit the assignment of FCs to markets. The network may be generated through solving an optimization model or using a justified smart heuristic.*
2. *For each FC, estimate its required storage capacity and throughput capacity. Based on these results, decide on the small, medium, large FC sizes. Assign each FC to a given size. For each size, specify the number of racks of each height, number of dock doors, number of workers, and a rough-cut layout.*
3. *Estimate the European DC's required throughput capacity and storage capacity, number of racks of each height, number of dock doors, and number of workers. Provide and justify a layout for the DC.*
4. *Estimate the required capacity of the factory to be built given the production and inventory strategy. Estimate the amount of stock to be expected during the various periods of the year.*
5. *Propose an optimized combination of assembly lines, indicating how many lines of each type are to be implemented in each year in the 2026-2033 horizon.*
6. *Estimate the supply warehouse's required storage capacity, number of racks of each height, number of dock doors, and number of workers.*
7. *Estimate and depict BotWorld's inter-facility flows (in terms of MyBots, pallets, weight, and volume) over the 2026-2033 horizon.*
8. *Based on 2.6, propose a fleet with estimated numbers of vehicles of each type, and number of truckers, in each year of the 2026-2033 horizon. Using representative daily scenarios, demonstrate the way you propose inter-facility routings to be done, and how this justifies the proposed fleet sizes. Assess overall travel, vehicle fill rates, induced fuel consumption and greenhouse gas emissions, using published estimation formulas.*
9. *Expand your simulator to model daily aggregate operations of the planned capacitated factory, supply warehouse, distribution center, and fulfillment centers operations, and fleet vehicles, and use it to assess the feasibility and performance of the proposed network's facilities over the 2026-2033 horizon.*

The simulator can be leveraged in providing answers to tasks 2.2 to 2.7. As several students have not been schooled in discrete-events simulation, the simulator can be built with a daily clockwork, advancing one day at the time, creating randomized demands through the markets, making all aggregate decisions each day, implementing them, and tracking performance measures.

10. *Using publicly available data and statistics (to be referenced), estimate the expected investments, operating cost, energy consumption, and greenhouse gas emission over the 2026-2033 horizon for the distribution center, the fulfillment centers, the supply warehouse, and the fleet.*

Task 3: Critical Assessment

1. *Identify and discuss the strengths and weaknesses of your designed dedicated supply chain for BotWorld.*
2. *Synthesize in a one-to-two-pages executive summary your key findings and recommendations for BotWorld.*
3. *Qualitatively assess what you believe would be the impact on the supply chain design and performance if Europe had already achieved a mature comprehensive Physical Internet implementation across its entire territory, notably in terms of demand fulfillment, transportation, storage, production, and supply.*
4. *Synthesize in one-to-two-pages your key learnings from realizing this casework.*

*Start early and work smartly as a team,
concurrently addressing tasks,
leveraging the capabilities of each team member,
and calibrating approaches and answers for the available time window.*