

## ISYE 6202 Supply Chain Facilities

### CoPal Demand and Resource Requirements Modeling and Planning

#### Professional Casework 1

*Due at the latest on October 13, 2019, at 23h59  
To be realized solo or in teams of up to 4 students  
Five equal-weight tasks to realize*

#### **Introduction to the CoPal Casework**

*You have to realize a set of tasks hereafter specified, jointly having you model and project demand, and to model and plan production, storage and fulfilment resource requirements for a fictitious business called CoPal.*

*Before each task specification, relevant knowledge is transferred from CoPal.*

*For each task, you have to rigorously describe your methodology, present your results, analyze them, and discuss them relative to the current task and, when pertinent, relative to previous tasks.*

*When coding algorithms and simulations, exploitation of Python and linked tools is preferred. All developed codes are to be provided.*

#### **CoPal Knowledge Transfer**

*CoPal is a technological venture that has been thriving since launching its leading-edge product line of lightweight collaborative robots. Demand for its industry-focused gradually launched WorkPal1 to WorkPal20 has been superbly strong, as can be analyzed from the demand history log provided in the data worksheet. Demand is spread across all US states, with each state demand share roughly proportional to its gross domestic product (GDP).*

*Building on its industrial market success, CoPal has launched a consumer-oriented product line, growing to a current portfolio of 5 products MyPal1 to MyPal5. Demand has exceeded CoPal's wildest expectations, as can again be analyzed from the demand history log provided in the data worksheet.*

*CoPal aims to launch four new WorkPals yearly during the next five years. It aims to launch two, three, four, five and six MyPals in each of the next five years respectively. As of now, CoPal expects each new product to have the same market potential as its current products, subject to adjustment for overall market growth, yet with significant uncertainty relative to which ones will perform better or worse.*

*Whereas the industry market for WorkPals accepts that CoPal engages in order-to-shipment (OTS) times from its Sandy Springs factory near Atlanta, the consumer market for MyPals requires order-to-delivery (OTD) time engagements to their location. The key OTD promises are to be enforced mainly in urban areas within the following US*

*megaregions: Northeast, Great Lakes, Piedmont Atlantic, Florida, Gulf Coast, Texas Triangle, Front Range, Arizona Sun Corridor, Cascadia, Northern California and Southern California. MyPal demand share per megaregion is to be proportional to overall urban population in the megaregion, as can be estimated from available public US demographic data.*

### **Task 1: Demand Projection and Simulation**

Provide yearly, weekly and daily demand forecasts, with prediction intervals, globally for both product lines and specifically for each product, over the next five years. Provide estimates for demand constituents, such as day-in-week factors, seasonality factors, and growth trends. For MyPal and WorkPal products, your forecasts should respectively go down to the megaregion and state levels.

Based on the above, develop a demand simulator capable of generating demand log scenarios over the next 5 year, each scenario corresponding to the equivalent of the historical demand log provided in the data worksheet. You should be able to generate hundreds of scenarios, to store them, and to compile the empirical distribution from the set of generated scenarios.

### ***CoPal Knowledge Transfer***

*When CoPal started business, it was among the few capable of delivering smart lightweight collaborative robots meeting capability and quality expectations from the industrial market. This has allowed CoPal to get away with shipping its products 20 days and more after ordering time. As the world gets more used to lightweight collaborative robots, and competitors are entering this explosive market, CoPal knows that there will be much tighter requirements for order-to-ship (OTS) time. Below are the expectations of CoPal regarding customer requirements for OTS time, with the Tables available in the data worksheet.*

WorkPal	Customer share requiring a specific OTS promise for them to order				
OTS Days	Year 1	Year 2	Year 3	Year 4	Year 5
[20,+]	20%	12%	10%	6%	4%
[15,20[	20%	15%	12%	9%	6%
[10,15[	20%	18%	15%	10%	7%
[5,10[	20%	21%	18%	15%	8%
[3,5[	20%	24%	20%	25%	25%
2	0%	10%	15%	20%	30%
1	0%	0%	10%	15%	20%
0	0%	0%	0%	0%	0%
All	100%	100%	100%	100%	100%

MyPal	Customer share requiring a specific OTS promise for them to order				
OTD Days	Year 1	Year 2	Year 3	Year 4	Year 5
[20,+]	5%	0%	0%	1%	1%
[15,20[	5%	0%	0%	2%	1%
[10,15[	10%	0%	0%	4%	1%
[5,10[	15%	12%	9%	7%	4%
[4,5[	20%	16%	12%	8%	5%
3	20%	20%	18%	16%	14%
2	15%	18%	20%	22%	24%
1	10%	20%	30%	40%	50%
All	100%	86%	89%	100%	100%

*For example, in year 3, CoPal estimates that 16% of its WorkPal customers and 9% of its MyPal customers will require a promise between 5 and 9 days from the time they order to the time CoPal ships them their requested product, otherwise they will not buy the products from CoPal.*

## **Task 2: Demand Satisfaction Capacity Requirements Planning**

Provide daily demand satisfaction capacity requirements over the five-year planning horizon for each of CoPal's products, assuming CoPal aims for a 99% service level regarding its performance in meeting customer requirements regarding OTS time. Perform a sensitivity analysis, with service levels ranging from 95% to 99.9%. Repeat at the product line level, assuming that demand within a product line can be pooled. Then repeat at the global level, assuming that all product demands can be pooled. Validate your results by exploiting your demand simulator, extending its capabilities as needed

### ***CoPal Knowledge Transfer***

*Industry-focused WorkPal assembly is performed in cells that combine human and robotic assemblers, according to a strict assembler-to-order policy.*

*WorkPal assembly cells are flexibly designed so that each can:*

- *Change from one product group to another in one day, during which day the cell is not available for production (group changeover)*
- *Change between any of the three different assembly paces in one hour, during which hour the cell is not available for production (pace changeover);*
- *Change from one product to another within the same product group in one hour, during which hour the cell is not available for production (product changeover).*

*The distinct paces at which cells can be operated are to respectively assemble one WorkPal every 20, 30 or 40 minutes. Depending on the pace and the WorkPal, a cell has to be staffed according to the Table below.*

Assembly Cycle Time	Required Assemblers	WorkPal Product Group											
		1-4	5-7	8-10	11-13	14-15	16-17	18-20	Year +1	Year +2	Year +3	Year +4	Year +5
20 min	Humans	5	4	3	4	3	2	1	2	1	2	0	1
	Robots	1	3	2	2	4	3	4	4	3	3	4	6
30 min	Humans	4	2	2	3	2	2	1	2	1	2	0	1
	Robots	1	3	2	2	3	2	3	3	2	2	3	5
40 min	Humans	3	2	2	2	2	1	1	1	1	1	0	1
	Robots	1	1	1	1	2	2	2	2	1	2	2	4

*Note that CoPal is planning a concerted launching of new product groups in the forthcoming years. This means you may assume that all products launched in a given year form a new product group, with pace-related staffing planned according to the above Table.*

*According to CoPal, for planning purposes, you are to assume:*

- Each human assembler costs 40\$/hour in regular time, with a 1.5 extra cost factor for overtime;*
- It has a policy of guaranteeing each human assembler a yearly minimum of 1500 hours of paid work to each;*
- Each mobile robotic assembler costs 3,000\$/month;*
- Each group-specific cell, with its tooling, jigs, workstations and buffer devices, costs 200,000\$ to implement, 40,000\$ a year to maintain, and 250\$/day to operate (beyond the cost of assemblers, and not charged when cell is not used in a day);*
- It has a policy of having the factory working 10 hours a day, 7 days a week, with usual shifts of 35 hours a week per human assembler, extendable by up to 5 hours a week through overtime;*
- Due to quality issues, there is to be a 3% product reject rate during first-year production after product launch, then 2% in the 2<sup>nd</sup> year, 1% in the 3<sup>rd</sup> year, and a stable 0.5% afterward;*
- Daily cell efficiency is to be between 80% and 88%;*
- Weekly cell reliability is to be between 75% and 100%;*
- Each WorkPal is packed in a modular reusable packaging container (hereafter termed 'pack') of 1.2m long, 0.8m large and 0.8m high. The WorkPal + container combination weighs between 24 and 48 kg.*
- Transporting WorkPals through 53-foot semi-trailer truck is costing 2 \$/mile;*
- Transporting WorkPals by less-than-truck load (LTL), the cost is 0.07\$/m<sup>3</sup>-mile, referring to the volume shipped to a location and the road-based distance between the origin and the destination;*

### **Task 3: WorkPal Resource and Production Planning**

Given the demand satisfaction capacity requirements plans you have elaborated in task 2 to support a 99% OTS service level, you are to develop resource plans over the five-year planning horizon for WorkPal assembly cells, human assemblers and robotic assemblers. In order to so achieve you are to provide plans for production of

WorkPals. You are to aim for resource plans expected to minimize induced costs while achieving the targeted OTS performance.

Validate your results by extending the simulator you designed for task 3 so as to take into consideration your resource plans, exploiting it to daily generate production schedules and to assess OTS performance.

Perform a sensitivity analysis on the impact of:

- Service level targets ranging from 95% to 99.9%;
- Group, pace and changeover time capability respectively changed to one hour; fifteen minutes and zero minute, assuming an extra investment of 100,000 \$ per cell.

### ***CoPal Knowledge Transfer***

*Consumer-focused MyPal assembly is performed in cells, similarly as for WorkPal assembly. CoPal has designed compact and agile MyPal cells capable of assembling any of MyPal products according to a rate of one product unit per five minutes, seamlessly switching between units of distinct products, with one human assembler and four robotic assemblers.*

*Due to the short order-to-delivery expectations across the USA, CoPal plans to implement a fulfillment center in each of the megaregions. These regional fulfillment centers (RFCs) are to be replenished from a central distribution center (CDC) adjacent to its Sandy Springs factory. The CDC is to be replenished from production in the factory. This production, even though aimed to be as just-in-time as possible, is planned to build anticipatory and safety stocks to ensure that it is capable to meet demand with the targeted service level. It is unsure yet whether to consider the Sandy Spring located fulfillment center to be a RFC restricted to fulfilling only demand from the Piedmont Atlantic region or for it take a broader CFC role, coupling its RFC role with fulfillment of all USA orders that can be prepared and shipped from it while satisfying the OTD targets.*

*According to CoPal, for planning purposes, you are to assume:*

- *The same types of human and robotic assemblers as for WorkPal cells are to be used, with the same costs and work policies;*
- *Each group-specific cell, with its tooling, jigs, workstations and buffer devices, costs 300,000\$ to implement, 50,000\$ a year to maintain, and 300\$/day to operate (beyond the cost of assemblers, and not charged when cell is not used in a day);*
- *Due to quality issues, there is to be a 2% product reject rate during first-year production after product launch, then 1% in the 2<sup>nd</sup> year, and a stable 0.5% afterward;*
- *Daily cell efficiency is to be between 85% and 88%;*
- *Weekly cell reliability is to be between 90% and 100%;*
- *Each MyPal is packed in a modular reusable packaging container (hereafter termed 'pack') of 0.8m long, 0.6m large and 0.8m high. The MyPal + container combination weighs between 12 and 24 kg;*

- *Transporting MyPals through 53-foot semi-trailer truck is costing 2 \$/mile;*
- *Transporting MyPals by less-than-truck load (LTL), the cost is 0.027/m<sup>3</sup>-mile, referring to the volume shipped to a location and the road-based distance between the origin and the destination;*
- *Storage costs are 2\$ and 2.50\$ per week per MyPal unit, respectively in the CDC and in a RFC;*
- *Handling costs in and out of the CDC and a RFC are respectively 1.5\$ and 2\$ per MyPal unit.*

#### **Task 4: MyPal Resource, Production, Storage and Fulfillment Planning**

Given the demand satisfaction capacity requirements plans you have elaborated in task 2 to support a 99% OTS service level, you are to develop resource plans over the five-year planning horizon for MyPal assembly cells, human assemblers, robotic assemblers, CDC and RFCs. In order to so achieve you are to provide plans for production, storage and fulfillment of MyPals. You are to aim for resource plans expected to minimize induced costs while achieving the targeted OTS performance.

Validate your results by extending the simulator you designed for task 3 so as to take into consideration your resource plans, exploiting it to daily generate production, schedule, transportation and fulfillment schedules, and to assess OTS performance.

You have to realize this task for feasible combinations of production, fulfillment and replenishment options described hereafter.

##### Production Options

- Assembly of MyPals is done strictly in the Sandy Springs factory;
- Assembly of MyPals is performed in regional factories next to the RFCs.

##### Fulfillment Options

- All customer demand is replenished, prepared and delivered from RFCs, each RFC keeping sufficient stock to fulfill all regional demand within OTD service targets;
- Customer demand is replenished and prepared and delivered from the CFC and then shipped to the appropriate RFC where it is consolidated for delivery to clients, as long it meets the OTD service targets; otherwise, it is replenished, prepared and delivered from the RFC; inducing RFCs to keep sufficient stock to meet the fast-delivery-target regional demand.

##### Replenishment Options

- RFCs are replenished only through single-region full 53-ft semi-trailer truck load shipments;
- RFCs are replenished only through full 53-ft semi-trailer truck load shipments, allowing shipments to replenish demand from 2-3 neighboring RFCs;
- Each RFCs is replenished with daily shipments through less-than-truckload transportation.

**CoPal Knowledge Transfer**

*The WorkPal and MyPal cells require the same types of mobile robotic assemblers and human assemblers, so that they can be easily transferred from any cell to any other cell as pertinent.*

**Task 5**

Tasks 3 and 4 have been realized independently, without taking into account any potential synergies between WorkPal and MyPal operations. Taking into consideration the identical nature of mobile robotic and human assemblers for both product lines, explore the potential of some unconsidered supply chain facility network alternatives to be able to satisfy demand over the next five years at the targeted service level sat lower induced total cost.