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Content

1. Description of the environment

AsteGIOx is an alumnus of the best Industrial Engineering School resisting the Roman invasion. He has been exiled in Belgium for a couple of years at the headquarters of Fast & Farm Tires, one of the largest multinationals specialising in manufacturing tires for agriculture. From his small office located in the heart of Europe, he manages the entire supply chain of the company, but also the production planning of the factories distributed throughout Europe. There are many concerns and responsibilities, but he knows that the students of UPV would be happy to face a couple of challenges where the lack of time does not allow them to design tools that could help them analyse the situation and make better decisions.

After several meetings with the most Gallic of the Valencians, he agrees to pose some challenges for the two most intense subjects of semester A because he understands that you need to work hard so that the kings bring you something.

Different main axes need to be worked on. First, the company's demand forecast process is introduced. Then, operations planning is presented to understand why the demand forecast and product classification are relevant. Finally, the inventory classification process is introduced. Some recommendations to enrich the work is proposed.

2. Demand forecasting

2.1. Forecasts are debated

Every month, AsteGIOx meets with marketing managers from each of the eight regions of the continent. Each region comprises a set of countries because each region has its network of distributors, and the promotions and updates in the offered catalogue depend on each country (Table 1).

Table 1: List of countries for each of the regions of Europe.

CER DACH	CER NORD	EER	EEXP	NOR	SOR	SWR	WER
Austria	Denmark	Poland	Belgium	Ireland	Italy	Spain	France
Germany	Finland	Czech Republic	Italy	Great Britain	Romania	Portugal	Netherlands
Switzerland	Sweden	Hungary			Bulgaria		Belgium
Austria	Finland	Poland			Romania		
		Slovakia					
		Latvia					
		Lithuania					

During this monthly meeting, there are numerous discussions because an inadequate demand forecast leads to an excess of stock and complaints from management or supply problems that lead to dissatisfaction for the farmers (and better not to anger them).

The idea of the meeting is as follows. Every month, each region manager must keep a demand forecast for each reference in the catalogue for the next 18 months.

Currently, these forecasts are made by CPI (The Product, also called Material) and the Target Market. A concrete example can be seen in Table 2.

Table 2 CPI 1060 demand forecast with a technique for 12 specific months in its different markets.

TOOL	Year_ForecastCycle	Month_ForecastCycle	Sales Organization	Market	IP	01 2022	02 2022	03 2022	04 2022	05 2022	06 2022	07 2022	08 2022	09 2022	10 2022	11 2022	12 2022
ChatStatForecast	Y2021	M12	SAU1	REP	1060	1	2	2	3	1	1	2	2	0	1	1	0
ChatStatForecast	Y2021	M12	SBE1	REP	1060	7	7	8	8	9	8	8	9	8	8	8	8
ChatStatForecast	Y2021	M12	SCR1	REP	1060	0	14	22	4	2	2	2	3	2	2	2	2
ChatStatForecast	Y2021	M12	SDK1	REP	1060	1	0	0	0	0	1	0	1	0	1	0	1
ChatStatForecast	Y2021	M12	SDL1	REP	1060	88	86	37	27	18	29	26	33	24	24	21	25
ChatStatForecast	Y2021	M12	SDL2	OE	1060	43	41	47	43	45	45	43	47	45	43	45	45
ChatStatForecast	Y2021	M12	SES1	REP	1060	3	4	3	4	2	3	4	3	3	3	7	4
ChatStatForecast	Y2021	M12	SEY4	EXP	1060	0	0	0	0	0	0	0	0	0	0	0	0
ChatStatForecast	Y2021	M12	SFN1	REP	1060	1	1	1	1	1	2	0	2	1	2	1	0
ChatStatForecast	Y2021	M12	SFR1	REP	1060	15	16	20	16	14	17	17	18	17	17	17	17
ChatStatForecast	Y2021	M12	SHU1	REP	1060	4	0	4	1	0	2	0	0	2	2	2	1
ChatStatForecast	Y2021	M12	SIT1	REP	1060	3	10	9	9	9	17	2	2	19	5	8	2
ChatStatForecast	Y2021	M12	SLV1	REP	1060	0	4	4	7	10	2	1	3	2	3	0	2
ChatStatForecast	Y2021	M12	SNL1	REP	1060	4	4	4	4	3	2	3	1	5	2	4	2
ChatStatForecast	Y2021	M12	SPO1	REP	1060	0	0	0	0	0	0	0	0	0	0	1	0

To be able to prepare their forecast, the manager has two inputs.

On the one hand, "**The magic DL black box**" is designed by a former employee whose operation is unknown, but it is rumoured that there is Artificial Intelligence which gets it right from time to time. No one knows how it works, but historically, it has been regarded as the benchmark.

On the other hand, they bought a specific demand forecasting software (**ChatStatForecast**) based on advanced statistical techniques at such a price that they can not use it.

However, human intelligence considers that expert systems work better, and each region manager wants to adjust the forecast of the ChatStatForecast. I create a manually adjusted forecast (from now on, **NAForecast**) based on their knowledge of the terrain, future commercial offers, economic policies and the weather situation of each European nation.

2.2. Forecasts are measured

Every month, for years, it has been decided to measure the quality of forecasts at three horizons (last month, three months and six months) with two indicators (Figure 1).

On the one hand, the FE is used, which measures the average forecast error by CPI-Market. An IPC is a *Stock-Keeping-Unit* for a target market. The company considers three different markets (Sales Organization): the Replacement Market – REP – (ends the code in 1), the Source Equipment Market – OE – (ends the code in 2 or 3), and the Export Market – EXP – (ends the code in 4).

The FE is calculated as follows. Be:

- i the product (CPI)
- m Market (REP, OE, EXP)
- r la región (CER DACH, CER NORD, EER, EEXP, NOR, SOR, SWR, WER)
- t the period
- h the forecasting technique (1 **= magic DL Blackbox, 2 =** ChatStatForecast, and 3 = **NAForecast)**
- $A_{i,r,m,t}$= the historical sales of product i in market m during period t
- $F_{h,i,m,t}$= the forecast of sales of product i in market m during period t by technique h

To calculate the APE for a given market, in a certain region, in a certain period according to a technique (it will be called FE), the value of last month's error (the original forecast and the actual sales level) is then calculated for each CPI-Market-Region and divided by the actual sales value and the values in the market are averaged.

$$APE_{h,r,i,m,t} = \frac{F_{h,r,i,m,t} - A_{i,r,m,t}}{A_{i,r,m,t}}$$

$$MAPE_{h,r,m,t} = \frac{\sum_{\forall i} APE_{h,r,i,m,t}}{\sum i}$$

On the other hand, *bias* (bias) is used, a value that measures the total percentage deviation in sales volume of an entire region by comparing the total expected volume and the total volume sold.

$$bias_{h,r,m,t} = \frac{\sum_{\forall i} F_{h,r,i,m,t} - \sum_{\forall i} A_{i,r,m,t}}{\sum_{\forall i} A_{i,r,m,t}}$$

	Short-Term M-1								Long Term Aggregated			
	FE				Bias				3-Months		6-months	
Region	M-3	M-2	M-1	Target	M-3	M-2	M-1	Target	Region	FE%	Bias%	FE%	Bias%
CER DACH				70%				5%	CER DACH				
CER NORD				70%				5%	CER NORD				
EER				70%				5%	EER				
EEXP				70%				5%	EEXP				
NOR				70%				5%	NOR				
SOR				70%				5%	SOR				
SWR				70%				5%	SWR				
WER				70%				5%	WER				
Global				80%				3%	By Prod.				
									Global				

Figure 1: Template used to report information every month for each region

Currently, the company sets itself the target of an EF of less than 70% but does not achieve it often, and no one explains why. In the last month, the minimum EF was 81%, and the maximum was 152%. As for the Bias, having it at an absolute value of less than 5% is the goal, but the values by region fluctuated last month between -20% and +250%. Globally, it was only 9%, but AsteGIOx is not very satisfied, and it is unclear what the root cause of all this is.

To understand the possible errors in each region for each market, a table is shared each month comparing the results of the three methods used (Figure 2)

	Forecast Error (FE)		
Region	**magic DL Blackbox**	**ChatStatForecast**	**NAForecast**
CER DACH			
CER NORD			
EER			
EEXP			
NOR			
SOR			
SWR			
WER			
Global			

	Bias		
Region	**magic DL Blackbox**	**ChatStatForecast**	**NAForecast**
CER DACH			
CER NORD			
EER			
EEXP			
NOR			
SOR			
SWR			
WER			
Global			

Figure 2 Comparison of forecast results by region for a given month

And in addition, it is evident (see yellow) who has got it right each month (Figure 3).

The comparison is always made at the end *of month t based on the month t forecast that was* made in month *t-1* against the actual value of sales in t.

Forecast Error (FE)					
	ene-22	feb-22	mar-22	abr-22	may-22
magic DL Blackbox					
ChatStatForecast					
NAForecast					

Bias					
	ene-22	feb-22	mar-22	abr-22	may-22
magic DL Blackbox					
ChatStatForecast					
NAForecast					

Figure 3 Comparison of month-to-month forecast reliability

2.3. A significant historical database

To work, AsteGIOx shares with you a database of historical sales where it has monthly data from January 2014 to September 2023. The available data includes:

- 3 product brands: FS, BS and LA
- 7 product families: AR7, AR2, AR4, AR1, AR3, AR5, AR6
- Over 800 SKUs
- three different markets (the last digit of the Sales Organization) can be broken down into eight business units grouped into more than 40 Sales Units.
- 22 European sales countries grouped into seven sales regions

Historical sales result from many factors (evolution of the product range, acquisition/sale of brands, external disruptive effects – COVID-19, war, weather, etc., internal decisions – promotions, etc.).

With all this information, AsteGIOx is counting on you. There are many possible lines where you can work, but a tool based on Excel or Python is a minimum. Finding a more reliable method would be a must. Asking yourself the right questions can only lead to good answers.

3. Operations Planning

AsteGIOx has other vital responsibilities. He oversees the production planning of the company's Cantabrian plant. This plant manufactures all the references present in the sales history presented in the previous point.

Aggregate planning is essential to him because many decisions must be made, and the consequences can be significant. On the one hand, the plant is located in a country where each community has its work calendar, and if that were not enough, each province and each municipality has its work calendar. It is a complicated situation to understand from the outside, but that can have a particular impact since not every week is the same.

The plant has the machine needed to run the typical tire manufacturing process, as seen in Figure 4.

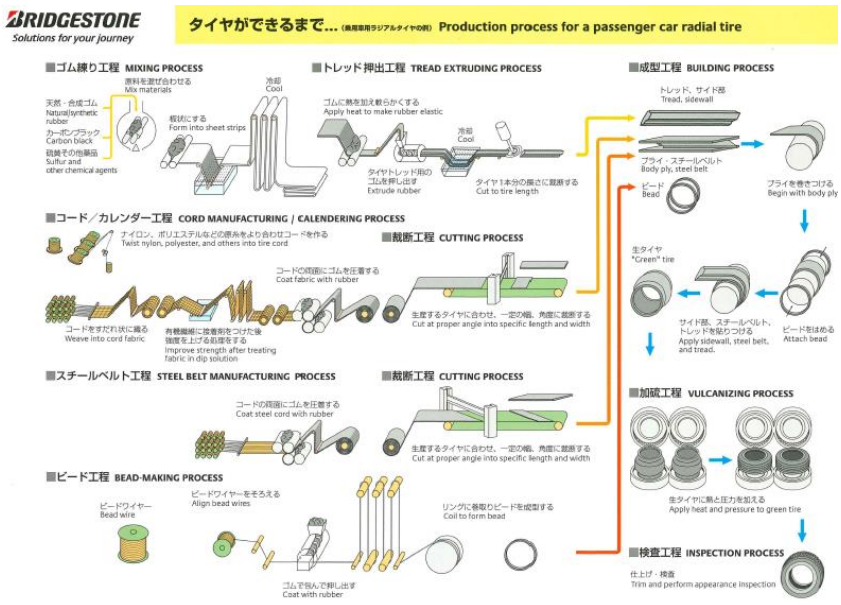

Figure 4 Manufacturing process of a tyre (source: https://www.bridgestone.co.jp/corporate/library/process/pdf/process_01.pdf)

The Cantabrian plant is a highly automated line as it is a mature technology and involves bulky and heavy products. However, the human factor is essential despite declining over the last few decades[1].

The plant can currently work with different production configurations. Each configuration implies an overall maximum pace and maximum capacity per line. In any case, the total units produced cannot exceed the output of each line.

- 550 units per day with about 60 employees (250 C; 350 B; 250 A)
- 400 units per day with about 50 employees (200 C; 300 B; 200 A)

[1] Bradley, L. G., Pattanayak, S. K., Depro, B. M., & Bingham, T. H. (2000). Economic analysis of the rubber tire manufacturing MACT. *Abt Associate Report*, 1-48.

- 300 units per day with about 40 employees (150 C; 250 B; 150 A)

Absenteeism is a relevant factor estimated at 15% and fluctuates every time the plant's production rate changes. Changing settings is challenging for HR as it takes two months to be effective. Dispensing with workers is difficult, but so is finding new workers.

Due to the complex procurement logistics and to ensure specific stability in the supply chain, the planner works with three weeks of frozen periods. Currently, planning is done based on the level of total on-hand inventory in regional warehouses distributed throughout Europe minus the uncommitted available stock. Demand has two primary sources: on the one hand, the monthly demand forecast for each material and on the other hand, the firm orders they receive week by week.

The company aims to have a month's total stock available anytime. However, this is used to hedge against the existing uncertainty. Holidays in August are mandatory, and stock pilling must cover the holiday periods or Christmas and Epiphany.

A couple of years ago, the company bought an app that sets the number of days/weeks/months of stock to keep for each product. This will be explained in the chapter related to the classification of each material. With this software, the desirable stock level is established for each product.

When deciding on production levels, each SKU has a set batch size. Any lot should be of this multiple.

There are three essential product families:

- The A family consists of the CPIs whose category is M67 & M68
- Family B consists of the CPIs whose category is SP75
- The C family consists of IPCs whose category is BP >75

In the factory, ten lines correspond to the construction machines (Building or Tams):

- two lines are for family A, four lines for family B and four lines for family C
- Per day, a maximum of 6 SKUs can be manufactured on each line.
- Any change in reference implies a loss of capacity equivalent to 10 units.
- Complete batches have to be manufactured; each reference, depending on its category, has a different batch (A=80, B=60, C=40)
- The production rate of all lines in each period always has to match the total overall capacity given a configuration.
- Globally, the target stock level is 2.5 months.
- No product can have more than six months of stock demand.
- There are different priorities for products depending on the target market. For example, EMBs are a higher priority than the replacement market. The BS brand has more priority than FS, and FS more than LA.

4. Classification of each product

The company bought software to apply appropriate stock management policies to each product a couple of years ago. An ABC analysis is performed based on the profitability of each product. The result is presented in Table 3.

Table 3: Result of the 2021 ABC Analysis based on the benefit of each product

Category	Recount	%
To	244	23%
B	236	23%
C	265	25%
D	196	19%
Unprofitable Product	107	10%
Total	1.048	100%

The preliminary analysis does not consider sales volumes, so the company performs another study based on sales characteristics. This complementary classification includes two parameters:

- Variability in CV= Quantity $\frac{Standard\ deviation\ of\ a\ population}{Average\ value\ of\ a\ population}$
- The average time between ADI orders = $\frac{Total\ number\ of\ periods}{Number\ of\ demand\ buckets}$

The numerical value used to discriminate by ADI is 1.32, and for CV is its squared value (CV2 > 0.49)

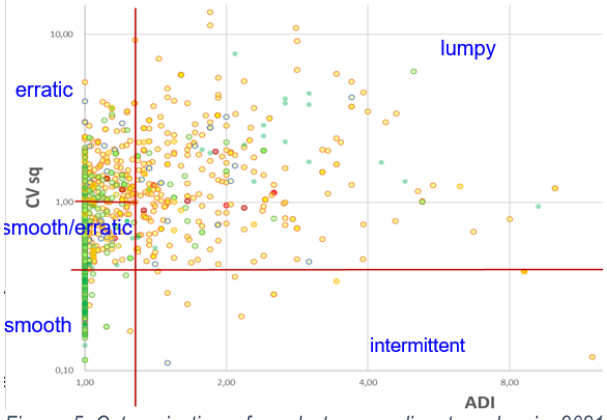

Figure 5 Categorization of products according to sales in 2021 (source: Internal company document)

Table 4 Result of the analysis based on historical sales for the year 2021 (source: Internal company document)

Classification	Recount	%
smooth	225	15%
smooth/erratic	222	15%
Erratic	297	20%
intermittent	42	3%
lumpy	256	17%
Subtotal	1042	70%
You don't go out	437	30%
Total	1479	100%

To determine the current stock, the company considers a maximum volume of units when storing (approximately 10,000 units). Based on a uniform distribution, the company applies the following corrective factor:

According to the demand analysis:

- Smooth: Apply a correction factor of 0.8
- Smooth erratic: Do not apply any corrective factors
- Erratic: Apply a corrective factor of 1.2
- Lumpy: Applying a Model (s, Q)
- Intermittent: Applying a Model (R,s, Q)

According to the profitability analysis:

- A: Increase by 5%
- B: Increase by 0.025%
- C: Reduce by 0.025%
- D: Reduce by 50%

Despite having a tool, the pressure to redefine stock levels well is constant. Defining the level of stock to be maintained determines the level of service. With the current situation, the company has no visibility into the level of service. The total volume of products to be kept in stock is a criterion that decreases year after year, and instead of recalculating everything, adjustments are made by hand.

AsteGIOx thinks a categorisation tool that can work and interact with stakeholders would be a luxury. Setting global criteria (total volume, maximum total cost of product in stock) and establishing control parameters such as the level of service (Fill Rate, Cycle Service Level, etc.) would allow us to apply better decisions.

5. Teacher's Recommendations

- The actual data of the case will only be given to the students within the framework of the collaboration between the company and the subjects. The data will only be shared if the confidentiality agreement is signed.
- If information does not exist or has not been given, it will be because it has not been requested or they have never stopped to do so. Make your assumptions and estimates, leaving the company with the possibility of modifying these parameters.
- In the company, everything is done in MS Excel, but designing the tools in Python is a must (don't forget that the integration of Python with MS Excel® exists).
- If the statement sets out values or indicators, it does not mean they are all adequate or the best. Justifying the use of new indicators can be interesting. The fact that the tools designed can analyse sensitivity to written values can also be interesting.
- FTL is the imperative strategy in the daily management of shipments
- There are interesting libraries in Python that are recommended, if applicable:
    - Panda Numpy for Data Structure and Calculations
    - Matplotlib and Seaborn for visualisation
    - Pulp for Mathematical Programming
    - Cplex or Gurobi with an academic license for the resolution of optimisation models
    - Simpy for discrete event-based models
    - Pickle for Big Data Structures
    - Prophet, Statmodels, Statsforecast, skforecast, PyCaret for demand forecasting with time series and other methods.

6. Acknowledgment

The elaboration of this case study has been possible thanks to Alejandro P.B., a former student of GIOI of the UPV, responsible for the Supply Chain in Brussels of the B company. Thank you very much for all these hours.