Proposal for the Application of Big Data and Analytics for Forecasting Demand of Packages - A Case Study in the Automotive Segment

Jonas Vitor Rodrigues Inacio
Ugo Ibusuki
Claudio Nogueira de Meneses
Universidade Federal do ABC

ABSTRACT

This article demonstrates the efficiency of the use of data modeling and statistics tools to search for the better resources and results for prediction of demand and optimization of logistic operations at a vehicle manufacturer plant in the city of São Bernardo do Campo (SP). This article aims to approach the entire modeling process to create a method to predict and optimize the operations and demand performing a production simulation from a data history to obtain a prediction of package usage for production items stock, guaranteeing an executable application capable of performing a production simulation and generating information on the volume of packages occupied.

INTRODUCTION

It was in May 2017 that the renowned newspaper The Economist published an article entitled “The world's most valuable resource is no longer oil, but data” and drew attention for the great importance that data is reaching and how it is causing changes and remarkable enrichment in large companies such as Alphabet (a conglomerate owned by Google), Amazon, Apple, Facebook and Microsoft, considered the five largest companies in market value in the world (1).

Data is growing faster than ever, that's a fact. Studies indicate that in the year 2020 the information generated per second for each human being will be approximately 1.7 megabytes (2), furthermore for that same year there is an expectation that the accumulated volume of big data will increase from 4.4 zettabytes to 44 zettabytes (44 trillion gigabytes) (3) and that business done primarily based on data usage will bring nearly $430 billion in productivity benefits (4).

This new way of using large volumes of stored information is very much in line with the concept of Big Data, a term used to refer to a huge volume of data (structured or unstructured) that ends up impacting the activities of the business. Big Data works with 5 pillars in its solution proposal, namely: Volume, Velocity, Variety, Veracity and Value.

- Volume: the main characteristic that makes Big Data something “big” is the immense amount of data that is generated every second in everyday life. It is estimated that 90% of the world's data today has been generated in the last two years alone and current data output approaches about 2.5 quintillion bytes per day (5).

- Velocity: referring to the speed at which data is created and processed. To get an idea of the speed of information, according to the Data Never Sleeps 5.0 report, every minute: Google conducts 3,607,080 searches, around 4,146,600 videos are watched on YouTube, 456,000 tweets are sent on Twitter, the Amazon makes $258,751.90 in sales, 45,787 rides are taken on Uber, and 103,447,520 of the 156 million emails sent are spam (6).

- Variety: the huge amount of information currently available is available in different ways: texts, videos, audios, images, links, etc. All this diversity of data types can be processed through big data (7).

- Veracity: with such speed, volume and variety of data, it is necessary to guarantee the reliability of the data, verify its qualification of sources, determine standards and then select the data that will actually collaborate for the purposes of the organization.

- Value: Big Data must have value, so it is necessary to invest in the right infrastructure to obtain, analyze and select data at a large scale to provide insights so that the data is more accurate and adds value.

This new real-time decision-making structure added to several other innovations in the technological field such as Internet of Things (IoT), Internet of Services (IoS), data science, cloud computing, blockchain and Application Programming Interfaces (API) have been transforming the market and the situation in what experts have been calling the 4th Industrial Revolution, marked by a period where data analysis reaches an importance never seen before for the reformulation of strategies and decisions of companies (8).

THE EVOLUTION OF INDUSTRY TO INDUSTRY 4.0

The first industrial revolution took place in the second half of the 18th century and one of its main characteristics was the improvement of steam engines and the mechanical content, making the invention of machines and the adoption of heat energy bring a great advance in manufacturing techniques and consequently a greater increase in production, with considerable emphasis on the use of iron and coal, also boosting the development of the railway sector (9).

After a long period of time, dating after the end of the Second World War, science and robotics became more intensely integrated into industry, agriculture, commerce and the provision of services, facilitating commercial relations and giving greater importance to information. The advancement of robotics gave industries more cutting-edge technology at all stages of production and ensured a greater and more efficient production capacity, as the human labor that dealt with more menial tasks was replaced by automated systems. machines, computers and industrial robots [10, 11]. In addition, the use of the internet and information technology not only by manufacturers but also by consumers was able to break the barriers of distance, causing globalization to end up providing the production of products with parts manufactured in several parts. in the world, in addition to bringing greater communication with the customer, who at one time would have greater access to the products of companies and their competitors, making information a powerful tool for industrial development, as the customer could make a decision more quickly once would have more access to the market (12).

As information has gained an increasingly important role in the organizational strategy of companies, for industrial productivity and for globalized commercialization, the meeting of several developments within technological development has brought a strong trend towards automating industries, promoting full computerization of manufacturing and bringing a concept of “smart factories”. This recent transformative vision is based on the emergence of some advances in the field of technology such as Artificial Intelligence, Cloud Computing, Internet of Things, cyber-physical systems, Big Data and Data Science. Such technological advances, once merged with the real world, are capable of promoting interoperability, that is, greater interaction between humans, robots, software and machines (7).

Industry 4.0 is considered in the business world as the natural path for industrial development and a means of increasing the competitiveness of factories through digital technologies. For consultancy McKinsey, by the year 2025, processes related to Industry 4.0 will be able to reduce equipment maintenance costs between 10% and 40%, increase work efficiency between 10% and 15% and reduce energy consumption between 10 % and 20% (13). In addition, according to the World Economic Forum, by the year 2025 some technological advances are estimated, such as the first pharmaceutical robot in the US, 10% of people wearing clothes connected to the internet, 5% of consumer products made in 3D printers and the possibility of governments replacing the Census with Big Data sources (14).

LOGISTICS: HISTORY AND CONCEPTS

Although it is the focus of attention in many companies today, logistics is not even close to being a modern concept and has been serving as a tool for man for longer than one thinks. In ancient Greece, the Roman Empire and the Byzantine Empire, the military who held the title of Logistikas were charged with taking care of the needs of securing financial resources and supplies during periods of war. In 1888, American Captain Charles C. Rogers introduced Logistics as a subject at the United States Naval War College, later being widely used as an object of study for battlefield strategies by the military until the end of the Second World War. World War (15).

It is possible to highlight that logistics is no longer seen as a tool for the flow of elements, but also requires a focus of attention for its ability to be precise in the ideal distribution for the necessary demand. This requires great harmony in the internal and external organizational system of a company and, consequently, requires that the strategy to be used works in an integrated way so that the supply chain can differentiate itself positively in both inbound and outbound logistics. Inbound logistics comes from the English in which means entry, its main scope is in pre-production and production operations, encompassing all material flow control from the purchase of raw materials to production, being responsible for managing the stock of the company. raw material and product packaging, for example. While outbound logistics takes care of the final part and output of the process (out), covering productive and post-productive operations, which will be part of the output of materials from the factory to the distribution points and final customers (16).

A production system that is currently highlighting the importance of reducing inventories and costs in manufacturing processes is the Just in Time system. This system, developed in Japan in the mid-1970s, aims to continuously improve the production process and advocates that everything must be produced, transported or purchased at the exact moment it is needed, without having a stock. The Just in Time system uses concepts related to production by real demand, a method that firstly aims at selling the product and then purchasing the raw material so that the product can be manufactured, adapting better to the cases in which that the demand for parts and raw materials are relatively predictable and without many fluctuations, as long as suppliers are able to deliver the necessary batches at the desired frequency (17).

For an organizational planning as complex as the Just in Time system, it is necessary for the company to be able to make a prediction of what can be expected in a given period of time, so it is able to try to create a premise that is closer to the reality and that can collaborate with the planning and decision-making of activities according to the resulting forecast. For this, many companies do what is called demand forecasting, an estimate that aims to predict what will happen in the future and how this can collaborate in the strategy and planning of the supply chain, supporting decision making in accordance with the information that can be drawn from this (18).

Demand forecasting is essential for inventory management, since the risk of excesses or absences can lead to financial losses. In addition, demand forecasting also influences production budget planning, labor requirements and final product pricing strategies. In general, the most used forecasts can be classified into two types: quantitative and qualitative. Qualitative forecasts are usually best when you don't find much historical data or when the analyzes come from specialists with deep knowledge of the business. Quantitative forecasting uses available historical data to perform some future projection using a mathematical model, and analyzes using time series and causal models are well known. There are also mixed forecasts that are able to combine the two types of forecast, combining the results obtained (19).

THE USE OF DATA APPLIED IN LOGISTICS

With the revolution caused by the use of technologies from machine learning and big data, many business areas have benefited from the use of information and data as a source of decision-making and operational efficiency, logistics was one of the areas that entered this new analytical and strategic way of looking at processes and decisions [7, 20].

According to DHL, a giant logistics company, most companies find themselves with a huge pile of data about their processes and supply chain and, as logistics processes have been increasingly computerized, each order and delivery have generated information and data structures in some part of the company's system. However, in most cases, this information is not used for any purpose, only being stored as a historical record (20).

A study by Deloitte found that less than 24% of the 400 companies surveyed had some kind of supply chain prediction tool. Despite this, this number did not indicate a lack of understanding or lack of concern on the part of companies regarding the importance of this data, since about 70% of the companies responding to the survey had the intention of implementing some measure or prediction tool in the future, despite having difficulty in find know-how and qualified labor to perform in these functions. A survey carried out by Accenture revealed that the expectations of logistics companies in analytical tools to use data are in the opposite direction with the search for their adoption due to the difficulty of their implementation (21):

> "97% of executives said they had an understanding of how big data tools could help their supply chains, yet only 17% of respondents had implemented any analytics in one of their supply chains." (21)

In companies where logistics have already been affected by the use of analytical solutions, several gains could be observed, including (22):

- Cost reduction, such as the prediction of maintenance and failures, allowing replacements or repairs in advance;
- Operational efficiency, since a more accurate forecast of demand is capable of guaranteeing fewer occurrences of bottlenecks in production;
- Dynamic pricing, since processes and operations are developed more quickly and the reduction of risks in cargo transport with the identification of dangerous and long routes impacting the final price of the product, making it more competitive.

A successful case where the use of analytical solutions in the logistics area occurred with the Danone group, a food company that stands out for dairy products, beverages and infant nutrition. Through the Disc'Over project, Danone managed to find a partnership that had the knowledge and technology needed to analyze the data and manage to find a way to identify the best way to invest in advertising media and predict its level of sales, where the variability of demand and its planning were circumvented so that the forecasting process proved to be able to solve production demands more efficiently, in addition to creating a predictive model for effective planning in the area of marketing, sales and supply chain (23).

Nowadays, companies have a vast amount of stored information, so for an optimal use of this data to be effective, it is necessary that the top management has an understanding of what they can do with this information and how far they are willing to invest their resources. resources and time for the analytical vision combined with the use of technology to transform this large amount of data into value [7, 14, 21].

METHODOLOGY

For any kind of construction of a data-driven solution, that is, oriented to the use of data as a potential for a response, a relevant and significant set of raw data is necessary, which, once understood, can become information based on existing knowledge. about a possible application, so that any raw data ends up becoming a source of domains that can be manipulated, studied and analyzed (24).

In this way, together with a vehicle manufacturing company in São Bernardo do Campo (SP), an applied research was started, which began with qualitative and quantitative exploratory work, evaluating the types of actionable ends for the business as well as how to understand if the existing data presented the potential aspects of the 5 V's of Big Data, so that it became possible to present and explain about the development of the case study in the automotive sector present in this work, finally creating an executable application capable of collect and organize a historical series of data in order to obtain a predictive result where it was possible to acquire outputs on the stock of parts of manufacturing items due to production demand.

From the first interactions on the basis of establishing a partnership between the public institution UFABC and the private initiative given by the vehicle factory located in São Bernardo do Campo, the need to build an application capable of performing simulations of the purchasing processes was visualized. of items in order to guarantee that the production plan could allow better reliability in the available stock items, so that the stock replacement carried out based on the future need arising from the demands respected the PV (production vorlauf, or production advance) and the DV (disposition vorlauf, or advance disposition) of parts for the manufacture of vehicles, also considering the complexity that there are nationally manufactured parts and others that are imported, which can further increase the PV and DV in this inventory replacement logistics , leading to a considered dynamic and not so much static and periodic level of replacement.

In short, the PV represents the number of days in which it is necessary to receive the part before assembling the vehicle on the final production line and being considered a kind of lead time for the sale of the item, while the DV is given by the amount of days required before disposition and serves as a lead time period for item production. As the parts are ordered and with a level of PV and DV already stipulated, a bond of multiples in the packaging must also be considered and, therefore, there is a minimum and multiple packaging capacity from which orders can be made. For example:

PV	3
DV	2
Múltiplo de Embalagem	20

Média 16.71

WD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Necessidade										17	16	19	14	11	16
Necessidade Acumulada										17	33	52	66	77	93
Entrega					20	20	20	20	0	20	20	20	20	20	20
Entrega Acumulada					20	40	60	80	80	100	120	140	160	180	200
Estoque					20	40	60	80	80	83	87	88	94	103	107
Necessidade do Dia					10	11	12	13	14	15	16	17	18	19	20
Dias de Estoque					1.2	2.4	3.6	4.8	4.8	5.0	5.2	5.3	5.6	6.2	6.4

WD	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Necessidade	16	18	19	21	22	25	23	21	15	12	11	11	13	14	15
Necessidade Acumulada	111	129	148	169	191	216	239	260	275	287	298	309	322	336	351
Entrega	20	20	20	20	20	0	20	20	0	20	0	0	0	0	0
Entrega Acumulada	220	240	260	280	300	300	320	340	340	360	360	360	360	360	360
Estoque	109	111	112	111	109	84	81	80	65	73	62	51	38	24	9
Necessidade do Dia	21	22	23	24	25	26	27	28	29	30					
Dias de Estoque	6.5	6.6	6.7	6.6	6.5	5.0	4.8	4.8	3.9	4.4	3.7	3.1	2.3	1.4	0.5

Table 1: Representation of logistics applied in the factory according to need and delivery of items.

As can be seen in the representation of table 1, where it is assumed that the PV of the part is 3 days and the DV is 2 days, whenever a certain amount of stock is needed, as in the case of the 10th day of WD (Working Day / working day) where 17 pieces are needed, it is necessary to purchase the minimum lot of packaging, which in this case is 20 pieces, which requires that the piece has its sum PV + DV of 5 days fulfilled, where the delivery is already ordered on the 5th. On the 14th, the fifth day of production, it is not necessary to order new items because 20 units had been ordered in each package between the 5th and 8th, leaving 14 units of the 80 stocked (66 pieces had been used in the first four days of WD production), so it guarantees the capacity of the 11 drives needed by the 14th.

DATA AND MATERIALS

Once the initial alignments regarding the project were made, the choice of programming language for the application would be Python, taking advantage of several functional libraries for the use of data manipulation.

Meanwhile, on the part of the company, the following data were made available:

- Bill of Materials (BOM), containing the parts considered raw materials of manufacture of the vehicle variants that are part of the production program, containing 27,930 different parts for 955 different vehicle variants;
- Production Schedule, showing the total monthly number of vehicles of each vehicle variant that were scheduled for production during the 12-month period for 289 distinct vehicle variants in 2020 at the factory;
- Item Catalog, bringing enriched information for 18,327 different items and classifying them between national or imported production, in addition to informing their PV and DV periods, as well as information such as their respective type of packaging and storage capacity, as well as the batch multiple and minimum for inventory acquisition;
- Packaging Dimensions, content that informed the length, width and height measurements of each possible packaging for stock, so that it was possible to later calculate the total volume of occupation of the same during the production phase.

SOLUTION DEVELOPMENT

From the visualization of the problem detected, the architecture of the project's development was based on the construction of a solution capable of carrying out a simulation that would take the monthly plan and, given its historical records, elaborate a daily production capacity for the vehicles, in a way that that the maximum capacity was stipulated by the user of the application, as it would take into account the number of work shifts and other variables that could be considered at the time of the factory.

Thus, the production capacity would take into account the average number of vehicles according to the historical record of production data, in addition to also considering the maximum production capacity, making it necessary to calculate the monthly average and standard deviation for each variant, then generating a function from a random seed that generates pseudorandom results, however respecting the capacity and historical average rules for the period of time for which the simulation is to be estimated, which can be 1 month or even 12 months, since a correction of the production adjustment takes place later, so that the variants that have production above the monthly average end up being replaced by others that were below due to pseudorandomness.

Since there is a daily simulation record of the vehicle variants, all the content present in the bill of materials (BOM) is collected in order to build a transposed matrix where an identification of all items and their quantities for each variant can be obtained. vehicle, facilitating the grouping between the components. As soon as the BOM transposition is carried out, the application tries to get the set and quantity of items for each vehicle variant and then connect to the simulation already carried out so that, in this way, the total number of items is stipulated according to the daily production needs, multiplying according to the quantity of each vehicle variant and then adding up all the fabrications to be made.

After estimating the total number of parts resulting from the assembly of all vehicles per day, it is necessary to estimate the delivery for the order of the same to the factory according to the sum of the PV and DV of each item, taking into account that all imported items end up having a 20% longer delivery period due to the maritime lead time, as detailed by the company, and, in the case of numbers with decimals, always rounding up to a higher natural number.

From the measurement of all the logistics by PV and DV, the application then creates a real Gregorian calendar and according to the date of execution of the application, which will extend from the period of greatest delivery (PV + maximum DV) to the first WD manufacturing business day (working day), assuming that there is no part of this item in the factory, that is, zero stock for a given part.

Once the initial calendar is made, where there is a real need for the parts and their order according to PV and DV for the first day of production in stock, the application then follows a logical rule so that, according to the multiple and minimum batches of the order, the order calculations for the packaging are carried out and, dynamically and recursively, its evolution and quantity continue to appear in the calendar, that is, establishing and keeping it fixed when not used or being able to generate residual stock for the next day in case of use of only part of all material in stock.

In an abstract way, the handling logic for items in stock dynamically follows this way:

- From the moment that there is no type of stock for a given item, its stock value is considered zero because it does not exist, and the first day of the calendar is considered as the interval of the maximum logistics date and farthest from the first day. of work (highest PV + DV until the first day of production of the item that it is necessary to request a purchase order), which the item with the longest delivery time will then already have some unit of items due to its need for production at the factory;
- If there is no production involving the item on the day, the item is therefore not consumed, remaining as it was in quantity on the previous day;
- If the difference between what is in stock and the amount of items needed for manufacturing is satisfactory, that amount is subtracted from the stock, leaving only the remainder for the previous day;
- If there is a smaller quantity in stock than necessary for production, the quantity of items on that day is given by the number of parts existing on the previous day plus the minimum common multiple necessary for there to be an adequate number of items for consumption in manufacturing;
- If the number of items needed to manufacture the vehicles equals the value in stock, the value is then subtracted normally.

In this way, when obtaining the total number of items on each day and their alternation moving according to production needs, it was then possible to obtain the sum of the quantities of packages from the capacity of each package for each item as informed in the catalogs of items and, thus, the total volume of packaging is measured as described in its dimensions in the materials supplied by the company, a result that informs the total volume space that ends up being occupied by the stock daily while the production program is performed.

In summary, the final application ends up running as shown in the following figure:

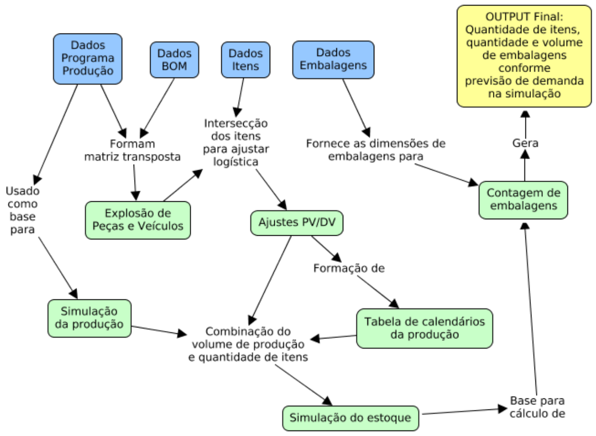


Image 1: Flowchart representing the sequence of steps where the application executes and models the data.

RESULTS

The application was made and tested with an eye on the application in the industry and, therefore, it was designed in a way to guarantee an easy use and of uncomplicated implementation. For this reason, all the code was abstracted to become an executable program together with all its pending libraries, thus making a kind of container where it is only necessary to be clicking on the program icon to start the application.

In this way, it is possible that the company does not have risks or problems with different versions of the language interpreter or some type of library or function existing within the code, in addition to also hiding the source code, safely protecting the application from being exposed. to third parties and not exposing all stored logic.

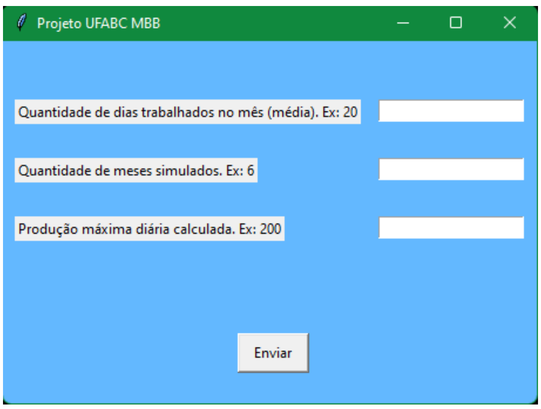
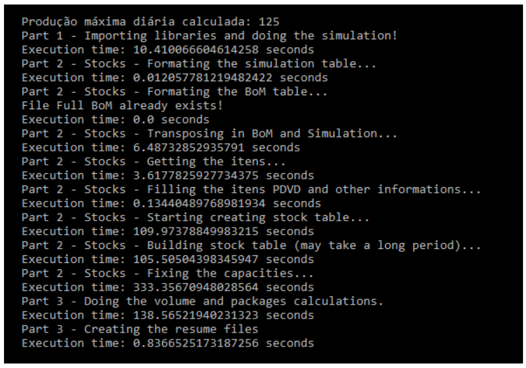


Image 2: Graphical interface present at the beginning of the program for adding the input variables.

In general, the program has an execution that can take a few hours (on average 6 hours in case of 6 months of simulation) based on an Intel i7-1065G7 1.3 Ghz processor with 4 cores and 40 GB of RAM in a WIndows 11, but mostly due to the high volume of data present, since there is an explosion during the production of the BOM file in order to separate and then add all the parts and all the vehicle variants, which generates a very expensive processing, but the main component of processing takes place in the establishment of stock capacities as all items are assimilated with production days so that there is calendar calibration and dynamism in the control of items and packaging, so the longer the period, the more processing must Be done. Despite this, it is worth remembering that such an application serves as an auxiliary support in the decision making of a medium to long term period, between weeks to months, and not for such a high frequency of execution as from one day to the next, because after all it is It was found that in many cases the logistics of delivering items, via PV + DV, takes a long time, making any simulation more urgent a proposal without many actionable purposes.



```
Produção máxima diária calculada: 125
Part 1 - Importing libraries and doing the simulation!
Execution time: 10.410066604614258 seconds
Part 2 - Stocks - Formating the simulation table...
Execution time: 0.012057781219482422 seconds
Part 2 - Stocks - Formating the BoM table...
File Full BoM already exists!
Execution time: 0.0 seconds
Part 2 - Stocks - Transposing in BoM and Simulation...
Execution time: 6.48732852935791 seconds
Part 2 - Stocks - Getting the itens...
Execution time: 3.6177825927734375 seconds
Part 2 - Stocks - Filling the itens PDVD and other informations...
Execution time: 0.13440489768981934 seconds
Part 2 - Stocks - Starting creating stock table...
Execution time: 109.97378849983215 seconds
Part 2 - Stocks - Building stock table (may take a long period)...
Execution time: 105.50504398345947 seconds
Part 2 - Stocks - Fixing the capacities...
Execution time: 333.35670948028564 seconds
Part 3 - Doing the volume and packages calculations.
Execution time: 138.56521940231323 seconds
Part 3 - Creating the resume files
Execution time: 0.8366525173187256 seconds
```

Image 3: Warnings presented by the application regarding the steps taken and the time spent.

RESULTS

The present work demonstrates how the use of data can enrich the analysis and visualization of important sectors in a company, such as the logistics of its products and the possibility of estimating demand forecasts of its production line according to a recorded history, and the higher the the number of present data available, greater potential and return is possible to be brought by the application.

This project is currently under discussion for improvement, such as having some balancing and conditioning of weights to simulate some type of vehicle considered of greater importance in some seasonality. Despite this, the simulation allows scenarios consistent with the pattern found in the existing data history, ensuring the possibility of anticipation and organization of all logistics and stock at the factory, being able to optimize and avoid risks in the production program.

However, the study was carried out with partial data from the company and that were hit by the impacts of the pandemic in 2020, for example. Therefore, as more data is acquired for use and manipulation, the better the efficiency will be for the simulation to be able to have a reliable representation of all items for the manufacture of vehicles that, with more data, will have a more efficient production simulation. consistent with a realistic scenario.

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