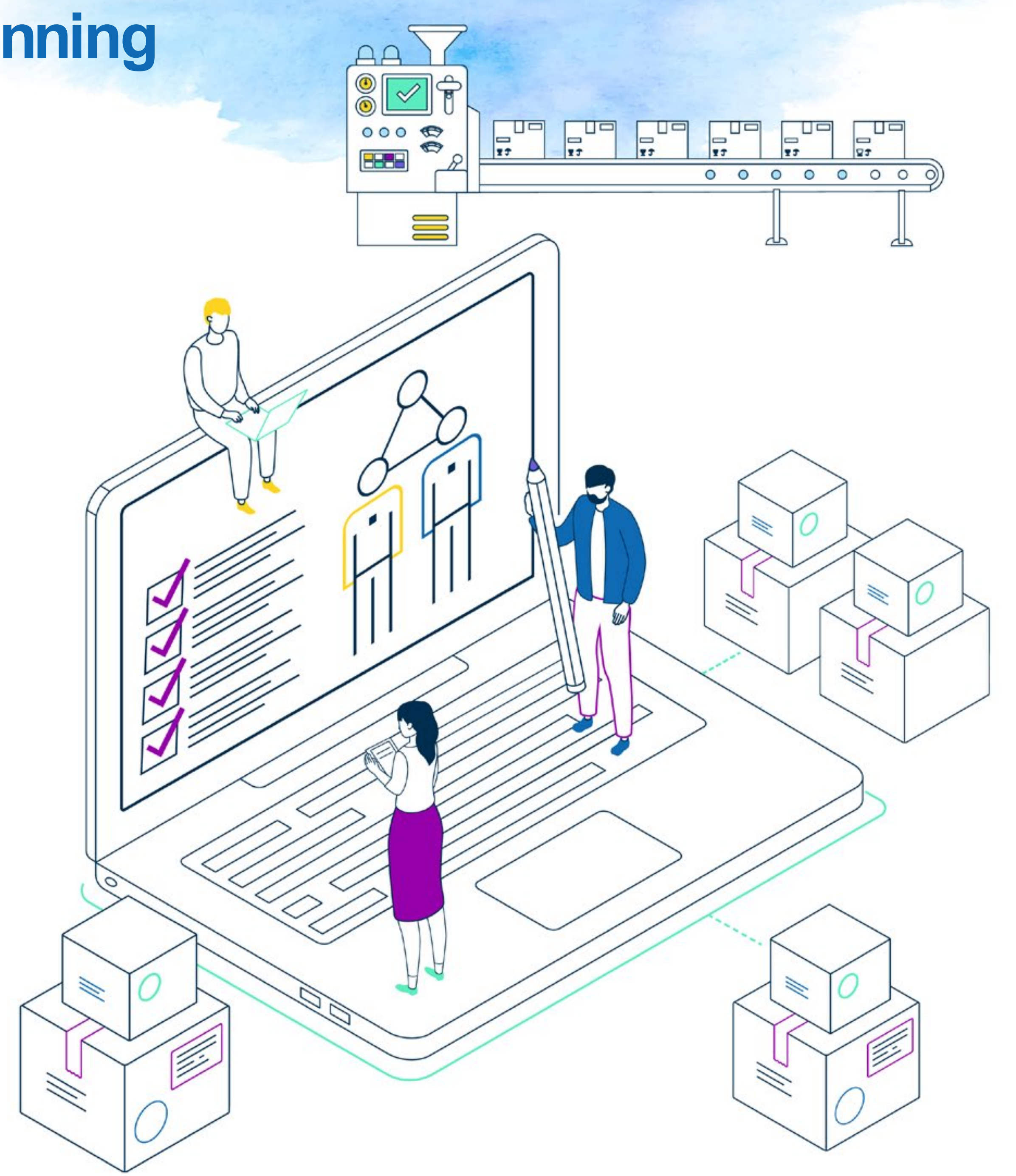
ADEXA Predict, not just response

Use Cases of AI/ML in Supply Chain Planning –

An Introduction to use of AI/ML in Supply Chain Optimization and Planning



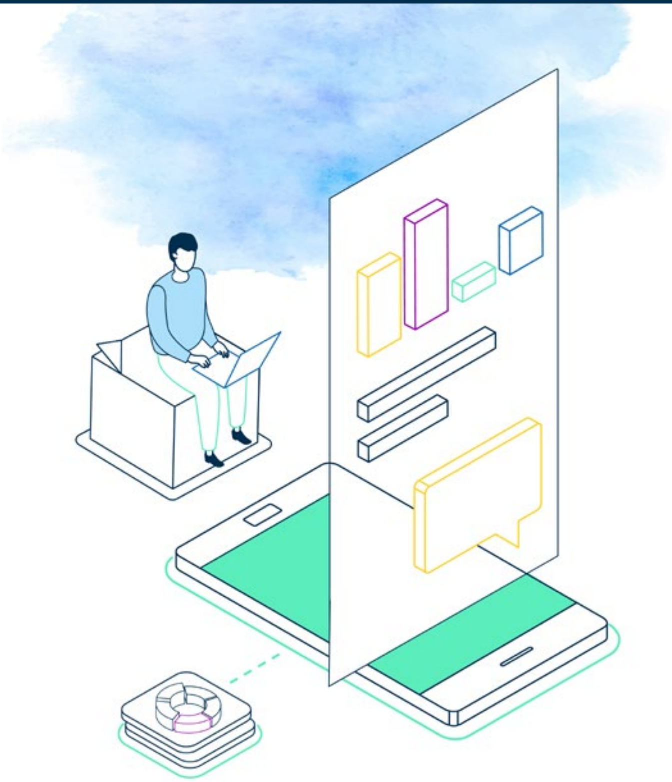
With recent popularity of AI and ML, companies are making fast moves to learn and use these techniques in order to gain competitive edge and gain insight into their operations as well as come up with new processes, designs, modes of operations, and discover what was previously hidden from the end-users. In this short article, we summarize some practical uses of AI and ML in the context of supply chain planning and how some of our clients have made quantum leaps in their processes because of what the technology has to offer.

Given the exponential growth of data from streaming sources, IOT devices, transaction platforms and others, the question is how do we analyze and understand the impact of data. Just receiving notifications and alerts is a very primitive way of managing supply chains. In order to understand the impact and relevance of data a *model* is needed. Some refer to this as a *digital twin* of the physical supply chain. Essentially it is a representation of what is going on in a digital format. Examples of models are airplane cockpit simulators or Maxwell equation that predicts the relationship between electricity and magnetism, or even a primitive spread sheet that shows resource capacities.

In supply chain planning we build these models to understand the impact of events and with enough *intelligence* predict what could happen in the future. The latter is done either by *simulating* the future or having enough data from the past so that we can predict the future based on our past experiences, i.e. *learning*. But in the process, with enough intelligence we can also do discovery of new approaches to the same problem. An example of this will be given in demand planning section below. A process called *mutation*.

Demand Planning & Forecasting

The use of ML techniques has become more popular especially in forecasting applications. In a way, the conventional statistical methods of forecasting constitute a learning strategy, except that the cause-effect relationship examined has to do with how the demand changes against time. However, as we all know there are many more variables that can impact the forecast including weather, competition, pricing, life cycle of the product, regions, events and so on. Machine learning techniques are capable of discovering the most influential factors that may cause the forecast to change and thus predict future based on how these factors have caused demand changes in the past and therefore do the same in the future.



"Planners' role becomes more of an analyst and data engineer."

Moreover, there are currently available techniques to not just use the right policies but also generate, or mutate, new policies by the system. This is a very exciting progress for the system to discover new ways of finding the best forecast not based on what we know and what algorithms are known, but what parameters can be changed to form new policies. One such parameter is the level at which the forecast is made, i.e. product family or individual SKU. Or relationship between volume and price of the product. For example, high-volume low-price products are treated differently from low-volume high-price items. Another parameter could be how far back the data is analyzed. Having a window that is too long may make the data irrelevant. Too short a window may not be reliable enough.

Inventory Optimization

There are a number of ways that the amount of needed inventory can be predicted at every stage of the supply chain. There are of course many different types of inventory safety stock, hedging inventory, raw material, finished goods, anticipation inventory, WIP (buffer) inventory etc. Techniques that maybe used to decide on what level of inventory is needed, use a combination of stochastic theory, optimization and machine learning techniques, in order to decide how much inventory is adequate. For example, Multi Echelon Inventory Optimization (MEIO), uses certain type of **iterative optimization** in order to find the best way of keeping inventory at different points in the supply chain. Of course, the "best" implies the right balance between cost of keeping inventory downstream to reduce delivery leadtime; or keeping the inventory at earlier stages of the supply chain at the cost of longer leadtimes for delivery. The users can examine such scenarios of cost vs. delivery performance to decide on different policies depending on the product, desired service level and/or customer.

ML is also used to decide on the right levels of safety or hedging stock. The right level of safety stock, for example, depends on many factors such as demand variability, availability of resources, and the velocity at which demand changes during different seasons amongst other factors. Using ML techniques, past data is examined to find the relationships between potential influencing factors and use of safety stock for each product. Such systems are extremely useful to use in order to recommend reference points to be compared with the existing policies. Their training time can be very fast and the data is generally available in transaction systems such as ERP.

Supply & Operations Planning

Supply can be as probabilistic as demand. There are many factors that are variable and changing including the delivery behavior of the suppliers and sub-contractors, availability of key equipment, changes in the product mix and skilled labor availability and readiness. Other factors could be variation in transportation times from suppliers or to customers, rush orders from customers, disruptions due to Acts of God and geo-political and socio-economic events, the likes of which we are seeing more and more in recent years.

In order to be prepared and know what options are available to be able to predict and respond faster, a digital twin, or a digital representation, of the supply side must be constructed. This entails modeling the physical supply side at a level of detail that is adequate enough to make intelligent decisions. Unfortunately, S&OP systems cannot provide an adequate level of detail for deployment of ML on the supply side. This is simply because, if one does not have a good understanding of the environment, one cannot make decisions no matter how much "intelligence" has been put into the system.

An accurate digital representation requires S&OE solution to be able to know the different options that are available and deploy intelligence to make a good decision that is known to be feasible. Otherwise, an abstract model such as S&OP, not knowing all the different options, would require a great deal of human intervention.

Once a digital twin, or a true digital picture of the physical supply chain is built then ML algorithms can be used in three different ways:

Self- Correcting the model; the ever-changing digital representation—the twins need to change together

Self-Improving the policies; the system learns more about what and how it can be done better using machine learning—an example of this was given earlier for inventory optimization and safety stock level determinations

Self-Optimizing of the algorithms themselves. The system can also improve its own performance by learning how to go about searches when it is exposed to more and more data. Hence it can optimize its own performance

Examples of self-correcting the model, i.e. digital representation, of the supply chain:

- Adjusting resource capacities if dependent on seasonality or if they have changed over time
- Making sure that supplier lead-times are up-to-date and monitor their variability during different months of the year depending on the region and cultures
- Making sure the set-up times are as assumed correctly and adjust for changes

Examples of self-improving of policies:

- Monitor and measure cost of alternate suppliers or transportation means
- Excessive use of more expensive substitute parts
- Monitoring and adjusting number of customers which giving rush orders
- Adjusting inventory levels
- Re-prioritizing customers to get better productivity and customer service
- Plan based on commodity prices
- Plan based on sustainability of products, customers, suppliers and materials used, their carbon emission and land fills

“Supplier behavior changes over time... Monitoring their performance and delivery pattens, using ML, enables you to predict expected delivery time of goods *even before a response is received* from the supplier!”

Supplier Management

Companies are heavily dependent on their suppliers and their reliability and service level is critical to their business. However, supplier behavior is subject to change over time for better or worse. Monitoring their performance and understanding their pattens of delivery using ML techniques enable the companies to predict when goods are expected to be delivered so that more accurate plans can be generated. For example, a supplier might take 2 weeks to deliver goods in summer and 2.5 weeks in winter but in December 4 weeks.

Knowing such behavior ahead of time enables us to make more reliable and accurate plans. In addition, AI can help to monitor promised due dates. For example, automated messaging with the suppliers to make sure delivery is on time as promised. And if not, then how many days of delay and what the impact would be, can be known. Use of Natural Language Processing (NLP) to understand messages from the supplier can help to automate the process. At Adexa we use a robotic process, AKA **Adexa Genie**©, whose dedicated job is performing above functions and learning from its experiences.

Allocation

Allocation of goods to clients becomes a critical issue when demand is high and resources such as material and capacity are limited. Optimal allocation of capacity and material becomes a very complex problem when dealing with thousands of orders and customers. Both optimization and AI techniques can be deployed to allocate and commit to order in real-time. This is done by a combination of the use of expert systems to understand the rules of allocation and the ability to understand the impact of each order on the rest of the committed orders already in the system. In this process of allocation and the ability to perform ATP/CTP in real time, there are both soft and hard constraints that need to be observed and the intelligence to know what combination of these constraints are admissible to respond back to the customer and provide a reliable due date.

Once a due date is committed based on customer requested date then the execution needs to ensure that it is delivered on time and if not possible, for whatever reason, what should be communicated back to the customer and if it is acceptable. Or examine the possibility of finding another solution such as partial delivery or a close substitute of the product at slightly higher or lower price that can be delivered at the requested date.

Our next topic below is about the role of execution systems, also known as respond planning or S&OE, and how AI/ML is used to ensure deliveries made as promised.

Network Optimization

Optimization of the supply chain network can have an enormous impact in terms of cost savings and better delivery performance. Network optimization helps to dynamically decide on sourcing decisions to minimize cost and improve delivery performance. In addition, **strategic network optimization** can help to reduce cost of inventory and transportation cost as well as their carbon emission.

A number of techniques drawn from AI and Operations Research (OR) can be used to design and improve the operations of the supply chain network. By the use of AI heuristics in conjunction with Mixed Integer Linear Programming (MILP), one can decide on levels of inventory, sourcing locations and reduce transportation costs amongst other factors such as land fill and carbon emission.

"Plans should be based on sustainability of products, customers, suppliers and materials used, their carbon emission and landfills."

Production Planning and Execution

Our philosophy is that planning and execution are not separate but a continuum. To this end going from planning to execution means plans are made realistically so that they can be executed and if anything goes wrong in execution, then replanning is done at the appropriate level to adjust accordingly.

Merging planning and execution need to be seamless just like an autonomous car that senses both short term bumps on the road and corrects them with the shock absorbers; and also looks ahead for potential traffic delays and prevents them. For this to happen a supply chain or factory digital twin needs to have intelligence and constantly learn and change to be the same as its physical twin. Hence self-correcting of the model and self-improvement of algorithms to update both structure and behavior of the supply chain.

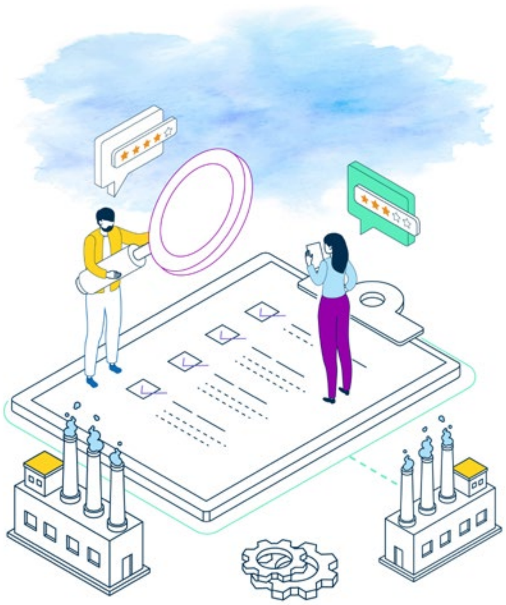
In execution much must be monitored and adjustments made by learning about the underlying physical environment so that it is mirrored in the digital representation. Examples are monitoring supplier delivery and knowing the impact on production and what to do, understanding email content from supplier and customers to make decision in planning and execution, monitoring and adjusting set-up times as the tools wear out or product mix changes, knowing the actual capacities of the key resources and availability of labor and estimating transportation times, depending on the season, are just a few examples. This requires using ML to constantly correct the representation of the digital twin so that decisions are made based on a realistic understanding of the world we are mirroring.

Also, in execution there is much data that the system is constantly exposed to. Examples are data from the shop floor regarding movement of orders, equipment breakdowns, and quality issues just to name a few. Furthermore, data from suppliers regarding late or early arrivals, changes made by customers and weather-related issues. Most, if not all, need to be dealt with in real-time which means system needs to be intelligent enough to understand the impact of each event rather than sending hundreds of alerts to users to correct the issue. The intelligence needed here is based on Robotic Processes Automation (RPA) technology that we refer to as digital experts or **Adexa Genies**© capable of sensing relevant data, acting on the event, learning from them over time and collaborating with each other.

RPA approach allows the system to scale and grow without suffering from data and decision latency which is problematic with almost all current S&OP systems. Dealing with multi-dimensional supply chains including a circular economy, compliance and regulations, horizontal and vertical integration, transportation, and financial as well geo-political factors or socio-economic events such as social media. Monitoring all such events and data require very unique set of intelligence and know-how. We believe this can be accomplished in the form of processes and agents that undertake and specialize in such tasks and collaborate with each other not just to come to a consensus but to the optimal level of performance.

Collaboration

AI/ML techniques have opened the door to automation with enough intelligence to take over a lot of mundane and not so mundane tasks in supply chain planning and operation. With this trend continuing, collaboration is not just between users in different departments and companies or suppliers and customer but mainly for processes to understand each other and make or recommend decisions collectively. This is very similar to the way bees and ants collaborate by taking into account not just their own individual objective but the good of the entire community. This approach is also known as **Swarm** technology. Using Swarm technology, the focus is not necessarily on the consensus decision making but what is the *right* decision for the whole company.



"Intelligent distributed Processes can understand the impact of each event, the need to collaborate with another process or human, and then learn from their experience."

To this end, the processes need to *understand* the impact of each event, if there is a need to collaborate, with another process or human, and then learn from their experience. Thus, processes can take over communication and basic understanding of messages from suppliers and customers as described in the earlier sections above.

Types of AI and ML tools

It might be helpful to say a few words about AI/ML tools. AI has been around since 1957. Nothing new about it. However, the abundance of memory and powerful processes have made possible the use of these techniques. Much of AI is based on heuristics where conventional Operations Research (OR) techniques may not be feasible due to the intractability of the problem to find the optimum solution. Some of these techniques that we are using are Gradient Descent, Constraint Propagation and Taboo search (self-improving tree search). We also use pattern recognition techniques extensively with both structured data and non-structured data to find patterns and cause-effect relationships. Neural nets are deployed with multiple layers for deep reasoning in figuring our safety stock levels, and finally Knowledge graphs that define relationships between different objects are used to show the users root causes of potential late deliveries and what is causing them every time we plan. This same information is then used to learn patterns of lateness behavior and what are the main causes.

Finally, Adexa's deployment of *Expert System* technology, in conjunction with **Attribute-Based Planning**, enables defining rules and policies as the behavior of the supply chain changes. The rules become soft or hard constraints for the system to find the right optimal solution. The main advantage of this technology is that as the business changes the business rules can change in order to ensure the digital twin remains true to the physical operations and policies. In the absence of this feature, manual intervention is needed whenever a plan is generated to make the corrections and adjust the parameters to fit the new environment.

Artificial Intelligence and Machine Learning have a lot to contribute to elevate the role of humans to more creative and innovative functions. With the kind of technology described above, planners' role becomes more of an analyst and data engineer. Their role would be to correct trends that are observed by the system and analyze how the system can become more intelligent by adding data that maybe unknow to the system.

Furthermore, they can make strategic decisions based on the issues that are trending and impeding the supply chain to perform better and faster. Such examples are improving relationship with suppliers, helping customers to understand the implication of their orders and their impact on sustainability or making investments in better training of skilled labor or additional equipment that keep causing quality or bottleneck problems. For more information and use cases of how AI or ML can be used to improve supply chain operations.

For more detail on the above topics please refer to **www.adexa.com**

Let's make **accurate** plans together!

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