Pitfalls of supply chain for aeronautics

10 Ways To Avoid Them

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WHITE PAPER

LOKAD
Quantitative Supply Chain

Executive Summary

Aeronautics companies are fundamentally risk adverse – for very good reasons – and this reflects in the management of the companies' activity in every area. However, this mentality can be a hindrance when it comes to supply chain, as avoiding risk and not integrating the very concept of risk at the heart of the supply chain means losing sight of what you are optimizing.

Risk, as a manifestation of the uncertainties in the process, is an integral part of supply chains. It can be reduced to some extent, but never erased. A common practice in supply chain is to try and handle the issue through an oversimplification of reality. To focus the company's efforts on artificial concepts like safety stock, or to enforce artificial segmentations like high value/rotation vs. low value/rotation parts are typical examples of ill-suited widespread practices; they are quite straightforward to put in place and they do allow the teams to remain in a comfort zone of sorts, but they end up crippling significantly the optimization capacity. Even forecast accuracy, in the traditional sense of the term, which is often depicted as the ultimate ingredient of an efficient supply chain, tends to act as a smoke screen and prevents focus on what really matters.

So, what are we optimizing really? If your company's answer to this question revolves around the notions of service level, safety stock or forecasts, it probably means that your optimization journey is just beginning. At some point in the future, in order to keep up with the technology evolution and, quite simply put, the competition, your company will have to undergo changes that will have a deep impact on how your supply chain optimization is engineered and how your teams handle it.

Supply chain optimization should revolve around the crafting of a unique, financial, company-specific optimization metric that will integrate, to the maximum extent possible, the subtleties of the different conflicting driving forces underlying your supply chain.

Yes, it is a strenuous process, and by all means, not easily achieved - that is why most companies don't do it. However, it would be a mistake to believe that the exercise is impossible, or that it can be avoided indefinitely. Yes, for the longest time, companies managed to do without. But the same can be said for software vs manual operations. Companies managed to do without, until it became unavoidable.

Of course, this approach and all that derives from it calls for relevant tools, sets of skills, as well as some degree of collaboration between finance and operations personnel. It is worth mentioning though that aeronautics, as a quite mature industry when it comes to its processes, is one of the industries where crafting this indicator can be done with relatively little need for assumptions. What it requires, first and foremost, is the will to embrace risk as a reality that is here to stay and that needs to be financially quantified. This whitepaper aims at uncovering the main steps of this journey.

The optimization journey in a nutshell

Ask yourself the right questions

Step 1: What are we optimizing?

Not Service Level, nor safety stock, but a comprehensive financial representation of the tangible/intangible drivers of your business.

Step 2: What stands between you and perfection?

Taking into account variability and the chaotic nature of reality (as well as human behavior…) beyond demand signals.

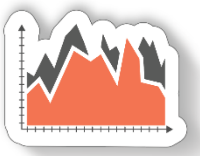
Face the facts

Step 3: Aeronautics is a risk adverse environment… sometimes to a fault

Ratchet effects, *post mortem* analysis and the many ways to pile up dead stocks through well-meaning but short-sighted practices.

Step 4: Gut feeling is not a good way of solving complex systems of non-linear equations

Sourcing options, criticality, dependencies, compatibilities… The human brain can only take so much into account.



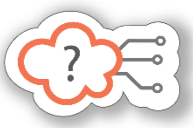
Draw your conclusions

Step 5: Optimize the decisions

Define your goals and craft your unique optimization metric. Think like a data science powered intelligence, not "just" a human being.

Step 6: Don't over-simplify reality else it bites you

Facing and quantifying complexity: a difficult but rewarding exercise for the company as a whole.



Choose your weapon

Step 7: Build a realistic data representation

Data management is a capitalistic process. Capture the right data for the right purpose with proper accessibility.

Step 8: Power up your optimization capacity

Don't force legacy concepts on your business, even if they are widespread. Customization is key.

Share your vision with your team

Step 9: Tactics are better left to computers, strategy belongs to humans

Find the right balance between humans and algorithms and make better use of your team's time.

Step 10: Change management

Changing old habits is never easy. Get your team's acceptance by showing them their continued added value in the process.

Introduction

Though companies in aeronautics use different internal processes and follow different optimization policies, they tend to follow very similar paths when it comes to inventory and supply chain optimization. This may seem as the sign of a consensus on what good practices are, but unfortunately, this could also be that all companies, by force of habit or technical and organizational limitations, are naturally converging towards the limitations of the same "not-so-good" practices.

The situation those companies end up in is usually the same. With service level targets being set as the number one goal in this industry (which may seem rational considering the cost of being out-of-stock), companies have put in place over the years, through a sort of "trial and error" process, higher and higher safety stocks. This has allowed them to reach the desired service level. It also usually leads the company to a situation of acceptable service quality, but at a cost that the company itself feels is much higher than necessary.

"KPIs will conflict with one another. There is nothing simpler than increasing service level: just add more stock. There is nothing simpler than decreasing stock: just accept a service level drop."

In this whitepaper, we will try to highlight what experience has led us to identify as the usual pitfalls of supply chain for aeronautics and what we perceive as the essential steps to try and avoid them. As is often the case, the most complicated journeys can start with very simple questions…

Ask yourself the right questions

1. What are we optimizing?

Trivial isn't it? But if your answer to this question involves the words service level, safety stock, or forecasting accuracy, your approach is missing the point. None of those concepts truly reflect the real interest of the company; they are simply a means to an end.

Considering the amount of money at stake, inventory levels and service levels are topics that involve quite a few people in the company. This automatically gives rise to a certain number of KPIs followed by those different stakeholders and that they use to analyze the situation. This may seem logical, as any problem can be viewed from different perspectives, but it usually comes with catastrophic consequences, as it is obvious that those KPIs will conflict with one another.

There is nothing simpler than increasing service level: just add more stock. There is nothing simpler than decreasing stock: just accept a service level drop. Similarly, there is nothing simpler than making a repair shop more efficient: just reduce its workload. Those individual KPIs, though useful from a reporting perspective, cannot be used for optimization as they do not provide a way to tell if a given situation is fundamentally better than another.

Optimizing a supply chain requires being able to systematically judge fairly whether a given position - stock or process - is superior to another. But the most important thing is that this judgement must represent the interest of the company **as a whole**. Relying on several indicators like service level and safety stock levels for example, is not a practical approach, as those indicators will end up conflicting with one another.

One needs to craft a unique, financial and company specific metric to be used as the common denominator by all stakeholders in the company on this subject.

Why company specific? Because this metric will be a representation of your company's strategy, processes, strong points and weaknesses, which are different from any other. Its purpose is to integrate, to the maximum extent possible, the subtleties of the different conflicting driving forces underlying your supply chain.

Why financial? Because currency is the only metric that speaks to all departments of the company in the same way and because, in the end, a company is not a charity. A situation will be judged as "superior" to another if its "reward" is greater. Of course, this does not mean that indirect or less tangible aspects will be ignored. On the contrary, they should all be quantified, and integrated, especially if they allow the company to avoid being too short-sighted.

Can anything be represented financially? When it comes to supply chain processes and their underlying driving forces, yes. And there is nothing cynical or unrealistic in this statement. Of course, some aspects of the optimization are harder to translate than others and may require a few assumptions. In aeronautics, the main elements to be integrated for stock optimization are usually the following:

a) Cost of inventory: this is probably the most straight-forward component. It can be described as the sum of costs attached to holding a part in stock over time. This includes the cost of working capital, as well as all relevant operational costs. Though it may require some efforts in terms of analytical accounting, this is something that companies should be able to generate quite easily.

b) Cost of stock-out: this is most probably the most dominant aspect of the calculation and also the reason why aeronautics companies reach for very high service levels. But it is also the trickiest one. Evaluating the cost of stock-out means getting a financial estimate of the consequences of a stock-out-incident. In turn, it involves:

- **Estimating the downstream consequences** (potential AOGs, work-stoppage, clients' bad will, contractual penalties…) and attaching a cost. Though it may seem difficult, aeronautics is probably one of the industries where this evaluation is easiest. Penalties are usually part of the maintenance contracts, AOG costs have been analyzed - even if roughly -, and the tolerance of clients to OOS incidents or delays is more or less known, as you usually have a pretty good idea at what service level you run the risk of losing the contract mid-term.
- **Estimating the cost and impact of safety measures**: when OOS incidents occur (or are about to occur), companies don't stay idle. They actively work to mitigate the problem. Safety procedures can take the form of an emergency swap / lease / exchange / purchase, or pushing internal repair processes for example. Those safety measures come at cost that is negligible compared to the cost of a prolonged shortage and thus are used to limit the cost of OOS incidents.

c) Gain attached to service: In most industries, there is a gain attached to the service. In the case of a sale, the profit attached to the sale will be considered as the gain. However, for aeronautics maintenance activities, there seldom is a direct gain. In the case of PBH contracts for example, the company gains nothing in performing a single repair. The value of the success is rather the value found in "not failing", and thus is contained in the OOS component described above. Success in this industry is the norm, and thus companies will be judged on their failures instead.

2. What stands between you and perfection?

Much like for human nature, perfection can never be achieved. However, when it comes to supply chain, perfection can be defined, even if only in theory.

If all parts could be made available in a perfect just-in-time manner, with maximum usage of every single one of them, your supply chain processes could be considered perfect, at least financially speaking. Though this state can never be achieved, understanding what elements are separating you from this blissful state is in fact key to conduct a realistic modeling of the optimization problem.

The reason why perfection is unattainable is due to the chaotic nature of the components of the problem. Most of the key factors of the processes carry an inherent variability; it can be reduced to some extent, but never erased.

The problem with traditional, even well-known methods, is that they rely on the assumption that those variable components (demand, lead times…) can be approximated by a single value - assumed or forecasted - and they build all their action plan on this. In other words, these methods lead you to assume that you are perfect in order to act perfectly.

"Any relevant variable element that is part of the supply chain should be represented by a distribution of probabilities, and never a single/static value."

First rule to solving a problem: recognizing that there is one. Assuming that you are perfect is certainly not a step in the right direction. So, what is the problem that makes you imperfect?

a) What should be obvious: demand is uncertain, and though some part of the demand may be known in advance, **there will always be some degree of uncertainty**. Trying to approximate future demand through an average/median forecast is a delusion meant to simplify the problem, but that is stopping you from any sort of progress.

b) What should never be neglected: processes are uncertain. Lead times more specifically carry some degree of variability. This is something that most companies will conveniently neglect by setting lead times at a static value in their models, but this is a mistake. First, studying that variability is the only way to understand how to reduce it in a cost-efficient manner. Most importantly, setting a static value is an unnecessary simplification. Though most tools don't have this feature yet, we now have the capacity to integrate lead times and other process factors as true random variables and to combine them with the demand aspect of the problem. At Lokad, this is done via an algebra of distributions that is one of the foundations of our tools.

c) What should never be forgotten: people are also part of the processes, and as such, they introduce variability. This should be fought but will always remain true. Therefore, "mistakes" or "malfunctions" should not be treated as "one-time" mishaps that would be excluded from the data, but rather as an integral part of the variability of the system.

From a practical perspective, the company should consider that any relevant variable element that is part of the supply chain should be represented by a distribution of probabilities, and never a single/static value. More importantly, this line of reasoning should not be limited to just the demand aspect.

Face the facts

3. Aeronautics is a risk adverse environment… sometimes to a fault.

Aeronautics is an industry that works relentlessly to reach for a "zero failure" standard. Even though this is something that cannot be achieved, the general idea is that the closer we can get to this status, the better. This way of thinking has affected the processes in place and, to some extent, the people working in this industry, making them risk adverse to the extreme. How does this manifest itself?

It is common practice for companies to conduct post-mortem analysis following costly out-of-stock (OOS) incidents. Though this can (sometime) make sense to investigate potential malfunction in the operations, it can also have very adverse effects if this analysis is used to take stock investment decisions. Unfortunately, this is often the case, as out-of-stock incidents are often wrongly linked to safety stock being too low.

There are fundamental flaws in the reasoning behind this practice.

- Service level is a cause not a consequence: out-of-stock incidents, however costly, are a part of the normal proceedings of the company and their frequency is a consequence of the targeted service level. Statistically they will occur, as the concept of 100% service level does not exist. The analysis of one incident has no statistical value and is totally insufficient to determine whether a stock level policy is adequate or not. Stock optimization is a game of numbers, not emotions (much like a well-known card game).
- Ratchet-effect: adding parts to your stock is "easy". All you need is money. But we need to consider that repairable parts/rotables, once added, will stay in stock for a long time, while going through several cycles of repair. As such, any investment decision is a true commitment of the company, sometimes over several years.
- Emotions: post-mortem analysis tends to be an "emotional" process that leads professionals to make irrational decisions. People can be tempted to accept unreasonable levels of investment in an attempt to bring a sort of "never again" comfort relative to a recent incident.

The combination of those flaws leads to a situation where companies pile up dead stock. What might have seemed a good idea at the time, usually turns out to be a rash decision when considering the big picture. This can be qualified as a sign of "short-sightedness" in the management of the stock level and processes, where the consequences of a recent incident tend to be magnified, even if the incident has very little chance of occurring again in the near future.

This type of behavior, though perfectly understandable, is one of the reasons why the human instinct needs to be challenged through a real financial optimization logic. In most cases, the financial logic will show that the amount of money that the professional was willing to spend on a high-cost critical part would bring much more value for money if invested on several - more modest but also critical - parts that can solve less flashy but more numerous incidents.

4. Gut feeling is not a good way of solving complex systems of non-linear equations

Based on current practices, the aeronautics industry's supply chain optimization relies in no small part on gut feeling. It may seem weird, considering the amount of effort that is put in those decisions, but it is true nonetheless.

Let us consider the "usual suspects" of an optimization:

- The forecast of the demand itself, though often based on a forecasting software/in-house method, is more often than not overridden manually.
- Lead times are set at a fixed value that "is supposed" to represent reality, as estimated by the user.
- The importance of parts relative to one another is, at best, "guesstimated" based on criticality level, scrap rate or price. Humans are comfortable with simple classifications, but much less so with continuums, though the latter is usually much more relevant for representing characteristics.
- Investment opportunities in different parts/SKUs are almost never put in competition based on objective criteria.
- Risk assessment often shows little concern towards ratchet-effect, fleet evolutions, asset-management possibilities, etc.

The truth is that demand or lead time forecasting, even if done correctly, is only part of the optimization process. The optimization algorithm should be able to combine the numerous other elements that play a role in defining how interesting it is to invest in a part: purchase price, cost of detention, cost of transportation, criticality, dependencies, classification, compatibilities, scrap rate, corresponding fleet type, alternative sourcing, emergency sourcing possibilities, and so on and so forth…

Each of these components has an impact on the final result, but some of them are not trivial to represent in the optimization equations. Thinking that a human being, however proficient, can, based on gut feeling, estimate the result of the combination of all those non-linear elements is wishful thinking.

"Purchase price, cost of detention, cost of transportation, criticality, dependencies, classification, compatibilities, scrap rate, alternative sourcing (…). Thinking that a human being, however proficient, can, based on gut feeling, estimate the result of the combination of all those non-linear elements is wishful thinking."

At best, an experienced professional can, with time, evaluate if the results make sense - though the results may sometime be quite counter-intuitive. However, this is not optimization, this is *a posteriori* validation that the result is remotely reasonable.

Draw your conclusions

5. Optimize the decision

Optimizing a supply chain is a real financial optimization, and a complex one at that. If there is one thing that the science of quantitative optimization tells us, is that optimizing different sub-elements of the problem separately gives absolutely no guarantee that the ultimate result will be made any better. In fact, it can be made much worse.

Based on the elements reviewed above, this optimization is difficult, but by no means impossible, as long as we recognize the limitations of traditional methods, and go through a more structured thought process:

a) Define the end goal of the optimization: it has to be **a decision, not a forecast**. In the case of stock optimization, this is usually what to put in stock, where and when to maximize return on investment. Knowing what the demand is going to be for a given part over a given week is nothing but a means to an end.

b) List the different economic/operational drivers of the process we are trying to optimize

c) List the corresponding ideal dataset that would be necessary to conduct a proper modelization of the optimization and review the availability (actual or potential) of this data. One piece of data being unavailable is not necessarily a problem; it can be replaced by an assumption or considered negligible if relevant. But this missing data needs to be acknowledged as a limitation of the optimization itself and considered as a potential for improvement in the future.

d) Craft a unique optimization metric corresponding to the financial drivers

e) Start an optimization process based on this metric with the appropriate methods and tools

Based on the elements reviewed above, we need to accept that, however much effort is expanded, the traditional methods are limited because they take as premise that any optimization process needs to be done the way the human mind would do it. They tend to see computers as just pieces of equipment made to help the mind operate faster.

Humans need to separate the problem in different segments, both from a process and a category perspective, in order to be able to grasp the problem. However, modern machine learning based methods have no need for such simplification and thus can be built with a more holistic perspective on the problem.

6. Don't over-simplify reality, else it bites you

The aeronautics industry is complex, and it may seem that creating a model that would consider all the underlying components that should drive decisions is an impossible task. That being said, we are left with two options:

- Either simplify the situation in order to represent it in a way that can be handled by hand - or through standard rule-based engines -,
- Or face that complexity and consider that, though a few assumptions may be necessary, we can still afford to tackle the optimization as it is.

The former may seem appealing, as it allows people to avoid a black box effect if the simplification reaches the extent where the results become intuitive enough. Unfortunately, this train of thought only provides one advantage: it more or less guarantees that the results won't be crazy, as they can be easily validated by a human being. But this is not enough.

At first glance, the latter may seem more difficult, even perhaps too big of a challenge. However, if we accept to rely on appropriate tools and modern optimization techniques and we consider the elements stated above, it is not the case.

Variable components (demand, lead times…) should be represented as distribution of probabilities. They can then be manipulated and combined through an algebra of distribution. Financial components (some of which were described in the first step above) should be estimated, even if it feels difficult.

"As a rule of thumb, when it comes to data, you want "purpose" to come before "capture", not after."

On the first hand, this exercise is extremely beneficial for the company as a whole, even outside of a specific optimization project: it leads the company to a better understanding of the forces driving its activity.

On the other hand, those elements have an impact on the final result, whether you like it or not. Not looking at them individually and instead "guestimating" their combined impact is still an estimation, except a much inferior one.

This will of course require the combined effort of professionals in the company from different departments, as well as proper tools and data representation. It is not an easy undertaking, but the further you can take this exercise, the better for the company.

Choose your weapon

Now that we have a broad understanding of what we should aim for, the question is: what do we need to be able to achieve it?

7. Realistic data representation

In order to model the reality of the processes, we will need to have a realistic representation of the different components through data.

By definition, **data management is a capitalistic process**. Data that is not captured is lost forever and thus can no longer contribute to future improvement. This does not mean that data should be captured left and right in the hope that they will be useful one day, but rather that professionals should have a systematic approach when investigating data requirements for a project, taking into account the nature of the data necessary, as well as their structure and dependency graphs. It should also involve a more long-term vision of the ideal dataset that could be wished for, for future versions, so that over time, new sets of data can be captured with an intended purpose. As a rule of thumb, when it comes to data, you want "purpose" to come before "capture", not after.

When it comes to MRO activities, an example of dataset that is often not of sufficient quality is the one representing the tracking of the parts all through the demand/repair cycle, and as a consequence, the status of the parts themselves at any given time.

In theory, this tracking is pretty straightforward, but in practice, getting a clean representation of all time-stamps attached to a part going through the full demand, mount/dismount, repair/scrap steps within or out of the company is not easy. However, once this information is correctly captured and qualified, thus allowing a correct tracing of each tag end-to-end, it opens the door to real financial optimization of the supply chain on all aspects:

- Representation of the efficiency "as is": the end-to-end tracking allows the company to generate realistic lead time distributions of the different steps isolated and combined, thus showing real dependencies and correlations. This last aspect also happens to allow for an estimation of the impact of human actions on the supply chain. In reality, when one part gets stuck too long at a given step, professionals may intervene to speed up the process of the following steps for this particular part when necessary, thus introducing dependencies between different seemingly independent steps.
- Estimation of the impact of recent/potential improvements: supply chain professionals usually don't lack ideas on how they could improve processes. What they usually lack is a systematic and objective way to estimate the returns that can be expected from a given initiative. Having access to the clean end-to-end data representation of the processes and using them for the optimization, as proposed above, allows the company to generate "what if" scenarios. This can be done by replacing real lead time distributions by the expected new improved lead time and simulate the consequences of such a change on the overall process, or by following the gradual modification of the observed lead time distributions.

As for the data concerning the financial aspect of the problem, the issue is usually not that this information is not captured - it usually is, if only for the finance team - but rather that it is not often accessible to the operational team. This means that most optimization projects should involve members of the finance department, if only for a few meetings to get the key numbers right.

8. Optimization capacity

We also need to consider that some aspects of the traditional optimization methods are so deeply ingrained that they have become a part of the tools themselves, thus leading people to consider them as compulsory.

A good example of this is the concept of "safety stock". This concept is so commonly used that many systems try to optimize it directly. But even a very quick analysis of what a supply chain is can lead anyone to understand that safety stock has no substance. It is a pure product of the human mind that tries to divide stock between two different entities: one that would be there to cover "sure" demand, while another would cover risk. Though this construct can understandably be needed to help humans cope with the difficulty and give a sense of comfort by segregating risk in an identified entity, it is totally useless, if not adverse, for a machine-based optimization.

Worse, when looking for new stock optimization tools, companies often request some sort of "safety stock optimization capacity". **However, safety stock should not be a subject of optimization, but rather of eradication.**

Optimization tools need to be able to reflect the complexity of the modelization work described above. At the very least, they should not impose on the company concepts that would force them towards ill-suited methods. Unfortunately, it is difficult to imagine an out-of-the-box tool that would be both generic enough to correspond to the setting of all companies, but also specific enough to be able to represent the reality of the processes of your particular supply chain.

To be able to achieve this, some degree of customization is going to be needed, ranging from a simple preference tick-box setup - which is simple enough but somewhat limited - to a full-on programmatic approach, which requires more effort, but also provides the highest level of customizability. At Lokad, we have chosen the latter: a fully customizable solution based on a programmatic platform which allows that company to represent the exact logic of its processes, as well as the exact subtleties of the underlying forces.

In addition, once we agree that risk needs to be properly represented, the tools need to be able to handle slightly more advanced objects like distributions of probabilities and, if possible, to generate natively probabilistic forecasts. Again, this is not something that many tools would provide out-of-the-box yet, but it is certainly a much-needed feature.

In a nutshell, selecting an optimization method and tools is in fact something that requires a deep understanding of the optimization that one wants to perform. The objective is not to select a solution (whether in-house or external) that would do the same thing but better, but rather that would be the best fit for the problem that the company is trying to solve. To quote Henry Ford's famous words: "If I had asked people what they wanted, they would have said faster horses". You're not looking for better safety stock or service level, you're looking for better profits.

"The introduction of optimization algorithms will in fact increase human control over the decisions, as the machines will be much better at combining the impact of the different forces that humans will have more thoroughly defined and fine-tuned to steer the solution in a rational direction."

Share your vision with your team

We have discussed the technical elements, but what about the human component? No amount of technology is going to be able to fully replace them, and if you want the technology to have any chance of improving your processes, you better get the humans on board.

9. Tactics is better left to computers, but strategy is a human's game

The words Artificial Intelligence are quite deceitful, in the sense that there is nothing dumber than a machine-learning algorithm. The machine will optimize based on the target that is set, without any regard for the validity or relevance of said target.

Fortunately, at a closer look, in the context of supply chain optimization, machine and humans are extremely complimentary:

- Humans are good at finding causes, while machines are not.
- Machines are good at analyzing complex correlations; humans are not.
- Humans are good at validating an overall picture coherence; machines are not.
- Machines are good at crunching a large set of data and variables; humans are not.
- Humans are good at defining complex problems; machines are not.
- Machines are good at solving complex optimizations; humans are not.

As a consequence, the wide-spread fear that computers may end up replacing humans to some extent and would lead to humans losing some degree of control over the decisions through a black box effect is largely a fantasy. On the one hand, responsibilities that may end up being transferred to machines are individually of low importance and are the ones for which humans are very ill-suited to begin with. On the other hand, the introduction of optimization algorithms will in fact increase human control over the decisions, as the machines will be much better at combining the impact of the different forces that humans will have more thoroughly defined and fine-tuned to steer the solution in a rational direction.

As for the so-called black box effect, it is necessary to clear one important point. One needs to make a very clear distinction between "what" the system is doing, and "how" it does it:

- "What" the system is doing should be made apparent, as much of a white box as possible. Of course, some aspects of it may not be trivial, and perhaps cannot be fully understood by everybody, but the principle of it should be explained and laid bare to the highest extent possible. This includes, first and foremost, the optimization metric used.

- "How" the system is doing it is another matter entirely. Requesting a white box on that aspect is essentially giving up on any advanced machine learning method as, in most cases, explaining a result is more difficult than generating it.

This does not mean that companies should just blindly trust a machine learning algorithm, but rather that they should acquire a good understanding of what the system is doing *a priori,* and judge if it is in line with the reality of the process and validate *a posteriori* the quality of the "how", based on the optimization metric output.

10. Change management

Compared to other industries, aeronautics benefits from notable advantages towards embracing the optimization approach advocated for in this paper. First, the relatively low volumes and high value of the parts considered in the optimization have led companies to operate with a low number of stock managers, who are not only skilled in stock management, but also in the business, technical and operational aspects of the problem. As such, they are a lot more likely to perceive the added value of such a system, as it will only take away the most mundane part of their tasks, and leave more time for the more high-level, value-added part of their activity.

Also, though the concept of risk is not always taken into account in the best way possible, aeronautics is an industry that is relatively mature when it comes to its understanding of the consequences of risk. As mentioned before, the crafting of the optimization metric is less painful in this industry than it might be in others, as many professionals, once presented with the method, usually find it easy to relate it to their business insight.

Finally, aeronautics is an industry that is very much driven by passionate engineers, and thus has had more contact with quantitative optimization methods than most industries.

Of course, it does not mean that changing old habits is going to be easy, especially since this approach requires challenging some of the most common success metrics used by different departments, and perhaps sometime, how incentives are calculated.

Therefore, it is highly desirable, in order to get acceptance from the teams, to have them involved in the strategic aspect of the optimization early in the process. First, they will bring their much needed experience of the reality of the company to steer the implementation of the new system and second, they will be able to feel that this system relies on a logic that is simply a more powerful and more holistic version of their own -one that still needs them at the wheel guiding the system through key strategic parameters.

In our experience, any solution using a fundamentally machine learning-oriented approach and trying to bypass the human factor described above in order to be as off-the-shelf as possible would struggle to get acceptance from the teams and would likely feel "alien" to the users.

Last but not least, you need to consider that the human factor will remain relevant over time. Its value won't disappear once the implementation of the new system is over. Supply chains - in aeronautics as in every other industry - evolve over time. Processes are not written in stone and the scope of activity itself will gradually change. Any modelization, which purpose is to represent reality, needs to evolve with it, thus requiring constant collaboration between the team in charge of the optimization solution, and the operations.

About the Author :

Simon Schalit is French Engineer from Cambridge University andthe École Polytechnique with 15 years of experience in process analysis and supply chain automation, notably in the aeronautics sector. As COO of Lokad since 2012, he has lead the development of revolutionary inventory approaches in collaboration with industry partners as Spairliners, Air France industries and MRO Holdings.