COLUMN

The total number of power transformers produced is around 20,000 units p.a., which sets the limit for the global market size for transformer components

Supply chain complexity in power transformer industry

The complexity of the supply chain in transformer industry is usually not well understood. This article aims to create a better insight into this area by first analyzing the characteristics of supply markets for power transformer industry.

Then the product characteristics are analyzed, and appropriate supply chain is defined. Finally, some of the methods for supply chain optimization are described.

1. Characteristics of supply markets for power transformer industry

Transformer component supply markets have very unique features, which are not similar to other industries. Let us try to describe these features:

- **Low volume business**: First of all, power transformer industry is not a high-volume business. If you consider that the total number of power transformers produced in a year is around 20,000 units, it is obvious that the global market size for transformer components is not in the order of millions of pieces. If a certain component is used as a one piece in a transformer, the global market size is then around 20,000 pieces. This restricts the volume leverage of the buyers.

- **Tailor-made product:** Power transformers are almost always a tailor-made product. Even if the customer orders the same transformers, the designers may still prefer to make a new design to optimize them based on the existing cost ratios of different raw materials. This enormously increases the number of variations for every part. For a good portion of transformer components, stock keeping is not possible. Consequently, the parts have to be produced "make-to-order" and they cannot be ordered before the design is completed. This shortens the available lead-time and increases the time pressure on the supply chain. Obviously, that has further negative impact on costs.

- **Small-sized supplier profiles**: Actually, a global market exists only for

some high value items like GOES, OLTC`s, HV bushings, etc. For lower value parts, the markets are local or regional. This limits the size of the companies. Typical transformer component suppliers are small, family-owned companies. This brings with it all the associated problems, like lack of a strong management structure, being dependent on one single person, risks related to succession, higher quality and delivery risks, etc.

- **Demanding technical specifications**: In general, the specifications on transformer components are quite demanding, which imposes another challenge. This creates relatively high barriers for potential new entrants. And it also makes it more difficult and time consuming for new suppliers to qualify for new supplies.

- **Customer-dictated component suppliers**: It is very common for transformer customers to specify the producers of transformer components. Sometimes it goes to the extreme where the customer accepts only one single producer for a certain component. This creates a de-facto monopoly and makes life extremely difficult for the buyers, especially if they do not have good relations with that particular supplier. Sourcing flexibility disappears, with negative consequences on costs and sometimes on availability.

For a good portion of transformer components, stock keeping is not possible, because they have to be produced "made-to-order" after the design is completed

- **Not enough suppliers in every region**: The supply markets for transformer components are far more consolidated than the transformer market itself. For global commodities, usually the number of suppliers is not bigger than handful. This reduces the level of competition. Supply markets show different characteristics in different regions. Europe and China are two regions where there are plenty of regional suppliers for most of the components. In contrary, North America, South America and Australia have few suppliers in each category and the level of competition is very low. Middle East has few local suppliers, but they have access to Chinese, Asian, Indian and European suppliers. India has a large supply base, but usually the maturity level is not high. In South-East Asia, there are a number of small local suppliers with relatively low level of maturity, but they also have access to European and Chinese suppliers. In general, it is possible to say that the level of competition in transformer component markets is lower than the transformer market itself.

- **Powerful suppliers:** In spite of being small, some of the transformer component suppliers can be quite powerful. This can be either due to low level of competition, end-customer pre-specifications, insufficient number of suppliers or simply reluctance of the organization to make supplier changes. The power balance does not allow the transformer companies to dictate their requirements to their component suppliers. Sometimes even the opposite happens and the suppliers may dictate their conditions to the transformer companies. Usually people coming from automotive industry have difficulty in understanding this environment.

- **Poor demand visibility**: This may seem difficult to understand when you think that it is quite usual for a power transformer factory to have an order back log of around 1 year. Someone who is not familiar with the business may assume that all the demand for the next year is clearly known. Unfortunately, that is not the case. First of all, even if the transformer order is

Typical transformer component suppliers are small, family-owned companies, with associated problems, like dependence on a single person, risks related to succession, etc

received, in order to place the orders for components, the purchasers need to wait for the design to be completed. In most cases, the final design is sent to the customer for approval. The design changes, either due to customer requests or correction of design mistakes are quite common. Then the production schedule changes are also quite common for different reasons. All these factors create a poor demand visibility and leave relatively short time for material supply.

- **Artisanal practices**: Power transformer is still a handcrafted product with low level of automation. Low volumes and tailor-made product nature make it difficult to justify the high investments for automation. This type of environment also creates a mindset, which accepts artisanal practices in procurement. Most of the modern supply chain optimization techniques explained in section 3 are not widely used in transformer industry. Many companies treat each transformer as a separate project and start the procurement process from scratch. They send RFQ's for every major component, collect offers from approved suppliers, handle the negotiations, place PO's, wait through the production time and organize individual shipment of each component. This is a lengthy process. For every power transformer, there are typically 50 - 100 component shipments from different parts of the world. It is nearly impossible to synchronize these shipments and assure that all of them arrive just in time. Production schedule changes increase the complexity further. Even when there are well-defined processes, ad-hoc practices are very common and deviations are the rule rather than exception.

- **Poor understanding of supply chain management concept:** Generally, supply chain management practices are not well-established in this industry. Many transformer companies do not have a supply chain management function, but rather a purchasing or procurement function and this is not only a matter of terminology. Without a fully authorized supply chain management function with the full support from the top management, nobody oversees the value flow through end-to-end supply chain.

- **Strong end customer:** Utility companies purchase roughly 70 % of the power transformers and typically each of these companies has large purchase volumes. Given the overcapacity in transformer market, utility companies have high power and usually have the capability to dictate their conditions to the transformer producers. This imposes further pressure on transformer industry and restricts flexibility.

2. Matching supply chain with product

After drawing the big picture of the characteristics of the supply markets for power transformer industry, let us try to analyze the supply chain, which is appropriate for such an environment.

Let us start with some theory.
A landmark analysis by Marshall L. Fisher [1] concluded that the choice of the supply chain should be dependent on the nature of the product. He categorizes the products as "functional/basic" or "innovative/complex". He has defined the criteria to differentiate between these 2 categories (Table 1). Let us go through these criteria for power transformers

Table 1. Functional versus innovative products: Differences in demand

Aspects of demand	Functional (Predictable demand)	Innovative (Unpredictable demand)
Product life cycle	more than 2 years	3 months to 1 year
Contribution margin(*)	5 % to 20 %	20 % to 60 %
Product variety	low (10 to 20 variants per category)	high (usually millions of variants per category)
Average margin of error in the forecast at the time production is committed	10 %	40 % to 100 %
Average stockout rate	1 % to 2 %	10 % to 40 %
Average forced end-of-seasom markdown as percentage of full price	0 %	10 % to 25 %
Lead time required for made-to-order products	6 months to 1 year	1 day to 2 weeks

(*) The contribution margin equals price minus variable cost divided by price and is expressed as a percentage and try to identify to which product category they fit.

- Product life cycle for power transformers is obviously more than 2 years (functional)

- Contribution margin is 5-20 % (functional)

- Product variety is extremely high; there could be unlimited number of variants since it is a tailor-made product (innovative)

- Average margin of error in the forecast is higher than 10 %, it is in 40-100 % range. (In this criterion, some interpretation is necessary. The author's examples are coming from consumer products area and he is referring to the forecast regarding the consumer's demand for the products. Since power transformers are always made-to-order, there is no need to forecast customer's demand. We refer to the forecast when we are trying to establish the demand for transformer raw materials and components) (innovative)

- Average stock-out rate: this one is also complicated. The author is again referring to consumer goods and he is describing the case where demand is underestimated and, as a result, not fully satisfied. For transformers, these should be interpreted as cases where component/raw material demand is underestimated and material shortage occurs. These cases are typically more than 2 %, but less than 10 %; somewhere in-between (functional/innovative)

- Average end-of-season forced markdown: this is a phenomenon related to consumer products and not relevant for power transformers

- Lead time required for made-to-order products: 6 months to 1 year (functional)

What conclusion can we derive from this analysis? It is not possible to categorize power transformers as either functional or innovative product; but they are rather a hybrid product, and have mixed features from both categories. They are not black or white, but rather in a gray area. This may seem surprising to many people. If you make a poll and ask the people

Table 2. Matching supply chains with products

	Functional Products	Innovative Products
Efficient Supply Chain	match	mismatch
Responsive Supply Chain	mismatch	match

The specifications on transformer components are quite demanding, which imposes another challenge and creates relatively high barriers for potential new entrant

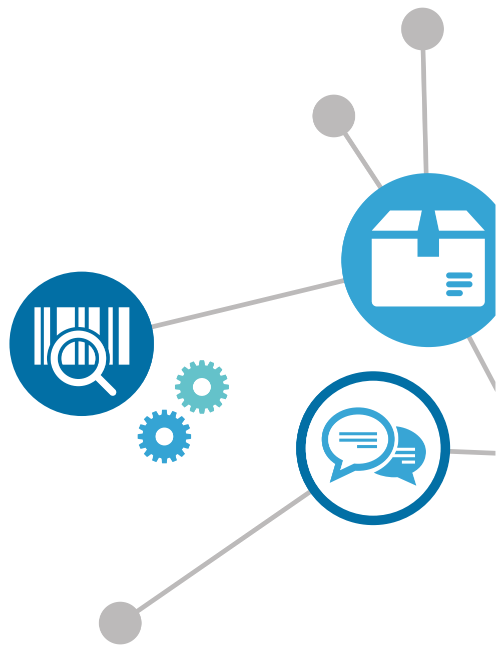
whether they see power transformers as a functional product or innovative product, the majority would probably classify them as a functional product. It is correct that power transformers are not fast cycle products like consumer goods or IT products and they don't evolve very fast, but being a tailor-made product makes them more complicated than purely functional products.

After this analysis, let us move to the next step. What do these conclusions tell us about the appropriate supply chain for power transformers? The author says that the correct match for functional products is efficient (cost-effective) supply chain and the right supply chain for innovative products is responsive (agile) supply chain (Table 2).

The detailed definition of efficient and responsive supply chains is given in Table 3, which should be self-explanatory. Other combinations between the product type and the supply chain are mismatches. A functional product with a responsive supply chain would not cover the costs and would be financially bleeding. An innovative product with an efficient supply chain will face frequent operational problems and would lose market opportunities.

The conclusion is that power transformers require a supply chain, which is both efficient and responsive. To combine these conflicting demands is the major challenge, which explains the chronic problems of this industry. The mismatch between the product nature and the supply chain is one of the major reasons for the low profit margins in this industry. One needs to find a compromise between efficient and agile supply chains by fine-tuning the right mix of these

It is very common that transformer's buyer specifies the producers of transformer components, sometimes going to the extreme accepting only one single producer



conflicting demands. It is like trying to walk on a tight rope. The complexity of the power transformers does not originate only from the product features, but from the market characteristics as well as explained in detail in the previous section.

3. Supply chain optimization methods

What tools and methods do we have to fine-tune the supply chain to make it both efficient and agile? How can we optimize the supply chain?

People usually take the existing supply chain as a given and do not even consider that there might be other ways of designing the supply chain. In most power transformer companies, supply chain management function either does not exist or they do not have a mandate to re-design and optimize the supply chain. This leaves supply chain optimization task without an owner and therefore the optimization does not happen.

As a general principle, any action, which reduces the complexity of the supply chain will reduce the supply chain costs and will decrease the supply and quality risks. The opposite of this statement is also correct. Anything that increases the supply chain complexity, will have a negative impact on supply chain costs and risks.

Now let us have a look at some of the potential techniques.

Standardization: it is a powerful tool to reduce the complexity of the supply chain. Unfortunately, it is not widely used in power transformer industry. Having a customized end product does not make it easy to drive standardization of the components. Obviously, standardization has to be implemented by designers and not procurement. However, without a strong drive from procurement function, designers are typically reluctant to standardization. They try to optimize each and every project and each and every component. They sincerely believe that they optimize the costs to the lowest levels by doing so and they generate enormous variations of components. Designers optimize using piece prices, which are static. Piece prices do not include the supply chain costs and risks, which are dynamic and may show fluctuations. By definition, supply chain costs and risks for non-standard parts are higher than for standard parts.

For any standardization project, the first important task is to decide on the priorities. Which parts should be targeted for standardization? This can be decided by analyzing the ease of standardization vs. the expected benefits from the standardization.

The first immediate benefit of standardization is the elimination of design costs

Table 3: Physically efficient versus market-responsive supply chains

	Physically efficient process	Market-responsive process
Primary purpose	supply predictable demand efficiently at the lowest possible cost	respond quickly to unpredictable demand in order to minimize stock-outs, forced markdowns and obsolete inventory
Manufacturing focus	maintain high average utilization rate	deploy excess buffer capacity
Inventory strategy	generate high turns and minimize inventory throughout the chain	deploy significant buffer stocks of parts or finished goods
Lead-time focus	shorten lead time as long as it does not increase cost	invest aggressively in ways to reduce lead time
Approach to choosing suppliers	select primarily for cost and quality	select primarily for speed, flexibility and quality
Product-design strategy	maximize performance and minimize cost	use modular design in order to postpone product differentiation for as long as possible

and time. If a part is standard, it does not need to be designed. But this is only a small portion of the standardization benefits. The bigger benefits will come with the change of the supply chain. It is possible to use much simpler supply chains (2-bin, consignment stock, etc.) for standard parts compared to customized parts.

The supply markets for transformer components are far more consolidated than the transformer market itself

Modularization: by creating standard modules, it is possible to create enormous number of combinations. One of the best-known examples of modularization in a different industry is Ikea. By using standard modules in different combinations, one can create enormous variation in the final configuration of Ikea furniture. One example, which would fit to this concept easily in transformer industry, would be control cabinets. One can define a number of standard modules to cover different functionalities needed in a control cabinet. Having the standard modules would enable the design of the standard supply chains for them, which would bring simplification and efficiency.

Vendor managed inventories (VMI): This method passes the responsibility of inventory management to the supplier. Based on the information provided by the user, the supplier plans and maintains an agreed inventory level, usually at the customer's site. The customer receives a higher level of service from the supplier and the supplier secures the business with this arrangement. The underlying assumption is that the supplier is in a better position to manage the inventory and fulfillment of the demand is improved at a lower total cost.

Consignment stock: is an arrangement between the supplier and the customer, where the supplier establishes a stock at customer's site and makes it available to the customer for consumption; but the ownership still stays with the supplier until it is consumed. The invoicing will be done based on the actual consumption. This can be seen as a special form of VMI.

2-bin system: This is simple, but foolproof system for inventory management. Two physical bins are placed at the point of consumption. In the beginning, both are full and once one of them is empty, the second bin is taken for consumption and the empty one is placed for a re-fill. Provided that the replenishment time is shorter than the consumption time of a bin, supply security is fully assured, and the administration of the system is very easy and efficient. Once the 2-bin system is created for an item, supply disturbances are completely eliminated. This is an example of a very efficient, low cost supply chain.

Insourcing: usually insourcing and outsourcing projects are initiated for cost savings purposes or as a solution to operational problems. However, insourcing and outsourcing could have a significant impact on the supply chain and usually this is not considered in business cases. The process should start with clearly identifying the target. Why are we doing this? What do we want to achieve? If we talk about insourcing, there is a general assumption that it would increase the control over the process. Unfortunately, that is not always the actual outcome. If one does not have direct experience with the process, which will be insourced, the challenges may be underestimated. One very important point to consider is the following. When we are buying the product from external sources, we can create benchmark, we can have competition, we can decide to switch suppliers. Once we insource, all these possibilities are gone. We are on our own. External companies have to survive by competing on the market. They have to make money; otherwise they will disappear. An internal operation does not have the same pressure. Even if the costs are high and the operational performance is low, that may not get the right attention from the management and they may survive indefinitely. These arguments are not listed here to discourage anyone from insourcing. It is important to be aware of these risks before a strategic decision is made and they need to be addressed properly. However, if there are no suppliers with satisfactory performance on the market and if it does seem realistic to be able to develop new suppliers in the foreseeable future, insourcing might be the right strategic decision.

Outsourcing: has its own challenges. Usually internal production processes are not well documented. Even the drawing may not be complete or fully correct. This may not create problems when the production is in house since the same people might be producing this product for many years. But when it is moved to a new location and done by new people, a lot of problems will pop up. And again, one has to be very clear on the purpose upfront. Are we convinced that the quality, lead times, cost will be at the right level? Do we have a long-term assurance of this? Is the supplier competent and experienced when it comes to the product? Will this bring a supply chain improvement or not? Or are we compromising the supply chain efficiency for a lower purchase price?

Late stage customization: Although this method is extensively used in some industries, its potential application areas in transformers are not very wide. One example might be keeping the stock of unpainted radiators and painting them at a later stage based on customers' requests. Another example might be given for HV bushings. Porcelain and a few other long lead-time items for some frequently used voltage levels can be kept in stock and the final assembly can be done very fast at a later stage based on the exact details. This will improve the responsiveness of the supply chain.

Many transformer companies do not have a supply chain management function, but rather a purchasing or procurement function and this is not only a matter of terminology

Order batch sizes: have a clear impact on the supply chain. Due to management pressure on the inventory levels, frequent deliveries in small batches are preferred. It is correct that this would reduce the inventory levels and help the cash flow. But we should see the full picture. The highest negative impact would be increasing the risk that one batch does not come out on time. Is this risk foreseen and mitigated? Then, each delivery triggers a full chain of process steps and paperwork, which increase the administration costs. If we look at the impact on the supplier side, if we are talking about an item produced with high level of automation with high set-up costs, ordering small batches will increase the cost of the product. It is important to see the complete picture to make the right decision and avoid sub-optimization. As a general rule, it would make more sense to restrict small batch size policy for high value items.

Single sourcing: is seen as a risk and therefore usually avoided by procurement function. From a strategic sourcing point of view, it is correct that there are serious commercial risks associated with single sourcing. However, it has a positive impact on the supply chain efficiency provided that the single source is selected very carefully and it performs very reliably. Having multiple sources increases product variability and therefore increases quality risks. Managing a supply chain with multiple sources is always more complicated than single source supply chains. Managing multiple sources requires more internal resources, which increases costs as well as opportunity costs.

However, if the company wants to benefit from the efficiency of a single source supply chain, the associated risks need to be addressed and mitigated. The main

risk is creating dependency, which can then be commercially exploited. Another risk is the deterioration of the performance of the single source originating from relaxed behavior due to lack of competition. Both of these risks potentially have negative impact on the supply chain. The best way to mitigate these risks is to assure that the relation is not a unilateral dependency but rather interdependency, which is structured within the frame of a long-term strategic partnership.

It should be obvious that this option cannot be applied in large scale. Companies have to be very selective and restrict this method to few, really strategic items/suppliers.

Sub-system suppliers: in this model, the customer switches to buying sub-systems/sub-assemblies instead of parts. One lead-supplier will be responsible for collecting the parts from the others, assembling and delivering them as a sub-assembly to the customer. This simplifies the supply chain. The customer will have fewer suppliers to deal with. All the parts in the sub-assembly will be synchronized to arrive at the same time, which would be impossible in case of separate parts. Any potential risk of mismatch of parts will be eliminated by the lead supplier as well. The overall efficiency of the supply chain will be improved in this model.

Modes of transport: also has a significant impact on the supply chain. The faster modes of transport (air transport) increase the speed and agility, but at the same time, they increase the cost. Contrarily, the slower modes of transport (sea transport) reduce the cost at the expense of speed and responsiveness. The weight and volume of the item, differences among the freight costs and criticality in the whole supply chain are important factors in making the right decision. In general, for bulky items coming from overseas, sea transport is the preferred choice. For items that are less than 50 kg, which come from overseas, airfreight is usually preferred.

Creating a supply ecosystem with suppliers in close proximity: this model is widely used in automotive industry. The advantage is minimizing logistic costs and delivery times, improving the communication and responsiveness. However, this model cannot be applied for power transformers on a large scale. There are several specialized components, which have to be sourced globally. Besides, for certain components, local suppliers may not be economical in high cost countries. However, this concept can still be applied selectively on a more limited scale. It would be an advantage to have a number of suppliers in close proximity, who can act very fast if they can offset higher costs with other benefits. A good example may be to have a tank supplier close to the transformer plant.

Contract manufacturing: This is a very popular method especially in electronics industry. There are very large international companies, which offer contract-manufacturing services to big electronic brands. It is possible to apply the same concept in transformer industry. Outsourcing windings, core cutting, core stacking during peak load periods are some examples. This can be applied in a more systematic way if the company keeps a base capacity in-house and outsources anything exceeding the base capacity. This method is especially useful if the business volume of the company is showing large fluctuations. It will avoid

The choice of the supply chain should be dependent on the nature of the product

having idle capacities, which would add to the cost. Having reliable partners is critical for success.

4PL (Fourth party logistics): usually, the competence level in logistics operations in transformer factories is low. There are not many experienced people in this area. This is usually perceived as an administrative/clerical task. This results in frequent operational problems and supply disturbances. In such cases, 4PL can be considered as a way for a quick improvement. 4PL is a newer concept. The idea is employing a specialized logistics company (4PL) and outsourcing the management of 3 PL (Third party logistics service providers) to them. However, the required efforts for implementing such a model should not be underestimated. Nobody should expect that when 4PL is called, all the logistics problems would disappear overnight. Besides, maturity and competence level of 4PL has to be carefully assessed and the whole transition must be organized as an important project with top management sponsorship.

Blanket orders: This is also a simple, but efficient method, which increases the supply security and creates commercial leverage. The buyer issues a blanket order to the supplier typically for an annual quantity. Then the deliveries are triggered by call-off orders. Buyer has to decide on a volume to which he is ready to commit. This should preferably be a safe percent of the forecasted quantity. Having a volume commitment will allow the supplier to produce the quantities more flexibly in order to maximize the capacity utilization. Mostly, the suppliers would be ready to offer commercial benefits in return.

Unfortunately, most of the companies do not have a blanket order process and they lose the potential benefits of this method.

Capacity reservation: this is a simple but effective method to increase supply security and reduce response times. It allows the buyer to notify the supplier about a future demand before the full details of the demand are described. In return, supplier reserves capacity and waits for the full details before starting the production of the component. Especially in tight market conditions, this could act as a lifesaver. In order to apply this method smoothly, a well-defined process describing the responsibilities of each party is critical.

ATO (Assemble to order): ATO model requires a number of standard designs, which will be assembled based on customers' orders and it is an alternative to the current dominant business model of ETO (Engineer to order) in the power transformer industry. This model allows a faster business cycle since design phase is eliminated. And since all the components are already defined, supply chain can be organized in more standard ways, which would ensure low cost and high speed. Based on today's market conditions in the industry, it would be impossible to switch to this model for the whole volume in a factory; but a certain part of the product portfolio can be switched to this model in order to capture the corresponding benefits.

Long-term contracts: create a more stable supply environment, which would support efficiency of the supply chain. They allow the definition of the rules of the game for the buyer and the seller and avoid ad-hoc negotiations, which will take time and might cause friction and supply disturbances.

Parallel processes instead of serial: Typically material planning and procurement processes in transformer companies (like many other industries) are serial. One process does not start before the previous process is finished. "One single process at a time" is the motto. The

Conflicting requirements for the supply chain to be both efficient and responsive is the major challenge, which explains the chronic problems of this industry

customer completes the design, makes the production and material planning, issues purchase requisitions, supplier is selected and PO is issued. Then the processes on the supplier side start. Actually, it is possible to run several processes in parallel and compress the whole supply chain to a much shorter time, which would increase the responsiveness.

Exclusive supply relations: this is a very popular method especially in apparel industry. However, it is rarely used for transformer components. The idea is to ask a supplier to work exclusively for one customer based on a long-term contract and defined conditions. The advantage would be in receiving a very high service level and responsiveness from the supplier. In return, the customer assures a certain agreed business volume to the supplier. With this arrangement, the supplier can eliminate marketing expenses and can rely on a uniform loading, which allows him to use his capacity efficiently. This allows the supplier to reduce his costs and offer competitive prices to the customer. It is an interesting example of creating an economic and responsive supply chain. The exclusivity is normally not mutual. By allocating the base load to the exclusive supplier and sourcing the fluctuating load from other suppliers, the user can assure a smooth execution of this model.

The pre-requisite for this model is mutual trust between the supplier and the customer.

Low cost country (LCC) sourcing: has been a very fashionable term. For labor-intensive items, moving to low labor cost countries may bring impressive cost savings. However, the impacts on supply chain should not be ignored. For Western countries, buying from Asia typically adds 5-6 weeks extra transportation time, which reduces the responsiveness of the supply chain. Besides, this creates a more complex supply chain and increases the risks. It would be wise to invest a smaller portion of the savings into the measures that would offset this negative impact, like intermediate warehousing, consignment stock, etc.

Sharing real time planning and production information with the suppliers:
One of the basic requirements for a collaborative supply chain is sharing information among the supply chain partners. The bullwhip effect demonstrated in beer game is a good example of the consequence of not fulfilling this requirement. A further and more advanced step of this concept would be sharing information in real-time and creating the mechanisms/systems to assure that. Defining some of the critical suppliers as "internal workshops" in your ERP system and allowing all parties to access planning and work floor management data in real time would create a very efficient and fast collaborative supply chain.

4. Last words

The supply chain optimization methods listed above should be seen as a toolbox, which can be used by selecting the appropriate method matching the case and purpose. If applied in the right occasion with the right competence, they will help to fine-tune the supply chain according to the business needs.

They are not specific for transformer industry; they are general methods and can be applied in many industries. Some of the readers from other industries may find some of them to be very relevant for their problems.

On the other hand, these methods are not academic, textbook concepts, but proven real life methods. The author has experience in using all of these methods in transformer industry in different occasions.

A question about distribution transformers may be raised. Where do the distribution transformers fit in this picture? In comparison to power transformers, distribution transformers, especially in lower power ratings, are more standardized products. But there is a gray area, where these 2 products overlap, which is called large distribution/small power transformers. So, depending on the range, some of these points may apply partly or totally to distribution transformers as well.

As a last word, recognizing the supply chain challenges in transformer industry and addressing them with high priority, non-traditional thinking and creativity and full management support might be a way to overcome one of the historical problems of the industry and achieve a decent profitability even in depressed market conditions.

References:

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