

Supply-Chain Fragility and Black-Swan Events

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Overview

Now we are in the midst of what will probably be another forever war, Black-Swan disruptions to our supply chains will become more frequent. In this paper we will look at what appears to be a Black-Swan event for make-to order-manufacturers and industrial distributors, namely you go to pick the parts for a job or a shipment and some are unexpectedly missing, causing a failure to make or ship products needed by our customers. This in itself will probably cause a cascade of Black-Swan events.

In this paper we look at likely causes of such Black-Swan events and possible mitigations, including using intelligent agent technology.

Introduction

I have been reading the books “The Black Swan” and “Antifragile” by Dr. Nassim Taleb¹ and thinking about how these apply to manufacturing supply chains, especially in times of war.

Up to a few weeks ago, before the latest Israeli-Iran War, our focus was on Lean supply chains, minimizing product costs, and optimizing Just-in-Time delivery. Now the focus has shifted to Robust supply chains, where we seek to answer the question of “How do we deliver products at all to customers, when our supply-chains are shot to hell?”.

This is especially true for make-to-order and engineer-to-order products where it is impractical to keep enough inventory on hand to outlast the duration of the war, bearing in mind that the Vietnam war lasted 19 years from the first US Marine expeditionary force landing at Da Nang to the fall of Saigon!

¹ Published 2010 and 2014 by Random House. Available in Paperback from Amazon.com

Here the work of Dr. Nassim has a lot to tell us, as supply chain disruptions, especially in war time, tend to be unexpected “Black Swan” events. These events cannot be predicted in advance, as they are in Donald Rumsfeld’s words “Unknown, Unknowns”. This makes planning and scheduling of materials flow almost impossible as there are an infinite number of possible black-swan events that could occur.

Fortunately, the work of Dr. Nassim can help a lot, in two possible ways:

1. Understanding that supply chain failure lies not in failure to be able to ship products at minimal cost in a few days but in the failure to ship product at all, within an acceptable time frame to the customer.
2. Understanding that black-swan events cause disruption at the points where our supply chains have fragility. Thus, we can mitigate the effect of these black-swan events by examining each link in our supply chains that have fragility and devising work-arounds in the case an unforeseeable black-swan event could impact that fragility.

Thus, we are able to reduce the problem of trying to make guesses about an infinite set of possible black-swan events, which may occur in the future and might directly or indirectly impact our supply chain, to the problem of making sure that each link in our supply chain has enough redundancy to survive possible black-swan events.

In this white paper we also look at how intelligent-agent technology can be used in make-to-order manufacturing and industrial distribution to increase supply-chain robustness and prevent failure to deliver customer orders when needed.

It should be noted that the intelligent-agent technology described here is very different from that used by regenerative AI chatbots, such as ChatGPT, which use self-adapting statistical matrix correlator methods and require large training sets of example data.

These algorithms cannot be used in these cases to predict or manage black-swan events, as black-swan events are by their nature rare and unknown until they occur, thus precluding the development of large sample training sets. Also, as the financial community is fond of saying: “Past performance does not guarantee future outcomes” (except that they will take their fees no matter what happens ☺).

Fragile Supply-Chain Links

The starting point for this paper is the paper² “A Tariff Avoidance Strategy for US Manufacturers” that I wrote in September 2025, where we looked at how to optimize supply chains to minimize the cost of Tariffs. Now all that has changed as we are forced to confront fragility issues.

In that paper, we looked at the example of making a smart electronic controller for furnaces. We discussed how components, such as circuit boards can be sourced inexpensively from Vietnam and the metal cases, damper motor assemblies, and other such components from Mexico. Here, the cost of outsourced components is low, as are the tariffs paid. But add a US made

² See www.SmartOpsMgt.com, Educational Resources/White Papers link at bottom of web page.

microcontroller chip to the board and add some US designed software and the manufacturers can sell this controller for hundreds of dollars in the USA with minimal tariffs.

But now all of that has changed!

Let us first look at some examples of how we can make the external supply chain more robust for this manufacturer of semi-custom electronic furnace controller:

1. The aluminum chassis and case – comes from Mexico. Supply could be disrupted by border closings, trade disputes, and cartel activities. Backup plan is to make it locally in the USA. In support of this plan, stock sheets of aluminum in USA and have backup supply contract in place with local sheet metal shop.
2. Electronic controller board – comes from Thailand. Comes by container ship through Red Sea, as would any alternative from Asia Pacific producers. First line of defense – air-freight boards – but still subject to outbreak of war in Pacific basin. Next line of defense – have a stock of PC boards (PCBs), without components for controller, stocked locally. Then make boards locally as needed in times of crisis. But this approach needs supply of electronic components – preferably available from two or ideally three distributors in USA.
3. CPU Controller Chip – already stored locally. Do not rely on distributor stock for this critical component. But, if supply is problematic, have PCB designs for two alternate controllers, from sources with different supply chain vulnerabilities, in local stock.
4. Components such as relays and capacitors, which are normally ordered from local or national distributors. Be aware of the distributors supply chain vulnerabilities for the components that you use and have alternative replacements selected and tested before the distributor responds to an order with an unacceptable backorder delivery schedule.

Note that we are not trying to maximize “Lean” or to minimize cost, either in engineering or production. But we are trying to be smart about this. Our backup plan is not to simply keep a large stock of the parts we need to make all possible variations of our products. We do need enough stock on hand to cover the time period to put a backup plan in action but, especially for make-to-order manufacturing or engineer-to-order projects, we do not need to keep months or years of stock on hand for all the possible product variation that our customers could possibly order.

In addition to this, we need to “harden” our manufacturing plant and distribution warehouse operations against fragility. Some examples include:

1. Have a military-grade backup diesel generator for the facility to maintain operations in case of power failure (and test run it at least once a week). With an aging electric grid, the transition to renewables and the reduction in base-load power grid generation, in combination with climate change events, rolling blackouts will become more frequent.
2. Do not rely on the availability of the Internet for operations tracking and management, including job, inventory, receiving and shipping tracking, planning and scheduling. We are seeing increasing outages, both in frequency and duration, in Internet availability as processing gets concentrated in large, power-hungry data centers, some of which are in

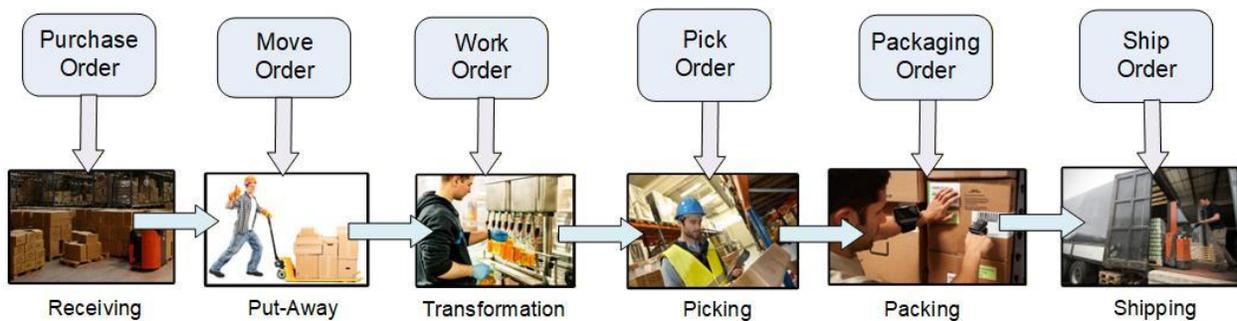
conflict zones, and communications channels get overloaded. Instead rely on local computers, which are plugged into uninterruptable power, can run autonomously, and which can communicate with Cloud-based ERP and other systems, when the Internet is available.

3. Cross-train production people and materials handlers, so that production and distribution activities are not dependent on a single person. Also automate real-time planning and scheduling of jobs and materials movement so that production people and material handlers are not reliant on the immediate availability of their supervisor to decide what they should do next.
4. Implement technology that will alert managers when supply chains are breaking down before they become a crisis. Black swan events have a way of sneaking up on supply chains and finding their fragilities. These intelligent agent systems can give managers enough warning before failure occurs to activate the backup plan in an orderly manner, rather than as a crisis panic activity.

To paraphrase Ernest Hemingway in his 1926 Novel “The Sun Also Rises” - supply-chain failure happens slowly at first and then all of a sudden.

The Usual Process

A typical make-to-order manufacturing plant or a distribution warehouse performing secondary operations runs on a series of orders to receive and put-away raw materials, transform these into intermediate and finished products and then to pick, pack and ship, or possibly install these products.



In many smaller and mid-sized make-to-order operations, these orders are generated manually, often as Excel spreadsheets, based on customer orders or drawings based on customer orders. In larger organizations, some or all of these orders are generated by the organization’s ERP system.

For smaller organizations, raw materials Inventory may be tracked using an Excel spreadsheet or a simple Inventory Tracking system where the quantity of materials entered and withdrawn is recorded. For larger organizations, with an ERP system, the quantity of each item in stock is recorded as an addition when received against a Purchase Order and reduced, by a process known as “back flushing” when a product is shipped to a customer, based on the Bill of Materials (BOM) of raw material parts for that product.

Usually customer orders, when they arrive, are converted into work orders and (sometimes) ship orders, either directly or through engineering, which produces semi-custom product designs,

complete with needed BOMs. From these, any special raw materials or purchased sub-assemblies are then handed to the materials manager to be ordered for that job.

The materials manager is also responsible for periodically checking on common stock levels and ordering more input materials to maintain a safety stock of each part.

Parts are ordered from the usual suppliers on Purchase Orders and are entered into inventory when they arrive.

The work orders are scheduled through production with an appropriate allowance in time for the delivery of any special parts. Production workers then record the withdrawal of parts from inventory as they need them for work order operations.

After proceeding through a sequence of operations, the resultant products are either shipped immediately to customers or placed in the finished goods warehouse, to be picked, packed and shipped with other semi-custom products and some common stock, according to a scheduled ship order.

This is the normal process; it even has one or more SOPs (Standard Operating Procedures). So, what could possibly go wrong?

A Tale of Woe

I was sitting in the office of Joe, the production manager of a manufacturer of fire suppression systems. Joe had just finished telling me that he didn't need our real-time operations tracking system as his Oracle ERP did everything he needed. Then there was a knocking on Joe's office door and a worried looking Mario, who was one of Joe's production workers blurted out that they had run out of tubes of epoxy.

Now this was serious, as they could not ship fire suppression systems without first coating the controller boards with a special fire-proof epoxy, which took about 6 weeks to reorder.

Joe immediately turned to his computer terminal and typed in a few words, then turned back to Mario and said, with great certainty, see our Oracle ERP system says there are 19 tubes in stock. To which Mario responded but the cupboard where we keep them is empty.

Nonsense said Joe. Let us go see. And so, Joe and Mario walked down to the production area, followed by me and a few other people who also wanted to see what was going on. But when we arrived there and all stared at the cupboard, it was certainly empty.

Mario also explained that when they took a tube from the cupboard, they took a KanBan card from the card holder inside the cupboard and placed it on their supervisor's desk. Mario's supervisor was then supposed to enter the inventory withdrawal into their Oracle ERP system, which would automatically reorder more tubes, when the stock fell below a minimum. And, Mario's further explained, you can see we did our job as there are no more KanBan cards in the card holder.

So, what was by now a small crowd of people, headed into the supervisor's office where, on his desk, set a stack of KanBan cards. When asked whether he had entered these into the Oracle system, the supervisor answered no, he was too busy taking all these courses on Lean manufacturing, which were mandated by corporate HR, to have time to do data entry!

And so, the plant had to shut down for 6 weeks, until they could get more tubes of fireproof epoxy. This was truly a Black-Swan event that could have been mitigated by attention to points of fragility in their process.

Points of Fragility in the Usual Process

Usual processes, even when accompanied by an SOP, are a simplification of all the actions that have to take place and usually ignore what to do when actions with conflicting priorities, each requiring access to the same limited resources, have to take place at the same time. Or, actions that needed to be taken days or weeks ago, did not happen or happened too late. Time is often a critical factor in Black-Swan events!

Two major points of process fragility for a typical make to order manufacturer are as follows:

1. Undetected out-of-stock of common parts used in many products.
2. Unexpected late delivery of custom ordered parts for a job.

These typically result in “undetected” out of stock parts, that is until someone goes to pick the parts for a job, work order operation or shipment and discovers that there are not enough parts in stock.

There are a number of reasons for this. One of the biggest reasons is using the backflushing capability of an ERP system, automatically reducing inventory counts according to the bill of material (BOM) for the parts shipped. With this method, parts are physically withdrawn from inventory long before they are electronically withdrawn from inventory as products may not be shipped for weeks after they are made. As a result, parts may not be reordered in time to replenish inventory when needed.

Another reason is failing to accurately account for materials scrapped in the manufacturing process. This can cause ERP backflushing errors, especially when BOMs do not include expected scrap or wastage. It can also occur when materials recorded as consumed on a work order operation are based on expected values, rather than the actual materials consumed.

One organization thought that they had “lost” nine big rolls of paper, valued at \$90,000 per roll, when, in fact, this was simply consumed as unrecorded scrap in their manufacturing process.

For this reason, most organizations periodically “take inventory”. But, with a standard inventory tracking system, which simply tracks the total counts of parts, this requires stopping production and all entries and withdrawals of inventory, while inventory is taken. As a result, this is only done infrequently, such as at year end, because it interrupts production and distribution operations. As a result, the discrepancy between the values shown in the inventory tracking system and what is physically in stock accumulate over time.

Even worse, inventory demand is a time dependent function. I might have 19 widgets in stock but with two jobs to run, one needing 15 widgets and one needing 10 widgets to make. According to the inventory tracking system, I have enough materials in stock to run either job when checked alone before issuing the work order or ship order. So, I pull the materials for the first job or shipment leaving 4 widgets in stock and, if I don’t replenish the inventory in between, I will not have enough widgets in stock to run or ship the second job.

Another major fragility is in ordering special parts for a job from an external distributor. This is the way it typically goes: You order the parts, you get an order confirmation that the parts will be delivered in 3 days, and then you assume that the distributor, who has always been reliable, will deliver the parts on time and so you forget about them. That is until you go to use or pick the parts next week, only to find that they are not there.

This can be because:

1. A delivery mistake. Parts do get lost or delivered to the wrong address or put on the wrong truck.
2. The dealer's inventory system did not accurately reflect their physical inventory and so they were unable to ship the parts when planned. They sent you a belated back-order notice but this was sent by postal mail and did not arrive for another week or was ignored because it looked like junk mail or a junk Email.
3. Parts got stolen from delivery truck or the delivery truck had an accident or some other Black Swan event occurred.

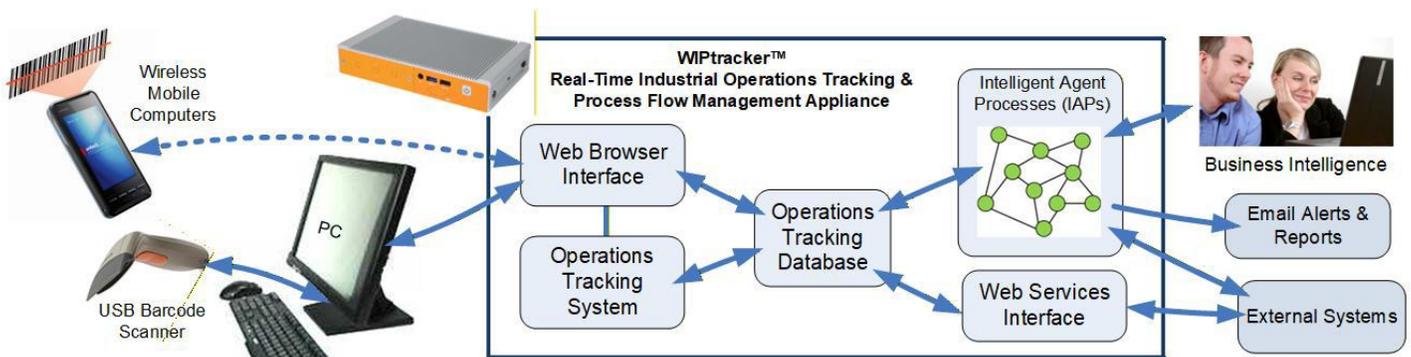
Other possible sources of our Black Swan problem are

1. Parts are taken for some unplanned process, such as repairing units or for engineering projects.
2. Parts are used as substitute parts for another job or project when shortages occur.
3. Consumption of parts on work order operations is not correctly recorded, such as entering 9 or 999 instead of 99 parts withdrawn from inventory.
4. Parts are "lost" by storing them in overflow locations in a warehouse and then forgetting about them.
5. Rolls, reels and sheets of material, or other dimensioned material are pulled from stock for a job and then left over material is not correctly.

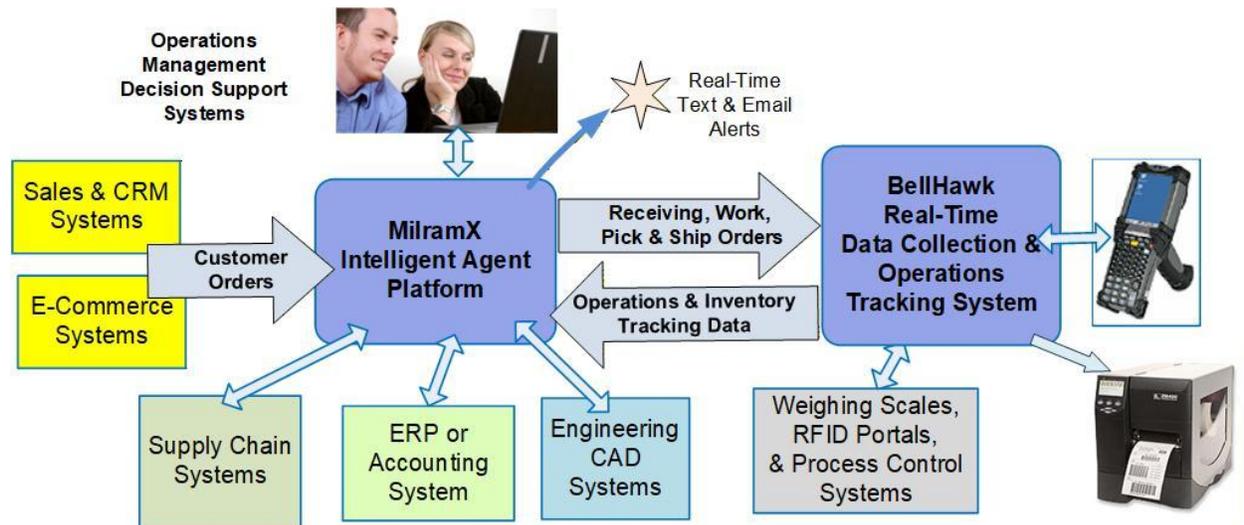
There is also a myriad of other possible causes of missing parts, some of which we can foresee and other that we cannot because they are caused by other Black Swan events.

We have already discussed how we can reduce the fragility in our external supply chain by using alternate sources of supply. In the next section, we will look at how we can use intelligent agent technology to get advanced warning of our black-swan event occurring and to mitigate the effects.

Intelligent Agents to the Rescue



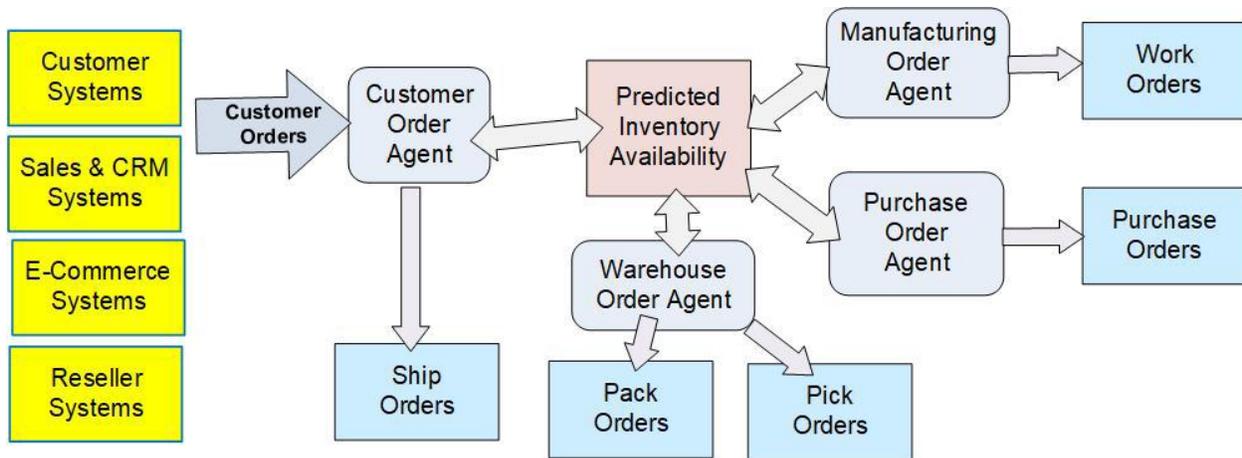
The comments in this section are based on a WIPtracker™ configuration, as shown above, but apply equally to other similar intelligent-agent based configurations. WIPtracker is part of the SmartOps24x7™ software suite, distributed by SmartOpsMgt LLC. Please see www.SmartOpsMgt.com for details.



With WIPtracker there are two major solution components:

1. A BellHawk data collection, job and materials tracking system.
2. A MilramX intelligent agent platform, with periodical scheduled intelligent agent processes that interpret data from one or more sources to generate information that is sent to other systems or as Email alerts to people.

When a Purchase, Work/Manufacturing, or Shipping Order is received or entered into BellHawk, BellHawk uses this to maintain a table of predicted inventory levels for each part in stock. It does this by starting with the current inventory in stock for each part and then adds planned receipts of material against POs (purchase orders) or the making of parts against work orders. It then subtracts the projected consumption of parts on Work Orders or through planned customer shipments. This is done on a time-tagged basis with each planned addition or subtraction tracked by date.



In many cases this process starts with the electronic receipt of a customer order and the resultant entry of a ship order, with line items into BellHawk. An intelligent agent can then periodically examine the predicted inventory and generate work-orders, as needed, to make the final products, if there are not enough in stock.

The entry of the work orders will then reduce the available predicted inventory based on the BOMs for the products, as will the entry of ship order line items for stock parts. Another intelligent agent can then periodically examine the quantity of purchased parts in stock and automatically issue corresponding purchase requisitions, typically to an ERP system, for the needed parts.

This predicted inventory process is layered on top of real-time data collection using barcode or RFID scanning so that materials added to, or withdrawn from inventory are recorded in real-time.

This process eliminates several sources of fragility caused by making or ordering too small a quantity need for customer order shipments based on faulty assessment of available inventory:

1. Errors in physical inventory due to delayed recording of physical inventory changes such as use of ERP Backflushing or simply delays in manual data entry of changes recorded on paper forms.
2. Errors due to using current physical inventory rather than predicted inventory in making decisions about how many parts to buy or make and when.
3. Not allowing for the same parts being needed by multiple jobs that are scheduled to run at the same time.

These problems are exacerbated when intermediate stock parts are made to be used in multiple make-to-order products. Some organizations go as far as to use separate raw materials stock rooms and intermediate materials “supermarkets”, whose shelves they keep stocked using a KanBan card system. But, in general it is much simpler to allow BellHawk’s predicted inventory tracking, combined with MilramX intelligent agents to propagate backwards from Customer Orders, through needed intermediate materials that need to be made, to POs for materials to order.

Another complexity arises when make-to-order parts need to go through engineering to be designed before BOMs can be generated and work orders issued. Again, this process can be augmented by intelligent agents to minimize “intelligent grunt work” data entry into multiple systems at appropriate times in the process.

In most Engineering departments the drawing BOMs use the manufacturer’s part number for readily available parts. But what happens when the specified part is not available within the delivery time required by the customer, as the BOM part for a Work Order is no longer available.

BellHawk has the ability to track substitutable parts from other suppliers for parts specified on a work-order BOM. This allows these parts to be recorded into a work order instead of the original part. Or a completely different BOM specified, if needed for a specific work order.

Many events can be handled automatically by intelligent agents, such as generating work-orders or ship orders for standard products. But, as the situation gets more complicated, requiring expert general knowledge, then the agents are programmed to send alert Emails to a person to sort the issue out, such as which parts to substitute for which unavailable parts.

These alert messages are also used to alert managers and their staff if parts ordered from an external supplier have not arrived when expected. They can also be used to alert managers when work orders have taken too long to run or materials needed for a ship order are predicted not to be available when needed.

A final comment on reducing fragility is that unlike most inventory tracking systems, BellHawk tracks individual containers of material, just like FedEx, UPS and Amazon, and not simply the quantity of each material at a location. This results in much improved accuracy in the real-time tracking of inventory as well as the ability to frequently check on inventory.

Commentary

As Dr. Talib stated, we cannot predict all the possible Black-Swan events that could happen. But we can use a mix of alternate suppliers and intelligent agent technology, such as WIPtracker, to mitigate their effect on our supply chains and our ability to ship products within a reasonable time frame to our customers

Author

This white paper was written by Dr. Peter Green, who serves as the Technical Director of a number of software companies. Dr. Green also consults to manufacturing companies on the application of real-time intelligent agent systems to improve their manufacturing and supply chain operations.

Dr. Green obtained his BSC (Hons) in Electrical Engineering and his Ph.D. Degrees in Electronics and Computer Science from Leeds University in England. Subsequently Dr. Green was a senior member of technical staff at Massachusetts Institute of Technology and a Professor of Computer Engineering at Worcester Polytechnic Institute.

Dr Green is a Systems Architect who is an expert in using real-time artificial intelligence methods to implementing real-time operations tracking and management systems for industrial organizations. He has led the implementation of over 100 such systems over the past decade.

Dr Green also led the team which developed the SmartOps24x7 real-time artificial intelligence software platform and the BellHawk operations tracking software.

For further discussion, or to send comments, please contact Dr-Peter-Green@SmartOpsMgt.com.

For More Information

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