Supply Chain Risk Management

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A typical car manufacturer on average assembles ~10 cars per minute. Each car consists of tens of thousands of mechanical, electronic and software components produced and supplied by a few thousand companies spanning the globe. An event in a far corner of the world could easily affect component suppliers in another part of the world, propagating the impact through the whole supply chain, causing manufacturing delays and affecting equipment readiness. Today we are seeing the huge economic effects as this plays out with the current semiconductor shortages.

"Traditionally, in supply chain planning, as in most other areas, process trumps technology. A company designed its business process and then looked for technology to enable it. The evolution of technology, therefore, followed process evolution. Technology now trumps process." According to Gartner[1]. "To have a competitive advantage in Supply Chain Planning, a company must figure out how to embrace these innovations into their Supply Chain Planning roadmap."

Franz, employing its decades of experience in Artificial Intelligence (AI), Machine Learning (ML) and Semantic Graph Database technology, develops and deploys applications to solve complex problems in supply chain management, including uncovering and preventing risks, automate onboarding, enable rapid identification of alternate suppliers to prevent delays, and uphold compliance needs. This allows customers to focus on product development and sustainment effort, while knowing that all supply risks are rapidly identified and future risk predicted with the AllegroGraph platform from Franz.

The Incessant March for Efficiency

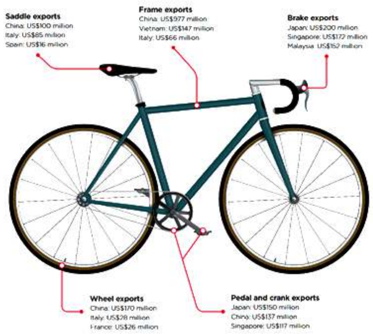
Over the last 3 decades, companies all over the world have endeavored to reduce production costs and improve product performance by adopting the following practices:

- Outsourcing production to lower cost countries
- Single sourcing to better control quality of advanced product components
- Employing just-in time deliveries to reduce logistics expenses
- Maintaining lean inventories to save carrying costs

The rapid globalization over the same period provides the infrastructure to make such practices practical. As a result, supply chains for materials, components and even finished products have become ever more complex. Here is an example of assembling a simple bicycle in the US.

[1] "Hype Cycle for Supply Chain Planning Technologies 2020", Gartner Research, November 2020

Almost all its components are supplied by multiple vendors from abroad. The 8 top importing countries include China, Japan, Singapore, Italy, Malaysia, Vietnam, France, and Span.



Top Exporting Countries of Bicycle Components to US (million $)						
	Saddle	Frame	Brake	Pedal	Wheel	TOTAL
China	$100	$977		$137	$170	$1,384
Japan			$200	$150		$350
Singapore			$172	$117		$289
Italy	$85	$66			$28	$179
Malaysia			$162			$162
Vietnam		$147				$147
France					$26	$26
Span	$16					$16

If the supply chain for a simple bike involves many 1st-level vendors from 8 countries, imagine how many vendors from how many countries are providing components for producing and maintaining a jet aircraft today.

Major Supply Chain Risks

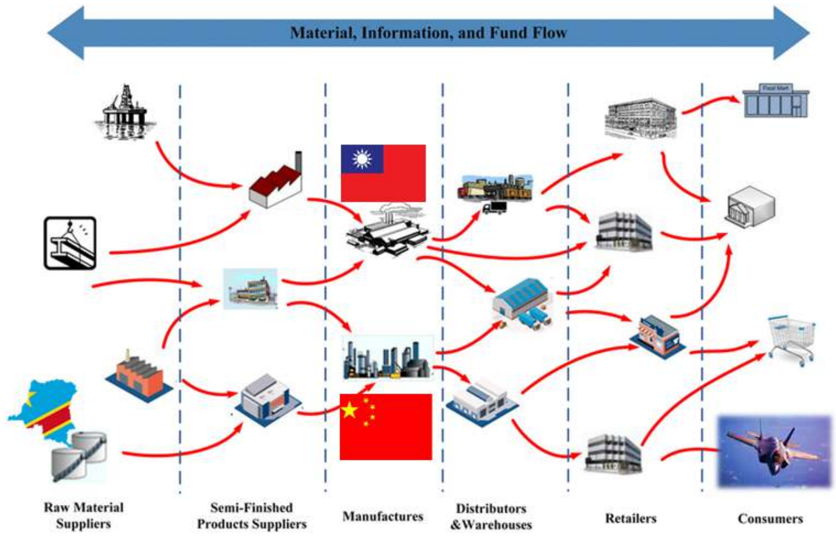
With today's large-scale outsourcing and offshoring comes major risks to the supply chain.

- Offshore outsourcing to lower costs – Little control over supplies during conflicts or emergencies (e.g., shortage of PPE and Covid testing chemical agents)
- Single sourcing to control quality – Single point of failure (e.g., semiconductor shortage has stopped car manufacturing)
- Just-in time deliveries to reduce logistics complexity – Subject to shipping disruptions and delay
- Lean inventories to save carrying costs – Limited operating/sustainment capacity

Consequently, the current supply chains have become ever more brittle and riskier, which is a dangerous exposure from a national security point of view. For example, The Democratic Republic of Congo (DRC) is by far the world's largest producer of cobalt, accounting for roughly 60 percent of global production, which is a critical raw material for alloys, batteries and magnetic materials needed for manufacturing electric cars, cell phones and many other advanced equipment. Congo happens to be located in a volatile region of Africa and its government is considered weak and corrupt. Any adverse event in Congo could disrupt cobalt supply and have a significant ripple effect throughout the supply chain, affecting production of critical machine components.

Similarly, the recent shortage of semiconductors (dominated by TSMC in Taiwan) has literally stopped global car assembly for months. Furthermore, "the global supply chain is an intricate ballet of container ships, airplanes, trucks and trains. The coronavirus pandemic threw it out of whack"[2] resulting in product shortage or price inflation.

[2] "Why Is the Supply Chain Still So Snarled? We Explain, With a Hot Tub", By Austen Hufford, Kyle Kim and Andrew Levinson, The Wall Street Journal, Aug. 26, 2021



A schematic depiction of the convoluted supply chain dependency

Supply chain risk is even more inevitable and serious for defense products because many of them have a very long sustainment period. For example, the F-15(E) fighter jet was first produced in 1972, and is still in service today in the US, Japan, Saudi, and Israel. Any number of supply chain risks are bound to happen during a long sustainment period of the jet and all its supporting equipment, impacting their war-fighting readiness.

Current Supply Chain Risk Management

To mitigate risks to critical supply chains, we need to use modern technology such as AI to proactively manage potential risks, especially in today's volatile geopolitical environment. Supply chain resiliency depends on constant risk identification, assessment, monitoring and response. However, most supply chain risk management (SCRM) systems rely too much on guidance and policies, which, while important, are not enough. These systems:

- Lack visibility: No complete picture of the supply chain
- Contain limited granularity of data (perhaps only one level deep)

For instance, European car manufacturers faced an expensive and hugely disruptive supply chain issue when the US imposed sanctions on the Russian aluminum giant United Company Rusal in April 2018 in retaliation for Moscow's interference in the 2016 U.S. election. Rusal happens to make a specialized aluminum product that was vital to European car manufacturers, who suddenly had to worry about paying vast fines if they continued doing business with Rusal. Backlash from the European governments eventually forced the US to backtrack and lift the sanctions. This embarrassing episode could have been avoided if the US has a complete visibility to its critical supply chains.

One of the reasons for the inadequacy of the current supply chain risk management systems is technological mismatch. For example, a car contains tens of thousands of components, many of which are shared by many different car models. furthermore, a single component may be produced by many suppliers in different countries, and each supplier supplies many components to different car manufacturers. These many-to-many-to-many relationships cannot be easily modeled with rigidly linked relational tables. While supply chain is better modeled as a connected graph, most existing SCRM systems are based on relational tables. Additionally, the supply chain evolves continuously, requiring constant updates with new information and data model revisions. Without complete visibility, it greatly hinders the effectiveness for supply chain risk management.

Furthermore, many legacy supply-chain, inventory or logistics systems tie closely to the business processes of the operating organizations. It is impractical to replace them with brand new, albeit better, systems. For large organizations (such as Defense and multinational companies), the number of units and systems involved can be huge and span the globe.

A New Supply Chain Risk Management (SCRM) System Architecture

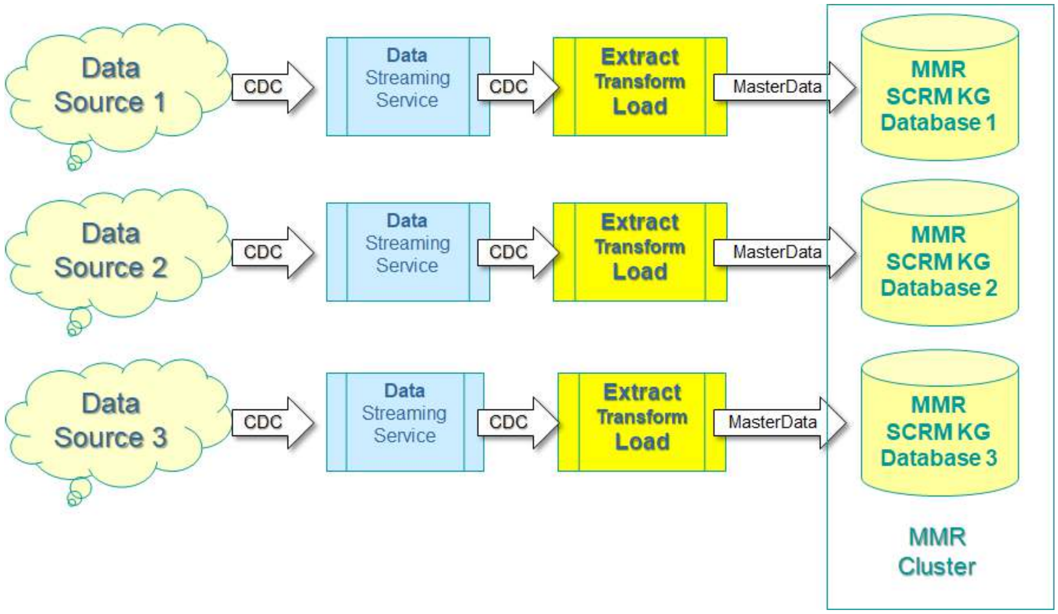
To perform risk analysis, we first must collect and aggregate the silos of data from all relevant supply chain systems. While data continues to get updated 24/7, not all information in the database of operation systems is needed for risk analysis. Only certain product configuration and supply chain data (the master data) need to be extracted from existing operating databases for the SCRM system. This master data may be extracted from many existing inventory, supply chain and logistics systems, transformed and mapped into a single taxonomy and semantic data model, then loaded into a semantic knowledge graph database.

To ensure continuous, 24/7 data input, the system employs a data streaming service so that data exported from the sources will not get lost during any system interruption or down time. Additionally, only the newly updated data from the sources will be exported via Change Data Capture (CDC https://en.wikipedia.org/wiki/Change_data_capture). The traditional Big Bang approach of exporting a complete updated view of the data in batch is both costly and time consuming.

Data needed by SCRM may come from many heterogeneous data sources. It must undergo an ETL (Extract, Transform, Load) process. There will be one ETL process for each data source.

- E – Extract only master data needed for SCRM from CDC
- T – Transform and map CDC data according to a unified taxonomy and ontological structure
- L – Load data into the Knowledge Graph

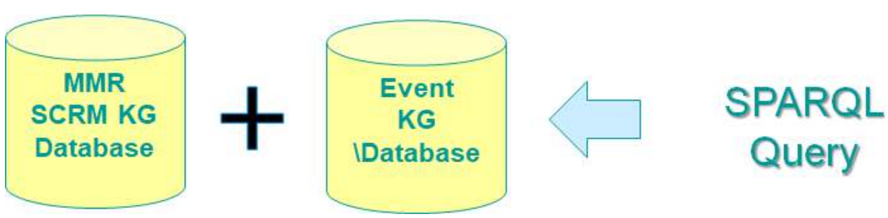
Individual ETL processes may run on the same server or different servers depending upon the workload. Furthermore, each ETL process may control a single knowledge graph to minimize data I/O contention. While updating data in multiple knowledge graph databases individually, these databases will be synchronized automatically via the Multi-Master Replication (MMR https://en.wikipedia.org/wiki/Multi-master_replication) feature. At the end, all individual databases within the MMR cluster will contain the same knowledge graph data regardless where the data is updated.



After collecting and aggregating all the supply chain information, it's now possible to perform risk assessment, which must consider the impacts of likely events. For example, the 2011 Tohoku earthquake disrupted the supply of many electronic components, resulting in electronics production costs in Taiwan increasing by 6%. The 2020 US administration sanctions against using Huawei 5G equipment delayed the UK's 5G rollout by at least one year. An accurate risk assessment needs to incorporate relevant events, i.e., the likelihood of

- Supplier failure
- Strategic (geopolitical) risk
- Natural disasters

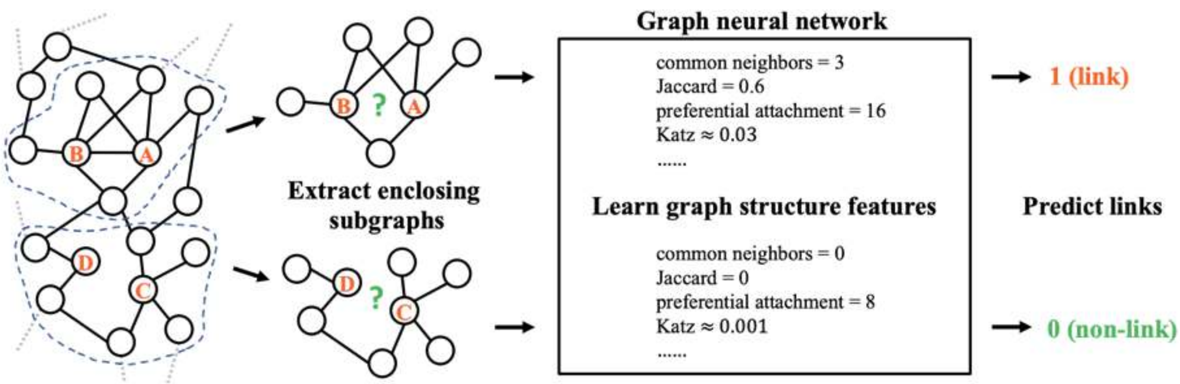
Therefore, the supply chain knowledge graph must be federated with up-to-date event databases (such as the ICEWS Coded Event Data from Harvard) before performing query or analysis with Machine Learning (ML) to detect risk patterns.



Traditional ML algorithms require, as input, tables of data, which can be easily generated from SPARQL query on the federated database. The difficult question is what parameters or features to choose in the query to get good results from ML. This is an iterative process.

Risk Assessment with Graphic Neural Network (GNN)

While traditional ML works well with Euclidian data (i.e., tables and grids, such as image, voice, video, etc.), it does not produce good insights with non-Euclidian data such as graphs because these algorithms are not able to consider the context surrounding entities in a graph (e.g., neighbors and relations around nodes). The solution, Graph Neural Networks (GNN) are specifically designed to perform contextual machine learning on a graph. Graph Neural Networks generalize the deep neural network models to graph data. It is a new way to effectively learn the representations of graph-structured data either from the node level or the graph level. GNNs deliver the Deep Learning needed for graph data.



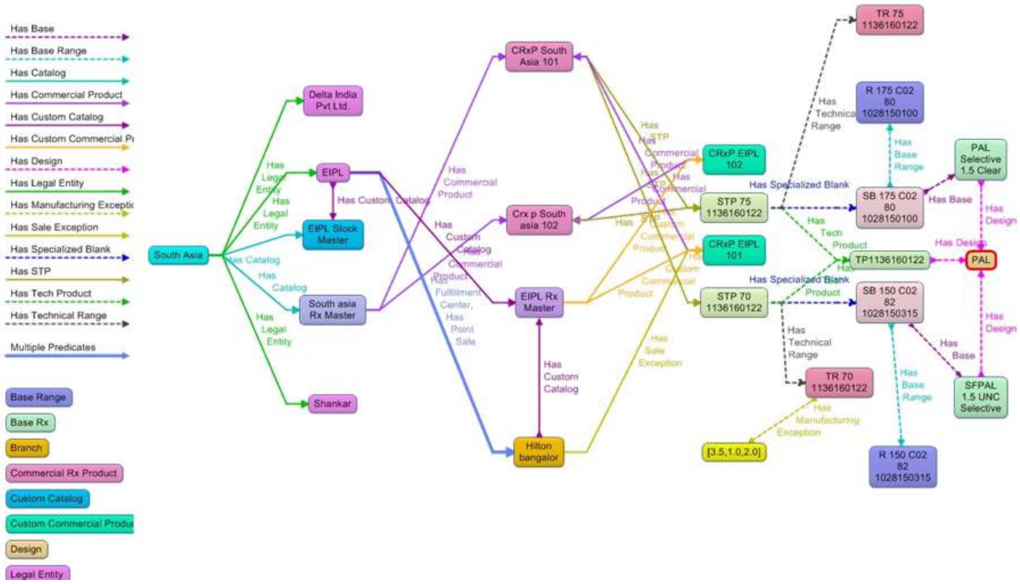
With GNN machine learning, we may be able to predict whether one event (an event node) will propagate to other areas (country/region nodes) to affect our supply chain. It can also calculate the probability of such happenstance, enabling proper and timely response to potential risks.

Case Study at Essilor

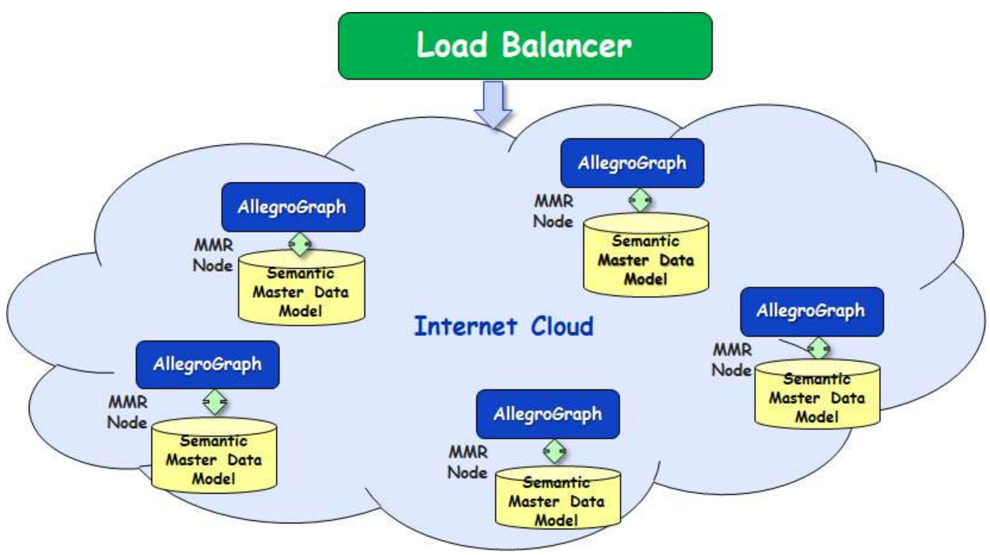
Essilor, part of the EssilorLuxottica SA group (which sells global brands such as Ray-Ban, Oakley and Varilux among many others), is a French-based vertically integrated, multinational ophthalmic optics company and the world leader in the design, manufacture and distribution of lenses to correct or protect eyesight. Including sundries, Essilor carries hundreds of thousands of stock and finished products that are fabricated at many different labs in different countries and are sold all over the world.

Tracking product packaging and fulfilling orders efficiently had always been difficult at Essilor in the past. They tried to modernize their product tracking system with 3rd party software solutions and in-house relational database applications but without success, because relational databases lack the ability to model complex relationships. They needed the freedom of a schema-less graph database, like Franz's AllegroGraph, which uniquely provides the flexibility to model relationships and evolve their data model, so that they can seamlessly add new applications to address rapid growth and changing needs at Essilor.

Here is a sliver of the complex data model of the Essilor application.



Essilor developed and deployed to production their first AllegroGraph based application, an order fulfillment system (i.e., an internal supply chain system), in only a few months after engaging Franz. They found AllegroGraph's W3C standard SPARQL query language is much easier to use than SQL but most importantly, AllegroGraph is a very stable and highly scalable platform with its Multi-Master Replication (MMR) cluster feature. To date, they have deployed several AllegroGraph servers to a cloud environment (see picture below), which can easily handle 100,000 concurrent queries per minute at peak hours. Essilor's success in deploying production systems with AllegroGraph has made them a firm believer in the power of semantic graph database technology.



System architecture at Essilor

Summary

Finally, there is a Supply Chain Risk Management system that captures all important product and supply chain information, which contemporaneous events can be incorporated into for accurate risk assessment (and prediction). This is difficult to do with traditional supply chain applications based on relational database that can't model the complex connections, but rather natural for a semantic graph database like AllegroGraph.

Furthermore, we propose an architecture that is totally scalable running 24/7 while not disrupting existing systems. This architecture has been tested and proven in mission critical production. We also provide advanced machine learning capabilities via our Graph Neural Network machine learning algorithm that is more suited and more accurate for predictive analytics on graph data structure.

We expect Franz's new Supply Chain Risk Management architecture can help enterprises and the defense industry with timely actions to changing events and re-prioritize responses to supply risk. It will enable stakeholders to develop a realistic crisis management and recovery plan, to enhance product resiliency.