Automotive supply chain challenges and software solutions

AUTODESK ams automotive manufacturing solutions Automotive LOGISTICS cdn

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1. Executive summary

1.1 Automotive supply chain challenges

Since 2020, the automotive industry has experienced a seemingly relentless series of unprecedented supply chain challenges which have all driven VUCA – volatility, uncertainty, complexity, and ambiguity. In the post-Covid recovery, inflationary pressures and price volatility have further compounded the challenges around managing supply chains. Furthermore, simultaneously, OEMs face an existential challenge not only in the transition to electrification and alternative powertrains to overcome internal combustion engine (ICE) bans, but now also in the efforts to meet wider carbon net-zero targets across the entire value chain, including production and manufacturing, which will require transformative reinvention of the supply chain with all the new challenges that brings.

1.2 Supply chain disruption and shortages

The pandemic, chip shortages, and the Ukraine/Russia conflict have caused a succession of challenges that have made supply chain disruption the 'new normal' as many OEMs have described it. This VUCA plays havoc with supply chains and exposes a fundamental weakness in highly developed automotive lean manufacturing principles and just-in-time (JIT) just-in-sequence (JIS) processes, as it ultimately leads to potentially very costly production line stoppages. In that context, there has been a slight change in strategy whereby in some cases the long term 'just in time' supply chain is being supplemented and complemented by a near-shored 'just in case' supplier for the short-term supply shocks. Similarly, some particularly critical components, such as semiconductors, are often over-ordered to try and achieve 'safety stocks' – buffer inventory levels to mitigate against potential disruption.

Furthermore, in response to these component shortages, many OEMs are limiting non-essential optional extras on vehicles to reduce demand upon limited semiconductors supplies. For example, by restricting more advanced infotainment options, HUD, heated seats, driver assist options etc. However, this approach can impact revenue per unit as these options are usually highly profitable.

The Covid pandemic also exposed how uniquely vulnerable single-sourcing agreements are to supply shocks. The resulting poor on-time delivery and inability to meet demand has led OEMs and tier suppliers to re-evaluate single-sourcing models and explore supplier diversification and the possibility of dual-sourcing or even multi-sourcing, but only where it is feasible or practically viable and cost-effective.

Multi-sourcing strategies have a clear competitive advantage. For example, as electric vehicle (EV) technology progresses, OEMs and tier suppliers can rapidly switch to the leading battery technology at any given point. For example, most OEMs, such as VW, Tesla, Stellantis, and Volvo, have migrated from single sourcing to the multi-sourcing of cell suppliers. And in the upstream, OEMs are also diversifying raw material suppliers. However, supplier diversification also means dealing with a greater range of suppliers, components, and specifications, which multiplies the complexity of supplier management.

1.3 Lack of supply chain visibility and transparency

One of the key effects of a lack of supply chain visibility is its impact upon production planning and execution. Forward planning can only be effectively achieved by having good reliable data throughout the long and complex automotive supply chain.

For a long time, the communication between tier suppliers has been fraught with poor visibility, low collaboration and a lack of standard processes that make finding alternative suppliers challenging due to data incompatibility. Data is often held in silos, in different formats, on different systems, and this is compounded by concerns around sharing commercially sensitive data. However, Covid accelerated the need for enhanced supply chain visibility. Furthermore, global plant stoppages revealed that there was a wide array of IT systems in use. Most OEMs and tier-one suppliers have supply chain management (SCM) systems with reasonable transparency, visibility, and inventory tracking, but further down the value chain at tier-two and tier-three suppliers, visibility becomes much more fragmented with ad-hoc offline systems that cannot easily be integrated to industry-wide systems, with

some suppliers even tracking inventory levels on basic spreadsheets, with no way of knowing the timeliness or accuracy of the static data.

As a case in point, in early 2022, when Russia invaded Ukraine, it exposed a fundamental weakness. Ukraine has a high concentration of wiring harness suppliers, including Leoni, Yazaki, Fujikura, Nexans, Forschner, Kromberg & Schubert, Prettl, and SEBN. Within days, supply chains were disrupted, and major European OEMs were reporting costly line stoppages. Therefore, carmakers had to find alternative suppliers at very short notice. However, it's not a simple case of swapping one wiring harness for another, as they are unique to each vehicle. Furthermore, a new wiring harness would need to pass tests to validate its supply chain compliance. The challenge is not only in finding and qualifying a new supplier, but in communicating specifications and the bill of materials (BOM) between software systems with a common data format that different systems can manage.

Therefore, one of the more interesting aspects would be to explore how there could be agreed mandates for data to be held in specific formats across the supply chain from OEMs to tier suppliers, or alternatively the ability to read any data format.

1.4 Inflationary pressures and price volatility

Post-Covid recovery and the Ukraine/Russia conflict have driven up the prices of fuel, energy, raw materials, logistics and labour costs, impacting all business verticals, but especially energy-intensive manufacturing sectors. These rising cost inputs are hugely challenging for suppliers in automotive manufacturing and erode into already slim margins. In response to these price pressures, there is a need to constantly innovate by exploring new methods and processes to overcome these challenges. Furthermore, sharp inflationary pressures and price volatility make forward planning and execution challenging and, notwithstanding hedging strategies, can create a need to rapidly find, validate and switch to lower-cost alternative suppliers. Of course, a further risk of supply chain disruption and escalating prices is that it could make the component unaffordable and unviable to continue supplying or to even continue doing business. In short, companies could exit the sector suddenly or cease trading, and the supply chain itself could collapse at short notice.

1.5 Electrification and complexity

The transition to electrification over the next decade requires the wholesale replacement of the legacy ICE supply chain with a new electric vehicle supply chain and an amended supplier base. This involves embracing an entirely new range of chemical and mining sectors as well as for electric motors, power electronics, and software. While EVs have fewer components, in theory leading to simpler supply chains, in this transitionary phase, the powertrain mix actually becomes more varied for traditional OEMs and suppliers, greatly amplifying supply chain complexity. To allow for more variants and flexibility in production, and to respond better to component supply volatility and disruptions, sequential assembly lines are also gradually being replaced by more modular production systems. Furthermore, modern vehicles are increasingly complex, with exponential growth in electronics and software potentially resulting in a growing BOM. This clearly puts an extra emphasis on data, visibility and collaboration in the increasingly complex supply chain.

1.6 Evolving manufacturing strategies impacting supply chains

To manage the growing manufacturing complexity, OEMs need to carefully consider and develop their overall vehicle manufacturing strategy; balancing make vs buy decisions. There is a trend, especially with EVs, towards OEMs increasingly opting for whole vehicle contract manufacturing agreements and leveraging suppliers for right size systems assembly to reduce risk and final assembly complexity and disruptions. Other evolutionary manufacturing changes include the trend towards regionalisation, localisation, onshoring, near-shoring, and right-shoring all impacting supply chain structures. Furthermore, the gradual increase in platform and technology sharing and also the introduction of microfactories are also influencing automotive supply chain dynamics.

1.7 Sustainable supply chains

Beyond vehicle emissions, the automotive industry is now also being compelled to address the wider sustainability and lifecycle assessment (LCA) of the entire vehicle emissions, including supply chains, component manufacturing and logistics footprint, final vehicle assembly and the vehicle's after-life in terms of recycling. Clearly, to conduct a carbon-impact assessment across the entire automotive value chain is only possible with end-to-end visibility and transparency of the complete supply chain, enabling tracking of emissions down to individual component and even to the raw material level, and facilitating the sourcing and switching to more sustainable materials and components.

1.8 Competitiveness and shorter product lifecycles

Companies fear being last to market, which means that competition, regulatory pressures and consumer demand are driving traditional 7–8-year product lifecycles inexorably downwards towards 3-4 years. Suppliers are therefore under increasing pressure to become faster, cheaper, and better. They must be able to adapt mid-model cycle to fast-evolving EV and battery technology, or changes in materials to meet new regulations and consumer expectations. Sustainability also increasingly plays a role as OEMs try to integrate new materials to reach environmental targets. Also, they may have to find an alternative supplier for a component due to a spike in raw material prices, which may require a new design. All of this results in less time to innovate or to explore design options. Therefore, the challenge remains around change management, agility and supply chain compliance, testing requirements and validating changes in a connected way

The wider context is also that OEMs have a strong reliance upon key tier 1 suppliers. in this era of the rapid technological transition to electrification, there is a growing need for closer strategic partnerships to collaboration to accelerate competitively decisive product development.

In this continuing period of disruption, often dubbed the 'new normal, or 'new never normal' by OEMs and tier suppliers, the challenges facing the automotive industry all point to the compelling need for enhanced supply chain resilience, agility, flexibility, transparency, and visibility. And it's clear that supply chain strategy is rapidly becoming a critical competitive advantage.

Of course, there are many ways to achieve enhanced supply chain resilience and it is important to remain solution-agonistic, as the differing options vary enormously in speed, cost, feasibility, efficacy and relevance to each individual stakeholder. However, this whitepaper evaluates the range of supply chain, operational and data strategies, with a focus on software solutions. In particular, it reveals that data visibility, agility and flexible collaboration are best achieved through industry wide cloud-based software solutions that empower all stakeholders within the automotive supply chain.

1.9 Supply chain strategy, operational strategy & data strategy

There are multiple approaches to achieving enhanced supply chain resilience and this means companies should remain open-minded to the available solutions. However, they can be categorised into three main approaches that require supply chain, operational, and data strategies.

Figure 1.1 Strategies to enhance supply chain resilience

Supply chain strategy

These are high-level, such as **(semi) vertically integrated industry models** through formal M&As, JVs, or more informal partnerships, collaborations and supply agreements that exert more control over supply chains.

Companies are re-evaluating single-sourcing models and, where feasible, exploring the potential of **dual or even multi-sourcing models**.

They are also reassessing the wisdom of just-in-time practices from the lowest cost suppliers and considering **near-shoring or 'right-shoring'**, a procurement model that chooses the optimal combination of cost and security of supply.

Operational strategy

OEMs are pursuing **value over volume** by prioritising high- margin vehicles.

Other approaches involve **reducing variants and customisation options** etc.

Many OEMs are only building vehicles where there is a customer order attached – a so-called **'build to order'** rather than traditional 'build to stock' approach.

OEMs and tier suppliers are also boosting supply chain security by establishing **buffer/safety stocks** for key components that don't require significant warehouse space, such as semiconductors.

The industry is also gradually embracing **Industry 4.0 / smart manufacturing** principles.

Data strategy

A data-led strategy centres around **enhanced supply chain visibility** through using common software platforms to share data with suppliers provisioned in real time, and utilising **supply chain simulations and other digital tools** the cloud and supply chain digital twins to achieve **greater collaboration across industry** stakeholders and the wider value chain.

No system can or should operate within a silo and **data integration and cohesion** between systems across industry is crucial.

The way to achieve that is by migrating the systems to the cloud to allow that vital 'data layer' of **interoperability** between legacy/proprietary and new systems.

Software solutions

Software fundamentally underpins all of these strategies to enhancing supply chain resilience. When implementing supply chain strategies, the resulting extended value chain necessitates software in achieving those major structural changes. Likewise, with operational strategies, these approaches require greatly enhanced software to facilitate the transparency and visibility necessary across the supply chain and wider value chain. And data strategy fundamentally relies upon software to facilitate the enhanced supply chain visibility. Ultimately, software is the key enabling technology across all of these strategies to achieve automotive supply chain resilience.

The key software types include -

- **Cloud architecture**
- **Digital twins**
- **Sales and operations planning**
- **Product lifecycle management**

Source: Automotive from Ultima Media

2. Cloud architecture

As we alluded to earlier, in response to supply chain disruption, 'just in case' dual-sourcing, multi-sourcing and supplier diversification is increasingly being deployed throughout the value chain to mitigate against supply chain disruption. Of course, supplier diversification inevitably means dealing with a greater range of suppliers. components and specifications. This increased complexity drives the need for software solutions such as cloud architecture.

2.1 The software-defined supply chain

Software solutions must be viewed within the context of the wider gradual migration of the automotive industry towards an Industry 4.0/smart manufacturing framework. Industry 4.0 is the foundation of the digitalisation of the supply chain and improving of supply chain management (SCM) though real-time information transparency, interoperability, decentralised decision making and technical assistance in the form of automation and robotics.

OEMs and tier suppliers currently deploy a wide variety of different SCM systems ranging from basic spreadsheets to older proprietary IT systems and advanced enterprise-level ERP systems. This fragmentation creates the overriding issue of incompatibility and lack of standardisation. Fundamentally, the data already exists but is in silos and highly fragmented. One of the solutions to integrating data from multi-layered supply chain management systems is cloud technology.

Most major OEMs have implemented a cloud architecture solution and the landscape is quite consolidated amongst the major vendors. Cloud solutions adds another cloud/ data layer, or industrial integration layer, above existing proprietary IT systems, which allows those systems to sync and integrate, thereby providing some level of industry interoperability despite the incompatible legacy systems. An additional benefit of cloud solutions is the value that they bring to other stakeholders in the supply chain enabling collaboration and transparency.

Renault uses a cloud layer that combines data from around 20 global plants and more than 5,000 machines and assets, including part identification and tracked logistics activities.

The system is to be extended across plants, suppliers, and distribution. The combined data is then fed into a machine learning and data analytics platform.

"We are working strongly with Google to introduce artificial intelligence tools, and we will soon have a very powerful and complete digital system that gives us the ability to monitor our supply chain end to end, from tier one to 'tier N' suppliers, and also downstream to our dealers."

Jean Francois Salle, Global Vice-President for Supply Chain, Renault Group

In addition, Renault has been using AI-based digital simulations, data analytics and machine learning to help plan supply chains in advance of operations, for replenishment of small automotive parts.

Volkswagen's Industrial Cloud is intended to optimise manufacturing efficiency, achieve productivity gains, allow production flexibility and logistics processes across its worldwide network of plants and facilities and global supply chain. VW's platform leverages technologies including the Internet of Things, machine learning, data analytics and computing services. The open platform includes numerous integration partners across industry. Ultimately, VW plans to include all of its 1,500 suppliers and partners in the project. Its Industrial Cloud uses an app-based approach allows partner companies to connect with VW plants and to contribute, scale and develop a growing marketplace of industrial apps, saving development costs and sharing efficiency gains across all partners.

The European Catena X network is an example of an industry-wide collaborative agile solution, involving a consortium of 28 automotive companies. The cloud-based system allows end-to-end data chain details to be synced with other company systems, like a 'meta-ERP' system. The cloud network allows ZF to have a connected ecosystem across the company's 200 manufacturing plants with apps available for each plant, allowing wider data sharing and development of AI leading to further integration of, and enhancements in, process automation, predictive maintenance, and sales and operations planning (S&OP). According to Dr René Deist, chief digital officer, ZF Group, "every problem has a cloud solution," and only a cloud-based solution has the flexibility, compatibility, and commonality to be able to adapt to each use case.

"Every problem has a cloud solution."

Dr René Deist, Chief Digital Officer, ZF Group

"With the Industrial Cloud we are creating a platform allowing partners to contribute their solutions. This will help the Volkswagen Group achieve global efficiencies at its plants. At the same time. we are creating the pathway for partners to scale their applications and optimise their own operations. This way, everyone will benefit."

Nihar Patel, Executive Vice-President, New Business Development, Volkswagen AG

Table 2.1 Cloud solutions: strengths and opportunities

Strengths	Opportunities
Powerful end-to end supply chain visibility	Encourages industry-wide cooperation
Compatible with other industry stakeholders	Flexibility to adapt to future challenges
Can integrate with in-house legacy IT systems	Cloud potentially offers better cyber security

Source: Automotive from Ultima Media

3. Digital twins

Visibility, transparency, and inventory tracking are vital to managing disrupted, volatile and unpredictable supply chains. The recent case of the Russia / Ukraine conflict and the resulting sudden shortage of wiring harnesses highlighted a key example of how end-to-end supply chain visibility, finding alternative suppliers at short notice and communicating specifications between disparate software systems is central to mitigating and responding to these scenarios.

A supply chain digital twin is a virtual representation of a supply chain that consists of hundreds of physical assets that can include warehouses, logistics and inventory positions. Using advanced analytics and AI, the digital twin simulates the supply chain's performance, including all the complexity that drives value loss and risks. It identifies where volatility and uncertainty exists, as well as where optimisation is possible, and enables scenario planning to allow decisions to be made on the basis of business needs, rather than resolving issues as and when they arise. The software can integrate the Internet of Things (Industry 4.0) with the AI and analytics to enhance output further.

"The digital twin is not new technology. What is new is the scale; we model an entire company and model a single system and environment and supply chain, as opposed to a single product."

Romain Ropitault, Senior Product Manager, Cosmo Tech

The supply chain digital twin software landscape is quite fragmented with a significant number of vendors. In fact, the Digital Twin Consortium also features many of the leading industry players amongst its members.

Dr Peter Weber, director of BMW's Munich plant, illustrated the real-world benefits of a supply chain digital twin: "We are developing a digital twin of the structure and processes. New buildings have digital models of those bodyshop, assembly and logistics structures, and this

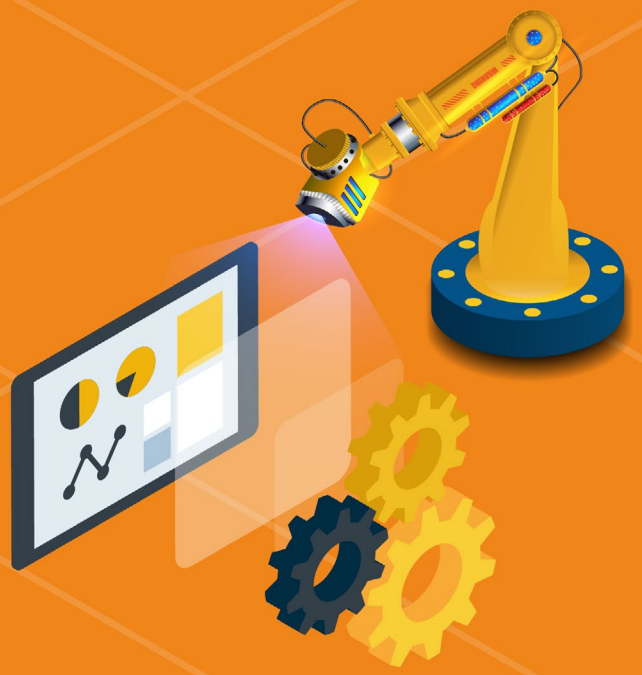
platform offers the opportunity to integrate the digital twin of the production structure and new models of new structures. We are able to realise a fast, precise update based on the digital twin".

An important aspect of supply chain digital twin software is that to effectively simulate the supply chain it should comprehensively incorporate all aspects of manufacturing design, the line design, factory design, and Manufacturing Execution System (MES). Therefore, the full potential of a supply chain digital twin can only be fully realised by integrating the supply chain and logistics with the operations of production.

Furthermore, supply chain digital twin software is able to decide the optimal logistics method based upon a complex set of factors, including time, cost, CO2 emissions and transport mode. The software allows you to run "what if?" scenarios, integrating all factors and inputs from both manufacturing and supply chains.

However, within supply chain digital twins, data quality is critically important and the challenge for manufacturers is to ensure that tools are acquiring valuable and essential data. If the data is not accurately representing the physical processes, then it cannot help to optimise the real-world system. However, at the same time, perfect must not become the enemy of the good. Data can never be, and does not need to be, 100% perfect or complete to produce a good digital-twin system.

One cautionary view when it comes to implementing digital twins is to not try and start with a complete digital twin, as a complete digital twin is impossible to achieve and does not exist. In fact, becoming overly ambitious can potentially lead to a data project with no end. An important consideration is to scale the digital twin to enable it to provide the necessary metrics required within operations, so that it provides the appropriate level of insight required for decision making.



Another requirement of digital twins and the simulation of manufacturing processes is not just to operate in the perfect digital world, but in real world conditions. For a digital twin to be effective, production data must be accurate and must be fed back to the engineering lifecycle to ensure that accurate visualisation of the process is available across all the stages of the manufacturing process.

Romain Ropitault gives an example of a 'what-if?' scenario that can be modelled to ascertain the impact of a decision: "We rapidly built a web application on top of the digital twin to give the key for an end-user to interact with the digital twin to run an experiment that could be very complex."

Another challenge around digital twins is that there is the potential to collect so much real-time data that it can potentially interfere with production cycle times, as Raman Mehta, chief information officer and senior vice-president at Johnson Electric, observes. "You do not want new technologies to disrupt cycle time," says Mehta.

"So how do you create an architecture that can move quickly [and] can accumulate all data in real-time, from temperature to testing? The solution is to collect the large amount of data, detach it from the real production flow, and stream it on a cloud-based network." But despite all of the differing approaches to implementing digital twins, the direction of travel towards digitalisation remains clear.

"All objectives are driving manufacturing in the same way, towards optimising digital twins – the capability to put different factors together simulate and optimise."

Romain Ropitault, Senior Product Manager, Cosmo Tech

Table 3.1 Digital twin solutions: strengths and opportunities

Strengths	Opportunities
End-to-end simulation of the supply chain	Potential for efficiency gains
Allows 'what-if' scenarios to be run	Optimises manufacturing processes
Greatly enhances supply chain resiliency	Can assist in reducing carbon footprint

Source: Automotive from Ultima Media

4. Sales and operations planning

The Covid crisis brought to the fore the need for greater visibility, not only in the supply chain and along the production value chain of tier 1,2 and 3 suppliers i.e. the supply side, but also across the entire enterprise and incorporating data in terms of sales and marketing. i.e. the demand side.

This is where S&OP comes in as a powerful digital tool that brings together enterprise-wide data for critical decision making. This includes marketing and sales data and forecasts for demand sensing and planning, production data, inventory levels, costs, utilisation, logistics, and also upstream to 'tier-n' suppliers, with data on capacity constraints and forecasts to achieve enhanced transparency of costs and availability across the entire supply chain and wider value chain.

"Over the past few years, different crises have shown the importance of S&OP," says Jean-François Salles, global vice-president for supply chain, Renault Group. "S&OP has proved key to keep [Renault's] business focused on priorities, value creation and more profitable products and activities. We are coordinating this activity with sales and marketing across the brands, with purchasing, financing and industrial locations."

S&OP also supports longer-term planning, influencing design and purchasing decisions, and better insight into cost and lead-time implications for engineering changes. "Getting approval for products requires time, and it is the supply chain that needs to interact across each stage," says Salles. "For example, in understanding the lead time on making a decision to dual source a part, redesign or react to products, so that we can then know what we will have available on the purchasing and manufacturing side." Furthermore, better process insight helps reduce product complexity, reducing time and inventory in the supply chain. "The less complexity and diversity in a product, the more confidence we can have to supply without having high stock of parts in our flows" adds Salles. "This is changing the logic and rationale of parts sourcing and decision making for logistics."

Table 4.1 Sales & operation planning (S&OP) solutions: strengths and opportunities

Strengths	Opportunities
Strong end-to end visibility of the entire value chain	Encourages enterprise wide collaboration
Effective in short-term and long-term planning	Potential to increase efficiency & profitability
Greatly enhances supply chain resiliency	Optimises logistics and inventory management

Source: Automotive from Ultima Media

5. Product lifecycle management

When designing a physical product, collaborating with a range of suppliers is essential. However, many operate in design silos or have proprietary data, differing CAD software, and inefficient processes that make sharing and collaborating on highly technical data challenging. And a lack of communication on product development can have costly repercussions if not resolved early on during the development process.

Product lifecycle management (PLM) software brings multidisciplinary teams together to collaborate and disseminate real-time information throughout the enterprise and wider supply chain. Teams have visibility into the entire product lifecycle from design and engineering, materials (sometimes even generating the BoM automatically) and manufacture to servicing and product disposal. PLM systems can also be thought of as a centralised data and process management system or product development log that everyone can access, achieving workflow automation, reducing errors, avoiding miscommunication, and saving time, thereby improving productivity. For example, when manufacturers are having to cope with large model variations, it's critical to get involved in the product development process early on. "We achieve the best results through close collaboration between product development and production in order to incorporate the expertise of all departments during the vehicle development" says Erwin Fandl, vice-president manufacturing, Magna Steyr.

"We achieve the best results through close collaboration between product development and production in order to incorporate the expertise of all departments during the vehicle development"

Erwin Fandl, Vice-President Manufacturing, Magna Steyr

PLM systems also enhance the 'digital thread', delivering traceability and compliance, accelerating time to market, reducing costs and ultimately acting as one of the key tools for boosting supply chain agility and resilience.

PLM solutions have excelled in managing product lifecycles, however, there is real potential in integrating more into the wider supply chain and incorporating those gains into the commercial aspects of the business.
Whilst PLM has demonstrated clear benefits across mechanical engineering applications, there are opportunities to further incorporate those capabilities around electrical and electronic products.
One notable aspect of the PLM landscape is that the sector is highly fragmented with a large number of vendors and this means that there are wider variety of solutions applicable to cater to each individual business and application.

PLM systems are often slowly implemented, and even years after their implementation they sometimes do not achieve their intended functionality and/or provide limited access, leading users to fill the gaps with basic spreadsheets, local storage and emails, which defeats the overall objectives of a centralised source of data. Therefore, there still remains considerable opportunity to more fully realise the significant gains that PLM solutions can deliver.

To this objective, what is becoming essential for maximising the potential for PLM, is that it is cloud-based for quicker deployment and integrates seamlessly with other systems, including product data management (PDM), manufacturing execution systems (MES), enterprise resource planning (ERP) and customer relationship management (CRM) systems, and Internet of Things IoT) technologies to achieve enhanced end-to-end visibility. Raman Mehta reinforces this point: "How does a product behave in that situation? Because now you're not done selling your product, you're actually making the revenue on the usage model. And our trick has been to really collect all the data with Internet of Things, with smart factory, and bring it back, that feedback, into our engineering lifecycle, and that's where I think you get the full benefit of these modern technologies".

"Our trick has been to really collect all the data with Internet of Things, with smart factory, and bring it back, that feedback, into our engineering lifecycle, and that's where I think you get the full benefit of these modern technologies."

Raman Mehta, SVP & CIO, Johnson Electric

As vehicle technology rapidly evolves, it's becoming important to think of PLM more as product innovation management, so that the new players in the new supply chains – for batteries, electronics, software – can work collaboratively with partners and suppliers to develop, produce and sell the new generation of electric vehicles.

Table 5.1 PLM solutions: strengths and opportunities

Strengths	Opportunities
Manufacturing collaboration in a central system	Enhances product innovation management
Strengthens supply chain agility and resilience	Enhances 'digital thread', traceability, and compliance
Accelerates time to market, reducing costs	Best when integrated with smart factory, IoT & cloud

Source: Automotive from Ultima Media

6. Conclusions

There are multiple solutions to automotive supply chain challenges and enhancing supply chain resilience. However, there is no single panacea or magic bullet. Within the context of the automotive industry's lean manufacturing principles and just-in-time processes, any cost-effective solution can inevitably only realistically be designed to mitigate against and soften the impact of the most likely supply chain disruptions. Fundamentally, the automotive industry will continue to follow just-in-time processes, because despite the costs of recent disruptions, in the long run it is still by far the most cost-efficient approach compared to building in very costly excess capacity that is rarely used.

However, the solutions chosen to mitigate against supply chain disruption will depend on a wide array of factors, including company size, position within the industry and budget availability. In most scenarios it is likely to be a mixture of supply chain, operational and data strategies that best respond to supply chain resilience, and that mixture of approaches will need to be tailored to the particular stakeholder and company's structure and position within the industry. The key to the solution is that data management, agile and flexible collaboration across industry as well as across all parts of the value chain helps to achieve the necessary visibility and transparency within the supply chain. This industry-wide traceability is critical to proactively deal with potential bottlenecks. Therefore, any improvement in supply chain resilience requires the following characteristics:

Supply chain resilience is only achieved through end-to-end visibility and transparency

Visibility is enhanced by real-time collaboration, cooperation & partnership

Collaboration is best achieved through data sharing with all stakeholders

Industry transformation is best enabled by integration of suppliers in change-management

Competitiveness is optimised by business agility, flexibility and adaptability

Ultimately, supply chain resilience, flexibility and adaptability is only possible through an industry wide shift away from a reactive model to a more proactive and predictive business model

Essentially, whilst supply chain strategy, operational strategy and data strategy all have their merits, it is software solutions which fundamentally underpins all of those approaches and which are the most cost-effective enablers, have the most tangible effects and, most importantly, can be implemented more immediately than any other solutions.

The major software solutions available to stakeholders include cloud architecture, digital twins, sales and operations planning, and product lifecycle management. However, none of these software systems can or should operate within a silo, and there needs to be data integration and cohesion between legacy ERP, PLM, S&OP, CRM and digital twin software systems, not just within companies, but across global enterprises and throughout supply chains and the wider industry. That is best facilitated by a migration to the cloud, to allow that vital 'cloud/data layer' of interoperability between legacy and new software systems.

Ultimately, individual employees, teams and companies need to move away from thinking individually and operating in silos, towards acting as stakeholders within a wider industry ecosystem, symbiotically collaborating towards the common goal of supply chain resilience. To this end, software solutions are the key enabler through their ability to achieve enhanced real-time visibility across the entire automotive supply chain and achieve business critical production planning to optimise competitiveness and supply chain resilience.

Source: Automotive from Ultima Media

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