SUPPLY CHAIN COMPLEXITY AND RISK MANAGEMENT: GLOBAL AUTOMOTIVE

Supply chain complexity is unavoidable for Global Automotive (GA)- the organization competes in over 120 global markets with very different customer needs. GA employs unique complexity management competencies and capabilities which lead to improved revenue generation, reduced cost, improved relationships within the supply chain.

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ABOUT THIS REPORT
As part of the Supply Chain Management: Beyond the Horizon research initiative, faculty and staff from the Eli Broad College of Business at Michigan State University conducted in-depth interviews with a number of organizations to obtain insights into the development and implementation of various supply chain strategies, practices, and processes. The focus was intentionally on the future and what challenges are driving future supply chain decisions in the current environment. The following report summarizes key findings from the visit to Global Automotive (GA)* with regard to supply chain complexity management.

BACKGROUND
One of the challenges identified in the Beyond the Horizons (BTH) research relates to complexity and complexity management. While there are many industries and firms that have begun to focus on rationalizing supply chain and product complexity, the BTH team identified the automotive industry as both one of the most challenged and one of the best. The automotive industry is experiencing a significant conundrum as it attempts to balance the increasing customization desired by consumers with the need to reduce product complexity and resulting product cost.

While many automotive firms have started complexity management initiatives, the BTH team found that Global Automotive (GA) has realized that complexity is not something to be avoided, and is instead demonstrating some unique complexity management competencies and capabilities. GA competes in over 120 global markets with very different customer needs. As a result, complexity was a reality — one that had been forced upon GA by a combination of market, competitive, and technology forces. Consequently, GA management decided they had better get good at managing complexity. Otherwise, it could ruin them.

* Global Automotive is a pseudonym. The firm discussed in this study asked to remain anonymous.
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GLOBAL AUTOMOTIVE REVIEW
GA is the eleventh largest automaker in the world. It designs, engineers, manufactures, and sells passenger cars, sport utility vehicles, light commercial vehicles, components, and production systems globally. GA’s automotive brands are recognizable worldwide. In addition, GA provides extensive after-sales parts support through its parts and service brand and its performance automotive division. GA businesses also include production systems, components, and iron and castings divisions.

Worldwide, GA employs over 80,000 employees. It also operates over 30 manufacturing facilities, 10 regional business centers, 20 parts distribution centers, and 10 training and test facilities. In 2015, GA US shipped more than 2.5 million vehicles.

THE CHALLENGE OF COMPLEXITY
GA US’s supply and distribution functions are both highly complex. On the supply side, GA US must collaborate with hundreds of domestic and international suppliers to develop new innovations where appropriate and determine optimum sources for components. On the distribution side, GA US must collaborate with its dealer network to minimize the cost of vehicle delivery while being responsive to customers who desire customization.

Since GA operates on a pull scheduling system, the production schedule is driven by dealer orders. In many cases, a major source of complexity can be traced to the dealers. It is the dealers who place the orders for cars. Dealers attract customers who have unique tastes and would like their offerings to be customized. In addition, consumers want to pay only for the options that give them value. So, the dealers must determine which options and configurations will make them most successful.

Further complicating affairs is the government, with its changing requirements for vehicle safety, vehicle emissions, employee safety, and employee well-being. And governmental jurisdictions may have different technology requirements or regulatory requirements such as fuel economy, not to mention the many requirements from customs and participating government agencies — all of which add additional complexity.

In addition, there is technological change. Like other automotive firms, GA US has to update its products to accommodate new developments such as global positioning systems, advanced communications systems, improved driving technology (such as improved cruise control), drive train technology improvements, and ultimately autonomous or self-driving technologies. Finally, there is demand to improve ease of vehicle disassembly at end of life. When all of these factors are combined, the result is continuously increasing complexity over time.
For example, the GA US managers indicated that they could engineer 500,000 different combinations for a single vehicle platform. However, they know customers are likely going to buy only about 200,000 of those vehicle variations — creating the quandary of how to manage such a high level of complexity. It also reinforces the notion that complexity management is essentially an issue of evaluating trade-offs, requiring management to question continuously whether they have made the right trade-offs.

After investigating these issues, GA US management realized that complexity management could be segmented into two facets. The first is the industrial side, which focuses on part numbers being purchased by the firm. The second is the commercial side, which concerns the features that make the vehicle unique on the dealer lot. The firm has to address both facets if it is to effectively manage and reduce complexity. Central to this effort is to develop and apply metrics that focus on complexity in both facets. While such metrics provide ongoing visibility into complexity, they also communicate to the organization the importance of effective complexity management.

GA US is increasingly realizing that industrial complexity management represents a trade-off between minimizing a piece price to get a part that meets the minimum requirements or commonizing a part that can meet the minimum requirements for many applications. That is, GA US could be creating new part numbers when an existing part number would quite easily meet the requirements. It’s a trade-off between complexity and piece price (e.g., while a higher amp alternator could be used to meet the requirements of a number of vehicle models, one sized to meet the size requirements for each model would reduce the piece cost). Resolution of this facet of complexity requires the active involvement of product engineering, since it is the engineer who is ultimately responsible for the design and establishment of new part numbers. One approach used by GA US to increase visibility into this facet of complexity is to measure and evaluate the engineering time per vehicle. When this metric increases, it indicates an increasing complexity level. Another approach is to require that the number of components be reduced prior to the addition of others.

While industrial complexity also results in the firm ordering more components from more suppliers, GA typically purchases a commodity from the same supplier whether it has one variant or five. But increasing the number of variants requires GA to validate multiple different designs and processes. This, in turn, means that GA US must develop requirement plans for more parts, and then communicate those requirements to its suppliers. As a result, industrial complexity offers more opportunities for unanticipated problems to emerge — problems that could adversely affect the quality, quantity, or timing of orders being placed and/or received. More component variation results in less standardized interfaces, which increases the potential for problems. That is, more complexity in industrial supply management can adversely affect quality and supplier capacity. It impacts supplier capacity by requiring more changeovers. For GA US, these issues are critical.

The quality impact has multiple dimensions. First, there is simply the challenge of getting the right parts. Creating more component variations increases the probability that an incorrect one will be ordered. Second, and more important, there is the issue of whether the features, when integrated into the vehicle, will operate correctly with the other components to provide the capabilities desired by the customer. Third, as more features are added, they interact with each other, and in some cases there are unanticipated issues in which one feature negatively interacts with the operation of another one. Fourth, there is the challenge of post-sales support.
The obligation of GA US to its customers does not end with the sale of the vehicle — it extends far beyond the sales transaction. That means that GA US is legally required by US federal law to provide quality spare parts for customers for a minimum of 10 years after the vehicle sale. Again, the more features and the more variation in those features, the greater the need for inventory support and the more concern over issues such as inventory control and damage.

The discussion determined that it was the combination of these characteristics that really drives complexity. However, these industrial issues are further exacerbated by factors emerging from the commercial or demand side:

**First**, customers (either end consumers or dealers) often desire certain standalone options. This characteristic significantly complicates forecasting, pricing, and scheduling. The combinations of standalone options quickly increase the number of permutations. While many features come in predefined combinations, standalone options are often unique and increase vehicle complexity because they are non-standard.

**Second**, dealers demand an appropriate mix of products to meet the demands of their local markets. This means that a firm such as GA US is faced by the “paradox of choice” — that is, how to offer the flexibility of having the product done the customer’s way without the resulting challenge of having to manage an overwhelming amount of complexity.

**Third**, GA US has experienced recent sales growth. This sales growth has created the additional dimension of volume, on top of all the other factors discussed previously. In the past, when GA US had only a 6 percent market share, these issues were present — but the scale made them somewhat manageable. Now, GA US has experienced a doubling of its market share, resulting in a higher volume that places a constraint on capacity and makes scheduling even more complex due to the number of changeovers required.

**Fourth**, there is the impact of third-party quality ratings coming from such organizations as J.D. Power and Consumer Reports. These evaluations assess the quality — initially and after a period of time — of the vehicles that GA US makes. These ratings also evaluate the ability of GA US to effectively manage complexity in production (the industrial side). Specifically, the number of combinations limits GA’s ability to substantially validate every combination, since it is cost-prohibitive to build that many prototypes. These quality issues continue to be a source of concern for many automotive companies.

**Finally**, there are increasing challenges in dealing with both domestic and international consumers (something that GA US must do because of its global position). There is a marked difference between the buying behaviors of domestic consumers and international (specifically European) consumers. Domestic consumers tend to buy off the lot — that is, they most often buy what is on the lot (so getting the right product mix at the dealer level is critical). In contrast, international consumers are often more willing to wait and to customize their vehicles. While the complexity level may be similar, domestic consumers require that the correct combination be on the lot while European consumers are willing to wait for the appropriately customized vehicle.
These demand-side factors have forced GA US to take a more deliberate approach to complexity management. GA US must be able to better serve its customers (dealers and consumers) without trying to be all things to all people. Furthermore, GA US must manage this complexity without impacting customer loyalty. It must also address these issues within a limited amount of time, since response time to consumers has strategic impact. That is, if GA US requires more time to address these specific customer complexity issues relative to its competition, then its market positioning will be damaged. Similarly, GA US can create a competitive advantage by meeting customer needs better than competitors do.

**THE GLOBAL AUTOMOTIVE US APPROACH TO MANAGING COMPLEXITY**

GA US has learned that managing complexity through a piecemeal, “changing one component alone and forgetting how it interacts with the other components” approach is fundamentally flawed. Instead, an integrated, comprehensive approach is required that can embrace and accept complexity rather than trying to eliminate it. This is the approach GA US management shared — an approach that builds on advanced analytics, working with dealers, and effectively capturing and communicating the “cost of complexity.”

Analytics, combined with better monitoring and management of data coming from the websites, offers GA US better insight into what the end consumers are looking at, what they configure, and what they don’t configure. The resulting insights can be compared to the market demand to identify “gaps.” For GA US, the broad view offered by combining both the consumer and dealer perspectives is important. Without it, GA US would be limited to the insights provided by its dealers.

The problem with these insights is that they are uneven and very limited. Dealers tend to know their local markets very well, but they often lack the broader perspective needed to identify trends and emerging developments. Second, dealers’ sophistication with respect to data and consumer analysis/segmentation is highly variable — some dealers are very sophisticated, while many others are not. Some dealers are willing to collect web data about their products and use the data provided by GA US to determine what they should order. Yet there are other dealers who don’t collect much data and/or don’t use it.

For GA US, this means working with dealers to enhance their ability to place better orders — orders for vehicles with the options that consumers really want. GA US recognizes that it is the dealer who ultimately determines what is ordered. GA US also recognizes that it is governed by US franchise laws. These laws, in turn, drive how GA US allocates production and how it plans production at certain mix levels. It influences what models and engine combinations are produced. As a result, GA US must work with the dealers, applying data and analysis to identify and develop better ordering policies and strategies. The goal of this cooperation is to facilitate dealer order placement for vehicles that will “turn” more quickly (spend very little time sitting on the lot).

Inventory turns are not the only focus of this strategy of working more closely with the dealers. There is also the issue of helping dealers anticipate which features will be desired by consumers on those vehicles delivered to the lot prior to a customer order, resulting in increased profitability for GA US and its dealers. GA US
accomplishes this through use of better information regarding feature requests, promotions and reduced lead times. For example, if GA could respond to customer demand signals faster, it might be able to stock what the consumer wants ahead of time so the consumer wouldn’t need to custom-order a vehicle. This management process is an ongoing one in which GA US makes tweaks every month to get the right set of products to market. For example, incentives are used to get certain slow-moving vehicles off the lot and simultaneously to encourage the consumers to go into certain higher-priced but more profitable product lines. Ultimately, though, this tweaking process is driven by analysis and the “numbers” — it is based on numbers, analysis, and strategic priorities.

Another goal of effective complexity management is to help dealers improve their own performance. This is done by drawing on the collective knowledge base developed by GA US. This knowledge base provides insight to individual dealers regarding what is selling and what is not. GA US complexity management systems can also share lead times and availability. Within limits, the GA US systems provide some insight regarding the performance of other dealers in the area. But ultimately, GA US recognizes that the effectiveness of this approach is dependent on dealer acceptance. They are individual businesses that have the right to draw on these insights or to ignore them.

Before leaving this discussion, it is important to realize that GA US treats complexity management as a total corporate activity. That is, there is an attempt to involve everyone in this process, including marketing and manufacturing. Without this collaboration, complexity becomes a source of conflict with marketing wanting to offer more complexity and operations, engineering, purchasing, finance, safety, human resources, and strategy wanting to offer less. This conflict is one area where management is working to improve the visibility of complexity with top management, since they are often unaware of the potential issues it creates.

The third element of this integrated approach is the need to measure and compare the benefits of complexity relative to cost — cost that is often hidden and overlooked. The result is a “cost of complexity” framework, as shown in Figure 1. The cost of complexity is very similar to the cost of quality (COQ) framework that is so widely used.
The cost of complexity framework forces everyone involved in complexity management to recognize and capture, if possible, the hidden costs. Most are aware that complexity can generate revenue because it offers the customer more choice and in many cases, greater perceived value. However, many are less aware of the various hidden costs. These hidden costs include increased changeover cost, sourcing cost, inventory carrying cost, warranty cost, increased stockouts and, sometimes, decreased quality. The framework forces people to at least be aware of these costs. It also provides a mechanism for identifying the point where the costs of complexity exceed the revenue it generates. At this point, it is not economically justifiable to pursue increased complexity.
The various cost of complexity elements have been discussed in one form or another throughout this case situation. However, it is important to reiterate their meaning:

**Understanding what is wanted.** This means knowing what the end consumer really wants as opposed to what we think the consumer wants.

**Designing it in.** Here, we focus on whether we can use an existing component or assembly to meet the need or whether we have to design a newer set of parts (along with their support information, such as part numbers, item masters, and sourcing contracts, to name a few). This is where good design/engineering discipline has its greatest impact.

**Buying for it.** Here, we release the parts to the supply base for fulfillment. Within this element issues such as cost, lead time, quality, and capacity (specifically at the part level) are considered. It is also here that the issue of supply chain visibility becomes a major concern. GA US must be able to “see” deep enough into the supply chain to identify any potential problems before these problems adversely affect production and customer commitments.

**Building it in.** This is where issues of internal capacity, inventory stocking, training, and introducing the new components or options into the line must be considered. Every time a new option is developed, it must be introduced. The people on the line must know how to incorporate it into the existing design and how to carry out the associated actions. It also means scheduling the options frequently enough that the people on the line remember how to add them efficiently and without creating any quality problems. It also affects capacity utilization. The management at GA US shared data that showed how low runners affected capacity utilization. When a low runner is introduced into the line, production slows as people (especially the temporary employees) stop to remember how to incorporate the parts or they look for someone who can explain how it’s done. There was evidence that this “syndrome” affected not only internal operations, but also the operations of the supplier base.

**Does it work?** As previously noted, every time a new variation is added, the question arises of whether it will work correctly with the existing components or whether the option combinations will conflict.

**Supporting it in the field.** This final element recognizes that once an option or feature is introduced, the company is obligated to support it through inventory, information, capacity, and logistics (to get the part from the distribution centers to the dealer and/or the customer). Driving this element is recognition that this is a long-term obligation to the customer — one lasting, as in the case of GA US, 10 years.

This framework helps to ensure that the firm does not simply react to the demand for increased complexity but manages it as an integrated, largely economically driven decision.
COMPLEXITY — PART OF RISK AND RESILIENCE

An interesting feature of GA US’s complexity management is that it does not exist by itself. Instead, the GA US leadership team has decided to make the management of complexity an integral element of its risk and resilience activities. This actually makes a great deal of sense. Complexity can affect the firm’s ability to meet its operational (make production schedule), financial, and strategic objectives in the same way an earthquake or hurricane can isolate a key supplier, or a supplier bankruptcy or labor strike can affect a key supplier.

First, by integrating complexity into risk and resilience management, complexity can make the firm aware of how new options and features impact risk and resilience. In most organizations, there is an existing function or area that is responsible for the activities and decisions associated with risk and resilience. Second, in most organizations, risk and resilience has high visibility and recognition with top management. Third, many of the tools and procedures developed for managing risk and resilience can be effectively used to deal with complexity. For example, risk and resilience management often works to improve organizational visibility into the supplier base. Visibility is also valuable for complexity management. Finally, there are measures and metrics that have been developed for the management and assessment of risk and resilience that can be applied to complexity management as well.

KEY EFFECTIVE PRACTICES

GA US makes complexity management an ongoing affair. It is something that must be continually measured, managed, and addressed. The GA US team knew its current system was not perfect, but knew it had established a solid foundation on which it could effectively manage complexity — both now and into the future. GA US has developed a better understanding of what complexity is, how it affects performance, and what can be done to better manage it.

Based on the GA US case interviews, a number of complexity management effective practices were identified:

Supply and demand complexity is a fact of life. It is something the consumer wants and demands and it is something the firm must be willing not only to accommodate but also to manage effectively.

Complexity must be managed in an integrated, systematic manner. In the case of GA US, complexity occurs as the result of factors affecting both the supply and demand sides. Consequently, a firm has to address complexity from both perspectives. In addition, complexity is something that requires the involvement of everyone in the organization — marketing, engineering, sales, purchasing, operations management, and strategy.

Business analytics can be used to better understand complexity. Data and analytics can be used to replace urgency-driven reactive actions with reason and insights that can be supported with data. In this regard, complexity can be viewed as another example of the lean principle of “manage with data.”
Identify, quantify, and develop all decisions considering the “cost of complexity.” Recognize that at some point, the cost of complexity can exceed the benefits. The only way of identifying this point is to identify and quantify (through data) the six elements that make up the cost of complexity:

- Understanding what is wanted.
- Designing for it.
- Buying for it.
- Building it in.
- Does it work?
- Supporting it in the field.

Understand that complexity is simply a trade-off. Specifically, the cost of complexity is not well understood and the system is sub-optimized when the firm chooses to go for lowest piece cost.

Understand the links between complexity, risk, and resilience. If poorly managed, complexity can threaten the company’s ability to meet its financial, operational, and strategic objectives in the same way that an earthquake, a supplier bankruptcy, or a breach in internal cyber security can.

Measure for complexity. Woven throughout the previous discussion is the incorporation of measures and metrics. This makes a great deal of sense. Measures and metrics not only provide control, they also communicate the importance of complexity. It is a well-known axiom of business that “you manage what you measure.” Furthermore, by measuring complexity, everyone in the organization is informed that complexity is important and that it must be managed. Such measurement facilitates communication throughout the organization — between operations and top management, between operations and marketing, between GA US and its suppliers, and between GA US and its dealer network.

While management did not share direct financial data, there was the sense that these various complexity management practices and systems had improved revenue generation, reduced cost, improved relationships within the supply chain, and enabled GA US to proactively manage complexity rather than reacting to it.

**CONCLUSION**

Readers may wonder how studying complexity in an automobile company could provide relevant insights for their own firms. After all, cars are perceived as very complex products, while fast-moving consumer goods may be viewed as relatively simple. However, when you consider pricing, labeling, promotional offerings, and changes in the marketplace, you can understand how the profound experiences of GA US in terms of complexity management are highly relevant and applicable to addressing the issues and concerns currently plaguing other firms.

Specifically, complexity in the automotive or any other industry intensifies the challenge of forecasting capacity. In a capital-intensive industry where there are many combinations, if you cannot predict, it requires the firm either to over-capacitize or leave demand on the table. The conclusion is that complexity is not something to be avoided but instead is something that must be managed. Complexity is a fact of life and will continue to increase for most firms — but it is also an opportunity for improvement.
ABOUT APICS
APICS is the premier professional association for supply chain management and the leading provider of research, education and certification programs that elevate supply chain excellence, innovation and resilience. The APICS Certified in Production and Inventory Management (CPIM), APICS Certified Supply Chain Professional (CSCP), APICS Certified in Logistics, Transportation and Distribution (CLTD) and APICS Supply Chain Operations Reference Professional (SCOR-P) designations set the industry standard. With over 45,000 members and approximately 300 channel partners, APICS is transforming the way people do business, drive growth and reach global customers.

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