



Closing the Loop on a Circular Supply Chain

By Edgar Blanco and Ken Cottrill

Edgar Blanco, Ph.D., is research director of the MIT Center for Transportation & Logistics (MIT CTL). He can be reached at eblanco@mit.edu. Ken Cottrill is global communications consultant of the MIT CTL. He can be reached at kencott@mit.edu.

While conventional supply chains seek to efficiently move products in a linear fashion from raw materials to end consumers, a “circular” or “closed-loop” supply chain is one that is also dependent on feeding used products back as raw materials. The resulting circular supply chain poses unique challenges and opportunities for supply chain professionals.

Successfully building and managing such a system requires new and unconventional thinking. That’s what the Milwaukee, Wisc.-based global manufacturer Johnson Controls has done to incorporate automotive battery recycling into its business.

Distinguishing Features

There are plenty of economic incentives for rethinking the auto battery supply chain. As much as 80 percent of the materials used to make auto batteries can be derived from recycled batteries. The metals, plastics, and acid used to make conventional auto batteries can all be recycled. This creates a significant business benefit by minimizing the impact of price volatility of these commodities and providing raw materials at a more competitive cost. Moreover, automotive batteries contain hazardous materials. The best and most responsible form of minimizing the health and environmental risks is to recycle them.

Managing the reverse flows of a circular supply chain differs from managing a linear one on a number of fronts, from engaging customers to rethinking the distribution processes. In the specific case of Johnson Controls, it has to manage three linked supply chain processes simultaneously.

Consumer provided raw materials. The Johnson Controls supply chain starts with consumers, when their existing batteries have reached their end-of-life. Rather than calling this a “reverse flow,” Johnson Controls considers the supply of used batteries the beginning of its raw materials supply given the large amount of recycled content that

comprises its products.

Consumers often go to auto repair shops or specialized retailers to replace a non-functional battery. Johnson Controls has partnered with these outlets to provide an easy to follow process to collect, sort, and send the units to recycling centers. Currently over 97 percent of automotive batteries are responsibly recycled. Johnson Controls is actively working to achieve 100 percent recycling rates for automotive batteries in the United States.

A unique challenge of collecting raw materials from consumers is the variability of supply. The rate at which consumers replace batteries is highly cyclical and typically peaks twice per year. Batteries fail over time mainly due to extreme temperatures. As temperatures rise in the summer, older batteries will begin to expire at increasing rates. However some batteries that are nearing their end of life will survive the summer but will not have enough energy storage capacity to start the car when the first cold snap occurs the next winter. As a result, the demand for replacement batteries—and in turn, the collection of used batteries—typically rises in summer and spikes again in the winter months. However, this is all dependent on the temperature the battery has experienced. Mild summers and winters will extend battery life. Predicting this demand seasonality is not simple and leads to significant short-term variability. Supply chain professionals work with cross-functional business teams, including marketing and manufacturing, to plan for and mitigate this variation.

Recycling center operations. A network of Johnson Controls recycling centers throughout North America uses furnaces to recover the metals from the batteries. Once a furnace is activated, it is more cost effective to keep the furnace hot as long as possible. As a result, the company needs to recycle batteries at a constant rate.

Because the used batteries don’t come in at a steady rate, there is a need to either stockpiling used

batteries or varying the number of furnaces used throughout the year and then stockpiling the recycled materials. Deciding how many used batteries to process is a fairly complex optimization. The cost of capital equipment, current raw material market pricing, inventory carrying costs, labor planning, and distribution lead times and costs all need to be considered.

Battery manufacture and distribution. Once the recycling center processes the batteries, the resulting materials are sent to manufacturing plants to make new batteries. The finished product is delivered through a distribution network with multiple channels. Like any other seasonal consumer good, these distribution channels have to build inventory to prepare for the eventual demand spikes. As a result, peak demand for recycled materials required to manufacture batteries occurs a few months ahead of peak consumer demand, typically in the early summer and late fall. Johnson Controls is continuously re-evaluating its models, assumptions, forecasts, and plans to manage this mismatch.

Circular Challenge

Because these three linked supply chains run at three different seasonal schedules, the timing of the demand for new batteries and supply of used batteries is never 100 percent in sync. It is important for supply chain professionals to optimally plan and manage all three simultaneously. In a linear supply chain, managers start by looking downstream and then plan for upstream impacts (inventory pooling, demand shaping, network optimization). In a circular supply chain, finished good consumer behavior dictates raw material supply and both processes need to be planned simultaneously.

The Network Challenge

Keeping the many components of this circular supply chain in balance is a major task.

One example of this sophistication required is the use of a set of network optimization models on a daily, monthly, and annual basis. The models help Johnson Controls determine where to process recycled materials, which plants should make new batteries, and how to distribute the units down to the individual customer level. They take into account several factors: The costs and capacity of recycling centers; which batteries are produced in which plants; and the locations and capabilities of distribution networks for shipping new and collecting used batteries. Vehicle load factors on each route are also built into the model, although it is important to understand that this is a network—not a route—optimization model. It's a very detailed one too. Batteries are heavy and therefore transportation is expensive. Specific location data is an input; the geographic area is too broad if less granular location data is used.

A linear model must have a beginning and an end—circu-

lar equations are not as clear-cut. Used batteries come from separate supply sources mirrored to represent the same locations as final product customers. As a result, these models tend to be rather large, as they need to manage significantly more variables and constraints than a typical supply chain. In addition, care must be taken to aggregate products and customers while balancing the need for geographic granularity.

The Transportation Challenge

Another unique challenge is ensuring that the batteries are transported safely and efficiently. That requires special training for drivers and a program to help customers make sure that the units are packed correctly for transportation.

Drivers are trained to handle hazmat materials. They are also aware that used batteries carry a residual charge and represent an electrical hazard. Certain logistical skills

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are also required. Because trucks deliver new and collect old batteries, drivers must manage load balancing and repositioning during the delivery route while meeting the required safety and transportation standards.

Johnson Controls has concluded that the economic and environmental efficiency of the closed-loop system is optimized by a one-to-one exchange of batteries between retailers and delivery trucks. Under this scenario, a new battery that comes off a truck at a retail point-of-sale is replaced with a used battery, from the retailer, that is placed on the truck. This leverages the full truck capacity on each run, turning each truck into a two-way warehouse on wheels. This cuts costs and emissions and maximizes efficiency.

Lessons Learned

The biggest lesson learned by Johnson Controls is that in a highly integrated, circular supply chain like this one, every element is connected; when one fails, the entire system is affected. Channels and customers also need to have the right incentives to participate in the closed loop.

If Johnson Controls loses sight of the entire loop when planning each component of the supply chain, the system's efficiency breaks down. Supply chain interaction with marketing and manufacturing takes a new dimension, as they all affect the flows of products toward customers and of raw materials.

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