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The Four Horsemen of wire harness manufacturing

Executive summary

Growing demands for automotive electrical and electronic (E/E) features are driving increased complexity in the wiring harnesses that carry power and data signals to components around the vehicle. As a result, the wire harness manufacturing industry is expected to see significant growth, expanding into a 91 billion dollar industry in 2025. Wire harness manufacturers, however, often operate on small profit margins where unexpected costs can quickly prove disastrous. It is therefore critical for harness manufacturers to minimize costs during harness production and delivery. In this paper, we examine the four main sources of unexpected costs during wire harness manufacturing and shipping and discuss how modern digital solutions can help control these costs.

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Introduction

The increase in electrical and electronic features in modern vehicles places more emphasis on the wiring harness, which transmits power and signals between actuators, sensors and ECUs. ADAS and automated driving systems are particularly demanding due to the external sensors that the systems need to perceive the vehicle's environment, such as approaching objects or speed limit signs.

Increasing demand for highly automated and electrically propelled cars directly translates to a growing wire harness manufacturing industry. Currently, the industry generates sales of over 150 billion dollars every year. Almost 30%, 50 billion dollars in 2018, of those sales come from the automotive industry, and automotive wire harness sales are growing. Analysts predict that by 2023 the automotive wiring harness industry will grow to over 70 billion dollars in yearly revenue and more than 91 billion dollars by 2025 (Future Market Insights, 2016).

Even still, wire harness manufacturing is a low-margin business. Harness manufacturers often operate on margins of six to eight percent, and sometimes as low as 3 to 4 percent. As a result, one significant slip-up in the quality or logistics of harness production can spell disaster for a harness manufacturer's entire fiscal year. Minimizing costs related to harness production and delivery, therefore, is of critical importance to harness suppliers.

There are four primary sources of cost variability that arise during harness production and delivery: rework, obsolescence, premium freight and manufacturing inefficiency (figure 1). Collectively, we have come to think of these as the 'Four Horsemen of wire harness manufacturing'. These sources of cost are common across the industry, and their effects on the bottom line of a harness manufacturer can be significant. Reduction or elimination of harness rework alone can save millions of dollars each year for the harness manufacturer. This is, of course, easier said than done. The Four Horsemen are highly intertwined and driven by several factors that are hard to control.

Rework	Obsolescence	Premium freight	Manufacturing inefficiency
Causes: • Design change • Insufficient quality • Order fluctuation	Causes: • Design change • Insufficient quality • Order fluctuation	Causes: • Design change • Raw material changes • Order fluctuation	Causes: • Operator skill • Production layout • Line balancing

Figure 1. Rework, obsolescence, premium freight and manufacturing inefficiency are the main sources of cost variability for harness manufacturers.

Fortunately, modern electrical system and wire harness engineering software solutions feature capabilities designed to combat the root causes of rework, obsolescence, premium freight and poor manufacturing efficiency. In this paper, we will discuss each of the Four Horsemen and their most common drivers. Then, we will demonstrate how today's advanced software solutions can help prevent these costs from occurring in the future.

The zero-pipeline exception

The Four Horsemen are common, but not universal. The potential of three of the Four Horsemen (rework, obsolescence and premium freight) to create unplanned cost impacts is heavily dependent on the size of the manufacturer's inventory pipeline. Many manufacturers choose to locate production facilities in the lowest cost regions around the globe. Labor accounts for a significant portion of the cost of wiring (up to 40 percent), providing some significant cost advantages. However, production facilities located a great distance from the customer will result in longer inventory pipelines, due mainly to longer shipping lead times, and thus greater risk of incurring costs from one or more of the Horsemen. In contrast, KSK or modular production methods are less vulnerable to these costs because they employ just-in-time delivery and zero inventory production pipelines. Such methods build and ship custom harnesses for specific vehicles (i.e. VIN specific) in the order of vehicle production, thus preventing harnesses from being caught in lengthy production pipelines. KSK or modular production methods also come with their own disadvantages, causing many manufacturers to continue to employ traditional part number-based ordering models. For these companies, the Four Horsemen remain as a significant threat to their profitability.

The Four Horsemen: causes and effects

Rework

Harness rework is often used to save as much cost as possible even in the case of a widespread error or other issue. Rather than scrapping all affected harnesses and starting over, harness manufacturers can rework existing harnesses to resolve an issue, incorporate a design change or adapt the harness to a new level (figure 2).

There are many potential causes for harness rework. These root causes converge into three main drivers. The first of these drivers is design change. Broadly, design changes are introduced when wiring harnesses need to be modified to better support the production of the vehicle. Such changes are most often made to address an issue with the form, fit or function of the harness as-produced. For example, excess bundling material may cause a clearance issue with vehicle bulkheads or other components. Once the issue is identified, the harness manufacturer must implement a design change and rework any harnesses already produced to meet the updated specification.

Figure 2. Harness rework allows suppliers to resolve issues in as-produced harnesses, adapt to changing customer orders and more, but it is very costly.

Next, finished harnesses sometimes fall short of design intent and quality requirements. Quality issues are often attributable to errors introduced during the harness design stage. Traditional design flows rely on manual transfers of data between engineering teams and domains. Such manual transfers are error prone and may lead to insufficient harness quality downstream if not caught and resolved during design. Even small errors can lead to widespread harness quality issues, driving an expensive rework campaign in turn.

Third, OEM customers sometimes change the mix of harnesses in their orders. Such late order changes often leave the harness manufacturer with a surplus or shortage of specific harness levels. For example, during a new model ramp-up, the original marketing take rates are based on expected annual sales. Early on, actual dealership orders may have a higher percentage of high-content vehicles to entice early adopters, who are less cost sensitive, with high-spec vehicles. The OEM customer will then change their order to include a higher percentage of high-content harnesses at the final eight-week order cutoff.

At the eight-week cutoff, the harness manufacturer may have already produced and shipped harnesses (particularly if they are produced overseas and shipped by boat) based on the initial take rates. The harness manufacturer will need to build and airfreight the needed high-content harnesses to fulfill the updated customer order. Then, they will need to decide if they expect future usage or if they must rework the lower content harnesses to match future orders.

Harness rework is essentially a 'best of a bad situation' strategy. While it prevents total loss of finished harnesses due to an error or change in order volume, rework is still very costly for the harness manufacturer. As harness suppliers prepare for delivery of harnesses to a customer, they will build up a pipeline of materials both in their local harnesses and in shipment. This pipeline can often contain ten weeks of harnesses and materials. If these materials all contain a common design error, need a design change or are otherwise obsolete due a change in customer order, the harness supplier now has ten weeks of harnesses to rework. The unplanned cost impact of this rework can quickly add up to hundreds-of-thousands of dollars in cost.

Obsolescence

If harness rework is making the best of a bad situation, obsolescence is that bad situation. Obsolescence occurs for many of the same reasons as harness rework. In cases of obsolescence, however, the affected harnesses cannot be reworked. Some engineering changes require the addition of new circuits or the increase of takeout lengths. Such changes cannot be implemented by reworking existing harnesses; you can't stretch out existing wires, for example. These design changes do not always come from the electrical domain either. Engineering changes can be caused by a variety of cross-domain issues.

Customer order fluctuation can also drive obsolescence. Consider a scenario in which, 12 weeks from delivery, a customer predicts a ten percent take rate of a level C harness. Then, at the 3 week firm point, the customer decreases the take rate of that level C harness to only five percent. Harness suppliers are then left with the remaining harnesses that are no longer required by the customer. Such fluctuations in orders can coincide with the end of a vehicle model-year, leaving the harness supplier with extra harnesses that will become obsolete at the end of the year.

Quality issues with finished harnesses are a third source of obsolescence. As with rework, harnesses that do not meet specifications or quality standards cannot be delivered to the customer. While some of these issues can be resolved through rework, many cannot. These harnesses have to be scrapped, costing the supplier a great deal.

Obsolescence is the harness manufacturer's worst nightmare. As a result, harness manufacturers will often choose, whenever possible, to absorb the relatively less expensive options of harness rework to make parts usable, or premium freight to avoid overstocking of obsolete parts at the end of a model year. Ultimately, reducing obsolescence as much as possible can realize major cost savings.

Premium freight

Premium freight options allow harness manufacturers to quickly move harnesses, components and other materials to their customers or intermediary facilities. In general, this happens when a sudden need arises at either the component or harness level, driving the harness supplier to rush new materials through the pipeline. These sudden needs can arise from a variety of places, even from outside the harness supplier's control. Late changes in the raw materials called for in the harness bill-of-materials (BOM) often drive the use of premium freight. Shipping pipelines for raw materials can stretch for up to 16 weeks (or longer for specialty items like HDMI, coax or FAKRA cables). Harness suppliers

cannot wait this long when a late design change requires rapid implementation. Premium freight allows the supplier to bring the needed materials in and implement the needed change quickly.

Figure 3. Raw material shipping can take up to 16 weeks, driving harness manufacturers to use premium freight options if they need materials immediately.

Furthermore, sizeable design changes or quality issues can cause entire harness levels to become obsolete. Along with the cost of replacing the now obsolete harness level, the supplier may also need to use premium freight options in parallel with traditional shipping to deliver the new harness level on time. Finally, order fluctuations can also create a need for premium freight. A supplier's inventory levels for a given harness level can run short in the event of a sudden increase in take rate. To catch up to this demand, the supplier may need to rely on premium freight options.

Overall, premium freight often occurs in tandem with one of the other Four Horsemen, compounding the cost incurred by harness rework or obsolescence as the supplier rushes to deliver correct, high quality harnesses. Therefore, by reducing the errors that lead to rework and obsolescence, a supplier can also reduce their expenditure on premium freight.

Manufacturing inefficiency

Last, manufacturing efficiency issues can drive cost variability for wiring harness suppliers. Some of these manufacturing issues arise along with the other three Horsemen. Design changes, as with harness rework, obsolescence and premium freight, can be a driver of manufacturing cost. It takes time to set up and validate production processes and train operators for a new harness revision level. As these changes are made, manufacturing efficiency will suffer.

Other factors influencing manufacturing costs are independent of the first three Horsemen. Overall manufacturing productivity is heavily influenced by operator skill, experience and training. Experienced and skilled operators will have greater familiarity with the product and general processes. Due to their experience, these operators will be able to meet or exceed production takt time targets. However, as these operators retire, move to new jobs or leave the harness supplier for other reasons, manufacturing efficiency is likely to drop. This reduction in efficiency will endure while new operators are trained and brought up to full productivity.

Production plant design and layout can also play a role in the cost impact of manufacturing. Inefficient production design and plant layout can contribute to cost variability within harness manufacturing. During production, excess movement of material around the facility and work-in-process (WIP) inventory can both lead to increases in manufacturing cost. Production changeover between harness levels at the structured BOM (SBOM) and final BOM levels also takes time to setup and validate, thus impacting efficiency.

How a full digital flow can foil the Four Horsemen

Today, advanced wire harness engineering and manufacturing software can help harness manufacturers greatly reduce unplanned costs because of the Four Horsemen. Modern solutions leverage automation, design rules, and an unbroken digital thread, from initial requirements through to manufacturing and harness delivery, to minimize errors and ensure delivery of high-quality products (figure 4). Such a digital thread ensures that harness suppliers have access to correct engineering data on time, which enables harness projects to be set up correctly from the start. Additionally, the extension of this digital thread to the larger data landscape, including enterprise resource planning (ERP), manufacturing execution systems (MES), product lifecycle management (PLM) environments, simulation, testing and other specializations, is crucial to gaining a holistic understanding of complex project data. Several harness production issues can be avoided with such an understanding.

The digital thread and automation capabilities of modern engineering solutions help to eliminate design change by improving first-pass harness designs. Configurable design rules and automated design rule checks (DRC) catch errors during the initial design process. Improved 3D to 2D flattening also helps to communicate design intent clearly. With these capabilities, we have seen OEMs reduce their engineering changes by up to 50 percent. Fewer engineering changes and better first-pass designs directly prevent costs related to the Four Horsemen.

Next, when changes are unavoidable, a robust digital flow from harness design to the plant floor can greatly reduce the time needed to incorporate the changes for a 'good' product. A digital flow can eliminate days out of the change incorporation process, saving the supplier rework and premium freight costs for every day sooner the changes are implemented. This digital flow can also prevent the introduction of errors in 'ok-to-tool' alerts to the production facilities. In the past, these alerts included manually marked up designs that often would introduce new errors through misinterpretation or unclear instructions.

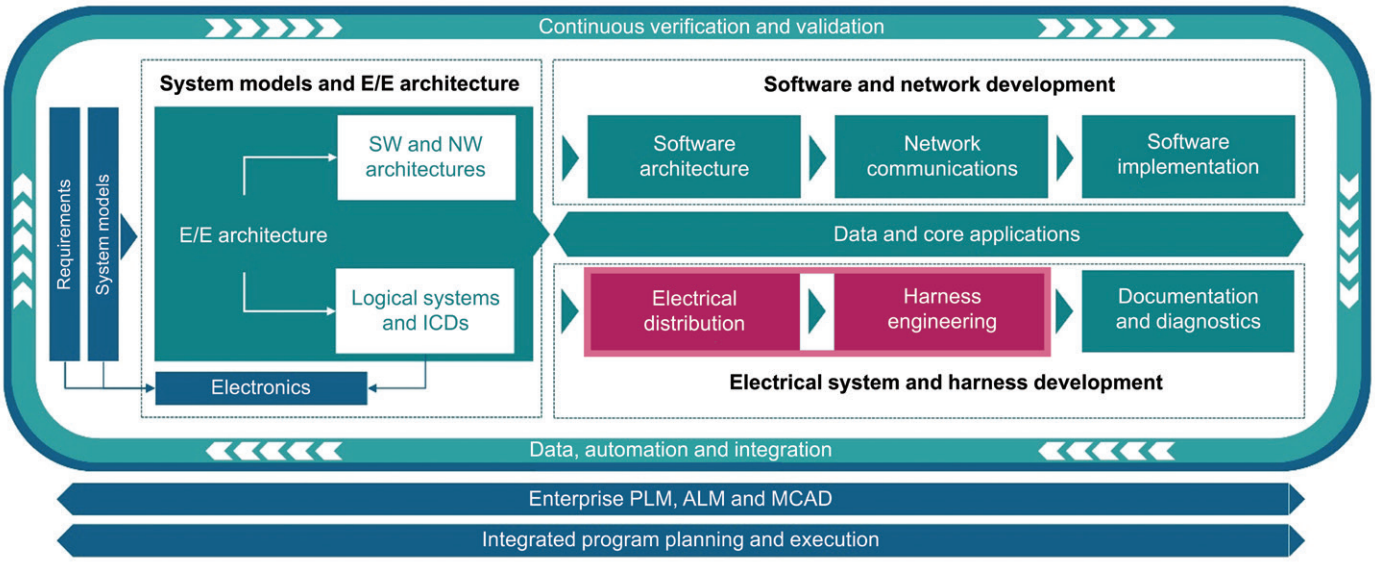

Figure 4. Modern electrical systems and wire harness engineering solutions maintain a robust digital thread from initial requirements through to manufacturing and service. Electrical distribution and harness engineering (highlighted in red) are shown in the context of this holistic digital thread.

A large percentage of harness quality issues can also be eliminated with a full digital flow from the harness design to the production floor. The manual creation of harness formboards, SBOMs and work instructions is an inherently error-prone process. A fully digital flow allows engineers to extract and create these documents directly from the harness design data. These connections ensure the accuracy of manufacturing documentation and greatly increase the likelihood that the product as produced will meet requirements and match the designs. In addition, by tying the engineering BOM to an ERP system, new material procurement can be reviewed and approved much more quickly, reducing BOM-related premium freight costs and shortening the pipeline ordering process.

To eliminate manufacturing efficiency costs, advanced wire harness manufacturing solutions can aid suppliers examine and optimize production plants, lines and processes. New line balancing tools can help engineers to quickly analyze and optimize production lines for every design change and harness level (figure 5). Proper balancing of tasks for each operator and workstation will greatly improve productivity ramp-up at launch. Integrated production line simulation capabilities also allow engineers to validate the production line for each change in harness release or customer orders on a weekly, or even daily, basis. Overall production plant layouts can also be examined virtually. Engineers can study various operations at the plant level through detailed visualizations and simulations. Plant-level simulations can, for instance, drive reductions in material movement to improve production efficiency.

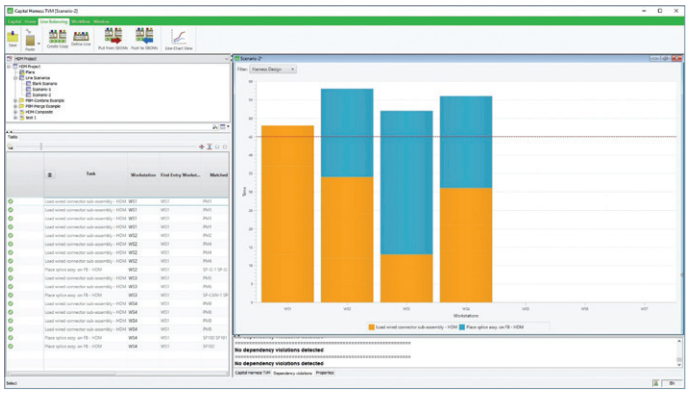

Figure 5. New line balancing tools accelerate line balancing with intuitive interfaces and guidance for production engineers.

Summary

The Four Horsemen of wire harness manufacturing present a continual challenge for today's harness suppliers. Unexpected costs related to the Four Horsemen can quickly derail a harness manufacturer's fiscal year. Managing these costs is of critical importance to harness manufacturers that operate in a highly competitive and low-margin business. Fortunately, modern wire harness engineering and manufacturing software, such as Capital from Siemens Digital Industries Software's Xcelerator portfolio, offer capabilities and tools to help harness suppliers attack the Four Horsemen at their roots.

Capital's robust digital thread, which connects harness design and manufacturing, and automation features prevent design errors upstream, ensuring they never reach the production floor. Traceability of design revisions and harness levels back to the initial requirements ensures that harnesses are produced to meet specifications and original design intent. Engineering changes can also be incorporated into harnesses more quickly and safely, preventing potential rework cost. Integrated manufacturing planning and simulation tools can then help top optimize harness production and even adapt to changes in take rates or late engineering changes.

The wire harness industry is poised for significant growth as demand for highly automated and electrically propelled cars increases. Capital's robust digital thread, automation and connection to the larger data landscape (including ERP, MES, MCAD and PLM systems) can help harness suppliers maximize their effectiveness and attract customers in this exciting time.

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