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General assembly manufacturing

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white paper

Automotive manufacturers must have the flexibility to produce a wide range of products in any of their plants anywhere in the world to ensure that they maximize the use of plant assets, and that they can meet market demand. This requirement creates the need for a new approach to general assembly manufacturing.

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Answers for industry.

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Executive summary

For both automotive OEMs and suppliers, today's global environment presents many challenges in planning the assembly process. Plants need to be flexible in their assembly capabilities; at the same time they must operate at maximum efficiency. Cost and time-to-market pressures also are factors, as competition forces margins lower and faster product development cycles can mean the difference between being the first or the last to market. The way process planning is executed today has to change. This includes all cross-functional aspects of the planning process – from strategic manufacturing planning to product development, manufacturing quoting and change management, planning and validation, plant design and optimization and production execution. The effectiveness of the overall manufacturing planning process is dependent on how well these aspects are linked and interactively managed.

Automotive companies' primary barriers to effective manufacturing planning for general assembly are:

- *Inadequate synchronization between product and manufacturing engineering*
- *Wasted time and effort due to inadequate management of manufacturing data*
- *Insufficient ability to optimize and validate critical aspects of the manufacturing process prior to launch*
- *Inability to work collaboratively and manage change within a shared context*
- *Inability to manage manufacturing execution for continuous process improvement*
- *Lack of a precise, reliable way to estimate manufacturing costs*

In order to remove these barriers, automotive companies are progressing towards digital manufacturing tools based on product lifecycle management, or PLM. These tools can help companies remove the barriers to effective manufacturing planning, resulting in:

- *Improved initial build quality*
- *Reduced development time*
- *On-time launch and delivery*
- *Improved capital utilization*

Introduction

In order to have the most flexible and efficient production assembly capabilities, manufacturers must have the ability to continuously validate and optimize their manufacturing processes. This means that they also have to be prepared for the potential of assembling any product in their portfolio at any plant anywhere in the world, and to be able to change the production mix quickly while still maintaining high quality.

In the past, automotive OEMs and suppliers were able to focus their manufacturing plants on dedicated product lines or platforms. They produced and assembled the same set of products year after year. Today, there are many more products in the market, and demand for those products changes much more rapidly. The need to respond to changes in demand across global production capabilities presents a significant challenge for manufacturing engineering.

In order to define and implement new manufacturing processes correctly, and to continuously improve manufacturing operations, manufacturing engineering must effectively collaborate with product engineering, procurement and plant operations. Tasks can no longer be completed serially and process planning cannot be done independently of the other functions. There are so many dependencies among them that they must work in parallel to shorten the overall product development time.

Even as these groups try to work together, they struggle with some significant barriers to effectively defining and validating the best possible processes. For example:

- Product development typically has little or no visibility into the manufacturing planning process. This makes it difficult to consider the impact their design decisions have on the cost to manufacture. The opposite holds true as manufacturing engineering has little visibility into development, and has trouble keeping track of changes in designs that may have significant cost ramifications. Often these costs aren't discovered until the change has been approved and implemented in development, and manufacturing has to address the problem. In general, keeping manufacturing engineering and product development synchronized is a challenge for most companies
- Information is hard to find. Knowledge about what's been done before remains in the heads of those who did it. People either have to figure it out again, or locate the person who did it the last time. This leads to a significant amount of wasted time and effort
- Just as physical prototypes of the product are tested and validated to ensure they perform as planned, the manufacturing processes and plants need to be tested and validated to make sure they function properly and as efficiently as possible. For most companies, this means prototyping the actual plant, fixtures and tooling. But how can that be done? It's not feasible to build a prototype plant; nor is it acceptable anymore to shut down a plant for weeks to "try out" the new tooling and processes. This is why there is so much anxiety around launches on most product teams. No one fully knows what problems will occur because they don't have the ability to optimize and validate all critical aspects of the manufacturing process prior to launch

- Understanding how the design affects others in the overall process is important, especially with the constant onslaught of design changes. In most companies, collaboration among departments and the ability to design within the same assembly context isn't possible unless the engineers are physically present in a common location. To a great extent, today's global structure with decentralized engineering centers and global suppliers makes this extremely difficult
- Continuous process improvement is a must. Plant personnel apply Kaizen principles to the assembly process on a daily basis, especially during the initial execution of a new product or process. However, in most cases, the knowledge of these fixes or best-in-class processes isn't managed very well and doesn't consistently get fed back into the assembly planning process
- Both OEMs and suppliers need a more precise and reliable way of estimating manufacturing cost, whether it's for a new product program or understanding how a change will affect the current assembly process

In order to make efficient use of the investment that manufacturers have made in their plants and equipment, they must be able to meet varying demand by quickly changing the products that are produced at each manufacturing facility. However, it is extremely difficult to conduct the assembly planning process in a common, repeatable fashion, striving for as much commonality as possible while still allowing for flexibility and localization. This requires an enterprise approach to process planning for each product implemented at each plant, allowing for certain variations based on current production product mix, differences in suppliers, labor and other variables that must be considered. To create this enterprise view of the bill of process (BOP), companies must put tools and processes in place that allow anyone who is affected by or contributes to the BOP to collaborate effectively on its creation and implementation.

Manufacturing Planning for General Assembly is a cross-functional activity that involves numerous processes across the company. This paper discusses those processes, including:

Strategic manufacturing planning

- Manufacturing planning at the portfolio level

Product development

- Providing early and accurate access to product design and bill of material information
- Maintaining alignment between evolving product and manufacturing process definitions

Manufacturing quoting and change management

- Delivering accurate manufacturing cost estimates
- Managing change context for collaborative decision making
- Applying proactive tools for accurate impact assessment

Assembly process planning and validation

- Accurately defining and documenting manufacturing processes for all product variants
- Proactively optimizing and validating assembly processes

Plant design and optimization

- Creating accurate digital representations of plants and resources
- Proactively optimizing and validating manufacturing facilities
- Optimizing and validating material distribution networks

Production execution

- Controlling execution quality
- Capturing information for continuous improvement

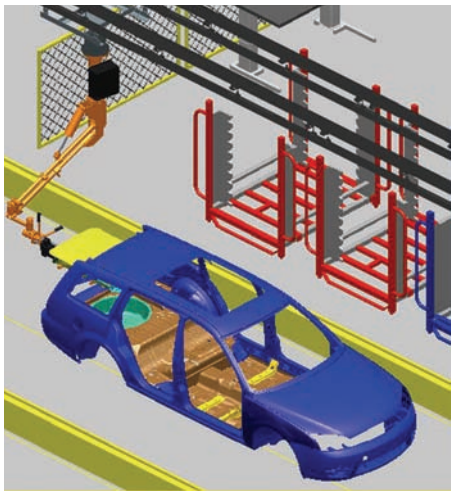
Have you visualized your future operational needs?

The strategic manufacturing plan sets the direction for the future manufacturing approach that will lead to a competitive advantage for the automotive manufacturer. Throughout the planning process, manufacturing engineering must take many things into consideration. The strategic manufacturing plan not only requires input from product engineering on the new product, but also needs input from tooling suppliers on new and upcoming tooling and technologies, market segments, government requirements, local labor laws and environmental concerns. Manufacturers also must review their current assembly facilities and decide whether or not it would be worthwhile to invest in updates or expansion.

Most companies spend a significant amount of time planning their product portfolio. But how many companies do the same with manufacturing? While many companies realize this holistic view of portfolio planning is important, few are good at doing it today. In developing the manufacturing strategic plan, manufacturers have difficulty:

- Designing and validating new manufacturing processes, tooling and techniques without building physical prototypes of the manufacturing process. Building manufacturing prototypes becomes very expensive
- Getting physical prototype parts and assemblies from product engineering and suppliers when they need them
- Accessing support data, such as future market segmentation and local labor laws

Automotive companies that want to give themselves a competitive edge are creating a digital manufacturing environment to assist them in strategic, portfolio-level manufacturing planning. This environment helps them by eliminating the lead time required to produce multiple versions of physical tooling prototypes. Physical prototype parts aren't required either, as the digital representation of the part can be used instead. New assembly processes can be validated within a digital representation of current and future facilities. Having a shared environment to manage the planning process also gives other organizations the ability to input their data, such as marketing and suppliers. This alleviates the need to hunt for the information they need when they need it. When digital manufacturing is used for strategic manufacturing planning, companies can make the plans become reality much faster and at much lower cost than is otherwise possible.



Double sunroof assembly line.

Do manufacturing and product development *REALLY* work together?

During product development, product engineers define and validate product assemblies and components, and generate bills of material (BOMs) for the various product configurations. Manufacturing engineers define and validate the assembly processes, fixtures and tools required for assembling the product, along with plant designs and material distribution plans.

Most companies want manufacturing to work in parallel with product engineering in order to reduce the overall product development time, but sometimes the link between them is weak at best. Tight collaboration does not exist, forcing the overall process to be more serial. Manufacturing and design engineers have trouble working concurrently because:

- They lack access to up-to-date product information early in the design process and as the design progresses because of inconsistent and unreliable change management procedures
- It's a struggle to synchronize or link evolving manufacturing process definitions with the evolving product definition, resulting in delays in the manufacturing planning process and the overall product development cycle. Sometimes errors in the process definition get passed to the plant floor at product launch

A better way to manage assembly process planning is to enable manufacturing engineers to gain early access to design information and to collaborate digitally with design engineering, so that manufacturing considerations can influence design decisions. Leading companies are implementing a digital manufacturing environment that is tied to product BOM configurations and the associated CAD data early in the design process and as the design progresses. This digital manufacturing environment allows companies to automatically synchronize their bill of process to related product information, so that accurate manufacturing processes can be defined.

In addition, automotive companies are achieving greater engineering synchronization through collaboration within the context of the manufacturing environment. All parties can conduct their design work in a digital representation of the plant floor. This makes it much easier for everyone to understand how their design affects the others. Now, design teams don't have to meet in a single location or go to the physical plant to work in context. They can simply collaborate around the digital version from wherever they are in the world. Synchronizing product and manufacturing engineering leverages the strengths of the entire team to arrive at decisions that represent the best course of action for the business.

Are you making timely and accurate financial decisions?

In the planning and quoting phase, OEMs and suppliers must manage changes from product engineering, suppliers and from within manufacturing. If a change is initiated by product engineering, manufacturing must be notified before the change is approved for implementation so that they can accurately assess its impact on production. Conversely, product engineering must also be notified if manufacturing makes a change to either the tooling or the manufacturing process. Manufacturing, either at the OEM or supplier, must then communicate the cost of these changes to a product program manager in the form of a quote.

It is difficult for companies to manage these changes and accurately assess their cost in a timely fashion. This is especially true for suppliers that have multiple OEM customers and provide hundreds of different parts to each one. What they find particularly difficult is:

- Notification to manufacturing that a change request has been made. Manufacturing and engineering typically use different systems to manage the change process, if they use change management systems at all. This makes it difficult to ensure that both parties are in sync on changes and both are involved in assessing their impact
- Tracking the status of changes as they move from department to department. Because different systems are used, people can't see across organizational boundaries and understand change status
- Assessing the true manufacturing cost impact to the product. Most knowledge about the impact of changes on manufacturing is contained in the heads of the people who've experienced something similar before. Finding that knowledge can be time-consuming at best, and impossible if the experience has left the company or retired. This usually means that people estimate cost – or make their best guess

The root cause of cost estimation problems lies in the way that automotive companies capture and retrieve manufacturing cost data today. In order to generate accurate and meaningful manufacturing cost data, virtual process planning tools are required. Various assembly alternatives can be designed and assessed for both throughput and cost to select the best alternative for the product before anything is physically assembled. The same analysis can be made for the cost of moving building steel or adding conveyors. These all have an impact on the cost and timing to produce the product. Companies need to have the ability to validate these factors before capital is expended and production begins. When manufacturing cost information is available at key decision points, suppliers and OEMs are able to rapidly conduct a thorough impact analysis and establish accurate estimates of the cost of either a new design or a change.

Are you adequately optimizing and validating assembly processes before launch?

Throughout assembly process planning, manufacturing engineering develops the method, tooling and sequences required to assemble a product, along with the plant design and material distribution. Manufacturing engineering uses the BOM created by product engineering to generate a manufacturing BOM. A BOP is then created and linked to the manufacturing BOM. As the assembly process is designed, manufacturing engineering usually validates and optimizes the tooling and processes in a physical prototype environment before releasing it to the plant.

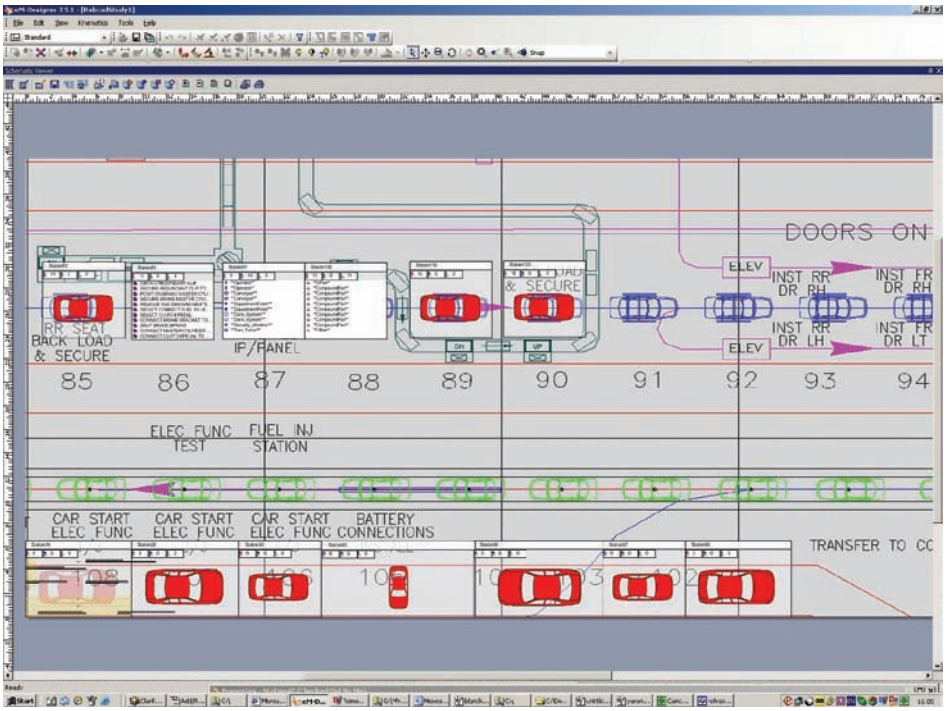
Numerous people representing the many functions involved in planning the assembly process need to work together to create the best possible process. Complete collaboration does not occur unless all of these people are physically present in one location for a design review. Only then do they fully understand how the design of one part of the process affects the others. However, when that collaboration session ends, people go back to their individual jobs and collaboration becomes difficult again. As things evolve throughout the development and planning process, the lack of continued collaboration leads to assembly processes that don't match the latest part revisions or process changes and/or tooling that impedes the overall assembly process. These problems then become evident at production, leaving the plant personnel to resolve them and the company to bear the cost of the mistake.

The barriers to effective assembly planning can be summarized as:

- Lack of synchronization with product engineering. Today, when manufacturing engineering works with product engineering, the communications between them are somewhat disconnected and chaotic
- Lack of effective change management practices and systems. Changes within the product or the manufacturing process don't get communicated to the right people in a timely fashion. Most of the time, companies have no idea whether or not the change is being implemented
- Insufficient and inefficient optimization and validation of the assembly process. Tools used for either optimization or validation are not sufficiently capable of giving a true representation of real-world results. Creating a physical prototype to test theories can become either costly or time-consuming
- Inadequate management of the manufacturing data. Even within manufacturing engineering, getting and receiving necessary information in a timely manner is difficult. Each department has a tendency to operate within its own silo and ignore the upstream or downstream impact of its designs

To alleviate these problems, manufacturers can implement a digital manufacturing environment that manages the entire workflow of the assembly planning process. This environment allows engineers to collaborate from anywhere in the world around the clock, removing physical and geographical barriers. Engineers can be notified immediately if their designs need to be revised or if someone else in the workflow requires information from them. Engineers can design their tooling, fixtures and processes within the context of the virtual plant floor and access data from other departments without physically having to track it down. Processes, tooling and fixtures also can be stored and re-used within this environment, saving overall product development time and fostering continuous improvement. For the first time, engineers have a digital representation of an entire work cell and can determine if material bins are blocking the operator walk path or if current tooling will work with a new part.

Automotive manufacturers are embracing digital manufacturing and manufacturing process management (MPM) efforts that are evolving into collaborative systems using advanced 3D simulation. General Motors Corp. (Detroit), Ford Motor Co. (Dearborn, MI), DaimlerChrysler



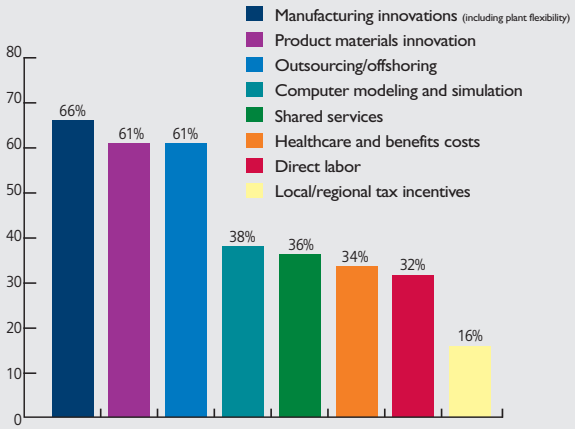
AG (Stuttgart, Germany) and Toyota Motor Corp. (Tokyo) have all mounted significant efforts to use the technology to streamline product development[1].

Major opportunities for cost savings

Innovations in manufacturing are seen to be the greatest source of cost savings, closely followed by materials innovation and outsourcing to countries like China and Eastern Europe.

Please tell me how great an opportunity for future cost savings each of the following areas offer auto manufacturers and suppliers, using a scale of 1 to 5, where 1 means "no opportunity" and 5 means "major opportunity."

Major opportunity/ opportunity (4-5 on a 5 point scale).



Source: Momentum 2007 KPMG Global Auto Executive Survey, 2007.

Asian respondents were significantly more likely to see cost savings opportunities in computer modeling and simulation than North American and European respondents.

North American respondents were sigificantly more likey to see cost savings in health care and benefits costs than European and Asian respondents.

[1] "Digital manufacturing taking hold", *Manufacturing Engineering*, Jan 2003 by Patrick Waurzyniak

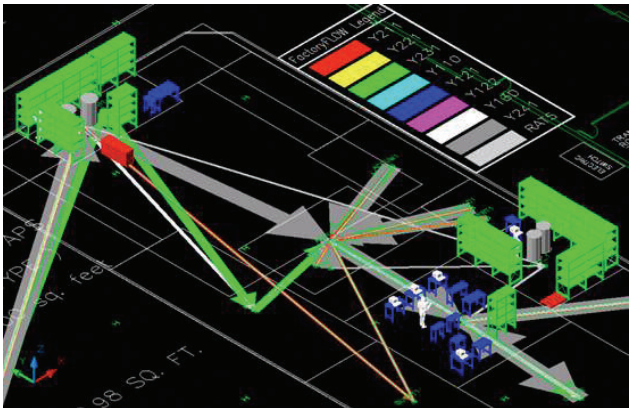
Are you validating that your plants will run efficiently before you build them?

Plant design and optimization must be done whether a company is dealing with a green field or brown field assembly facility. When the facilities engineers design the plant, they must consider everything that is required to assemble a product. Plant designers receive information from manufacturing engineering, industrial engineering, materials handling and the plant (if it is a brown field). They also must consider other factors such as environmental, local government and ergonomic requirements. The assembly process itself is primarily the responsibility of the process engineers within industrial engineering. They must decide on the assembly sequence and method of assembly, and validate that the correct tooling is used in each plant.

Having global production capabilities has presented new challenges for plant design. While the process has always been a complicated one, its complexity has been brought to a whole new level. There are many more things to consider on a global or holistic level, such as commonality across all plants, real-time plant floor layout updates, change control and country-specific requirements. The barriers to effectively design and validate these plants can be summarized as the:

- Lack of realistic (3D) virtual definition of the plant and work cells. Even though most plant designs are created digitally today, they are limited in their value because they are static and 2-dimensional
- Inability to validate plant processes before equipment is in place and can be physically tested. It is very difficult to validate the plant floor without a physical prototype. Otherwise, people take their best educated guess based on past experience or help from plant personnel
- Lack of access to information on which to base critical decisions. Getting the most up-to-date information from manufacturing engineering, industrial engineering and the plants also is a challenge. There is no central environment to facilitate these design iterations
- Lack of early feedback from plant operations to product development. In most cases, optimization can't take place until the new design is in production. At that point, plant personnel must Kaizen the design. In addition, improved designs typically are not communicated back to engineering where they can be used to improve future designs

Assembly plant management should not have to worry about validating and optimizing plant designs. That's why manufacturers are now beginning to use 3-dimensional digital tools in the plant design process to ensure that their design is valid. With these tools, engineers can walk through the plant as if they were in the physical structure themselves. They can see the plant in operation and validate the number of products being produced per hour. What-if scenarios can be run to optimize the design configurations of the building, tooling, carriers, material handling devices, operator walk path and more. Manufacturers can actually run a plant before they ever put a shovel in the ground to build it.



Material flow planning and simulation.

3D virtual plant optimization leads to higher quality products

General Motors' Lansing Grand River assembly plant was named the highest-ranking assembly plant in North and South America, and the world's third best plant, for initial quality in the J.D. Power and Associates 2004 Initial Quality Study. Overall, the company achieved a 10 percent improvement in initial quality. GM simulated and optimized the Lansing Grand River plant design in a 3D virtual environment before construction began. As a result, GM (and companies like it) have seen the value of full digital plant design in direct application to the quality of their finished products[2].

[2] *GM Press Release*
http://email.gmcanada.com/corpdb/cachq/pressrel.nsf/7a15ac9c7647fb7985256790005e5a02/0f717f3615bc5a0d85256e89005ee7ab?OpenDocument

Are you capturing the information you need to accelerate continuous improvement?

Today, manufacturing engineers and suppliers take up temporary residence at the assembly plant as they prepare to launch a new product. They work with their counterparts in the plants to ensure that new processes, methods, layout and tooling are implemented as designed.

With more global product programs, this practice takes the engineers away from their primary roles for too long. The impact of waiting until the product is released to the plant to fix problems has become a growing financial burden for companies, as have expenses related to travel. The major barriers to effective production execution include the:

- Lack of ability to completely simulate plant operations without a physical prototype. Statistical simulators are used, but don't provide a full realistic view of the entire process as if the engineer were physically there
- Lack of production input in the manufacturing planning and product development process. Without a common environment in which plant engineers can consistently provide input during the assembly planning phase, they typically must "fight fires" at the start of production. This makes product launch one of the most stressful times in the vehicle development process
- Lack of ability to provide lessons learned feedback into the process. As the plant eliminates start-up issues, there is no common environment for it to provide feedback in support of continuous improvement. Nor is there a way during normal production for the plant to feed its best-in-class processes back into the overall assembly planning process so that other plants can capitalize on lessons learned

Companies that don't want to leave surprises for the assembly plant are taking a different approach. First, they realize that all parties need to be involved in the assembly planning process, including the plants. Since plant personnel can't afford to leave the plant for extended periods of time, companies want to have a common environment that allows the plant to fully participate in the overall collaboration while making the best use of their time. Second, companies also want to be able to capture the best practices and lessons learned on the plant floor, so that they can be leveraged across other plants and for future process improvements. They have found that this can be done very effectively through a digital manufacturing environment that can be accessed by anyone, anywhere.

Autocar, LLC, a category 8 cab-over-wheel truck assembler, has taken the first step in ensuring that the plant is prepared to assemble each unique product. The plant uses the same digital environment to assemble the product that engineering uses to design it. Assemblers refer to a digital build sheet on a computer in each workstation that includes both the BOM for a particular VIN and a 3D graphical representation of that VIN. This way, the assemblers know exactly what parts they are supposed to put on the vehicle, what those parts look like and how and where those parts are to be attached.

Summary

For automotive OEMs and their suppliers, success depends on the ability to deliver innovative products to market faster than the competition. The market is too dynamic to allow for process inefficiencies. Manufacturers must have the ability to validate and optimize future conditions and capabilities before expending any capital on new facilities or tooling.

According to Dick Slansky, Senior Analyst PLM and Digital Manufacturing, ARC Advisory Group, companies are transforming how they define their manufacturing processes through digital manufacturing. With this approach, manufacturers are focusing on the optimization of production processes, reducing time to product launch and cutting the cost of commissioning production systems[3]. Product lifecycle management (PLM) solutions provide the ideal tools to implement a digital manufacturing environment. They allow companies to build a digital manufacturing backbone that links all cross-functional aspects of the planning process.

PLM ensures that all production and assembly issues can be anticipated and resolved well before product launch, eliminating the need to debug at the plant level. Virtual prototyping of parts, tooling or entire product portfolios greatly improves strategic planning, ensuring that plants hit full capacity as soon as products are released for production. Detailed scenarios ensure synchronized, flexible and highly efficient production and assembly processes. Built-in feedback mechanisms make it possible to establish continuous improvement as a standard practice.

Digital manufacturing eliminates the primary barriers to effective general assembly manufacturing, including:

- Inadequate synchronization between product and manufacturing engineering
- Wasted time and effort due to inadequate management of manufacturing data
- Insufficient ability to optimize and validate critical aspects of the manufacturing process prior to launch
- Inability to work collaboratively and manage change within a shared context
- Inability to manage manufacturing execution for continuous process improvement
- Lack of a precise, reliable way to estimate manufacturing costs

PLM-enabled digital manufacturing solutions transform the way companies do business by providing:

- A universally accessible digital environment that automatically synchronizes all manufacturing process information with related product, plant and resource information so that accurate manufacturing processes can be defined and implemented
- In-context collaboration, based on the manufacturing data backbone, that allows geographically dispersed product and manufacturing engineers to work together within a shared knowledge context to accelerate and improve decision making
- Rich visual planning and validation applications that enable companies to proactively define, optimize and validate manufacturing processes prior to launch. Quoting, cost estimates and change management can be vastly improved
- Configuration-driven execution management for high quality execution and as-built traceability

[3] "Managing Automation's Manufacturing Advantage", *Web Event*, January 29, 2007.

In order to remain competitive and to ensure that they have the most capable, low-cost general assembly manufacturing process, automotive manufacturers and suppliers need to fully embrace PLM. Companies that implement PLM-based digital manufacturing can manage today's complexity and optimize their assembly operations from a strategic global perspective. PLM removes the barriers to effective assembly manufacturing planning, resulting in:

- Improved initial build quality
- Reduced development time
- On-time launch and delivery
- Improved capital utilization

To learn how automotive companies are addressing their assembly manufacturing barriers and dramatically improving production efficiency through PLM, visit:
http://www.plm.automation.siemens.com/en_us/industries/automotive/

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