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Sustainable Mobility: Automotive Industry Challenges, Opportunities and the Role of PLM

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Executive Summary

This report seeks to frame the issues, challenges and opportunities presented by the global automotive industry's drive toward sustainable mobility. Through in-depth research and interviews with executives, policy makers and thought leaders at automotive OEMs and suppliers, government agencies, and nongovernmental bodies influencing policy and practice, we sought to:

- Identify the challenges these initiatives pose for the auto industry and its stakeholders today
- Explore the range of technologies, entrenched and emerging alike, now being evaluated and adopted to help meet these challenges
- Explore in particular the value of product lifecycle management (PLM) solutions in meeting these challenges, today and going forward

The perspectives in this report are intended to benefit – and foster mutual understanding among – corporate executives, compliance officers, product development executives, program managers, PLM system leads, discipline leads, engineers, designers and other stakeholders in the automotive industry's present and future. We believe informed, coordinated engagement by all these is crucial to meet the triple-bottom-line challenge – people/planet/profit – posed by sustainability, and to emerge from today's industry turmoil strengthened and poised to lead.

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Sustainable Mobility's Triple Bottom Line: People / Planet / Profit

Sustainable mobility principles connect transportation and accessibility issues to holistic strategies for sustainable economic development. They entail the improvement and long-term well being of the environment, the development of local and regional economies, and engagement with a range of social justice issues. Sustainable mobility goals integrate efficient and accessible private, public and pedestrian mobility systems, vehicles and technology into a systems-based vision of a cleaner, more equitable society. The automotive industry has a critical role to play in ensuring, independently and in partnership, more responsible product creation, in more sustainable facilities, and for more efficient, eco-friendly and innovatively imagined personal transport options for a burgeoning global population.

How companies in the automotive value chain respond to the complex needs of the marketplace, of the environment, and of society is central to their long-term survival and competitive advantage. For these companies, the power of sustainable mobility is how it invites an engaged and proactive approach to the entire product lifecycle – challenging organizations to apply a wider, more holistic lens and strategy to their business ecosystem by shifting away from short-term, compliance-driven tactics toward strategies that optimize overall business performance.

The reality is that sustainable mobility is as much about the sustainability of the automotive and transport sector from a business and economic perspective as it is about meeting environmental and social needs. The well being of all three – People/Planet/Profit – is the foundation of the *Triple Bottom Line* of meaningful sustainability paradigms. As a result, business units, companies and the industry at large have a crucial partnership role to play in addressing the creation of not just "green products" but, rather, high-performing and successful products that continually develop to limit environmental impact while supporting a flourishing, highly mobile society.

Global drivers Globally, drivers for achieving sustainable mobility include:

- Climate change and environmental concern
- Energy scarcity, diversity, and security
- Resource constraints
- Regulatory intensification
- Regionally varied regulatory frameworks and policies
- Urban congestion and urban sprawl
- Deteriorating or inadequate infrastructure
- Public health and safety issues
- Growing consumer demand for more responsible products and companies

A representative industry view of these issues was set forth by Josephine Cooper, Group Vice President for Public Policy and Government/Industry Affairs, Toyota Motor North America, at the Center for Automotive Research's Management Briefing Seminars[1] in August 2009:

[1] Center for Automotive Research Management Briefing Seminars, Traverse City, MI, August 4-7, 2009. http://mbs.cargroup.org/

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*"At Toyota, our top public policy priority is **sustainable mobility**. This means making vehicles that meet customer needs and expectations, while also being safe, sustainable, and better for the environment. We take a systemic approach to sustainable mobility, with four basic components.*

*"The first part involves our **vehicles** and the vast array of emerging automotive technologies. We must reduce CO_2 and smog-forming emissions through pursuit of diverse and alternate technologies.*

*"The second component is the **energy** required to power these products. What sources and forms of energy will be sustainably available in the future? Which of these can be scaled up to accommodate hundreds of thousands, or possibly millions, of vehicles? Can we contribute to energy security?*

*"The third component is **partnerships**…The issues we all face – auto manufacturers, cities, states and countries – are so great that solutions require partnerships across many different sectors…*

*"Finally, our approach considers tomorrow's **urban environment**. For example, we know urbanization is increasing globally. This year, the United Nations reported that half the planet's citizens now live in cities, for the first time in history. We need to address this trend with new kinds of vehicles. At the same time, we must localize production and ensure our business decisions result in sustainable communities in which our products contribute to improving people's lives." – Josephine Cooper, Group Vice President for Public Policy and Government/Industry Affairs, Toyota Motor North America*

Regional drivers Current and emerging regulatory environments present auto industry actors with a set of compliance frameworks related to environmental impact, emissions performance, efficiency standards, and diversified energy and fuel strategies. Additionally, the globalized reality of the industry presents the automotive value chain with site-specific challenges as well as areas of opportunity that directly impact the technological needs and development schemas supportive of successful, sustainable product lifecycles.

USA U.S. auto makers' sustainability initiatives are, at present, primarily focused on meeting aggressive CAFE (corporate average fuel economy) and greenhouse gas (GHG) emissions targets imposed by the federal government. The challenges are to develop and deliver compliant vehicles, on schedule, at prices consumers will pay. Sustainable manufacturing processes and facilities are also on the radar, though of less urgency at present.

EU The European Commission reports that "about 80% of European citizens live in urban areas and mobility is becoming an everyday problem for them because cars are causing so much congestion. Increased car use has also been accompanied by safety and environmental problems." One way being pursued to address this challenge is for Europeans to embrace electric cars. But, as in the U.S., barriers to electrification remain. As noted by CLEPA, the European Association of Automotive Suppliers, "With batteries costing thousands of dollars and limited to about a 100-mile range, consumer appetite is unclear. Infrastructure for recharging batteries is largely absent; utilities are wary of investing."

India is challenged with a massive and unevenly developed urban network, anchored by a series of megacities, in the throes of urban sprawl. Indian sustainable mobility issues are marked by an extreme emphasis on public health and safety, pollution, and skyrocketing demand for personal vehicles.

China faces explosive population growth, burgeoning consumer recognition and demand for affordable mobility, and low consumer awareness of global green pressures which are, however, coupled at the producer and federal government level with strong awareness of the urgency of sustainable-development paradigms.

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The table below illustrates how the automotive industry's sustainability priorities are framed by the geographic specificity of sustainable mobility issues in these key geographic markets:

Key Sustainable Mobility Challenges & Priorities by Geographic Region						
	Societal / economic growth	**Infra-structure concerns**	**Energy demand**	**Regulatory issues**	**Technology lag**	**Consumer issues**
U.S.	Intensifying urban and suburban traffic congestion Urban expansion/ sprawl	Deteriorating transportation infrastructure Inadequate public transport systems Insufficient power infrastructure to support electric vehicles in volume	Need to increase energy independence as a matter of national security	CAFE standards Emerging national standards for GHG emissions Lack of suffi-ciently integrated approaches and technology across stake-holder groups	Inadequate supply of alternatively fueled vehicles Barriers to electrification including high cost and limited range of current battery technology	Rising demand for eco-friendly vehicles Weak consumer economy
Europe	Political pressure: climate strategy, energy security, petroleum dependency Intensifying urban congestion	Insufficient power infrastructure to support electric vehicles in volume	Need for clean energy, fuel diversity, energy security Fuel shortages, rising fuel costs	Increasingly strict environmental, safety regulations (WEEE, RoHS, REACH) Significant emphasis on ELV regulations Regulations vary across regions	Barriers to electrification including high cost and limited range of current battery technology Need for clean production facilities to support sustainable manufacturing practices	Rising demand for eco-friendly vehicles, but not at premium prices Changing demographics – impact of an aging society on mobility requirements
India	Major challenges of poverty, poor public health, and basic education Spiraling population growth and density Major mobility divide Poor air quality and increasing noise pollution	Narrow road system and inadequate parking infrastructure Inadequate infrastructure for high volume of pedestrians Erratic driver and pedestrian behavior plus weak emergency response system yields world's highest rate of road deaths	Need for clean and stable fuel and energy options Need to support energy needs of major infrastructure projects Insufficient energy supply for present population compounded by explosive demand rise as population grows	Challenge of having a voice on international stage while bal-ancing industry and regional government resistance to aggressive climate policy Presently the world's 5th largest emitter of GHGs – emis-sions expected to more than triple by 2030	Majority of population without formal access to electricity for basic needs Many vehicles on the road are quite old, inefficient, and/or in poor repair High cost of technology development	Rapid motorization and demand for personal transport Undeveloped consumer awareness and demand for eco-friendly vehicles
China	Aggressive population growth and density Poor air quality and increasing noise pollution Major rural / urban disconnect	Demand outpacing capacity despite major planning schemes Weak emergency response system plus high incidence of auto accidents and fatalities Land availability and usage constraints	Need for clean and stable fuel and energy options in the face of explosive industrial expansion	Challenge of implementing national environmental regulation across multiple regions Ineffective exe-cution of policy at regional level Mounting internal and external pressure to align with global emissions reduction commitments	High cost of technology development Need for clean production facilities to support sustainable manufacturing practices	Rapid industrialization, motorization and demand for personal transport

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Getting there from here To date, the automotive industry has taken up the challenges of sustainable mobility with varying degrees of thoroughness and success. While sustainable mobility is formally integrated into the language of overall industry rhetoric and vision, the integration of a holistic strategy for sustainable product creation remains, for many, limited and/or narrowly implemented as companies chiefly react to the exigencies of regulatory compliance mandates for vehicle emissions and efficiency. Additionally, the regional specificity of sustainable mobility goals and challenges have clear implications for creating products that not only comply with a given regulatory framework, but also meet the mobility needs and market demands of specific regions.

Such issues add to the difficulty of not only effectively envisioning but also executing sustainability, on the ground, in the product lifecycle process. The sustainability governance statements and reports of numerous OEMs attest to these companies' efforts to achieve this – but also acknowledge the challenge to "embed sustainability more deeply across all functions," as Ford puts it.[2] Therefore, even as sustainability's strategic importance is given strong recognition at the executive levels across the automotive industry, the manner in which it is communicated and integrated throughout auto industry organizations – and into the product creation cycle – remains a central concern.

Implementing Sustainable Mobility: PLM's Benefits, Challenges and Opportunities

Today the global auto industry's sharpest sustainability focus is on attaining target vehicle attributes for fuel economy and emissions – the sense of urgency, if not near-alarm, communicated by senior executives from the U.S., Europe and Asia alike is striking. To these ends, PLM's value in supporting effective decision-making is well understood, and widely applied.

But greener vehicles are only a first step in what must necessarily be a much more broadly conceived and deeply implemented set of goals. PLM technologies hold the potential to help advance the global automotive industry toward its sustainability objectives by supporting and optimizing five major functional areas that, together, span sustainability's triple bottom line of people/planet/profit:

- ***Planning for sustainability*** – PLM supports portfolio and requirements planning and management.
- ***Design for sustainability*** – PLM supports designer decision-making around key product attributes that impact product and business sustainability – consumer appeal, regulatory compliance, materials selection, cost information, etc.
- ***Sustainable manufacturing*** – PLM includes capabilities for optimizing manufacturing processes and equipment to conserve power, water and other resources consumed in production.
- ***Sustainable service and end-of-life*** – PLM provides a managed information backbone to support designer decision-making around service part definition, repair procedures, and part/fluid recycling/disposal.
- ***Governance, compliance and reporting*** – PLM provides a managed information backbone to support these issues cradle-to-cradle.

[2] http://www.ford.com/microsites/sustainability-report-2008-09/governance-sustainability-integration

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Sustainability in product planning The ability to effectively identify and address the needs and wants of the marketplace is the cornerstone of any successful product planning effort. Add sustainability to the mix and the challenge becomes that much greater. Specifically, sustainability in product planning must encompass not only general product requirements planning and management, but must capture "green" product specifications and take into account current and anticipated regulatory compliance requirements, as well; must support the ability to identify and source suitable sustainable materials, must provide the ability to perform effective sustainability scenario planning and product lifecycle assessments, and in general must support effective sustainable product portfolio management, capable of comprehending the environmental, social and economic impact of product planning decisions. A PLM system can support this planning effort in a number of ways – from enabling companies to perform sustainability-related "what-if" analysis early in the design cycle to identifying suitable "sustainability-focused" suppliers and sources of materials.

Dashboard views into materials databases and ERP data One key opportunity for PLM is to provide tighter data integration and dashboard views into materials databases used to quantify and control environmental-impact vehicle attributes. Indeed, since the PLM system has the power to track both what's in the product, and what the product emits, it is an excellent candidate for calculating not just the product's potential environmental impact, but its actual performance against a continually changing landscape of environmental regulations and controls:

> *"The PLM vendors have a good understanding of what's in the product, and what the product emits, since their systems manage the attributes. They should be able to tell us what the footprint of that product is." – Automotive OEM*

Related to this is the view that such PLM-enabled dashboards can also provide a valuable link into sustainability-related product data currently stored in manufacturers' ERP systems:

> *"Today, the ERP system often contains much of the data that's needed to determine overall compliance/sustainability in terms of material control and actual environmental footprint/impact. So, why not simply have a PLM sustainability dashboard that provides a view of this data?" – Automotive OEM*

Sustainable product design and development The application of sustainability principles to the product design phase is critical for companies seeking to achieve the kind of triple bottom ROI benefits reported by leading manufacturers, since it is during this early phase of the product lifecycle that product design decisions can have the greatest impact – whether on cost, performance or the environment. To this end, it becomes important for organizations seeking to support sustainable design to be able to capitalize on engineering design and analysis tools and other analytics to validate product concepts against specific sustainability criteria "up-front" prior to manufacture (ie. weight reduction, fuel efficiency, emissions control, etc.) and to examine key product attributes that impact product and business sustainability: consumer appeal, regulatory compliance, materials selection, cost information, etc. Here, a PLM system excels in its ability to support sustainable design initiatives, because of its roots in the product design and development environment. More specifically, a PLM system is uniquely positioned to support sustainable design across the following key areas:

Managing systems complexity: mechatronics Faced with increasingly strict fuel efficiency requirements and emissions guidelines, a key sustainability strategy for many leading automakers' today is to embrace hybrid and electric powertrains. However, these hybrid systems, as well as the many other mechatronic systems being introduced or extended in new auto models to improve the driver experience– drive-by-wire, automatic stability control,

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intelligent braking, active all-wheel drive – require new levels of coordination between design of hardware, software, electrical and electronic subsystems. Critical to answering these challenges is to move from a physical prototype-based development environment to the digital simulation and functional modeling environment that is the domain of today's PLM systems. As GM's Kent Helfrich explains, in describing the development of the hybrid powertrain control system on the 2008 GMC Yukon and Chevrolet Tahoe SUVs:

> *"The name of the game in hybrid systems is integration. You can't make an engine and a transmission separately any more and then integrate them at the last minute. This has to be conceptualized as a family – as a system. [In fact], I don't think you could do a hybrid control system without model-based design and development. We can now perform iterations virtually, which saves us a lot of money in terms of eliminating [physical] prototypes and rework." – Kent Helfrich, Director of Software Engineering, General Motors Powertrain*[3]

Achieving vehicle-level optimization and integration PLM can also play a key role in optimizing the design of a vehicle from a sustainability perspective – from improving vehicle aerodynamics, reducing weight and achieving mass efficiency in every component and system, to minimizing tire rolling resistance while meeting vehicle dynamics requirements, designing high-efficiency and low-loss electrical systems optimized for battery charging, and optimizing the control systems governing all these.

> *"Segment-leading fuel economy requires comprehensive reduction of energy losses with vehicle-level optimization during the early stages of design and throughout vehicle development." – Michael Ableson, GM Global Advanced Vehicle Development*

> *"[Our sustainability] efforts in product leadership boil down to fuel economy. That breaks down into powertrain technologies, vehicle weight and, to a small extent, aerodynamics… A level below that is overall efficiency in the vehicle – efficient electrical motors, lighting, heating, cooling." – Automotive OEM*

High-fidelity representation of vehicle content, high-level view of vehicle functional attributes In their quest to achieve their sustainability goals, auto makers are also seeking high-level, highly integrated views into key functional attributes of the vehicle, as well as high-fidelity representations of vehicle materials content. Successful sustainability initiatives also require organizational processes that break down functional silos and support cross-functional teamwork and innovation, which requires different tools for, and ways of, creating, viewing, sharing and analyzing data, as well as tracking performance and communicating to stakeholders. PLM can be used to help bridge such organizational and functional disconnects:

> *"The fact is, a vehicle is not 4,000 parts flying through space in close proximity – it is a highly integrated machine. From both a performance and manufacturability standpoint, [this requires] a highly integrated toolset, and one that provides you with highly integrated forms of data." – Automotive OEM*

> *"We work in an industry that is multifunctional. Not only do we have a highly complex product with lots of interdependencies, but we also have a list of requirements to meet. The PLM system should serve up whether we are on track to meet them." – Automotive OEM*

[3] "GM Simulates Software to Speed Hybrid Development," *Automotive News*, December 15, 2008.

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Sustainable manufacturing tools and processes Sustainable manufacturing – with its emphasis on "environmentally-friendly" practices and the ability to reduce the environmental footprint of its manufacturing facilities and processes – must provide effective capabilities for optimizing manufacturing operations and equipment to conserve power, water and other resources consumed in production. In this regard, PLM systems that support factory simulation can play an extremely important role in allowing manufacturers to perform sustainability-related "what-ifs" pertaining to waste reduction, material reuse and recycling, and improved overall energy efficiency.

Sustainable manufacturing processes and facilities Digital manufacturing presents a strong sustainability-related opportunity for PLM. Again, as with product attributes, auto makers seek high-level, tightly integrated capabilities:

> *"In the plant-related aspects of environmental sustainability, we want to design plants so that they consume a minimal amount of water and other resources. Ideally, I'd like to be able to press a button and get the environmental footprint of the plant – i.e. how many thousands of gallons per hour of water I consume, what the HVAC draw is, and so on." – Automotive OEM*

Sustainable product delivery, use and support Increasingly, manufacturers are also looking beyond the design and manufacturing phase and are taking steps to reduce the environmental impact and support the sustainability of their products during actual use, service, and retirement. Indeed, guidelines for proper disposal, disassembly, and retirement are increasingly becoming the responsibility of the manufacturer. With this in mind, leading manufacturers today are also focused on sustainability principles as applied to actual product use, performance, maintenance, repair, disposal (end-of-vehicle life, etc.), as well as initiatives related to minimizing environmental impact through such efforts as CO_2 emissions reduction, recycling programs (reduce/reuse/recycle), lean principles (fewer parts, use of recycled materials, etc.). Here, as a data management system that spans the lifecycle of the product, PLM can play a valuable role in facilitating design for environmentally-friendly performance, ease of use, ease of disassembly, providing instructions for repair and proper disposal and identifying opportunities for emissions reduction, recycling and reuse.

Managing CO_2 emissions at the fleet level

> *"Our blueprint for sustainability is well ahead of any recent legislation. We had the California bill looming out there, but it was really around our commitment to doing our bit within the framework of what transport contributes to CO_2 emissions, both from an energy security standpoint and a climate change perspective. We laid out a plan based on an evolution of technology – having the right technology at the right time to support a CO_2 emission glide path, translated back to new fleet targets. We then developed some high-level, proprietary fleet modeling tools which would allow us to optimize the technologies and attributes in the vehicle, at the fleet level. Should a PLM system be able to provide this type of modeling capability? Sure. In fact, with all the product data that is tracked and managed by a PLM system, all kinds of sustainability reporting should be possible." – Automotive OEM*

Governance, compliance and reporting With the ability to manage product data and information relating to regulatory and environmental compliance becoming increasingly important for manufacturers around the globe, many are beginning to take a more proactive stance towards sustainability reporting. Indeed, the ability to, for example, provide an audit trail in the event of a product recall is critical for many manufacturers today. As a comprehensive product data management system, PLM can offer manufacturers the ability to

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both track and manage compliance requirements, and provide the framework necessary to support internal governance, auditing and reporting.

Regulatory compliance

> *"The big [PLM opportunity] in regulatory compliance [comes from] the fact that the state of the art in regulatory compliance is to take all the data out of your systems, primarily your production systems and copy that over to the systems whose job is regulatory compliance. That is a waste." – Automotive OEM*

The road ahead PLM systems are where vast amounts of highly granular, high-fidelity information about a product under development is created, revised, annotated, housed and leveraged through the product creation chain. What automotive industry users – engineers, program managers, PLM IT leads – seek now is solutions for integrating this information more tightly, in a more automated fashion, and without costly, lengthy investments in software customization.

The value of PLM lies in its power to provide higher-level, better unified views into the product design – giving users system-level and even full-vehicle-level views of key functional attributes and their interrelatedness. The benefit that users seek to advance their sustainability objectives is a greatly automated and accelerated ability to trade off among attributes and optimize toward targeted objectives.

Conclusion: Sustainability and PLM for Competitive Advantage

Sustainability represents a holistic, multi-stakeholder framework for addressing challenges of increasing import politically, economically, environmentally and socially. As public discourse on economic, environmental and social challenges increases, consumer, government, civic-sector and private-industry engagement in more responsible, and responsive, approaches to the issues intensify. In the context of a hyper-visible and globalized digital environment, we can expect ever greater critique of, and clamor for, private-sector action and responsibility – the analysis and outcomes of which will also be intently and publically debated. The challenge and opportunity of sustainable mobility is that it represents a major shift in vision and action, on multiple levels, that impacts everything from what and how products are created, to which products are chosen for creation.

In a word, sustainable mobility is about a cultural shift in societal ideas of values, and in definitions of performance and success, vision and action. By aligning with the culture and strategy of sustainability, auto manufacturers stand to gain both short- and long-term competitive advantages by:

- Efficiently and quickly creating products that address social and environmental issues
- Creating internal cultures of collaboration, communication and innovation
- Participating in the development and expansion of an educated consumer culture
- Developing technology appropriate to address region-specific needs and challenges
- Gaining thought leadership by moving from reactive "green" compliance tactics to high-performance sustainability strategies
- Implementing the processes and technologies to achieve internal and external alignment with long-term goals

How can auto makers realize these goals and objectives? The answer, we believe, starts with the quest for ways to more fully apply existing, installed tools and technologies in their

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sustainable product design and manufacturing efforts. In particular, PLM-enabled sustainability analysis and reporting promises to let manufacturers leverage their current broad and deep investments in product lifecycle management and product data to address not only environmental and regulatory compliance, but much more – including the ability to effect product development and delivery in such a way that triple-bottom-line – social, environmental and economic, or people/planet/profit – benefits are realized in both the short and long terms.

PLM technologies have long been vital to optimizing vehicle performance. Extending the application of PLM's capabilities to achieve sustainable vehicle design and manufacture, and ultimately sustainable mobility from a holistic perspective, is the logical next step. Indeed, with all the valuable product design, engineering and manufacturing data currently being managed by PLM systems industry-wide, it is difficult to imagine PLM *not* playing a central role in addressing these new and increasingly central challenges. In short, PLM-enabled sustainability tools and capabilities present a tremendous opportunity both for manufacturers seeking benefit from their sustainability programs, and for the solution providers supporting them.