# Collaborative Product Lifecycle Management in Virtual Enterprise Ecosystem – Business Challenge and Research Strategy

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ABSTRACT: Companies are moving towards quickly providing better customer-centric products and services improve market share and market size with continuously growing revenue. As such, the effective collaboration among customers, developers, suppliers, and manufacturers throughout the entire product lifecycle is becoming much more important for the most advanced competitiveness. To address this need, a framework with technology solutions for product lifecycle collaboration is proposed in this study. The details of these collaboration models throughout the entire product lifecycle are depicted. The integration of the developed product lifecycle collaboration model with other application systems in a virtual enterprise ecosystem is described. It is hoped that the proposed model of product lifecycle collaboration will lay a frontier basis for further research and development in product lifecycle management.

Keywords: Product Lifecycle Management, Product Lifecycle Collaboration, Virtual Enterprise, Enterprise Ecosystem, Collaborative Manufacturing.

## 1 INTRODUCTION

Manufacturers are facing increasing challenges of better product quality with tighter delivery requirements for customers, more profitability shareholders. Global competition is increasing with pressure on prices, smaller orders, shorter life cycles, more suppliers, more governmental regulations, and increasing material and energy costs. These new business drivers make manufacturers pursue more competitive business model, such as collaborative manufacturing, to closely collaborate with their customers, suppliers, manufacturers and partners for the most advanced competitiveness by leveraging core competencies throughout the entire product lifecycle (MESA 2004).

In collaborative manufacturing, Product Lifecycle Management (PLM) has recently been recognized as a new strategic business model to support collaborative creation, management, dissemination, and use of product assets, including data, information, knowledge, etc., across extended enterprise from concept to end of life - integrating people, processes, and technology. PLM systems support the management of a portfolio of products, processes and services from initial concept, through design, engineering, launch, production and use to final disposal. They coordinate and collaborate products, project and process information throughout the entire product value chain among various players, internal and external to enterprise. They also support a product-centric business solution that unifies product lifecycle by enabling online sharing of product knowledge and business applications (CIMdata 2003) (AMRResearch 2003) (Sudarsan et al 2005).

As such, PLM enables manufacturing organizations to obtain competitive advantages by creating better products in less time, at lower cost, and with fewer defects than ever before. In summary, PLM not only provides process management throughout the entire product lifecycle, but also enables effective collaboration among networked participants in product value chain, which distinguishes it from other enterprise application systems, such as Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM) etc.

To tackle the collaboration challenges in PLM, this study begins with business drivers, new industry requirements, recent status review, and gap analysis in section 2. Based on the analyzed gap, a model for product lifecycle collaboration is proposed in section 3. The detailed research trend for product lifecycle collaboration is depicted in section 4, including product portfolio management, collaborative product customization, collaborative product development, collaborative component supply, collaborative product manufacturing and extended product services. The integration of collaborative PLM with other application systems in a virtual enterprise ecosystem is explored in section 5. Finally, section 6 concludes the study with future perspectives.

## 2 STATE-OF-THE-ART REVIEW

Modern enterprises are facing ever increasing challenges of shorter product lifecycles, increased outsourcing, mass customization demands, more complex products, geographically dispersed design teams, inventories subject to rapid depreciation, and rapid fulfillment needs.

To effectively tackle these challenges in modern collaborative business environment, new industrial capabilities are required in order to obtain competitive advantages in today's Internet economy:

1 Geographically scattered design teams and supply chain partners need to collaboratively design products on a virtual basis.
2 Static designs need to be replaced by mass customization, often using predefined modules or building blocks to rapidly configure new product platforms that can be flexibly managed through their lifecycle.
3 To exchange and control product information and to perform real-time program/project management.
4 A system needs to emerge as the dominant technology for managing inter-enterprise data, information and knowledge, and providing design teams with a virtual design space.

To meet these addressed requirements, new technology solutions are imperatively required:

1 To provide an information continuum to deliver pervasive, real-time analytics, querying and reporting throughout the entire product lifecycle,
2 To provide a collaborative environment bringing together multiple roles, constituents and stakeholders in threaded discussions beyond four walls of enterprise,
3 To enable interactive viewing and commentary upon product lifecycle through multiple devices, channels and systems involved with product lifecycle,
4 To be an open but integrated solution supporting key enterprise value disciplines of product leadership, customer intimacy, and operational excellence.

Such a new system will provide customers, developers, manufacturers, suppliers and partners with following capabilities:

1 Product lifecycle collaboration across virtual enterprises.
2 Effective management of product lifecycle activities.
3 Convenient integration with other enterprise systems.

To satisfy continuously emerging new business challenges, in several past decades, both academic and industrial researchers have engaged tremendous efforts in research and development of industrial information technologies to pursue the most competitive business advantages in product lifecycle.

A recent academic state-of-the-art review for the research effort related to PLM show that the academic pioneer in product lifecycle research is the product life cycle modeling group at University of Tokyo, focusing on the topics of life cycle engineering, life cycle design based on simulation, life cycle planning, life cycle optimization, reuse and rapid life cycle, eco-design, service-quality, etc. (Tokyo 2004). The other effort includes center for design research at Stanford University (Stanford 2004), center for innovation for product development at Massachusetts Institute of Technology (MIT 2004), web based design, process planning and manufacturing system at University of California at Berkeley (Berkeley 2004), systems realization laboratory at Georgia Institute of Technology (Georgia 2004), design process and knowledge management at engineering design center of Cambridge University, computer aided concept design at engineering design center of Lancaster University, FIPER project funded by National Institute of Standard and Technology in USA (FIPER 2004), iViP project funded by Fraunhofer in Germany (iViP 2003). Such research effort focused on product design and development activities by using modern computing and Internet technologies to facilitate design collaboration and potential innovation. These reported achievement forms the strong basis for further research and development in product lifecycle management. However, little effort has been documented on product lifecycle technology, as what Tokyo University reported, and the result obtained is still far from satisfactory.

The recent industrial status review of PLM solutions from world leading vendors shows that UGS PLM solution provides the capability of collaboration platform, collaborative project management and so on based on Teamcenter infrastructure (UGS 2004). PTC provides the solution extended from traditional Product Data Management (PDM) to link with supplier and project management (PTC, 2004). IBM supports extended PDM solution for both Multi-National Companies (MNCs) via Enovia and Small & Medium-sized Enterprises (SMEs) via Smarteam (IBM, 2004). MatrixOne supports solutions of collaborative application, lifecycle application, and modeling studio (MatrixOne, 2004). Agile Soft provides solutions of product definition, product collaboration, product sourcing, etc. (Agile 2004). These solutions from different vendors, particularly the PDM solutions, have been widely applied in manufacturing industry and created beneficial impact to enterprises.

However, current product design and development in most companies still encounter a lot of difficulties, such as

- Shifting design from a departmental and sequential process to a cross-company and concurrent activity has been discussed for several years.

- Using traditional product data management systems and exchanging engineering data with suppliers has proved difficult, slow, and geographically limited.
- Flawed coordination between teams, systems and data incompatibility, and complex approval processes are common.
- Too often result is late product introductions, distraction of high-value staff, quality problems, or supply chain complications.

This is because that, traditional application systems, e.g., Computer Aided Design (CAD) / Computer Aided Manufacturing (CAM) (Szykman et al 2001), Computer Aided Process Planning (CAPP) (Zhang and Alting 1994), helped to make design process more efficient, but they were usually separate from a manufacturing company's mainstream operations. Design engineers and possibly manufacturing engineers could access these systems, but others who may have been able to add value to the design had no systematic process by which to influence or even comment on product design. By the time these other participators provided their input, changes were either very costly to implement or were not made at all, resulting in high costs or — even worse — an inefficient product design that did not meet customer needs. Even though the modern manufacturing application systems, such as, Product Data Management (PDM), Supply Chain Management (SCM), Enterprise Resource Management (ERP), Manufacturing Execution System (MES), Customer Relationship Management (CRM), Demand Chain Management (DCM), and so on, have been developed to overcome certain aspects of the above difficulties, they still cannot adequately address the need for collaborative capabilities throughout the entire product lifecycle because they focus on special activities in an enterprise and are not adequately designed to meet new collaborative business requirements (Anthony et al 2001) (Ciocoiu et al 2001) (Svensson and Malmqvist 2002).

## 3 PRODUCT LIFECYCLE COLLABORATION

In order to tackle new challenges in modern collaborative business environment, there needs a new collaborative business solution to enable

1 Changing the way the world brings products to market by leveraging the power of product collaboration across global value chains of trusted partners, employees, suppliers, and customers.
2 Delivering product collaboration solutions for successful value chains that are specially designed to:
   - Speed product development.
   - Manage programs effectively.
   - Enable strategic sourcing.
3 Early strategic supplier, customer and partner involvement in collaborative product and supply chain processes:
   - Reduces development costs
   - Increase product innovation
   - Dramatically speeds time to market
   - Results in a strategic impact on revenue

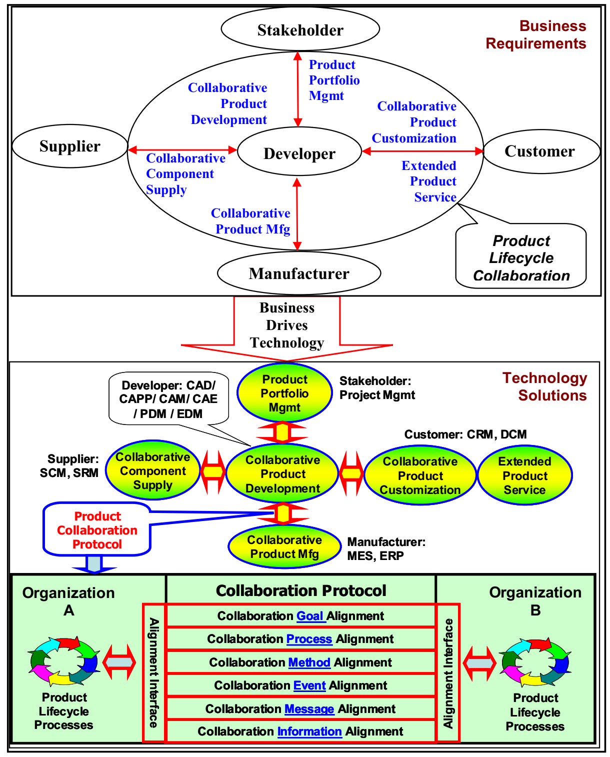

Figure 1. From business requirements to technology solutions for collaborative PLM.

As such, a new technology solution, called, "product lifecycle collaboration", is developed (Figure 1). Functions of to enable product lifecycle collaboration include, but not limited to, Product Portfolio Management (PPM), Collaborative Product Customization (CPC), Collaborative Product Development (CPD), Collaborative Product Manufacturing (CPM), Collaborative Component Supply (CCS), and Extended Product Service (EPS). In particular, the collaboration protocol, which provides different companies with general regulation to facilitate real time collaboration throughout the entire lifecycle, is imperatively required. This collaboration protocol includes different layers of collaboration alignment, such as goal, process, method, message, and information.

It is expected that the development of collaborative solutions for product lifecycle collaboration will provide enterprises with technical advantages as follows.

1 Providing effective collaboration for product lifecycle users.
2 Breaking down barriers to innovation.

3 Servicing customer much better.

## 4 TECHNOLOGY SOLUTIONS FOR PRODUCT LIFECYCLE COLLABORATION

This section describes the research trends of functions to enable product lifecycle collaboration, which includes product portfolio management, collaborative product customization, collaborative product development, collaborative component supply, collaborative product manufacturing and extended product services.

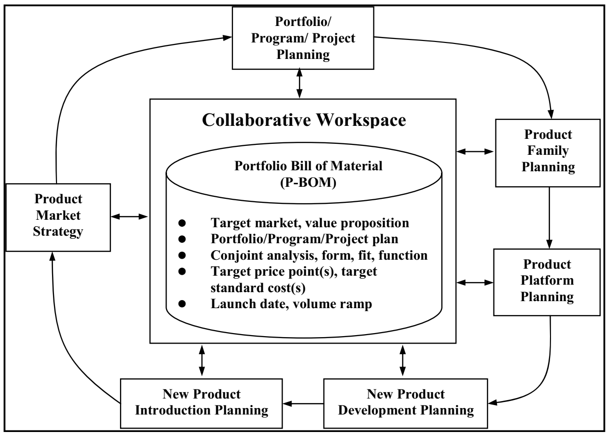


Figure 2. Technical Elements of Product Portfolio Management (PPM).

### 4.1 *Product Portfolio Management*

Technical aspects of product portfolio management (Figure 2) include collaborative tasks of portfolio/program/project planning, product family planning, product platform planning, new product development planning, new product introduction planning, and product market strategy. Portfolio Bill of Material (P-BOM) information is shared among these collaborative tasks.

### 4.2 *Collaborative Product Customization (CPC)*

Technical aspects of collaborative product customization (Figure 3) include collaborative tasks of requirements management, customer collaboration, and customer-driven design. Customer Bill of Material (C-BOM) information is shared among these collaborative tasks. The capability of customer driven design enables

- Customer becomes far more integral to the design process, making designs more relevant to the needs of the marketplace
- To know how customers prioritized various criteria and directly influenced styling and concept design
- To tightly link design decisions to the actual sales behaviors of real customers
- Collaborative sessions between store manager, central planners, and suppliers then guide design decisions

### 4.3 *Collaborative Product Development (CPD)*

Technical aspects of collaborative product development (Figure 4) include collaborative tasks of product content management, product content creation, collaborative simulation, and workflow management. Engineering Bill of Material (E-BOM) information is shared among these collaborative tasks.

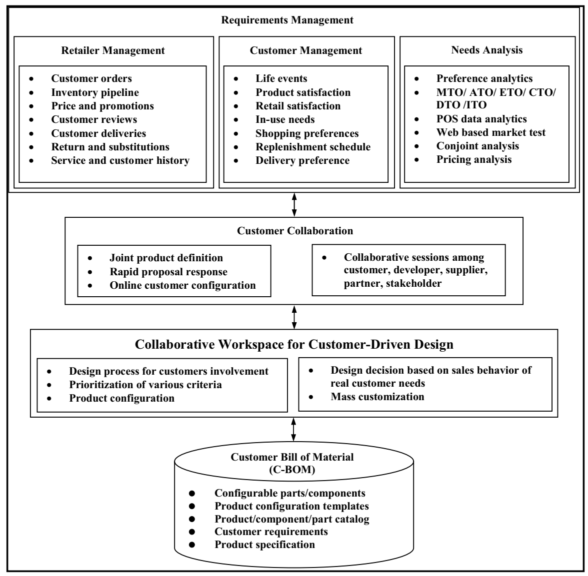


Figure 3. Technical Elements of Collaborative Product Customization (CPC).

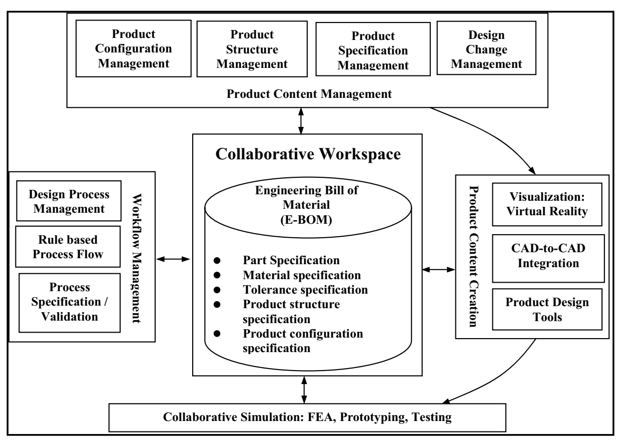


Figure 4. Technical Elements of Collaborative Product Development (CPD).

### 4.4 *Collaborative Component Supply*

Technical aspects of collaborative product development (Figure 5) include collaborative tasks of supplier management, sourcing management, component supply management, direct material sourcing and supply driven design. Supply Bill of Material (S-BOM) information is shared among these collaborative tasks.

### 4.5 *Collaborative Product Manufacturing (CPM)*

Technical aspects of collaborative product development (Figure 6) include collaborative tasks of manufacturing process management, manufacturing resource management, manufacturing capacity management, product quality management, and manufacturing history management. Manufacturing Bill of Material (M-BOM) information is shared among these collaborative tasks.

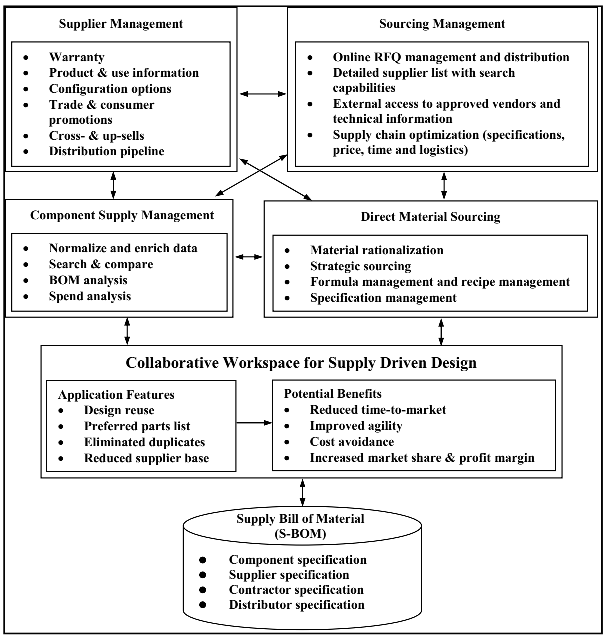


Figure 5. Technical Elements of Collaborative Component Supply (CCS).

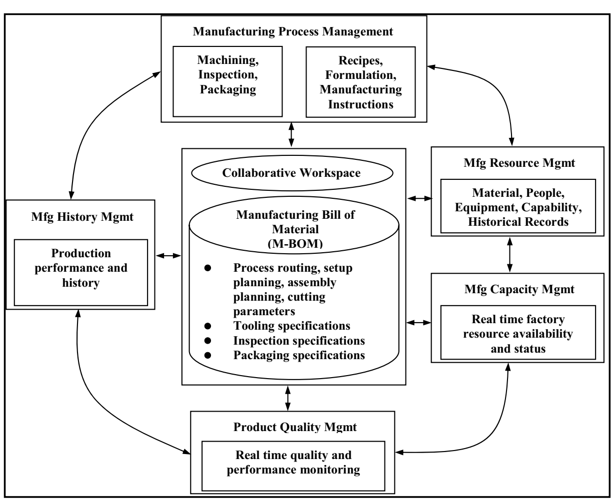


Figure 6. Technical Elements of Collaborative Product Manufacturing (CPM).

### 4.6 *Extended Product Services (EPS)*

Technical aspects of collaborative product development (Figure 7) include collaborative tasks of tangible product services, intangible product services, and also other supporting capabilities, such as product service generation, concurrent enterprising, product and knowledge management, etc. Operation Bill of Material (O-BOM) information is shared among these collaborative tasks.

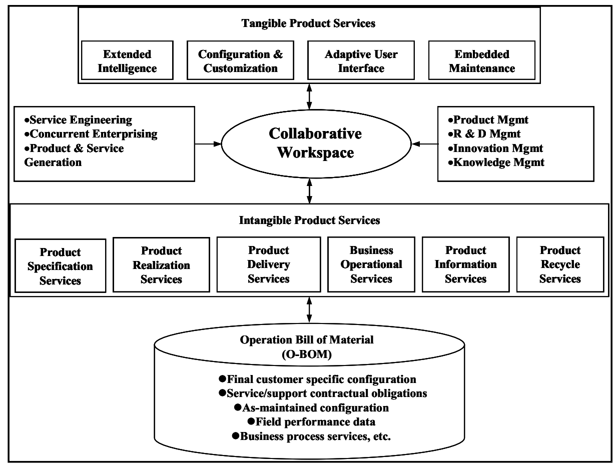


Figure 7. Technical Elements of Extended Product Services (EPS).

## 5 COLLABORATION IN VIRTUAL ENTERPRISE ECOSYSTEM

It is foreseen that future enterprise application systems will virtually integrate together to become virtual enterprise ecosystem. It consists of computing infrastructure, enterprise infrastructure, application systems and inter-organizational collaboration. Computing infrastructure includes hardware infrastructure, operation systems and application servers, web service, grid computing, and semantic web. Enterprise infrastructure is composed of enterprise information management, enterprise knowledge management, enterprise application integration. Application systems are consist of Demand Chain Management (DCM), Customer Relationship Management (CRM), Product Lifecycle Management (PLM), Enterprise Resource Planning (ERP), Supply Chain Management (SCM), and Supplier Relationship Management (SRM), Shop Floor Control (SFC), Manufacturing Execution System (MES), and Business Intelligence (BI). Inter-organization collaboration supports the functions of collaborative enterprise portal, marketplace and exchange hub, virtual value chain collaboration and management.

In such a virtual enterprise (VE) ecosystem, the integration and collaboration of PLM system with other enterprise application systems is important for the operational excellence of the entire virtual enterprise with the seamlessly integrated business processes (Figure 9). These business processes include not only the product lifecycle processes, but also the processes from other enterprise application systems, e.g. Product Management (PM), Demand Chain Management (DCM), Customer Relationship Management (CRM), Supplier Relationship Management (SRM), Supply Chain Management (SCM), Enterprise Resource Management (ERP), Manufacturing Execution System (MES), Shop Floor Control (SFC), to address the entire needs in a VE. Collaboration in PLM is further categorized as five major areas from the viewpoint of stakeholder, customer, developer, manufacturer, and supplier respectively. All these collaborative services form a complete solution for collaborative manufacturing throughout the entire product lifecycle.

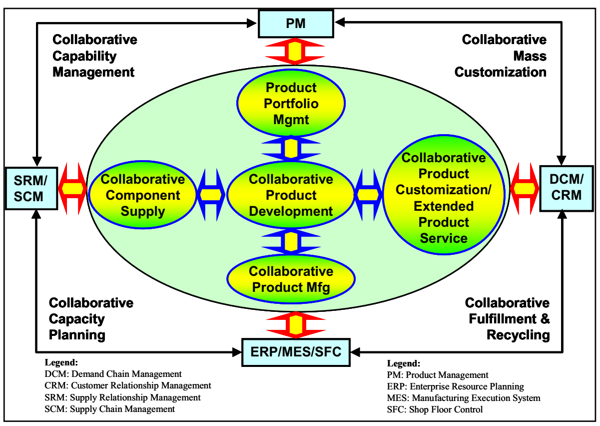


Figure 8. PLM collaboration in virtual enterprise ecosystem.

By developing the above new technologies, following potential end user benefits are expected:

- Shorter product leader time due to effective collaboration among developer, customer, manufacturer, and supplier.
- Higher customer satisfaction due to the active customer involvement in product development.
- Quick time-to-volume by collaborative manufacturing support.
- Lower product cost by leveraging intellectual property and thus the result of collaborative innovation in virtual enterprise environment.

## 6 CONCLUSION

To respond to new business requirements of effective collaboration throughout the entire product lifecycle to leverage core competencies, a framework of product lifecycle collaboration has been proposed in this study. The detailed technical trends of this framework have been depicted, including product portfolio management, collaborative product customization, collaborative product development, collaborative component supply, collaborative product manufacturing, and extended product service. The integration of collaborative PLM with other application systems in a virtual enterprise ecosystem has been explored as well.

Future research will focus on the development of collaboration protocols in product lifecycle, including semantic and mathematical models, and heuristics, business rules, optimization algorithms to improve the performance of such dynamic collaboration among business value networks.

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