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The attached educational project, by **Susan Q. Ding,** entitled ***The Impact of Product Life Cycle Management (PLM) on Supply Chain Strategy*****,** when completed, is to be submitted to the Graduate Faculty of the University of Wisconsin- Platteville in partial fulfillment of the requirements for the (MASTER OF SCIENCE IN INTEGRATED SUPPLY CHAIN MANAGEMENT) degree.

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TITLE PAGE

THE IMPACT OF PRODUCT LIFE CYCLE MANAGEMENT (PLM) ON SUPPLY CHAIN STRATEGY

A Paper

submitted to the Graduate Faculty of the

University of Wisconsin-Platteville

by

Susan Qiuyang Ding

in Partial Fulfillment for the Degree of

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ABSTRACT

Operating an integrated supply chain requires a continuous information flow, which, in turn, assists in achieving the best product flows (Labbert and Cooper, 2000). The purpose of this paper is to emphasize the importance of information flows to supply chain coordination, and that developing a product life-cycle management (PLM) system is critical to improve supply chain performance. The role of PLM is to enhance organizational alignment and synchronization across all functions. A successful PLM solution streamlines the flow of product and process information and reduces communication gaps caused by the "bullwhip" effect -- or silos -- throughout the life of the product. Research findings indicate a strong correlation between PLM systems implementations and supply chain improvement. An effective PLM system can improve the development efforts on new products and significantly increase the company's supply chain performance. A deductive research approach was used as the methodology of the paper.

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I. INTRODUCTION

Statement of the Problem

Supply chain management is considered an "art" and a "science." The mapping of the supply chain business process requires the art of storytelling because it requires creativity, vision, skills, and knowledge. Day (1994) has suggested that capabilities and organizational processes are closely entwined. When a firm is more proficient with its process management through process integration than its rivals, the firm has a distinctive advantage, which can lead to superior profitability. Information technology and collaboration play key roles in furthering the goals of supply chain integration. An effective, integrated business process is critical for companies to support operational planning decisions and improve their end to end value chain of business.

Purpose of the Study

A successful product life cycle management (PLM) system can reduce communication gaps resulting from the bullwhip effect and silos to improve information visibility. However, information sharing in an organization can face several challenges as a result of a lack of strategies about culture, process, and technology. There are two points of view to every process: the physical point of view, which people can easily grasp, and the nonphysical point of view, which supports all processes but is usually challenging to see and understand on the surface. In order to design effective PLM processes, it is necessary to more intuitively understand the storyline that rests beyond the surface.

Tim Brown, CEO and president of the innovation and design firm IDE, is best known for his work for advancing user-centered design—and in particular for developing the idea of "design thinking". Brown has emphasized the importance of applying design thinking in business. He stated that design thinking is a human centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success. Design thinking is an approach to problem solving in which inspiration, ideation, and implantations occur not in sequence, but as a system of overlapping spaces (Brown, 2008). Effective business process and integration of resource flow in supply chains require understanding the problems from the user perspective and addressing them with a human-centric design approach.

Significance of the Study

This study examines how supply chain management impacts business. Porter (1985) has suggested that the value creation process extends beyond the boundaries of the firm, and involves integrating business processes among the entities of the chain, such as the supplier, manufactures and customers. Supply chain planning includes the activities that focus on evaluating demand for material and capacity, together with the processes of formulating plans and schedules to meet demand and company goals (Gupta and Marranas, 2003). Thus, a constructive business process and integration of resource flow in supply chains has become imperative for firms to effectively communicate with customers and suppliers and to responsively align supply and demand. Product life cycle management (PLM) matters to business success because supply chain integration directly impacts cost and customer orientation of the business.

Assumptions

Design business process is a human-centered design. It is an iterative process of creating solutions to help humans and businesses overcome obstacles and reach their goals. Product Lifecycle Management (PLM) is a business solution that aims to streamline the flow of information about the product and related processes throughout the product's lifecycle. Product lifecycle management is an integrated business process which requires strategic planning. Developed PLM processes can improve supply chain process integration, support business operations, and, most importantly, enable innovation.

Delimitation of the Study

In this research paper, I would like to understand how networks in the supply chain are connected, how trading partners communicate with each other, and how an effective flow of information can connect all parts of the product lifecycle. In addition, the strategic, operational, and financial issues that affect the product lifecycle systems. The limitations of this study are:

- Sample size: the sample size may be too small to identify significant relationship in the data
- Lack of available data: a lack of research data might limit the scope of analysis
- Culture and other type of bias: I have selected research papers with the same focus of information sharing and business process. None of these studies have provided information strategies regarding sales, marketing and procurement activities

Methodology

The developed Product lifecycle management (PLM) process can also improve other area's process integration, support business operations and enable innovation. CIMdata defined PLM as:

> *PLM is a strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination and use of product definition information across the extended enterprise from concept to end of life – integrating people, processes, business systems and information (CIMdata, 2018).*

The focus of the research is to better understand the supply chain environment and the effects of contingencies on information flow strategy. In future research, I would like to analyze performance factors which are believed to be improved by higher levels of information flows and thus influenced by the choice of information flow strategy. This goal of the analysis is to assist PLM managers by helping them better understand the impact of contingency factors on supply chain integration and performance improvement.

II. REVIEW OF LITERATURE

Table 1: Studies on selecting a product lifecycle management and supply chain strategy

Research paper	**Authors**	**Focus of the study**
2.1 Implementation of product lifecycle Management tools uses enterprise integration engineering and action-research	Penaranda, Gutierrez, Romero & Molina (2010)	Align the corporate strategies with the use of PLM technologies
2.2 Product lifecycle management through innovative and competitive business environment	Gecevska, Paolo & Anisic (2010)	PLM through innovative and competitive business environment
2.3 The impact of new product introduction on supply chain ability to match supply and demand	Crippa, Larghi, Margherita & Andrea (2010)	New product development/PLM's impact on supply chain ability
2.4. Coordinating new product development with supply chain management	Hilletofth & Eriksson (2010)	Coordinating new product development with supply chain management
2.5 Relational antecedents of information flow integration for supply chain coordination	Patnayakuni, Rai & Seth (2006)	Information flow integration can improve supply chain coordination

2.6 Enriching knowledge in business process modelling	Simoes, Autunes & Cranefield (2006)	Information and knowledge improve business process modelling
2.7 Supply chain risk assessment during new product development: A group decision making approach using numeric and linguistic data	Chaudhuri, Atanu Mohanty, Bhaba Krishna, Singh & Kashi (2012)	Supply chain risk assessment during new product development
2.8 Product development process Managing in supply chain. complex systems concurrent engineering	Santos, Andrea, Kieckbusch, Rafael Forcellini, & Fernando (2007)	Managing product development process in supply chain is a complex system
2.9 Supplier involvement in product development process (PDP) and new product performance: the mediating role of new product advantage.	Chaudhuri, Atanu Mohanty, Bhaba Krishna, Singh & Kashi (2012)	Supplier relationship is an important business strategy

2.1 Align the corporate strategies with the use of product lifecycle management (PLM) technologies

In the study, *Implementation of Product Lifecycle Management Tools Uses Enterprise Integration Engineering and Action-Research*, Penaranda, Gutierrez, Romero, and Molina (2010) proposed the AS-IS model and EIE reference framework to help organizations to create KPIs and Performance Measures to support the business strategies. The authors suggested in this research that aligning product lifecycle management with a company's business objectives can improve collaboration around concurrent product developments between separate offices and also supply chain partners.

Product lifecycle management (PLM) is an important integrated business process. PLM is a tool used to plan, manage and execute lifecycle activities, which include identifying business opportunities, prioritizing R&D efforts, developing new products, and supporting their production and introduction to the market (Roswell & Halpern, 2004, Penaranda et al., 2010). PLM integrates information and coordinates supply chain processes. Its decisions have a direct impact on cost and customer orientation of supply chain performance; the authors suggested only a developed PLM process can improve other area's process integration and support business operations.

Product lifecycle management (PLM) is a business solution that aims to streamline the flow of information about the product and related processes throughout the product's lifecycle. According to the authors, PLM creates activities of integrated product development by identifying the information flow through the product lifecycle, resources, controls, inputs, and outputs incorporated in each event (Molina and Medina, 2003, Penaranda et al., 2010). Four

domains must represent to build the AS-IS model for the identification of the current enterprise state: process, information/knowledge, organization, and resources (Penaranda et al., 2010). The use of product data management systems, which centralizes all the information in a shared database is an essential strategy for information management. For users to retrieve information without asking other team members, PLM information systems must have the capability to link related data, and these characteristics of PLM information systems can improve process efficiency and reduce product development time (Peñaranda et al., 2010).

Product lifecycle management (PLM) communication has a direct impact on supply chain risk, inventory cost/ level, cash flow, operation effectiveness, and sales. Strategy and performance measurements should be associated with performance measures to evaluate the impact of the strategy pursued in an organization. PLM needs to support three plans of actions in the enterprise, namely: (1) Competitive strategy, and how it translates into a set of decisions regarding how an organization can deliver value to the customer. (2) Value chain strategy is about making decisions of how an enterprise will establish an organizational model (external and internal) that will exploit different possibilities to build an effective and efficient value chain. (3) Production/service strategy should define how the enterprise will produce or deliver its products and services (Penaranda et al., 2010).

Table 2: EIE reference Framework components for PLM implementations

EIE Components	Activities	Tools
Strategy and Performance Evaluation Systems	• Define strategies: competitive strategy, value chain strategy and production/service strategy. • Define KPIs: quality, volume, time, costs, flexibility and environment.	• SWOT. • Porters 5s. • Scenario planning. • Balanced scorecards.
Reference Models for Enterprise Modeling	• Define enterprise model and core processes. • Describe Enterprise Model AS-IS and TO-BE: functions, information, resources and organization. • Determine KPIs of core-process.	• Enterprise modelling languages (IDEF0, UML). • Business Process Model Notation (BPMN). • Event-driven Process Chains (EPC).
Decision-making and Simulations Models	• Define logic models of best business practices and IT and its impact on KPIs. • Design AS-IS and TO-BE simulation models to evaluate decision-making. • Evaluate KPIs based on the use of best business practices and IT implementation.	• Program logical models. • System dynamics models. • Discrete event simulation. • Business process analysis.
Knowledge/Information Technology	• Define data, information and knowledge models. • Decide type of IT application: functional, coordination, collaboration or knowledge management. • Design IT architecture. • Determine IT infrastructure.	• Product Lifecycle Management (PLM). • Business Process Management Systems (BPMS). • Business Process Intelligent (BPI). • Enterprise Systems (ERP, CRM, SCM, etc.). • Enterprise Content Management (ECM).

Table 2: Penaranda, Nicolas & Mejia-Gutierrez, Ricardo & Romero, David & Molina, Arturo. (2010). Implementation of Product Lifecycle Management Tools using Enterprise Integration Engineering and Action-Research. Int. J. Computer Integrated Manufacturing. 23. 853-875. 10.1080/0951192X.2010.495136.

- The competitive strategy aims to achieve a competitive advantage by following at least one of these three possible strategies: (a) operational excellence, (b) product leadership, or (c) customer focus. Competitive strategy is related to cost leadership (operational excellence strategy), differentiation (product leadership strategy), and focus (customer focus) (Porter, 1996; Penaranda et al., 2010). In order to translate the business into a set of decisions and decide how the organization can deliver its value proposition to the customers, the competitive strategy must be carefully analyzed and measured.
- The value chain strategy is about making decisions on how an enterprise will establish an organizational model that will take advantage of the opportunities to build an effective

and efficient value chain. Supply chain strategy should be considered and adopted as a value chain strategy that integrates vertical integration, strategic business units, horizontal integration, and collaboration in both vertical or horizontal networks.

- Production/service strategy is based on three elements: information and knowledge, product description, and customer and supplier's characterization. Information and knowledge are required to design a production and service strategy; product description is needed for an enterprise to qualify or to win an order in a specific market, and customers and supplier's characterization are required to define customers' expectations and requirements that are imposed on suppliers.

Figure 1: Enterprise Model and Integrated Business Processes

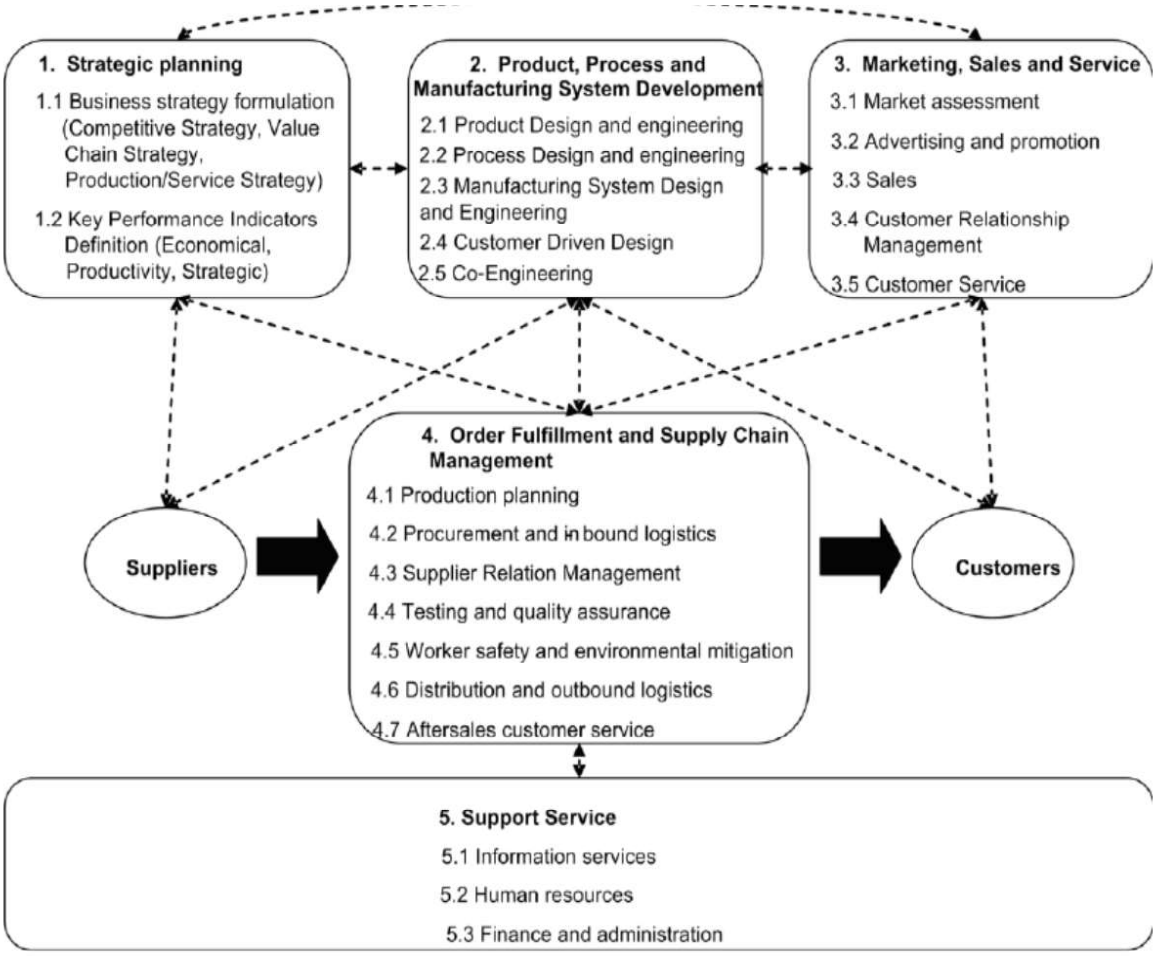

Figure 1: Penarandam, Mejia, Romero and Molina (2010). Implementation of Product Lifecycle Management Tools using Enterprise Integration Engineering and Action Research. Int. J. Computer Integrated Manufacturing. 23. 853-875. 10.1080/0951192X.2010.495136

PLM systems require support from five main business processes: (1) strategic planning, (2) product, process, and manufacturing system development, (3) sales and service, (4) order fulfillment and supply chain management, and (5) support services.

Table 3: Definition of the PLM implementation using a Logical Mode

Activities	Results	Changes/Effects	Impacts	Benefits
FIRST CYCLE: AS-IS Model Understanding *PLAN* • Define work team, responsibilities, activities and resources • Analyze the enterprise vision, mission and strategic objectives. • Define the project scope, impacts and benefits for the enterprise • Analyze the business strategic elements and KPIs • Identify the key business process with highest impact	*FIRST CYCLE: AS-IS Model Understanding* • Project benefits, impacts, strategies and work team defined • Objectives and priorities of the enterprise identified • Key business process identified • KPIs identified • AS-IS model developed • Improvements proposed in the AS-IS model	*Enterprise:* • Organize nodes to disseminate best practices in design, manufacturing and management practices • Evolve to process oriented engineering projects *Business Process:* • Improvement in Product , Process and Manufacturing System Development process *Organization* • Change team structure and sequence of	*Performance Indicators:* • Value added for invested capital • Profitability • Productivity • Customer satisfaction with final product • Customer satisfaction with service provided • Time to deliver-Product Development time (on a like-to-like project basis) • Time to deliver-Product Development time predictability (variation from	*Economical:* • Bring products to market faster, reducing costs • Decrease process cycle time and cost *Productivity:* • Efficiently find and reuse successful designs • Identify duplicated activities, increasing value added by employee *Strategic:* • Operational Excellence: - Leverage the experience gained in related design

Table 3: Penaranda, Nicolas & Mejia-Gutierrez, Ricardo & Romero, David & Molina, Arturo. (2010). Implementation of Product Lifecycle Management Tools using Enterprise Integration Engineering and Action-Research. Int. J. Computer Integrated Manufacturing. 23. 853-875. 10.1080/0951192X.2010.495136

The table above shows solutions to improve visualization of enterprise knowledge, processes, and associated performance measures. Penaranda, et al. (2010) suggested to develop a PLM process requires knowledge and understanding of the problems from the user's perspective to address them with the human-centered design approach. The main barrier to the success of a PLM implementation is weak project management leadership, weak participation and commitment of team members, and a lack of integration with geographically distributed partners. In order to improve the process design and application of workflow systems, a clear definition of each activity must be developed based on the user's perspective.

2.2 PLM through innovative and competitive business environment

In this research study*, Product Lifecycle Management through Innovative and Competitive Business Environment,* Gecevska, Paolo, and Anisic (2010) claimed the product lifecycle management (PLM) is the process of managing the entire lifecycle of a product from inception, through engineering design and manufacture, to service and disposal of manufactured products. The PLM process includes the early stages of a product, starting from generating an idea, concept description, and business analyzes, product design, solution architecture, and technical implementation to successful market entry and product improvement. This research recommended six critical metrics for PLM success:

1. PLM managers must determine if appropriate PLM processes were implemented: a method for documenting, analyzing, tracing, and prioritizing requirements, sourcing and procurement, and distribution quote/order generation.
2. PLM managers must define strategies to measure customer satisfaction and map the customer journey. The customer journey is a diagram that illustrates the steps a customer goes through in engaging with the company from the product's development stage to its decline in value and eventual retirement from the market.
3. PLM managers must examine the efficiency and effectiveness of whether the outputs can meet customer needs. (e.g., requirements traceability, visualization, concepts, design capture & accessibility, change control & change capacity, configuration management, commercial cost of risk, product quality).

4. PLM managers must determine if desired results are being achieved from step 4, in the area of generation of new business, software integration, cost performance, market share, cost reduction, and design reuse.
5. PLM managers must measure the impact of the implementation of PLM by measuring the extent to which procedures and controls have been integrated and the returns on investment, for example, waste reduction, innovation/ new products, continuous improvement, and sustainable green manufacturing. This step often is the most complex and challenging for the PLM manager.
6. PLM managers must apply the technique of systematically gathering and analyzing to analyze customer or market product requirements.

Figure 2: PLM business value

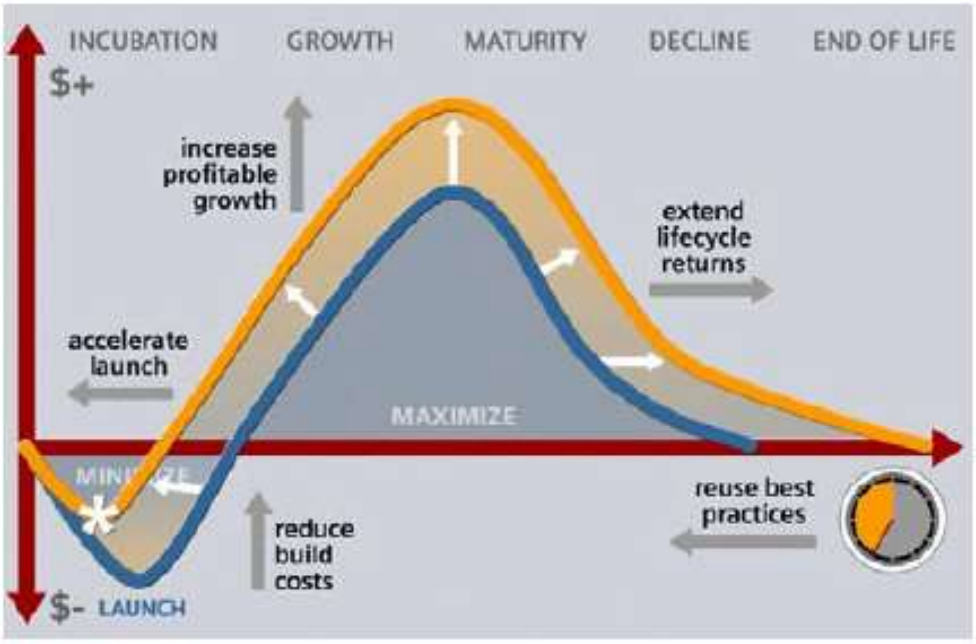

Figure 2: Gecevska, Valentina & Paolo, Chiabert & Anisic, Zoran & Lombardi, Franco & Cus, Franc. (2010). Product lifecycle management through innovative and competitive business environment. Journal of Industrial Engineering and Management. 3. 10.3926/jiem..v3n2.p323-336.

PLM managers have the responsibility to update product information within the organization's design, manufacturing, marketing, and procurement divisions, as well as collaborate with an internal team with external users, suppliers, and customers for iterating new designs. Bringing a new product to market is a complex and collaborative process. This study suggested to improve productivity, accelerate time to market, and lower cost, PLM systems must have the ability to integrate people, processes, and business systems. Moreover, the organization must apply appropriate resources to the PLM process and define what business goals are and planned investment from stakeholders.

2.3 New product development/PLM's impact on supply chain ability

In the research, *The Impact of New Product Introduction on Supply Chain Ability to Match Supply and Demand*, Crippa, Larghi, Margherita, and Andrea (2010) studied the negative effect of misalignment between product features and supply chains. The research proposed a set of misalignment indicators along with an action plan to align supply chains to product development.

Supply chain managers should redesign their supply chains in response to the introduction of a new product because product development decisions have a direct impact on supply chain performance. Supply chain strategies must be aligned with product development decisions to ensure products are delivered at the targeted cost, time, and quality. On the other hand, PLM Managers should be aware that new product development affects supply chain performance in terms of direct production costs and inventory levels and lead time. The authors suggested three key concepts in this research study:

- New product development is connected to supply chain management, and product features affect supply chain performance.
- New product development integrates information and coordinates supply chain processes.
- New product development and supply chain management share common processes and knowledge.

New product development is connected to supply chain management, and product features affect supply chain performance. The NPD process needs to be coordinated with SCM in general and the SCD process in particular. The magnitude of the effects of product features on supply chain performance is determined by supply chain decisions concerning supply chain structure, supply chain strategy, or the degree of collaboration among the actors of the supply chain (Doran, 2007, Crippa et al., 2010).

New product development aims to create a consumer-oriented business by organizing the firm around understanding how consumer-desired products are developed (e.g. innovative, customized, and affordable) and how products are sourced, manufactured, and delivered to consumers efficiently (SCM) (Crippa et al., 2010). It is crucial that firms not only need to work with these domains concurrently but also coordinates them with one another on a macro-level and in a systematic way. New product development integrates information and coordinates supply chain processes. In the research paper, the authors proposed the critical role of joint planning between marketing managers, product developers, and supply chain managers in the product roadmap. A two-step methodology has been suggested:

- Marketing managers join with product developers to set a product vision and strategy. They are responsible for conducting competitor analysis, market research, and communicate with the sales team to inform the strategic positioning of the product to customers, partners, and market influencers, and identify in detail, the 'why,' 'what' and 'when' of the product that the engineering team will build.
- In the second stage, PLM managers and supply chain managers work together to define PLM strategic Value & Capability assessment. Both managers need to decide on what product features will be selected based on the critical drivers throughout the value chain to develop a plan for PLM strategy/Roadmap development.

Table 4: Sales, Marketing and Supply Chain Matrix

Step		*Area*	*Analysis*	*Action*
1	Requested variety definition		Market analysis and forecast of future trends	Definition of "risky" products list (where risky products are those that may generate managerial problems for the supply chain, e.g. products with strong expected demand variation and/or high uncertainty on the demand mix)
2	Matching product features and supply chain features	Product feature	Reverse engineering and analysis of the product structure of the above identified "risky" products	Definition of possible architecture and bill of materials modification to the apply to "risky products"
		Plan	Analysis of demand variance expected for risky products	Setting of specific "Strategic Stocks" (apart from usually computed Safety Stocks) on critical components more likely involved in unexpected variety and volume growth
			Analysis of present and emerging planning needs	Renewal of the Planning System: introduction of an Advanced Planning and Scheduling (APS) application
		Make	Analysis of manufacturing flows	Manufacturing flows simplifications
			Analysis of machine loadings	Internal capacity increase on most critical (saturation and/or short-term outsourcing difficulties) technologies
		Source	Part commonality and product components analysis	Alternative sources opening
			Analysis of demand variance expected for risky products	Pre-identification of product clusters for tactical outsourcing, in case of sudden demand increase on risky items

Table 4: R, Crippa & L, Larghi & Pero, Margherita & Sianesi, Andrea. (2010). The impact of new product introduction on supply chain ability to match supply and demand. International Journal of Engineering, Science and Technology. 2. 10.4314/ijest.v2i9.63861.

Crippa et al. (2010) stated, to remain competitive, firms should be able to sustain innovation by coordinating the two processes of NPD and SCM. NPD-SCM alignment is fundamental for reaching NPD-SCM coordination. Companies should develop strategies to reduce misalignment between product features and the supply chain. Different NPD and SCM activities influence each other, how they can be coordinated, what benefits that can be obtained by organizing them, and what the requirements are to succeed with the coordination (Carillo & Franza, 2006; Van Hoek & Chapman, 2007).

Supply chain managers should redesign their supply chains in response to the introduction of a new product to reach performance targets. Companies should involve supply chain specialists as early as possible in the NPD process to gain a competitive advantage in driving further product success by ensuring the product can be supported functionally and profitably by the supply chain. Product structure, product variety, and product innovativeness, both internal and external, should be created jointly. The goal is to catch and rectify any potential negative or suboptimal supply chain consequences for efficiency, cost, service, and quality across the end-to-end supply before there is a downstream impact on launch or post-launch activity (Shipley & Hamburger, 2017).

2.4 Coordinating new product development with supply chain management

In the research study, *Coordinating New Product Development with Supply Chain Management,* Hilletofth and Eriksson (2010) suggested supply chain-related decisions, impact on supply chain performance, and new product development decisions are not identified in product development projects. Even though a product development manager has a significant desire to get their decisions involved in product development projects, they often feel less interest regarding how product development decisions affect supply chain performance.

Supply chain performance plays a critical role in the NPD process because it not only drives the investment of capital into production and distribution capabilities but also, in many cases, determines the critical path for product launch dates. Coordinating new product development with supply chain management is the essence to balance value creation with value delivered. Hilletofth and Eriksson (2010) identified four success factors for new product development within four characteristics, including market characteristics, product characteristics,

strategy characteristics, and process characteristics. The research finding indicated two key points:

- **How supply chain related decisions are considered in the product development project**

  The supply chain organization is divided into two main divisions, inbound supply, and outbound distribution. Under each division, different supply chain functions are involved in product development projects in various extents, and they are heavily influenced by the decisions made in the product development projects. These supply chain decisions have a direct impact on product development projects, for example, inbound supply and production teams work together to simulate how the parts are assembled, and they can provide instant feedback to the design. However, concerns about the costs can cause significant delays in the entire system when they choose a component, and this will lead to weak performance in prototype testing.

- **Product development-related decisions should be considered in supply chain decisions**

  The identified decisions are divided into two categories. The first category involves strategic decisions that focus on product architecture, functionality, and product launch. The second category focuses on tactical decisions regarding other product development-related issues, such as the new product introductions in the internal logistics systems, product instructions, and design changes. The authors emphasize identifying decisions in these two categories, a clear separation of responsibility among these different stakeholders is required.

Table 5: The identified product development related decisions in product development that have an impact on supply chain performance.

Decision	Category	Function
What type of product architecture and platform will be used to optimize design to cost objective?	PD-STRA	PD Project management, Inbound supply
What are the required functionalities that the target markets ask for?	PD-STRA	PD Project management, Mechanical design
What will the extent of product modularization be?	PD-STRA	PD Project management, Mechanical design
How many different parts will be included in a certain product?	PD-STRA	PD Project management, Mechanical design
What time will the final products be launched?	PD-STRA	PD Project management, outbound supply
When should the new products be introduced to the internal system?	PD-TACT	PD Project management, Mechanical design, Inbound supply.
How should external and internal stakeholders be involved to establish long-lasting collaboration?	PD-TACT	PD Project management,
When should the design changes be frozen?	PD-TACT	PD Project management, Purchasing, Planning
Which organization will be responsible to send instructions of the product introduction?	PD-TACT	Supply-Product management
What are the possible impacts of the design changes on the relationships with internal and external stakeholders?	PD-TACT	PD Project management, Planning
Where do product instructions come from?	PD-TACT	Supply-Product management

Table 5: Hilletofth, Per & Eriksson, David. (2010). Coordinating new product development with supply chain management. Industrial Management and Data Systems. 111. 10.1108/02635571111115173

Hilletofth and Eriksson (2010) explained the benefits of instant feedback about supplier performance and prototype quality to supply chain management. They suggested that creating a plan and process and joint plan with supply chain functions is the key to a successful supplier development program. Suppliers play a crucial role in achieving corporate competitiveness, and, as a result, selecting the right suppliers is a critical component of these new strategies. By implementing a specific supplier's selection criteria, it's possible to identify companies that will work with you to meet the demands of your customers. Thus, supply chain managers must understand the customer's needs first and select suppliers based on the supplier's capability to meet companies' requirements.

It is essential to bring people from the supply chain and product development functions to work together and form project teams; however, it is not as easy as it sounds. Such collaboration and integration are built upon a certain number of motivational factors and conflicting objectives. Motivational factors and conflicting objects are evaluated from the lenses of internal collaboration, organizational complexity, and diversity. The authors identified critical motivational factors and conflicting objectives and their impact on the level of supply chain integrations. They suggested that the identification and understanding of conflicting goals and the motivating factors behind these decisions may provide support for the inclusion of supply chain-related decisions in product development projects.

Figure 3: Motivation factors and conflicting objectives

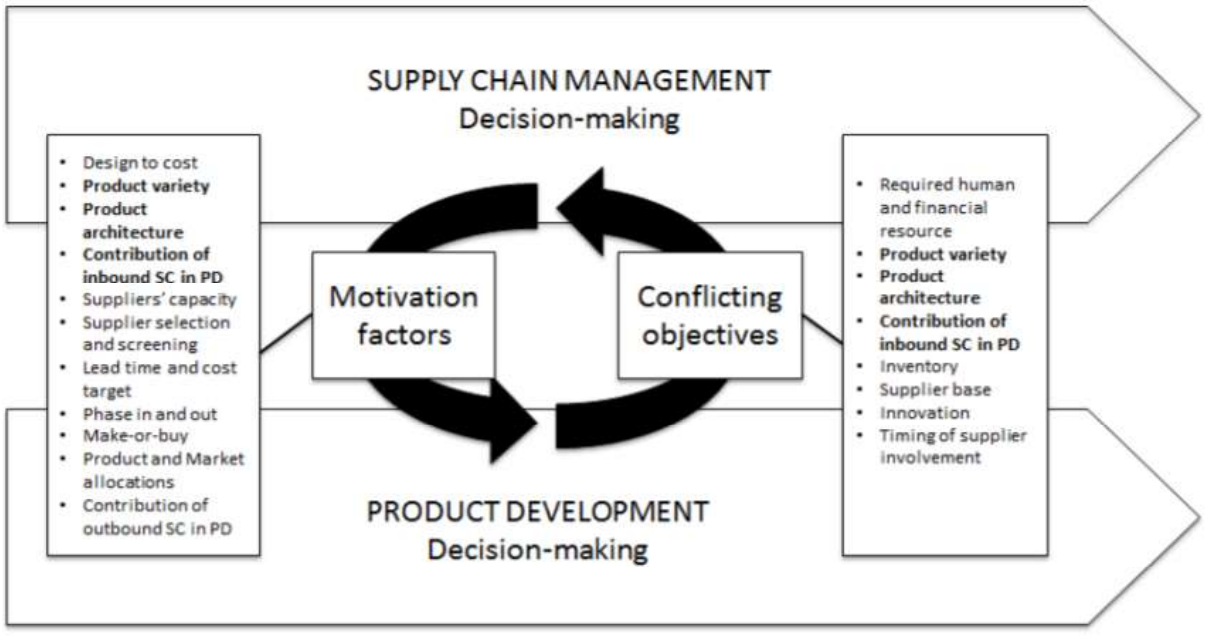

Figure 3: Dynaics of decision-making
https://pdfs.semanticscholar.org/4971/cf7e82413fe4bec44ac551a269e6fa10426e.pdf?_ga=2.171214694.714196168.1585712061-1887162114.1568584624

The supply chain improves operational performance, but there are conflicting objectives in the supply chain, such as cost and inventory. The goal of supply chain management is to minimize costs. Sourcing professionals negotiate with suppliers to purchase in large quantities so that they may obtain quantity discounts and take advantage of economies of scale. Still, this situation puts pressure on other departments like inbound supply who need to align inventory turnover and cost targets. Inventory is another conflicting objective in supply chain management. Companies keep inventory in their warehouses to improve their operational flexibility since they will be able to respond to changes in the demand pattern immediately, but an increase in inventory will also increase the cost.

Hilletofth and Eriksson (2010) have concluded in their study it is crucial to have bridge functions act as a coordination mechanism between product development and supply chain functions that are based on their job descriptions. They communicate the requirements and demands from different supply chain functions (i.e. supply, sourcing) and product development functions (i.e. design and development. There are two reasons for such a settlement. First of all, companies need to enhance the coordination capabilities to balance organizational diversity and complexity (Narasimhan & Kim, 2002, Hilletofth & Eriksson, 2010), and the bridge functions help the teams to alleviate the complexity and diversity originating from different motivations and conflicting objectives. Second, bridge functions enable frequent communication inside the organizations and among the teams (Fawcett et al., 2012, Hilletofth & Eriksson, 2010) so the supply chain and the product development functions can discuss their conflicting objectives and reach an agreement as well as presented, the factors that motive the different functions to agree on the decisions.

2.5 Information flow integration can improve supply chain coordination

In the research study, *Relational Antecedents of Information Flow Integration for Supply Chain Coordination*, Patnayakuni, Rai, and Seth (2006) introduced a research model that was developed based on the data collected from 110 supply chain and logistics managers in manufacturing and retail organizations. The research suggested that tangible and intangible resources invested in supply chain relationships enable the integration of information flows with supply chain partners. To integrate and realize performance gains from those participating in cooperative supply networks, PLM managers need to understand the role of information sharing in global supply chain operations.

Patnayakuni et al. (2006) suggested that the relational antecedents of this critical aspect of supply chain integration are information flow management. Information sharing can be applied to almost all the core domains of corporate operational activities. Along with supply chain, many functions play a critical role in making PLM a success, including sales, marketing, and research and development. Authros, Patnayakuni et al. (2006) investigated the relationships between business functions and identified the strategies listed below to manage the information flow more effectively. Their analysis was based on the factors of the long-term orientation of supply chain relationship, asset specificity, and interaction routines and the integration of information flow between a firm and its supply chain.

Table 6: The role of information sharing in the supply chain

Construct	Definition
Information flow integration for supply chain coordination	The extent of operational, tactical, and strategic information sharing that occurs between a focal firm and its supply chain partners for coordination.
Relational orientation	The degree to which a focal firm's relationship with its supply chain partners is based on long-term contracts, information sharing routines, trust, and asset-specific investments.
Relational asset specificity	The degree to which a focal firm's suppliers make partner-specific investments in tangible physical resources and intangible know-how.
Long-term orientation	The degree to which long-term considerations, mutual gains, and informal governance characterize a focal firm's relationships with its partners.
Relational interaction routines	The degree to which informal and formal mechanisms are established for the exchange of information and knowledge between a focal firm and its supply chain partners.
Consumer demand predictability	The length of the product life cycle and likelihood of forecasting errors.
Organization size	The total number of full-time or equivalent organizational employees.

Table 6: Patnayakuni, Ravi & Rai, Arun & Seth, Nainika. (2006). Relational Antecedents of Information Flow Integration for Supply Chain Coordination. J. of Management Information Systems. 23. 13-49. 10.2753/MIS0742-1222230101.

Patnayakuni et al. (2006) indicated that organizations need to define supply chain coordination as the extent to which operational, tactical, and strategic information between a firm and its supply chain partners is organized. Downstream information flows in supply chains must focus on coordinating capacity, delivery schedules, and product information. In contrast, upstream information flows must focus on the organization of orders, demand forecasts, point-of-sales information, and performance metrics. The pooling of complementary demand-related information enables collaborative forecasting and planning, and the sharing of performance

metrics can be used to identify bottlenecks in supply chain operations and orchestrate joint action for correction and avoidance.

Without proper information management, firms cannot know customers' expectations when their orders are coming. On the contrary, without adequate working capital and financial flexibility, the company won't be able to pay its suppliers and expand the business. The author explained four ways to improve information sharing across multiple supply chain tiers and suggested investments in relation-specific assets and long-term orientation in relationships that enable the development of these interaction routines. Firms should share information with their supply chain partners about:

- Event: data such as lead time, order receipt and production
- Stock: data such as work-in-process and finished goods inventory
- Flows: data such as shipment and delivery
- Outcomes: data such as operational performance, profit margins, revenues, and sales

Table 7: How to measurement the effectiveness of information flow

Information flow integration for supply chain coordination
- Production and delivery schedules are shared across the supply chain.
- Performance metrics are shared across the supply chain.
- Supply chain members collaborate in arriving at demand forecasts.
- Our downstream partners (e.g., distributors, wholesalers, retailers) share their actual sales data with us.
- Inventory data are visible at all steps across the supply chain.

Relational interaction routines
- We have created formal and informal arrangements for information exchange with our partners.
- Partners are involved in quality and improvement initiatives.
- We share best practices with our partners.
- We learn about new technologies and markets from our partners.

Relational asset specificity
- Partner tools and machinery are customized to our needs.
- Partners have dedicated significant investment and capacity to our relationship.
- Partner knowledge of our procedures, culture, and technological know-how is difficult to replace.

Long-term orientation
- We have long-term relationships with our strategic partners.
- In key partner relationships, trust and goodwill have the same or greater significance than formal contracts.
- Both sides in the relationship do not make any demands that can hurt the relationship.

Consumer demand predictability
- There is a high margin of error in product forecasts.
- Products have a short life cycle (< 1 year).

Table 7: Patnayakuni, Ravi & Rai, Arun & Seth, Nainika. (2006). Relational Antecedents of Information Flow Integration for Supply Chain Coordination. J. of Management Information Systems. 23. 13-49. 10.2753/MIS0742-1222230101.

2.6 Enriching Knowledge in Business Process Modelling: A Storytelling Approach

In the study, *Enriching Knowledge in Business Process Modelling*, Simoes, Autunes and Cranefield (2006) have suggested the main goal of Business Process Management (BPM) is conceptualizing, operationalizing and controlling workflows in organizations based on the process models and that both BPM and Supply chain collaboration are important for improving the performance of PLM systems. This research sheds light on the challenges and the obstacles that those companies faced during their journey to integrate their supply chain. To improve the business process, the company must be value-driven and focus on the development of better process modeling languages and tools.

The objective of SCM is to maximize value in the supply chain. Supply chain management (SCM) is about competing for value, collaborating with customers and suppliers to create a position of strength in the marketplace based on a value derived from end consumer (Chopra & Meindl, 2007). Value is not inherent in products or services but rather is perceived or experienced by the customer (Handfiel, Monczka, Giunipero & Patterson, 2009). The value a supply chain generates is the difference between what the final product is worth to the customer and the cost that the supply chain will incur to fulfill the customers' request (Marcus, 2010). The authors suggested that within an organization, customer value is created through collaboration and cooperation to improve efficiency (lower cost) or market effectiveness (added benefits) in ways that are most valuable to critical customers.

Supply chain integration and supply chain flexibility have a high correlation with 'financial performance' followed by 'logistic performance' and then 'operational performance.' As a result, critical business processes must be managed from the perspective of supply chain coordination.

A supply chain system can bring benefits such as a competitive advantage to organizations. The authors proposed eight key supply chain management processes and introduced a product development model that supported a knowledge-intensive process that embraced communication and coordination throughout the organization:

- Customer relationship management: *Customer relationship management* is an approach to manage a company's interaction with current and potential customers. It uses data analysis about customers' history with a company to improve business relationships with customers, specifically focusing on customer retention and ultimately driving sales growth (" customer relationship management," 2020).
- Supplier relationship management: *Supplier relationship management* is the discipline of strategically planning for, and managing, all interactions with third-party organizations that supply goods and services to an organization to maximize the value of those interactions. The supply relationship management process defines how a company interacts with its suppliers.
- Customer service management: *Customer service management* is the supply chain management process that represents the firm's face to the customer. It operates at the customer interface and provides a critical point of contact for administering the PSA and can give the customer information on orders, shipping dates, and product availability (Syspro, 2020).
- Demand management: *Demand management* is a planning methodology used to forecast, plan for, and manage the demand for products and services. It allows a company to be proactive in matching supply to demand. The demand management process should

employ customer intelligence, historical sales information, and planned marketing efforts to forecast and influence demand.

- Order fulfillment: *Order fulfillment* is in the most general sense the complete process from the point of sales inquiry to delivery of a product to the customer. The process involves more than just filling orders. It includes all activities necessary to define customer requirements and to design a process that allows a company to meet customer requests while minimizing the total delivered cost. The objective is to develop a seamless process from the supplier to the organization and its various customer segments ("order fullfillment"2020).
- Manufacture flow management: *Manufacturing flow management* is the supply chain management process that includes all activities necessary to move products through the plants and to obtain, implement, and manage manufacturing flexibility in the supply chain. Manufacturing flexibility reflects the ability to make a wide variety of products at an appropriate rate and at the lowest possible cost (Goldsby & Garcia, 2003). Planning and execution extend beyond the production site to encompass the entire supply chain and can increase manufacturing flexibility.
- Project development: the role of the product development team is to coordinate with customer relationship management to identify customer articulated and unarticulated needs. They are also responsible for selecting materials and suppliers in conjunction with the supplier relationship management process and developing production technology in manufacturing flow to manufacture and integrate into the best supply chain flow for a given product/market combination (Syspro, 2020).

- Return management: *Returns management* is the supply chain management process by which activities associated with returns, reverse logistics, gatekeeping, and avoidance are managed within the firm and across key members of the supply chain. The correct implementation of this process enables management not only to manage the reverse product flow efficiently but to identify opportunities to reduce unwanted returns and to control reusable assets ("SCM Research" 2020). Effective returns management is an essential link between marketing and logistics, offering an opportunity for competitive advantage.

Figure 4: Eight key business process for SCM and the product development process

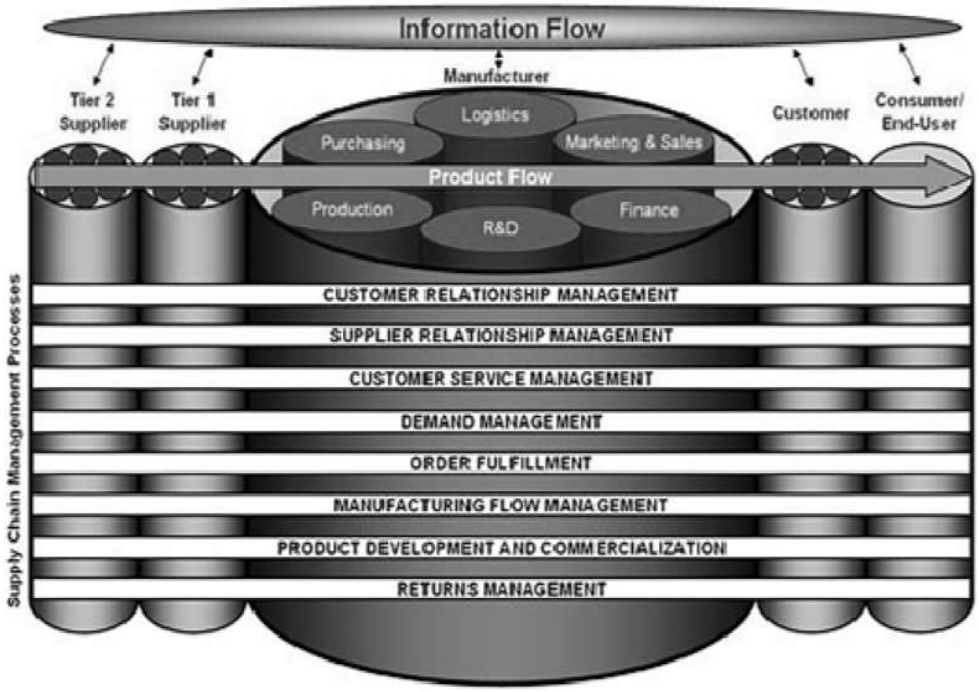

Figure 4: Simões, David & Antunes, Pedro & Cranefield, Jocelyn. (2016). Enriching Knowledge in Business Process Modelling: A Storytelling Approach. Intelligent Systems Reference Library. 95. 241-267. 10.1007/978-3-662-47827-1_10.

The model above supports the theory that integrated and collaborative supply chains lead to win-win relationships, resulting in improved productivity, better demand planning, reduced inventory levels, reduced cost, and higher margins. In short, the model is suited for organizations that believe that supply chain management revolves around relationship management—that the supply chain is managed link-by-link, relationship-by-relationship, and that the organizations that maintain these relationships best will reap the most benefits. (Moberg,Vitasek,Stank &Pienaa, 2008).

Figure 5: Four possible combinations between product and priorities

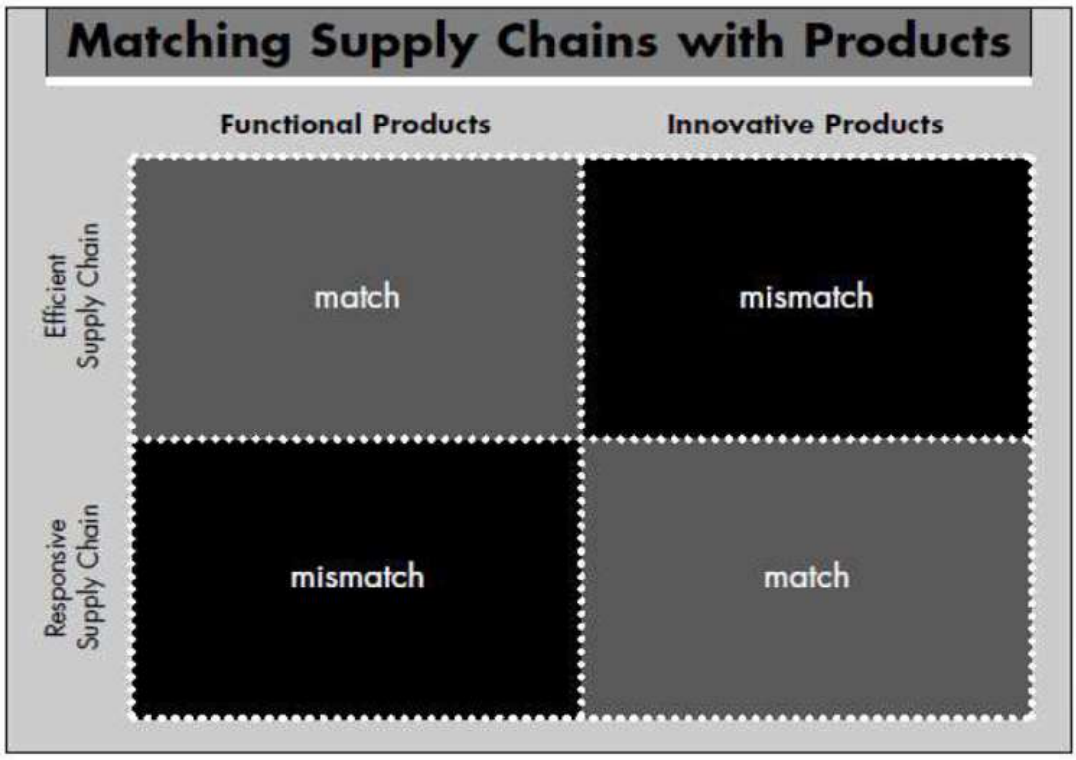

Figure 5: Simões, David & Antunes, Pedro & Cranefield, Jocelyn. (2016). Enriching Knowledge in Business Process Modelling: A Storytelling Approach. Intelligent Systems Reference Library. 95. 241-267. 10.1007/978-3-662-47827-1_10.

2.7 Supply Chain risk assessment during new product development

In the research study, *Supply Chain Risk Assessment during New Product Development*, Chaudhuri, Mohanty, Chaudhuri, Mohanty, Bhaba and Singh (2012) claimed several benefits of successful PLM systems. For example, faster time to market, improved productivity and collaboration, better product quality, decreased cost of new product introduction, reduced prototyping costs, improved design review and approval processes, identification of potential sale opportunities and revenue contributions, maximization of supply chain collaboration, and reduction environmental impacts at the end of product life (Udroiu & Bere, 2018). However, only a few companies have reaped the benefits of PLM; in fact, many organizations still face challenges assessing the vulnerabilities of their globally dispersed supply chains during the product development stage. As a result, any glitch while developing new products can lead to considerable delay in product launch with severe financial implications.

In the research paper, the authors identified a step-by-step approach, using both numeric and linguistic data during new product development, to manage supply chain risk assessment. This method helps to determine the vulnerability scores of various sub-systems and for each supplier (Mohanty, Krishna & Kashi, 2012). The study reviewed organizations can better manage supplier-related risks during new product development by focusing on these metrics:

- *Understanding the impact of suppliers' metrics:* The engineering metrics of each supplier and their potential impact on other suppliers were assessed upfront during the kick-off meeting of the core team. The team creates a chart showing the specification flows across components and develops component level coupling indices to understand the integration issues (Kamath & Liker, 1994).

- *Understanding the impact of the material.* Subject matter experts from the customer and concerned suppliers conducted necessary tests and simulations of the "new" material of construction on a prioritized basis (Kamath & Liker, 1994).
- *Quality improvement and process optimization,* Specific members of the team are assigned to identify deviations in process parameters and their root causes, conduct design of experiments and simulations to understand the interaction effect of process parameters and improve the process to optimize performance (Kamath & Liker, 1994).
- *Manufacturing processes:* Once the design validation is done, A team of manufacturing process engineers from the supplier and customer, along with some external experts, provide technical guidance in ramping up production (Kamath & Liker, 1994).

2.8. Product development process managing in supply chain is a complex system

In the research study, *Product Development Process Managing in Supply Chain Complex Systems Concurrent Engineering,* Santos and Rafael (2007) explained that enterprise business information technology is an information system and is a complex system. Its main domains include product lifecycle management (PLM), enterprise resource planning (ERP), customer relationship management (CRM), and supply chain management (SCM). Businesses depend on strategic relations with their customers and suppliers to create value to develop products and to obtain better market-share. The authors suggested that managers pay attention to five factors of product development processes:

- Knowledge and collaboration engineering and management
- Systems engineering, analysis, modeling, simulation and optimization (including value, cost, risk, and schedule issues)

- Product realization processes, methods, technologies, and techniques
- Business, management and organization issues (product life cycle processes other than development and manufacturing)
- Information technology and systems.

Santos and Rafael (2007) suggested that since processes are the ingredients in today's fast-developing markets, a business should design products to align with the operations and supply chains. Companies should develop plans to match product platforms and supply chains, and design supply chain processes to match the product platforms. If this joint-design is done well by coordinating the product development process with the supply chain, the product will cost much less overall, and the time-to-market will decrease substantially.

2.9 Supplier relationship is important business strategy

In the research study, *Supplier Relationship is Important Business Strategy*, Wangbenmad and Rashid (2014) suggested that supplier management strategies can improve the cost and value of the entire supply chain. Suppliers with dynamic capabilities can have a positive effect on product innovation. Moreover, gaining collaboration with key suppliers can have a significant impact on the business. This paper investigated the relationships among supply chain participants' involvement at various stages of new product development (NPD), and suggested a conceptual framework regarding the relationships among different types of supplier involvement and different types of new product development performance.

Table 8: Supplier involvement in the NPD stage

NPD stage	Supplier involvement
Stage 1: Idea development and initial screening	During idea development, supplier involvement can contribute heterogeneous ideas and know-how about products and the market (Chung & Kim, 2003). With high supplier involvement and direct participation in the customer's product development team they can be entrusted with especially developing and screening product ideas (Handfield et al. 1999). In addition, supplier involvement in product concept development would provide (1) technological capabilities and expertise, (2) advice in identifying new materials and new products, and (3) manufacturing advice to the concept (Mohamad et al. 2007).
Stage 2: Business and market analysis	Supplier involvement in market study can advise the firm to exploit new market opportunities in the future, such that, the company can match its technological needs with the technological opportunities available in supplier markets (Handfield et al., 1999, Monczka et al., 2000).
Stage 3: Technical development	Supplier involvement in designing process would be able to supply (1) simplified product designs, (2) useful information for making decisions regarding the choice of product components, (3) the design/use of standard components, (4) component design that meets buyer specification, (5) designing resource, (6) tooling and equipment. Supplier involvement in prototype development would be able to provide (1) timeliness and reliability in making prototypes, (2) information relating to modification carried out during prototyping stages, and (3) product or process technology to development. The supplier's involvement in – house product testing can enable the firm to gain Better information regarding the technical features of works which need improvement, so that suppliers can work on the product's technical features and improve it specification at a very early stage (Song & Parry, 1997).
Stage 4: Market Testing	Supplier involvement in product testing can help the firm to gain better information about the customer needs of and make changes that could ncrease customer satisfaction as early as possible (Song & Parry, 1997).
Stage 5: Commercia-lization	Supplier involvement during product commercialization would provide market information specially in launching products tat are new to the market in which new technology is incorporated in them, because suppliers have more knowledge regarding new technology in the target market, due to their experience with the use of technology in other applications.

Table 8: Wangbenmad, Chutima & Nik, Ramli & Nik, Abdul & Rashid,. (2014). Supplier Involvement in Product Development Process (PDP) and New Product Performance: The Mediating Role of New Product Advantage. Journal of Marketing Management. 2. 227-238.

III. SURVEY METHODOLOGY

Phrase 1: Procedures	• Manifestation • Developing research objectives • Prediction • Investigation
Phrase 2: Participants	• Select primary studies/participants • Literature reviews • Data collection
Phrase 3: Instrumentation	• Define research methods

Procedures

Manifestation

PLM is a strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination and use of product definition information across the extended enterprise from concept to end of life – integrating people, processes, business systems and information (CIMdata,2018, Gecevska et al,.2010).

Developing research objectives

Product lifecycle management (PLM) is an integrated business process. Yet, few companies have adequately aligned the PLM process with the business strategy, and acknowledged that effective PLM systems could improve information visibility.

Prediction

PLM systems can reduce the misalignment between satisfying customers and other business objectives related to revenue and profitability. A developed PLM process can improve other area's process integration as well as support business operations.

Investigation

Research question: What is the relationship between PLM and supply chain management, and how to effectively improve PLM processes and workflow?

Participants

Four groups of research data are listed below: 1) strategic process, 2) integrated business process, 3) knowledge and information, and 4) workflow coordination:

Table 9: Research Participants

Authors	**Research**	**Determinants**
Penaranda, Gutierrez, Romero &Molina (2010)	2.1 Implementation of product lifecycle Management tools uses enterprise integration engineering and action-research	Group 1, 2 ,3
Gecevska, Paolo & Anisic (2010)	2.2 Product lifecycle management through innovative and competitive business environment	Group 1,2 and 3
Crippa, Larghi, Margherita & Andrea (2010)	2.3 The impact of new product introduction on supply chain ability to match supply and demand	Group 1, 2, 3,4
Hilletofth & Eriksson (2010)	2.4. Coordinating new product development with supply chain management	Group 2,3,4
Patnayakuni, Rai & Seth (2006)	2.5 Relational antecedents of information flow integration for supply chain coordination	Group 1,2,3,4
Simoes, Autunes & Cranefield (2006)	2.6 Enriching knowledge in business process modelling	Group 2, 3

Chaudhuri, Atanu, Mohanty, Bhaba Krishna, Singh & Kashi (2012)	2.7 Supply chain risk assessment during new product development: A group decision making approach using numeric and linguistic data	Group 1, 2,3, 4
Santos, Andrea & Kieckbusch, Rafael, Forcellini & Fernando (2007)	2.8 Product Development Process Managing in Supply Chain. Complex Systems Concurrent Engineering	Group 1,2,4
Chaudhuri, Atanu Mohanty, Bhaba Krishna , Singh & Kash (2012)	2.9 Supplier Involvement in product development process (PDP) and new product performance: the mediating role of new product advantage.	Group 1,3 and 4

Instrumentation

Figure 6: Case Study Research: Design and Methods

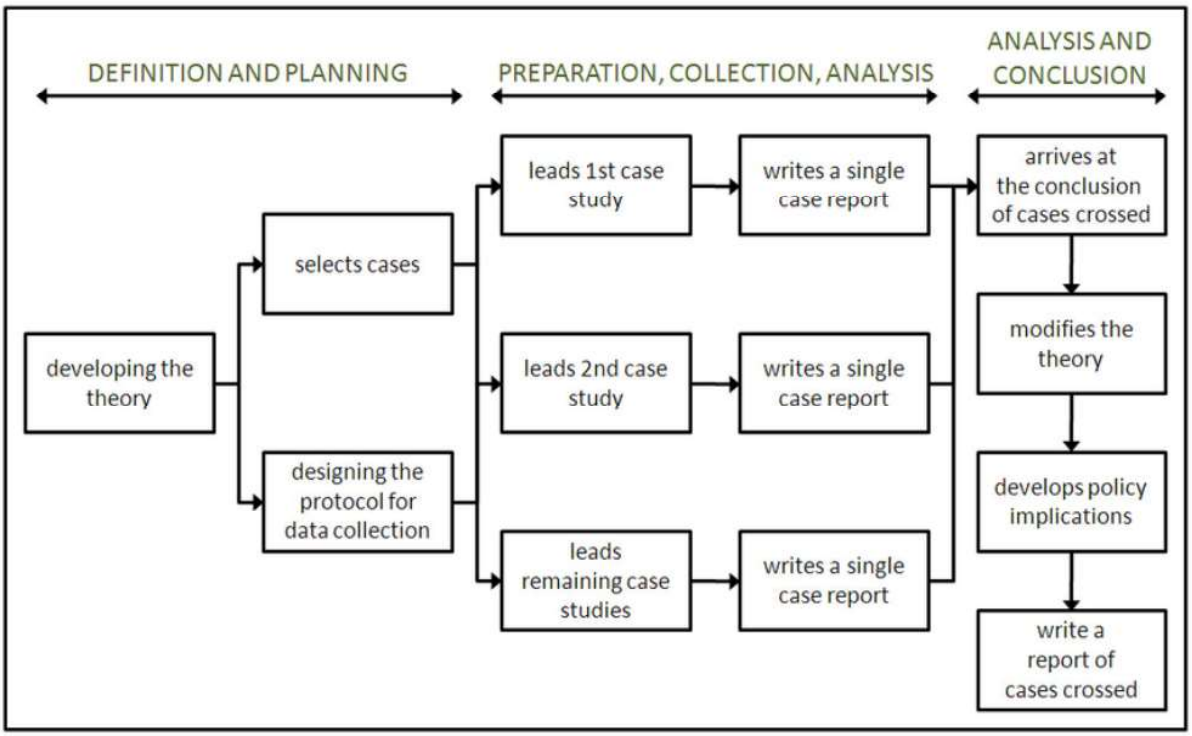

Figure 6: Case Study Method of COSMOS Corporation based on cross case analyses on explanatory factors for planning approach (Yin, 2003)

Research method	**Designing the protocol for data collection**	**Data analysis**
• Multiple case study (Yin, 2003). Research articles selected based on the cumulated experience, or validate the methods and approaches for the proposed study (Yin. 2003).	• Benchmark study and literature survey The theory developed from a review and synthesis of a range of primary industry cases, practical strategies, and partial solutions available within the existing literature. (Hines et al., 2006).	• Data include different views and perspective of PLM and supply chain theories and Frame work. Four groups of data have been analyzed 1, Strategic process 2, Integrated business process 3, Knowledge and information 4, Workflow coordination

IV. ANALYSIS OF THE SURVEY DATA

Phrase 1: Compare studies	• Summary of comparison • Discussion
Phrase 2: Review	• Research findings • limitation of the research and future research

Comparison of the study

Table 10: Literature review analysis and results comparison

Research study case	**PLM and supply chain strategies**
2.1 Implementation of product lifecycle Management tools uses enterprise integration engineering and action-research	• Successful PLM requires strategic planning, and its process needs to align with strategy and performance evaluation systems. • Supply chain strategy: competitive strategy, value chain strategy, and production/service strategy. • Business process: strategic planning, product, process, and manufacturing system development, sales and service, order fulfillment and supply chain management, and support services.

2.2 Product lifecycle management through innovative and competitive business environment	• Successful PLM systems can help a company to get ahead of the competition in the market. • PLM strategies focus on satisfying customer requirements (timing, function, performance, style, and price). • PLM strategies need to focus on business objectives related to growth, revenue, and profitability.
2.3 The impact of new product introduction on supply chain ability to match supply and demand	• Successful PLM requires collaboration from supply chain management and support from other business functions. • Product development is connected to supply chain management, and product features affect supply chain performance. • Product development integrates information and coordinate supply chain processes.
2.4. Coordinating new product development with supply chain management	• Successful PLM strategies focus on improving both demand-side activities and supply chain-side activities. • NPD activities need to align with SCM activities on a strategic level, • Trust between supply chain partners is the key. • PLM strategies need to focus on market characteristics, product characteristics, strategy characteristics, and process characteristics.

2.5 Relational antecedents of information flow integration for supply chain coordination	• Successful PLM systems need to support operational, tactical, and strategic information between a firm and its supply chain partners. PLM managers need to understand the value of Lifecycle information flow. • Downstream information flows in supply chains focus on coordinating capacity, delivery schedules, and product information. • Upstream information flows to focus on orders, demand forecasts, point-of-sales information, and performance metrics. • Collaborative forecasting and planning.
2.6 Enriching knowledge in business process modelling	• Successful PLM systems require better process modeling languages and tools to support knowledge-intensive processes that embrace communication and coordination. • PLM strategy focus on eight essential business process: customer relationship management, supplier relationship management, customer service management, demand management, order fulfillment, manufacture flow management, product development, and commercialization, return management.

2.7 Supply chain risk assessment during new product development: A group decision making approach using numeric and linguistic data	• Successful PLM systems focus on identifying potential sale opportunities and revenue contributions, maximize supply chain collaboration, and reduce environmental impacts at the end of product life. • PLM strategies enable faster time to market, improved productivity and collaboration, better product quality, decreased cost of new product introduction, reduced prototyping costs.
2.8 Product Development Process Managing in Supply Chain. Complex Systems Concurrent Engineering	• Successful PLM requires an effective information system and product development process. • Design products to match the processes and supply chains. • Design processes to match product platforms and supply chains. • Develop Information system: product lifecycle management (PLM), enterprise resource planning (ERP), customer relationship management (CRM), and supply chain management (SCM).
2.9 Supplier Involvement in product development process (PDP) and new product performance: the mediating role of new product advantage.	• Successful PML requires supplier involvement in product development and collaboration from customers. • Supplier collaboration can have a positive effect on product innovation, which in turn to innovation performance. • PLM strategy attain shorter time-to-market of new products and to achieve cost targets (product costs and R&D costs).

Discussion

Research question: *What is the link between PLM and supply chain management and why it is important?*

PLM systems are essential for managing the vast quantity and variety of data associated with complex products; the integration of PLM and supply chain is becoming more sophisticated to support the increasing complexity of products and supply chain. For example, in the early stage of the product lifecycle, the engineer needs to initiate the design of the overall product, assembly, or components, that is, the bill of material (BOM) (Clint,2014). These decisions for product variety and product architecture have significant impacts on lead-time and inventory costs.

Staying competitive in today's dynamic business environment is challenging for any organization that wants to deliver products and services better. Adopting advanced information systems which enable efficient information sharing between the members of supply chains has become the solution. However, to take full advantage of PLM across the supply chain, it needs to involve all significant users of and contributors to the product data (Tony,2015). The research study indicates PLM systems can improve other area's process integration, support business operations, and enable innovation.

Research findings

Dimension	Activities	Process and Tools
Strategic planning	• Define competitive strategy, value chain strategy, and production/ service strategy • Define KPI (economical, productivity, strategic)	Focus on cost leadership (operational excellence strategy), differentiation (product leadership strategy) and focus (customer focus) Focus on order-qualification and order winning characters Focus on supply chain coordination between operational, tactical, and strategic information
Integrated business process	• Improve information integration and synchronized planning • Workflow coordination, and new business modes	Improve product, process, and manufacturing system development. Sales and service. order fulfillment and supply chain management, and support services Improve information flow strategies: Customer relationship management, supplier relationship management, customer service management, demand management, order fulfillment, manufacture flow management, product development, and commercialization, return management. Design strategic metrics to improve supplier involvement

Knowledge information management	• Information sharing • Transparency, and direct real time accessibility. • Collaborative planning forecasting, and joint design • Improve data, information and knowledge models	Identify bottlenecks in supply chain operations. Downstream information flows in supply chains focus on coordinating capacity, delivery schedules, and product information, Upstream information flows to focus on orders, demand forecasts, point-of-sales information, and performance metrics. *Information and knowledge models:* Product lifecycle management (PLM) Business process management system (BPMS) Business process intelligence (BPI) Enterprise system (ERP, CRM, SCM,etc) Enterprise content mangment (ECM)

Work flow coordination	• Improve collaboration and resolve conflicts • Aligning the incentives/profit of information sharing to all supply chain partners	Coordinate and balance the motivation factors/conflicting objectives of supply chain management and product development decision-making PLM-Required human and financial resource, product variety, product architecture, innovation, the timing of supplier involvement, PLM contribution to SCM SCM-Design to cost, product variety, product architecture, supplier's capacity, suppliers selectin and screening Leadtime and cost target, phase, make or buy, product and market allocations, SC contribution to PLM Design metrics and align the incentive of information sharing.

Limitation of the Study

The limitations of this study are:

- Sample size: the sample size may be too small to identify significant relationships in the data.
- Lack of available data: a lack of research data might limit the scope of analysis.
- Culture and other type of bias: I have selected research papers with the same focus of information sharing and business process. None of these studies have provided information strategies regarding sales /marketing, procurement activities.

Future research

There are some knowledge gaps in my research, which would benefit from further research to extend and further test the theory I have developed here. In further research, I would like to explore the role of PLM systems in fostering organizational innovation success.

V. SUMMARY AND CONCLUSIONS

Summary

The research presented throughout this paper explored different approaches to explain how successful PLM systems implementation was carried out. Product development integrates information and coordinates supply chain processes. The research study also described the impact of information sharing in the supply chain. PLM systems need to align and integrate people, technology, and processes through engineering design and manufacturing, to optimize supply chain performance. These results can be summarized as follows:

- PLM is a business solution that aims to streamline the flow of information about the product and related processes throughout the product's lifecycle such that the right information in the proper context at the right time can be made available. (Ameri and Dutta, 2005).
- PLM is an essential integrated business process because PLM communication has a direct impact on supply chain risk, inventory cost/ level, cash flow, operational effectiveness, and sales.
- The developed PLM process can improve other area's process integration, support business operations, and enable innovation.
- PLM has a vital role in balance and harmony between the inventory postponement and business activities.

Conclusion

Operating an integrated supply chain requires a continuous information flow (Lambert and Cooper 2000). Organizations need to adapt and develop new products and services and to improve their processes to maintain their goals of increasing profits, securing growth, and supporting continuous improvement throughout their organization. Although the effective integrated business process is critical for companies to support operational planning decisions and improve their end to the end value chain of business, many organizations have not reaped the actual benefits of PLM. One primary reason is their lack of supply chain visibility and silos (conflicted leadership). Successful PLM systems can reduce the communication gaps, which is the result of the bullwhip effect and silos, to improve information visibility. In addition, PLM is both a business and technology strategy that contributes to manufacturers' successes in all of these initiatives.

Effective business processes and integration of resource flow in supply chains require understanding the problems from the user perspective and addressing them with the human-centered design approach. Product lifecycle management is the iterative process of creating solutions to help humans and businesses overcome obstacles and reach their goals. To design effective PLM processes, managers must intuitively understand the storyline that remains beyond the surface by applying design thinking. According to IDEO founder Tim Brown, design thinking is "a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success (Brown, 2020).

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