Decision Engineering

John Stark

Product Lifecycle Management (Volume 1)

21st Century Paradigm for Product Realisation

Fifth Edition

Decision Engineering

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Preface

This is the fifth edition of what has become the PLM Reference Book. Product Lifecycle Management (PLM) is the business activity of managing, in the most effective way, a company's products all the way across their lifecycles, from the very first idea for a product all the way through until it is retired and disposed of.

PLM is about "managing products across their lifecycles", and it applies to any company with a product. It applies in all sizes of companies, ranging from large multinational corporations to small and medium enterprises. It's applied across a wide range of industrial sectors including aerospace, apparel, automotive, beverage, consumer goods, construction equipment, defence, electrical engineering, electronics, food, life sciences, machinery, machine tool, mechanical engineering, medical equipment, pharmaceutical, plastics, shipbuilding, shoe, software, transportation, and turbine.

In the middle of the twentieth century, between 1945 and 1970, things changed little in the world of products. Companies, and their executives, managers and employees worked out how to succeed in that environment. They had an accepted way of thinking, a paradigm, about the way products were managed. For example, companies were organised by department, there was a multilevel hierarchy of middle managers, information was on paper, secretaries produced technical reports on typewriters, and engineers used slide rules for calculations. The Iron Curtain divided the capitalist West from the communist East. In the USA and Western Europe, engineers were predominantly men, white and white-shirted.

The 1970s saw the beginning of a period of a change. It's worth remembering that Intel was founded in 1968, Microsoft in 1975 and Apple in 1976.

In the fifty years between 1970 and 2020, the product landscape changed rapidly and significantly. Many new products appeared as a result of the Electronics Revolution, the Software Revolution, the Biotechnology Revolution and the Nanotechnology Revolution. The Internet and the World Wide Web emerged. Many new products were mechatronic, containing mechanical, electrical, electronic and software components. The development time and the lifetime of many products was slashed. As well as changes in products, there were changes in the environment in which products were sold and used. There were geopolitical changes such as globalisation, the end of the Cold War and the emergence of China as a major manufacturing country. Other changes resulted from concerns about global

warming, the environment and sustainability. In response to all these changes, the paradigm for managing products changed. The new paradigm, PLM, emerged at the beginning of the twenty-first century.

What is this new paradigm? In other words, how should a company, its executives, managers and employees be organised and work in this new environment? And another question, how should a company transition from the old paradigm to the new paradigm? What set of actions will a company have to execute to achieve the change? This book answers these questions.

The PLM paradigm emerged at the beginning of the twenty-first century and has been evolving since then. It was described in the first edition of this book, which was published in 2004. The second edition of the book was published in 2011, the third in 2015 and the fourth in 2019. Since then, the paradigm has continued to evolve. There have been more changes in technologies, products and the PLM environment. PLM has become more and more important. And, due to technological advances, new opportunities for PLM have appeared. This fifth edition of the book addresses these advances and the ever-increasing application of PLM. As for the previous editions, it draws on the extensive PLM consulting activities and experience of the author.

The underlying logic for the structure and content of the book is built on the PLM Grid, a concept outlined in the first chapter. The PLM Grid shows the ten components: product; business processes; product data; the Product Data Management system; other PLM applications; facilities and equipment; techniques; people; management and organisation; and objectives and metrics that have to be addressed when managing a product across the lifecycle.

The book has eighteen chapters. Chapters 1 and 2 introduce PLM and the PLM environment. Chapter 3 addresses products. Chapter 4 focuses on business processes. The subject of Chap. 5 is product data. Chapter 6 addresses Product Data Management systems. Chapter 7 looks at other PLM applications. The content of Chap. 8 includes techniques and methods in the PLM environment. The subject of Chap. 9 is the Internet of Things. That of Chap. 10 is Industry 4.0 and the manufacturing environment. Chapters 11 and 12 address Digital Twins and Digital Threads. Chapters 13 and 14 look at Organisational Change Management (OCM) and project management. The subject of Chap. 15 is the role of executives in PLM, and that of Chap. 16 is the PLM Initiative. Chapter 17 gives examples of PLM in industry.

Many of the chapters address subjects, for example, OCM, that are huge areas in themselves. There are already many books addressing these subjects. The intention of these chapters isn't to repeat everything known about the subject. Instead, it's to provide, for the specific environment of PLM, an introduction that will enable people to work more effectively on PLM activities. The book can be thought of as "PLM 101". It will be useful for those working on a company's PLM activities. It will be a good on-boarding tool for anyone joining a PLM Initiative. It will also be useful for undergraduate and postgraduate university students learning about PLM.

The author has worked with more than 100 companies of many sizes, and in many industries, during the emergence and growth of PLM. Sharing the resulting

experience and knowledge meets the innate human desire to improve the world. PLM is, of course, important for companies. By adopting and improving PLM, companies increase product revenues, reduce product-related costs, maximise the value of the product portfolio and maximise the value of current and future products for both customers and shareholders. But, in a wider sense, PLM is also important for mankind. The planet's 7 billion inhabitants all rely on products of various types, and the great majority would benefit from faster, easier access to better products. PLM is a win-win for us all.

Geneva, Switzerland John Stark

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Product Lifecycle Management (PLM)

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1.1 What Is PLM?

1.1.1 Definition of PLM

Product Lifecycle Management (PLM) is the business activity of managing, in the most effective way, a company's products all the way across their lifecycles; from the very first idea for a product all the way through until it is retired and disposed of.

PLM is the management system for a company's products. It doesn't just manage one of its products. It manages, in an integrated way, all of its parts and products, and the product portfolio. PLM manages the whole range, from individual part through individual product to the entire portfolio of products.

At the highest level, the objective of PLM is to increase product revenues, reduce product-related costs, maximise the value of the product portfolio and maximise the value of current and future products for both customers and shareholders.

1.1.2 Definition of the PLM Initiative

The PLM Initiative of a company is an initiative with two objectives. The first of these is to improve the product-related performance of the company (Fig. 1.1). The other objective is to put in place, or to improve, the capability to manage products across their lifecycles.

Whereas PLM is an ongoing endeavour, a PLM Initiative is a temporary endeavour. Most companies will have a PLM Initiative at some time between 2020 and 2025.

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Rate of introduction of new products	+100%		Lifecycle control over products	100%
Revenues from extended product life	+25%		Lifecycle visibility over products	100%
Costs due to recalls, failures, liabilities	-75%		Part reuse factor	x 7
Revenues from new services on existing products	+40%		Cost of materials and energy	-25%
Number of significantly innovative new products	x 3		Recycling of products	+90%
Development time for new products	-50%		Product traceability	100%

Fig. 1.1 Typical targets of a PLM Initiative

1.1.3 A Paradigm

The title of this book refers to PLM as a twenty-first century paradigm. A paradigm is a generally agreed and shared conceptual structure that people use to work with a complex subject. It's a simple picture that helps them think about, describe, analyse and communicate about the subject. In this book, the "complex subject" that is addressed is the management of a company's products.

A paradigm is questioned and tested in everyday work and by everyday experience. A paradigm shift occurs when the majority of people find, through everyday experience and analysis, that the existing paradigm no longer fits to the practical reality of the subject.

1.1.3.1 The Paradigm Before PLM

The PLM Paradigm emerged in 2001. The previous paradigm for the management of a company's products was departmental:

- The Marketing Department decided which products were needed by the market
- The Engineering Department designed them
- The Manufacturing Department produced them
- The After-Sales Department supported them.

This departmental paradigm was generally agreed and shared for most of the twentieth century. The reasoning behind it was that the specialists in a department are the best equipped to carry out the activities of that function. For example, specialists in the Engineering Department were believed to be best equipped to carry out Engineering activities. The logic behind this was that engineers learn about these activities at school or university, are further trained about them, are hired to do them, learn about them from Engineering colleagues, and practice them for years in the company. So who could do them better?

Over time, though, this reasoning and belief in departmental ability implicitly extended so that each department didn't just carry out activities for which it had specialist functional know-how. It went much further and decided everything about its operations. For example, each department decided independently how to organise its activities, its documents and its data, and its computer systems. Even though, for example, Marketing specialists aren't specialists in organising activities, any more than Engineering specialists are specialists in IS.

With time, the departmental approach led to an environment of departments working independently, interdepartmental barriers, incompatibilities at departmental borders, waste, gaps, contradictory versions of the same data, information silos, islands of automation, overlapping networks, duplicate activities, serial work, ineffective fixes and product recalls. The end result was long product development and support cycles, customers having problems with products, reduced revenues and higher costs. These anomalies showed that something was wrong with the departmental paradigm for the management of a company's products.

A paradigm shift resulted. In 2001, a new paradigm for the management of a company's products, the PLM Paradigm, emerged. It will be described in Sect. 1.5, after brief introductions to this chapter, and the acronym and scope of PLM.

1.2 This Chapter

1.2.1 Objective

The objective of the first chapter of this book is to provide an introduction to PLM, answering the questions: "What is PLM?"; "Why PLM?"; "When did PLM appear"; and "Where is PLM used?" The answers to these questions will help those working with PLM in a company, including those involved in a company's PLM Initiative, to understand the basics of PLM and why it's so important. It will allow them to add more value and participate more fully in the PLM Initiative and PLM activities. This chapter also aims to give students, for whom this book is a course book, a basic understanding of PLM and its importance in industry.

1.2.2 Content

The first part of the chapter gives definitions of PLM and a PLM Initiative. The second part of the chapter looks at the meaning of the letters P, L and M in the PLM acronym. The third part addresses the scope of PLM. It introduces the PLM Grid, describes activities within the scope of PLM and identifies the resources managed in PLM. The fourth part of the chapter describes the PLM Paradigm, detailing concepts, consequences and corollaries. The fifth part looks at the potential benefits, strategic and operational, of PLM and a PLM Initiative. The sixth part shows how PLM has spread since its emergence in 2001. As of 2022, it's used throughout manufacturing industry and throughout the world. The seventh and final part of the chapter looks at the problems that PLM solves and the opportunities it enables.

1.2.2.1 Skills

From this chapter, students who've been assigned the book for coursework will gain a basic understanding of PLM, a PLM Initiative and the PLM Paradigm. They'll find out about the meaning of the PLM acronym. They'll understand the scope of PLM.

They'll know about the problems that PLM addresses. They'll see how PLM has spread throughout industry and across the world. They'll learn about the benefits of PLM. They'll be able to explain, communicate and discuss about PLM.

1.2.3 Relevance

People starting to work with PLM in a company are likely to ask questions like: "What is PLM?"; "Why PLM?"; "When did PLM appear"; and "Where is PLM used?" They'll find the answers in this chapter. It will enable those working in activities across the product lifecycle to rapidly understand PLM. After they've read the chapter, they should understand the PLM Paradigm and its essential characteristics and concepts. They'll know about the operational and strategic benefits of PLM. They'll be able to work more effectively in PLM activities.

1.3 The P, L and M of PLM

1.3.1 The P of PLM

1.3.1.1 Importance

The product is important. Whether it's a chair, a beverage, an aircraft, some software or an anaesthetic, it's the product, and perhaps some related services, that the customer wants. The product is the source of company revenues. Without a product, the company doesn't need to exist and won't have any customers. Without a product, there won't be any related services. The product is important! The company generates revenues from an ongoing stream of innovative new and upgraded products. Great products make it the leader in its industry sector. Great products lead to great profitability.

1.3.1.2 Range of Products

There's a huge range of products in the world. There are tangible products, products you can touch, products such as a computer and a car. And there are intangible products such as software, insurance policies and mortgages. There are products as diverse as an Airbus A380 and a dollar bill, a book and a beverage.

Products come in all sorts of shapes and sizes. The movement of a Swiss watch may be little longer and wider than a postage stamp, and only a few millimetres in thickness. A postage stamp is even smaller. Many other products are much larger. For example, an Airbus A380 is 73 m long, with a wingspan of nearly 80 m.

A product may actually be a service. A product can also be a package of services, or a bundle of products and services, or a solution containing several products, or a solution containing products and services.

The product is often more than what seems, at first glance, to be the product. Product packaging is often a part of the product. So is product labelling.

The product may include wires and plugs that connect it to the outside world. The product may include product literature, such as user documentation or regulatory documentation. The product may be a six-pack or a single can. If it's a six-pack, it may have additional packaging, but the product you drink is the same as if it's a single item. The delivery mechanism may be part of the product. For example, inside the packaging of an anaesthetic may be a sterile syringe.

A company's products may have been developed by the company itself. Or they may have been acquired as a result of merger and acquisition (M&A) activity.

1.3.1.3 Range of Number of Parts

A company's product may be made of many assemblies and thousands of parts or components or constituents or ingredients depending on the type of product. An assembly may also be made of a large number of parts. These assemblies and parts could be made by the company itself, or could be the products of other companies, its suppliers. Many products contain industrial components (products) of various types, such as hardware, software, electrical, electronic and chemical. Many products also contain other types of components, such as agricultural, forestry and fishery products.

As Fig. 1.2 shows, many products contain a lot of parts. Many companies have hundreds or thousands of products each of which may contain different parts. All of these need to be managed. Whatever the product, PLM is the management system for a company's products and parts.

1.3.2 The L of PLM

There are five phases in the product lifecycle (Fig. 1.3). In each of these five phases, the product is in a different state. During the ideation phase, the product is just an idea in people's heads. During the definition phase, the ideas are being converted into a detailed description. By the end of the realisation phase, the product exists in its final form (e.g. as a car) in which it can be used by a customer. During the use/support phase, the product is with the customer who is using it. Eventually the product gets to a phase in which it's no longer useful. It's retired by the company and disposed of by the customer. It may be recycled by the customer or the company or a third party.

Fig. 1.2 Typical number of parts, or ingredients, in a product

Product	*Typical number of parts*
Deodorant	20
Sandwich	30
Shampoo	50
Watch	300
Machine tool	2000
Car	25000
Aircraft	400000
Space shuttle	2000000
Software (lines of code)	20000000