

# Preface

*“The only thing we know about the future is that it will be different.”  
Peter Drucker (1909–2005)*

Change has become a constant in today’s manufacturing environment. While change is inevitable, it is important to take advantage of it and make it happen efficiently through good designs and by developing effective change enablers. The advantages of **change ability** are well known, and have been demonstrated by many examples as early as the invention of the movable type printing machines.

Globalization, unpredictable markets, increased products customization and the quest for competitive advantages are but a few of the many challenges facing manufacturing enterprises now and in the future. Frequent changes in products, production technologies and manufacturing systems are evident today along with their significant implementation cost. One key strategy for success is to satisfy the market need for products variations and customization, utilizing the new technologies, while reducing the resulting variations in their manufacturing and associated cost. This trend is on the rise in view of the paradigm shifts witnessed in manufacturing systems and their increased flexibility and responsiveness to cope with the evolution of both products and systems.

A host of external and internal change drivers exist that affect the manufacturing enterprises at various levels from strategic planning for re-positioning the business, down to the actual production facilities to achieve a high degree of adaptability. The drivers relate to business strategy modification, market volatility and products/production variations. The changing manufacturing environment, characterized by aggressive competition on a global scale, scarce resources and rapid changes in process technology, requires careful attention in order to prolong the life of manufacturing systems by making them easily adaptable and facilitating the integration of new technologies and new functions. Changes can most often be anticipated but some go beyond the design range. This requires providing innovative change enablers and adaptation mechanisms to achieve modularity, scalability and compatibility. While changes may not always be anticipated, the behavior of their enablers should be pre-planned for all scenarios to ensure cost effective adaptability.

Changeability is defined as the characteristics to economically accomplish early and foresighted adjustments of the factory's structures and processes on all levels, in response to change impulses.

Several manufacturing systems paradigms have emerged as a result of these changes including agile, adaptable, flexible and reconfigurable manufacturing. The ability to cope with change is the common denominator among all these paradigms, each of which presents a set of technological solutions to enable changes to occur efficiently and profitably. Flexible manufacturing for example changes the system behavior without changing its configuration, while reconfigurable manufacturing would change the system behavior by changing its configuration.

There are two types of change enablers: hard or physical enablers and soft or logical enablers. The "physical/hard" change enablers include the physical attributes that facilitate change. These characteristics are not only limited to the machinery but they also apply to the factories infrastructures, physical plant and buildings. Hardware changes also require major changes at the "logical/soft" enablers level, such as the software systems used to control individual machines, complete cells, and systems as well as to process plan individual operations and to plan and control the whole production. The logical enabling technologies extend beyond the factory walls to the strategic planning levels, logistics and supply chains. In addition, manufacturing changes are not limited to the technical systems; they include the business organization and employees that should also be planned and managed effectively.

The role of changeability enablers can be well illustrated, as mentioned, by the example of the invention of the movable type printing machine. In the early days, books were either copied out by hand on scrolls and paper or printed from hand-carved wooden blocks, each block is used to print a whole page, a part of a page or even individual letters. This took a long time, and even a short book could take months to complete. The woodwork was extremely time-consuming, the carved letters or blocks were very fragile and the susceptibility of wood to ink gave such blocks a limited lifespan. Moreover, the same hand-carved letters did not look the same. Johannes Gutenberg (1397–1468) is generally credited with the invention of practical movable type. He made metal moulds, by the use of dies, into which he could pour hot liquid metal, in order to produce separate letters having the same shape as those written by hand. These letters were consistent, more readable and more durable than wooden blocks. They could be arranged and re-arranged many times to create different pages from the same set of letters. The Koreans (in 1234, over 200 years ahead of Gutenberg's feat) and the Chinese (between 1041 to 1048) have independently invented movable type. However, it was not until Gutenberg introduced around 1450 the use of the enabling printing press technology (used in his times by the wine industry) to press the arranged type letters against paper that this invention took off. The press enabled sharp impressions to be made on both sides of a sheet of paper and allowed many repetitions as well as letters re-use.

Movable print is a perfect example of early applications of standardization, modularity, compatibility, inter-changeability, scalability, flexibility and reconfigurability. Regardless of earlier introductions of the movable print, it was Gutenberg's com-

bination of the printing press; movable type, paper and ink that helped the invention evolve into an innovative and practical process. By combining these elements into a production system, he made the rapid printing of written materials feasible, which lead to an information explosion in Renaissance Europe. The print invention is regarded by many as the invention of the millennium, thanks to Gutenberg, who provided the *change ability* and *technological enablers* to make it a success, which lead to mass printing practices that changed our world.

In this book, the technological enablers of changeability are particularly emphasized. Many important perspectives on change in manufacturing and its different facets are provided. The book presents the new concept of Changeability as an umbrella framework that encompasses many paradigms such as agility, adaptability, flexibility and reconfigurability, which are in turn enablers of change. It establishes the relationship among these paradigms and presents a hierarchical classification that puts them in context at all levels of a manufacturing enterprise. It provides the definitions and classification of key terms in this new field. The book places great emphasis on the required change enablers. It contains original contributions and results from senior international experts, experienced practitioners and accomplished researchers in the field of manufacturing. It presents cutting edge technologies, the latest thinking and research results as well as future directions to help manufacturers stay competitive. In addition, most chapters contain either industrial applications or case studies to clearly demonstrate the applicability of these important concepts and their impact.

The book is organized in 5 parts and 22 chapters by authors from Canada, Europe, Japan and Asia. It offers balanced and comprehensive treatment of the subjects as well as in depth analysis of many related issues. **Part I** introduces manufacturing changeability, its definitions, characteristics, enablers and strategies, presents models and enablers for changing and evolving products and their systems, and discusses the concept of focused flexibility in production systems. **Part II** deals with the physical technological change enablers for machine tools and robots configuration and re-configuration and control, including new unified dynamic and control models, and highlights the important, but less discussed, changeable and reconfigurable assembly systems. **Part III** focuses on the logical change enablers. It presents new unified dynamic and control models for reconfigurable robots as well as reconfigurable control systems. It introduces novel methods for reconfiguring process plans, new perspectives on adaptive as well as change ready production and manufacturing planning and control systems, and models for capacity planning and its complexity. **Part IV** discusses the topic of managing and justifying change in manufacturing including the effect of changeability on the design of products and systems, the use and programming of CNC machine tools, quality and maintenance strategies for reconfigurable and changeable manufacturing and the economic and strategic justification of these systems. **Part V** sheds light on some important future directions such as the cognitive factory, the migration manufacturing new concept for automotive body production and an architectural view of changeable factory buildings.

The book will serve as a comprehensive reference in this subject for industrial professionals, managers, engineers, specialists, consultants, researchers and academics in manufacturing, industrial and mechanical engineering; and general readers who are scientifically bent and interested to learn about the new and emerging manufacturing paradigms and their potential impact on the work place and future jobs. It can also be used as a primary or supplementary textbook for both post-graduate and senior under-graduate courses in Manufacturing Paradigms, Advanced Manufacturing Systems, Flexible/Reconfigurable Manufacturing, Integrated Manufacturing, and Management of Technology.

I hope you will enjoy reading this book, and would like to leave you with a final thought best expressed by the following interesting quote:

*“I do not know whether it becomes better if it changes.  
But it must change if it should become better.”*  
German Philosopher,  
Georg Christoph Lichtenberg (1742–1799)

Windsor, Ontario, Canada  
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