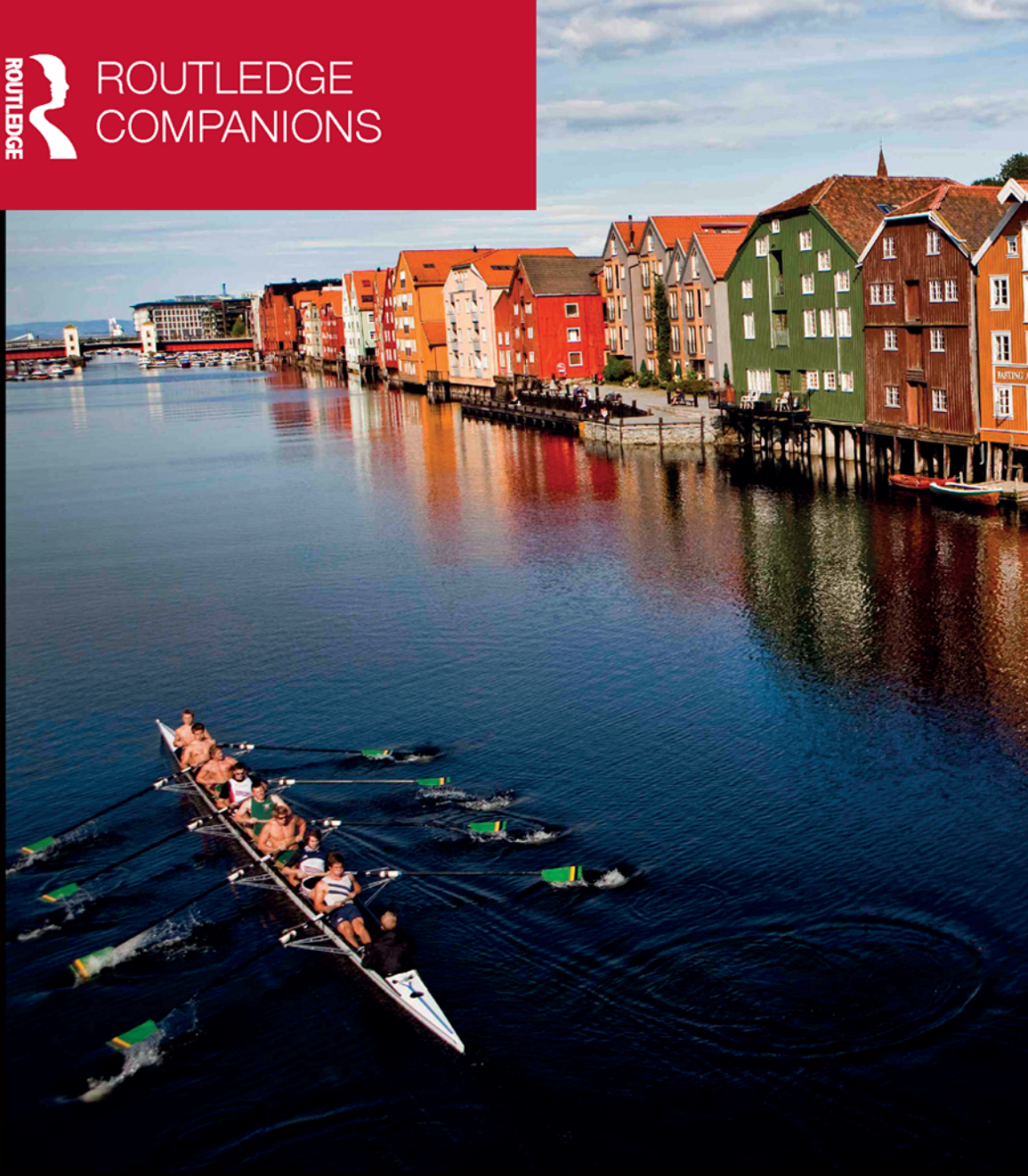
ROUTLEDGE COMPANIONS



The Routledge Companion to Lean Management

Edited by Torbjørn H. Netland and Daryl J. Powell

THE ROUTLEDGE COMPANION TO LEAN MANAGEMENT

Interest in the phenomenon known as "lean" has grown significantly in recent years. This is the first volume to provide an academically rigorous overview of the field of lean management, introducing the reader to the application of lean in diverse areas, from the production floor to sales and marketing, from the automobile industry to academic institutions.

This volume collects contributions from well-known lean experts and up-and-coming scholars from around the world. The chapters provide a detailed description of lean management across the manufacturing enterprise (supply chain, accounting, production, sales, IT etc.), and offer important perspectives for applying lean across different industries. The contributors address challenges and opportunities for future development in each of the lean application areas, concluding most chapters with a short case study to illustrate current best practice. The book is divided into three parts:

- The Lean Enterprise
- Lean across Industries
- A Lean World

This handbook is an excellent resource for business and management students as well as any academics, scholars, practitioners, and consultants interested in the "lean world."

Torbjørn H. Netland is Chair of Production and Operations Management at the Department of Management, Technology, and Economics at ETH Zürich, Switzerland.

Daryl J. Powell is Lean Program Manager at the Subsea division of Kongsberg Maritime AS, Norway, and a visiting professor at the Faculty of Economics and Business at the University of Groningen, Netherlands.

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CONTRIBUTORS

The Editors

Torbjørn H. Netland, Ph.D., is Chair of Production and Operations Management at the Department of Management, Technology and Economics at ETH Zürich, Switzerland. He was until recently an Associate Professor at the Norwegian University of Science and Technology (NTNU) and a Senior Researcher at SINTEF, both Trondheim, Norway. He has been a visiting researcher at the University of Cambridge, UK, and a Fulbright Research Fellow at Georgetown University, Washington, DC, USA. His research on corporate lean programs appears in several peer-reviewed journals. Netland serves on the Board of the European Operations Management Association (EurOMA) and the *Lean Management Journal*.

Daryl J. Powell, Ph.D., is Lean Program Manager at the Subsea Division of Kongsberg Maritime AS, which has its main office in Horten, Norway. He holds both an M.Sc. and a Ph.D. in lean, and has more than 10 years of experience working with lean implementations as both a practitioner and an academic. Currently he leads the global implementation of Kongsberg Maritime Subsea's corporate lean program. Powell is also a Visiting Professor at the Department of Operations at the University of Groningen in the Netherlands. His research appears in several peer-reviewed international journals. He is a member of the Editorial Advisory Board for the *International Journal of Lean Six Sigma*.

Introduction

Chapter 1 The Evolution of Lean Thinking and Practice

Daniel T. Jones is the Founder and Chairman of the Lean Enterprise Academy in the UK. He is also senior advisor to the Lean Enterprise Institute, a management thought leader, and a mentor on applying lean process thinking to every type of business. He is the co-author of *The Machine that Changed the World*, *Lean Thinking*, *Seeing the Whole Value Stream*, and *Lean Solutions*. He is the publisher of *Breaking through to Flow*, *Creating Lean Dealers*, and *Making Hospitals Work*. Jones also has organized Lean Summit conferences in Europe, including the Frontiers of Lean Summit, the First Global Lean Healthcare Summit, and the Lean Transformation Summit. Jones was the European Director of MIT's Future of the Automobile and International Motor Vehicle

Programs. He is advisor to the European Efficient Consumer Response movement and editor of the *International Commerce Review*. Jones holds a bachelor's degree in economics from the University of Sussex.

James P. Womack, Ph.D., is the founder and senior advisor to the Lean Enterprise Institute, Inc., Cambridge, MA, USA. He is a co-author of *The Machine that Changed the World*, *Lean Thinking*, *Lean Solutions*, and *Seeing the Whole Value Stream*. He has published several articles in the *Harvard Business Review*. Womack received a BA in political science from the University of Chicago in 1970, a master's degree in transportation systems from Harvard in 1975, and a Ph.D. in political science from MIT in 1982 (for a dissertation on comparative industrial policy in the US, Germany, and Japan). During the period 1975–1991, he was a full-time research scientist at MIT directing a series of comparative studies of world manufacturing practices. As research director of MIT's International Motor Vehicle Program, Womack led the research team that coined the term "lean production" to describe Toyota's business system.

Chapter 2 The Toyota Way: Striving for Excellence

Jeffrey K. Liker, Ph.D., is Professor of Industrial and Operations Engineering at the University of Michigan and President of Liker Lean Advisors, Ann Arbor, MI, USA. He is the author and co-author of numerous international bestsellers such as *The Toyota Way*, *The Toyota Way Fieldbook*, *The Toyota Product Development System*, *Toyota Culture*, and *The Toyota Way to Lean Leadership*, among others. He has a B.S. in industrial engineering from Northeastern University and a Ph.D. in sociology from the University of Massachusetts.

Part I: The Lean Enterprise

Chapter 3 Lean Production

Pauline Found, Ph.D., is Professor of Lean Operations Management at the University of Buckingham, Buckingham, UK. She is co-author of *Staying Lean: Thriving Not Just Surviving*, for which she holds a Shingo Research and Professional Publication Prize (2009). She was President of the POMS (Production and Operations Management Society) College of Behavior from 2009 to 2011.

John Bicheno is Professor of Lean Enterprise at the University of Buckingham, Buckingham, UK. Previously he was with the Lean Enterprise Research Centre, Cardiff, where for 12 years he was course director of the M.Sc. program in Lean Operations. He is has written 11 books on lean, one of which, *The Lean Toolbox*, has sold over 110,000 copies.

Chapter 4 Lean Leadership

Michael Ballé, Ph.D., is a business writer and executive coach with 20 years' experience in lean research and practice. He is also associate researcher at Telecom Paristech and co-founder of the Institut Lean France, Paris, France. He has co-authored three books (*The Gold Mine*, *The Lean Manager*, and *Lead with Respect*), and is the author of the Gemba Coach column at lean.org.

Chapter 5 Lean Innovation

Günther Schuh, Ph.D., holds the Chair of Production Engineering at the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, Aachen,

Germany. He studied mechanical engineering and economics at RWTH Aachen University from 1978 until 1985 and received his doctorate in 1988. He became Professor for Economic Production Management at University of St. Gallen in 1993.

Stefan Rudolf, Ph.D., is Head of the Department of Innovation Management at the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, where he started in 2009 as a researcher, and Managing Director of the Complexity Management Academy, Aachen, Germany. He studied mechanical engineering and economics at RWTH Aachen University and Tsinghua University, Beijing.

Christian Mattern is Research Assistant and Ph.D. candidate at the Department of Innovation Management at the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, Aachen, Germany. Mattern holds a M.Sc. in mechanical engineering and business administration from RWTH Aachen University.

Chapter 6 Lean Product and Process Development

Monica Rossi, Ph.D., is a Postdoctoral Researcher at Politecnico di Milano, Milan, Italy. Since 2010, she has been engaged in research on lean product and process development. She has held visiting researcher positions at both Massachusetts Institute of Technology (MIT), USA, and Tokyo Metropolitan University, Japan.

James Morgan, Ph.D., has served in numerous lean product and process development leadership roles throughout his career, most notably when he was part of the team that led Ford Motor Company's product-driven turnaround during the recent global financial crisis. Jim is currently leading the Lean Product & Process Development initiative at the Lean Enterprise Institute, Cambridge, MA, USA.

John Shook is a business executive, industrial anthropologist, and author who currently serves as Chairman and CEO of the Lean Enterprise Institute, Cambridge, MA, USA, and Chairman of the Lean Global Network. Shook is a graduate of the Japan-America Institute of Management Science. He is the former director of the University of Michigan, Japan Technological Management Program, and faculty of the university's Department of Industrial and Operations Engineering. Shook learned about lean management while working for Toyota for nearly 11 years in Japan and the US, helping it transfer production, engineering, and management systems from Japan to New United Motor Manufacturing Inc. (NUMMI) and subsequently to other operations around the world. As co-author of *Learning to See*, he helped introduce the world to value stream mapping.

Chapter 7 Lean Systems Engineering

Cecilia Haskins, Ph.D., is an Associate Professor in Systems Engineering at the Norwegian University of Science and Technology (NTNU, Trondheim, Norway). Cecilia entered academia after more than 30 years in industry. Her educational background includes a B.Sc. in chemistry from Chestnut Hill College, an MBA from Wharton, University of Pennsylvania, and a Ph.D. from NTNU. She is a member of The International Council on Systems Engineering (INCOSE).

Bohdan W. Oppenheim, Ph.D., is a Professor of Mechanical and Systems Engineering at Loyola Marymount University, Los Angeles, CA, USA. He is the founder and co-chair of the

Lean Systems Engineering Working Group of INCOSE and serves as the local coordinator of the Lean Aerospace Initiative Educational Network. His 30-year industrial experience spans space, offshore, software, and mechanical engineering, including several major aerospace programs. Oppenheim has worked for Northrop, the Aerospace Corporation, and Global Marine, and has served as a lean consultant for Boeing and 50 other firms. His credits include six books, 30 journal publications and book chapters, and externally funded grants. He has a doctorate in dynamics from the University of Southampton (UK). He is a member of INCOSE.

Chapter 8 Lean Logistics

Michel Baudin is a trained engineer who got his feet wet in production in 1980, and later apprenticed under Japanese consultant Kei Abe. He has consulted on lean in many industries worldwide since 1987. Baudin has taught with UC Berkeley extension, the University of Dayton, and HKPC. He is the author of four books: *Manufacturing Systems Analysis with Application to Production Scheduling* (1990), *Lean Assembly* (2002), *Lean Logistics* (2004), and *Working with Machines* (2007). He is the owner of the Takt Time Group based in Palo Alto, CA, USA

Chapter 9 Lean Safety

Robert B. Hafey has worked in manufacturing operations and maintenance for 40 years. He is the owner of RBH Consulting LLC based in Chicago, IL, USA. The first part of his career was with US Steel Corporation followed by 20-plus years at Flexco. He has been an AME (Association for Manufacturing Excellence) volunteer for the past 14 years and acquired much of his lean knowledge through this involvement. He holds a B.S. in professional arts from the University of St. Francis.

Chapter 10 Lean Teams

Desirée H. Van Dun, Ph.D., obtained her doctorate in operations management and organizational behavior at the University of Twente, Enschede, in the Netherlands. She has been a management consultant since 2008 at House of Performance in the Netherlands, primarily in the service industry. Her professional interests include lean management, leadership, industrial and organizational psychology, organizational behavior, and change management.

Celeste P. M. Wilderom, Ph.D., holds the Chair in Change Management and Organizational Behavior at the University of Twente, Enschede, in the Netherlands. In 1987, she obtained her Ph. D. in psychology from the State University of New York, Buffalo (USA). She has been associate editor of the *British Journal of Management*, *Academy of Management Executive/Perspectives*, and the *Journal of Service Management*. Her current research pivots on effective leader- and followership.

Chapter 11 Lean IT

Pär Åhlström, Ph.D., is the Torsten and Ragnar Söderberg Professor and Vice President of Degree Programs at the Stockholm School of Economics, Stockholm, Sweden. He has published frequently on lean in manufacturing, product development, and services. He is the co-author of the bestselling book *This is Lean: Resolving the Efficiency Paradox*.

Ryusuke Kosuge, Ph.D., is an Associate Professor at Ritsumeikan University in Japan. He received his doctorate from the University of Tokyo, and was a visiting researcher at the

Stockholm School of Economics. His research interests focus on lean capability development in service settings.

Magnus Mähring, Ph.D., is a Professor at Stockholm School of Economics, Stockholm, Sweden. His current research interests include public sector digitalization, governance of IT projects and programs, and organizational practices involving IT use. He has published in various peer-reviewed journals.

Chapter 12 Lean Sales and Marketing

Brent Wahba, MBA, has been leading and coaching lean sales and marketing, product development, and strategy for over 20 years. He serves on the Lean Enterprise Institute Faculty, is the President of the Strategy Science Inc. consulting network (Dallas, TX, USA), and regularly writes/speaks about many business improvement topics. His book, *The Fluff Cycle*, specifically addresses lean sales and marketing concepts and organizational change. Wahba holds an M.S. in materials science and engineering from the Rochester Institute of Technology, and an MBA from the University of Rochester.

Chapter 13 Lean Branding

Laura Busche is the author of *Lean Branding*, part of Eric Ries' Lean Series. She is a consultant, researcher and entrepreneur with a fundamental interest in consumer psychology. Busche's multifaceted approach to branding emerged from the combination of a summa cum laude degree in business administration (American University), a master's degree in design management (SCAD), and doctoral studies in consumer psychology as part of a fellowship awarded by the Colombian government.

Chapter 14 Lean Accounting

Brian H. Maskell is the President of BMA Inc., Cherry Hill, NJ, USA, and has more than 30 years' experience in the manufacturing and distribution industry. Over the past 20 years, Maskell's consulting practice has worked with manufacturing and distribution companies, large and small, throughout the world, assisting these companies in lean transformation, lean accounting, lean manufacturing and distribution, lean healthcare, and lean business management. He is the author of many books within the field of lean accounting.

Chapter 15 Lean Auditing

James C. Paterson works as a consultant specializing in risk assurance, lean auditing, and other aspects of internal audit effectiveness. Paterson has worked as the Chief Audit Executive for the Internal Audit function of AstraZeneca Plc. In 2005, he led work to apply lean techniques to the internal audit function. His book *Lean Auditing* was published in 2015.

Chapter 16 Lean Remanufacturing

Elzbieta Pawlik works in the research and development department within the Lean Enterprise Institute Poland. She is also currently engaged in Ph.D. research at the University of Strathclyde in the UK. Pawlik's research interests focus on the application of lean management principles to support sustainable development.

Winifred Ijomah, Ph.D., is Director of the Scottish Institute for Remanufacture and has elements of her work incorporated in British Standards (e.g. BS 8887-2:2009—Terms and definitions). She is initiator and Editor-in-Chief of Springer's *International Journal of Remanufacturing* and heads the University of Strathclyde remanufacturing research group.

Jonathan Corney, Ph.D., is a Professor of Design and Manufacture at the University of Strathclyde in the UK. His research interests range from mechanical remanufacturing and intelligent CAD/CAM to design innovation and advanced manufacturing. He is currently deputy director of the Scottish Institute of Remanufacturing.

Chapter 17 Lean and Green

Keivan Zokaei, Ph.D., is an Honorary Visiting Professor at University Polytechnic Madrid, Spain and Managing Director of Enterprize Excellence. He is a winner of the 2014 Shingo Research and Professional Publication Award. He has been a director at the Lean Enterprise Research Centre (LERC) in Cardiff. He has specialized in operations excellence, supply chain optimization, and "lean and green."

Ioannis Manikas, Ph.D., holds a bachelor's degree in agriculture and a master of science in the field of logistics from Cranfield University. He holds a Ph.D. from the Department of Agricultural Economics in Aristotle University of Thessaloniki and his primary interests include supply chain management, logistics, and agribusiness management. Manikas has conducted research for projects regarding supply chain modelling and development of IT solutions for agri-food supply chain management and traceability both in Greece and the UK. He also works as a self-employed project manager and consultant in the agri-food sector.

Hunter Lovins is the President and Founder of Natural Capitalism Solutions, Longmont, CO, USA, a non-profit formed in 2002. A renowned author and champion of sustainable development for over 35 years, Lovins has consulted on sustainable agriculture, energy, water, security, and climate policies for scores of governments, communities, and companies worldwide. Lovins has co-authored 15 books and hundreds of articles, and was featured in the award-winning film *Lovins on the Soft Path*. Her book, *Natural Capitalism*, has been translated into more than three dozen languages and summarized in *Harvard Business Review*.

Chapter 18 Lean Purchasing

Tim Torvatn, Ph.D., is an Associate Professor at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. He took his Ph.D. in purchasing management at the same university. He also holds an MBA from Queen's University, Kingston, Canada. His research interests are in purchasing and logistics management, organizational and inter-organizational theory, and industrial networks.

Ann-Charlott Pedersen, Ph.D., is a Professor at the Norwegian University of Science and Technology (NTNU), Trondheim, Norway. Pedersen's research in the areas of purchasing and supply management, supplier relationships and development, supply networks and strategizing in networks has been published in several peer-reviewed journals.

Elsebeth Holmen, Ph.D., is a Professor at the Norwegian University of Science and Technology (NTNU) , Trondheim, Norway. Holmen has published papers on supplier relationships and supply

networks, supplier development, supplier involvement in product development, capability development in networks, and, more generally, managing and strategizing in business relationships and networks.

Chapter 19 Lean Supply Chains

Jonathan Gosling, Ph.D., is a Senior Lecturer in Supply Chain Management at Cardiff University, Cardiff, Wales, and undertakes research in engineer-to-order environments. He is Deputy Head of the Logistics and Operations Management Section for Research, Innovation and Engagement. Prior to becoming an academic, he worked in the automotive industry as a supply chain analyst.

Maneesh Kumar, Ph.D., is a Senior Lecturer at Cardiff Business School, Cardiff University, Cardiff, Wales. He conducts cross-disciplinary research in the area of operational excellence including topics such as Lean Six Sigma, process/service innovation and knowledge management within SMEs, the automotive industry, service industries, and public sector organizations.

Mohamed Naim, Ph.D., is a Professor in Logistics and Operations Management. He is Deputy Dean of Cardiff Business School, Cardiff University, Cardiff, Wales. He undertakes theoretical and empirical research on supply chain resilience, applying whole systems approaches to creating sustainable value.

Chapter 20 Lean Distribution

Matthias Holweg, Ph.D., is Professor of Operations Management at Saïd Business School at the University of Oxford, Oxford, UK. Prior to joining Oxford, he was on the faculty of the University of Cambridge and a Sloan Industry Center Fellow at MIT's Engineering System Division. Holweg is widely recognized as a thought leader in the field of lean management.

Andreas Reichhart, Ph.D., holds a doctorate in management studies from the University of Cambridge, where he researched how automotive supply chains built up flexibility. After his Ph.D. studies he joined a global management consulting firm for five years, and he has been working for a leading online retailer in the areas of supply chain management, pricing, and product management since 2012.

Chapter 21 Lean After-Sales Services

Barbara Resta, Ph.D., has been Research Assistant at the University of Bergamo, Bergamo, Italy since 2012. Her main research activities are focused on the corporate social responsibility topic, with a particular attention to the textile industry, and on the investigation of the role of the human factor in lean management applications.

Paolo Gaiardelli, Ph.D., is an Associate Professor at the University of Bergamo, Bergamo, Italy. His research activities mainly focus on organization and management of after-sales service, with a specific interest in service chain configuration, organization, and performance measurement. Recently Gaiardelli has extended his research to lean management applications in product-service systems.

Stefano Dotti, Ph.D., is an Assistant Professor at the University of Bergamo, Bergamo, Italy. His academic research interest is mainly focused on the development of eco-friendly equipment and processes, with a specific interest in the textile industry. Lately Dotti has extended

his research activities to lean management applications in production and product-service systems.

Dario Luise is a Dealer Development Manager at the Italian subsidiary of DAF Trucks N.V. Dario is responsible for ensuring the territory coverage and qualitative growth of sales and after-sales networks. This work is enabled by a significant competence in dealership organization and management, which he has acquired in over 30 years' experience in the automotive industry.

Chapter 22 Lean Global Corporations

Torbjørn H. Netland. See "Editors."

Part II: Lean across Industries

Chapter 23 Lean Healthcare

Daniel T. Jones. See Chapter 1 "The Evolution of Lean Thinking and Practice."

Chapter 24 Lean Construction

Glenn Ballard, Ph.D., is the Research Director of the Project Production Systems Laboratory at the University of California, Berkeley, USA. He is the co-founder and has been the Research Director of the Lean Construction Institute (LCI), a non-profit organization dedicated to applying lean theory, principles, and techniques to create a new form of project management to design and build capital facilities. Ballard is the leading expert on lean construction.

Chapter 25 Lean Engineer-to-Order Manufacturing

Daryl J. Powell. See "Editors."

Aldert van der Stoel, M.Sc., is a researcher at HAN University of Applied Sciences, Arnhem, the Netherlands, with expertise in lean and quick response manufacturing (QRM). Van der Stoel has been working closely with more than 50 small and medium-sized enterprises to evaluate the implementation and use of lean and QRM practices.

Chapter 26 Lean Mining

Behzad Ghodrati, Ph.D., is an Associate Professor of Maintenance and Reliability Engineering at Lulea University of Technology, Luleå, Sweden. He obtained his Ph.D. on spare parts planning from the same university. He was awarded a Postdoctoral Research Fellowship from the University of Toronto in 2008. Ghodrati has published widely within his field.

Seyed Hadi Hoseinie, Ph.D., is an Assistant Professor in the Department of Mining Engineering at Hamedan University of Technology, Hamedan, Iran. His research interests are: mining machinery, reliability centered maintenance, mechanical excavation, and mine automation. Hoseinie has published widely and he holds one patent.

Uday Kumar, Ph.D., is Professor and Head of Operation and Maintenance Engineering at Lulea University of Technology, Luleå, Sweden. He has published widely in peer-reviewed international journals, mainly in the field of reliability and maintenance. His research interests

are product support, equipment maintenance, reliability and maintainability analysis, life cycle costing, and risk analysis.

Chapter 27 Lean Maintenance, Repair, and Overhaul

Mandyam M. Srinivasan, Ph.D., is the Pilot Corporation Chair of Excellence in Business at the University of Tennessee, Knoxville, TN, USA. He has many years of experience in the automobile industry. He has written five books on lean and global supply chains. Srini received his Ph. D. from Northwestern University.

Chapter 28 Lean Public Services

Zoe Radnor, Ph.D., is Dean of the School of Management at the University of Leicester, Leicester, UK, and a Professor of Service Operations Management. Her interest lies in performance, process improvement, and service management in public services. Radnor held a research fellowship that considered the sustainability of lean in public services. She has published over 100 articles, book chapters, and reports.

Chapter 29 Lean Armed Forces

Nicola Bateman, Ph.D., is a Senior Lecturer in Operations Management at Loughborough, Loughborough, UK. She has published in both lean operations and public service, presented to organizations such as the Confederation of British Industry, and participated in a Department of Trade and Industry (UK government) economic evaluation unit. Her current research includes the fire service and the use of visual tools to support lean environments.

Peter Hines, Ph.D., is the co-founder of the Lean Enterprise Research Centre at Cardiff University, Cardiff, Wales. He has undertaken extensive research into lean thinking and written or co-written several books including *Staying Lean* and *Creating a Lean & Green Business System*, both of which won a Shingo Research Award. Peter is Chairman of S A Partners, a specialist consultancy organization, as well as a visiting professor at Waterford Institute of Technology, Ireland.

Chapter 30 Lean Policing

Harry Barton, Ph.D., is Professor of Human Resource Management and Head of Research at Nottingham Business School (NBS), Nottingham Trent University, UK. His wider research interests are in the areas of international HRM, lean in public services, and police performance management. His research has resulted in both national and international publications.

Rupert L. Matthews, Ph.D., is a Lecturer in Operations Management at Nottingham Trent University. He researches in the areas of process improvement, organizational learning, small and medium-sized enterprises, supply chain disruption risk, and public sector operations, and teaches in the areas of operations, supply chain, and innovation management.

Peter E. Marzec, Ph.D., is a manager in KPMG's Lean Practice, and a visiting fellow at the Nottingham Business School. He attained his Ph.D. from the University of Nottingham and researches in the area of process improvement, knowledge management, entrepreneurship, and innovation.

Chapter 31 Lean Justice

Ana Lúcia Martins, Ph.D., is an Assistant Professor and Head of the Operations and Logistics area at University Institute of Lisbon, Portugal. She has published in several peer-reviewed journals, co-authored a logistics handbook, and participated in consultancy and research projects concerning lean in justice and healthcare.

Isabell Storsjö is a doctoral student in supply chain management and social responsibility at Hanken School of Economics, Helsinki, Finland. She is writing her doctoral thesis on collaboration in public service supply chains, particularly focusing on the justice system and judicial proceedings.

Simone Zanoni, Ph.D., is Associate Professor in Industrial Systems Università di Brescia, Brescia, Italy. He has published more than 50 papers in various journals, and serves as subject editor for several journals. Zanoni has experience of applying lean principles across a variety of sectors from several consultancy projects.

Chapter 32 Lean Public Water Supply

Kirstin Scholten, Ph.D., is Assistant Professor in Operations Management in the University of Groningen, the Netherlands. She has a background in supply chain management, specializing in supply chain resilience and disaster management. She is a member of EurOMA and a winner of the first Nigel Slack Teaching Innovation Award.

Benjamin Ward is a graduate of the Master of Supply Chain Management program at the University of Groningen, Groningen, the Netherlands. He conducted his thesis research with the Waterbedrijf Groningen, the focal company of this chapter. Ward is now pursuing a supply chain career at one of the world's leading sports fashion and apparel companies.

Dirk Pieter van Donk, Ph.D., is Professor in Operations Management in the Department of Operations, University of Groningen, the Netherlands. His major field of research is supply chain management and integration in different contexts, incorporating aspects such as ICT and supply chain resilience. He has co-organized several EurOMA workshops and two annual EurOMA conferences.

Chapter 33 Lean Dealerships

David Brunt, MBA, works at the Lean Enterprise Academy, Herefordshire, UK, helping firms making lean transformations. He was the Porsche Improvement Process Manager at Porsche Cars Great Britain and carried out work to develop lean in after-sales, used car processing, and parts operations. Brunt has an MBA from Cardiff Business School, where he specialized in lean and supply chain management. He is co-author of the book *Manufacturing Operations and Supply Chain Management: The Lean Approach*.

Chapter 34 Lean Software Development

Mary Poppendieck has been in the information technology industry for over 40 years. She has managed software development, supply chain management, manufacturing operations, and new product development. A popular writer and speaker, Poppendieck is the co-author of four books:

Lean Software Development (2003), *Implementing Lean Software Development* (2006), *Leading Lean Software Development* (2009), and *Lean Mindset* (2013).

Chapter 35 Lean Printing

Ken Macro, Ph.D., is a Professor and Chair of the Graphic Communication department at the California Polytechnic State University in San Luis Obispo, California, USA, where he teaches lean printing and continuous improvement concepts. He is also the co-developer of the Customized Lean Implementation Plan (CLIP) model.

Chapter 36 Lean Retail

Paul Myerson, MBA, is Professor of Practice in Supply Chain Management at Lehigh University, Bethlehem, PA, USA and holds a B.S. in business logistics and an MBA in physical distribution. Prior to joining the faculty at Lehigh, Myerson had been a successful change catalyst for a variety of clients and organizations. He is the author of the books *Lean Supply Chain & Logistics*, *Lean Wholesale and Retail*, and *Supply Chain and Logistics Management Made Easy*, as well as a lean supply chain and logistics management simulation training game and training package.

Chapter 37 Lean Education

Vincent Wiegel, Ph.D., is one of the leading experts in the field of lean in the Netherlands and founder of and professor at the Research Group for Lean & World Class Performance, HAN University of Applied Sciences, Arnhem, the Netherlands. Wiegel is involved in lean education and initiates research into the effectiveness of lean implementations. Besides his wide range of general knowledge and experience, his specific expertise is in lean product development and lean in non-manufacturing environments such as healthcare and education.

Lejla Brouwer-Hadzialic, MBA, combines her economic background and years of management experience with her knowledge and understanding of applying Lean Six Sigma. She works at HAN University of Applied Sciences, Arnhem, the Netherlands. As certified Lean Six Sigma Black Belt, Brouwer-Hadzialic also trains and guides colleagues in continuous improvement projects. Her expertise in the service sector in particular relates to application, research, and development of lean (Six Sigma) in education. Furthermore, she is a co-creator of and a lecturer in the undergraduate course World Class Performance/Lean Management.

Chapter 38 Lean Schools

Jan Riezebos, Ph.D., is Associate Professor of Operations and Academic Director of Career Services and Corporate Relations, University of Groningen, Groningen, the Netherlands. He is an active researcher in the fields of lean production, planning and shop floor control, quick response manufacturing, and lean education. His research has resulted in several practical tools and methods that help organizations to apply lean.

Chapter 39 Lean Universities

Steve Yorkstone is an acknowledged authority on applying lean in universities, leading successful initiatives in a number of institutions. He currently works applying lean in Edinburgh Napier University, Scotland, UK. He is an editorial board member of the *Lean Management Journal*, and chairs an international community of practice for lean in higher education.

Part III: A Lean World

Chapter 40 A Lean World

Torbjørn H. Netland. See "Editors."

Daryl J. Powell. See "Editors."

PREFACE

Since the dawn of lean production in the 1990s, lean has continued to develop as the foremost philosophical management approach of the 21st century. The term itself was first introduced in the 1988 *MIT Sloan Management Review* article "The triumph of the lean production system" by John Krafcik, and two years later was popularized in the famous book *The Machine that Changed the World* by James Womack, Daniel Jones, and Daniel Roos. In fact, when the MIT's International Motor Vehicle Program suggested the term "lean" in the late 1980s, it was a result of five years of intensive international research collaboration within the global automotive industry. Since then, researchers and practitioners have continued to show how lean can improve the performance of companies across a wide array of industries outside of the automotive arena.

Even though lean and its early proof-of-concept clearly stems from "the industry of industries"—the auto industry—lean has now spread to all kinds of industries and application areas. Womack and Jones were the first to convey that such simple management ideas can significantly improve any company or economic activity, in their book *Lean Thinking* (1996). Having evolved from *lean production* through *lean thinking* to what we today call "lean management" or simply "lean," we have truly seen an evolution in the way that businesses are organized and run. Today, we have lean innovation, lean construction, lean logistics, lean healthcare, lean education, and the list continues to grow.

Interestingly, the augmentation of the lean concept has also provided the world with a great deal of confusion. Much of this confusion arises from the various abstraction levels that can be adopted in defining the lean approach. Many fall into the trap of defining lean in terms of a set of tools and techniques developed by Toyota Motor Manufacturing. Though the ad hoc adoption of these tools and techniques can generate limited gains and benefits for those who apply them, much greater rewards can be expected by adopting a principle-based lean approach that structures the application of tools in order to support the deployment of lean principles.

Lean is far from just another management fad. Its significance has been proven by both an abundance of successful practical applications and scientific research over a sustained period of time. Considering the spread of lean, it is timely to ask if the deployment of lean concepts implies the same across different application areas. This companion aims to do exactly that. By closely examining how lean has been developed and applied across numerous application areas, the

chapters in this book provide the reader with a clearer understanding of what lean can be for his or her application area. Most chapters also include a short and helpful case study. The companion draws together contributions from a cross-section of established researchers regarded as experts in their respective fields.

The companion starts with two introductory chapters. In Chapter 1, Dan Jones and Jim Womack present their view of the evolution of lean thinking and practices. In Chapter 2, Jeff Liker expands on Toyota's role in the development of lean. The rest of the companion consists of three parts:

- Part I: The Lean Enterprise
- Part II: Lean across Industries
- Part III: A Lean World.

Part I of the book, "The Lean Enterprise," presents how lean has spread from *lean production* to the entire enterprise, including lean thinking in both primary and supportive business processes. Leading researchers provide short and informative chapters in their specific areas of expertise—ranging all the way from *lean production* to *lean corporations*.

Part II of the book, "Lean Across Industries," gives insights as to how lean has been developed and applied in diverse types of industries and sectors. Again, leading researchers provide short and informative chapters in their specific areas of expertise—ranging from *lean healthcare* to *lean universities*.

Part III summarizes the contributions from the individual chapters. We call this concluding chapter "A Lean World."

We hope this companion will be a helpful resource for practitioners, researchers, and consultants in the field of lean management.

Prof. Dr. Torbjørn H. Netland
Chair of Production and Operations Management, ETH Zürich, Zürich, Switzerland

Dr. Daryl J. Powell
Lean Program Manager, Kongsberg Maritime Subsea, Horten, Norway
Visiting Professor, University of Groningen, Groningen, the Netherlands

INTRODUCTION

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THE EVOLUTION OF LEAN THINKING AND PRACTICE

Daniel T. Jones and James P. Womack

Introduction

Lean thinking and practice has arguably become the most successful approach to business improvement of our generation. It has outlasted many other improvement approaches and been taken up by organizations in all kinds of industries across the world. Almost every large organization now has some form of lean program or internal lean improvement group and lean has spawned an army of lean consultants. Interest in lean has also resulted in a huge and growing literature on all aspects of lean, and lean is beginning to be taught on university courses in engineering and management. But as lean spreads it has been reinterpreted many times, and has been bolted onto other improvement approaches like "Lean Six Sigma" and "LeanAgile." This has led to considerable confusion. For a precise definition of lean terms see Lean Enterprise Institute (2003).

What distinguishes lean thinking and practice is that it did not derive from theory, but through observing business practices at Toyota that deliver superior performance in terms of time to market for new products and better product quality using less capital and human effort and hence lower costs in production. This enabled Toyota to grow into the largest and most innovative car maker in the world. Although lean involves several different practices that lead to different ways of thinking about working together, it is the way these practices are combined and used that distinguishes lean as a different business system.

The full significance of lean as a business system is learned step by step through experience in using these practices, rather than through classroom learning. Lean is in fact both a personal journey and a path of organizational development. Although Toyota has had its setbacks, it has proven to be highly resilient by going back and deepening knowledge of the basic lean practices in the face of each of these challenges. Toyota also continues to act as a powerful reference model for lean practitioners in taking the next steps on their lean journeys and as a way to clarify the confusion that surrounds lean today.

The Birth of Lean at Toyota

Toyota was a successful textile loom maker in the 1930s and developed a device for stopping the loom immediately on detecting a broken thread, enabling one person to supervise several looms

instead of just one. In 1935, Toyota decided to begin making automobiles. Toyota was determined to develop its own cars rather than license foreign designs and to fund this development itself rather than rely on banks. After a big strike in 1950 it also agreed with the unions not to make employees redundant in the future. Its response to this challenge was to create product development and production systems that could learn to improve product design and process efficiency faster using less resources in order to be able to compete with global car makers when the Japanese car market was opened and as they entered foreign markets. This story is told in Womack et al. (1990) and Shimokawa and Fujimoto (2009).

The Toyota Development System (TDS) was developed by Kenya Nakamura and Tatsuo Hasegawa. Powerful chief engineers, who are responsible for the success of their products and who negotiate for the necessary resources with department heads, lead the system. The chief engineers lead cross-functional teams, including production and suppliers, who initially spend more time exploring alternative design solutions using set-based concurrent engineering. This helps to avoid the rework and delays in realizing the chosen design solution. The progress of the work is reviewed on a daily and weekly basis in a visual management room, called *obeya,* where the team can respond quickly to delays and problems. Reusable knowledge is captured in many ways, including design check sheets, A3 reports, trade-off curves, and standard work sheets, so engineers can focus on developing new knowledge and deepening their own skills through solving new problems. These measures all contribute to being able to launch a new model every four years or less, rather than the eight to ten years that was common in the industry in 1990. More recently this system has also enabled Toyota to pioneer new technical innovations like hybrid engines and hydrogen powered cars. TDS is described in Morgan and Liker (2006) and the underlying concepts in Ward and Sobek (2014).

The challenge facing Taiichi Ohno, the architect of what became the Toyota Production System, was how to build several different products on the limited equipment that Toyota could afford at that time. Instead of resorting to producing in batches he carried out many pioneering experiments to build an integrated production system that was able to make a variety of products in single-piece flow in line with demand. This challenged the assumptions that there is a trade-off between quality and productivity and that bigger batches result in lower costs. His experiments led to the development of an interconnected set of practices called the Toyota Production System (TPS), described in Ohno (1978) and Shingo (1989).

After spreading the TPS thinking across Toyota's manufacturing operations, Ohno's group collected these practices and wrote them down for the first time in the early 1970s in order to teach them to their Japanese suppliers, and in the 1980s translated them into English as they opened their first joint-venture plant in the USA. The original TPS training material is contained in Narusawa and Shook (2009).

However, the distinguishing feature of Ohno's approach was to engage the whole workforce in seeking improvements, rather than relying solely on expert engineers. He challenged and taught front-line and support staff how to define and improve their own work, using the Training Within Industry system pioneered during World War II in the USA (see Dinero, 2005). This enabled the front line to establish a standard way of doing each task as a local base line for improvement, which in turn enabled them to see and respond quickly to any deviations from this standard. In analyzing the root causes of the many issues that interrupted their work he also taught them how to use the scientific approach to solving problems, using Deming's plan, do, check, act (PDCA) method (see Deming, 1982).

Indeed, it is the repeated daily practice of PDCA, using the perspectives of TPS, that develops the capabilities of individuals and teams to continually improve their work and improve the performance of the system as a whole. Toyota is often quoted as saying it "makes people in order

to make cars." These enhanced problem-solving capabilities enabled Ohno to link activities together, remove all kinds of buffers and delays, and with much shorter lead times to use simpler planning systems driven by demand rather than by forecasts. This accelerating continuous improvement system is called *kaizen* (see Imai, 1991). The net result of deploying TPS was to achieve double the productivity and one-third of the defects of American assembly plants by the mid-1980s (see Womack et al., 1990).

Similar logic was used to develop very different approaches in other areas of the business, including production engineering of right-sized tooling, supplier coordination, and sales and marketing. Eiji Toyoda, the long-time president and then chairman of Toyota, also used these principles to build a management system to support kaizen and to focus and align activities towards key corporate objectives, which was finally written down in the Toyota Way (Toyota Motor Corp, 2001). Again, the key to doing so is building common capabilities at every level of management to plan and solve business problems using another version of PDCA, called A3 thinking, and a planning framework, called *hoshin kanri* (see Dennis, 2009 and Shook, 2010). It also involves a very different way of supporting, mentoring, and challenging front-line teams. The evolution and details of Toyota's management system are described in Hino (2002), Liker (2004), and Liker and Convis (2011).

The Evolving Understanding of Lean

Our understanding of lean has deepened over time. The MIT International Motor Vehicle Program (IMVP) benchmarked Toyota's superior performance and coined the term lean to describe this system in Womack et al. (1990). The results reported in this book caused quite a stir across the global auto industry and beyond. But it quickly became apparent that simply collecting and training with all the lean tools was not enough for others to follow Toyota's example. So we set out to observe Toyota's practices in more detail, along with some of the pioneering organizations who had learned directly from Toyota. From this, we were able to distil a set of five principles—value, value stream, flow, pull, and perfection—behind a lean system and a common action path to realize them in Womack and Jones (1996).

This triggered a wave of interest from practitioners across the world and led us to establish the Lean Enterprise Institute in the USA (www.lean.org), the Lean Enterprise Academy in the UK (www.leanuk.org), and 15 other non-profit institutes across the globe, now members of the Lean Global Network (www.leanglobal.org). Their mission is to research, teach, and publish do-it-yourself guides to the building blocks of lean, including Rother and Shook (1999), Rother and Harris (2001), Brunt and Kiff (2007), Baker and Taylor (2009), Dennis (2009), Glenday (2009), Smalley (2009), Shook (2010), Harris et al. (2011), and Jones and Womack (2011).

In observing the pioneer firms outside of Toyota building their own functional equivalent of Toyota's management system we discovered three challenges all firms face. The first is to build a daily management system to enable front-line team leaders and managers to make the work visible, to be able to respond to problems immediately, and review obstacles on a regular cadence. The basis for this is helping the team to define their standard work, improve on it, and gradually link these steps with upstream and downstream into a continuous flow. The next step is to link separate activities with customer demand using Kanban pull systems and to level the workload to establish stability and responsiveness. This all depends on team leaders and line managers developing the problem-solving skills of their subordinates, described in Sobek and Smalley (2008), Shook (2010), and Rother (2010).

The second challenge is that no one can see or is responsible for the horizontal sequence of activities that creates the value customers pay for, from concept to launch, from raw material to

finished product, and from purchase to disposal. Vertically organized departments instead focus solely on optimizing their activities and assets to make their numbers.

To help teams see the end-to-end processes or value streams they are involved in, Toyota uses another tool which we call value stream mapping (see Rother and Shook, 1999; Jones and Womack, 2011). As teams map their value streams they realize the problem is not the people but a broken process and, having stabilized their own work, they then see new opportunities for collaboration to improve the flow of work and align it with the pull from real customer demand.

In industry after industry, we have seen value streams that used to take many months from beginning to end now take a matter of days, with far fewer defects and more reliable delivery. This is only possible because front-line staff know how to react quickly and tackle the root causes of problems that will arise in any tightly synchronized and interdependent system. It is also much easier to adapt to changing circumstances. Over time, these emergent capabilities achieve performance superior to systems designed and supported solely by experts. This is a key difference between value stream analysis and business process reengineering.

The third challenge is that the traditional approach to managing by the numbers and through functional politics at headquarters wastes a lot of management time, fails to align activities with corporate objectives, hides problems, and takes management away from front-line value-creating activities. Relying on expensive enterprise systems to force compliance with the command and control instructions from the top has in many cases made things worse and much harder to adapt to changing circumstances.

Toyota's planning process, *hoshin kanri*, is used to define the overall direction of the organization and to conduct a dialogue up and down the organization on proposed actions to achieve it, again based on PDCA (see Dennis, 2009; Shook, 2010). As a result resources and energies are prioritized and aligned through a visual process that reaches right down to the front line. This also lays the basis for collaboration across functional silos. Management in turn spends a lot more time at the front line, understanding its issues, eliminating obstacles and coaching problem solving. In this way management learns by helping colleagues to learn and does this by asking questions rather than telling them what to do. This builds very different behaviors and an environment where employees are challenged to fulfill their potential.

There have been several different descriptions of the lean business system, including three novels by Ballé and Ballé (2005, 2009, 2014), a collection of articles by Womack (2013), a CEO's perspective (Byrne, 2013) and a review of the spread of lean by Stoller (2015).

The Spread of Lean and Lean Consumption

Lean thinking and practice has spread across almost every sector of activity, from retailing and distribution to discrete and process manufacturing, service and repair, financial services and administration, construction, software development and IT, healthcare, and service delivery in government. It has even created a framework for improving the viability of digital start-ups. While the focus on value creation, value streams, and learning has been common, the sequence of improvement steps has varied for different types of activity. Fortunately, we have found that lean practices work equally well in different cultures.

The full potential of lean is realized when it is embraced by the whole supply chain. Toyota's aftermarket parts distribution system is still the global benchmark supply chain, delivering near perfect availability of the basket of parts at the point of use with only a tenth of the lead time and inventory in the pipeline from the point of production. Not surprisingly this inspired retailers like Tesco and Amazon to develop their own rapid response distribution systems that are essential for convenience retailing and home shopping. Manufacturers like GKN have also moved away from

concentrating activities in focused factories in distant low-cost locations to creating rapid response supply chains to serve customers in each region. GE Appliances (now owned by Haier) is also using lean to design a new product range and production system for household appliances in North America, bringing this activity back from China.

While most of the attention has been focused on the upstream supply chain, lean actually begins with the customer's use of the product or service. We developed a framework for using lean to define value from the user's perspective (see Womack and Jones, 2005). Consumption is in fact a series of processes that interact with the provider's processes. Mapping both processes shows where they are broken and cause mutual frustration and unnecessary cost. This reveals opportunities for improving user experience at lower cost and even generating new business models. In the digital age it is now possible to track the customer's use of the product or service and enter into a two-way dialogue with them. In a very real sense customers and users are becoming an important part of the supply chain delivering today's products and services and co-developing tomorrow's solutions.

Conclusions

From this chapter it should be clear that lean is not just another improvement methodology, but a very different set of behaviors and a management system. It is not just a set of tools for production operations in the auto industry, but a much broader framework for creating more productive value creation systems in all kinds of sectors and activities. Readers should beware of the confusion that is caused by partial descriptions of lean, which often miss the key elements that make it work as a system.

Lean shares the same scientific approach to the analysis of work with many improvement methodologies, like BPR, Six Sigma, and TQM. But it differs from them in how it is used. Rather than relying on experts to design better systems, lean builds superior performance by developing the problem-solving capabilities of the front line, supported by a hands-on management system.

Lean is therefore a path or journey of individual and organizational learning and leads to more challenging and fulfilling work for those involved. It is learned by doing it and through repeated practice rather than by studying it in books or in the classroom. While it is driven by practice and not theory, lean raises many interesting new hypotheses about learning and collaborative working for different academic disciplines to think about and research.

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2
THE TOYOTA WAY
Striving for Excellence

Jeffrey K. Liker

The Problem? The Misunderstanding of Lean and "How it Applies Here"

Lean (along with its variations, such as Six Sigma, theory of constraints, Lean Six Sigma, and specialties in different industries like agile IT development, lean construction, lean healthcare, lean finance, and lean government) has become a global movement. As with any management movement, there are true believers, resisters, and those who get on the bandwagon but do not care a lot one way or the other. There are a plethora of service providers through universities, consulting firms of various sizes, and not-for profit organizations, and there is a book industry.

For zealots like me, this is, in a sense, a good thing—there are consumers of my message. But there is also a downside. As the message spreads and goes through many people, companies, and cultures, it changes from the original, like the game of telephone in which the message whispered to the first person bears little resemblance to the message the tenth person hears.

In the meantime, well-meaning organizations that want to solve their problems are searching for answers. What is lean? How do we get started? How do these tools developed within Toyota for making cars apply to my organization? How do these methods apply in our culture, which is very different from Japanese culture? Do the tools have to be used exactly as they are in Toyota, or can they be adapted to our circumstances? And how does Toyota reward people for using these tools to improve?

These are all reasonable questions and, unfortunately, there are many consultants and self-appointed "lean experts" ready to answer them, often in very different ways. But the starting point should be the questions themselves. Are these the right questions? As reasonable as they may seem, I believe they are the wrong questions. The underlying assumption in each case is that lean is a mechanistic, tool-based process to be implemented as you would install a new piece of computer software. Specifically, the assumptions can be summarized as follows:

1 There is one clear and simple approach to lean that is very different from alternative methodologies.
2 There is one clear and best way to get started.
3 Toyota is a simple organization that does one thing—makes cars—and it uses a core set of the same tools in the same way, every place.

4 The tools are the essence and therefore must be adapted to specific types of processes.
5 Because lean was developed in Japan, there may be something peculiar about it that needs to be modified to fit cultures outside Japan.
6 Toyota itself has a precise method of applying the tools in the same way in every place that others need to copy.
7 The formal reward system is the reason people in Toyota engage in continuous improvement and allocate effort to support the company.

In fact, none of these assumptions are true, and that is the problem. The gap between common views of lean, and the reality of how this powerful thing Toyota has been pursuing for almost one century *actually* works, is preventing organizations from accomplishing their goals. The Toyota Way, by contrast, is a generic philosophy that can apply to any organization, and if applied diligently, will virtually guarantee improvement (Liker, 2004). It is a way of looking at organizations, a philosophy, and a system of interconnected processes and people who are striving to continuously improve how they work and deliver value to customers.

Having dismissed the common and simplistic notion that it is a program of tools for taking waste out of processes, in this chapter I wish to convey the deeper meaning of the Toyota Way. I will briefly describe the origin of the Toyota Way within Toyota, the principles I have distilled, and what it looks like to pursue it in practice.

The Toyoda Family: Generations of Consistent Leadership

To understand a company's culture, we should always begin with its roots—the core values of its founders—and Toyota is no exception. Many companies have drifted so far from their roots that the initial values are barely visible, but Toyota has maintained a remarkable degree of continuity of culture over most of a century, starting with its founder, Sakichi Toyoda.

Sakichi Toyoda: Creating Looms and Values

Sakichi Toyoda was born in 1867, the son of a poor carpenter in a rice village. He learned carpentry from the ground up, and he also learned the necessity of discipline and hard work. A natural inventor, he saw a problem in the community. Women were "working their fingers to the bone" using manual looms to make cloth for the family and for sale, after a full day of work. To ease the burden, he began to invent a new kind of loom. His first modification used gravity to allow weavers to send the shuttle of cotton thread back and forth through the weft by manipulating the foot pedals instead of by using their hands. Immediately, women worked half as hard and were more productive. Sakichi Toyoda continued to make improvement after improvement, some small, some big, and in 1926 formed Toyota Loom Works.

He was a devout Buddhist and always lived strong values. One of his favorite books was called *Self-Help*, by British philanthropist Samuel Smiles ([1859] 1982). Smiles dedicated much of his life to mentoring juvenile delinquents so they could become successful contributors to society. He wrote about the inspiration of great inventors who, contrary to popular opinion, were not always privileged and gifted students, but achieved great things through self-reliance, hard work, and a passion for learning. This fit well the story of Sakichi Toyoda, who raised himself from a poor background as a carpenter's son, and did not appear particularly outstanding, but who through the passion of contributing to others, the hard work of learning the fundamental skills of carpentry, and a clear picture of the problems he wanted to solve, relentlessly made improvement after improvement, each to solve the next problem.

As Sakichi Toyoda grew, his ambitions and contributions also grew. He began to envision a fully automatic loom and each individual innovation moved him nearer to that idea, continually improving toward his vision. He started by helping the women in his family, then the community, then helping to industrialize Japanese society, and ultimately contributing to all society. He is considered by many to be the father of the Japanese industrial revolution and is given the title "King of Inventors" in Japan. Along the way, he cultivated himself and his own values. These values eventually became the guiding principles of Toyota Motor Company, and included: contribute to society, put the customer first and the company second, show respect for all people, know your business from the ground up, get your hands dirty, work hard with discipline, work as a team, build in quality, and continually improve toward a vision.

Built-in quality was most evident in one of his most influential inventions—the loom that could stop itself when there was a problem. Every innovation by Sakichi Toyoda was problem-driven based on what he learned from earlier innovations. After the loom was reasonably automatic and could run at a relatively high speed, he noticed that when a single thread broke on the weft to make cloth, the cloth would be defective. A human had to stand and watch the loom and stop it when that happened, which he considered a tremendous waste of human capability. Yet another invention used gravity. This time, he added a piece of metal onto each thread in the weft. When a thread broke, the metal would interfere with the threads and stop the loom. He called this *jidoka*, a word which was formed by adding to the Chinese kanji for automation a symbol for a human. Thus, he had put human intelligence into automation so the loom could stop itself when there was a problem. He later added to this a small metal flag that would pop up, signaling "I need help." Jidoka would become a pillar of the Toyota Production System, conveying the notion of stopping when there is a quality problem and immediately solving the problem.

Based on the teachings of Sakichi Toyoda, the Toyota Precepts were created, which still guide the company today (Toyota, 2012):

1 be contributive to the development and welfare of the country by working together, regardless of position, in faithfully fulfilling your duties;
2 be ahead of the times through endless creativity, inquisitiveness, and pursuit of improvement;
3 be practical and avoid frivolity;
4 be kind and generous; strive to create a warm, homelike atmosphere;
5 be reverent, and show gratitude for things great and small in thought and deed.

In 1937 Toyota Motors was formed by Kiichiro Toyoda as a division of Toyota Loom Works. Kiichiro's father, Sakichi, had asked him to do something to contribute to society and Kiichiro chose automobiles, a highly risky major challenge. Automobile companies are very capital-intensive and it seemed Toyota was a lifetime behind Ford Motor Company, which at the time was pumping out over one million vehicles per year and getting all the attendant economies of scale. Why would a tiny start-up in an obscure part of Japan have any chance of competing, outside perhaps of the protected market in Japan? Like his dad, Kiichiro Toyoda saw a need, an opportunity, and believed in his team. One of the decisions in the start-up of the company was that Kiichiro, a mechanical engineer, and his team would learn about all the technologies from the ground up and get their hands dirty. This reflected the Toyota principle of self-reliance. Another core principle was announced in a speech Kiichiro gave in which he said: "I plan to cut down on the slack time in our work processes . . . As the basic principle in realizing this, I will uphold the 'just in time' approach."

What was this "just in time" approach? Operations management courses in MBA programs would not teach JIT for decades and there were no books or articles about it. It seems he

made it up! And he was not exactly sure what it was. Taiichi Ohno, a brilliant young manager in Toyota Automatic Loom Works, was given the assignment to develop the manufacturing system that would become the next great innovation in Toyota beyond automatic looms—the Toyota Production System (TPS).

The methodology for Ohno's innovation was the same as Sakichi Toyoda's for the loom—relentless *kaizen*. Kaizen literally means "change for the better," but in Toyota's case it means systematically working toward a challenge overcoming obstacle after obstacle one at a time. When Ohno started, he was running the machine shop for engine and transmission components and just started trying things—small experiments—to solve problem after problem. Nothing was worth talking about for Ohno until he actually tried it on the shop floor. Like Sakiichi Toyoda, the more problems he solved, the more problems were revealed.

For example, the factory was organized in the traditional way by type of process—lathes over here, drilling machines over there—and there were specialist workers for each machining department. Ohno's idea was to create a cell for a product family and have all the machines set up in sequence to make complete parts. He wanted the cells to build to *takt*—the rate of customer demand—with no inventory in the cell except one part here or there as a buffer between machines. He also wanted the flexibility to adjust the number of people in the cells based on the rise and fall of customer demand without losing productivity. This meant that as demand went down, there would be fewer people and some would have to operate more than one type of equipment, such as a lathe and a drill.

The concept of a cell building to takt was a magnificent idea, but proved to be much harder to implement than Ohno expected. Lathe operators did not want to operate drilling machines and vice versa. His solution? Go to the *gemba* (where the work is done) every day and spend time with the workers showing them, and getting them to try the new system. Over time, they found it was a better way to work as it produced higher quality with less wasted effort, and was even safer. Ohno learned a critical lesson—simply thinking of an idea is only the start and the real work is the time-consuming process of training and developing people through repeated practice so the new system becomes "the way we work."

Much later, after the bugs had been mostly worked out, the system was put into writing, and represented as a house (see Figure 2.1). The term "system" is not incidental, but very intentional. The two key pillars were Kiichiro Toyoda's just-in-time and Sakichi Toyoda's jidoka (built-in quality). If Toyota was going to work with very little inventory and build in quality at every step, the foundation had to be extremely stable. There had to be reliable parts delivery, equipment that worked as it was supposed to, well-trained team members, and essentially no deviations from the standard. Ideally, the foundation would provide the ability to build consistently to a leveled production schedule, without huge ups and downs, supporting the customer takt. Leveled production would provide a steady rhythm for the factory.

To maintain this high level of stability, quality, and just-in-time production would require intelligent team members who were vigilant in noticing all the many problems that occurred every day and who took the time to think about and test countermeasures to address deviations from the standard as they occurred. At the center of the house are highly developed and motivated people who are continually observing, analyzing, and improving the processes. These individuals are focused on the purpose, and on correcting any deviations from the standard that adversely affect the purpose. The process gets closer to perfection through continuous improvement by thinking people; therefore, some in Toyota have described TPS as the *Thinking* Production System.

The purpose of the system is represented by the roof—best quality, lowest cost, on-time delivery, in a safe work environment with high morale. The house was a type of system—weak pillars, unstable foundations, a leaky roof, and the house will come tumbling down. Perfect

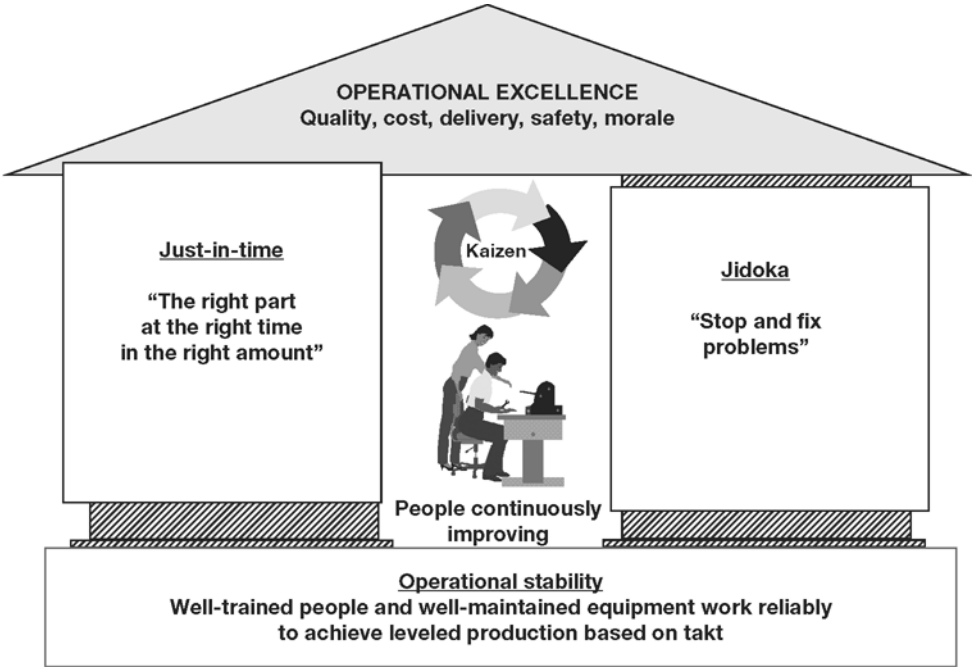

Figure 2.1 The Toyota Production System house

Source: Liker (2015).

adherence to the TPS vision was never possible, but it provided a picture of perfection that could always be striven for—the purpose of kaizen.

What is Lean?

It is very difficult to define "lean," but let's start with the term's origin as a descriptor of organizational excellence. It is not a term you will hear a lot around Toyota. It was first introduced in 1990 in the book *The Machine that Changed the World* (Womack et al., 1990), which was the result of a five-year study at the Massachusetts Institute of Technology (MIT) comparing the American, European, and Japanese auto industries. The researchers consistently found, regardless of the process or metric, that the Japanese automotive companies were far superior to the European and American companies in a wide range of areas, including manufacturing efficiency, product quality, logistics, supplier relationships, product development lead time and efficiency, distribution systems, and more.

The message was that the Japanese had developed an integrated enterprise based on a fundamentally different way of looking at the company, work processes, and people that can be best viewed as a new *paradigm* of management. The word "lean" was suggested by then graduate student John Krafcik (1988), who argued that lean means doing more with less, like a superior athlete, and that the Japanese, especially Toyota, were doing more of everything they needed to do for the customer with less of almost everything. It was a holistic concept for the enterprise, not a toolkit for a specific type of process. It applied both to routine work, such as is done on the assembly line, and to very non-routine work requiring specialized knowledge, like engineering design and sales.

The concept of "waste" in lean is central but often misunderstood. Waste is more than specific actions or objects that need to be eliminated. Waste is anything that causes a deviation from the perfect process. The perfect process gives the customer exactly what they want, in the amount they want, when they want it, and all steps that deliver value do so without interruption.

The concept of "one-piece flow" is the ideal. Each step in the value-adding process does what it is supposed to do perfectly without the various forms of waste that cause processes to be disconnected by time, space, or inventory. Toyota often uses the metaphor of a free-flowing stream of water without stagnant pools. Of course, one-piece flow requires perfection in everything that is done by people or technology and is therefore an impossible dream. Toyota says this is their "true north" vision which is not achievable, yet always the goal—striving for perfection while recognizing there is no perfect process.

I submit that any organization should desire this state of perfection, regardless of the specific product, service, or culture of the organization. The organization that can deliver pure value to its customers without waste, while continuously innovating to improve the product, service, and processes, will be successful. This ideal, or some would say *idealistic*, vision arose in Toyota from some very special people, starting with the great inventor Sakichi Toyoda.

Womack and Jones (1996) then built on *The Machine that Changed the World* with the book *Lean Thinking*. Lean was even more than a highly effective system for delivering value to customers—it was a different way of thinking about the total enterprise. They made clear in that book that the lean model was not based on Japanese automotive companies in general, but on Toyota specifically. Toyota had the best performance at the time of any of the Japanese auto companies and was the best model for "lean thinking."

The Toyota Way: A Philosophy and Way of Thinking

The Toyota Way begins with a passion for solving problems for customers and society. To do this requires deep respect for people and their ability to adapt and innovate. Building an enterprise that can withstand being beaten and battered by the harsh environment, decade after decade, requires a degree of adaptation that can only come from relentless kaizen from everyone possible. Since people are not born with the spirit or skills for kaizen, they must be taught them. As with any other advanced skill, teaching requires some direction and persistent practice.

If you believe findings by cognitive psychologists, such as Dr. K. Anders Ericsson, mastering any complex skill requires "deliberate practice" for 10 years or 10,000 repetitions (see Ericsson et al., 2007). Deliberate practice requires a self-awareness of weaknesses and drills to correct them, one by one, and is helped by a teacher who can see the weaknesses and suggest the drills. Ohno had been doing this throughout his career. As he learned, he then taught, not through lecturing, but at the gemba by challenging students, giving them (often harsh) feedback, and letting them struggle.

After the TPS was well established in Japan, Toyota had a dilemma. Could this finely tuned system work in a foreign country, without the Japanese workers and culture that seemed to fit so well with its principles? Toyota did what Toyota does—experimented. They decided not to go it alone and partnered with General Motors in a 50–50 joint venture called New United Motor Manufacturing Inc. (NUMMI). NUMMI started up in 1984 hiring back over 80 percent of the workers from the GM plant in Freemont, California that had been closed down in 1982. A reason for closing down the plant was horrible labor relations that led to low productivity and quality. With these workers and the Toyota Way, NUMMI quickly became the best automotive assembly plant in North America in quality, productivity, low inventory, safety—in short, more like a high-performing Toyota plant in Japan than a low-performing GM plant. Toyota learned a

lot and then decided to start up its own plant in Georgetown, Kentucky (TMMK) which started production in 1988.

Fujio Cho was selected as the first President of TMMK. If anything it had surpassed the performance of NUMMI and all seemed well. But Fujio Cho saw a weakness. As the Japanese trainers left and Americans were increasingly taking over responsibility for the plant they needed explicit training in the Toyota Way. He realized there was more to Toyota's company philosophy than is captured in the TPS, which is mainly a prescription for manufacturing. The broader philosophy was learned tacitly in Japan, by living in the company and repeatedly hearing the stories and being mentored. What he experienced in America was a lot of variation in the understanding of the core philosophy which Toyota expected all of its leaders to embrace.

Fujio Cho's work over a period of about 10 years led to many versions of a document that never got approved. Toyota works toward consensus, and it could not get consensus. When Fujio Cho became President of Toyota Motor Company globally in 1999, he revived the effort, this time for the company as a whole. He still struggled to get consensus because others said the philosophy was a living and breathing entity and could not be frozen in time as a document. He finally got agreement to call the document "The Toyota Way 2001," with the understanding that it was the best they had in 2001 and could be modified in the future (it has not been so far).

It is represented as a house (see Figure 2.2). The two pillars are continuous improvement and respect for people. Continuous improvement means just what it says: everybody, everywhere, constantly challenging the way they are currently working and asking, "Is there a better way?"

Respect for people goes far beyond treating people nicely. In Toyota, respect means challenging people to be their best, and that means they are also continually improving themselves as they improve the way they work to better satisfy the customer. Respect for people is intentionally generic. It is not only respect for people who are employed by Toyota. It starts with the purpose of the company, which is to add value to customers and society by providing the best means of transportation possible. Respect for society includes respect for the environment, respect for the communities in which Toyota does business, and respect for the local laws and customs of each community.

It is difficult to respect people who are treated as temporary, disposable labor. So Toyota makes a long-term commitment to its employees and to the communities where it sets up shop. Though it does happen, people rarely lose their jobs. Even in the Great Recession, Toyota carried tens of

Figure 2.2 The Toyota Way 2001 house

Source: Liker (2015).

thousands of people globally who they did not need to make vehicles at the low level of demand (see Liker and Ogden, 2011). They worked on continuous improvement and on developing people through education and training, waiting out the bad economy and preparing for the inevitable pent-up demand when things got better. Toyota did not close factories, and this saved local communities from the devastating effects of massive job loss.

There is a particular right way to achieve continuous improvement and respect for people represented by the core values in the foundation of the house. It begins with developing people who will gladly take on a challenge, even when they have no idea how they will achieve it. Examples of challenges that Toyota has achieved from 2000 to 2016 include:

- 20 percent reduction in resources for new model development;
- 25 percent improvement in fuel economy with 15 percent more power;
- 40 percent reduction in cost of a new plant;
- 50 percent reduction in launching a new model, with almost zero downtime;
- eventual target of 75 percent reduction in part numbers.

Each of these remarkable achievements was the result of relentless kaizen. Someone got the assignment to achieve a breakthrough objective, they got a team together, and they followed a well-defined process to systematically improve, step by step, toward the challenge. The challenge provided the direction. Toyota Business Practices (TBP) provides the process (see Figure 2.3). Those familiar with improvement processes will recognize the plan-do-check-act (PDCA) cycle, which is often attributed to Dr. W. Edwards Deming. It is through many cycles of PDCA, essentially constant experimentation and study reflecting on what was learned at each step, that Toyota achieves its breakthrough objectives. And as the leaders work through obstacle after obstacle to meet the challenge, they develop as better leaders and people.

	Concrete actions	Drive and dedication (values)
PLAN	Define the problem relative to the ideal. Break down the problem into manageable pieces. Identify the root cause for each piece. Set targets for improvement. Select the appropriate countermeasure among several alternatives.	Customers first. Always confirm the purpose of your work. Ownership and responsibility.
DO	See countermeasures through.	Visualization of process. Judgment based on facts.
CHECK	Check both results and processes.	Think and act persistently. Follow each process with sincerity and commitment.
ACT	Adjust, standardize, and spread.	Thorough communication. Involve all stakeholders.

Figure 2.3 Toyota Business Practices—Toyota's systematic improvement process

One hard-and-fast rule of TBP is to practice it at the gemba, or what Toyota calls *genchi genbutsu*, meaning, "go and see the actual place to observe directly and learn." Toyota leaders are obsessive about direct observation. In fact, they distinguish between data (abstractions of reality) and facts (direct observation of reality). Both are invaluable in understanding the current reality and determining what happens when you attempt some sort of intervention.

The final two values focus on people. People work to be the best contributors possible to the team. As stated in "The Toyota Way 2001," "We stimulate personal and professional growth, share the opportunities of development, and maximize individual and team performance" (Liker, 2004). The team is always given credit for accomplishments, while there is always an individual leader accountable for the results of the project.

Then we come right back to respect as the way in which improvement is carried out. This includes respect for stakeholders, mutual trust and responsibility, and sincere accountability. Accountability is described in the following way: "We accept responsibility for working independently, putting forth honest effort to the best of our abilities and always honoring our performance promises" (Liker, 2004).

What happened to the TPS, you ask? What about just-in-time (JIT) and built-in-quality and stable processes? In "The Toyota Way 2001," these are part of "lean systems and structure" which contributes to kaizen (see Figure 2.4). These are the tools and concepts which we should consider when working to meet the challenging objectives. At the start of this chapter, I argued that lean management has lost perspective. It almost seems to be an end unto itself. Companies think, "Let's implement JIT to reduce inventory" or "Let's install quality systems to build in quality" or "Let's put in standard work so that processes are stable." In the Toyota Way, however, these are but tools and concepts to consider when doing kaizen to strive toward excellence. The focus is on the objective and the right way to achieve the objective. Lean systems are side by side with innovative thinking and promoting organizational learning, and collectively, these contribute to kaizen. This is an entirely different mindset than the mechanistic view of implementing tools to get specific results.

Figure 2.4 Lean systems are a contributor to kaizen in the foundation of the Toyota Way

Applying the Thinking of the Toyota Way to your Organization

As we reflect on the beginning of the chapter, when we discussed the problem of companies and their many advisors viewing lean as a toolkit for waste reduction, perhaps it is clearer just how far afield these mechanistic "lean programs" have come from the rich tradition developed within Toyota. I hope the chapters in this book help put our readers back on track to the original purpose of the Toyota Way: to create a culture of people continuously improving to adapt and grow through the many challenges of the environment.

This is not to say that anywhere you go and anyone you meet in Toyota follows all of these principles to the letter. Think of "The Toyota Way 2001" as a holy document like the Bible or a governmental constitution. The fact that people deviate from the doctrine, or misapply it, is not an indictment of the doctrine. It is simply that we as humans are far from perfect, sometimes misinformed, sometimes using bad judgment, rarely being perfectly disciplined, and often giving in to immediate needs and desires. In fact, if we were perfect, we would not need any written or spoken doctrine. We would just be.

The Toyota Way is often spoken about as "true north," a beacon that guides daily behavior and helps us to detect whether we are on track or off track. The very basis of continuous improvement is to identify gaps between the actual and ideal and work relentlessly to reduce those gaps, including gaps in our own skills and behaviors.

If we think about trying to improve our bodies physically through exercise and healthy eating, we would all admit that we err from time to time—eating too much or skipping exercise. The vision is a great one, but the execution is often flawed. For those who have lost control of their bodies and are obese, it is extremely difficult to even get started. We have so far to go and need tremendous discipline and a great deal of social support. Those in relatively good shape may already have some of the skills and may have developed a degree of willpower. And the more we exercise that willpower to create positive habits, the easier it becomes to follow our daily regime.

Being mediocre as an organization with few well-defined habits and poorly defined processes is like being obese. It is painful to even think of getting started on the path to true north. But as we try, sometimes fail, but also have small wins, we get more and more skilled in overcoming our weaknesses. Success breeds success and diligent practice is the only true path to excellence.

Toyota is far from perfect, but is comparatively healthy in many parts of the organization and in many different cultures. It has passionately developed leaders who strive to live the values—striving for true north. They have the social support of senior leaders consistent in their vision of true north—consistent over decades of growth. Even for an organization very far from Toyota's maturity level, it is never too early to start the process of looking with brutal honesty at where you are and where you would like to get to—your true north. Then we need to take a first step, then a second step, and continuously improve our way to the vision.

As you think of how to get started in your organization, review the principles of the Toyota Way. Review Toyota Business Practices, which gives you an idea for getting started. Where will you start? Identify a challenge that will bring your organization to a new level of customer service. Define the ideal state. Understand the current state. Then break down the problem into manageable pieces—step by step. For each step, identify a short-term target and begin to experiment toward each target through PDCA cycles. Every step is worthwhile, successful or not, as long as you learn something. Additional guidance is provided by Mike Rother (2010) in his book *Toyota Kata*. He has gone deeper into the essence of Toyota thinking, providing practice routines to work your way toward the habit of daily improvement.

If you already have a lean program started, I encourage you to think about that program as part of the current state and compare it with the ideal state. What are the critical gaps in how the

program is being executed? How are you doing at developing people in a respectful way? Where is a culture of continuous improvement starting to take root and where is there stagnation? Investigate personally at the gemba. You will begin to understand the true condition of your organization and yourself as a leader. Striving for perfection always begins with working on yourself as a role model for continuous improvement and respect for people.

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PART I

The Lean Enterprise

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3
LEAN PRODUCTION

Pauline Found and John Bicheno

Introduction

At the time of writing, it is more than one quarter-century since the term "*lean production*" was first introduced to the management lexicon by John Krafcik, a researcher from the Massachusetts Institute of Technology (MIT), who was working on the International Motor Vehicle Program (IMVP) (Krafcik, 1988). Womack, Jones, and Roos later popularized lean in the bestselling book *The Machine that Changed the World*. However, it was Richard Schonberger and Robert Hall who wrote the two books, in 1982 and 1983 respectively, that effectively launched (or relaunched) the concept that became known as lean production in the West. Schonberger (2007) noted that while *The Machine that Changed the World* is commonly perceived to mark the beginning of the lean movement, in reality lean manufacturing was actually already well established in the US in the early 1980s, albeit under different names.

In *The Machine*, the authors contend that the findings of the IMVP large-scale study revealed that there was a dramatic performance gap between Japanese and Western car producers and asserted that lean production should be universally adopted: "Our conclusion is simple: Lean production is a superior way for humans to make things . . . It follows that the whole world should adopt lean production, and as quickly as possible" (Womack et al., 1990, p. 225). The impact of *The Machine* has been far-reaching and the book led to the commissioning of two follow-up studies that provided further support for the existence of a substantial performance gap (Anderson, 1992; Oliver et al., 1994). These studies were publicized extensively to the manufacturing community at the time.

In the period since the introduction of lean, huge changes have taken place, yet it is also true that, for the majority of operations organizations, the lean potential has hardly been tapped. This chapter looks at the evolution and spread of lean and opens the discussion on lean as the dominant operations paradigm of the 21st century.

Evolution of Lean Production

Lean emerged in the West as a result of great interest in Japanese production and management methods stimulated by the second oil crisis when automotive production in the US fell by almost 22 percent as consumers turned to the more fuel-efficient small Japanese cars. The golden days of mass manufacturing in the US were over in 1976 as Chrysler declared bankruptcy and both GM

and Ford were losing money. The interest in Japanese manufacturing techniques and, in particular, Toyota's production system, led to the publication of two English language articles in 1977, one by Sugimori et al. in the *Journal of Production Research* and the other by Ashburn in the *American Machinist* (cited in Schonberger, 2007) which raised concerns in US and European automotive companies, but it was an NBC-TV broadcast by producer Claire Crawford-Mason in 1980 entitled "If Japan Can, Why Can't We?" that prompted a quality revolution, which led to the five-year, five million dollar IMVP research program.

The ideas behind what is now termed "lean" originate from several sources, including great industrialists like Henry Ford in the US, Frank Woollard in the UK who developed the concepts behind flow manufacturing and moving assembly lines and management thinkers such as W. Edwards Deming and Peter Drucker who criticized mass manufacturing and won support in Japan to think differently. In Japan, one of the main sources is considered to be Sakichi Toyoda in the Toyoda loom factory, who originally developed the philosophy and methods associated with lean production at the turn of the 20th century; these influenced his son Kiichiro Toyoda to develop what is known as the just-in-time (JIT) method at the Toyota Motor Company in the late 1930s which became one of the pillars of the company.

The Second World War reconstruction of Japanese manufacturing and the lack of available capital resources and severe economic slump saw these ideas extended and combined with a discipline of daily improvements (*kaizen*) at Toyota that was supported by Eiji Toyoda, the new chairman, and enforced by chief engineer Taiichi Ohno, who had transferred from Toyoda Loom Works to Toyota Motor Company in 1943. The new approach, created by Taiichi Ohno, became known as the Toyota Production System (TPS). The philosophy and methods of TPS evolved over time, extending to Toyota's supply base in the 1970s, its distribution and sales operations in the 1980s, and became a competitive weapon as Toyota competed openly with US and European automakers. Toyota's business success and world-leading product quality is an established fact. Rother (2010) recently summarized Toyota's success into four key statistics: Toyota has shown sales growth for over 40 years (at the same time other car makers' sales have reached a plateau or declined); Toyota's profit exceeds that of other car makers; Toyota's market capitalization has for many years exceeded that of other car makers; and in sales rank Toyota has become the world leading car maker. This success is often attributed to the production system Toyota developed during 1950s and 1960s as a result of intense post-war competition.

TPS is characterized by a systematic approach to the organization of production that emphasizes the elimination of all forms of waste (Ohno, 1988). However, over time TPS has been discovered to be a complex, multifaceted element of Toyota's broader management system and culture, something that has been reflected in the prolific lean literature. In his book *The Evolution of a Manufacturing System at Toyota*, Takahiro Fujimoto (1999) describes how Toyota developed three layers of manufacturing capabilities: a routinized manufacturing layer, a routinized learning layer, and a non-routine and dynamic evolutionary learning capability which gives Toyota the capacity and strength to adapt and change over time. Spear and Bowen (1999, p. 99) attempted to codify TPS and describe four key rules that describe the tacit knowledge and guide the design, operation, and improvement of every activity, connection, and pathway of products and services and it is these rules that are the essence, or DNA, of TPS. These rules are as follows:

1 All work shall be specified as to content, sequence, timing and outcome.
2 Every customer–supplier connection must be direct.
3 The pathway for every product or service must be simple and direct.
4 Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest level in the organization.

In spite of a plethora of academic and practitioner books and articles on lean, however, there is still not a precise and agreed-upon definition (Shah and Ward, 2007). Referring to the old fable of the blind men touching an elephant and imagining very different animals, Shah and Ward suggest that over time commentators on lean have focused on single, visible aspects of the process while missing the invisible highly inter-dependent links of lean systems as a whole. As well as being a poorly defined construct, interpretations of lean have continued to evolve over time. Originally presented by Womack et al. (1990) as a counter intuitive alternative to traditional manufacturing, it is now presented, by some at least, as a new paradigm for operations management (Bartezzaghi, 1999; Holweg, 2007). In addition, lean has expanded beyond its original applications on the shop floor of vehicle manufacturers to other functional areas within organizations, to other manufacturers and to non-manufacturing organizations. Consequently, lean means different things to different people (see Table 3.1).

Lean is described as a philosophy (Bhasin and Burcher, 2006), a management system (Hines et al., 2004), and an operating system of production planning and control (Standard and Davis, 1999).

Lean Production as a Philosophy, Management and Operating system

Lean as an Operating System for Production Planning and Control

A shop floor-based view of lean still emerges as the prominent means of implementation. The essence of this view is smoothing and improving operational processes through the application of lean tools. Often, these are not even a set of tools but completely independently introduced by companies trying to emulate the TPS. For example, managers employ a variety of mapping tools

Table 3.1 Lean viewed as a philosophy, a management system, and an operating system for lean production planning and control

Lean philosophy
Systems thinking
Value for the customer
Waste elimination
Lead time reduction
Humility and respect for humans
Continuous improvement
Lean management
Hoshin kanri (policy deployment)
Value stream (cross functional and "gemba" management)
Visual management and visual controls
Kata
Leader standard work
TWI (Training Within Industry)
Lean operations
Value stream management
5S
Standard work
TPM (total productive management)/SMED (single-minute exchange of dies)
Pull systems/Kanban
Demand and capacity management

Source: Adapted from Slack et al. (2004).

to identify the value-added and non-value-added activities of each process. From this they can reduce the operating costs by eliminating non-value-added activities, waste, and reorganizing value-added activities. In these cases, the primary goal of the shop floor tool-based method is to efficiently improve the organization's performance at an operational level, by enhancing quality and reducing waste, inventories, and lead times (Manos and Vincent, 2012).

Womack and Jones began their book *Lean Thinking* with the words "Muda. It's the one Japanese word you really must know" (Womack and Jones, 2003, p. 15). Today there is widespread awareness of waste. Fujio Cho, former President of Toyota, defined waste as "anything other than the minimum amount of equipment, materials, parts, space and worker's time, which are absolutely essential to add value to the product" (Suzaki, 1987, p. 8). The concept of *muda* primarily originated from Taiichi Ohno's production philosophy in the early 1950s (Dahlgaard-Park, 2000) although Toyota also talks about three Ms—*muda* (waste), *muri* (overburden), and *mura* (unevenness). Knowing about all three gives a more complete understanding of lean; the three are interlinked and lean is about mobilizing people to reduce all three. While total quality management (TQM) was not mentioned in *The Machine that Changed the World*, possibly because TQM was not a well-known management philosophy in the West at that time (Dahlgaard and Dahlgaard-Park, 2006), the mention of muda in lean thinking is very significant as it links the two management philosophies and confirms that the aim of lean production is to eliminate waste.

Lean is often described as a pull system, compared with a materials requirements planning (MRP), or push, system. Toyota implemented a JIT pull system in post-World War II Japan as the capital resources to support the high levels of inventory that were often the consequence of push and MRP systems were not available. The concept behind JIT is described by Monden (1983, p. 2). JIT means "to produce the necessary units at the necessary quantities at the necessary time" and core to implementing a JIT and pull system is managing demand and capacity to reduce the lead time between customer order and cash received. Therefore, pull systems are based on responding to actual customer demand, not in response to orders *pushed* on to the shop floor from schedules based on forecasts. Pull is based on a sell-one (or use-one), make-one concept of small batches. To run a successful pull system, demand needs to be leveled as much as possible to eliminate spikes and to allow the products to flow without disruption and diversion, thus reducing the need for excess inventory. This is managed by understanding the "load" and the "capacity" of the system. Load is the amount of work imposed on the system and capacity is the resources available to do the work. Ohno used a simple formula to show that present effective capacity is the sum of work and waste:

Present capacity = work + waste.

While this is a simple way to demonstrate that you can get more work out of the current system by reducing the waste, this can be misunderstood and may suggest that you can increase capacity if you increase waste. There are actually three factors that influence queues or lead time. These are arrival variation, process variation, and utilization, as in the equations: *Utilization = load/capacity* and *load = real demand + mistake demand* (mistake demand could be rework, work done due to errors, failure demand). Therefore, *present capacity = base capacity – waste*. Hence, there are four things that should be tackled: arrival variation, process variation, mistake demand, and waste.

The key to realizing JIT is not relying on a central planning approach to production control which "pushes" a product through production by simultaneously scheduling the individual processes but, rather, that work (or value) should flow through the system at the pace of the demand without deviation, detour, or delay. Where flow is not possible, pull systems might use a *kanban*

system as the way to manage JIT production. Kanban is a signal from a process to the preceding process to indicate that product has been consumed and that it is necessary to produce more to replenish the quantity withdrawn. The signal can be in the form of a card system, a square or, indeed, any suitable signaling system that is visual and recognizable by the operators (Harmon and Peterson, 1990). Kanban is not the only control system used in a lean environment. *Drum buffer rope* (DBR) and *constant work-in-process* (CONWIP) are often the most effective pull-oriented hybrid production control systems in other situations, such as process plants (Hopp and Spearman, 2000).

To be implemented successfully, JIT/pull systems need to be aligned to strategy, supported by senior management and operated by skilled people. Pull may not be the best strategy for all products; some products that are made infrequently may be better "made to stock" and replenished when needed. There are several lean tools that support small batches and pull systems, such as *single-minute exchange of dies* (SMED) to reduce changeover times, *total productive management* (TPM) to increase availability and 5S to organize the workplace. JIT is supported by *jidoka*, or autonomation, which may be interpreted as "automation with a human touch" that prevents defects from disrupting the flow from process to process. JIT and jidoka are the two pillars of the Toyota Production System (TPS) and, consequentially, in lean production systems (Bicheno and Holweg, 2008).

While, for many, lean production starts with "tools," Toyota did not start with this way. It started with the unremitting focus on how to use its resources to produce a product that is defined to be as close as possible to what the customer wants to buy and how to align the flow of production as close as possible to the flow of cash. The five lean principles (Figure 3.1) presented in the book *Lean Thinking*, by Womack and Jones (1996), represent a "roadmap" for those organizations attempting to implement lean or emulate TPS.

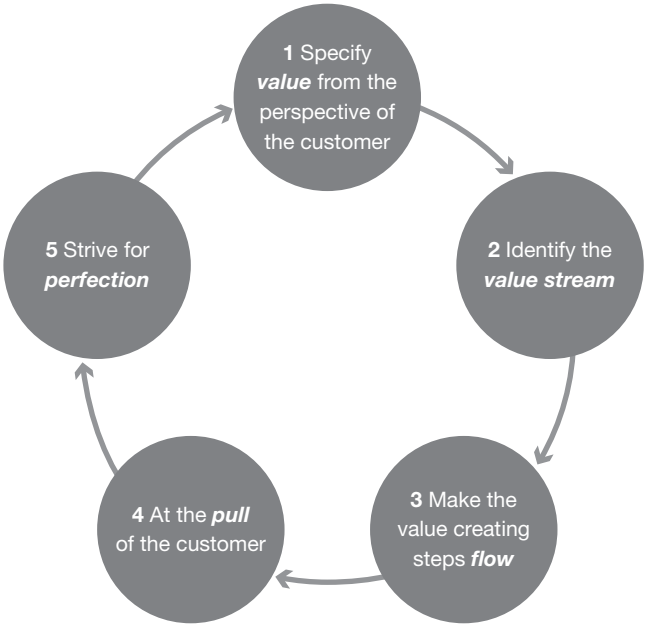

Figure 3.1 The five lean principles

Source: Based on Womack and Jones (1996).

The empirical data in *Lean Thinking* is based on case studies of companies that have successfully adopted the lean imperative to become lean organizations. The five lean principles defined introduced a structure, or framework, to better describe the approach at Toyota and the focus moved from the "tools" approach towards the principles of self-help, and respect and responsibility towards staff, customers, and society. At this point some lean commentators began to realize that "real" lean (Emiliani, 2007) is behavior-driven and linked to a mindset of creating thinking people who can solve real production problems and the focus shifted in the literature from tools to problem solving (Spear and Bowen, 1999; Hines et al., 2004, 2011; Liker, 2004; Spear, 2009) and becoming a learning organization (Senge, 1990).

Lean as a Management System for Process Improvement

The Japanese word *kaizen* quite literally means change, or changing (kai), for the better, or good (zen), and the term entered popular Western management terminology in the 1980s (Imai, 1986) to refer to problem solving and continuous improvement. Continuous improvement is the essence of the fifth lean principle: Strive for Perfection. This principle recognizes that lean is not a single project that has an endpoint, but rather a journey of daily improvements as identified by Eiji Toyoda and Taiichi Ohno in TPS. Problem solving, experimentation, and continuous improvement are part of the culture of the whole organization and built in to the day-to-day management system. Deming's improvement cycle, *plan, do, check* (or *study*), *act* (PDCA or PDSA) is often used by organizations as a vehicle by which to maintain and sustain improvement activities.

Not all of the quality influences on Toyota came from the West; one of the most influential Japanese authors on quality and problem solving is undoubtedly Kaoru Ishikawa who gave his name to the "*Ishikawa diagram*," more popularly known as the "fishbone" cause-and-effect diagram. The diagram is so-called because it resembles the skeleton of a fish when it is drawn. The method is used to determine problems within a workplace and then to identify the root cause of the problem before assigning it to a theme, or category. The head of the fish is the visual problem (symptom) and the skeleton forms the possible underlying causes, sorted into themes that resemble the spines of the fish skeleton. Along each spine the issues (causes) are highlighted. The original main themes used in such kaizen and problem solving were the methods used, the machinery used, the materials used, the measurements used, the management of the process (often known as manpower), and the working environment or mother nature (six themes that can all begin with the letter M), but these can be adapted to be specific to a particular setting and are used in many organizations as part of their kaizen and problem-solving events (Bicheno, 2006).

Kaizen is well established as an improvement methodology in manufacturing and is increasingly being used in the service sector. Three types of kaizen improvements are often employed within organizations to tackle different levels of problems (Figure 3.2):

1 Daily problem solving, which focuses continuously on small problems that can be tackled immediately, or over a few days.
2 Kaizen events (blitz) actions which usually last for one week and focus on medium-sized problems such as reducing changeover times. Kaizen events are not typically used in Japan. They are actually a US innovation, suited to using outside experts and consultants (cited in Stoller, 2015).
3 System kaizen for the few strategic, large problems that are longer in duration, possibly up to three to four months. The scope of the problem would be a process redesign at a departmental level.