

Participation Based Intelligent Manufacturing

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Participation Based Intelligent Manufacturing: Customisation, Costs, and Engagement

EDITED BY

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United Kingdom – North America – Japan – India – Malaysia – China

Emerald Publishing Limited
Emerald Publishing, Floor 5, Northspring, 21-23 Wellington Street, Leeds LS1 4DL.

First edition 2025

Editorial matter and selection © 2025 Birutė Mockevičienė.
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British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN: 978-1-83797-363-7 (Print)

ISBN: 978-1-83797-362-0 (Online)

ISBN: 978-1-83797-364-4 (Epub)



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Abbreviations

ACSI	American Customer Satisfaction Index
AI	Artificial intelligence
ANN	Artificial neural networks
AR	Augmented reality
ATO	Assembly to order
B2B	Business-to-business
BA	Business analyst
BD	Big data
BDA	Big data analytics
CBR	Case-based reasoning
CEO	Chief executive officer
CM	Cloud computing
CNC machinery	Computer numerical control machinery
CPS	Cyber-physical system
CRM	Customer relationship management
DARPA	Defense Advanced Research Projects Agency
DM	Direct materials
ERP	Enterprise resource planning
ETO	Engineer to order
FBA	Forecasting by analogy
FI	Frugal innovation
HMI	Human-machine interaction
ICT	Information and communication technology
IDS	Intrusion detection systems
IL	Indirect labour
IM	Indirect materials
IoT	Internet of Things
IPNs	Industry peer networks
IT	Information technology
KBE	Knowledge based engineering
KPIs	Key performance indicators
MDS	Multidimensional scaling
MES	Manufacturing execution systems
MFA	Multifactor authentication
ML	Machine learning
MOH	Manufacturing overhead

xvi Abbreviations

MTO	Manufacturing to order
MTS	Manufacturing from stock
PCA	Principal component analysis
PLM	Product lifecycle management
PSS	Product and service systems
RBAC	Implement role-based access control
RBF	Rule-based forecasting
RF	The Random Forest
SAPA	Semantic annotation and processing agent
SEJ	Structured expert judgement
SME	Small and medium enterprise
VBP	Value based pricing

About the Editor

Birutė Mockevičienė is the author of the idea to use machine learning to address the problem of customised furniture production orders, the initiator and the leader of all the research work carried out in order to prove this innovative approach. She developed both the concept of the innovative solution and the research methodology combining multidisciplinary approach. She also initiated and carried out the empirical data collection (interview process, survey process, process of collecting, compiling and updating historical data, process of testing the prototype under real conditions). The prototype design was developed and a list of functionalities of the prototype for the price evaluation was prepared.

She is a Professor of Management since 2017. She started her career in the field of Social Sciences in 2006, and currently works at Mykolas Romeris University, Institute of Management and Policy Studies, as a Director. Her basic education (Ph.D. in Physics) has allowed her to work at the frontier of scientific fields, bridging the approaches of mathematics, physics, management and economics.

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About the Contributors

Anca Hanea is a renowned structured expert judgement (SEJ) expert. In this work, she has ensured the validity of the method of involving employees in price forecasting, the technicalities of integrating the SEJ methodology into the prototype and the processing and interpretation of the experimental data. Her extensive experience enabled the precise implementation of the SEJ method.

She is a probabilistic modeller interested in uncertainty quantification using data (when available) or SEJ (when data are sparse or missing). She was instrumental in building a COST European network for SEJ elicitation and aggregation, and related standards for the European Food Safety Authority (EFSA). Together with colleagues from the University of Melbourne, she has developed, tested and co-authored guidelines for the IDEA protocol for SEJ. She has taken part and facilitated numerous expert elicitations in various projects undertaken by World Health Organization, EFSA, the European Framework Seven Programme, Defense Advanced Research Projects Agency (DARPA), Cawthron Institute, the Australian Department of Agriculture, Fisheries and Forestry and many universities around the world.

Julija Moskvina was responsible for analysing the furniture sector in Baltic countries, and the sociological interpretation of the interview and survey data working in a team with Birutė Mockevičienė. The qualitative data analysis performed by her covered transcribing interviews, data cleaning, developing categories, data coding, interpretation and report drafting.

She is a Senior Researcher at the Labour Market Research Division of the Lithuanian Centre for Social Sciences. She received her Ph.D. in Sociology from Vilnius University. While participating in national and international research projects, she has developed thorough experience in qualitative and quantitative analysis of labour market processes and employment policies with a particular focus on vulnerable groups in employment.

Tomas Vedlūga is a Doctor of social sciences, specialising in performance management, performance evaluation systems in modelling, selection of indicators and their measurement. While participating in national and international scientific conferences, he gained experience in process evaluation, data analysis and prototyping. In his research, he pays a lot of attention to the modelling and evaluation of prototypes in terms of sustainability.

–He assisted in the justification of sustainability or further use of the collected data for the functioning of the prototype and the transfer of ERP logic in the design of the prototype.

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Chapter 1

Introduction

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Abstract

This chapter aims to introduce the book's research field and the primary challenges faced by the modern manufacturing sector in terms of operational planning and process cost reduction. It will focus on the impact of technology and social technologies, such as digital employee involvement in process assessment, which facilitates organisational innovation through ICT and high-value collaborative technologies. In other words, this chapter presents solutions to the issues that arise from using current production data and employee collaboration to develop future expert predictive solutions tailored to the furniture manufacturing process.

Keywords: Customised manufacturing; structured expert judgement; machine learning; furniture industry; frugal innovations

A Problem for Customised Manufacturing That Deserves a Response

Worldwide, engineering contributes positively to national GDP growth. However, the manufacturing sector is facing significant challenges around the world: increasing global competition and consumers' desire for customised solutions that prioritise design. This phenomenon has reoriented the existing supply-driven market towards *consumer-driven production*. The success of customised production now relies on efficient planning. This planning should consider the required amount of materials, the time and effort needed to complete the project, and the evaluation of all the client's requirements. It is also important to choose the

**Participation Based Intelligent Manufacturing:
Customisation, Costs, and Engagement, 1–5**

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doi:[10.1108/978-1-83797-362-020241001](https://doi.org/10.1108/978-1-83797-362-020241001)

best strategies, creative design, and project implementation. Production process for construction. Customised production requires completely new technological solutions, long and careful prototyping and testing. This increases *the cost of the product*, lengthens the *production time* and leads to persistent errors in *product quality*. Therefore, the customised manufacturing sectors are intensively looking for new solutions with quite specific requirements: to perform the predictive evaluation of a customised order quickly (*in less than 30 minutes*) and reliably (to reduce the likelihood of prediction errors). Following the global trends in the furniture industry and considering the production organisation solutions used in this field (Amarilli & Spreafico, 2010), in order to reconcile a number of different objectives at the same time, the need for rapid information transfer and efficient decision-making is becoming more and more critical (Kucharska et al., 2015). In customised furniture production, where design is an added value to the product, the preparation of design drawings and estimates to determine the cost and lead time of an order can take from four working days to two weeks and account for as much as 30% of the company's total working time. Unfortunately, even with this amount of time, errors due to the complexity of the structural elements and the innovativeness of the design elements can reach up to 70%. This situation creates *tensions between designers, engineers, and managers* at various levels, and the company starts to avoid complex and innovative orders. Therefore, to preserve the sustainability of the company, support instruments are needed (Bagchi et al., 2003), which allow to react in an increasingly shorter period of time to the content of the user's customised order, and to properly assess and plan the production processes, costs and deadlines (Gawroński, 2012; Møller, 2006). As different employees in a company have different experiences in product evaluation (designers anticipate design strategy, engineers are better at predicting lead times, managers are better at 'feeling' the pulse of the market – acquisitions and consumer expectations), an instrument based on the *involvement of different levels of employees* is needed (Wilkinson et al., 2010), with a reactive (learning from past mistakes and the growing experience of the employees) production process evaluation system.

A Solution in Under 30 Minutes?

This issue calls for innovative solutions that can revolutionise how we manufacture products to meet the unique needs of our customers. For the sake of accuracy, the time needed for the specialists to prepare the initial start-up of the system is not included in the formulation of the performance indicator for the cost evaluation module, that is, the time needed to collect the historical data, the time required to get used to working with the system are not taken into account. Also, the time spent working with the client to understand the client's needs is not part of the working time of the price evaluation module. The 30 minutes is the suggested timeframe for the manager to gather the required information for price evaluation: log in, access the order details, execute the task, choose the experts, and request them to conduct the evaluation.

Why would it seem important for a manufacturing company to have an order price forecasting system that is capable of solving the task at hand (analysing the

order price) in some specific time frame, for example, the time frame we have proposed, which would be shorter than 30 minutes? We have to look for the answer in innovation theory. Those 30 minutes can be used as a baseline to measure the effectiveness of the innovation. This time period must be so short that it can demonstrate a significant change in the practice of price evaluation and initiate the development of a new paradigm. In 2018, when this idea was submitted as a project application for peer review, the idea of fixed 30-minute processes sounded unlikely given the IT technologies used at the time.

Today, from a historical perspective, it turns out that this was not a completely random guess. The application of the latest Industry 4.0 technologies and approaches has succeeded in demonstrating this, confirming a paradigm shift towards cost in a traditional industry such as furniture. Analogous situations related to the paradigm shift can be found in other sectors. Quite illustrative is the experience of Rolls Royce (Rodríguez et al., 2020). The Rolls Royce case is interesting because it coincided with a desire to set the price in an unconventional way (without linking it to the sector's usual indicators, as in the furniture industry with the usual resource volumes). We are talking about Rolls Royce's 'Power by the hour' programme (Smith, 2013), in which the pricing mechanism of the contract is based on the number of hours the aircraft engine is running, as opposed to the traditional method where the customer buys the equipment and is billed according to the results of the support services that keep the engine running.

Rationality of the Research

Custom furniture companies, large and small, in both developed and developing regions, suffer from a detailed, cost-modelling, early pricing process for new products at the product order stage. This process is demanding in terms of specialist effort and man-hours, but it does not avoid both costing, planning and quality errors in production processes. There is therefore a need for a symbiosis between science and practice which, in addition to theoretical assumptions, examines scientific progress in the context of Industry 4.0 and addresses the practical problems of furniture production in the early pricing of newly developed products. Industry 4.0 offers a broad perspective on the complex challenges of manufacturing business. Industry 4.0 tools (e.g. robotics, sensors, and big data analytics) fully address manufacturing issues only when applied in an integrated manner. That is, solutions often require an interdisciplinary approach combining social context with technological capabilities. There is still, no ready-made solution.

Therefore, the book will present an evidence-based innovative digital solution to address pricing issues in early new product development, presenting methodological and production embedding aspects. This innovation will be referred to hereafter as the *Integrated early price assessment system*.

The Purpose of the Book

The purpose of the book is to review existing knowledge in the field of furniture manufacturing, combining capabilities of artificial intelligence and discuss the

availability of human involvement into rigid prognostic process of price estimation. At the same time, we want to present the innovation approach we created to predict the early price of customised product development, which, being cheap, can be accessible to a wide range of users, including small businesses.

The dimensions of issues solved here, can be distinguished as following:

- *Manufacturing* itself constantly raises many managerial questions, many of which can be solved by innovative technological solutions of the industry (robotisation and digitalisation). Unfortunately, solutions for all manufacturing sectors are not easily available due to the large initial investment in innovation and the availability and accessibility of big data. The furniture sector, which is largely composed of small and medium-sized enterprises, faces greater challenges due to low levels of innovation and financial capacity.
- *Customisation*. Production customisation comes with its issues when it is necessary to control the customer's needs, the desire to get involved and create a unified product together. Management challenges arise in controlling time and quality while maintaining a competitive price.
- *Regionalisation*. The challenges posed by regionalisation are related to customisation, when an individual product must be developed locally, close to the customer.

The motivation to write a book is related to the completion of a 4-year project supported by the Lithuanian state called Participation Based Intelligent System to Estimate Customise Production Process (this project has received funding from the European Regional Development Fund [project No 01.2.2-LMT-K-718-01-0076], duration 2018–2021 under a grant agreement with the Research Council of Lithuania). The support scheme is aimed at increasing applied scientific research and commercialisation capabilities. This book presents the theoretical material that underpinned the methodology and research, which was not presented in the report due to its applied nature. We believe it will contribute to a better understanding of the field of both scholars and practitioners who would like to deepen their knowledge in the field.

In this book, *we fill the gap* for frugal innovation that helps manufacturing changes adapt to the market, describing the possibilities of interdisciplinary integration to create real-world working and science-based smart instruments for direct business use. This book can be seen as a synthetic work that presents a unique innovation. The described innovation was tested as a prototype. Its verification in practice is valuable in a scientific sense. The content of the book is extremely new and innovative, because when solving an old problem (determining the forecast price of a new product), innovatively combining approaches from several sciences. It is a completely new way to manage production processes and use the available historical data together with the knowledge of the employees.

Relevance and Challenges

The relevance of this study is underlined by the fact that it has been launched at the same time as preparatory research initiatives to assess the potential of Industry 4.0 are being launched across Europe. One of the noteworthy projects is

titled ‘Industry 4.0 for SMEs – Smart Manufacturing and Logistics for SMEs in an X-to-order and Mass Customisation Environment’. This project is funded by the European Commission H2020 through the MSCA Research and Innovation Staff Exchange (RISE) program. The fact that initiatives have been launched in a totally uncoordinated and spontaneous way in different parts of the world, raising very similar issues, shows the timeliness of the problem.

In fact, 2017–2018 was seen as still so early in the perspective of the introduction of Industry 4.0 tools. Many initiatives have been limited to the identification of needs and problems.

Our idea was to look deeper and propose operational ideas for manufacturing, specifically for the SME sector, which is not able to do it on its own.

In tackling this scientific question, we had to face paradigmatic difficulties. In today’s dynamic market, relying solely on manufacturing costs to evaluate product pricing is no longer sufficient. To stay competitive, it’s crucial to take a fresh approach to pricing that considers various factors such as market trends, consumer demand, and the overall value of the product. By doing so, businesses can ensure that their pricing strategy is not only cost-effective but also effective in meeting the needs of their customers. Therefore, the proposed solution of using machine learning algorithms to evaluate price destroys the existing perception and requires a change in business behaviour. Making such transformations can be mentally demanding and time-consuming.

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Chapter 2

Intelligent Manufacturing From A Theoretical Perspective: The Technological Revolution and Social Participation

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Abstract

This chapter is designed to provide an overview of the challenges facing Industry 4.0, focussing on the manufacturing sector, and highlighting the specifics of small to medium-sized enterprises. Recent technologies for data science, analysts, robotics, and other smart manufacturing trends are discussed, and the opportunities, difficulties, and limitations for break-through development are highlighted.

Keywords: Industry 4.0; digitalisation; big data; customisation; smart manufacturing; engagement; SME

A Historical Perspective for Industry 4

The year 2011 marks the beginning of a major transformation in manufacturing. The industrial environment is starting to change radically, and this is linked to a new concept of manufacturing based on technology, in particular IT capabilities and the development of the internet. Since 2011, Industry 4.0 has been discussed, which refers to three areas of activity: manufacturing, IT, and the Internet.

The Industry 4.0 paradigm marks a substantial transformation in manufacturing, presenting a novel approach to products and their consumers. In this approach,

**Participation Based Intelligent Manufacturing:
Customisation, Costs, and Engagement, 7–45**

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doi:[10.1108/978-1-83797-362-020241002](https://doi.org/10.1108/978-1-83797-362-020241002)

the consumer assumes the dual role of both customer and designer within the product development process. The manufacturer is then tasked with identifying and satisfying the consumer's needs accurately and efficiently. This approach differs greatly from the one that led to Henry Ford's success in 1914, where he famously stated 'Any customer can have a car painted any colour that he wants, as long as it is black' became a prerequisite for Ford Motors to reduce costs, while ensuring the quality of the car manufacturing (Ford & Crowther, 1922). Today, however, this phrase is a matter of historical artifice, as more and more instruments are being developed to meet the needs of the consumer in ever greater depth.

The concept of Industry 4.0 was launched in Germany at the Hannover Fair in 2011 and has become a concept for a broad change in manufacturing. At the same time, similar movements started in the USA with Smart Manufacturing programmes. In 2010, the Smart Manufacturing Leadership Coalition (SMLC) brought together a group of more than 50 industry leaders and published a report on the goals of smart manufacturing (Smart Manufacturing Leadership Coalition, 2011). Later South Korea launched a program for Smart Factory (Park, 2015) and Japan recognised the value of Smart Manufacturing in 2015 (Nishioka, 2015). It is not long since the European Union announced its strategic direction in this area as the 'Factories of the Future' (Davies, 2015) initiative. The emergence of Industry 4.0 is summarised in Fig. 2.1.

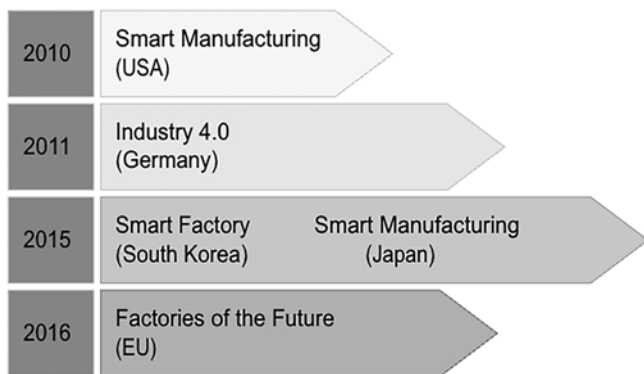


Fig. 2.1. The Emergence of Industry 4.0 as a New Phenomenon.

The importance of the Industry 4.0 concept has also been reflected in the strategies of every other national state, highlighting that the technological shift towards robotics, online live processes, and smart analytics is an inevitability that will be the subject of coherent efforts, both at the level of the manufacturing company and the state. All countries have moved along this path, recognising the need to accelerate digitalisation, as the realisation has become more than clear that innovation and change are right on the doorstep and that delay could cost regional competitiveness. And here we see a whole series of movements: