

# PROCEEDINGS OF THE DESIGN SOCIETY

the **Design Society**  
a worldwide community



**CAMBRIDGE**  
UNIVERSITY PRESS

## INTERNATIONAL DESIGN CONFERENCE - DESIGN 2024

20-23 MAY 2024, CAVTAT, DUBROVNIK, CROATIA

### Editors

**Mario Štorga**, University of Zagreb FSB, Croatia  
**Stanko Škec**, University of Zagreb FSB, Croatia  
**Tomislav Martinec**, University of Zagreb FSB, Croatia  
**Dorian Marjanović**, University of Zagreb FSB, Croatia  
**Neven Pavković**, University of Zagreb FSB, Croatia  
**Marija Majda Škec**, University of Zagreb FSB, Croatia

### Programme Committee

**P. John Clarkson**, University of Cambridge, United Kingdom  
**Tim C. McAloone**, Technical University of Denmark, Denmark  
**Julie Stal-Le Cardinal**, CentraleSupélec, France  
**Sandro Wartzack**, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany  
**Stanko Škec**, University of Zagreb FSB, Croatia  
**Mario Štorga**, University of Zagreb FSB, Croatia

### Scientific Advisory Board

**Abi Akle, Audrey**, ESTIA, France  
**Acharya, Shakuntala**, Indian Institute of Technology Guwahati, India  
**Ahumada-Tello, Eduardo**, Autonomous University of Baja California, Mexico  
**Ali, Wafa**, Indus Valley School of Art & Architecture, Pakistan  
**Allais, Romain**, APESA, France  
**Almefelt, Lars**, Chalmers University of Technology, Sweden  
**Ammersdorfer, Theresa**, Technische Universität Clausthal, Germany  
**Aoussat, Améziane**, Arts et Métiers ParisTech, France  
**Arlitt, Ryan Michael**, Denmark  
**Arrouf, Abdelmalek**, LEMPAU, Batna1 University, Algeria  
**Attia, Amir Ibrahim**, California State University, Monterey Bay, United States of America  
**Auricchio, Marco**, Imperial College London, United Kingdom  
**Bartz, Marcel**, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany  
**Basan, Robert**, University of Rijeka, Faculty of Engineering, Croatia  
**Baxter, Weston**, Imperial College London, United Kingdom  
**Becattini, Niccolo**, Politecnico di Milano, Italy  
**Behdinan, Kamran**, University of Toronto, Canada  
**Bencetic, Sanja**, University of Zagreb Faculty of Architecture, School of Design, Croatia

**Bender, Beate**, *Ruhr-Universität Bochum, Germany*  
**Benjamin, Stacy**, *Northwestern University, United States of America*  
**Bergsjö, Dag**, *Chalmers University of Technology, Sweden*  
**Bertoni, Alessandro**, *Blekinge Institute of Technology, Sweden*  
**Bertoni, Marco**, *Blekinge Institute of Technology, Sweden*  
**Blandino, Graziana**, *Politecnico di Torino, Italy*  
**Boahen, Samuel**, *Kwame Nkrumah University of Science and Technology, Ghana*  
**Bojčetić, Nenad**, *University of Zagreb FSB, Croatia*  
**Bonjour, Eric**, *Université de Lorraine, France*  
**Bordegoni, Monica**, *Politecnico di Milano, Italy*  
**Borg, Jonathan**, *University of Malta, Malta*  
**Borgianni, Yuri**, *Free University of Bozen|Bolzano, Italy*  
**Boujut, Jean-Francois**, *Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP, France*  
**Bouwhuis, Dominic G.**, *Eindhoven University of Technology, The Netherlands*  
**Brahma, Arindam**, *Chalmers University of Technology, Sweden*  
**Brisco, Ross**, *University of Strathclyde, United Kingdom*  
**Bursac, Nikola**, *Hamburg University of Technology, Germany*  
**Bylund, Nicklas**, *United States of America*  
**Cagan, Jonathan**, *Carnegie Mellon University, United States of America*  
**Caldwell, Nicholas**, *University of Suffolk, United Kingdom*  
**Calvo, Rafael A.**, *Imperial College London, United Kingdom*  
**Campean, Felician**, *University of Bradford, United Kingdom*  
**Cantamessa, Marco**, *Politecnico di Torino, Italy*  
**Carulli, Marina**, *Politecnico di Milano, Italy*  
**Caruso, Giandomenico**, *Politecnico di Milano, Italy*  
**Casakin, Hernan**, *Ariel University, Israel*  
**Cascini, Gaetano**, *Politecnico di Milano, Italy*  
**Cash, Philip**, *Northumbria University, United Kingdom*  
**Chamberlain, Paul**, *Sheffield Hallam University, United Kingdom*  
**Chantzaras, Christos**, *Technical University of Munich, Germany*  
**Chen, Liuqing**, *Zhejiang University, China*  
**Chiarello, Filippo**, *University of Pisa, Italy*  
**Childs, Peter R. N.**, *Imperial College London, United Kingdom*  
**Choi, Christina Youngmi**, *Royal College of Art, United Kingdom*  
**Chong, Leah**, *Massachusetts Institute of Technology, United States of America*  
**Chulvi, Vicente**, *Universitat Jaume I, Spain*  
**Ciliotta Chehade, Estefania**, *Northeastern University, United States of America*  
**Clarkson, P. John**, *University of Cambridge, United Kingdom*  
**Cluzel, François**, *Laboratoire Genie Industriel, CentraleSupélec, Université Paris-Saclay, France*  
**Colombo, Samuele**, *Politecnico di Torino, Italy*  
**Conrad, Franziska**, *University of Southampton, United Kingdom*  
**Conrad, Jan**, *Hochschule Kaiserslautern University of Applied Sciences, Germany*  
**Coskun, Aykut**, *Koç University, Türkiye*  
**Coutellier, Daniel**, *INSA Hauts-de-France, France*  
**D'Amico, Enrique**, *National University of La Plata, Argentina*  
**Deininger, Michael**, *Technical University of Denmark, Denmark*  
**Dekoninck, Elies Ann**, *University of Bath, United Kingdom*  
**Del Curto, Barbara**, *Politecnico di Milano, Italy*  
**Del Giorgio Solfa, Federico**, *National University of La Plata, Argentina*  
**Demke, Niels**, *Helmut-Schmidt-Universität/Universität der Bundeswehr Hamburg, Germany*  
**Eckert, Claudia**, *The Open University, United Kingdom*  
**Ehlers, Tobias**, *Gottfried Wilhelm Leibniz Universität Hannover, Germany*

Eifler, Tobias, *Technical University of Denmark, Denmark*  
Eisenbart, Boris, *Swinburne University of Technology, Australia*  
Ellman, Asko Uolevi, *Tampere University, Finland*  
Eneberg, Magnus, *KTH Royal Institute of Technology, Sweden*  
Eppinger, Steven, *Massachusetts Institute of Technology, United States of America*  
Erbe, Torsten, *ASML BV, The Netherlands*  
Erden, Zuhul, *Atilim University, Turkiye*  
Ericson, Åsa, *Luleå University of Technology, Sweden*  
Eriksson, Yvonne, *Mälardalen University, Sweden*  
Eynard, Benoit, *Université de Technologie de Compiègne, France*  
Fain, Nuša, *Carleton University, Canada*  
Fantoni, Gualtiero, *University of Pisa, Italy*  
Fargnoli, Mario, *Universitas Mercatorum, Italy*  
Farrugia, Philip, *University of Malta, Malta*  
Favi, Claudio, *Università degli studi di Parma, Italy*  
Fazelpour, Mohammad, *University of Maryland, United States of America*  
Ferrise, Francesco, *Politecnico di Milano, Italy*  
Fillingim, Kenton Blane, *Oak Ridge National Laboratory, United States of America*  
Finger - CMU, Susan, *Carnegie Mellon University, United States of America*  
Fiorineschi, Lorenzo, *University of Florence, Italy*  
Fischer, Xavier, *ESTIA, France*  
Formentini, Giovanni, *Aarhus University, Denmark*  
Forte, Sven, *CONTACT Software, Germany*  
Fortin, Clement, *Skolkovo Institute of Science and Technology, Russia*  
Fujita, Kikuo, *Osaka University, Japan*  
Gaha, Raoudha, *Université de Technologie de Compiègne, France*  
Gembariski, Paul Christoph, *Leibniz Universität Hannover, Germany*  
Georgiev, Georgi V., *Center for Ubiquitous Computing, University of Oulu, Finland*  
Gerhard, Detlef, *Ruhr-Universität Bochum, Germany*  
Gero, John, *UNC Charlotte, United States of America*  
Göbel, Jens Christian, *University of Kaiserslautern-Landau, Germany*  
Goker, Mehmet, *United States of America*  
Gomes, Giovana Monteiro, *Technical University of Denmark, Denmark*  
Gonçalves, Milene, *Delft University of Technology, The Netherlands*  
Gooch, Shayne, *University of Canterbury, New Zealand*  
Gopsill, James, *University of Bristol, United Kingdom*  
Götz, Stefan, *Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany*  
Goucher-Lambert, Kosa, *University of California, Berkeley, United States of America*  
Goudswaard, Mark, *University of Bristol, United Kingdom*  
Grafinger, Manfred, *TU Wien, Austria*  
Graziosi, Serena, *Politecnico di Milano, Italy*  
Grierson, Hilary, *University of Strathclyde, United Kingdom*  
Guagliano, Mario, *Politecnico di Milano, Italy*  
Guertler, Matthias R., *University of Technology Sydney, Australia*  
Gunn, Wendy, *Aalborg University, Denmark*  
Gupta, Ravi Kumar, *National Institute of Technical Teachers Training Bhopal, India*  
Hackenberg, Georg, *University of Applied Sciences Upper Austria, Austria*  
Hashemi Farzaneh, Helena, *MTU Aero Engines, Germany*  
Hassannezhad, Mohammad, *Queen Mary University of London, United Kingdom*  
Hatchuel, Armand, *MINES ParisTech, France*  
Hehenberger, Peter, *University of Applied Sciences Upper Austria, Austria*  
Hicks, Ben, *University of Bristol, United Kingdom*

**Hirz, Mario**, *Graz University of Technology, Austria*  
**Holder, Daniel**, *University of Stuttgart, Germany*  
**Horvat, Nikola**, *University of Zagreb FSB, Croatia*  
**Howard, Thomas J.**, *Technical University of Denmark, Denmark*  
**Howell, Bryan**, *Brigham Young University, United States of America*  
**Huang, Tao**, *East Tennessee State University, United States of America*  
**Hurst, Ada**, *University of Waterloo, Canada*  
**Husung, Stephan**, *Technische Universität Ilmenau, Germany*  
**I. Hallstedt, Sophie**, *Chalmers University of Technology, Sweden*  
**Iijima, Junichi**, *Tokyo University of Science, Japan*  
**Ilies, Horea**, *University of Connecticut, United States of America*  
**Inkermann, David**, *Technische Universität Clausthal, Germany*  
**Ioannou Kazamia, Kika**, *University of Nicosia, Cyprus*  
**Ion, William**, *University of Strathclyde, United Kingdom*  
**Isaksson, Ola**, *Chalmers University of Technology, Sweden*  
**Jagtap, Santosh**, *Indian Institute of Technology Guwahati, India*  
**Janković, Marija**, *CentraleSupélec, France*  
**Jean, Camille**, *Arts et Métiers ParisTech, France*  
**Johansson, Glenn**, *Lund University, Sweden*  
**Johansson Askling, Christian**, *Blekinge Institute of Technology, Sweden*  
**Jowers, Iestyn**, *The Open University, United Kingdom*  
**Jung, Eui Chul**, *Seoul National University, South Korea*  
**Jurčević Lulić, Tanja**, *University of Zagreb FSB, Croatia*  
**Juuti, Tero Sakari**, *Tampere University, Finland*  
**Kattwinkel, Daniela**, *Ruhr-Universität Bochum, Germany*  
**Keates, Simeon**, *University of Chichester, United Kingdom*  
**Keiding, Villads**, *Technical University of Denmark, Denmark*  
**Keldmann, Troels**, *Keldmann Healthcare A/S, Denmark*  
**Keshwani, Sonal**, *Indraprastha Institute of Information Technology, Delhi, India*  
**Khan, Mohammed Rajik**, *National Institute of Technology Rourkela, India*  
**Kiessling, Jonathan Max**, *University of Stuttgart, Germany*  
**Kim, Harrison**, *University of Illinois Urbana-Champaign, United States of America*  
**Kim, Yong Se**, *University of Turku, Finland*  
**Koch, Alexander**, *Bundeswehr University Munich, Germany*  
**Koh, Edwin**, *Singapore University of Technology and Design, Singapore*  
**Köhler, Christian**, *htw saar - University of Applied Sciences, Germany*  
**Kokkolaras, Michael**, *McGill University, Canada*  
**Komashie, Alexander**, *University of Cambridge, United Kingdom*  
**Komoto, Hitoshi**, *National Institute of Advanced Industrial Science and Technology (AIST), Japan*  
**Koronis, Georgios**, *University of the Aegean, Greece*  
**Kota, Srinivas**, *Birla Institute of Technology and Science, Pilani, India*  
**Kovacevic, Ahmed**, *City, University of London, United Kingdom*  
**Krause, Dieter**, *Hamburg University of Technology, Germany*  
**Krauss, Gordon**, *Harvey Mudd College, United States of America*  
**Kreimeyer, Matthias**, *University of Stuttgart, Germany*  
**Krus, Petter**, *Linköping University, Sweden*  
**Kwak, Minjung**, *Soongsil University, South Korea*  
**Lamé, Guillaume**, *CentraleSupélec, France*  
**Lee, Boyeun**, *University of Exeter Business School, United Kingdom*  
**Legaard, Jesper Falck**, *Design School Kolding, Denmark*  
**Legardeur, Jeremy**, *University of Bordeaux, ESTIA Institute of Technology, France*  
**Leroy, Yann**, *CentraleSupélec, France*

**Li, Jamy**, *Toronto Metropolitan University, Canada*  
**Liao, Ting**, *Stevens Institute of Technology, United States of America*  
**Lindhahl, Mattias**, *Linköping University, Sweden*  
**Liu, Ying**, *Cardiff University, United Kingdom*  
**Liu, Yuan**, *Beijing Institute of Fashion Technology, China*  
**Livotov, Pavel**, *Offenburg University of Applied Sciences, Germany*  
**López Forniés, Ignacio**, *Universidad de Zaragoza, Spain*  
**Lugnet, Johan**, *Luleå University of Technology, Sweden*  
**Luo, Jianxi**, *Singapore University of Technology and Design, Singapore*  
**Mahdjoub, Morad**, *Université de Technologie de Belfort-Montbéliard, France*  
**Maier, Anja**, *University of Strathclyde, United Kingdom*  
**Malmqvist, Johan**, *Chalmers University of Technology, Sweden*  
**Mandolini, Marco**, *Università Politecnica delle Marche, Italy*  
**Maranzana, Nicolas**, *Arts et Métiers ParisTech, France*  
**Marcocchia, Giulia**, *CY école de design, France*  
**Marconi, Marco**, *Università degli Studi della Tuscia, Italy*  
**Marini, Michele**, *Technical University of Denmark, Denmark*  
**Marjanović, Dorian**, *University of Zagreb FSB, Croatia*  
**Martinec, Tomislav**, *University of Zagreb FSB, Croatia*  
**Marxt, Christian**, *ETH Zurich, Switzerland*  
**Maslet, Cédric**, *Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP, France*  
**Maselli, Vincenzo**, *Sapienza Università di Roma, Italy*  
**Matsumae, Akane**, *Kyushu University, Japan*  
**Matthews, Jason Anthony**, *University of the West of England, United Kingdom*  
**Maurya, Santosh Kumar**, *Hitachi, Ltd., Japan*  
**McAloone, Tim**, *Technical University of Denmark, Denmark*  
**McKay, Alison**, *University of Leeds, United Kingdom*  
**Menshenin, Yaroslav**, *Université Grenoble Alpes, Grenoble INP, France*  
**Merlo, Christophe**, *ESTIA, France*  
**Miehling, Jörg**, *Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany*  
**Milčić, Diana**, *University of Zagreb Faculty of Graphic Arts, Croatia*  
**Millet, Dominique**, *SeaTech, Ecole d'ingénieurs - Université de Toulon, France*  
**Moehringer, Stefan**, *Simon Moehringer Anlagenbau GmbH, Germany*  
**Moghaddam, Mohsen**, *Northeastern University, United States of America*  
**Montagna, Francesca**, *Politecnico di Torino, Italy*  
**Moon, Seung Ki**, *Nanyang Technological University, Singapore*  
**Morosi, Federico**, *Politecnico di Milano, Italy*  
**Mörzl, Markus**, *Technical University of Munich, Germany*  
**Motte, Damien**, *Lund University, Sweden*  
**Mougaard, Krestine**, *Technical University of Denmark, Denmark*  
**Murakami, Tamotsu**, *University of Tokyo, Japan*  
**Ndiaye, Yakhoub**, *Singapore University of Technology and Design, Singapore*  
**Nespoli, Oscar**, *University of Waterloo, Canada*  
**Nicolas Perry, Nicolas**, *Arts et Métiers ParisTech, France*  
**Nielsen, Brita Fladvad**, *Norwegian University of Science and Technology, Norway*  
**Nizamis, Kostas**, *University of Twente, The Netherlands*  
**Nomaguchi, Yutaka**, *Osaka University, Japan*  
**Nordin, Axel**, *Lund University, Sweden*  
**Oehmen, Josef**, *Technical University of Denmark, Denmark*  
**Oh, David C.**, *North Carolina State University, United States of America*  
**Öhrwall Rönnbäck, Anna**, *Luleå University of Technology, Sweden*  
**Ölvander, Johan**, *Linköping University, Sweden*

**Onkar, Prasad**, *Indian Institute of Technology Hyderabad, India*  
**Otsuka, Akimasa**, *Sanyo-Onoda City University, Japan*  
**Paetzold-Byhain, Kristin**, *Technische Universität Dresden, Germany*  
**Panarotto, Massimo**, *Chalmers University of Technology, Sweden*  
**Papalambros, Panos Y.**, *University of Michigan, United States of America*  
**Papantonopoulos, Sotiris**, *Democritus University of Thrace, Greece*  
**Pavković, Neven**, *University of Zagreb FSB, Croatia*  
**Peters, Diane**, *Kettering University, United States of America*  
**Petiot, Jean-François**, *École Centrale de Nantes, France*  
**Pigosso, Daniela C. A.**, *Technical University of Denmark, Denmark*  
**Pinquii, Romain**, *Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP, France*  
**Plaumann, Benedikt**, *Hamburg University of Applied Sciences, Germany*  
**Pradel, Patrick**, *Loughborough University, United Kingdom*  
**Prakash, Raghu Vasu**, *Indian Institute of Technology Madras, India*  
**Pulm, Udo**, *Hamburg University of Applied Sciences, Germany*  
**Purwaningrum, Lu'lu'**, *Universitas Sebelas Maret, Indonesia*  
**Quattelbaum, Bastian**, *Hochschule Niederrhein University of Applied Sciences, Germany*  
**Qureshi, Ahmed**, *University of Alberta, Canada*  
**Ranscombe, Charlie**, *Swinburne University of Technology, Australia*  
**Reich, Yoram**, *Tel Aviv University, Israel*  
**Riel, Andreas**, *Grenoble INP, France*  
**Rohmer, Serge**, *Université de Technologie de Troyes, France*  
**Rossi, Monica**, *Politecnico di Milano, Italy*  
**Roth, Daniel**, *University of Stuttgart, Germany*  
**Rotini, Federico**, *University of Florence, Italy*  
**Royo, Marta**, *Universitat Jaume I, Spain*  
**Ruiz-Pastor, Laura**, *Universitat Jaume I, Spain*  
**Sakao, Tomohiko**, *Linköping University, Sweden*  
**Sarkar, Prabir**, *Indian Institute of Technology Ropar, India*  
**Sastre, Ricardo Marques**, *Federal University of Rio Grande do Sul, Brazil*  
**Schabacker, Michael**, *Otto von Guericke University Magdeburg, Germany*  
**Schaub, Harald**, *University of Bamberg, Germany*  
**Schleich, Benjamin**, *Technische Universität Darmstadt, Germany*  
**Schulte, Jesko**, *Blekinge Institute of Technology, Sweden*  
**Schulze, Sven-Olaf**, *INCOSE, Germany*  
**Seering, Warren**, *Massachusetts Institute of Technology, United States of America*  
**Self, James**, *Ulsan National Institute of Science and Technology, South Korea*  
**Şener, Bahar**, *Middle East Technical University, Turkiye*  
**Shafiee, Sara**, *Technical University of Denmark, Denmark*  
**Shea, Kristina**, *ETH Zurich, Switzerland*  
**Silva, Arlindo**, *Singapore University of Technology and Design, Singapore*  
**Singh, Ravindra**, *Delhi Technological University, India*  
**Singh, Vishal**, *Indian Institute of Science, Bangalore, India*  
**Siyam, Ghadir**, *BP, Canada*  
**Smojver, Ivica**, *University of Zagreb FSB, Croatia*  
**Snider, Chris**, *University of Bristol, United Kingdom*  
**Song, Binyang**, *Virginia Tech, United States of America*  
**Sosa, Ricardo**, *Monash University, New Zealand*  
**Stal-Le Cardinal, Julie**, *CentraleSupélec, France*  
**Stanković, Tino**, *ETH Zurich, Switzerland*  
**Stark, Rainer G.**, *Technische Universität Berlin, Germany*  
**Stauffer, Larry Allen**, *University of Idaho, United States of America*

**Stechert, Carsten**, *Ostfalia University of Applied Sciences, Germany*  
**Steinert, Martin**, *Norwegian University of Science and Technology, Norway*  
**Stetter, Ralf**, *RWU University of Applied Sciences Ravensburg-Weingarten, Germany*  
**Stylidis, Kostas**, *Chalmers University of Technology, Sweden*  
**Sullivan, Brendan**, *Politecnico di Milano, Italy*  
**Škec, Marija Majda**, *University of Zagreb FSB, Croatia*  
**Škec, Stanko**, *University of Zagreb FSB, Croatia*  
**Štorga, Mario**, *University of Zagreb FSB, Croatia*  
**Tan, James Ah Kat**, *Singapore*  
**Tavčar, Jože**, *Lund University, Sweden*  
**Thoben, Klaus-Dieter**, *Universität Bremen / BIBA, Germany*  
**Thoring, Katja**, *Technical University of Munich, Germany*  
**Tiradentes Souto, Virginia**, *University of Brasilia, Brazil*  
**Todeti, Somasekhara Rao**, *National Institute of Technology Karnataka, Surathkal, India*  
**Tomiyama, Tetsuo**, *International Professional University of Technology in Tokyo, Japan*  
**Törlind, Peter**, *Luleå University of Technology, Sweden*  
**Trauer, Jakob**, *em engineering methods AG, Germany*  
**Tyl, Benjamin**, *APESA, France*  
**Udiljak, Toma**, *University of Zagreb FSB, Croatia*  
**Umeda, Yasushi**, *The University of Tokyo, Japan*  
**Ura, Sharifu**, *Kitami Institute of Technology, Japan*  
**Usenyuk-Kravchuk, Svetlana**, *Ural Federal University, Russia*  
**Valderrama Pineda, Andres Felipe**, *Aalborg University, Denmark*  
**Valjak, Filip**, *University of Zagreb Faculty of Architecture, School of Design, Croatia*  
**Vallet, Flore**, *Laboratoire Genie Industriel, CentraleSupélec, Université Paris-Saclay, France*  
**Van der Loos, Mike**, *The University of British Columbia, Canada*  
**van der Vegte, Wilhelm Frederik**, *Delft University of Technology, The Netherlands*  
**Vareilles, Elise**, *ISAE-SUPAERO, France*  
**Vasantha, Gokula**, *Edinburgh Napier University, United Kingdom*  
**Vezzetti, Enrico**, *Politecnico di Torino, Italy*  
**Vielhaber, Michael**, *Saarland University, Germany*  
**Vietor, Thomas**, *Technische Universität Braunschweig, Germany*  
**Vignoli, Matteo**, *University of Bologna, Italy*  
**Vrdoljak, Milan**, *University of Zagreb FSB, Croatia*  
**Vrolijk, Ademir-Paolo**, *Government of Canada, Canada*  
**Vukašinović, Nikola**, *University of Ljubljana, Faculty of Mechanical Engineering, Slovenia*  
**Vuletic, Tijana**, *University of Glasgow, United Kingdom*  
**Wan, Fang**, *Southern University of Science and Technology, China*  
**Wang, Yan**, *Georgia Institute of Technology, United States of America*  
**Wang, Yue**, *The Hang Seng University of Hong Kong, Hong Kong*  
**Wartzack, Sandro**, *Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany*  
**Watts, Regan**, *University of Antwerp, Belgium*  
**Watz, Matilda**, *Blekinge Institute of Technology, Sweden*  
**Wendrich, Robert E.**, *Rawshaping Technology RBSO, The Netherlands*  
**Wenngren, Johan**, *Luleå University of Technology, Sweden*  
**Wever, Renee**, *Linköping University, Sweden*  
**Whitfield, Robert Ian**, *University of Strathclyde, United Kingdom*  
**Wynn, David**, *University of Auckland, New Zealand*  
**Xiong, Xue**, *Tongji University, China*  
**Yanagisawa, Hideyoshi**, *The University of Tokyo, Japan*  
**Yannou, Bernard**, *CentraleSupélec, France*  
**Yildirim, Unal**, *Hubei University of Automotive Technology, China*



**Yip, Man Hang**, *University of Cambridge, United Kingdom*  
**Zainal Abidin, Shahrinan**, *Universiti Teknologi MARA, Malaysia*  
**Zhang, Wendy**, *University of Canterbury, New Zealand*  
**Zhang, Yanfang**, *Kyushu University, Japan*  
**Zhang, Zai Fang**, *Shanghai University, China*  
**Ziegler, Martin**, *Helbling Technik Bern AG, Switzerland*  
**Zimmermann, Markus**, *Technical University of Munich, Germany*  
**Zolghadri, Marc**, *ISAE-Supméca, France*  
**Zorn, Stefan**, *University of Rostock, Germany*  
**Žeželj, Dragan**, *University of Zagreb FSB, Croatia*

# INTERNATIONAL DESIGN CONFERENCE - DESIGN 2024

20-23 MAY 2024, CAVTAT, DUBROVNIK, CROATIA

## TABLE OF CONTENTS

### Design Theory and Research Methods

Circularity in product engineering - towards a forward-looking approach across product generations <i>Albert Albers, Leonard Tusch, Michael Jäckle, Moritz Seidler and Christoph Kempf</i>	pp. 1 - 12
Feedback thought at the intersection of systems and design science <i>Igor Czermainski de Oliveira, Daniel Guzzo and Daniela C. A. Pigosso</i>	pp. 13 - 22
Introducing a framework to translate user scenarios into engineering specifications with “action steps” <i>Ulugbek Vahobjon Ugli Ismatullaev and KwanMyung Kim</i>	pp. 23 - 34
Innovation of meaning: design-driven study based on the interpretive theory of new meaning <i>Shotaro Kushi and Hideyoshi Yanagisawa</i>	pp. 35 - 44
Virtual design hackathons: a data collection framework <i>Tomislav Martinec, Filip Valjak, Nikola Horvat, Mark Goudswaard, Daniel Nygård Ege, Robert Ballantyne, Martin Francis Berg, Tobias Glaser, Cornelius Grosse, Zvonimir Lipšinić, Fanika Lukačević, Marek S. Lukaszewicz, Robert Mašović, Adam McClenaghan, Teresa Monti, Henrik H. Øvrebø, Pascal Schmitt, Vegar Stubberud, Emmanuel TJ Taiwo and Ana Lisac</i>	pp. 45 - 54
Playing against the rules: a new perspective on the potential of games and play as convivial and critical tools for imagining futures <i>Anna O. Meshcheryakova and Fabian Hemmert</i>	pp. 55 - 64
Human- and design-centric source: comparison using requirements checklist <i>Gouri Naik and V. Srinivasan</i>	pp. 65 - 74
Prototyping future societies: GIGA-mapping and narratives as design material <i>Brita Fladvad Nielsen, Gunika Rishi and Mari Bjerck</i>	pp. 75 - 84
A proposed framework for data-driven human factors evaluation <i>Isabelle Ormerod, Henrikke Dybvik, Mike Fraser and Chris Snider</i>	pp. 85 - 94
Operationalizing community-based open scientific design research benchmarks: application to model-based architecture design synthesis <i>Romain Pinquie, Lionel Roucoules, Pierre-Alain Yvars and Raphaël Chenouard</i>	pp. 95 - 104
Human interaction with the physical world: a brief review of studies on affordances <i>Khyati Priya, Jayesh Pillai and Avinash Shende</i>	pp. 105 - 114
Replication studies in engineering design - a feasibility study <i>Jonas Rode, Ingo Jonuschies, Sven Matthiesen and Kilian Gericke</i>	pp. 115 - 124
Future design narratives: an interdisciplinary approach to a decolonial glossary <i>Victoria Rodriguez Schon and Manuela Celi</i>	pp. 125 - 134
New combination of methods for supporting a simplified set-based design approach <i>Mikael Ström, Göran Gustafsson and Hans Johannesson</i>	pp. 135 - 144

A theory landscape of design: mapping the theoretical discourse of the discipline <i>Katja Thoring and Roland M. Mueller</i>	pp. 145 - 154
Shame cues: detecting shame in disguise and playing with new perspectives to inform the design process <i>June Kyong Trondsen</i>	pp. 155 - 164
A new approach to derive variation shares by combining the C&C <sup>2</sup> approach and the PGE model <i>Peter Michael Tröster, Giorgi Tsutskiridze, Tobias Dieck and Albert Albers</i>	pp. 165 - 174
A novel approach towards utilizing graph analyzing objects arrangement - case studies from Airbnb homes in New York and Boston <i>Yanhua Yao</i>	pp. 175 - 184

### Design Organisation, Collaboration and Management

The Karakuri IoT toolkit: a collaborative solution for ideating and prototyping IoT opportunities <i>Álvaro Aranda-Muñoz, Yuji Yamamoto and Kristian Sandström</i>	pp. 185 - 194
Aligning production requirements with product and production maturities: enhancing production preparation during product development <i>Rohith Areth Koroth, Fredrik Elgh, Martin Lennartsson and Dag Raudberget</i>	pp. 195 - 204
On-site analysis of work-related stress to design workers-friendly manufacturing systems <i>Graziana Blandino, Samuele Colombo and Francesca Montagna</i>	pp. 205 - 214
Implementing an open innovation process in the premium marine industry <i>Jonathan Burgess, Rob Fanner and Christian McLening</i>	pp. 215 - 224
Investigating low data consistency in work planning processes - causes, measures, and opportunities <i>Valesko Dausch, Christopher Langner, Daniel Roth, Matthias Kreimeyer and Matthias R. Guertler</i>	pp. 225 - 234
Exploring space manufacturing: designing a lunar factory for space-bound products in the new space economy <i>Eva De Francesco, Anna Ettorre, Federica Acerbi and Brendan P. Sullivan</i>	pp. 235 - 244
Human in the loop: revolutionizing industry 5.0 with design thinking and systems thinking <i>Mohammad Hossein Dehbozorgi, James Postell, David Ward, Carlo Leardi, Brendan P. Sullivan and Monica Rossi</i>	pp. 245 - 254
Human-centred engineering design: a cross-disciplinary product innovation practice <i>Sindre Wold Eikevåg, Jan Auernhammer, Christer W. Elverum, Henrikke Dybvik and Martin Steinert</i>	pp. 255 - 264
Scientometric exploration of responsible innovation: mapping the knowledge landscape <i>Nuša Fain, Nikola Vukašinić and Andrej Kastrin</i>	pp. 265 - 274
Prototyping industry 4.0: enhancing efficiency and productivity in small enterprises through iteration and low-cost solutions <i>Håkon Havsgård, Daniel Nygård Ege and Martin Steinert</i>	pp. 275 - 284
Gamification as an innovative method in user experience design <i>David Kessing, Tim Katzwinkel and Manuel Löwer</i>	pp. 285 - 294
Nurture employees' creative behaviors: unveiling the impact of design thinking on human organizational behavior <i>Michele Melazzini and Gianluca Carella</i>	pp. 295 - 304
Relation between purpose of individual agile elements and the need for their adaptation in product design & development <i>Marvin Michalides, Stefan Weiss, Emir Gadzo, Kristin Paetzold-Byhain and Alexander Koch</i>	pp. 305 - 314
The relation between service and digital transition: implications for designers <i>Teresa Monti, Samuele Colombo, Francesca Montagna and Gaetano Cascini</i>	pp. 315 - 324

- Weak tie interactions in networking: five types of interaction structures pp. 325 - 334  
*Georgina Nightingall and Weston Baxter*
- Towards a method for human-centred analysis of external variety pp. 335 - 344  
*Olga Sankowski and Dieter Krause*
- Towards agile automotive development: benefits, challenges and organizational changes pp. 345 - 352  
*Franziska Scharold and Kristin Paetzold-Byhain*
- Drivers and barriers for design and designers in interdisciplinary product development - a literature-based conceptual model pp. 353 - 362  
*Bernd Stoehr, Christian Koldewey and Roman Dumitrescu*

### **Design Information and Knowledge**

- Understanding and definition of scanning and monitoring of the future space in the context of the product engineering process pp. 363 - 372  
*Albert Albers, Carsten Thümmel, Jessica Schmidt, Stefan Eric Schwarz, Michael Schlegel, Andreas Siebe and Tobias Düser*
- Supporting the digital thread through the principles of complementarity pp. 373 - 382  
*Yana Brovar, Saina Sadeghzadeh and Clement Fortin*
- Design delusions and prototyping: eliciting the link between prototypes and product performance pp. 383 - 392  
*Daniel Nygård Ege, Mark Goudswaard, James Gopsill, Ben Hicks and Martin Steinert*
- The evolution of design patterns in joint decision-making spaces pp. 393 - 402  
*Hermann Wolfram Klöckner and Katja Thoring*
- Enhancing design representations of information and knowledge of complex and long-living assets by applying system modelling techniques pp. 403 - 412  
*Fabian Niklas Laukotka, Markus Christian Berschik and Dieter Krause*
- Introducing a multipliable BOM-based automatic definition of information retrieval in plant engineering pp. 413 - 422  
*Max Layer, Sebastian Neubert and Ralph Stelzer*
- Automatic knowledge graph creation from engineering standards using the example of formulas pp. 423 - 432  
*Janosch Luttmer, Mostafa Kandel, Dominik Ehring and Arun Nagarajah*
- Intelligent competency mapping for improving knowledge management in consulting firms pp. 433 - 442  
*MohammadReza Mirafzal, Sabine Fhal, Piyush Wadhera and Julie Stal-Le Cardinal*
- How to facilitate comparability among product models: applying a standardizing description approach pp. 443 - 452  
*Lukas Paehler and Sven Matthiesen*
- Visualizing and analysing data-driven shift from decentralized to centralized automotive E/E architectures pp. 453 - 462  
*Tejas Pravin Phadnis, Nils Feyerabend and Joachim Axmann*
- Integration of product development data for further ontological utilization pp. 463 - 472  
*Jessica Pickel, Sebastian Bickel, Stefan Goetz and Sandro Wartzack*
- Enhancing knowledge management in the engineering design process through a communication platform pp. 473 - 482  
*Sinan Ugurlu, Manfred Grafinger, Detlef Gerhard and Pinar Demircioglu*

### **Design Methods and Tools**

- Evaluation of a multi-user requirements axiomatic design decision support tool for manufacturing process selection pp. 483 - 492  
*Edward Abela, Philip Farrugia, Pierre Vella, Glenn Cassar and Maria Victoria Gauci*

Applying a product modularization approach on the case of a battery pack <i>Julia Beibl, Katharina Zumach, Sven Wehrend, Marc Züfle, Eugen Hein, Benedikt Plaumann and Dieter Krause</i>	pp. 493 - 502
Modeling uncertain requirements <i>Lukas Block</i>	pp. 503 - 512
Designing a framework for actuators for adaptive structures <i>Matthias J. Bosch, Markus Nitzlader, Matthias Bachmann, Hansgeorg Binz, Lucio Blandini and Matthias Kreimeyer</i>	pp. 513 - 522
Using cluster analysis to enhance a method for the management of disturbance factors via product structures <i>Richard Breimann, Laura Luran Sun and Eckhard Kirchner</i>	pp. 523 - 532
Automatic evaluation of the misplacement risk during manual assembly based on a CAD design <i>Alexander De Cock, Ncamisile Khanyile and Bieke Decraemer</i>	pp. 533 - 542
Developing a method to improve unknown identification and design efforts for environmental transition: a case study in the packaging industry <i>Marion Deshoulières, Pascal Le Masson and Benoît Weil</i>	pp. 543 - 552
Challenges of the integrative product and production system development <i>Jan-Philipp Disselkamp, Ben Schütte and Roman Dumitrescu</i>	pp. 553 - 562
Data- and simulation-based material behaviour prediction <i>Anton Dybov, Carina Fresemann and Rainer Stark</i>	pp. 563 - 572
Data-driven support for CAD parts modelling based on automated estimated production planning - approach and user research <i>Martin Erler, Sebastian Langula, Christian Wölfel, Julia Schneider, Christiane Kunath and Michael Königs</i>	pp. 573 - 582
Learnings from developing a custom virtual assembly environment for mountability issues of cooling cabinets <i>Georg Hackenberg and Christian Zehetner</i>	pp. 583 - 592
From tears to tiers - architectural principles for federated PLM landscapes <i>Erik Herzog, Johan Tingström, Johanna Wallén Axehill, Åsa Nordling Larsson and Christopher Jouannet</i>	pp. 593 - 602
What can we learn from outstanding designers? The relationship between design expertise and prototyping <i>Birgit Jobst, Katja Thoring and Petra Badke-Schaub</i>	pp. 603 - 612
New methodology for the characterization of 3D model reconstructions to meet conditions of input data and requirements of downstream applications <i>Robert Joost, Stephan Mönchinger and Kai Lindow</i>	pp. 613 - 622
Enhancing the IFM framework based on a meta-analysis of other design methods <i>Merlin Krüger, Kilian Gericke and Stefan Zorn</i>	pp. 623 - 632
Future-robust product design - validating influencing factors on upgradeable mechatronic systems <i>Maximilian Kuebler, Carolin Lange, Bastian Glasmacher, Tobias Düser and Albert Albers</i>	pp. 633 - 642
A comparative study of VR CAD modelling tools for design <i>Aman Kukreja, Christopher Michael Jason Cox, James Gopsill and Chris Snider</i>	pp. 643 - 652
Engineering designers' CAD performance when modelling from isometric and orthographic projections <i>Fanika Lukačević, Niccolò Becattini and Stanko Škec</i>	pp. 653 - 662
The impact of specialized software on concept generation <i>Julian Martinsson Bonde, Richard Breimann, Johan Malmqvist, Eckhard Kirchner and Ola Isaksson</i>	pp. 663 - 672

Design methodology for optimal sensor placement for cure monitoring and load detection of sensor-integrated, gentelligent composite parts <i>Sören Meyer zu Westerhausen, Alexander Kyriazis, Christian Hühne and Roland Lachmayer</i>	pp. 673 - 682
Are generative design tools creative? A characterisation of tools throughout the design process <i>Owen Rahmat Peckham, Ben Hicks and Mark Goudswaard</i>	pp. 683 - 692
Reducing uncertainty regarding customer expectations for a sustainable car interior design integrated in a data-informed design approach <i>Bastian Quattelbaum, Lara Amelie Geiger, Kostas Styliadis and Rikard Söderberg</i>	pp. 693 - 702
An approach for reverse engineering and redesign of additive manufactured spare parts <i>Marija Rešetar, Filip Valjak, Marina Grabar Branilović, Mario Šercer and Nenad Bojčetić</i>	pp. 703 - 712
Assessing yacht design processes: a comparison of traditional and integrated methodologies <i>Ludovico Ruggiero, Massimo Piccioni and Arianna Bionda</i>	pp. 713 - 722
A novel heuristic approach to detect induced forming defects using point cloud scans <i>Muhammad Shahrulkh Saeed, Sheharyar Faisal, Boris Eisenbart, Matthias Kreimeyer, Muhammad Hamas Khan, Muhammad Zeeshan Arshad, Racim Radjef, Markus Wagner and Eiman Nadeem</i>	pp. 723 - 734
Factors that determine design similarity <i>Kazuko Sakamoto and Yuya Kinzuka</i>	pp. 735 - 744
Future-robust product portfolio development: insights into the advancement of product portfolios in companies - an interview study <i>Michael Schlegel, Markus Just, Ingrid Wiederkehr, Carsten Thümmel, Christoph Kempf, Christian Koldewey, Roman Dumitrescu and Albert Albers</i>	pp. 745 - 754
Management of rule-based product-portfolios with high variance: a systematic literature review <i>Thorsten Schmidt and Frank Mantwill</i>	pp. 755 - 764
Decision making support for designers at the early design stage regarding narrowing down the range values of design variables <i>Yoshiyuki Shimada, Daichi Akutsu, Shinnosuke Kodama, Shuichi Kondo, Shigeki Hiramatsu, Seiji Fukui, Hiroshi Unesaki, Takashi Hatano, Kazuhiro Aoyama and Masato Inoue</i>	pp. 765 - 774
Mixed reality prototyping: a framework to characterise simultaneous physical/virtual prototyping <i>Chris Snider, Aman Kukreja, Christopher Michael Jason Cox, James Gopsill and Lee Kent</i>	pp. 775 - 784
Designing lab-on-a-chip systems with attribute dependency graphs <i>Johannes Soika, Tobias Wanninger, Patrick Muschak, Sebastian Schwaminger, Sonja Berensmeier and Markus Zimmermann</i>	pp. 785 - 794
A model to describe logistics service architecture based on product architecture <i>Erika Marie Strøm, Tine Meidahl Münsberg and Lars Hvam</i>	pp. 795 - 804
Data-informed design in the automotive industry: customer acceptance study in Sweden and China on radical car design <i>Kostas Styliadis, Bastian Quattelbaum, Florian Konrad, Joe Simpson, Samuel Lorin and Rikard Söderberg</i>	pp. 805 - 814
Enhancing design automation for components of electric machines: a systematic approach <i>Niklas Umland, Anton Wiberg, Kora Winkler, Jakob Jung and David Inkermann</i>	pp. 815 - 824
Optimization-based design support for engineer-to-order product quotation <i>Olle Vidner, Anton Wiberg, Robert Pettersson, Johan A. Persson and Johan Ölvander</i>	pp. 825 - 834
Evaluation of the methodical framework for the management of uncertainty in the context of the integration of sensory functions <i>Peter Welzbacher, Sawa Vinzenz Witt, Yanik Koch and Eckhard Kirchner</i>	pp. 835 - 844
Perception-centric design considerations for low-cost haptic emulation in prototypes <i>Mike Miroslav Wharton, Christopher Michael Jason Cox, James Gopsill, Aman Kukreja and Chris Snider</i>	pp. 845 - 854

6 degree of freedom positional object tracking for physical prototype digitisation <i>Michael Wyrley-Birch, Aman Kukreja, James Gopsill, Christopher Michael Jason Cox and Chris Snider</i>	pp. 855 - 864
Criticality-based planning of prototype sequences <i>Stefan Zorn, Tobias Glaser and Kilian Gericke</i>	pp. 865 - 874
<b>Human Behaviour and Design Creativity</b>	
The imperative of assessing negative creativity in design: a multi-dimensional approach <i>Petra Badke-Schaub, Katja Thoring, Harald Schaub and Roland M. Mueller</i>	pp. 875 - 884
Breaking cultural barriers: an integrated methodology for challenge-driven co-creation projects <i>Annika Bastian, Christoph Kempf, Paulin Rudolph and Albert Albers</i>	pp. 885 - 894
Creativity of products as meant by ordinary people: to what extent do novelty and usefulness matter? <i>Aurora Berni, Yuri Borgianni and Demis Basso</i>	pp. 895 - 904
The use of occurrences of ideas for constructing and characterizing the design space <i>Hernan Casakin, Hadas Sopher, John S. Gero and Or Haim Anidjar</i>	pp. 905 - 914
Exploring metacognitive processes in design ideation with text-to-image AI tools <i>Hao-Yu Chang and Jo-Yu Kuo</i>	pp. 915 - 924
Chronobiology of pupil dilation in design students during idea generation <i>Samuele Colombo, John S. Gero, Alessandro Mazza and Marco Cantamessa</i>	pp. 925 - 934
Design strategies to facilitate second-hand clothing acquisition <i>Marie Das, Ingrid Moons and Els Du Bois</i>	pp. 935 - 944
Investigating differences in brain activity between physical and digital prototyping in open and constrained design tasks <i>Henrikke Dybvik, Adam McClenaghan, Mariya Stefanova Stoyanova Bond, Asbjørn Svergja, Tripp Shealy, Chris Snider, Pasi Aalto, Martin Steinert and Mark Goudswaard</i>	pp. 945 - 954
How designers think creatively: an exploratory study in the use of visual and emotional mental imagery <i>Ian Marcus Edgewood, Ross Brisco and Andrew Wodehouse</i>	pp. 955 - 964
Narrative drives design decision-making <i>Scott Ferguson, Lisa Retzlaff, Kris Bryden and Kenneth Mark Bryden</i>	pp. 965 - 974
The influence of culture on creativity in ideation: a review <i>Zhengya Gong, Milene Gonçalves, Vijayakumar Nanjappan and Georgi V. Georgiev</i>	pp. 975 - 984
Evaluating design approaches for encouraging behavior change in editors: exploring a digital nudging strategy in a non-personalized recommender system to promote adoption of augmented analytics <i>Tanja Heinrich and Oliver Szasz</i>	pp. 985 - 994
Unravelling experiences, barriers, and design strategies for encouraging reusable takeaway cup usage <i>Laure Herweyers, Els Du Bois and Ingrid Moons</i>	pp. 995 - 1004
Possession and dispossession: a dual phenomenon in digital artefacts <i>Pranati Kompella and Neelakantan Keshavan</i>	pp. 1005 - 1014
The EmotionProbe: an exploration of design students' emotions when designing <i>Hazar Taissier Marji, Paul Rodgers and Ross Brisco</i>	pp. 1015 - 1024
Mediators of the relationship between physical indoor spaces and individual creativity <i>Chris McTeague and Katja Thoring</i>	pp. 1025 - 1034

DS-Viz: a method for visualising design spaces <i>Esdras Paravizo and Nathan Crilly</i>	pp. 1035 - 1044
Exploring gesture generation for smartwatches: is user elicitation enough? <i>Saugata Pramanik, Sahil Pabbathi and Shakuntala Acharya</i>	pp. 1045 - 1054
Design to fail? The reasonably foreseeable failure and misuse <i>Harald Schaub and Petra Badke-Schaub</i>	pp. 1055 - 1064
Towards cycling engagement by mapping design interventions to observed barriers: an example from Glasgow's bike share programme <i>Mia Shepherd, Tripp Shealy, Lewis Urquhart, Deirdre Harrington and Anja Maier</i>	pp. 1065 - 1074
Characteristics of paralinguistic communication indicating pre-resonance during co-creative design grasped by decision tree analysis <i>Karen Shichijo and Akane Matsumae</i>	pp. 1075 - 1084
Assessment of structuredness of problems in design <i>Sanjay Singh and Amaresh Chakrabarti</i>	pp. 1085 - 1094
Effect of team diversity on teams' design space: a computational approach <i>Marija Majda Škec, Mario Štorga and John S. Gero</i>	pp. 1095 - 1104
"Ideas are really..." - supporting collaborative dialogues and community of practice for innovation via CO:RE cards <i>Safia Najwa Suhaimi, Andrew Walters and Jo Ward</i>	pp. 1105 - 1114
Co-design in virtual environments with 3D scanned childcare rooms in social virtual reality <i>Yuki Taoka, Momoko Nakatani, Takumi Sato, Kaho Kagohashi, Fuyumi Iwasawa, Shouichi Hasegawa, Shigeru Owada and Shigeki Saito</i>	pp. 1115 - 1124
Gender differences in design creativity <i>Virginia Tiradentes Souto, Luciane Maria Fadel and Carla Galvão Spinillo</i>	pp. 1125 - 1134
Exploring designers' cognitive abilities in the concept product design phase through traditional and digitally-mediated design environments <i>Muhammad Tufail, Shahab Zaib, Sahr Uzma, Raja Mubashar Karim and KwanMyung Kim</i>	pp. 1135 - 1146
An EEG study to understand semantic and episodic memory retrieval in creative processes <i>Yuan Yin and Peter Childs</i>	pp. 1147 - 1156
<b>Design for Sustainability</b>	
Interpretation of sustainability philosophies into product design for awareness, cohesion, and equity <i>Laura Isabel Acevedo, Daniela C. A. Pigosso and Tim C. McAlone</i>	pp. 1157 - 1168
Interdisciplinary Transition Innovation, Management, and Engineering (InTIME) Design: an intersection analysis of design approaches for whole-system sustainability <i>Florian Ahrens, Susan Krumdieck and Daniel Kenning</i>	pp. 1169 - 1178
Remanufacturing as a circular design strategy in healthcare: integrating socio-technical and environmental-economic assessments <i>Amanda Worsøe Andersen, Siri Fritze Jørgensen, Wendy Gunn and Monia Niero</i>	pp. 1179 - 1188
Uncovering rebound effects of sufficiency-oriented product-service systems: a systematic review <i>Elise Marie Andrew, Jeroen van den Bergh and Daniela C. A. Pigosso</i>	pp. 1189 - 1198
Circular products: the balance between sustainability and excessive margins in design <i>Arindam Brahma, Sophie I. Hallstedt, David C. Wynn and Ola Isaksson</i>	pp. 1199 - 1208
Product-service systems in large automotive OEMs: characterising the decision-making process when developing and introducing vehicle sharing/pooling schemes <i>Lucia C. Burtnik Urueta and Elies Dekoninck</i>	pp. 1209 - 1218



Durability as a techno-socio-economic concept <i>Felician Campean and Claudia Eckert</i>	pp. 1219 - 1228
Understanding a SPSS-aided packaging-free shopping practice <i>Ruihua Chen and Xueqing Miao</i>	pp. 1229 - 1238
Developing readiness levels for risk assessment in green transition engineering projects <i>Andy Mattulat Filipovic, Torgeir Welø and Josef Oehmen</i>	pp. 1239 - 1248
Assessing the disassembly performance of washing machines through the design for circular disassembly methodology <i>Giovanni Formentini, Thorvald Alrø Martiny, Christian Møller, Teodor Vernica and Devarajan Ramanujan</i>	pp. 1249 - 1258
Design and collaboration strategies for circular economy implementation across the value chain <i>Giovana M. Gomes, Daniela C. A. Pigosso and Tim C. McAlóone</i>	pp. 1259 - 1268
What Italian furniture companies do towards sustainable transition? Design actions and strategies showcased during Milan Design Week 2023 <i>Silvia Maria Gramegna, Francesca Mattioli and Xue Pei</i>	pp. 1269 - 1278
Identifying rebound effects in product-service systems: actors, mechanisms, triggers and drivers <i>Daniel Guzzo and Daniela C. A. Pigosso</i>	pp. 1279 - 1288
Scenario building guidelines for sustainable innovation <i>François Haeberle, Giacomo Parolin and Daniela C. A. Pigosso</i>	pp. 1289 - 1298
Operationalizing leverage points in business model design for sustainable systems change <i>Cadence Hsien and Steve Evans</i>	pp. 1299 - 1308
Modelling an ecosystem of business models in a circular value chain: the circular business ecosystem model canvas <i>Avyay Jamadagni, Marco Aurisicchio and Lars Nybom</i>	pp. 1309 - 1318
Systems thinking towards holistic, sustainability-oriented assessment and decision-making for lightweighting <i>Katharina Johnston-Lynch, Robert Ian Whitfield and Dorothy Evans</i>	pp. 1319 - 1328
Alignment of the functional structure with sustainability aspects in product development - combining the strengths of the functional structure with the MECO matrix <i>Björn Kokoschko, Laura Augustin, Michael Schabacker and Christiane Beyer</i>	pp. 1329 - 1338
Data-driven life cycle assessment for mechatronic systems: a comparative analysis of environmental impact assessments <i>Artur Krause, Steffen Wagenmann, Katharina Ritzer, Albert Albers and Nikola Bursac</i>	pp. 1339 - 1348
Navigating complexity: visualising sustainable product development knowledge through dynamic heatmaps <i>Gerald Kremer, Sarah Aboumorra and Rainer Stark</i>	pp. 1349 - 1358
Sustainability criteria for introducing new technologies in low-income contexts <i>Adam Mattias Mallalieu, Amanda Jonasson, Sara Petersson, Marlene Rosendal, Sophie I. Hallstedt, Lars Almefelt and Ola Isaksson</i>	pp. 1359 - 1368
Selecting sustainability indicators for smart product design based on industry 4.0/5.0 technologies: analysis and proposal of a methodological framework <i>Bertrand Marconnet, Raoudha Gaha, Carla Assuad, Kristian Martinsen and Benoît Eynard</i>	pp. 1369 - 1378
Design strategies for consumers' continued usage of reusable packaging systems (RPSS) <i>Xueqing Miao, Lise Magnier and Ruth Mugge</i>	pp. 1379 - 1388
Assessing sustainable recyclability of battery systems: a tool to aid design for disassembly <i>Fabio Marco Monetti, Pablo Zaguirre Martínez and Antonio Maffei</i>	pp. 1389 - 1398

What's the catch? Trade-off challenges in early design for sustainability <i>Giàcomo Parolin, Tim C. McAloone and Daniela C. A. Pigosso</i>	pp. 1399 - 1408
Designing products for material simplifiers: antinomy or prospective for design? <i>Céline Perea and Cédric Masclat</i>	pp. 1409 - 1416
Consumer behaviour in the context of circular economy: a systematic literature review <i>Nicole Sofia Rohsig Lopez and Jérémy Legardeur</i>	pp. 1417 - 1426
Driving sustainable mobility: a study of electric vehicle adoption in rural India <i>Aniruddh Dnyandeo Satpute, Parinita Rai and Prasad Onkar</i>	pp. 1427 - 1436
Incorporating sustainability into product lifecycle management: a systematic literature review <i>Anne Seegrün, Louis Hardinghaus, Theresa Riedelsheimer and Kai Lindow</i>	pp. 1437 - 1446
A virtual reality experience to raise sustainability awareness within the fashion industry <i>Elena Spadoni, Andrea Fiocca, Gianluca Zoni, Lina Maria Useche Infante, Lidia Cerutti, Paolo Maccarrone, Marina Carulli and Monica Bordegoni</i>	pp. 1447 - 1456
Comparison of e-scooter tyre performance using rolling resistance trailer <i>George Stilwell, Shayne Gooch and Martial Lafitte</i>	pp. 1457 - 1466
Tactility in perception of biobased composites <i>Manu Thundathil, Nicholas John Emerson, Ali Reza Nazmi, Bahareh Shahri, Jörg Müssig and Tim Huber</i>	pp. 1467 - 1476
A transition approach for reuse and repair of manufactured products <i>Flore Vallet, Benjamin Tyl, François Cluzel and Cédric Masclat</i>	pp. 1477 - 1486
Using the low-tech concept to create scenarios: an analysis of its potential to design for sustainable urban future <i>Flore Vallet and Tjark Gall</i>	pp. 1487 - 1496
Explaining the rebound effects of sustainable design: a behavioural perspective <i>Imke G. H. Van der Loo and Daniela C. A. Pigosso</i>	pp. 1497 - 1506
Towards a unified absolute environmental sustainability decoupling indicator <i>Manon Villers, Daniela C. A. Pigosso, Thomas J. Howard and Tim C. McAloone</i>	pp. 1507 - 1516
Integration of sustainability into product development: insights from an industry survey <i>Sachira Vilochani, Tim C. McAloone and Daniela C. A. Pigosso</i>	pp. 1517 - 1526
Assessment of empowerment via inclusion of people in product lifecycle processes <i>Naz Yaldiz and Amaresh Chakrabarti</i>	pp. 1527 - 1536
Design measures to address carbon emissions in products' lifecycle: an empirical analysis <i>Thayla Zomer, Eduardo de Senzi Zancul, Paulo Augusto Cauchick-Miguel and Eloiza Kohlbeck</i>	pp. 1537 - 1546
<b>Design for Healthcare</b>	
Requirements elicitation in board game design for children with developmental language disorder (DLD) <i>Edward Abela, Emanuel Balzan, Philip Farrugia, Donia Stellini and Daniela Gatt</i>	pp. 1547 - 1556
Bridging the gap: a multidisciplinary approach to integrated care solutions for the aging population <i>Max John Bateson and Yonghun Lim</i>	pp. 1557 - 1566
Design of a healthcare ecosystem to improve user experience in pediatric urotherapy <i>Lola Bladt, Rose-Farah Blomme, Anka J. Nieuwhof-Leppink, Alexandra Vermandel, Gunter De Win and Lukas Van Campenhout</i>	pp. 1567 - 1576
Implementing the model-based systems engineering (MBSE) approach to develop an assessment framework for healthcare facility design <i>Tahere Golgolnia, Timoleon Kipouros, P. John Clarkson, Gesine Marquardt and Maja Kevdzija</i>	pp. 1577 - 1586

- Surveying factors that influence healthcare personnel in the transition to reusable surgical gowns pp. 1587 - 1596  
*Charlotte Harding, Ingrid Moons, Regan Watts, Gunter De Win and Els Du Bois*
- Designing remote patient and family centred interventions: an exploratory approach pp. 1597 - 1606  
*Julian Houwen, Ragini S. Karki, Veronica R. Janssen, Valeria Pannunzio, Douwe E. Atsma and Maaïke S. Kleinsmann*
- Design as a practice for implementing complex digital health: preliminary results from an interview study in the Netherlands pp. 1607 - 1616  
*Fredrik K. Karlsson, Valeria Pannunzio, Dirk Snelders and Maaïke S. Kleinsmann*
- Emotional design of medical devices: exoskeletons and post-stroke recovery devices pp. 1617 - 1626  
*Frederik Kiersgaard Lund, Luke Edward Eric Feast, Milo Marsfeldt Skovfoged, Hendrik Knoche, Mostafa Mohammadi, Lotte N. S. Andreasen Struijk and Linda Nhu Laursen*
- Towards designing for health outcomes: implications for designers in eHealth design pp. 1627 - 1636  
*Hosana Cristina Morales Ornelas, Maaïke S. Kleinsmann and Gerd Kortuem*
- Designing healthcare systems for earlier diagnosis and prevention of dementia pp. 1637 - 1646  
*Coco Newton, Jiwon Jung, Maaïke S. Kleinsmann and P. John Clarkson*
- StudyWell: a co-design project for enhancing student mental health and wellbeing through service design and relational welfare pp. 1647 - 1656  
*Brita Fladvad Nielsen, Nina Petersen Reed, Ottar Ness, Mari Bjerck, Arnfrid Farbu Pinto, Ipar Memet and Katie Aurora Lineer*
- Co-designing for the NHS: the development of sustainable theatre garments pp. 1657 - 1666  
*Paul Rodgers, Euan Winton, Lewis Urquhart, Jonathan O'Reilly and Carole Anderson*
- Toward a design methodology for configuring assistive wearables pp. 1667 - 1676  
*David W. Rosen, Christina Youngmi Choi and Anoop Kumar Sinha*
- Considerations in the testing of a minimum viable product in healthcare pp. 1677 - 1686  
*Komal Shah and Manish Arora*
- Evaluating a web-based guide for designing digital patient experiences: preliminary results of a user test with design students pp. 1687 - 1696  
*Tingting Wang, Yun Wang, P. John Clarkson, Judith Rietjens and Marijke Melles*
- Designing positive emotional experiences of wearable medical technology for type 1 diabetes pp. 1697 - 1706  
*Ryan Charles Williams and Yonghun Lim*

### **Design for Additive Manufacturing**

- Play well, print well: using LEGO bricks as an intuitive benchmarking tool for 3D printers pp. 1707 - 1716  
*Alan Air and Andrew Wodehouse*
- Additively manufactured 3D micro scarf adhesive joints pp. 1717 - 1726  
*Michael Ascher and Ralf Späth*
- Design and evaluation of non-planar material extrusion on a 3-axis printer pp. 1727 - 1736  
*Samuel Bengtsson, Axel Nordin and Jože Tavčar*
- Design challenges in leveraging binder jetting technology to innovate the medical instrument field pp. 1737 - 1746  
*Lorenzo Cocchi, Marco Mariani, Serena Graziosi, Roberto Viganò and Nora Lecis*
- A knowledge-driven, integrated design support tool for additive manufacturing pp. 1747 - 1756  
*Claudius Ellsel and Rainer Stark*
- Additive manufacturing of individual bone implants made of bioresorbable calcium phosphate cement using the example of large skull defects pp. 1757 - 1768  
*Stefan Holtzhausen, Philipp Sembdner, Martin Pendzik, Holger Wilhelm Rudolf Schmidt and Kristin Paetzold-Byhain*

The energy performance assessment method to establish the best part build orientation in additive manufacturing <i>Marco Mandolini, Mikhailo Sartini, Marta Rossi, Claudio Favi and Marco Marconi</i>	pp. 1769 - 1778
Investigating designers' preferred learning media to design for additive manufacturing <i>Martins Obi, Patrick Pradel, Matt Sinclair, Richard Bibb and Mark Evans</i>	pp. 1779 - 1788
Stress concentrations and design for additive manufacturing: a design artefact approach to investigation <i>Didunoluwa Obilanade, Owen Rahmat Peckham, Adam McClenaghan, James Gopsill and Peter Törlind</i>	pp. 1789 - 1798
Exploring high-stiffness pellets as filaments in fused filament fabrication <i>Martin Lilletvedt Rasmussen, Simen Gjethammer Grønvik, Henrik H. Øvrebø, Ben Hicks, Chris Snider, Martin Steinert, Christer W. Elverum and Sindre Wold Eikevåg</i>	pp. 1799 - 1808
A Bayesian expert system for additive manufacturing design assessment <i>Benedict Alexander Rogers, Neill Campbell, Mandeep Dhanda, Alexander James George Lunt, Elise Catherine Pegg and Vimal Dhokia</i>	pp. 1809 - 1818
An analytic cost model for bound metal deposition <i>Mikhailo Sartini, Iacopo Bianchi, Alessio Vita, Michele Germani and Marco Mandolini</i>	pp. 1819 - 1828
A proposal for guiding the selection of suitable DfAM support based on experiential knowledge <i>Pascal Schmitt, Lisa Siewert and Kilian Gericke</i>	pp. 1829 - 1838
Optical and mechanical testing of 3D printed parts made of high-viscosity silicone to identify process parameters and design advice for 3D printing and printer development <i>Joel Schön, Robin Löffler and Michael Koch</i>	pp. 1839 - 1848
Printing study and design guideline for small hollow structures in medical technology <i>Eve Sobirey, Marie Wegner, Fabian Niklas Laukotka and Dieter Krause</i>	pp. 1849 - 1858
Democratising dry adhesion development with consumer-grade AM <i>Vegar Stubberud, Martin Steinert and Håkon Jarand Dugstad Johnsen</i>	pp. 1859 - 1868
Providing a knowledge-based design catalog as an approach to support the development of design for additive manufacturing skills <i>Gregory-Jamie Tüzün, Daniel Roth and Matthias Kreimeyer</i>	pp. 1869 - 1878
Topology optimisation of multiple robot links considering screw connections <i>Tobias Wanninger, Jintin Frank and Markus Zimmermann</i>	pp. 1879 - 1888
Additive manufacturing in fluid power with novel application to hydraulic pump design <i>Anton Wiberg, Liselott Ericson, Johan A. Persson and Johan Ölvander</i>	pp. 1889 - 1898
Analysing shrinkage compensation in additive manufacturing: a comparative study of reverse engineering and gauge-based methods <i>Alessio Zanini, Marco Marconi and Gianluca Rubino</i>	pp. 1899 - 1908
 <b>Artificial Intelligence and Data-Driven Design</b>	
Machine learning-based virtual sensors for reduced energy consumption in frost-free refrigerators <i>Alejandro Alcaraz, Dennis Ilare, Alessandro Mansutti and Gaetano Cascini</i>	pp. 1909 - 1918
Datasets in design research: needs and challenges and the role of AI and GPT in filling the gaps <i>Mohammad Arjomandi Rad, Tina Hajali, Julian Martinsson Bonde, Massimo Panarotto, Kristina Wärmefjord, Johan Malmqvist and Ola Isaksson</i>	pp. 1919 - 1928
Critical component detection in assemblies: a graph centrality approach <i>Robert Ballantyne, Adam McClenaghan, Oliver Schiffmann and Chris Snider</i>	pp. 1929 - 1938

- Stimulating design ideation with artificial intelligence: present and (short-term) future  
*Aurora Berni, Yuri Borgianni, Federico Rotini, Milene Gonçalves and Katja Thoring* pp. 1939 - 1948
- Extending the function failure modes taxonomy for intelligent systems with embedded AI components  
*Felician Campean, Unal Yildirim, Aleksandr Korsunovs and Aleksandr Doikin* pp. 1949 - 1958
- Generative large language models in engineering design: opportunities and challenges  
*Filippo Chiarello, Simone Barandoni, Marija Majda Škec and Gualtiero Fantoni* pp. 1959 - 1968
- Assessing text-image patent datasets with text-based metrics for engineering design applications  
*Marco Consoloni, Vito Giordano and Gualtiero Fantoni* pp. 1969 - 1978
- Towards the digital factory twin - design guide for creating a 3D factory model  
*Jan-Philipp Disselkamp, Robin Grothe, Jonas Lick, Ben Schütte, Sascha Briüne, Luca Schröder and Roman Dumitrescu* pp. 1979 - 1988
- Sketch2Prototype: rapid conceptual design exploration and prototyping with generative AI  
*Kristen M. Edwards, Brandon Man and Faez Ahmed* pp. 1989 - 1998
- Benchmarking AI design skills: insights from ChatGPT's participation in a prototyping hackathon  
*Daniel Nygård Ege, Henrik H. Øvrebø, Vegar Stubberud, Martin Francis Berg, Martin Steinert and Håvard Vestad* pp. 1999 - 2008
- Automatic identification of role-specific information in product development: a critical review on large language models  
*Dominik Ehring, Ismail Menekse, Janosch Luttmer and Arun Nagarajah* pp. 2009 - 2018
- Integrating large language models for improved failure mode and effects analysis (FMEA): a framework and case study  
*Ibtissam El Hassani, Tawfik Masrouf, Nouhan Kourouma, Damien Motte and Jože Tavčar* pp. 2019 - 2028
- Surrogate-based design optimization of the binder cover combining performance and production cost  
*Pavel Ereemeev, Hendrik Devriendt, Alexander De Cock and Frank Naets* pp. 2029 - 2038
- A survey on the industry's perception of digital twins - a follow-up to the digital twin workshop at the DESIGN Conference 2022  
*Michel Fett, Julius Zwickler, Fabian Wilking, Stefan Goetz, Sebastian Schweigert-Recksiek, Ben Hicks, Oscar Nespoli, Kristina Wärmefjord, Sandro Wartzack and Eckhard Kirchner* pp. 2039 - 2048
- Towards an automatic contradiction detection in requirements engineering  
*Alexander Elenga Gärtner and Dietmar Göhlich* pp. 2049 - 2058
- Towards the extraction of semantic relations in design with natural language processing  
*Vito Giordano, Marco Consoloni, Filippo Chiarello and Gualtiero Fantoni* pp. 2059 - 2068
- A low-cost non-intrusive spatial hand tracking pipeline for product-process interaction  
*James Gopsill, Aman Kukreja, Christopher Michael Jason Cox and Chris Snider* pp. 2069 - 2078
- The digital thread for system lifecycle management with a native graph database in a polyglot architecture  
*Nico Kasper, Michael Pfenning and Martin Eigner* pp. 2079 - 2088
- Improving sustainability of additive manufacturing processes based on digital twins - a case study  
*Jessica Kos, Philipp Schröder, Jakob Trauer, Felix Endress, Markus Mörtl and Markus Zimmermann* pp. 2089 - 2098
- Challenges for capturing data within data-driven design processes  
*Christopher Langner, Yevgeni Paliyenko, Benedikt Müller, Daniel Roth, Matthias R. Guertler and Matthias Kreimeyer* pp. 2099 - 2108

D <sup>3</sup> IKIT: data-driven design innovation kit <i>Boyeun Lee and Saeema Ahmed-Kristensen</i>	pp. 2109 - 2118
Navigating from data-driven design to designing with ML: a case study of truck HMI system design <i>Yi Luo, Dimitrios Gkouskos, Nancy L. Russo and Minjuan Wang</i>	pp. 2119 - 2128
Nature's lessons, AI's power: sustainable process design with generative AI <i>Mas'udah Mas'udah and Pavel Livotov</i>	pp. 2129 - 2138
Minimizing occupant loads in vehicle crashes through reinforcement learning-based restraint system design: assessing performance and transferability <i>Janis Mathieu, Parul Gupta, Michael Di Roberto and Michael Vielhaber</i>	pp. 2139 - 2148
The DHSmart model for smart product-service system (smart PSS): dynamic, data-driven, human-centred <i>Nadia Mirshafiee, Ji Han and Saeema Ahmed-Kristensen</i>	pp. 2149 - 2158
Self-optimizing digital factory twin: an industrial use case <i>Christian Nigischer, Florian Reiterer, Sébastien Bougain and Manfred Grafinger</i>	pp. 2159 - 2168
From human-centred to humanity-ecosystem centred design. How can we dialogue with AI? <i>Zeynep Oğrak and Yener Altıparmakogulları</i>	pp. 2169 - 2178
Automating the assembly planning process to enable design for assembly using reinforcement learning <i>Rafael Parzeller, Dominik Koziol, Tizian Dagner and Detlef Gerhard</i>	pp. 2179 - 2186
An AI-based prosthesis framework fostering an adaptive amputee healthcare service <i>Nicholas Patiniott, Jonathan C. Borg, Emmanuel Francalanza, Joseph P. Zammit, Pierre Vella, Alfred Gatt and Kristin Paetzold-Byhain</i>	pp. 2187 - 2196
Large language models in complex system design <i>Alejandro Pradas Gomez, Petter Krus, Massimo Panarotto and Ola Isaksson</i>	pp. 2197 - 2206
Inspiration or indication? Evaluating the qualities of design inspiration boards created using text to image generative AI <i>Charlie Ranscombe, Linus Tan, Mark Goudswaard and Chris Snider</i>	pp. 2207 - 2216
Automatic movement pattern analysis for data-driven system optimisation - an example for fattening livestock farming monitoring system <i>Gurubaran Raveendran, Sören Meyer zu Westerhausen, Johanna Wurst and Roland Lachmayer</i>	pp. 2217 - 2226
Concept for enhanced intuition in development management through exploratory data analysis using an extended factor analysis of mixed data <i>Michael Riesener, Maximilian Kuhn, Benjamin Nils Johannes Lender and Günther Schuh</i>	pp. 2227 - 2236
Towards a process for the creation of synthetic training data for AI-computer vision models utilizing engineering data <i>Sebastian Schwoch, Maximilian Peter Dammann, Johannes Georg Bartl, Maximilian Kretzschmar, Bernhard Saske and Kristin Paetzold-Byhain</i>	pp. 2237 - 2246
Human-AI collaboration by design <i>Binyang Song, Qihao Zhu and Jianxi Luo</i>	pp. 2247 - 2256
A conceptual MCDA-based framework for machine learning algorithm selection in the early phase of product development <i>Sebastian Sonntag, Erik Pohl, Janosch Luttmer, Jutta Geldermann and Arun Nagarajah</i>	pp. 2257 - 2266
Designers' perceptions of a sensor-enabled diary method for enhancing user research <i>Yuki Taoka, Tomoyuki Tanaka, Momoko Nakatani and Shigeki Saito</i>	pp. 2267 - 2276
Digital twins to increase sustainability throughout the system life cycle: a systematic literature review <i>Malte Trienens, Rik Rasor, Aschot Kharatyan, Roman Dumitrescu and Harald Anacker</i>	pp. 2277 - 2286

- Harmonizing human-AI synergy: behavioral science in AI-integrated design pp. 2287 - 2296  
*Dirk Van Rooy and Kristof Vaes*
- Towards digital representations for brownfield factories using synthetic data generation and 3D object detection pp. 2297 - 2306  
*Javier Villena Toro, Lars Bolin, Jacob Eriksson and Anton Wiberg*
- How good is ChatGPT? An exploratory study on ChatGPT's performance in engineering design tasks and subjective decision-making pp. 2307 - 2316  
*Wanyu Xu, Maulik Chhabilkumar Kotecha and Daniel A. McAdams*

## Industrial Design

- Application of universal design principles on computer mouse interface: developing a universal mouse pointing and control system to provide affordance to the left-handed users pp. 2317 - 2326  
*Abhinav Basak and Shatarupa Thakurta Roy*
- An integrated survey-simulation approach for exoskeleton performance estimation pp. 2327 - 2336  
*Niccolò Becattini, Luca Patriarca, Diego Scaccabarozzi, Paolo Parenti, Andrea Dal Prete and Marta Gandolla*
- Research story telling: using the research journey map to communicate information, data, systems, and artifacts pp. 2337 - 2342  
*Jonathan Cagan*
- Crisis: a driver for tourism innovation and service design? pp. 2343 - 2352  
*Åsa Ericson, Johan Lugnet, Maria Ek Styvén and Thomas Zobel*
- Characterising the low-tech approach through a value-driven model pp. 2353 - 2362  
*Alexandre Gaultier, Cédric Masclat and Jean-François Boujut*
- The connection between impressions, user experience and design specifications in technology-driven products pp. 2363 - 2372  
*Fatma Nur Gokdeniz Zeynali and Ekrem Cem Alppay*
- Empathic empowerment: an exploration and analysis of a situated interaction through empathic modelling and role-play pp. 2373 - 2382  
*Amy Grech, Andrew Wodehouse and Ross Brisco*
- Territorial design: ethological design or political design or both? pp. 2383 - 2394  
*Stéphanie Hémon and Annie Gentès*
- Empowering design literacy: a toolkit for promoting the design of positive experiences through rules of thumb pp. 2395 - 2404  
*Björn Kokoschko and Martin Wiesner*
- Into the wonder - exploring the design of playables pp. 2405 - 2412  
*Jesper Falck Legaard*
- The aesthetics of robot design: towards a classification of morphologies pp. 2413 - 2422  
*Dean Aaron Ollah Mobed, Andrew Wodehouse and Anja Maier*
- User involvement in the design of complex digital tools for employees in a large organisation pp. 2423 - 2432  
*Anya Petyaeva, Joy Goodman-Deane and P. John Clarkson*
- Analyzing the dimensional aspects of 3D volumetric spaces: a product-oriented perspective pp. 2433 - 2442  
*Vighneshkumar Rana and Vishal Singh*
- Demystifying the design process of demonstrators: contextual inquiry of two cases pp. 2443 - 2452  
*Aleksandra Sviridova and Jouke Casper Verlinden*
- Unveiling key user experience issues to facilitate user-centred design of inertial motion capture systems pp. 2453 - 2462  
*Charu Tripathi, Manish Arora and Amaresh Chakrabarti*

The balance between a usable and emotional product design - a comparison of different methods for prioritising relevant influencing factors <i>Judith van Remmen, Dennis Horber, Jonas Händel, Jörg Miehling and Sandro Wartzack</i>	pp. 2463 - 2472
Exploring the barriers to innovation adoption in the UK construction industry <i>K-M White and P. John Clarkson</i>	pp. 2473 - 2482
Addressing cultural inertias for co-design: exploring Chinese participants' perceptions of design games <i>Ziheng Zhang, Rui Patricio, Tengjia Zuo, Wa An and Ruoqing Huang</i>	pp. 2483 - 2492
<b>Systems Engineering and Design</b>	
Justice-Embedded Requirements Engineering (JERE) for system design <i>Bettina K. Arkhurst and Katherine Fu</i>	pp. 2493 - 2502
Product changes from various viewpoints along the product lifecycle - an empirical study <i>Julia Beibl and Dieter Krause</i>	pp. 2503 - 2512
Supporting modular product family representations by methodically utilising meta-models <i>Markus Christian Berschik, Fabian Niklas Laukotka, Marc Züfle and Dieter Krause</i>	pp. 2513 - 2522
Systems engineering in design practice: a guideline for development service providers <i>Maximilian Burkhardt, Tilman Warns, Sebastian Endepols, Nikola Bursac and Katharina Ritzer</i>	pp. 2523 - 2532
Leveraging design thinking in MBSE: mitigating data and information uncertainties - an integration model approach <i>Emir Gadzo, Marvin Michalides and Alexander Koch</i>	pp. 2533 - 2544
Tailored metrics for assessing the quality of MBSE models <i>Iris Graessler, Dominik Wiechel, Deniz Oezcan and Patrick Taplick</i>	pp. 2545 - 2554
A matrix-based approach to step-wise assess the safety of collaborative robots in manufacturing <i>Matthias R. Guertler, Philipp Bauer and Alan Burden</i>	pp. 2555 - 2564
Principles for the design of system of systems exemplified using modularisation <i>Matthias Günther, Tobias Seidenberg, Harald Anacker and Roman Dumitrescu</i>	pp. 2565 - 2574
Service centric design methodology for integrated robot-infrastructure systems <i>Abhishek Gupta and Dietmar Göhlich</i>	pp. 2575 - 2584
Towards an ontology to capture human attributes in human-robot collaboration <i>Stephanie Hall, Mandeep Dhanda and Vimal Dhokia</i>	pp. 2585 - 2594
A proposed framework using systems engineering to design human-centric manufacturing systems for novel products to reduce complexity and risk <i>Malin Hane Hagström and Dag Bergsjö</i>	pp. 2595 - 2604
Utilization of the system architecture in the context of validation in the business-to-business (B2B) sector <i>Lynn Humpert, Daria Wilke, Sarah Brueggemann, Harald Anacker and Roman Dumitrescu</i>	pp. 2605 - 2614
Tool support for implementing a methodology in magnet development projects at CERN <i>Jens Kaeske, Erik Wagner, Albert Albers and Stephan Russenschuck</i>	pp. 2615 - 2624
AI-based analysis and linking of technical and organisational data using graph models as a basis for decision-making in systems engineering <i>Sebastian Katzung, Hüseyin Cinkaya, Umut Volkan Kizgin, Alexander Savinov, Julian Baschin and Thomas Vietor</i>	pp. 2625 - 2634
Variability in complex product/system design: case study in automotive industry <i>José Laméh, Alexandra Dubray and Marija Jankovic</i>	pp. 2635 - 2644



Supporting circular economy strategies for design of sustainable mechatronic systems using MBSE <i>Zvonimir Lipšinić, Stephan Husung, Neven Pavković and Christian Weber</i>	pp. 2645 - 2654
A tradespace exploration approach for changeability assessment from a system-of-systems perspective: application from the construction machinery industry <i>Raj Jiten Machchhar, Carl Nils Konrad Toller Melén and Alessandro Bertoni</i>	pp. 2655 - 2664
Reviewing the suitability of ICT-centered design methods for smart PSS development <i>Yevgeni Paliyenko, Daniel Roth and Matthias Kreimeyer</i>	pp. 2665 - 2674
Exploring indicators of system-of-systems resilience: outcomes of a health systems design workshop at an international conference <i>Valeria Pannunzio, Alexander Komashie, Sebastian Walsh, Richard Milne, Timoleon Kipouros, Guillaume Lamé, Anja Maier, Carol Brayne and P. John Clarkson</i>	pp. 2675 - 2684
Designing for systems-of-systems resilience: from the individual to the planet <i>Valeria Pannunzio, Timoleon Kipouros, Amber Khan, Laurie Friday, Carol Brayne and P. John Clarkson</i>	pp. 2685 - 2694
Using product profiles for retrospective case studies in SGE - system generation engineering <i>Felix Pfaff, Michael Schlegel, Thomas Alexander Völk, Karl Thomas Reinheckel and Albert Albers</i>	pp. 2695 - 2704
Bridging simulation granularity in system-of-systems: conjunct application of discrete element method and discrete event simulations in construction equipment design <i>Mubeen Ur Rehman, Raj Jiten Machchhar and Alessandro Bertoni</i>	pp. 2705 - 2714
Design for robotic disassembly <i>Lykke Margot Ricard, Emilie Folkmann, Lars Carøe Sørensen, Sofie Bach Hybel, Roberto de Nóbrega and Henrik Gordon Petersen</i>	pp. 2715 - 2724
Automatic derivation of use case diagrams from interrelated natural language requirements <i>Simon Schleifer, Adriana Lungu, Benjamin Kruse, Sebastiaan van Putten, Stefan Goetz and Sandro Wartzack</i>	pp. 2725 - 2734
Investigation of advantages of models and the modelling process by introducing a model evaluation concept <i>Thomas Schumacher and David Inkermann</i>	pp. 2735 - 2744
Enabling the design for circularity through circularity measures: breaking down the R-strategies into useful design measures <i>Marie Schwahn, Thomas Potinecke, Lukas Block, Maximilian Jakob Werner and Florian Stephan Tarlosy</i>	pp. 2745 - 2754
Merging agent-based simulation and vehicle dynamics: a hybrid approach for value exploration in the mining industry <i>Carl Nils Konrad Toller Melén, Raj Jiten Machchhar and Alessandro Bertoni</i>	pp. 2755 - 2764
Interdisciplinary system lifecycle management - a systematic literature review <i>Fabian Wyrwich, Aschot Kharatyan and Roman Dumitrescu</i>	pp. 2765 - 2774
<b>Design Education</b>	
Design for the real world: a problem-based learning approach <i>Shakuntala Acharya</i>	pp. 2775 - 2784
Incorporating transition design in the education of an established design subject to empower design students with systems thinking <i>Qingfan An and Pedro Sanches</i>	pp. 2785 - 2794
Approach of a virtual reality didactic toolkit - implementation and reflection <i>Hans-Patrick Balzerkiewitz, Carsten Stechert and David Inkermann</i>	pp. 2795 - 2804

A gamified approach to assessing mental rotation in virtual reality <i>Kristin Alicia Bartlett, Almudena Palacios-Ibáñez and Jorge Dorribo Camba</i>	pp. 2805 - 2814
“This is MY PhD project... or is it?” Understanding perceived doctoral project ownership through psychological ownership mapping <i>Michelle Rose Cedeno, Talya Porat and Weston Baxter</i>	pp. 2815 - 2824
VR headset vs. PC screen as virtual learning tour interface for Chinese architecture heritage investigation <i>Yuetong Chen and Min Hua</i>	pp. 2825 - 2834
Conceptualization of an artificial intelligence-assisted tutoring system for teaching technical drawing skills to undergraduate students <i>Jonas Fastabend, Benedikt Müller, Daniel Roth and Matthias Kreimeyer</i>	pp. 2835 - 2844
Understanding the art of design thinking facilitation: a novel instrument for observing instructional strategies used by facilitators <i>Sharon Guaman-Quintanilla, Isabel Alcivar and Katherine Chiluiza</i>	pp. 2845 - 2854
Towards simulation games in engineering design education - design and evaluation of a SE simulation game <i>David Inkermann and Theresa Ammersdörfer</i>	pp. 2855 - 2864
Gaps between reflection frameworks and students’ practice: implications for design education <i>Akira Ito, Yuki Taoka, Echo Wan, Malak Sadek, Celine Mougnot and Shigeki Saito</i>	pp. 2865 - 2874
Improving knowledge transfers in student engineering teams through the application of the InKTI - Interdepartmental Knowledge Transfer Improvement method <i>Monika Klippert, Robert Stolpmann and Albert Albers</i>	pp. 2875 - 2884
Engineering design education at German universities: potential for a common basis to create personalized e-learning content <i>Frederike Kossack and Beate Bender</i>	pp. 2885 - 2894
The sustainability and social entrepreneurship fellowship: transdisciplinary and multicultural problem-based engineering education <i>Gordon Krauss, Chris Rennick, Nadine Ibrahim and Sanjeev Bedi</i>	pp. 2895 - 2904
Descriptive study of the integration of sustainability through the doughnut in an engineering training material <i>Alexis Lalevée, Claudine Gillot, Nadège Troussier and Eric Blanco</i>	pp. 2905 - 2914
Challenges in design methods: perspectives of design students <i>Mayank Mayookh and V. Srinivasan</i>	pp. 2915 - 2924
Students’ perception of risks in computer-supported collaborative design teams <i>Beth Morman and Ross Brisco</i>	pp. 2925 - 2934
Fostering innovation through bio-inspired projects in engineering design education <i>Jacquelyn Nagel and Ramana Pidaparti</i>	pp. 2935 - 2942
Learning in a digital fabrication course on building tangible artefacts <i>Vijayakumar Nanjappan, Georgi V. Georgiev, Hernan Casakin and Sohail Ahmed Soomro</i>	pp. 2943 - 2952
A generative toolkit to help raise industrial design students’ awareness of low metal recycling rates <i>Konrad Schoch, Fabian Hemmert and Christa Liedtke</i>	pp. 2953 - 2962
Analysis of collaborative CAD user actions in design sprint: insights from an educational setting <i>Jelena Šklebar, Tomislav Martinec, Stanko Škec and Mario Štorga</i>	pp. 2963 - 2972
Bridging the green talent gap: a case study of product design education <i>Bernd Michael Weiss, Mohamed Elnourani, Didunoluwa Obilanade, Anna Öhrwall Rönnbäck and Arjoo Arjoo</i>	pp. 2973 - 2982

Proposing an SDGs education model: integrating design thinking and behavioral science “nudges” for high school students pp. 2983 - 2992  
*Yanfang Zhang, Leon Loh, Moe Shimomura and Noriko Takano*

### **Engineering Design Practice**

A review of hydraulic energy harvester designs - current practice and future improvements pp. 2993 - 3002  
*Lorenzo Giunta, James Roscow and Jingqi Liu*

Challenges in product variant costing - a case study pp. 3003 - 3012  
*Morten Nørgaard, Jakob Meinertz Grønvald, Carsten Keinicke Fjord Christensen and Niels Henrik Mortensen*

Optimization of the potting design using an approach for load path optimized designs of sandwich structures pp. 3013 - 3022  
*Johann Schellhorn, Lukas Schwan and Dieter Krause*

Approaches for exploration, analysis, and visualization of tradespace for engineering decision-making pp. 3023 - 3032  
*Meredith Sutton, Julia Daniels, Nafiseh Masoudi, David Gorsich and Cameron Turner*

Approaches to reducing gear mass and their effects on gearing stresses and deformations pp. 3033 - 3040  
*Dorian Vlašiček, Daniel Miler, Robert Mašović and Dragan Žeželj*

Computing solution spaces for gear box design pp. 3041 - 3050  
*Klara Ziegler, Kutay Demir, Thomas Luft, Thomas Mucks, Marius Fürst, Michael Otto, Karsten Stahl, Birgit Vogel-Heuser and Markus Zimmermann*

# What Italian furniture companies do towards sustainable transition? Design actions and strategies showcased during Milan Design Week 2023

Silvia Maria Gramegna , Francesca Mattioli and Xue Pei

Politecnico di Milano, Italy

 [silviamaria.gramegna@polimi.it](mailto:silviamaria.gramegna@polimi.it)

## Abstract

Manufacturing companies find themselves at the crossroads of innovation and sustainability in an era of growing emphasis on corporate social responsibility. This paper delves into Design for Sustainability, aiming to understand the practices Italian design furniture companies are implementing towards sustainability through case studies analysis of sustainable actions (SA) showcased in Milan Design Week 2023. The study categorizes SA according to the Design for Sustainability Framework, determining their role in furniture companies' transformative learning approaches towards sustainability.

*Keywords: sustainability, sustainable design, sustainable transition, furniture sector, design for sustainability*

## 1. Introduction

Manufacturing companies navigate the intersection of innovation and sustainability in an era marked by heightened environmental concerns and a growing focus on corporate social responsibility. This study explores Design for Sustainability in the modern manufacturing landscape, specifically within the furniture sector. The aim is to understand sustainable practices and strategies implemented by Italian design furniture companies, focusing on key questions: What sustainable actions, conducted by these companies, are presented in their public communication? The research analyses a sample of Italian design furniture companies using the DfS framework by [Ceschin and Gaziulusoy \(2016\)](#), adapted to assess sustainability transitions and identify areas for improvement. Qualitative research, centred on case studies from Milan Design Week 2023 (MDW2023), provides insights into sustainable practices presented by leading companies on a global stage. The study employs Ceschin and Gaziulusoy's DfS framework (2016) and integrates the transformative learning framework ([Sterling, 2010](#)) to reveal how sustainable actions signify transformative learning approaches in Italian design furniture companies. The study is part of a broader research that aims at collecting, analysing, and testing design approaches and methods for sustainable and circular transformation of Italian manufacturing in the furniture sector.

## 2. Research context and background knowledge

### 2.1. Need for actions towards a sustainable transition

In recent decades, a growing understanding of environmental issues and their repercussions has changed how people do business globally ([Dai et al., 2015](#)). Indeed, environmentally responsible organisations are more likely to connect with consumers, governments, investors, and other actors in the value chain

(Jansson, 2011). Concerning the sector analysed in this paper, manufacturing companies in the furniture sector, the sustainable transition can influence every phase of the companies' value chain. Accordingly, the literature on DfS has highlighted the need for more studies to investigate the journey of manufacturing companies in the furniture sector facing the transition toward sustainable processes and products (Bruno et al., 2022). In fact, consumers are increasingly concerned about environmental conservation to safeguard the planet's and future generations' survival. Corporate social responsibility considerably influences consumer purchasing behaviour regarding overall product quality and ecologically friendly content. In today's environment, there is a perceptible urgency among manufacturing companies in the furniture sector to align their operations with eco-centric ideals (Barbaritano, 2021). Companies are required to progressively examine and rethink their processes to reduce environmental effects, from material procurement to production practices. As manufacturers cope with this shifting terrain, various options arise, ranging from eco-friendly material innovation to incorporating circular economy ideas. New sustainability plans and related techniques should thus be aligned with company values and meet the needs of stakeholders (Epstein, 2018; Fagerlind et al., 2019). Spurred, at least in part, by these findings, an increasing number of manufacturing companies in the furniture sector in Italy are pursuing initiatives towards a sustainable transition, seeking a new synthesis between a product's relevance to consumers and its sustainability.

## 2.2. Italian furniture industries and sustainability challenges

The furniture sector is essential to the Italian economy because of its worth and significant part of worldwide trade; Italy is one of the world's major exporters. Regarding European furniture production and consumption, Italy (17.5 billion euros) is the largest manufacturer by value, followed by Germany (14.5 billion euros). Similarly, Germany (9.5 billion euros) and Italy (9.2 billion euros) are the largest exporters (Bruno et al., 2022). The European Union's furniture consumption is predicted to reach 68 billion euros per year, with Germany (16.8 billion euros), the United Kingdom (14.2 billion euros), and Italy (10.2 billion euros) being the leading users by value (European Commission, 2023). The sector rose to national prominence due to its proficiency in design production. Regardless of size, most businesses are small and medium-sized, and only a few can be considered large companies, with all associated benefits and drawbacks. According to Federlegno Arredo (Federlegno, 2016), environmental sustainability is now regarded as a significant competitive advantage for furniture producers, as it encourages the development of products that better suit consumer demand. The most promising path for innovation in this area today is environmental sustainability and circularity, which are inherent in product design logic. Sustainable and circular innovations lessen the environmental impact of production while allowing added value to be derived from consumer changes. According to recent studies, the Italian furniture industry still faces significant impediments to adopting CE-based sustainable practices (Silvius et al., 2021; Barbaritano & Savelli, 2020). The situation is no different in Europe than it is in Italy. Only in the last three years have leaders in the furniture sector shown a rising interest in circular inputs. This delay has been caused by a lack of regulatory coordination at the EU, national, and regional levels (Mura et al., 2020). The EU did not develop an action plan until 2020. Another significant obstacle to sustainable transitions is the view of environmental sustainability as a cost consideration (Savelli et al., 2019). According to the latest research, there are a few cases of furniture firms in the Italian landscape moving towards sustainable transition. They have adopted circular inputs from renewables or prior life cycles (reuse and recycling), low-impact procedures, and a life extension approach to products (Barbaritano & Savelli, 2020). Other practices that companies seek to follow in the next years are energy savings, the creation of low-resource-consumption manufacturing processes, and environmental criteria for supplier selection. Given the sustainability multidimensional nature, it requires the involvement of multiple levels of decision-making and the work of various actors (including public opinion), and a critical role is played by adequate levels of communication within and across companies, consumers and stakeholders (Genç, 2017). Communication strategies can influence the adoption and implementation of sustainable practices among companies. On a broader level, competitors and entrants competing for the same market position can affect the transition to sustainable strategies (Morgan et al., 2018). Global events showcasing sectorial advancements represent an opportunity to stimulate this transition towards sustainability. Accordingly, in the Italian context, events

such as the Salone del Mobile and Milan Design Week (MDW), in which furniture companies are involved, represent an important showcase to stimulate the debate across companies and for involving or informing consumers about the innovations in terms of sustainability organisations are implementing.

### 2.3. MDW2023: Salone del Mobile and Fuorisalone

MDW is an international key event for the furniture sector that takes place yearly in Milan; it encompasses two distinct yet intertwined events: the Salone del Mobile and the Fuorisalone. Salone del Mobile, the Milan Furniture Fair, is a preeminent event within furniture and interior design; this annual trade fair is held in Milan, in April. Its primary objective is to unveil and spotlight the latest developments, trends, and innovations within furniture, home decor, and interior design. Salone del Mobile dates back to 1961, and over the years, it has evolved into a global platform which gathers furniture manufacturers, designers, architects, and interior design professionals. These stakeholders utilise the fair to showcase their new collections and products to a discerning international audience. The 2023 edition focused on the theme "Designing Tomorrow", emphasising sustainability in design through reuse, regeneration, circularity, and energy conservation. The 61st edition adopted a planet-centric approach, reflecting the commitment of both the organisers, evidenced by sustainability certifications such as ISO 20121 and adherence to the UN Global Compact, and the exhibitors (Viganò, 2023). The 2023 designs were characterised by modularity and reusability, constructed from recycled wood and cardboard, hence departing from the tradition of monumental, short-lived stands. Additionally, several exhibitors chose to repurpose setups from previous editions or opt for materials designed for straightforward disassembly and reuse. With over 2323 exhibitors participating in the 2023 edition, Salone del Mobile underscored its standing as a global design authority, attracting influential brands and pioneering designers leading the charge in sustainable design practices (Viganò, 2023). Thus, this confluence emerged as a nucleus for networking, knowledge exchange, and exploring how sustainable design can transform the industry. The week-long exhibition also encompasses numerous events held throughout Milan, known as Fuorisalone (literally translating into Outside-fair), a comprehensive showcase of creativity and design excellence, extending beyond furniture to various design-related fields. MDW involves various satellite events, presentations, and installations spreading throughout the city. City districts (e.g., Brera, Tortona, and Lambrate) become vibrant hubs for design-related activities, with showrooms, galleries, and temporary installations transforming the urban landscape. Given the broader research project we are developing, mentioned in the introduction, MDW2023 became a field research opportunity to collect data on the actions and strategies presented by leading Italian furniture manufacturers, which became case studies analysed to understand the transformations in the sector.

### 2.4. Background knowledge: theoretical lenses for the study

Before the data collection, the researchers identified two theoretical frameworks that later guided the interpretation of data about sustainable actions presented by companies. In this paragraph, these two frameworks are briefly presented.

#### 2.4.1. Design for Sustainability framework

This research refers to the DfS framework developed by [Ceschin and Gaziulusoy \(2016\)](#), known as the "DfS Evolutionary Framework" (DfSE). This framework provides an interpretation of the evolution of structured approaches to integrate sustainability considerations into the design of products and services. The DfSE framework aims to promote sustainable practices by encouraging a shift from traditional product-centred design to a more holistic approach that includes services. Furthermore, [Ceschin and Gaziulusoy \(2016\)](#) discuss the concept of sustainability transitions, which involves designing more sustainable products and creating pathways for transitioning to sustainable socio-technical systems. This transition-oriented perspective recognises the need for systemic change in various sectors. The framework, rooted in a systemic perspective, extends beyond traditional product-centric models to encompass entire product-service systems, emphasising the interconnectedness of products, services, and their socio-economic contexts. Moreover, it delineates a transformative shift from a narrow technical and product-centric focus to a more comprehensive, system-level approach for environmental

and social benefits. This evolution is characterised by two crucial dimensions: the evolution from a technology-centric to a socio-technical perspective where user practices play a fundamental role and a shift from addressing internal firm issues to changing broader socio-economic systems. [Ceschin and Gaziulusoy \(2016\)](#) categorised DfS approaches into four innovation levels: Product innovation, Product-Service System innovation, Spatio-Social innovation, and Socio-Technical System innovation. By mapping these approaches onto a bi-dimensional framework based on the Insular/Systemic and Technology/People axes, their framework aimed to illustrate the overarching evolution of DfS. In this research, we adopted the DfSE framework innovation levels to analyse and categorise the sustainable practices and strategies Italian furniture companies are adopting towards a sustainable transition. The framework provides a structured approach to understanding and implementing sustainability in design processes and it can be adapted to assess and categorise the sustainability transition within different levels of innovation to identify areas for further improvement as they strive for more sustainable and responsible practices.

#### **2.4.2. Transformative Learning and Sustainability framework**

The idea of transformative learning presents the educational purpose and practices to change towards sustainability at individual and organisational scales. The Transformative Learning and Sustainability (TLS) paradigm is proposed by [Sterling \(2010\)](#) as a conceptual framework for incorporating sustainability ideas into education. The concept emphasises the importance of transformational pedagogy in fostering cognitive comprehension and emotional and ethical engagement with sustainability concerns. Sterling contends that such transformative learning is critical for developing a resilient and adaptable mindset in environmental and societal crises (*ibid.*). The TLS model emphasises the value of comprehensive learning experiences that inspire learners to challenge assumptions, develop critical thinking abilities, and accept responsibility for building a more sustainable future. Individuals are more equipped to critically engage with sustainability issues, question assumptions, and develop a feeling of responsibility for creating a more sustainable and resilient world when exposed to transformative learning experiences. The TLS framework involves three stages of learning: confirmative, reformative, and transformative. These stages represent different levels of engagement with sustainability concepts and practices. Sterling's concept of confirmative, reformative, and transformative learning within the TLS model outlines a developmental progression, encouraging a shift from unquestioning conformity to a profound and transformative engagement with sustainability principles. In the confirmative stage, individuals function within established societal standards without critically examining them. This phase acts as a baseline, recognising the dominant paradigms. Individuals progress from conformance to the reformative stage, marked by increased awareness and a desire to challenge prevailing standards. Individuals actively seek alternatives and may adopt more sustainable practices in this setting, but these changes may not be completely revolutionary. The TLS model recognises the importance of this transitional period as learners progress from conformity to more critical involvement. Finally, the transformative stage symbolises the model's peak, in which individuals experience a dramatic shift in their perspectives, attitudes, and behaviours. This transformative learning entails a comprehensive grasp of sustainability that includes cognitive, emotional, and ethical elements. The connection between transformative learning and sustainability stems from the awareness that addressing complex and interwoven environmental and socio-economic concerns necessitates shifting individuals' perspectives, attitudes, and behaviours. Transformative learning, expressed by theorists such as [Mezirow \(2003\)](#) and further elaborated by researchers such as Sterling, entails a significant change in how people perceive and interpret the world. When applied to sustainability ([Sterling, 2010](#)), transformative learning aims to go beyond traditional, fact-based education to raise awareness of the interconnection of ecological, social, and economic systems.

### **3. Research methods**

Given the exploratory and field-based nature of the study, the qualitative research employed the collection of case studies of sustainable actions and strategies presented and communicated by leading Italian manufacturing companies in the context of MDW 2023 as the primary method.

### 3.1. Criteria for case study selection

Hence, in the initial phase, the research team focused on identifying the company to include as case studies in the data collection on the field. An initial list of possible companies to include in the study was developed by analysing the program of the Salone del Mobile event and integrating such analysis with information collected by revising grey literature, such as publications by leading Italian manufacturer associations such as Federlegno Arredo, and organisations playing an essential role in promoting CE, such as Symbola. The study started with a grey literature search on Salone del Mobile online repository of exhibitors (isaloni.it). The grey literature search plan encompassed several techniques, including using a customised Google search engine, targeted websites, company websites, online magazines (i.e., Dezeen, Archdaily), and expert consultations. A list of 11 companies committed to design-intensive innovation (Design Council, 2018) was compiled at this stage. The list was further narrowed by reviewing each company's website and applying the following inclusion criteria: i) those that most consistently talk about sustainability on their websites or ii) those that most strongly represent Made in Italy - also based on the grey literature review previously mentioned. The list was reduced to nine companies. The companies manufacture design-based furniture, furnishing accessories, or appliances (e.g., tables, chairs, sofas, kitchens, and accessories). A last step of reduction of the list was made by including only the companies that had both a booth at the Salone del Mobile fair and a temporary exhibition in their city showroom or other location in the Fuorisalone, narrowing down the list to six companies. This criterion was introduced to guarantee a broader opportunity for observing the practices and strategies presented by the companies in two different venues, namely the fair dedicated to sectorial expert audiences and Fuorisalone event opened to a broader public. Finally, the research team decided to include one more company represented only in Fuorisalone and not in the Salone del Mobile fair because it is an Italian manufacturer committed to sustainability that often emerged in the national databases of virtuous sustainable furniture producers. The anonymised list of companies is reported in Table 1, together with information about the companies retrieved from the Italian business and professional services portal of the Chamber of Commerce called Chamber Office ([Openapi SPA Unipersonale, 2023](#)). All the analysed companies have their headquarters in northern and central Italy; they operate on a global scale and are from medium-sized to large-sized businesses with a turnover not exceeding €350 million and less than 940 employees.

**Table 1. The anonymised list of selected case studies companies for the data collection performed during Salone del Mobile 2023 ([Openapi SPA Unipersonale, 2023](#))**

Company	Manufactured products	Number of employees	Income (€)	Dimension
Company A	Furniture and furnishing accessories	150	60M	Medium/large
Company B	Contract and office furniture	140	50M	Medium
Company C	Home and office furniture, furnishing accessories, kitchens	928	340M	Large
Company D	Furniture, furnishing accessories, kitchens	710	235M	Large
Company E	Furniture and furnishing accessories	85	110M	Medium/large
Company F	Furniture and furnishing accessories	58	20M	Medium
Company G	Kitchens and furnishing accessories	166	30M	Medium

### 3.2. Data collection and analysis

The field data collection occurred on April 20–21, 2023, when the research team visited the stands of the selected companies at Salone del Mobile, and the showrooms opened and set up for Fuorisalone. The protocol for data collection consisted of observation of the setup to identify any references to the sustainability of the products presented. After initial observation, the team conducted brief semi-structured interviews with persons available at the booth, requesting, when possible, to speak with persons informed concerning the sustainability features of the products and the brands. The interviewed persons are mainly from the sales department (A, B, C, E, G) and the communication department (D,



F). Interviews were conducted by the same researcher to reduce the role of bias (Bowler et al., 2017; Savelli et al., 2021) and following three guiding questions:

- How is sustainability understood in your company?
- What initiatives or actions have you undertaken in the field of sustainability?
- Which of your products is the most emblematic example of your sustainable actions?

The process was documented by taking photographs of the displays and products presented by staff during the interviews and making notes. Data collected was organised into sheets per company to summarise the main information collected about the company (e.g., text and images); the data corpus was interpreted and discussed together by the researchers, analysing any further information provided by interviewees (e.g., pamphlets, website pages) or sourced by the research team. To analyse the results, the researchers mapped the sustainable actions undertaken by each case study company by employing an analysis tool built based on the two frameworks of references for the study. In the analysis matrix (Fig. 1), the columns represent the ten Dfs approaches framed by Ceschin & Gaziulusoy (2016), and the rows represent the three levels of the TLS framework as proposed by Sterling (2010): the actions collected during the field research have been positioned based on the interpretation according to the two dimensions of the Dfs approaches and the transformative orders. The lower close-up view of Fig.1 depicts an example of different actions and their positioning in the scheme. The interpretation was shared and validated with experts and design researchers, part of the research group working on the broader research project this study is part of to improve the overall quality of the analysis.

	Material and Product Innovation Level					Product-Service System Innovation Level		Socio-Social Innovation Level		Socio-Technical System Innovation Level		
	Green Design	Eco-design	Emotionally Durable Design	Design For Sustainable Behaviour	Nature-Inspired Design Cradle-To-Cradle	Biomimicry Design	Design For The Base Of The Pyramid (Bop)	Sustainable Product-Service System (PSS) Design	Design For Social Innovation	Systemic Design	Design For System Innovations And Transitions	
Case study company (example of actions from different companies)	1st Order Conforming	Lowering environmental impact through redesigning individual qualities of individual products.	Lowering environmental impact focussing on the whole life-cycle of products from extraction of raw materials to final disposal.	Strengthening and reinforcing and reinforcing to fine the emotional attachment between the user and the product.	Making people adopt desired sustainable behaviour and attitudes in consumable behaviour.	Emphasis on a regenerative approach for the industry and closing the loops. Focus on industrial wastes and future generations.	Mimicking nature in design of forms, materials and systems. By using nature as model, resource and source.	Improving the lives of people who live at the base of the pyramid. Focus on the design of product service propositions, moving beyond the sole product as a space to find sustainable solutions.	PSS design for eco efficiency, for sustainability, for the bottom of the Pyramid and approaches that focus on the design of product service propositions, moving beyond the sole product as a space to find sustainable solutions.	Adding with conceptual, development and scaling up of social innovation.	Designing locally based production systems in which users from one productive process become input to other processes.	Transformation of sociotechnical systems through strategic design.
	2nd Order Reforming	Substitute the old materials with sustainable one for a specific product that involved a specific local supplier to work with the wastes produced during the material manufacturing.	Design of a modular product to reduce the use of materials and complexity of production.	A special focus on maximize the sustainability of their iconic material (plastic) through a continuous R&D; they are developing extra supply chain collaboration with other manufacturers to promote a virtuous use of plastic waste.		They are pursuing a model for sustainable development that moves at the different stage of the supply chain, they have a specific focus on materials, characteristics, and performance.						
	3rd Order Transforming											

  

Case study company (example of actions from different companies)	1st Order Conforming	Substitute the old materials with sustainable one for a specific product that involved a specific local supplier to work with the wastes produced during the materials manufacturing.
	2nd Order Reforming	Design of a modular product to reduce the use of materials and complexity of production.
	3rd Order Transforming	A special focus on maximize the sustainability of their iconic material (plastic) through a continuous R&D; they are developing extra supply chain collaboration with other manufacturers to promote a virtuous use of plastic waste.

Figure 1. The analysis matrix to map the collection of sustainable actions undertaken by the case studies companies, with an example (bottom close-up view)

#### 4. Research results

The analysis results present how Italian furniture companies carry out their sustainable actions according to the analysis matrix (Fig.1). According to the ten design approaches of the DfsE framework, the 7 Italian furniture companies have mainly presented three design approaches towards sustainability: Green Design, Eco-Design, and Cradle-to-Cradle Design. The findings around these three main Dfs

strategies are presented in the sub-sections below concerning the analysed data. The other seven approaches were not observed in the selected furniture companies during MDW2023.

#### 4.1. Green Design approach to do things better

Three companies (i.e., A, C, F) have practised the green design approach, which aims to reduce environmental impact by redesigning individual furniture products. This approach mainly emphasises redesigning the physical product to reduce materials and resources and eventually limit the negative environmental impact (Ceschin & Gaziulusoy, 2016). The three companies have (re)designed their products by substituting traditional materials with recycled ones and creating durable forms and structures. For example, company F presented a chair made with recyclable materials created from the waste from one of their local suppliers. Companies are trying to change to a more sustainable way of doing their conventional business, including sustainability as part of their objectives. Therefore, in our interpretation, they mainly conduct a conformance learning approach towards sustainability, according to TLS framework, through sustainable activities to improve the efficiency of a physical product and production process. Apart from applying the green design approach to the physical products, sustainability is also addressed in the companies' communication in a relatively general way (i.e., dedicated web pages to the sustainable themes and sustainable reports). All three companies have used sustainability as an essential word in their communication during MDW2023. One typical example of practices emerging in this category is the restitution of traditional materials with recycled or recyclable ones to make furniture products. Company F launched a series of new products during MDW2023 by renewing their classic and iconic furniture pieces with recycled materials obtained from the recycling and other single-use ones, and the products are 100% recyclable. Similar cases could also be seen in companies A and C, which launched their new products made with recycled materials. Improvements in materials and product forms are an effective way to reduce the companies' environmental impact. The communication strategy of these actions also confirms this doing-things-better approach towards their sustainable transformation.

#### 4.2. Eco-design approach to make things better

An advanced approach to Green Design is to extend the consideration of improving an individual product's performance to the entire life cycle of products, from extraction of raw materials to final disposal – Eco Design (Ceschin & Gaziulusoy, 2016; Pigosso, McAloone & Rozenfeld, 2015). This requires companies to develop knowledge related to product design, production, distribution, take-back, and disposal, and to create solutions that could reduce the negative environmental impact at different phases of a product's life cycle. The furniture companies we observed during MDW2023 have worked on this approach with different projects and actions. Three companies (i.e., D, E, F) have been identified to carry out an Eco-Design approach to achieve sustainability through design for product material efficiency, product design for reliability and durability, and product design for standardisation and modularity (Bocken et al., 2016). Company D has followed the required regulations on raw material certification and European furniture products' toxic agent level. The fundamental design principle is to improve the furniture's durability. The company has made its whole production line very efficient and adapted it to avoid overproduction in advance and make the best use of available materials: do things better. Company F launched a very successful sofa designed for standardisation and modularity to reduce the use of materials and the complexity of production. The product has presented a solution considering reducing material inputs, simplifying product configuration, various product combinations, and end-of-life product disposal. In our interpretation, the sustainable actions of companies D and F are positioned at a conformance transition level as they aim to do things better, according to TLS framework. The applied design strategies have created unique and attractive solutions for consumers. Company E paid great attention to the materials: certified wood, reused or reusable plastics, and reused fabrics for making their furniture pieces to guarantee the low environmental impact of their products. Besides, the company also makes strategic partnerships with companies that produce high-end materials that give reused fabrics as the input of some components of their furniture products. Company E has developed new strategies and know-how on maximising the sustainability of their iconic material used to make furniture products and developing extra supply chain collaboration to promote a

virtuous use of waste. From the TLS perspective, Company E has begun to change their conventional way of doing, fostering a better and more significant way to achieve sustainability instead of improving the existing ones. They have tried to understand how to reform and reshape their business offerings (i.e., products and services) through a new partnership and include sustainability as one of the parameters in the design and development process. Hence, the organisation's practices have been interpreted as reformative, according to the TLS framework.

### 4.3. Cradle-to-Cradle Design approach to do better things

The Cradle-to-Cradle (CTC) approach fosters radical innovation and shifts the furniture companies' business-driven mindsets towards sustainability, also considering the environmental/biological and societal aspects of the impact of furniture products and production (Ceschin & Gaziulusoy, 2016). Companies B and G have incorporated the CTC principles into their corporate missions, infusing environmental and social considerations into the design and development processes of their furniture products and services. Company B's commitment to sustainability is backed by tangible and accurate data and numbers for each product, showcasing its comprehensive approach to various sustainability issues at both the product and supply chain levels. Its sustainability department spearheads strategic initiatives, exemplified by five specific products designed for complete disassembly, enhanced durability, responsible material usage, and local sourcing. While their communication strategy remains minimal, they have employed QR codes on product displays, enabling consumers to access detailed sustainability information through the company's website. On the other hand, Company G advocates a holistic model for sustainable development that encompasses every stage of the supply chain, with a specific emphasis on materials, characteristics, and performance. Their technical approach involves addressing sustainability through material considerations, dematerialisation, and customisation systems aimed at reducing waste, minimising toxic materials, simplifying disassembly, and extending product life. Moreover, their focus extends beyond physical aspects to encompass the well-being of users, considering both ergonomic and emotional dimensions. Company G actively engages in material research, explores technological solutions, collaborates with local artisans, and designs ad hoc solutions to bolster sustainability. Company G adopts a highly focused approach in terms of communication, providing explanatory and educational materials that underscore their commitment to sustainability. The company has been dedicated to sustainability and circularity since its inception, utilising product and design solutions to narrate the compelling story of its sustainable actions effectively. The sustainable actions and strategies of companies B and G go beyond the consideration of the environmental impacts of furniture products during the whole life cycle; they tried to involve the stakeholders in the supply chains to change towards sustainability, guide their consumers to realise the meaning of sustainability and promote the social dimension of sustainability. Thanks to these actions and strategies, these two companies actively explore alternative options and embrace more sustainable practices in conventional business practices and contexts, though only partially revolutionary.

## 5. Discussion

Given the exploratory nature of this research, DfSE framework proves to be a valuable tool for categorising and mapping the sustainable actions showcased by Italian furniture companies during MDW2023; its combination with Sterling's TLS (2010) principles, not only facilitates a systematic examination of the companies' practices but also highlights the specific strategies employed in pursuing sustainability goals, providing a clear and insightful overview of their transformative learning orders. However, the combined framework proves somewhat generic. The study underscores the necessity of developing specific models to map and analyse distinct levels of sustainable transition through specific companies' actions, hence, identifying strategies for more effective and context-specific sustainability assessments in future research. Concerning the data collected through field research, a vast potential emerges for implementing other DfS approaches in the furniture sector. In detail, based on our analysis, a quite limited panorama of undertaken actions and DfS approaches employed by companies emerged from the MDW2023. As presented in the previous paragraphs, most of the actions and strategies are driven by mandatory requirements and regulations by the national and European norms, underling a diffused conformative approach that indicates an early stage of transforming the companies to include

sustainability in different aspects and dimensions of the businesses and offerings. However, some companies (i.e., B, E, G) have developed more advanced sustainable actions that underlie a reformative approach (i.e., TLS second order), meaning they are currently working on particular aspects of the complete sustainability transition to "do better things". We inquired on the reasons that might have motivated such more advanced TLS order of these companies and, notably, we understood that two main phenomena determined it: i) when the core business was built mainly on sustainable values, and ii) when the company's product has, for various reasons, been singled out by public opinion as unsustainable. For the latter point, a clear example is Company E, which had to undergo a reformative process because plastic was the brand's reference material and, in the last decades, has been increasingly perceived as unsustainable by public opinion. We associate this phenomenon with what Mezirov called the "disorienting dilemma" (Laros, 2017), a fundamental step of transformative learning because it forces to change consolidated paradigms. Moreover, looking at the DfSE framework, the actions have mainly focused on materials substitution, product redesign (e.g., components, forms), and product life cycle management. This study's most notable sustainable actions refer to previously presented good examples in the cradle-to-cradle category. The limitation of these approaches is that they often focus on individual physical furniture pieces and their performance and marginally consider other aspects of sustainability. Indeed, the right side of the DfS framework still needs to be emptied, meaning there is a vast space and opportunity for Italian furniture companies to apply and implement advanced sustainable strategies and actions. The DfSE framework provides directions and trajectories to develop more significant approaches towards sustainability. Firstly, working on user or consumer engagement to extend the emotional attachment and foster sustainable behaviour is of vast potential to develop new ways to interact with furniture. Good design could make the emotional link between users and furniture products unique and continuously grow; this will increase the duration of furniture products and enable users to search for possibilities to maintain, fix, improve, and upgrade the original products instead of purchasing new ones. Secondly, transitioning towards service logic to achieve sustainability is another promising approach to maximising eco-efficiency, creating environmentally beneficial and economically competitive solutions. This design approach enables furniture companies to change from product sellers to service providers, who offer consumers more flexible and adaptive solutions to meet their use needs (for example, subscription service for renting furniture). Thirdly, the emerging systemic design approach could foster a sustainable transition of the whole sector because it deals with interdependencies and problems facing the entire sector. The systemic design strongly emphasises a comprehensive approach, considering not just the specific furniture products but their more significant effects on the environment, society, ecology, and the stakeholders in the supply chains and actors in the territories. The systemic design approach fosters sustainability transition by promoting collaborations across various disciplines and sectors, for example, cultivating strategic partnerships to close the furniture lifecycle loop by building collaborative know-how and win-win solutions for the whole supply chain. To conclude, we need to point out few limitations of this field research. Firstly, the companies involved in this study are just a small selection within the broad sector of Italian manufacturing furniture, and therefore they can't fully represent its heterogeneous panorama. However, they are recognized leading companies and their characteristics (span of size, income, typology of production and territorial distribution) turn them into a significant sample for the study. Moreover, different companies interviewed during MDW2023 revealed a discrepancy between the communication of sustainable actions, typically handled by marketing offices, and the actual practices undertaken. Many companies presented generic information during the event, while authentic, sustainable actions were evident in product details found in brochures, websites, or specific reports. This highlights the crucial need for more authentic and impactful communication strategies, emphasising transparency and alignment between intentions and actions. There is a growing demand for effective frameworks tailored to conduct context-specific sustainability assessments, aiding companies in better positioning themselves in sustainable transitions, but also capable of enhancing the awareness of the whole companies' members towards sustainable actions. These frameworks would not only aid companies in better positioning themselves within various levels of sustainable transition but also enhance the planning and execution of future sustainable actions. Notably, companies with sustainability as their core business exception to this trend, as they inherently communicate their commitment through their products.

## Acknowledgements

The research presented in this paper is part of " PE\_000004 Made in Italy Circular and Sustainable (MICS)", an Extended Partnership financed by the MUR (Italian Ministry of University and Research) with EU funds under the NextGenerationEU programme. In particular, the actions described are part of the project " EcoDeCK" ECO-Design Circular Knowledge, which aims to build a portfolio of eco-design-driven strategies by collecting, analysing, and testing design approaches, methods, and tools for sustainable and circular transformation.

## References

- Barbaritano, M. (2021), Design for innovation and competitiveness: new opportunities in the furniture sector.
- Barbaritano, M. and Savelli, E. (2020), Design and sustainability for innovation in family firms. A case study from the Italian furniture sector. *Piccola Impresa/Small Business* (1). <https://doi.org/10.14596/pisb.342>
- Bowler, K., Castka, P. and Balzarova, M. (2017), Understanding firms' approaches to voluntary certification: Evidence from multiple case studies in FSC certification. *Journal of Business Ethics*, 145, pp.441-456. <https://doi.org/10.1007/s10551-015-2880-1>
- Bruno, D., Ferrara, M., D'Alessandro, F. and Mandelli, A., 2022. The Role of Design in the CE Transition of the Furniture Industry—The Case of the Italian Company Cassina. *Sustainability*, 14(15), p.9168.
- Ceschin, F. and Gaziulusoy, I. (2016), Design for sustainability: An evolutionary review. in Lloyd, P. and Bohemia, E. (eds.), *Future Focused Thinking - DRS International Conference 2016*, 27 - 30 June, Brighton, United Kingdom. <https://doi.org/10.21606/drs.2016.59>
- Dai, J., Cantor, D.E. and Montabon, F.L. (2015) How environmental management competitive pressure affects a focal firm's environmental innovation activities: A green supply chain perspective. *Journal of Business Logistics*, 36(3), pp.242-259. <https://doi.org/10.1111/jbl.12094>
- Genç, R. (2017), The importance of communication in sustainability & sustainable strategies. *Procedia Manufacturing*, 8, pp.511-516. <https://doi.org/10.1016/j.promfg.2017.02.065>
- Epstein, M.J. and Buhovac, A.R. (2014), *Making sustainability work: Best practices in managing and measuring corporate social, environmental, and economic impacts*. Berrett-Koehler Publishers.
- European Commission, (2023), Eurostat Prodcom Statistics. Available at: <https://ec.europa.eu/eurostat/web/prodcom> (Accessed 02.11.2023).
- Fagerlind, T., Stefanicki, M., Feldmann, A. and Korhonen, J. (2019), The distribution of sustainable decision-making in multinational manufacturing enterprises. *Sustainability*, 11(18), p. 4871. <https://doi.org/10.3390/su11184871>
- Federlegno, S. (2016), Il Made in Italy abita il futuro. Il legno arredo verso l'economia circolare.
- Jansson, J., 2011. Consumer eco-innovation adoption: assessing attitudinal factors and perceived product characteristics. *Business Strategy and the Environment*, 20(3), pp.192-210. <https://doi.org/10.1002/bse.690>
- Lambert, R. and Flood, R. (2017), *Understanding design-intensive innovation: a literature review*. Reino Unido: Design Consul.
- Laros, A. (2017), Disorienting dilemmas as a catalyst for transformative learning. In *Transformative learning meets bildung* (pp. 85-95). Brill.
- Mezirow, J. (2003), Transformative learning as discourse. *Journal of transformative education*, 1(1), pp.58-63.
- Morgan, T.R., Tokman, M., Richey, R.G. and Defee, C. (2018), Resource commitment and sustainability: a reverse logistics performance process model. *International Journal of Physical Distribution & Logistics Management*, 48(2), pp.164-182.
- Mura, M., Longo, M. and Zanni, S. (2020), Circular economy in Italian SMEs: A multi-method study. *Journal of Cleaner Production*, 245, p.118821. <https://doi.org/10.1016/j.jclepro.2019.118821>
- Openapi SpA Unipersonale. (2023). Ufficio Camerale - Portale di Servizi alle Imprese. Available at: <https://www.ufficiocamerale.it> (Accessed 10.11.2023).
- Pigosso, D.C.A., McAloone, T.C. and Rozenfeld, H. (2015), Characterisation of the state-of-the-art and identification of main trends for Ecodesign Tools and Methods: Classifying three decades of research and implementation. *Journal of the Indian Institute of Science*, 95(4), pp.405-428.
- Savelli, E., Barbaritano, M. and Bravi, L. (2019), Circular Economy and Quality Management within the Furniture Sector: an exploratory study. on *Quality Innovation and Sustainability*, p.61. <https://doi.org/10.3390/su11113089>
- Silvius, G., Ismayilova, A., Sales-Vivó, V. and Costi, M. (2021), Exploring barriers for circularity in the EU furniture industry. *Sustainability*, 13(19), p.11072. <https://doi.org/10.3390/su131911072>
- Sterling, S. (2010), Transformative Learning and Sustainability: sketching the conceptual ground. *Learning and Teaching in Higher Education*, 5, 17-33.