XVIII International WoodEMA 2025 Scientific Conference

WOOD FOR THE FUTURE:
INTEGRATING SUSTAINABILITY ACROSS INDUSTRIES

Ohrid, North Macedonia

September 17th-19th 2025

Title of the paper: REGULATORY SANDBOXES IN THE FURNITURE INDUSTRY. CHALLENGES AND OPPORTUNITIES

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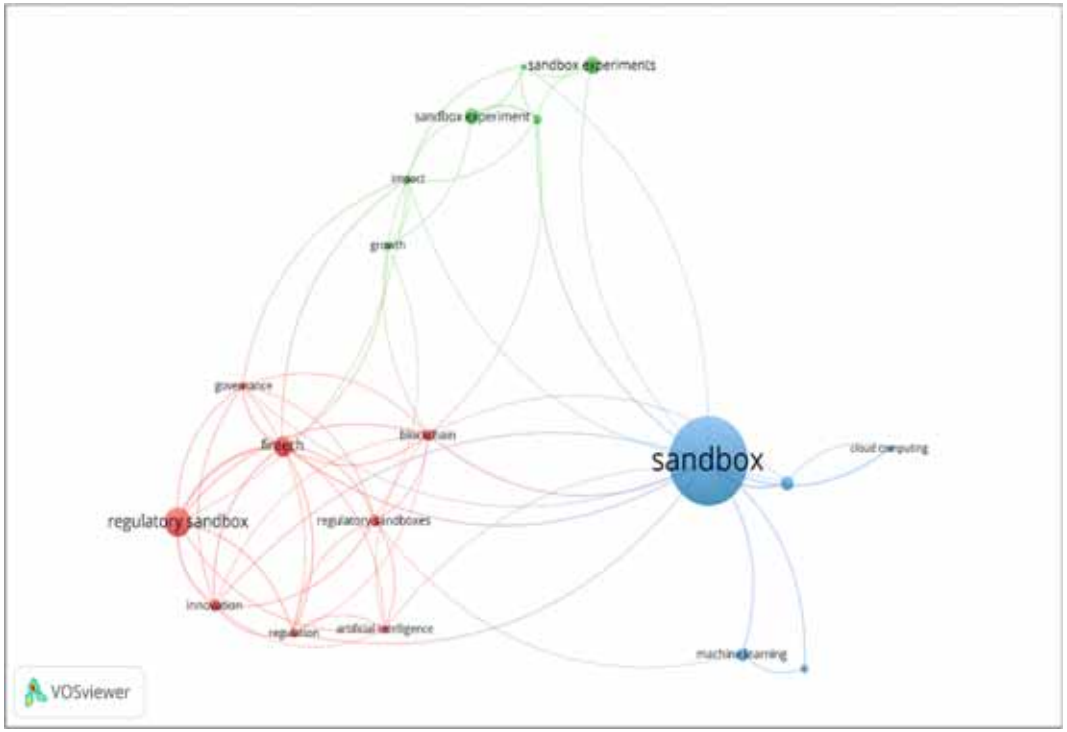
Regulatory and Technological Context
- Smart furniture raises issues of cybersecurity, privacy, safety, sustainability, and certification (El-Gizawi, 2023; Schwarz, 2021; Xu, 2024).
- Despite progress, the sector lags behind Industry 4.0 integration (Červený et al., 2022).
- The AI Act and EU product regulations apply cumulatively: compliance is required across multiple legal frameworks (EU "Blue Guide," 2022).
- AI Act (Arts. 57–58): explicitly recognises sandboxes as "measures to support innovation."

Manufacturers' obligations:
- Product safety
- Environmental standards
- Data protection and AI compliance.

Key challenge: Aligning innovation with multiple overlapping regulations.

Main goal: To analyse the potential of regulatory sandboxes as an instrument for testing and assessing the compliance of smart furniture models and systems on the example of Bulgaria.
Hypothesis: Regulatory sandboxes can support the transformation of the Bulgarian furniture industry by creating a controlled environment for testing and adapting smart technologies without breaching existing regulatory standards and with reduced risk for enterprises
Methodology: SWOT analysis to identify the strengths and threats associated with implementing regulatory sandboxes in the Bulgarian furniture industry, as well as a case study approach to determine suitable regions for the pilot application of regulatory sandboxes.

Fig.1. Map of the clusters by keywords of published papers on the sandbox



Source: based on data from WoS for the period 2018 – 2025, processed using VOSviewer, N=743 publications

The study uses bibliometric analysis of 743 sandbox-related publications in Web of Science. Keyword co-occurrence mapping (3,856 keywords) was conducted with VOSviewer.
The keyword *"sandbox"* connects three main clusters.

Blue (2018–2020): Technical sandboxes in computing, focusing on security, cloud, and AI testing—early but still foundational for later regulatory and experimental uses.

Green (2018–2021): Experimental and simulation sandboxes for testing policy and technology (e.g., smart mobility, transport) before large-scale adoption.

Red (2021–2025): Regulatory and innovation sandboxes in fintech, blockchain, AI, and governance—used as policy tools to foster innovation under regulatory control.

Regulatory Sandboxes
are

controlled environments for testing innovative products under supervision.
Dual role:
Supports business innovation.
Provides regulators with insights for rule adaptation.
Regulatory Sandboxes – Lessons from Broader Contexts
- Real-world laboratories (RwLs): Testbeds for sustainable construction, but often constrained by regulation (Jansen et al., 2022).
- Transport: Sandboxes support safe introduction of emerging tech like unmanned transport systems (Drozdova et al., 2023).
- AI & Algorithms: Machine learning can improve sandbox adaptability and regulatory accuracy (Di Porto, 2023).
- Finance: Effective sandboxes must balance innovation, legal stability, and human rights (Yordanova & Bertels, 2024).
Key conditions: Stable legal frameworks, alignment with real-world projects, and institutional learning (Beckstedde et al., 2023).
Risks: Market privileges and inequalities → require careful monitoring.

Strengths	Weaknesses
• **Provide a controlled environment for the safe testing of innovations without posing risks to core production.** • **Allow for significant cost reduction and shorter development time through virtual testing and simulations.** • **Support the early detection of defects and weaknesses, minimising the need for physical prototypes.** • **Facilitate the optimisation of furniture design through computer-aided simulations and topological optimisation.** • **Stimulate creativity and personalisation through 3D modelling and AI tools.** • **Support collaboration between industry, academia, and public institutions.** • **Provide a flexible testing framework for ensuring compliance with standards and regulations.**	• Require a high level of institutional capacity, legal flexibility, and political will. • Involve high initial costs for infrastructure, software, expert capacity, and training. • Sandboxes cannot always fully replicate real production conditions and market dynamics. • Companies with outdated technologies or a low level of digitalization may face difficulties in implementation.
Opportunities	Threats
• **Accelerate the integration of AI, IoT, and digital twins, supporting the transition to Industry 4.0 and 5.0.** • **Enable faster certification and reduce administrative burdens.** • **Support sustainable production and the circular economy through experiments with recyclable materials and energy-efficient solutions.** • **Improve strategic planning by collecting data on the interaction between new technologies and existing processes.** • **Can facilitate access to national and European funding programmes for innovation.**	• High initial investments and a risk of non-return, especially for SMEs. • Regulatory uncertainty and the absence of a harmonized European framework. • Risk of market inequality, as selected participants may benefit from more favourable conditions. • Possibility of a “race to the bottom” if rules differ across countries. • Potential misuse of more flexible regimes and a risk to consumer protection. Resistance from the workforce and a need for investment in reskilling.

Smart Furniture and Regulatory Sandboxes in Bulgaria

Market Dynamics of Bulgaria's Furniture Industry

- The furniture industry provides 3% of industrial added value and employs 30,000+ people in Bulgaria.
- Turnover growth: +€95.1M in 2022 (+12.16% vs. 2021).
- Market size forecast: ~€741M by 2025; USD 849.9M by 2029, CAGR 1.84% (2025–2029).
- Enterprises: Growing steadily at +1.1% annually (2019–2024).

Examples of smart furniture

- Smart school desks (Bulgarian Furniture Cluster)
- Smart home systems (ALL in Studio)
- Height-adjustable desks (Ergonomic Furniture BG)
- Smart solar benches (Profis BG)

Smart Furniture and Regulatory Sandboxes in Bulgaria

Challenges for smart furniture:
- Adoption is still limited.
- Weak collaboration with the IT & mechatronics sectors.
- Limited integration into global value chains.
- Market is still at an early/infancy stage.

Gap: Bulgaria has **no experience with regulatory sandboxes**, and integration of smart technologies in furniture has not been tested under such frameworks.

Findings from a 2024 Parliamentary study:
- Significant lack of understanding of sandboxes.
- Barriers: limited capacity, fragmented regulation, poor institutional coordination.
- Yet, **70% of businesses and civil servants** show interest in sandboxes for innovation

Cluster Analysis

Variables:
Employment, export value, settlements.
Three enterprise clusters identified:
- Low potential
- Medium potential
- High potential

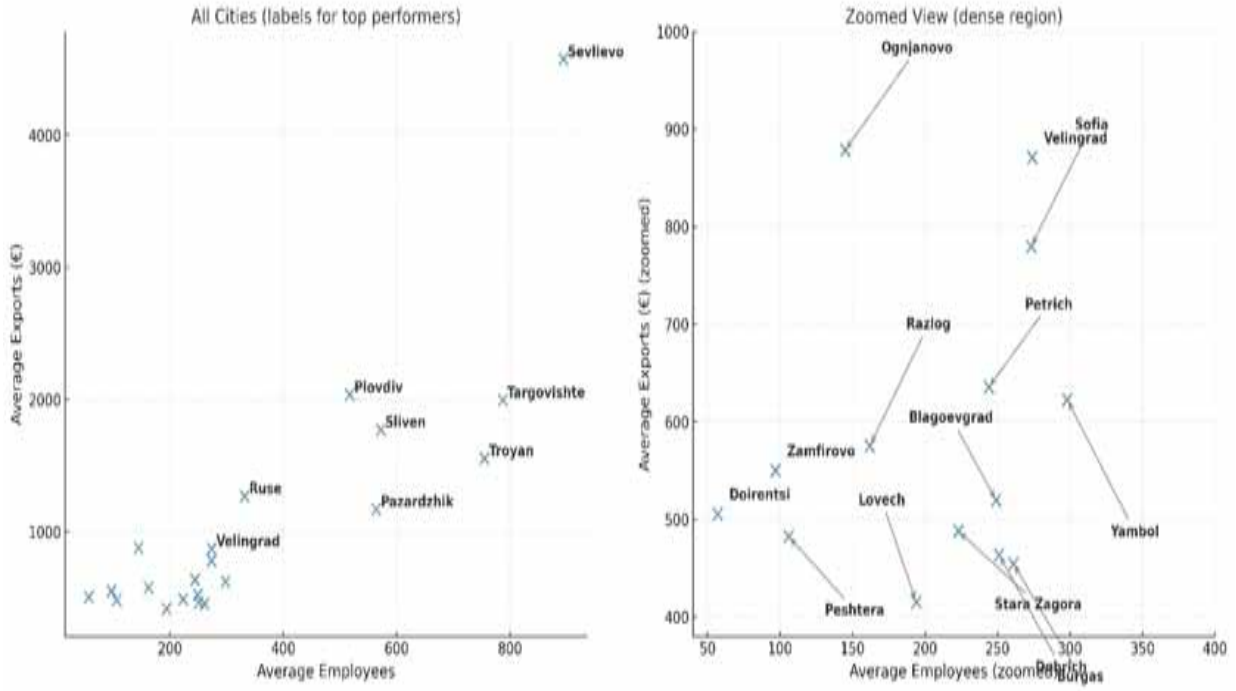
Medium & High Potential Clusters

◈ **Medium-potential cluster**
22 settlements
Avg. **234 employees**
Avg. exports: **€656K**

◈ **High-potential cluster**
18 settlements
Avg. **741 employees**
Avg. exports: **€2.7M**

Key towns: Sevlievo, Troyan, Plovdiv, Sliven, Pazardzhik, Targovishte, Ruse, Sofia, Velingrad, Petrich, Yambol, Blagoevgrad, Burgas, Lovech, Razlog, Peshtera.

Figure 2. Settlements with medium and high innovation potential, data from 2021, based on employment and average exports in the furniture industry in Bulgaria



Sandbox Pilot Selection

Landscape and opportunities in Ruse

Ruse & Gabrovo Together → 60% of Bulgaria's furniture exports.

Enterprise landscape: Large companies → modern tech, mass production vs SMEs → innovative, personalised client solutions. Focus on multifunctional & non-standard furniture solutions.

Enterprises:

- *Mebel Hit* (medium)
- *Mebeli IDEA* (small)
- *IKEA Bulgaria – mobile hub Ruse* (large)

Strategic location on the Danube River → gateway to international markets.

Angel Kanchev University of Ruse: Specialties in automation, industrial design, materials science.

Active business-university collaboration (projects, internships, R&D).

Workforce: 31% university graduates (above national avg. 28%); Steady supply of qualified professionals.

Digitalisation & Industry 4.0 in Ruse - Moderate but growing digitalisation pace.

Ruse Chamber of Commerce and Industry (RCCI) → active in projects:

- *Digital Twin*
- *BE-Digital*
- *DTAM*

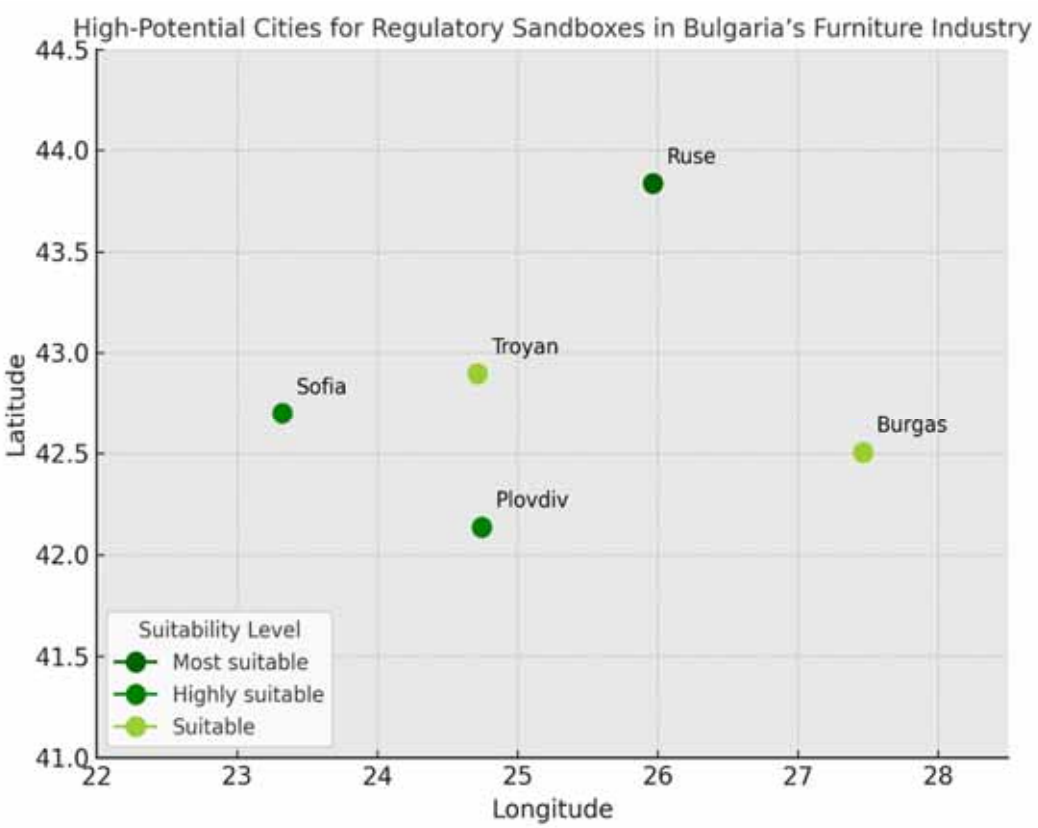
Companies already applying Industry 4.0 solutions:

- *SIVIKO, Bader Bulgaria KD, Husqvarna Ruse Ltd., Bullitt Engineering AD, SL Industries Ltd.*

Municipality of Ruse: Active in urban development projects; Investment in infrastructure & environmental improvements; Supported mainly by EU funding

Results:

- Favorable conditions for innovation and technology adoption.
- Strong potential for pilot regulatory sandbox projects.



Possibility for implementation of sandboxes in Ruse

Conditions for Success

- Careful planning & coordinated stakeholder efforts (government, academia, industry).
- Integrated design approach covering both sustainability and digital rules.
- Institutional support, legal clarity, and mechanisms to help SMEs overcome cost/technical barriers.
- Gradual, adaptive implementation to match the Bulgarian context.

Expected Benefits: Faster market access for smart/sustainable furniture, stronger SME–industry–academia ties, alignment with EU digital and green standards, potential to make Ruse a hub for regulatory innovation.

Risks

- High Costs: Requires significant funding and long-term institutional support.
- Regulatory Balance: Risk of too much flexibility vs. consumer protection.
- SME Barriers: Smaller firms may lack technical/financial capacity without aid.
- Scalability Issues: Results from Ruse may not transfer easily to other regions.

Conclusions

Regulatory laboratories and sandboxes are a promising tool to help the furniture industry adapt to the new European requirements for sustainability and digitalization. They provide a safe environment for experimentation, reduce risks and costs, and accelerate the introduction of smart and sustainable products.

At the same time, their success requires careful planning and strong coordination. Government institutions, business associations, academic institutions, and industry leaders must work together to create a supportive ecosystem. This includes:

- Developing a clear legal and regulatory framework that defines scope, rules, and evaluation criteria.
- Ensuring institutional capacity and securing sustainable funding from both national and European programs.
- Creating support mechanisms for SMEs, many of which lack the financial and technical resources to participate independently.

The European Green Deal and the rapid shift toward Industry 4.0 and 5.0 present not only regulatory challenges but also a unique opportunity. By leveraging digitalization, automation, IoT, and circular economy models, Bulgaria can position its furniture industry as a regional and European leader in sustainable and smart production.

Key industrial centers like Ruse, Plovdiv, Sofia, Troyan, and Burgas, already possess the skilled workforce, advanced infrastructure, and research capacity necessary for piloting regulatory sandboxes. With the right strategy, these hubs can become focal points for innovation, collaboration, and international competitiveness.

Thank you for your attention!

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