Regulatory sandboxes in the furniture industry: Challenges and opportunities

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REGULATORY SANDBOXES IN THE FURNITURE INDUSTRY. CHALLENGES AND OPPORTUNITIES

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Abstract: This report analyses the potential of regulatory sandboxes as an instrument to stimulate innovation in the Bulgarian furniture industry, with a focus on testing smart furniture. Through the use of SWOT analysis, the strengths, weaknesses, opportunities, and threats associated with introducing regulatory laboratories in the furniture sector are identified. Through a case study analysis, regions in Bulgaria with different levels of potential for the pilot implementation of regulatory sandboxes are suggested.
Keywords: smart furniture, regulatory sandboxes, furniture industry, innovation

1. INTRODUCTION

Smart furniture is an innovative segment within the furniture industry that integrates digital technologies, automation, sensors, and connectivity. They not only transforms the traditional appearance and functions of furniture but also raises new regulatory issues related to cybersecurity, personal data protection, safety, sustainability, and certification. El-Gizawi et al. (2023) points out that intelligent office furniture equipped with sensors and IoT solutions significantly improves working conditions and functional comfort for employees, but at the same time requires standardisation and clear regulation for its full-scale implementation. Schwarz et al. (2021) analyzes how smart furniture and IoT in smart homes increase the level of automation but raises concerns related to security and privacy. Xu (2024) examines trends in smart furniture design, emphasizing that IoT solutions and user experience are key factors for their widespread integration. Smart furniture is tailored to individual users, combining technology with craftsmanship, hence Červený et al. (2022) note that the furniture industry still lags behind the Industry 2.0 level. Yet the authors argue that with proper planning and cooperation among small and medium-sized enterprises, the implementation of Industry 4.0 can significantly enhance the efficiency and sustainability of production. However, this may prove insufficient. Manufacturers in such an innovative segment could also face serious regulatory burdens related to product safety, compliance with environmental standards, and supply chain transparency.

The integration of AI systems, both in the manufacturing process and in the final product, further binds manufacturers and suppliers to the obligations in the Artificial Intelligence Act for safety, health protection, and fundamental rights. As explained in the Commission's notice the "Blue Guide" (2022) on the implementation of EU product rules, the general principle is that "more than one piece of Union harmonisation legislation may apply to a single product." Placing a product on the market or putting it into service may only occur when it complies with all applicable legislation of EU for harmonization (Art. 46 of the Artificial Intelligence Act). This poses a serious challenge for all actors across the value chain, as well as for regulatory and market surveillance and control authorities. It requires a different and flexible approach to regulation and support for innovation, increasingly linked to the possibility of testing products in controlled environments before they are implemented on the market. This aims to provide a

controlled experimentation and testing environment through which both manufacturers and regulators can gain knowledge, assess risks, and develop effective rules. In this respect, as part of the "smart regulation" concept, regulatory sandboxes are viewed as regulatory instruments for fostering innovation (G20 Survey) as they perform a "dual role". On one hand, they support businesses in testing and implementing innovations in a real-world environment, and on the other hand, they provide a mechanism for regulatory learning and adaptation. They are described as "a limited form of regulatory waiver or flexibility, allowing firms to test new business models with reduced regulatory requirements" (Attrey et al., 2020). They are prescribed as „specific and structured experimental frameworks that enable the real-world testing of innovative technologies, products, services, or approaches for a limited period and in a limited part of a sector or area under regulatory supervision" (EP, 2022). Regulatory sandboxes have a special place in the Artificial Intelligence Act as "measures to support innovation" and receive their legal definition (Art. 3, point 55) and regulatory framework (Arts. 57 and 58). Hence, ensuring that appropriate safeguards are in place. Regulatory sandboxes can be seen as a key instrument for promoting innovation in the furniture industry, particularly for smart furniture, where end products combine design, functionality, and digital technologies.

The main goal of the paper is to analyse the potential of regulatory sandboxes as an instrument for testing and assessing the compliance of smart furniture models and systems in Bulgaria, following the relevant regulatory framework. The authors hypothesise that 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. The research methodology is based on a 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.

2. STATE OF THE ART

The furniture industry contributes over 3% of the added value in Bulgaria's industrial sector and employs more than 30,000 individuals, underscoring its economic significance (Ministry of economy and industry, 2024). Some examples of smart furniture in Bulgaria include the smart desks for schools under development by the Bulgarian Furniture Cluster. These desks come in three models for different student age groups and include tables for charging devices, integrating modern technology to improve the learning environment. The design firm ALL in Studio has implemented a smart home system in a two-story apartment in Sofia, allowing residents to control lighting, climate, and other features via smartphone, showing how smart furniture can enhance residential spaces. Ergonomic Furniture BG produces electric height-adjustable desks that support better posture and overall health. Profis BG develops smart solar benches equipped with solar panels, USB ports, wireless charging, environmental sensors, and LED lighting. However, the integration of smart technologies into furniture design and manufacturing in Bulgaria has not been analysed under the regulatory sandbox concept. Bulgaria has no prior experience in designing and managing experimental test environments such as regulatory sandboxes. In December 2024, the Library-Information and Research Parliamentary Centre at the National Assembly of the Republic of Bulgaria published a sociological study entitled "Regulatory Sandboxes as Part of Evidence-Based Legislative Policy" (Parliament.bg). The findings of the study indicate that a "significant gap in the

understanding of regulatory sandboxes and experimental clauses." The main challenges and barriers to introducing experimental regulatory environments in Bulgaria include limited administrative and financial capacity, lack of coordination among institutions and the legal framework, regulatory complexity, and fragmentation of emerging technologies. Although the study does not specifically address the furniture industry, the identified barriers mostly affect SMEs and start-ups, which is directly relevant to furniture manufacturers, who represent the largest share of this sector in Bulgaria. Moreover, the study's data show that more than two-thirds of civil servants, including municipal administration representatives, and 70% of business representatives indicate that the potential of regulatory sandboxes is of interest to them as a tool for fostering innovation. Given that, at present, the furniture industry is not a focus of regulatory experimentation (unlike financial instruments, automated credit algorithms, biometric systems, autonomous vehicles, and other frequently tested AI-based solutions), it can be assumed that it may still be too early to establish a regulatory sandbox specifically dedicated to smart furniture. Nevertheless, smart furniture is in constant, direct physical interaction with users. This interaction affects both the physical and digital environments of the user, an aspect explicitly highlighted in the definition of artificial intelligence under Article 3 of the Artificial Intelligence Act . Precisely because of this capacity to directly influence the surrounding environment and user behaviour, smart furniture deserves careful regulatory consideration. Testing within regulatory sandboxes, even on a cross-sectoral basis, is an appropriate mechanism for the early assessment of risks, regulatory compliance, and the need for legislative adaptation in view of ensuring safety, transparency, and trust in intelligent solutions integrated into everyday environments. In this respect, manufacturers can participate in cross-sectoral regulatory laboratories, drawing on the example of the cross-sectoral regulatory lab with a general purpose for innovation and the digital transformation of public administration called "Sperimentazione Italia". "Sperimentazione Italia" is an Italian cross-sectoral regulatory sandbox, which allows start-ups, companies, universities, and research centres to test their innovative projects for a limited period through temporary exemptions from existing regulations.

3. SWOT ANALYSIS OF REGULATORY SANDBOXES IN THE FURNITURE INDUSTRY

Regulatory sandboxes provide a controlled environment for testing innovations without posing risks to core production, which is a key advantage for companies that cannot afford disruptions to their ongoing manufacturing processes. Bauknecht and Kubeczko (2024) view regulatory experiments as a tool for sustainable transformations that, through sandboxes and living labs, enable the testing of new products and regulations, accelerating innovation and regulatory learning. Baldini and Francis (2024) emphasize the role of AI regulatory sandboxes in supporting the introduction of innovations in line with the GDPR and the AI Act, highlighting the need for ethical principles and corporate responsibility. Olszewski (2024) stresses the importance of regulatory sandboxes for the safe testing of AI and the prevention of legal and ethical risks across all economic sectors. In this respect, the application of regulatory sandboxes in the furniture industry highlights several strengths (see Table 1) that justify their role as a key instrument for the accelerated implementation of innovations and digital transformation. A major advantage is the potential for significant cost reduction and shorter development time through virtual prototype testing and simulations. This enables manufacturers to identify defects and weaknesses at an early stage, minimising the need for costly physical prototypes. Sandboxes can support the collection of data on the interaction

between new technologies and existing processes, which facilitates strategic planning and the alignment of innovation policies with market trends. Last but not least, sandboxes promote sustainable manufacturing and the transition to a circular economy by creating conditions for experiments with recyclable materials and energy-efficient production processes.

Implementing sandboxes also involves several weaknesses. Data from the OECD (2023) show that establishing sandboxes often requires a high level of institutional capacity, legal flexibility, and political will. The substantial initial costs for building infrastructure, acquiring specialized software, and ensuring the necessary training and expert capacity are often unaffordable for companies that lack sufficient technological and financial resources. Moreover, despite the high precision of virtual simulations, sandboxes cannot always fully replicate all the real conditions of the production process. Another significant risk is related to technological maturity. Companies operating with outdated production systems or with a low degree of digitalization may face difficulties integrating solutions from test environments into their actual operations, which limits their potential benefits and slows down effective implementation.

Alongside the challenges, there are also significant opportunities for expanding the use of sandboxes in the furniture industry. Sandboxes can be established as a natural platform for the accelerated integration of new technologies such as AI, automation, robotics, IoT solutions, and digital twins. Thereby directly supporting the transition to Industry 4.0 and 5.0, where a new balance between automation and the role of the human factor is sought (Dallasega et al., 2020; Yordanova & Bertels, 2024). From a regulatory perspective, these environments enable flexible testing and faster certification of new products and processes within a controlled and adaptive legal framework, which reduces administrative burdens and supports compliance with applicable standards (Olszewski, 2024). Sandboxes allow furniture companies to experiment with environmentally friendly materials, energy-efficient processes, and designs compatible with modern regulations, such as Regulation (EU) 2024/1781.

Despite these positive prospects, the implementation of sandboxes in the furniture industry is associated with certain real threats that should not be underestimated. Often, the return on investment in sandbox solutions materializes in the long term, making it difficult to justify significant capital expenditures in the short term (OECD, 2023). There are concerns that within the EU, divergent practices and regulatory approaches to sandbox mechanisms may emerge, increasing the risk of heterogeneous national regimes and complicating the creation of a harmonized European framework for such innovation environments (Ranchordas & Vinci, 2024). There is a risk of disrupting the balance between measures that support innovation and the safeguards that protect the public interest and consumer rights (Leimüller and Schwarzer, 2020; Pop and Adomavicius, 2021). The potential for “misuse” of sandboxes is linked to the possible negative impact on consumer protection caused by reduced safeguards and requirements used by supervisory authorities to attract innovators which is particularly evident in the “race” for innovation in the fintech sector (Allen, 2020). Industry stakeholders are calling for greater clarity regarding the interaction between national and European regulatory sandboxes that could be used for AI technologies. K. Yordanova (2022) notes that “since the application of sandboxes is not uniform among EU countries, the EC’s proposal could create confusion in the market. It could also encourage AI developers to choose EU countries with less stringent sandbox regimes, at least for regulatory compliance purposes.” Another threat could be the resistance to change among the workforce, especially if workers are accustomed to traditional production practices and are sceptical about digitalization and automation. This requires targeted investment in reskilling and the development of new competencies to

overcome the shortage of qualified personnel capable of working with advanced simulation technologies and to ensure the successful integration of sandbox solutions into real production environments.

Table 1. SWOT analysis results

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.

In summary, regulatory sandboxes represent a strong potential instrument for accelerating digitalisation, innovation, and sustainability in the furniture industry. To fully realise this potential, careful resource management, active support for small and medium-sized enterprises, a consistent regulatory framework, and effective programmes for workforce training and adaptation are essential.

4. OPPORTUNITIES FOR INTRODUCING REGULATORY SANDBOXES IN SMART FURNITURE MANUFACTURING IN BULGARIA

In 2021, data from the National Statistical Institute indicated that Bulgaria had 1,970 enterprises involved in furniture manufacturing. These companies are distributed across 517 settlements. Seventy-eight percent of these enterprises are classified as small, with a turnover below 500,000 euros. Medium-sized enterprises dominate the sector, accounting for 65% of total turnover, while large enterprises (with a turnover exceeding 5 million euros) make up only 3% of all companies but generate over 40% of the total turnover. Using the elbow method and considering the average number of employees, export value in euros, and the number of settlements, three clusters of furniture enterprises in the country can be identified. For analysis purposes and given the specifics of regulatory sandboxes, it is useful to focus on clusters with medium or high potential. The 'medium potential' cluster includes 22 settlements with an average of 234 employees in the sector and an estimated export value of 656 euros. The 'high potential' cluster comprises 18 settlements where an average of 741 people are employed and exports reach 2,727 euros. Notable towns and settlements within these clusters include Sevlievo, Troyan, Plovdiv, Sliven, Pazardzhik, Targovishte, Ruse, Sofia, Velingrad, Petrich, Yambol, Blagoevgrad, Burgas, Lovech, Razlog, and Peshtera. For possible future pilot projects of regulatory sandboxes within Bulgaria's furniture industry, a brief comparative analysis was performed on these settlements based on criteria such as industrial activity, digitalisation levels and Industry 4.0 integration, availability of a qualified workforce, access to universities and research institutes, presence of small, medium, and large enterprises, and potential to attract funding and regulatory support. Three groups of settlements can be distinguished according to their high, medium, or low potential for the implementation of regulatory sandboxes.

Settlements with high potential for introducing regulatory sandboxes in the furniture industry

This group may include cities such as Ruse, Plovdiv, Sofia, Troyan, and Burgas. The furniture industry in Bulgaria is most developed in Ruse and Gabrovo, which together generate over 60% of the country's furniture exports. The region stands out for its concentration of enterprises and a qualified workforce (Stoenchev and Stefanova, 2020). Large companies in Ruse invest in modern technologies, while small and medium-sized enterprises offer innovative and customised solutions. Examples include Mebel Hit, Mebeli IDEA, and IKEA Bulgaria. Located on the Danube River, Ruse is an important logistics centre with easy access to external markets. The Angel Kanchev University of Ruse trains specialists in automation, industrial design, and materials science, and works closely with businesses through internships and research projects. The Ruse Chamber of Commerce and Industry participates in initiatives such as "Digital Twin" and "DTAM," which develop digital skills and support Industry 4.0. The share of university graduates (31%) is above the national average, and the municipality actively invests in infrastructure with EU support, creating a favourable environment for the adoption of new technologies (https://ruse.egov.bg).

Plovdiv is the second largest industrial centre in Bulgaria and an important hub for the furniture industry. The city hosts the Thrace Economic Zone, which includes six industrial areas, over 3 billion euros in investments, and more than 50,000 jobs. Both large international companies and SMEs operate here, producing furniture for the domestic market and export, from mass production to boutique solutions. Leading manufacturers include Ted Bed EAD, Mebeli Kopanarski, Tsvete, REDO EOOD, Mebelor, Essenza, and Mebeli Ela. Plovdiv benefits from a skilled workforce thanks to the local branch of the Technical University of Sofia, the Paisii Hilendarski University of Plovdiv, and vocational high schools for woodworking. The city is an active participant in EU programmes and Industry 4.0 initiatives and benefits from support by the EBRD and the EU Regional Development Fund. The international "Industry 4.0" forum and the example of Schneider Electric's "smart factory" confirm Plovdiv's strong potential for regulatory laboratories for testing digital product passports and sustainable production models.

Sofia is a leading economic and technological centre with developed infrastructure, a qualified workforce, and a strong presence of universities and research institutes. More than 50% of the working-age population holds a higher education degree, and many companies implement innovative solutions such as IoT, automation, and AI. The Technical University, Sofia University, the Bulgarian Academy of Sciences, and Sofia Tech Park provide a scientific base and testing environments for new technologies and smart furniture. The city has broad access to European funding (for example, "Horizon Europe") and strong connections with international investors. Leading manufacturers include Interior-I, Buldecor, Era Stil, Videnov, METRON, Emiliano Mebel, MONEMA, and Pirinski Bor. In Sofia, there are both established furniture companies and start-ups focused on high-tech design and customised production.

Troyan is a traditional centre for furniture manufacturing, with more than 30% of local enterprises operating in the sector. The town has strong traditions in woodworking and craftsmanship (ceramics, solid wood) with leading companies such as "ELIMEKS – Ivan Radevski" and "Hemus Troyan." The absence of a university is offset by Troyan's proximity to Veliko Tarnovo and Gabrovo, which ensures access to a skilled workforce. Troyan has potential for regulatory testing of sustainable materials and biodegradable furniture.

Burgas is an important economic and logistics centre with access to the Black Sea, a strong industrial base, and active digitalisation programmes. The furniture sector is dominated by small and medium-sized companies such as Mebeli Dreams, Danista, and Estilo, which are implementing new technologies and automation. Vocational high schools and local universities (Burgas Free University and Prof. Dr. Asen Zlatarov University) train specialists for the industry. The city offers access to funding through the Rural Development Programme, the Operational Programme for Innovation and Competitiveness, and Industry 4.0 programmes, while the "Industrial and Logistics Park – Burgas" supports investment and innovation.

Settlements with medium potential for introducing regulatory sandboxes in the furniture industry

This group includes Sevlievo, Sliven, Pazardzhik, Targovishte, and Yambol. These are cities with developed or developing industrial zones and furniture enterprises, with a lower level of digitalisation and no universities or research institutes to support technological innovation. In Sevlievo, large companies such as "Paralel EAD" and "Abanos" operate alongside many small and medium-sized custom furniture firms. Vocational schools train specialists, and the proximity to Veliko Tarnovo and Gabrovo provides access to research institutes. There is good industrial infrastructure and funding for innovation. In Sliven, an active sector operates with companies

such as “NACHEVI 90,” “Sezoni,” and “Nimis.” SMEs offer customised solutions. The “Barshen” industrial zone is developing investments. In Pazardzhik, companies such as “Colorado” (with three factories) and “Piponkov” are active. Firms are modernising production with automation and planning new lines. Vocational high schools and proximity to Plovdiv provide a skilled workforce and access to universities. In Targovishte, “Mebel-stil,” “Mebeli Zdravec,” and “Lito-sin” are located. The city is developing an industrial park with modern infrastructure. The lack of a university is offset by proximity to Shumen and Varna for cooperation with research institutes. In Yambol, companies such as “NOV DOM,” “SNEP,” and “KAN” operate. More than 400 firms employ 3,000 people. There is progress in digitalisation and a trained workforce, and the proximity to Sliven and Burgas facilitates access to universities.

Settlements with low potential for introducing regulatory sandboxes in the furniture industry

This group comprises cities such as Blagoevgrad, Velingrad, Petrich, Lovech, Razlog, and Peshtera, which have limited industrial capacity in the furniture sector and a lower concentration of enterprises engaged in export-oriented production. These cities could be included in future phases of expanding regulatory sandboxes. Blagoevgrad lacks an industrial zone for large-scale production despite the presence of companies like “Perfect Mebel” and “Mebel 2010.” Velingrad is focused on tourism, and furniture manufacturing activity is limited. Petrich is mainly centred on agriculture and trade, without a developed furniture sector. Lovech has traditions in woodworking, but the modern furniture industry remains underdeveloped. Razlog is oriented towards tourism and agriculture, with no significant furniture industry. Peshtera is known for shoe and beverage production, while the furniture sector holds minimal importance.

In conclusion, Ruse, Plovdiv, Sofia, Troyan, and Burgas are the most suitable cities for launching pilot regulatory sandboxes in the furniture industry due to their high concentration of enterprises, good infrastructure, and the presence of research institutions. They have industrial activity, research capacity, access to international markets, and opportunities for digitalisation. As an initial step, it is appropriate to launch a pilot regulatory sandbox in Ruse, using the support of industrial clusters and universities to test new regulations under real conditions. Sevlievo, Sliven, Pazardzhik, Targovishte, and Yambol have potential for future inclusion in the initiative, while Blagoevgrad, Velingrad, Petrich, Lovech, Razlog, and Peshtera are less suitable for the introduction of such sandboxes at this stage.

3. CONCLUSIONS

Regulatory sandboxes can serve as a vital tool for fostering innovation and digitalisation within the furniture industry, particularly during the shift to smart furniture and Industry 4.0 and 5.0. The SWOT analysis highlights the benefits of sandboxes as controlled environments for experimentation, which help reduce development costs and speed up the market introduction of new products. They enable companies to safely test automation and smart manufacturing in a protected setting, minimise investment risks, and stay compliant with an ever-changing regulatory landscape. However, challenges such as high initial costs, the need for institutional capacity, and legal clarity demand well-coordinated efforts among businesses, academia, and regulators. Key locations like Ruse, Plovdiv, Sofia, Troyan, and Burgas possess the industrial and scientific capabilities necessary for piloting regulatory sandboxes and laboratories. These

areas benefit from a skilled workforce, advanced industrial infrastructure, and access to funding and research resources.

In conclusion, to fully realise the potential of regulatory sandboxes, targeted planning, the creation of a clear legal framework, and the provision of mechanisms to support small and medium-sized enterprises are necessary. In this way, the furniture industry will be able to position itself as a competitive player in the European market, ready to meet the requirements for sustainable and technologically advanced production.

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