

Innovation in Furniture Combining Ecology and ICT: The Green and Smart Furniture Research Project

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The present paper describes the Green and Smart (GSF) project developed by the Laboratory of Applied Marketing, Management and Economic of the Wood and Furniture Design and Technology Department of TEI of Thessaly Greece. The research outcomes produced a piece of smart entrance furniture made of ecological raw material, eco-based and recyclable IT material and under strictly sustainable production methods regarding energy, water and emissions. It also indicated the potential of co-operation between different stakeholders in a mature industry suggesting the transcendence to new concepts for furniture even for SMEs. The present success case indicates that the future of the emerging trend towards ICT use and sustainability is very encouraging and can offer new competitive advantages to the traditional furniture industry against economies of scale.

Field of Research: Management

1. Introduction

Furniture manufacturing constitutes a significant sector in the E.U. with a strong presence globally, mainly because of the high quality standards in technical and aesthetical level (UEA, 2005). European Union is still one of the biggest manufacturers, traders and consumers of wooden products in the world (European Commission, 2013). During the period 2000-2007 furniture industry has known significant growth; however, the crisis of 2008 and a series of global rearrangements of the sectoral players with Asian producers to take the lead and big players to change the rules of the game. Furthermore, the continuing severe crisis in Greece intensifies the rather negative and risky efforts of Greek furniture manufacturers to survive.

A number of studies (Petrakis et al., 2015; Trigkas et al., 2014, Kumar et al., 2013) indicate innovation and differentiation together with the development of extroversion as the only ways for these firms to stay active in the national and global markets. Companies need to develop specific capabilities and sense emerging opportunities which can be market or technology driven.

An emerging field for innovation regards the growing concern related to the environmental consequences either in regard of production and transportation or raw materials and the use and disposal of produced goods during their lifecycle (Fankhauser et al., 2013; Papadopoulos et al., 2010). Furthermore, technological advances and ICT applications offer the potential of novel concepts regarding comfort, usability and even production.

However, besides the increasing number of efforts to provide novel furniture using ICT and ubiquitous technology, there are scarce efforts to combine ICT to eco-concepts or to bring high-tech down to the level of micro and small companies.

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The GSF research project was based on this very gap and opportunity; i.e. the intersection of ecology, ICT and the tacit and existing needs of Greek micro, small and medium furniture manufacturers to develop capabilities for new competitive advantages. Selecting the elderly as the main target group, research focused on the development and market introduction of technologically supported furniture eco-solution to foster the targeted consumers' self-determined living in their homes.

The research was undertaken by the Laboratory of Applied Marketing, Management and Economic of the Wood and Furniture Design and Technology Department of TEI of Thessaly Greece (WFDT from now on). The research team included an ICT company, a furniture small company, two other Universities and a number of external collaborators. The research project has been co-financed by the European Union (European Social Fund - ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program "ARCHIMEDES III Investing in knowledge society through the European Social Fund".

The present paper describes the physical outcome of the GSF project; i.e. the design, the production technologies, opportunities and limitations. The emerging innovation and the way of its achievement may constitute best practice at sectoral level and a basis for theoretical research on the specificities of academia-based innovation and its application by low-tech industries to relevant global markets.

2. Background of the research project

2.1. Innovation and Furniture Product Development

In general terms and for the majority of European and Greek micro- and SMEs, innovation regards mainly restructuring of production methods based on advanced CIM systems or the introduction of novel materials elsewhere produced. Design continues to hold the lion's share with EU manufacturers to be overwhelmed mainly by Italian, Spanish or Scandinavian design. Easier transport, innovation regarding the enhancement of economies of scale, faster deliveries (advanced logistics) and established design are the main sources of competitive advantage. However, lately smart furniture is emerging, mainly based on the extensive applications of ICT. On the other hand, there is a growing trend and sensitivity towards environmental protection.

Green furniture: Eco-furniture or "green" furniture is broadly defined as a product of furniture designed to minimize the environmental impact during its whole life-cycle (Albino *et al.*, 2009) and thus; as furniture with characteristics of environmental compatibility, taking into consideration all the stages in furniture life-cycle (Alhola 2008; Progetto Life, 2005). According to recent research (Mantanis and Ntalos, 2007; Mantanis, 2007) normal home furniture and structural material of timber usually emit toxic and damaging gases and influence more or less human health. Formaldehyde emission, emissions of organic solvents, biocide, volatile organic compounds (VOC's), adhesive substances etc can cause serious diseases, such as genetic abnormalities and cancer. Furthermore, an emerging stream of research focuses on environmental friendliness of wood-based products and their production. For example, The 'Life Environmental Eco-friendly furniture project', launched in Italy during 2001, aspired to develop furniture prototypes regarding environmental protection at all the stages of a furniture life cycle (Progetto Life, 2005). However, to the best of our knowledge, eco-design has not been directly related to the specific group of aging population.

Smart furniture: Smart or intelligent furniture is a quite novel approach to furniture innovation moving from transformable pieces of furniture to interactive furniture (Tokuda *et al.*, 2003; Zongdeng and

Wenjin, 2010). Utilizing ICT solutions, a smart furniture product has the capability to alter a conventional space into an intelligent spot that includes computing systems (Ito *et al.*, 2003). For example, Ubiquitous Computing (UmpiComp) environments (Wuliji, 2009) have been developed to apply computing systems to our everyday living environment, making them at the same time "invisible" to the user (Weiser, 1993). There is a growing number of ICT-based smart furniture such as the *Dietary-Aware Dining Table*, developed by a research team of the National University of Taiwan (Chang *et al.*, 2006) or the *Drift Table* and the *Key Table* developed during the project for *residential technologies of Equator IRC* (Boucher *et al.*, 2006). Contrary to eco-furniture, smart furniture for elderly is a fast emerging field in both academic and practical level (e.g. Guennoun, and El-Khatib, 2009).

Aging populations are a major challenge for industries and firms, since they offer opportunities in regard of technical and social innovation and the emergence of niche markets. Innovative approach of the specific target group can turn apparent crises into opportunities (Kohlbacher & Herstatt, 2008) exploiting expectations and demands. Furniture industry starts adopting other industrial knowledge such as gero(n)technologies and information communication and technologies (ICT) and blending it with design in order to create novel and differentiated product categories (e.g. Goodacre *et al.*, 2007). The E.U. is also giving special attention in the development of smart furniture for the third age through the funding of the WIDER project (2014), in an effort to give the opportunity to furniture industries across Europe to innovate and differentiate.

The furniture industry can either adapt some of its existing products or create new ones to meet elderly people's changed sensory, perceptual, cognitive, and psychomotoric capabilities (Rogers & Fisk, 2003; Schäfer *et al.*, 2006). Therefore, user-centered approaches can be transferred to furniture-centered ones enhancing the relationship between producers and users in the specific markets.

2.2. Project concept and objectives

The aim of the research project under the name "GSF - Green and Smart Furniture" was the development of intelligent and purely ecological furniture that would provide a better experience of house life without overloading the users with technology and the pilot production of at least one of the product ideas and concepts.

Following the general principles of NPD management, the focus was on the improvement of in-house activities and operation regarding the furniture.

Besides the creation of a physical innovative, R&D based product, the project aspired to cover various areas at multiple levels, such as:

- The creation of a path to innovative niche markets and the cultivation of innovative and collaborative culture to the extremely traditional and introvert furniture industry in order to support the survival and recovery of the sector.
- The promotion of ecological innovation (eco-innovation) and its incorporation in the productive network of Greece as a main factor of growth and competitiveness.
- The encouragement of the networking to high-tech industries and the shift to intelligent furniture (technological innovation)
- The further support of environmental protection and the rational management of forestal wealth (wooden furniture)

A core aim of the project was the provision of best practices and new innovative strategic directions for the traditional sector of furniture, considering the fact that the sector is in a severe decline, due to the economic crisis and global competition.

The project was, to our best of knowledge, among the first worldwide to attempt the manufacture of a complete innovative furniture product which would be both smart and ecological.

In order to create a holistic best practice for the innovative process and in order to produce effective and applicable results, the WFDT team established collaborations with the Economic University of Athens, the University of Cyprus, the Department of Business Administration and the Department of Electrical Engineering (both of TEI of Thessaly), an ICT company and a furniture manufacturer.

The research team was further committed to follow the structured methodology of new product development as provided by Ulrich and Eppinger (2004) and transfer the knowledge of the integrated R&D-based, open-innovation process to stakeholders of the industry as a deliverable of the project. The project included six (6) Work packages and namely: (i) the delineation of the GSF Product Development process, (ii) the determination of GSF market in Greece and its tendencies (Targeting and trend analysis), (iii) the design of eco-logical - GS furniture, (iv) the production Technology of eco-logical GS furniture, (v) economic analyses and (vi) promotion and communication of the innovative product .

It should be mentioned that the Economic University of Athens was involved mainly in the phase of the economic analyses, while the University of Cyprus and the Department of Business Administration collaborated with the core research team mainly in the first, second and last step.

3. The physical outcome – “The heart”

3.1. The delineation of the GSF Product Development process:

The project was based on two pillars: the increasing number of environmentally sensitive consumers worldwide who constitute a very important target group and the knowledge pool of the Department of Wood and Furniture Design and Technology regarding ecology, such as the use of timber from sustainable managing forests, use of natural glues without chemical additives, use of natural dyes, and recent empirical research in the Department’s laboratories. However, the team contacted a thorough literature review on issues regarding ecological furniture, smart furniture, relevant market segmentation, legislation and regulation as well as relevant research efforts in Universities and Research centers. Following Ulrich and Eppinger (2004), the research team prepared:

- A delineation of the market research of consumers for their intention to buy eco-smart furniture.
- The Design Brief which included the vision and the purposes of the project, its milestones, the stakeholders, the new product development planning (time planning and processes), the establishment of the target group, criteria, limitations and hypotheses, product lists and timetables.

3.2. Design of eco-logical (Green and Smart) Furniture

Addressing the existing and tacit needs and requirements that were derived by the market research and the meetings with the Department’s designers required complementary competencies. For this reason, in this phase of the project, the Department’s research team combined their expertise and knowledge with the ICT and automation company, the Department of electrical engineering of the Institute and the furniture manufacturer. Thus, the GSF project combined competencies from wood

technology, ICT technology, furniture technology, design, electronics, NPD and innovation management, marketing, and all necessary research methodologies to design and later produce the innovative eco-smart piece of furniture.

The team listed the characteristics: a) located by the market research and consumers' indications (stated and perceived); b) imposed by the ecological character of the furniture; c) the smartness attempted; d) the manufacturers' indications (e.g. the potential for mass production and cost considerations and e) limitations imposed by the very nature of the furniture such as ergonomics, aesthetics etc.

The further elaboration and evaluation of the characteristics lead to a series of discussions on the kind of furniture among all stakeholders; in this phase, designers produced a number of ideas in sketches. Brain-storming and several controls for the satisfaction of the core criteria lead to the final choice of three different pieces of furniture with distinctive characteristics that seemed to satisfy the majority of the initial targets of the team: coaches, coffee tables and entrance furniture.

The three choices produced a number of sketches which were then presented in 2-D and 3-D designs as analytical as they could be. Another round of meetings with all stakeholders led to the final selection of a *main entrance furniture* which would also serve as an information provider. The main characteristics were decided to be:

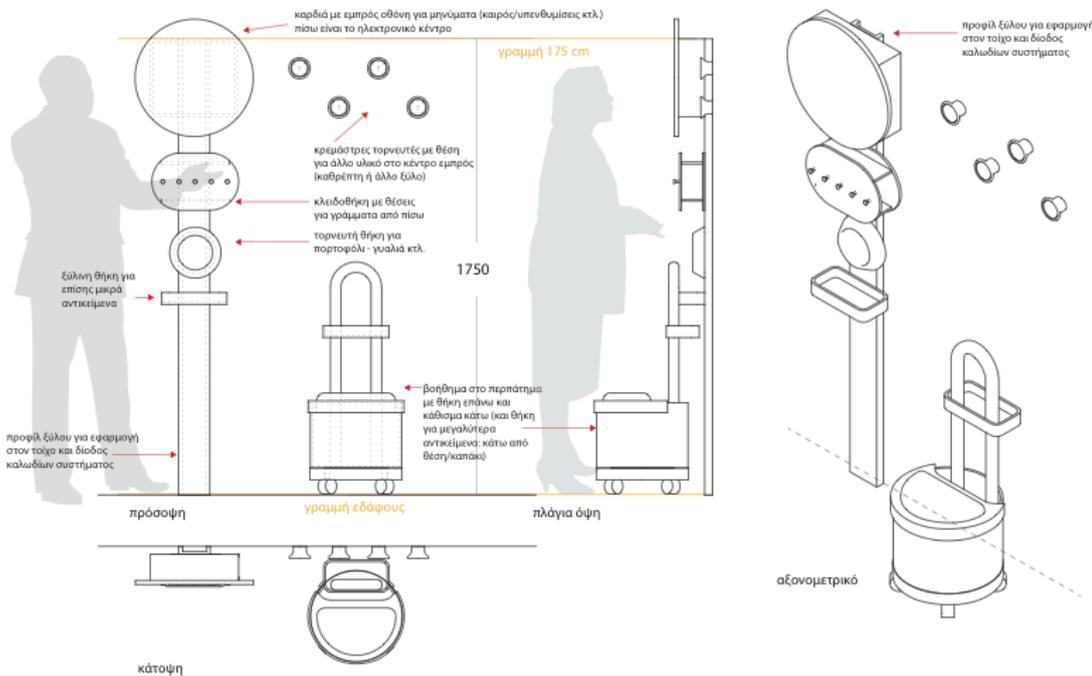
- a) Natural wood as core material
- b) Recyclable supplementary material
- c) Functions: mirror which could become an information screen (e.g. indications about clothing and accessories, reminder of pills or meals etc.)
- d) Store room for small objects, documents (e.g. letters, medicine descriptions etc) in interaction with the supplied info by the mirror
- e) Specific store room and relevant info on spectacle cases and keys
- f) A wheelbarrow with store room attached (as part of the furniture) serving as a sitting or supporting facility or a medium to carry heavy (in terms of the elderly) load.
- g) Supporting elements to hang objects (coats, hats, umbrellas etc).

Design would incorporate the potential to add or remove elements; it could adapt to specific individual needs enabling consumers to choose and buy the parts they needed. Furthermore, the screen would have the potential to add info-elements such as news and indications for close relatives and friends and it could also co-operate with other smart devices in a smart environment; i.e. inform on security issues.

The contribution of the stakeholders was once again of critical importance. The experts of the ICT Company co-operated with the designers to solve difficulties of turning common furniture pieces in sources of interaction. Indicatively, the mirror was turned to a face recognizer and a provider of information; i.e. regarding the weather it would remind the person who used it to take the umbrella for the rain or for the sun. Furthermore, the research team worked together with the furniture company members on eco-based materials such as natural wood, recycled or recyclable materials that would better suit the object and could be manufactured in energy and water-saving ways. At the same time the ICT company members had to indicate eco-based material and the best ways to incorporate the electronic staff in the furniture; i.e. to make it invisible.

The final design is presented in figure 1. The team decided to name it "The heart" which indicated the importance of it in the everyday life of the elderly.

Figure 1: Final Design of the entrance green-smart furniture “The Heart”



3.3. The production technology of eco-smart GS furniture

Once again expertise and knowledge of all three parts was needed to produce the pilot furniture product. There were certain difficulties in the challenge of implementing intelligence solutions in a sustainable furniture system; this actually included material, design and production. The team managed to overcome difficulties with a significant number of try-and-error efforts at all three laboratories. It should be mentioned that it was a highly iterative process since many of the initial suggestions had to be reconsidered due to limitations mainly imposed by the combination of intelligence and ecology issues.

The produced prototype was made mainly of American oak solid wood of the best quality. All supplementary material was recyclable or recycled material.

In regard of the ICT part, the system was composed of an Android tablet, a number of sensors and a PLC. JAVA was used in Eclipse environment using the Android Development Tools (ADT) which extends the IDE Eclipse for Android Projects development. Regarding face recognition, the open code OpenCV library was used. Table 1 presents the editions of the core elements and of the plug-ins used.

The mirror turns to screen when asked to do so; however it allows only to specific users to execute functions such as reminders, info seeking and management in general. The system recognizes the user by his /her face on the mirror and reacts by a message of the type “Hello, Nick!”. However, the system reacts only in case of direct use of the mirror (not every time the user passes in front of the furniture). There are certain symbols to refer to functions such as whether forecast and the reminders.

Table 1: editions of the core elements and of plug-ins

	Description	Edition	Namespace
1	Eclipse Platform	4.2.1.v20130118-173121-9MF7GHYdG0B5kx4E_SkfZV-1mNjVATf67ZAb7	org.eclipse.platform
2	Eclipse Java Development Tools	3.8.2.v20130116-090414-8-8nFu3FNOfwKLRuqgXKIy9z0I83	org.eclipse.jdt
3	Android Development Toolkit	23.0.4.1468518	com.android.ide.eclipse.adt.feature
4	Android Developer Tools	23.0.2.1259578	com.android.ide.eclipse.adt.package.feature
5	Android SDK Build Tools	4.4.2	API 19
6	Picasso Image Loader	2.4.0	com.squareup.picasso.Picasso
7	OpenCV	2.4.9	org.opencv

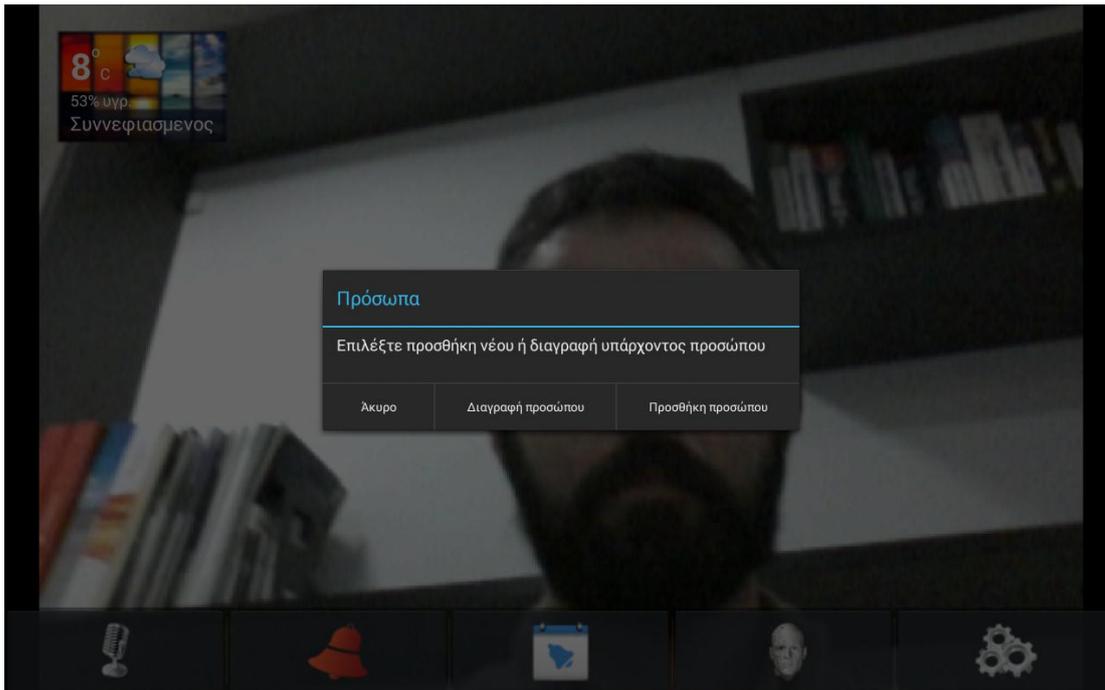
There are a number of sensors incorporated to remind and search for objects such as keys, wallet, hat, umbrella and coat. The system has been programmed to make suggestions in a number of cases. For example: If the weather is cold and the user has taken the keys but not the coat, the system will warn him/her that the coat is forgotten and the weather is cold.

While these are the functions of the prototype, the team works on the addition of functions. Indicatively, the system can use verbal communication, be connected to social networks (e.g. facebook), interaction with other functions of the house such as the protection alarm, and the use of RFID tags in objects such as bags, keys etc which would be in the same space with the GSF.

The assembly of the parts was realized in the firm's plant to simulate real conditions of manufacturing. Quality controls took place in the WFDT Department's laboratories with the assistance of the ICT Company as well.

The relevant know-how was then written down as a basis for the preparation of a manufacturing handbook for mass production or mass customization production. The general framework of the production technology and assembly has been delineated, while there is a range of natural wood species and eco-based supplementary material selected to be included in the relevant handbook of eco-smart furniture manufacturing suggestions. Furthermore, there are suggestions about minimal use of energy and water as well as regarding emissions and waste.

Figure 2: Introduction of a new face. Weather forecast (the icon in the top left hand corner)



The final technical and manufacturing drawing plans were submitted to Industry Property Organization (IPO) to be granted a certificate of registration as industrial designs and be patented.

Economic analyses followed in order to secure the feasibility of the product. The marketing plan a) stresses the benefits of the innovative product; b) delineates the main target groups and other potential users; c) discusses the messages to send to the market and ways to communicate them (e.g. media). The final report includes suggestions for branding since it plays a significant role in the success of new products.

4. Discussion and Conclusions

The competitive international environment and the need for highly differentiated and innovative products in the furniture industry impose the focus in the development of collaborative research and the co-operation among different areas of expertise.

The GSF project may constitute an exemplary integrated NPD process since it offers both codified and tacit knowledge and experience together with the launching of the innovative furniture product. Actually, it can be claimed that the specific research project has built a framework for the design and development of a Green and Smart furniture. It, furthermore, facilitated first contacts of the mature furniture industry in the Region of Thessaly with high-tech such as ICT and automation providers not for the sake of production processes and the machinery counterpart but for the creation of high-tech furniture end-products. This is an innovation approach for the sector at national level.

The touchable result was the manufacture of the first European ecological and at the same time intelligent furniture product supported by its handbook of production guidelines.

The overall results justified the initial vision of the research team as well as the selection of the collaborative partners. More specifically, the project resulted in: a) the acquisition of specific know-how on the ecological and the intelligent furniture, b) the creation of a database of all relative legislation on

ecological furniture, c) an integrated design study of ecological-smart furniture, d) patented industrial design of a specific model furniture, e) codified experience and learning material for excelling designing skills and capabilities, R&D collaboration, networking and NPD in the furniture education, training and industry in general.

It should be an omission not to mention benefits for consumers; advanced furniture products based on ecological approaches advance the wellbeing, secure health issues and support the tendency of aging populations to live independently. The project further indicated that actually the idea and product development for aging users can be a very complex task, since little is known about the specific characteristics of this target group. There were certain areas that needed to be approached from multiple angles; this was achieved by the collaboration of the diverse teams that bared knowledge from different perspectives and allowed the answers to common research questions.

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