Product design for sustainability: A collaboration example between the public, private and vulnerable community

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Abstract. This article shares the working experience of joining private interests with public support and talented apprentices, who come from a social and economic vulnerable area. It takes as an example a project proposed by a private company to design a biodegradable urn produced with local technology, materials and labor to control the cost of production without depending on the market and international currency fluctuations. This project took place in the “Tecnoparque Nodo Cazucá, Colombia” program, in the Design and Engineering area, where the design and manufacturing processes were carried out with the help of local students. It began with the development of the composite material and laboratory tests through a computerized product and production method design, done by Computer Aided Design and Computer Aided Manufacture systems. Finally, a family of containers were produced to dismiss the ashes of our loved ones by allowing their reintegration with the ground minimizing the impact on the ecosystems and generating both, employment and profits. The result was a complex co-creation research and development process that generated a sustainable product, proving that joining private profits, public investments and local talent is possible and can produce positive social, economic and environmental impacts.

1. Introduction

Mankind has proved to be one of the most determinant impact factors in the ecosystems. Taking into account recent data and projections, "the world population is expected to increase by 2 billion people over the next 30 years, from 7700 million today to 9,700 million in 2050" [1].

These impressive statistics force each of us to think about the effects of the actions we carry out as individuals from birth time until the moment "we return to the ground". The disintegration of human remains when an individual passes away, has had a tendency toward cremation processes since this is "the most ecological, cheapest and popular option in countries as: Japan with 99.95%, Taiwan 93%, India 85%, United Kingdom 76%, New Zealand 72%, Australia 70%, Peru 65%, USA 40%, Brazil 40%, France 38%, Colombia 35%, Mexico 28% and Argentina 25%, according to National Funeral Directors Association (NFDA) [2].

Currently there are many kinds of funerary urns in the market made of different materials and shapes. These containers usually affect the ecosystem negatively due to their manufacturing processes, materials, finishes and their final disposal.

As a response to this, degradable and biodegradable urns have been developed which minimize their ecological impact on soils and ecosystems. These products are predominately made in China and Europe and some companies, which supply the national demand, import them to Colombia. However,
fluctuations in international currency prices, transport costs and taxes make it difficult to have local price stability and importation increases the negative environmental impact of this product.

For these reasons, Imporexport Fenix approached “Tecnoparque Nodo Cazucá, Servicio Nacional de Aprendizaje (SENA)” program looking for support in developing a new urn to be produced locally, using local technologies, labor and raw materials with degradability characteristics and a unique aesthetic configuration. This innovation, research and development (R&D) process was carried out in the Tecnoparque’s Design and Engineering department. A variety of talents (developers) were involved in the project, including a developer who comes from Tecnoparques influence zone characterized by its very complex socio-economic problems.

The development stage was framed in a co-creation and collaboration process between the private company efforts, local talents collaboration and the Tecnoparques project manager advice, using the equipment, facilities and support offered by SENA, Colombia, the “Centro de Desarrollo Industrial y Comercial de Soacha (CIDE)” the “Red Tecnoparque nodo Cazucá, Colombia”, and its “Sistema de Investigación, Desarrollo Tecnológico e Innovación, Colombia”. This is an attempt to share this project experiences with those who carry out R&D processes and with the community at large.

2. Experimental procedure
Colombian Tecnoparque program provides its services to companies, entrepreneurs and citizens in general, supporting their Research and Development processes with equipment, facilities and qualified staff [3]. The company Imporexport Fenix registered an initial project in the design and engineering area, requiring a series of tests with diverse materials and processes to develop a composite material with specific characteristics.

After making a documentary review of existing processes and standards [4,5], a flexural strength tests based on the ASTM C1341-6 standard for composite materials [6] were applied to the samples, defining the suitable mixture of materials and the production process. In addition, tests were carried out to characterize the molding behavior of the material and its degradation rate.

After obtaining the composite, a 3D model was developed using computer-aided design (CAD) systems, including semiotic, aesthetic, functional, production and usage concepts. The implementation of a production system that uses local labor and technology was an important objective of the project.

Production molds were developed using CAD, computer-aided manufacturing (CAM) and computer numerical control (CNC) systems. The first mold was made in soft material to carry out several tests with the final composite, verifying the efficiency of the process.

Definitive production molds were designed and manufactured using the same previous method, this time in hard material, resistant to both, process material stress and water. These molds allowed carrying out the final production tests to obtain the final finishes, processes and times that would be used in the urns definitive production.

Finally, and as a consequence of an initial customer approach, a variety in the aesthetic and degradability characteristics were demanded. That meant a series of new finishing and post-production processes tests.

3. Results and discussion
Several results were obtained for each of the stages in the project development. Initially, the materials tests did not give positive results since the combination of fibers and binders did not present acceptable mechanical, aesthetic and process properties (Figure 1).

Finally, a trip made to a Colombian agrarian zone was the answer to find the appropriate natural fiber, a byproduct of a large-scale agro-industrial process, which combined with a ceramic mixture (materials naturally found in soil), allowed the creation of a composite with acceptable aesthetic, degradability and production characteristics. This fiber ensures its local availability and transportation, adds mechanical properties to the mixture and thanks to its "granulated" presentation, makes it easily to be measured, versed and mixed facilitating the manufacturing processes.
Once the composite material was obtained, mechanical strength and degradability tests allowed the finding of the adequate quantities of raw materials in order to achieve a better balance between hardness, dissolution time in water (degradation), aesthetic properties and production behavior. Flexural strength tests were performed based on the ASTM C1341-6 [5] standard for composite materials [6] with a 3-point loading system, using a universal test machine provided by the nanotechnology laboratory of the “Tecnoacademia Cazucá, Colombia” (Figure 2).

The results of the tests showed an improvement in the elastic limit of the composite material (Figure 3) and, therefore, a better resistance to stress. This meant that it was possible to build the urn without an excessive wall thickness, thus avoiding the use of a large amount of raw materials and the increase in both, the cost and weight of the final product.
Having defined the final composite, tests were carried out to establish its behavior in the production process and usage in a more complex mold (Figure 4). Then the design of the formal aesthetic configuration was done based on the values of wall thickness (result of the flexural tests), the internal volume (which for this kind of container is from 3000 cm³ to 3500 cm³ according to the regulations [7]), the production method, the usage requirements and the semiotic concept.

![Figure 4. Molding tests and surface finish.](image)

To shape the main volume of the urn, a golden ratio geometric analysis was conducted [8], defining the general dimensions in a smoothly contour. In addition, the company wished to include in the design the Hindu idea of purity and balance based on the relationship between the three Gunas (qualities of matter): Sattva (goodness, consciousness, light, purity, wisdom), Raja (passion, activity, movement) and Tama (darkness, ignorance, inertia, density) [9,10]. That is why the final design took as inspiration a Gunas linear interpretation (Figure 5), creating surface details to symbolize the passage from the material-dense state (tama) to the spiritual state (sattva) with a spiral that rises and blurs.

![Figure 5. Linear interpretation of the three Gunas [9].](image)

The symmetrical and clean product design allowed an easier and cheaper production process development. It was developed to use low complexity technologies and local labor, obtaining the two main parts of the product: the body and the lid. At the same time, a removable system was included in the lid design in order to add graphic elements, fulfilling an additional product requirement, personalization of it.

After defining the material and shape, production molds were developed using CAD-CAM systems (Solid Works and Master CAM) for the design (Figure 6) and CNC equipment for the manufacture. Initially, medium fiber density wood (MDF) [11] was used to perform several tests and verify the correct material and process behavior. Subsequently, a Zinc and Magnesium Aluminum alloy [12] was acquired...
by the company to produce a mold able to resist the serial production process stress and conditions (Figure 7).

![Figure 6. CAD modeling and CNC systems programming.](image)

These molds successfully allowed the serial production of the urn main parts but some additional processes were required to finish the product. To achieve this, SENA’s automation technology program apprentice’s participation was remarkable. He belongs to “Tecnoparque Nodo Cazucá” area of influence and was involved in the molds programming and machining. In addition, in a guided process, he developed the necessary techniques to obtain details and finishing processes, giving each urn its characteristic handicraft quality.

Finally, and after a customer’s first approach, it was identified the need to offer more surface finishes and usage characteristics. New laboratory tests were conducted (Figure 8) to reduce and increase the degradation time and to offer a wider variety of textures, colors and finishes. No mold changes were necessary but changes in raw materials proportions had as consequence new difficulties in the mold pieces extraction. However, the issues were solved and three new different kinds of urns were developed: One to last, one for fast disintegration and one to be exhibited.

![Figure 7. CNC machining process on aluminum alloy.](image)

![Figure 8. Final tests for surface finishes and degradability times.](image)
4. Conclusions
The objectives of the product development were achieved. The research and development process allowed the creation of a new composite with common raw materials, which can be applied in the product configuration, including degradable requirements and low environmental impact. The product and the production process were configured with local raw materials, labor and technology, which allowed the Company to control costs and product availability. Design and aesthetic characteristics offer differentiation and a variety of possibilities in finishes, degradable behaviors and personalization.

The design process left valuable experiences to each participant. It was a transversal activity through different fields of knowledge, combining scientific, project and creative methods to obtain a completely new sustainable product. Composite material and product design are suitable for registration and patent. This is why it is not possible to share more information about it in this article.

Human talent was a fundamental aspect in the whole process in order to achieve the pre-set-out goals. Socioeconomic diversity of collaborators, beyond becoming an obstacle, allowed to conclude that, no matter the differences, when the objectives are clear and there is perseverance, discipline and political will, it is possible to develop R&D processes, even in zones like Cazucá, and contribute to a more inclusive and sustainable world.

This work proves a successful collaboration example between a private company (interested in being part of the global market using innovation), government (investing and supporting technological development and research) and local talent (present no matter the harsh socioeconomic conditions) in a co-creation and technological based project to obtain a new sustainable product.

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