TECHNOLOGY CAPABILITY ASSESSMENT FOR SUPPORTING CIRCULARITY IN THE WOOD PRODUCTS INDUSTRY

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ABSTRACT: The paper presents a combined approach for technology capability assessment, that includes a generic analysis of circularity technologies and methods, and an applied case study for a Romanian wood products manufacturer. The methodology uses Analytical Hierarchy Process for ranking the potential circularity enabling technologies and Quality Function Deployment to determine the recommended strategy for product families that use them. Starting from mixed general and specific inputs, and applying these two investigation steps, the authors propose some organizational interventions. The results are useful for companies in the forestry sector that are considering technical and business transformations towards circularity, while remaining competitive.
KEYWORDS: circular economy, wood products, wood waste, reclaimed wood

1. INTRODUCTION AND CONTEXT

The present paper aims to contribute to better understanding the potential of existing and foreseeable technologies that are used in the wood products industry in order to align practices and processes with the requirements of the circular economy concept. This effort is part of an ongoing scientific preoccupation of the authors, and the teams they belong to, to support the digitalization drive [1], [2] and the sustainability efforts [3], [4], [5] in various sectors. The methodology proposed can be applied on a general level to any type of company in this field, while the case study is customized for the Romanian company Silvania International Prod and its line of products [6], in line with their research and development undertakings.

The international context is conducive to this type of approaches, as exemplified by some recent articles dealing with the topic of introducing or strengthening circularity in the forestry [7] / wood [8] / timber [9] sub-sectors of this domain. The overarching conclusion of these pieces of literature is that the targeted industry of wood-based products is a natural candidate for pioneering circularity, with technological and business transformations required to advance in tandem to produce the desired results in terms of economic competitiveness and environmental soundness.

We investigate in the current paper the situation in emerging economies, such as Romania, where companies practice a mixture of circularity methods, and are preparing to further develop their technological base in this respect, through EU supported investments and capability development.

2. RESEARCH METHODOLOGY

For achieving the stated goals, the authors have implemented a four-step approach that includes technology identification & in-house observations, ranking of the circularity techniques, deployment to the level of product families and the critical interpretation of results. The research methodology is summarized in Figure 1, below.

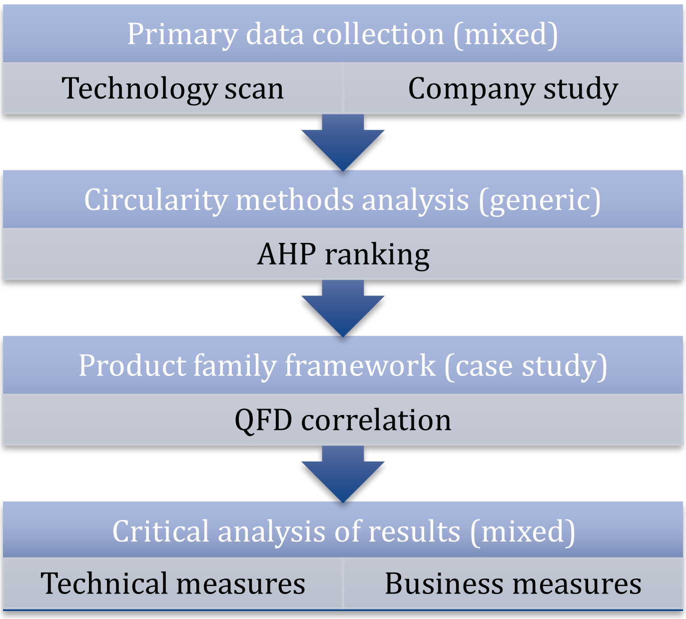


Figure 1. Concept for the assessment research demarche

The structure of the undertaking is a classical one in innovation studies and is meant to serve as a basis for developing coherent proposals for the companies in wood products sector. By aligning the product strategy with the capabilities of potential technologies, the firms will have better success in achieving the goals of the circular economy.

3. RESULTS AND DISCUSSION

The study of the current company processes at Silvania International Prod was complemented by a technology scan of the most mature technologies used in the wood industry to “close the loop”.

A list of 8 technologies and design and production methods has been generated by the authors and then ranked using the Analytical Hierarchy Process (AHP) with the support of the Qualica QFD software (see Figure 2 below) that permits the fine control of the pairwise comparison mechanism. An internal consistency index of 0,098 has been calculated using the CGI web software [10]. This is below the maximum acceptable value of 0,1 and shows a correct implementation of the method.

How Important is the Left Item (Row) as Compared to the Top Item (Column) ?

Group: Top Level ITEMS — Output — Completed: ☑

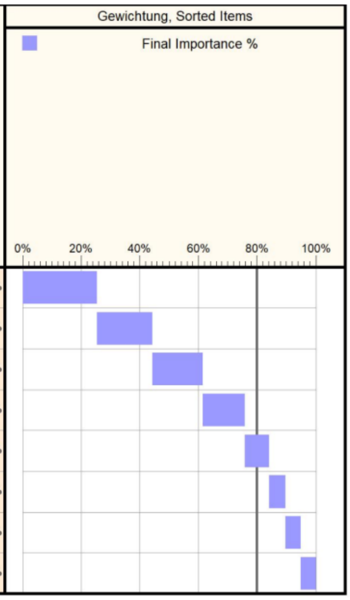
AHP Toplevel Matrix

9	9,00	an order of magnitude more important
8	8,00	absolutely more important (8x as important)
7	7,00	demonstrated more important
6	6,00	demonstrated more important (6x as important)
5	5,00	essentially more important
4	4,00	essentially more important (4x as important)
3	3,00	considerably more important
2	2,00	twice as important
+	1,50	somewhat more important
○	1,00	Equally important
-	0,67	somewhat less important
½	0,50	half as important
⅓	0,33	clearly less important
¼	0,25	essentially less important (other item 4x as important)
⅕	0,20	essentially less important
⅙	0,17	demonstrated less important (other item 6x as important)
⅐	0,14	demonstrated less important
⅛	0,13	absolutely less important (other item 8x as important)
⅑	0,11	an order of magnitude less important

Input	1 Lifecycle Product Management	2 In-process wood waste collection	3 Customer wood waste collection	4 Water-based varnishing/coating	5 Biomass/pellets energy generation	6 Metalwork extraction and recycling	7 Reclaiming and refurbishing wood	8 Hot composting of wood waste	Importance in group
1 Lifecycle Product Management		3	3	2	2	4	○	4	25,1%
2 In-process wood waste collection			○	3	2	4	2	3	17,0%
3 Customer wood waste collection				3	4	4	2	4	18,8%
4 Water-based varnishing/coating					3	2	½	○	8,4%
5 Biomass/pellets energy generation						½	⅓	○	5,4%
6 Metalwork extraction and recycling							¼	2	5,8%
7 Reclaiming and refurbishing wood								2	14,3%
8 Hot composting of wood waste									5,3%

Figure 2. AHP ranking of selected circularity technologies

Importances / Sorted ITEMS 1	Calculated Importance %	Final Importance %
1 Lifecycle Product Management	25,1%	25,4%
3 Customer wood waste collection	18,8%	19,0%
2 In-process wood waste collection	17,0%	17,1%
7 Reclaiming and refurbishing wood	14,3%	14,3%
4 Water-based varnishing/coating	8,4%	8,3%
6 Metalwork extraction and recycling	5,8%	5,6%
5 Biomass/pellets energy generation	5,4%	5,2%
8 Hot composting of wood waste	5,3%	5,1%
Most important item:	25,1%	
Least important item:	5,3%	



Most important item is 4,78 times as important as least important item

Make most important item 5,00 times as important as least important item

Figure 3. Final hierarchy of technology potential for the wood products industry

The AHP method was applied based on the industrial experience of the firm and the research team and has resulted in a clear two-tier situation. After the normalization performed by Qualica QFD (see Figure 3 above), 4 approaches have low scores, below 10%, while another 4 have high scores, between 14,3% and 25,4%, namely Lifecycle Product Management, Customer and In-process wood waste collection and Reclaiming & refurbishing of already used wood. All of them are partially implemented already by the company, but a full-fledged deployment requires additional investments, such as: procurement of new software packages, setting up a smart product development laboratory capable of integrating sensors and cyber-physical devices into products, developing a network of collection points and/or partners, new logistics and storage facilities for the wood waste and pre-used wood, buying additional equipment for certain operations (de-varnishing, chemical/biological treatment, pelleting, etc.), as well as the training of the personnel in handling the new types of raw materials and the new technologies.

For the next step of the methodology, the Quality Function Deployment (QFD) method has been used with the help of Qualica QFD, starting from the 7 possible product types that make-up the current product roster of the company [6].

Some positive and negative reciprocal influences have been documented in the "roof" of the template (see Figure 4 below), when considering the commercial interest of keeping and developing all product lines towards the best possible outcome. Unfortunately, by sharing the same source materials, some relations can be adversely affected, and this is reflected in the analysis. Also, the most complex product family (i.e., wood houses), which can integrate elements from all the others, has an interesting profile, with multiple positive and negative interactions, being both very suitable and significantly challenging for adopting circularity.

The main correlations determined in the QFD matrix have taken into consideration the impact of the possible technologies upon the product families, with additional focus on the two techniques considered most relevant in the current competitive environment, the wood waste collection from the customers and the ability to reclaim and refurbish wood, which involves business model changes, as well as new or modified production processes.

The deployment (see Figure 5 below) has indicated 3 types of products on which the company should focus once the circularity enabling methods are adopted, with scores around 20% importance: frames/pallets, flooring, and wood houses. Another 2 product lines, with scores around 14% can serve as temporary income facilitators, namely the timber/lumber for general use and the panels for interiors, while yet another 2 could be phased out (the stratified wood and the joinery elements).

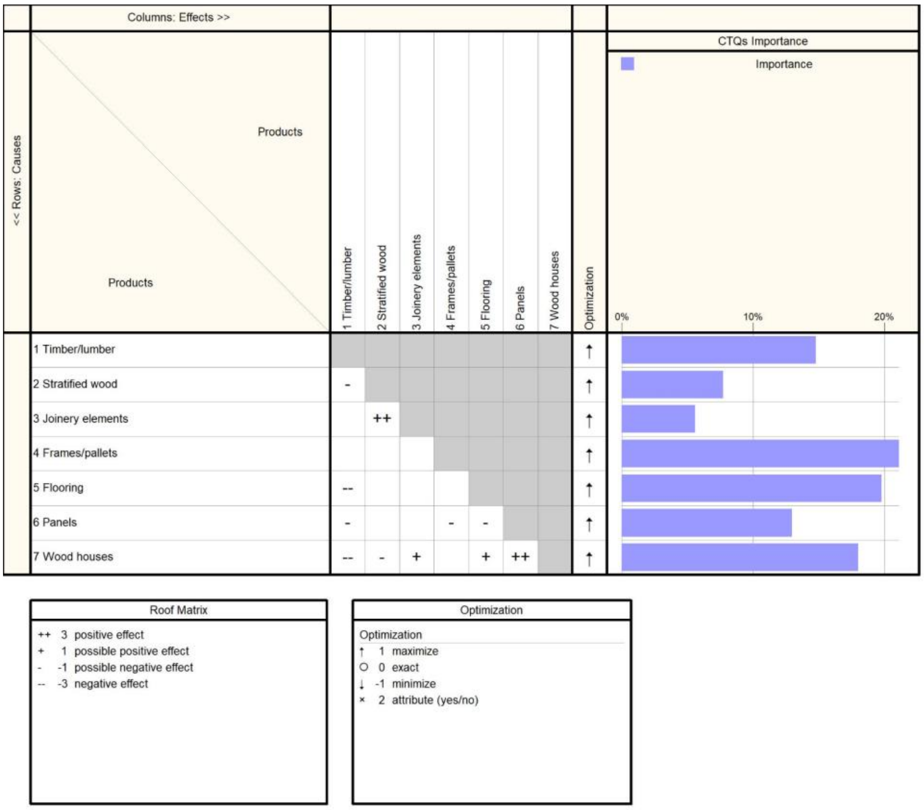


Figure 4. QFD roof interactions when optimizing the product offering

Figure 5. QFD deployment of technologies to the level of product families

Finally, the QFD analysis completes these product strategy recommendations with the identification of two possible bottlenecks regarding the frames/pallets and the wood house product lines, that have great importance in the new product family configuration, but also exhibit significant technical difficulties as identified by the research team. We consider that the former should evolve towards the intelligent product field, helping both customers with their businesses and the company with its scrap collection, while the latter should probably constitute an independent brad due to its overarching nature and aggregated difficulty. It is also important to note on the bottleneck chart (see Figure 6 beside) that no product line is in the lower left (or "easy") quadrant, thus requiring continuous efforts to sustain.

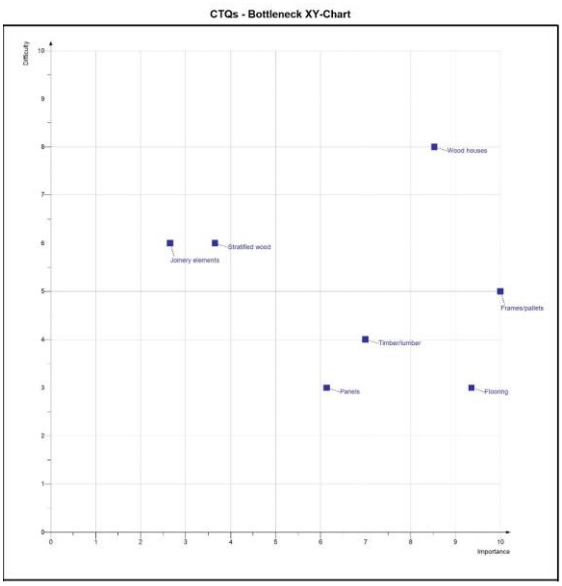


Figure 6. Bottleneck profile of the product families

4. CONCLUSIONS

The current study yields two types of conclusions. First, from a methodological perspective, we can surmise that using quality management and innovation management techniques, the know-how of the wood products manufacturers can be processed to generate useful insights for addressing the main challenges they face when implementing circular economy models. Second, for the specific case study investigated, there are 4 technologies with significant transformation impact, that have the ability to increase the environmental performance of the company, provided that a product strategy is implemented focused on 3 main types of products. However, since two of these also present complex technical issues when integrating the circular friendly technologies, we consider that the company should direct its efforts towards the category with the highest potential value added. We can conclude that, in order to maximize the competitive impact, the investment plan should include developing an external wood waste collection and refurbishing system that can create components for wood houses.

5. ACKNOWLEDGEMENT

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