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Remaining Socially Responsible in the Age of Smart Sustainable Production

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Abstract: This paper explores the transformations necessary in the field of social responsibility and social accountability employed by manufacturing companies as they transition to a model of smart and sustainable production. A focus group of managers in production companies has been interviewed concerning the challenges and support they derive for their environmental and community approaches, as the firms deploy advanced Industry 4.0 tools such as the internet of things, digital twins and virtual reality to upgrade their manufacturing systems and processes. The results are presented and discussed based on a set of ranked objective indicators, and proposals for a future implementation scenario are advanced.

Keywords: smart production; social responsibility; sustainable production

1 INTRODUCTION AND CONTEXT

Being a manufacturing company in this day and age, especially in Europe, is a challenging activity that can use up considerable resources just for surviving, let alone for being truly competitive. The European Union subscribes to a philosophy of twin transitions - green and digital [1], which is implemented over the complex background of social, economic, geopolitical, and medical emergencies. As the production sector transitions to a smart and sustainable model of operation, it is sometimes difficult to keep the proper focus on the social obligations that arise related to developing, designing, manufacturing, distributing and proper end-of-life treatment of consumer or industrial goods.

From establishing trust with the local community, and behaving in an ethical manner, to recognizing worker rights and ensuring their safety, to supporting worthy causes, the firms in this domain must not forget that although the present is characterized mostly by the technological transformations associated with Industry 4.0 and beyond (e.g., adoption of artificial intelligence or quantum computing), the human side of their impact is defining for their future success [2]. Both small and medium sized companies, and large businesses, must all be able to act with integrity and transmit the correct image of their efforts and results across many publicly scrutinized channels to large scale and globalized audiences.

The existing literature on this topic in the past 3 years has revealed some promising results, such as the need to establish strong holistic strategic innovation frameworks [3] and the decisive role of public reporting of performances [4]. Also, a considerable number of issues that are not yet properly addressed, such as the enabling factors for setting up successful co-production ventures [5] and the development of means to ensure long term operation of sustainable complex supply chains [6]. The consensus seems to be related to the need of manufacturing companies to develop innovative ways to tackle modern competitiveness and a modern social approach at the time [7]. However, from the point of view of costs, there are still a large number of unknown factors that can influence the feasibility of such a demarche [8, 9].

2 METHDOLOGY AND TECHNIQUES

The research approach utilized for the current undertaking is based on 4 steps (Fig. 1), including:

- a stage of literature review and identification of the state of the art based on existing article databases,
- an interview process with a questionnaire-based part and an open discussion,
- the ranking of indicators for the social responsibility approach derived from the interviews, using the Analytical Hierarchy Process (AHP) applied through the Qualica QFD program and
- a final discussion based on the correlation of the indicator and the most common smart sustainable production technologies also resulting from the questionnaire, implemented with the help of the Cause & Effect matrix from Qualica QFD.

The group of managers that was interviewed included 9 representatives from the following industries: metal fabrications (3 companies), automotive components (2 companies), furniture manufacturing (3 companies) and industrial goods (1 company). All of these can be considered part of the manufacturing sector in Transylvania, Romania.

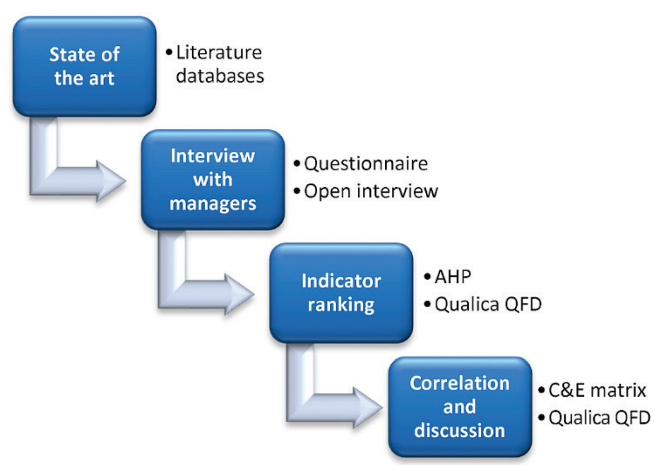

Figure 1 Research methodology employed and applied techniques

The starting questionnaire used for interviews and discussions was intended as a preliminary investigation and contained the following questions (the first four were multiple selection questions and the last one was an open question to collect proposals):

- What type of Industry 4.0 technologies have you implemented: IoT, AI, Digital Twins, Big Data, Robotics, VR/AR?
- How do these support your environmental approach in monitoring, reporting, product re-design, process reengineering, auditing?
- How do these support your social community involvement in the lifecycle management of products, the circularity approach, social accountability, and CSR projects?
- What challenges you encountered / What trade-offs have you made: reuse budgets, discontinued products / processes, relocate / outsource the business, train / hire additional people, employ specialized consultancy?
- Can you formulate some relevant indicators to assess the impact of the technologies upon the social (and environmental) footprint of the company?

After the consultations with industry, a number of 5 indicators have been selected and ranked with the help of the AHP template in Qualica QFD (Fig. 2). The consistency index of the pairwise comparison has been checked with the help of an additional calculator [10] and found to be 6.4 %, below the acceptable 10 % limit. The results are presented both the in the order they were entered and the ranked order after the application of the process (Fig. 3), with the standard normalization of the software at the 5X level being almost unnecessary.

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 Robustness & sustainability improvement of the production system	2 Feasibility of implementing the technology for social aspects	3 Life-cycle cost of using the technology in addresing social issues	4 Human resources development for implementing the new devices	5 Required external support and assistance for successful deployment	Importance in group
1 Robustness & sustainability improvement of the production system		2	3	4	3	39,6%
2 Feasibility of implementing the technology for social aspects			2	○	3	22,1%
3 Life-cycle cost of using the technology in addresing social issues				3	2	17,8%
4 Human resources development for implementing the new devices					○	11,0%
5 Required external support and assistance for successful deployment						9,4%

Figure 2 Analytical Hierarchy Process applied to the identified performance indicators

3 RESULTS AND DISCUSSION

In the final stage of the study, the ranked indicators have been correlated with the 6 main technologies used by manufacturing companies as part of the smart and sustainable production paradigm, discussed with the interviewees from industry. The scale used includes three levels of relationship, from weak to strong and the importance of the 5 criteria is imported from the previous ranking. Also, the first indicator has been considered critical for the operating safety of the transformed production system, while the second indicator has been marked as critical for the proper functioning of the technology framework (Fig. 4).

As it can be observed, the technologies receive a calculated importance score that permits for the establishment of a proper strategic and operational approach for companies that seek the competitive benefits of Industry 4.0 without losing their socially responsible behaviour. By far, the highest score, 29,5 %, is obtained by Big Data Analytics that is supports the processing and interpretation of all data from product and process sensors. It is considered mandatory for monitoring and improving the production system and in tracking and optimizing products performance. Important and desirable functions like enhancing product circularity, minimizing waste, tracking reliability, estimating impact upon user and so on, can be highly amplified by using proper techniques and tools for data analysis. The second place in terms of importance (of 21 % in this context) is occupied by artificial intelligence, which is a very promising technology and could be factored in decision making for product and process improvement, in public reporting and communication and in delivering the social value expected by the communities a firm interacts with through upgraded interactivity. However, we must take into account that this technology's image is now impacted by the booming interested sparked by ChatGPT, so it might be a good idea to revisit its usefulness for manufacturing companies after a certain amount of time has passed.

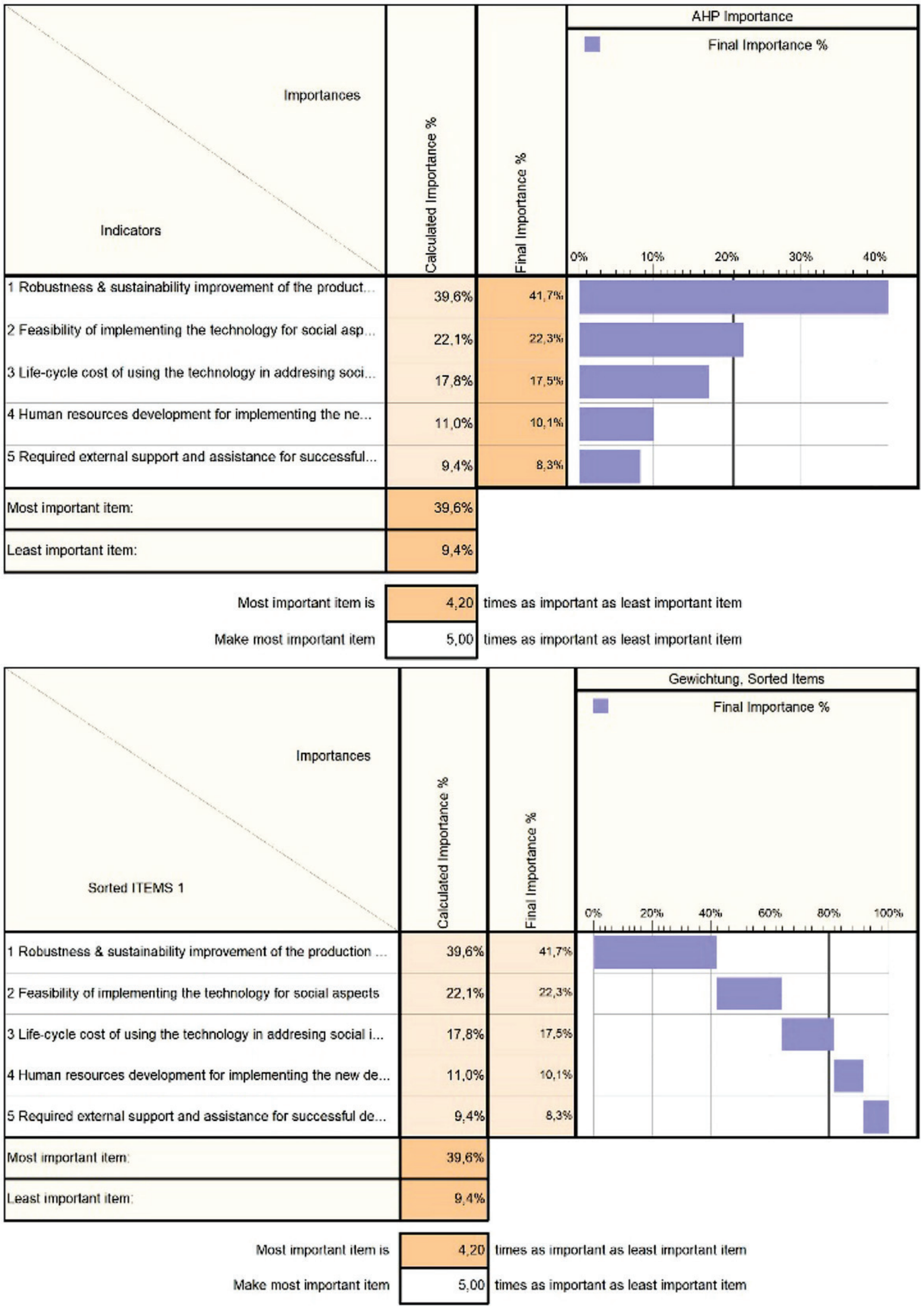

Figure 3 Original order and sorted normalized results obtained from Qualica QFD

On the third and fourth places, with similar scores, we can find Internet of Things and Digital Twins which form the backbone on which data analytics can run. Both of these technologies are at a high level of maturity, with many solutions available on the market. Moreover, the complex nature of production systems and processes and the discrete identify of manufactured products are particularly suitable to being assessed with the help of smart sensors and acted upon through digital twins solutions. The remaining two approaches, robotics and VR/AR are already part of many manufacturing systems, for increased productivity and better training and maintenance, but their use for retaining socially responsible and socially accountable behaviours is not that significant.

Technologies / Indicators	1 Internet of Things	2 Artificial Intelligence	3 Digital Twins	4 Big Data Analytics	5 Robotics	6 Virtual Reality / Augmented Reality	Number of relations	Importance	Critical for safety or function
1 Robustness & sustainability improvement of the production system	⊙	○	○	⊙	△	△	6	41,7%	S
2 Feasibility of implementing the technology for social aspects	△	⊙	○	○	△	○	6	22,3%	F
3 Life-cycle cost of using the technology in addresing social issues	△	△	○	⊙	△	○	6	17,5%	
4 Human resources development for implementing the new devices	○	⊙	⊙	⊙	○	○	6	10,1%	
5 Required external support and assistance for successful deployment	△	⊙	⊙	○	○	△	6	8,3%	
Number of relations	5	5	5	5	5	5			
Calculated Importance	18,7%	21,0%	16,9%	29,5%	5,6%	8,2%			
Critical for safety or function	S	S, F	S, F	F		F			

Figure 4 Cause & Effect Matrix relating socially relevant indicators to smart technologies in Qualica QFD

It is interesting to note that due to the correlations established by the research team based on information from industry, 3 of the technologies can be considered mandatory to achieve system safety and 4 are necessary to achieve its proposed function. Based on these, we must infer that 5 of the analyzed elements are obligatory for success (i.e. VR/AR must be included in the transformation).

4 CONCLUSIONS

Remaining socially responsible while undergoing significant transformations towards digitalization and smart production is a difficult goal for manufacturing companies. The study presented in this paper uses a systematic methodology within the confines of a limited focus group of managers involved in the activity of production firms, to determine the most relevant technologies associated with Industry 4.0 that are supportive in implementing social and environmental initiatives. Based on the findings, a customized strategy can be recommended in this case, including the following chronological steps:

1) Implement Big Data Analytics platforms and software, starting from existing production and product data and anticipating the exponential increase of data volume once the smart sensors are installed and connected through Internet of Things communication protocols. Based on the results, start making high reward improvements to the manufacturing system and the current product lifecycle approach.
2) Develop an integrated Digital Twin approach that makes use of a general Internet of Things approach employing low-cost high-autonomy sensors for the production equipment, the relevant supply chain interfaces and the products themselves, when achieving a certain level of complexity. Use the sensor data to enhance all environmental performance indicators, as well as to deliver a healthier and more cohesive work environment and community integration of the company. Use the digital twin of the production system to perform a massive amount of synchronous and asynchronous small reward improvements throughout the system.
3) Develop and use VR/AR applications, specific to the issues of the company, to supplement existing organizational operations, connect with external partners, suppliers and stakeholders to perform collaborative problem solving. Extend the use of the

application to increase the range of capabilities of the manufactured products. Integrate both types of applications with the digital twin and the data analytics platforms to create synergies.

4) Assess the potential of artificial intelligence solutions to bring additional value to the social responsibility projects of the firm by providing better interfaces with the community, detect and correct improper reporting and disseminate the contributions of the firm to the local community and general society.

In conclusion, we can surmise that by properly addressing both competitiveness and social impact issues with the help of up-to-date technologies, manufacturers in various industries can increase their chances of surviving on the market. In the next step of the research, we intend to introduce a full-scale questionnaire, that includes hypothesis testing and control questions, and to complement the manager interviews with actual production shadowing and validation based on key process indicators.

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