Identifying and Ranking Components of Manufacturing Sustainability in the Iranian Papermaking Industry

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Factors of manufacturing sustainability in the papermaking industry were identified and ranked using qualitative analysis and nonparametric tests. Based on a review of the literature on sustainable development and production, seven main factors of economic, environmental, technological, social, human, material and product, and regulations were identified to underpin the manufacturing sustainability in the papermaking industry, as well as some sub-factors. Then, a self-designed questionnaire was developed to take a poll among papermaking managers and experts regarding the effectiveness of the factors and sub-factors in manufacturing sustainability and their status. The factors affecting manufacturing sustainability in the papermaking industry were confirmed by the standard and significance coefficients in the structural equations and the predictive criterion. The cross-validated redundancy index showed that the data were valid enough for prediction. The research factors were ranked by the ordinal average affecting sustainability, current status, and distance to sustainability. The materials and product, environmental, technological, and economic factors had the greatest influence on manufacturing sustainability, and the regulation and human factors had the highest distance to sustainability. To achieve manufacturing sustainability in the papermaking industry, regulations and human factors need to be further studied. Their improvement has potential to achieve manufacturing sustainability.

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INTRODUCTION

Papermaking methods have evolved over time (Fortuna *et al.* 2011). A significant part of this development has been one-dimensional and only for the sake of higher profitability for the owners of papermaking companies. As the customers' awareness of the negative ramifications of one-dimensional growth and economic development has increased, environmental requirements of industrial development have gradually been expanded (De Silva *et al.* 2009; Kim and Sim 2016), and regulations for environmental conservation at the national and global levels have been enhanced (Berger-Walliser *et al.* 2016). With the increasing environmental, social, and economic expectations of stakeholders of industries, papermaking companies have faced various challenges in

satisfying these expectations. Companies need to select proper production methods to minimize the effect of these issues and challenges, including the supply of the resources required, the production and waste disposal conditions, the reduction of greenhouse gas emissions, and the consideration of working conditions and economic views (Stoughton and Ludema 2012; Sangwan *et al.* 2012). Moreover, recycling processes have drawn attention by prioritizing the reduction of production costs and the adherence to environmental requirements.

Presently, factors other than customers, competitors, and suppliers have gained importance in the supply chain – factors that have not been important in the past. For example, pro-environmental organizations are factors that influence production and competition (Hogevold *et al.* 2016). Satisfying all requirements and meeting the expectations of all stakeholders require the adoption of a new approach, which is called sustainable production (Gupta *et al.* 2016). Jawaher and Dillon (2007) have developed the concept of sustainable production in economic, environmental, and social dimensions. The US Department of Commerce (2010) states that sustainable production is "the creation of goods and services using processes and systems that minimize adverse environmental impacts, conserve energy and natural resources, are safe for workers, communities, and consumers, and are economical". In the past, the adoption of the sustainable production paradigm was optional, but today companies understand that this is an unavoidable necessity (Stoughton and Ludema *2012*). Companies must identify activities and implement them within some consecutive measures to transit from the present methods to the deployment of sustainable production paradigms. In this regard, the application of modern technology is an essential competitive advantage for improving the sustainable performance of organizations, which will create more advantages for customers and stakeholders and will create value for organizations in the social, economic, and environmental fields (Geissdoerfer *et al.* 2018). Because the world is entering the green economy (Cankaya and Sezen 2019), organizations need to consider the role of human, operational, and technological resources to achieve a sustainable business (Thakur and Mangla 2019). By focusing on human capital and environmental programs and integrating them into their activities, human resources management should provide interesting facilities and conditions for all activists and investors so that they can participate in these programs while improving their performance. An organization's environment and paying attention to sustainable development policies can contribute to a beneficial relationship for themselves. As such, they can use sustainable supply chain management to protect the integrity and solidarity of the suppliers and customers and improve the manufacturing organizations' responsiveness and resilience (Zaid *et al.* 2018; Baghersad and Zobel 2021*).*

The emergence of modern technologies and the drastic development of global markets make sustainable supply chain management essential. The main reasons for the increasing focus of manufacturing companies on production sustainability are the mitigation of risk, the enhancement of the economic performance of the supply chain, the absorption of customers who put a high value on sustainability, and efforts to increase production sustainability in the world. Sustainable supply chain management is a concept whose policies' effective implementation can improve the environmental performance of different industries and the financial performance of organizations as they encompass the environmental, social, and economic dimensions. Although multinational companies have increasingly adopted sustainable strategies for their operations, they have attempted to a lesser extent to involve their suppliers in the sustainable development process of their organizations. Therefore, the economic and environmental risks are more likely to jeopardize the operation and validity of these companies (Villena and Gioia 2018). Because a major issue in supply chain management is the decision on material supply or sustainable

procurement, the economic sustainability of the supply chain is highly important for manufacturing organizations so that if it is not considered, opportunities for saving may be lost. Therefore, organizations must understand the significance of sustainable supply chain management for their development and assessment and use sustainability indices at all dimensions to exploit them for achieving general system sustainability.

Considering only economic issues is not a sufficient strategy to advance organizational goals and achieve sustainable performance. The organization should include environmental issues and all aspects of green supply chain management (*i.e.*, *green procurement, green distribution, green packaging, environmental education, environmental management, and resource recycling*) in their analyses in addition to financial issues because organizations can satisfy the benefits of all groups by considering all these dimensions and particularly contribute to the balance in sustainable development in the present and future (Cankaya and Sezen 2019).

Essential and continuous efforts in past decades in the pulp and paper industry have significantly reduced its adverse impact on the environment. To accomplish production and development sustainability requires changes in industrial flow sheets and processes, resource types and quality, and the application of environmentally-friendly technologies in a context of legal and social support at the national and regional levels. The treatment of various types of wastewater and the sound management of garbage, the control of greenhouse gas emissions, and product quality also need changes in many industrial processes. To achieve this goal, the factors influencing achieving manufacturing sustainability in the papermaking industry should be identified. After these factors are identified, efforts can be made to enhance the current status of the papermaking industry and orient it with the paradigms of sustainable production. Therefore, the present research aims to identify and rank the indicators and sub-indicators underpinning the development and sustainability of production in the papermaking industry and to determine the status of the papermaking industry as a case study in Iran. The authors hope that the results may improve the level of manufacturing sustainability in the paper making industry.

Literature Review

Researchers have identified various components and sub-components for manufacturing sustainability in the micro and macro environments of different industries. Shankar *et al.* (2016) reported on the quality indicators, market capabilities, financial benefits, supply chain requirements, delivery speed, performance resilience, legal support, green purchase, resource use optimization, green innovation, environmental conservation, training and skill development, employees' and stakeholders' welfare, intra-organizational incentives, and customer expectations. These factors were identified as the most important indicators of sustainable production systems.

Dubey *et al.* (2017) listed green storage, supplier cooperation, environmental conservation, continuous improvement, information technology, logistic optimization, external pressures, institutional pressures, social values and ethics, company strategy and commitment, economic stability, and green product design as the indicators of a sustainable supply chain.

Rauter *et al.* (2017) reported that the most important drivers for the movement of manufacturing companies toward sustainable businesses included gaining competitive advantage, entering new markets, customer expectations, demand in the supply chain, government regulations and standards, personal values of managers and leaders, the reduction of costs, employee welfare, income enhancement, brand value, role-model and eminent employees, and organizational structure.

Bhanot *et al.* (2017) expressed that market pressures, government regulations, economic advantages, investment in innovation and technology, cost reduction, quality improvement, training and skill development system, direct foreign investment absorption, transportation infrastructure and facilities, and e-economy development were most effective in manufacturing sustainability.

Beltrami *et al.* (2021) argue that industry type, company size, and manager understanding of the importance of the sustainability index influence a company's performance management system. Larger companies that have a lower impact on the environment include more sustainability indices in their performance management systems, whereas companies from the environmentally-effective industries include social, but not necessarily environmental indices in their performance management systems.

In a study on the relative importance of external and internal pressures in guiding the environmental behaviors of Chinese companies, He *et al.* (2018) showed that government pressure, economic pressure, and internal pressure played a positive and significant role in the environmental behavior of papermaking enterprises. Economic pressure was the most important factor underpinning their environmental behaviors (including defensive, accommodative, and proactive behaviors). Internal pressure had the second most important effect on environmental behaviors (defensive and proactive), whereas government pressure was the weakest of the three. However, the role of social pressure imposed by the public and non-governmental organizations was not remarkable. Thus, policymakers should emphasize the interactions of economic mechanisms, government regulations, and internal incentive mechanisms to stimulate companies to adopt active environmental behaviors. More concerns of the public should be further investigated to reinforce their incentive effect on leading the environmental behaviors in the Chinese papermaking industry.

EXPERIMENTAL

The research aimed to determine and rank the manufacturing sustainability indices in the Iranian papermaking industry. It was an applied study in terms of goal, a descriptive survey in terms of data collection method, and a mixed-methods (quantitative-qualitative) study in terms of data type. The statistical population was composed of all manufacturers and industry owners, experts, managers, and academic and non-academic professionals involved in the papermaking industry (Table1).

The information in the above table shows that the majority of people in the statistical community are reported to have bachelors, post-diploma, diploma, Master's degree, and PhD respectively. It should be remembered that many managers in the private sectors of paper making industries do not have high educational qualifications. For this reason, the statistical population of diploma and post-diploma is also significant, the most frequent among the respondents are people with a history and work experience between 5 and 20 years.

Table 1. Distribution of Respondents According to Education and Work Experience in the Paper Industry

Distribution According to Work Experience			Distribution by Education		
%	Frequency	years of experience	%	Frequency	education
12.50	20	Up to 2 years	21.88	35	Diploma
18.75	30	2 to 5 years	28.12	45	Post-diploma
25.00	40	5 to 10 years	31.25	50	Bachelor's
31.25	50	10 to 20 years	12.50	20	Master's
12.50	20	More than 20 years	6.25	10	PhD
100	160	Total	100	160	Total

The sample, whose size was determined by Cochran's formula, was taken by the simple randomization technique. Finally, 160 questionnaires were subjected to analysis.

The research instrument was a self-developed questionnaire extracted from the literature, papers, and opinions of relevant experts and professionals. The questionnaire was first administered to specify the relative importance of the manufacturing sustainability indices. Then, it was revised and administered to determine the present status of the papermaking industry in terms of manufacturing sustainability. Likert's interval five-point scale was used for the measurement, assessment, and comparison of the results derived from the questionnaires.

Components

The research used the following main indices and sub-indices.

- Technological index – an index for the assessment of sustainable production that has been used by many researchers. Based on the literature, its sub-indices include research and development capability, technological capability (oriented with cleaner manufacturing paradigms for the sake of availability, pollution prevention, industrial automation for waste control, calibration up-to-date, quality goals monitoring, development, technology change speed and up-to-date, and technology transfer level), and designing capability.
- Regulations index with the sub-indices of sustainability, supportiveness, practicality, and effectiveness of regulations.
- Social index with the sub-indices of in-service training status, development of social activities, responsibility, and effectiveness of social processes.
- Economic index with the sub-indices of financial capacity, cheap resources, profitability margin, and competitiveness.
- Environmental index with the sub-indices of environmental planning, environmental management, environmental assessment, and effectiveness of environmental processes.
- Human resource index with the sub-indices of skill-raising, knowledge-raising, and succession planning.
- Material and product index with the sub-indices of material (for the capability of sustainable supply, sustainable quality, and proper diversity) and product (sustainable production, sustainable control and monitoring, sustainable delivery, and sustainable design).

These indices and sub-indices were measured by developing appropriate questions.

Reliability and validity

To ensure the appropriateness of the questionnaire items, the content validity and reliability by Cronbach's alpha method were used. To estimate the reliability, 30 questionnaires were distributed among the managers of active companies in Tehran City. The total alpha was estimated at 0.914 using the SPSS software package. Since Cronbach's alpha for all indices was greater than 0.7, the reliability of the questionnaire was confirmed.

Data collection and analysis

Data were collected in the research according to the research goals, research methodology, and the characteristics of the samples taken. The required data were collected by the library and field methods.

The collected data were analyzed by both descriptive and inferential statistics. The descriptive statistics included the calculation of mean and standard deviation by SPSS-24. The inferential statistics were applied to generalize the results derived from the sample to the whole population. The research employed Cronbach's alpha to estimate the reliability of the questionnaire. Also, structural equation modeling was applied to check the relationships of the variables and test the research hypotheses. Finally, the components and sub-components were ranked by confirmatory factor analysis and Friedman test. The effectiveness of the components in manufacturing sustainability was specified using structural equations and based on the standard and significance coefficients.

To gain a correct understanding of how to revise the variables for manufacturing sustainability, the predictive relationship method was used, and the criterion of the overall structural equation model was calculated for the papermaking industry. To gain an insight into the effectiveness and current status of all components and sub-components, a case study was conducted and reported in the Iranian papermaking industry.

RESULTS AND DISCUSSION

Little research has been conducted on manufacturing sustainability in different industries, but since manufacturing sustainability is a prerequisite to achieving sustainable development, research in the two fields of development and manufacturing sustainability is overlapped. This research selected technological, social, regulations, economic, human, environmental, and materials and product components as the main indices and 43 sub-indices. Azizi *et al.* (2016) selected the main indices for achieving sustainable development supports our selection.

Based on Table 2, the analysis of the data on the significance of indices for manufacturing sustainability in the papermaking industry shows the statistically significant effect of the materials and product, technological, environmental, economic, human, economic, social, and regulations indices on manufacturing sustainability. The results of the t-test revealed that the mathematical mean of the components influencing the sustainability of the papermaking industry was at a moderate to high level because all means calculated for the items related to the indices and sub-indices were greater than our hypothetical mean, *i.e.*, 3. All factors and sub-factors were confirmed to be important for achieving manufacturing sustainability (Table 2).

Table 2. Descriptive Statistics of the Factors Influencing Sustainability in the Papermaking Industry

Factor	Current Status	Sustainable Status					
		Mean	Standard deviation	Standard error	t-value	Degrees of freedom	Sig. level
Technological	2.24	4.76	0.32	0.032	38.825	159	0.000
Regulations	1.65	4.64	0.39	0.035	52.609	159	0.000
Social	2.18	4.67	0.31	0.035	52.203	159	0.000
Economic	2.43	4.75	0.23	0.033	46.147	159	0.000
Environmental	2.26	4.76	0.21	0.037	43.835	159	0.000
Human	2.19	4.72	0.23	0.041	34.928	159	0.000
Materials & product	2.65	4.77	0.13	0.049	44.942	159	0.000

Ranking the main factors of the sustainability of the papermaking industry

Based on the current status of the papermaking industry, the main factors were ranked as materials and product, economic, environmental, technological, human, social, and regulations. However, the scales devoted to each factor were at a lower level. The main indices were ranked as materials and product, technological, environmental, social, economic, human, and regulations in terms of effectiveness in achieving manufacturing sustainability. To propose suitable solutions, a composite index named the least distance to sustainability was used. This index put the materials and product, economic, social, and technological factors at the top of the list. The standard coefficients and the significance of the values of sustainability status based on the effectiveness in sustainable production showed the close relationship between the main indices and manufacturing sustainability. According to the least distance to manufacturing sustainability, more distant factors should be paid more attention to in decision-making to achieve manufacturing sustainability. The results of Friedman's test showed that the most important approach to manufacturing sustainability was the materials and product factor. The regulations index had the highest distance to accomplish sustainability, and it seems that in order to achieve sustainability of production, one should behave very competently in the field of laws and regulations. This relationship is statistically significant with a significance level of <0.05 (Table 3).

The index of laws and regulations had the greatest distance to achieve sustainability, and it seems that in order to achieve sustainability of production, one should behave very competently in the field of laws and regulations.

Table 3. Results of Confirmatory Factor Analysis and Ranking of Main Factors for Manufacturing Sustainability of the Papermaking Industry

Index	Status					Distance to Sustain-ability	Ranking: Least distance to sustain-ability		Coefficients		Mean value in sustain-ability for Friedman's test
	Current			Sustainability					Standard	Sig.	
	Scale	Rank		Scale	Rank						
Economic	2.43	2		4.75	3	-2.32	2		0.620	19.98	6.60
Social	2.18	6		4.67	5	-2.49	3		0.692	9.20	4.30
Environmental	2.26	3		4.76	2	-2.50	4		0.474	8.55	5.60
Technological	2.24	4		4.76	2	-2.52	5		0.643	8.26	5.35
Regulations	1.65	7		4.64	6	-2.98	7		0.709	9.11	3.05
Human	2.19	5		4.72	4	-2.53	6		0.681	2.04	3.75
Materials and product	2.65	1		4.77	1	-2.12	1		0.538	12.11	7.00

Ranking the sub-factors of the sustainability of the papermaking industry

At this step, all sub-factors were studied by confirmatory factor analysis based on the questions asked. The results are presented in Tables 4 though 10. In factor analysis, higher standard coefficients, which range from 0 to 1, show stronger relationships. Significant values only show significance. In other words, they only need to be greater than 1.96, no matter how much greater.

Table 4. Results of Confirmatory Factor Analysis and Ranking of Technological Sub-Factors in the Papermaking Industry

Sub-index	Status				Distance to Sustain-ability	Ranking: Least distance to sustainability	Coefficients	
	Current		Sustainability					
	Scale	Rank	Scale	Rank			Standard	Sig.
RandD capabilities	2.25	6	4.76	8	-2.51	7	0.681	6.132
Technological capabilities	2.21	7	4.78	5	-2.57	8	0.658	12.19
Cleaner production	2.13	9	4.71	13	-2.58	9	0.631	12.81
Availability	1.70	12	4.56	14	-2.86	13	0.452	9.85
Practicality	2.55	3	4.74	10	-2.19	3	0.643	8.59
Pollution prevention	1.80	11	4.55	15	-2.75	12	0.653	9.10
Industrial automation level	2.40	4	4.83	2	-2.43	6	0.543	14.25
Waste control	2.80	1	4.75	9	-1.95	1	0.520	7.36
Calibration	1.80	11	4.82	3	-2.02	2	0.691	5.54
Quality monitoring	2.60	2	4.91	1	-2.31	4	0.592	14.31
Level of development	2.10	8	4.79	4	-2.69	10	0.602	8.15
Novelty	2.00	10	4.72	12	-2.72	11	0.642	9.33
Speed of change	1.70	12	4.77	6	-3.07	15	0.601	7.54
Transmission level	1.90	9	4.78	5	-2.88	14	0.532	10.25
Design capability	2.32	5	4.73	11	-2.40	5	0.538	8.35

Table 5. Results of Confirmatory Factor Analysis and Ranking of Regulations Sub-Factors in the Papermaking Industry

Sub-index	Status				Distance to Sustain-ability	Ranking: Least distance to sustainability	Coefficients	
	Current		Sustainability					
	Scale	Rank	Scale	Rank			Standard	Sig.
Stability	1.34	3	4.63	2	-2.29	1	0.584	11.50
Practicality	1.70	2	4.62	3	-2.92	3	0.601	10.65
Support	1.33	4	4.60	4	-3.27	4	0.569	10.05
Effectiveness	2.22	1	4.69	1	-2.47	2	0.658	11.71

Table 6. Confirmatory Factor Analysis and the Ranking of the Social Sub-Factors in the Papermaking Industry

Sub-index	Status				Distance to Sustain-ability	Ranking: Least distance to sustainability	Coefficients	
	Current		Sustain-ability					
	Scale	Rank	Scale	Rank			Standard	Sig.
Education	2.15	3	4.76	1	-2.51	2	0.470	6.52
Development	1.40	4	4.54	4	-2.14	4	0.598	14.11
Responsibility	2.80	1	4.64	3	-1.84	1	0.609	4.58
Effectiveness	2.36	2	4.69	2	-2.33	3	0.579	1487

Table 7. Confirmatory Factor Analysis and the Ranking of the Economic Sub-Factors in the Papermaking Industry

Sub-index	Status					Distance to Sustain-ability	Ranking: Least distance to sustain-ability		Coefficients	
	Current			Sustainability						
	Scale	Rank		Scale	Rank				Standard	Sig.
Financial capability	2.87	1		4.81	1	-1.94	1		0.548	14.38
Profitability	2.72	2		4.74	3	-2.02	2		0.670	9.40
Competitiveness	2.42	3		4.58	4	-2.16	3		0.754	9.44
Cheap resources	1.70	4		4.76	2	-3.06	4		0.680	8.72

Table 8. Confirmatory Factor Analysis and the Ranking of the Environmental Sub-Factors in the Papermaking Industry

Sub-index	Status				Distance to sustainability	Ranking: Least distance to sustainability	Coefficients	
	Current		Sustainability					
	Scale	Rank	Scale	Rank			Standard	Sig.
Environmental planning	2.77	1	4.74	3	-1.97	1	0.474	15.16
Environmental management	2.10	3	4.80	1	-2.70	2	0.639	15.08
Environmental effectiveness	2.20	2	4.75	2	-2.55	3	0.582	19.25
Environmental assessment	1.95	4	4.65	4	-2.70	2	0.620	19.98

Table 9. Confirmatory Factor Analysis and the Ranking of the Human Sub-Factors in the Papermaking Industry

Sub-index	Status					Distance to Sustain-ability	Ranking: Least distance to sustainability		Coefficients	
	Current			Sustainability						
	Scale	Rank		Scale	Rank				Standard	Sig.
Skill creation	2.33	1		4.74	2	-2.41	1		0.524	6.29
Knowledge raising	2.28	2		4.72	1	-2.44	2		0.754	6.42
Succession planning	1.95	3		4.71	3	-2.76	3		0.487	8.23

As is evident in Table 4, waste control, quality monitoring, proper use of technology for cleaner production, industrial automation level, and design capability were reported to be currently at a more desirable level than the other sub-factors, whereas the sub-factors of quality monitoring, calibration, proper use of technology, technology development level, design capability, and technological capability were more important to and more influential on manufacturing sustainability. The lowest distance to sustainability was shown by waste control, calibration, proper use of technology, quality monitoring, speed of change, and design capability. The highest distance to achieve manufacturing sustainability was related to the sub-factors of technology transmission and change level, access to technology for greener production, the possibility of using technologies with higher capability of pollution prevention, novelty, and technology development level. Therefore, to reduce the distance to sustainability, it is necessary to purchase technologies that address environmental requirements in addition to providing proper manufacturing capacity. Although keeping up with technology change and using modern technology have

financial burdens, reinforcing design infrastructure and empowering research and development departments can be very effective on this path. The standard coefficients and their significance also showed a strong relationship between these sub-factors and the technological index.

An important factor for achieving manufacturing sustainability in papermaking companies is the technological factor. Technological capability, research and development capability, and design capability can contribute to this goal remarkably. The alignment of technology with greener production programs, the emission of no environmental pollutants, design, and access to these capabilities emphasize the application of new technologies more than ever. The up-to-datedness of the waste control programs, the up-to-datedness of calibration procedures, and quality monitoring programs develop a symbol of the level of industrial automation to achieve these goals. The up-to-datedness of the technologies used in the industry given the rapid change in technology capability and very drastic changes in customers' tastes and their choices has forced many owners of the cardboard manufacturing industry to align themselves with competitiveness and sustainability changes and requirements. In this regard, Buyukozkan and Berkol (2011), Gandhi *et al.* (2017), Azizi *et al.* (2016), Thakur and Mangla (2019) and He *et al.* (2020) have reported the sensitivity of the technological factor and its sub-factors for manufacturing sustainability.

Most problems related to manufacturing sustainability in the papermaking industries are related to the rules and regulations imposed on decision-making organizations. Sustainability regulations should not be conflicting, should be changed and modified within an acceptable timeframe, should be aligned for sustainable industrial development, and should be supportive and effective. In the present research, the sub-factors of the regulations factor were ranked in the order of effectiveness, practicality, stability, and supportiveness in terms of their scores. However, as far as the intensity of effectiveness in manufacturing sustainability was concerned, regulation effectiveness and stability were more influential than practicality and supportiveness. The index of distance to sustainability shows that the regulations in Iran are relatively stable and effective, but the shares of their practicality and supportiveness are much lower. To move toward sustainable production, regulations in society and the industry should be aligned with the development and sustainability goals. For this purpose, the regulations enacted at the enterprise and industry levels should be reliable. In other words, they should be enforceable and stable enough and should support production and producers. This makes the significance of the stability of executive procedures even more apparent. A glance at the regulations at the level of relevant companies, associations, and organizations reveals much confusion, which requires more attention to empowerment, the stability of procedures and guidelines, and their supportiveness. Azizi *et al.* (2016), Mohebbi *et al.* (2017), and He *et al.* (2020) reported similar results.

Regarding the sub-factors of the social index in the papermaking industry, the first to fourth ranks were assigned to responsibility, the effectiveness of training activities, the extent of training programs held, and the development of the training-related activities, respectively. However, the sub-factors of training and effectiveness of the related activities were found to be the best in terms of effectiveness in manufacturing sustainability. The social activities and training were also in better positions in terms of the least distance to sustainability.

The movement on the path of manufacturing sustainability is streamlined by the industry owners' social responsibility with respect to training, development, responsibility, and effectiveness in strengthening the human resource capability, the use of gender diversity, and the recruitment of disabled people in order to reinforce humanitarian and

philanthropic thoughts. Susanty *et al.* (2016), Mohebbi *et al.* (2017), Schaltegger *et al.* (2017), and He *et al.* (2018) have reported that sustainable development will face many challenges if proper attitudes and the acceptance of social commitments are neglected.

Among the economic sub-factors, the companies' financial capability was ranked at the top, followed by profitability, competitiveness, and access to cheap resources in the next ranks. In this regard, the results completely match the least distance to sustainability. But, in terms of effectiveness in manufacturing sustainability, the sub-factors of financial capability, access to cheap resources, profitability, and competitiveness were in the first to fourth ranks, respectively. The economic factor in manufacturing sustainability seeks to maximize profitability, increase financial capacity, allow competitiveness, and reduce costs by accessing affordable resources. This is possible by strengthening the financial and technological resources, as well as human resource infrastructure, through the methods of skill creation, succession planning, and knowledge raising. Unfortunately, the cardboard industries have been damaged by economic factors and human resource retention due to the current conditions and limitations, export recession, growing increase in material prices, and the decline in the demand. Presently, the supply and sustainable access to high-quality material along with preserving proper paradigms of material diversity is a big challenge in the cardboard industry, jeopardizing sustainable production that aims at sustainable designing, controlling, and monitoring, and finally sustainable delivery of the product. The results reported by researchers including Prajogo *et al.* (2016), Susanty *et al.* (2016), Azizi *et al*. (2016), and He *et al*. (2020) support the present findings as to the economic sub-factors, human resources, material and product, and the quality of service and product.

Among the environmental sub-factors, the sub-factors of environmental planning, environmental effectiveness, environmental management, and environmental assessment were ranked at the top, respectively. The environmental management, effectiveness, planning, and assessment sub-factors were ranked the highest in influencing manufacturing sustainability, respectively. The highest ranks were assigned to environmental planning, management, assessment, and effectiveness in terms of the least distance to sustainability, respectively. The main attitude in the environmental component is the reduction and/or prevention of the emission of environmental pollutants in all industrial processes. In this regard, environmental planning and the management of the implementation of environmental plans are the priorities for the decision-makers of industrial units to reveal the result and effectiveness of environmental procedures with assessment processes like environmental risk analysis. Environmental assessment naturally reveals the current status and how better results can be obtained. In cardboard manufacturing units, the emission of pollutants such as dust, noise, chemical vapors of cooking glue or other inks, and the amount and quality of wastewater have always been a source of concern. This reminds us of the need for using different resources and recycling them in the industry. The assessment of hazards arising from inattention to environmental issues strengthens the need for environmentally and socially friendly sustainable planning, designing, and development to alleviate the destructive effects of industrial processes on the environment. Buyukozkan and Berkol (2011), Mohebbi *et al.* (2017), and He *et al.* (2020) have also emphasized the need to comply with all environmental requirements.

As an empowering factor in paper and pulp-making companies, human resource plays a critical role in manufacturing sustainability. The results of all studied cases reveal that the sub-factors of skill development, knowledge raising, and succession planning are important in the human index, respectively. Based on the results, papermaking companies should have proper plans to enhance the skills and knowledge of their human resources and strengthen their succession plan to support the organization. The emphasis on the

importance of human resources by Thakur and Mangla (2019), Zaid *et al*. (2018), and Baghersad and Zobel (2021) also reflects the importance of this component for manufacturing development and sustainability.

Table 10. Results of Confirmatory Factor Analysis and Ranking of Materials and Product Sub-Factors in the Papermaking Industry

Sr. No.	Sub-index	Status					Distance to Sustain-ability	Ranking: Least distance to sustain-ability	Coefficients	
		Current			Sustainability					
		Scale	Rank		Scale	Rank			Standard	Sig.
1	Raw material	1.99	-		4.73	-	-2.74	-	0.621	8.59
1.1	Sustainable material supply	2.10	2		4.79	1	-2.69	3	0.601	9.85
1.2	Sustainable material quality	2.16	1		4.79	1	-1.63	2	0.643	6.132
1.3	Sustainable material diversity	1.70	3		4.60	2	-1.90	1	0.681	2.54
2	Product	3.13	-		4.74	-	-1.61	-	0.636	11.48
2.1	Sustainable production	2.70	4		4.79	2	-2.09	4	0.602	12.81
2.2	Sustainable control and monitoring	3.13	2		4.82	1	-1.69	3	0.658	9.15
2.3	Sustainable product delivery	3.60	1		4.79	2	-1.19	1	0.639	5.13
2.4	Sustainable design	3.10	3		4.56	3	-1.46	2	0.648	9.10

Table 11. Structural Equations for the Factors Affecting Manufacturing Sustainability in the Papermaking Industry

Index	Standardized Path Coefficient	Sig. Coefficient	Statistical Result
Economic	0.717	11.58	Confirmed
Regulations	0.709	9.11	Confirmed
Social	0.692	9.20	Confirmed
Technological	0.681	7.04	Confirmed
Environmental	0.674	8.55	Confirmed
Materials and product	0.643	8.26	Confirmed
Human	0.538	12.11	Confirmed

Table 12. Cross-validated Redundancy Values for the Pulp and Paper Industry

Research Variables	Cross-validated Redundancy Index
Regulations	+
Economic index	+
Environmental index	+
Technological index	+
Social index	+
Human index	+
Material index	+
Sustainable development	0.595

Papermaking factories should be able to supply their raw material in high quality and diversity and in a sustainable manner and produce and supply their products continuously and sustainably. So, they need to control and monitor their products in the

production process and design their products as per the customer requirements. The results showed that the sub-factor of product gained a higher score than the sub-factor of materials in all aspects. Regarding the raw material and its current status and impact on manufacturing sustainability, the stable quality of material, supply, and sustainable diversity were found to be in higher ranks, respectively. However, in terms of the least distance to manufacturing sustainability, sustainable diversity, sustainable quality, and sustainable supply were in higher ranks, respectively. Concerning the sub-factors of product in the present status, the higher ranks were assigned to sustainable product delivery, sustainable control and monitoring, sustainable design, and sustainable production, respectively. In terms of effectiveness in manufacturing sustainability, the sub-factors of sustainable control and monitoring, sustainable delivery, and sustainable production and design were found to be of higher importance. A look at Table 9 reveals that sustainable product delivery, sustainable product design, and sustainable control and production are more influential on manufacturing sustainability, respectively. Attention to the characteristics of materials and products is an undeniable necessity for achieving sustainable production and development and meeting consumer needs in the competitive atmosphere of the cardboard-making industry. This is supported by Roshanrou *et al*.'s (2016) and Pourmousa's (2019) research on the competitiveness and challenges of the corrugated box making and packaging industry. Presently, the price of paper for producing corrugated sheets and packages is fast growing due to the inappropriate situation of wastepaper supply for papermakers. This will threaten the manufacturing sustainability of the papermaking industry due to issues and restrictions imposed on the cardboard industry (improper margin of corrugated box production and the tendency of customers and consumers to other sorts of alternative packaging).

All factors influencing the manufacturing sustainability of the papermaking industry significantly differ between the status quo and effectiveness in sustainability. Also, the confirmatory factor analysis confirmed all indices and factors. The path coefficient shows the presence of a close linear relationship between these two hidden variables. In fact, the regression coefficient that was observed in the simpler models of simple and multiple regressions is in the standard status. It takes a value between -1 and +1. If it is equal to zero, that implies a lack of a linear causal relationship between the two hidden variables. In this model, all standardized coefficients were greater than 0.3, and the t-value was estimated at higher than 1.96. So, the model's validity was supported. The results of research hypothesis testing and statistical analysis of the pulp and paper industry by structural equation modeling in Table 10 show that all main factors of the research affect manufacturing sustainability positively and significantly according to the coefficients of path and significance.

Predictive relationship in the papermaking industry

The predictive relationship is another index to assess a structural model and its quality. This index aims to check the capability of a structural model in predicting by the ignoring method. The most famous criterion to measure this capability is Stone-Geisser's Q^2, according to which the model should predict the indicators of the endogenous hidden variables. A Q^2 value of >0 means that the observed values have been rebuilt properly and the model is capable of prediction. In other words, if all values obtained for cross-validated redundancy (CVRED) are positive, the structural model can be claimed to have good quality. It should be noted that this index is calculated for endogenous hidden variables.

As is evident in Table 11, all endogenous variables of the research gained positive Q^2 values, implying that they have been rebuilt well and are capable of prediction.

Criteria to test the general structural equation model in the papermaking industry

In SEM, the index used to measure the model is the goodness-of-fit (GOF) that has been proposed by Tenenhaus *et al.* (2005). GOF is used to check the validity or quality of a model in structural equation analysis. This index takes a value between 0 and 1. The closer it is to 1, the more valid the model is. This index considers both measurement and structural models and is used as a criterion to measure the general performance of the model. Henseler *et al.* (2009) determined the three values of 0.15, 0.2, and 0.35 as the low, moderate, and high prediction capability, respectively. According to the GOD equation, it was calculated for the paper and pulp industry as below:

$$\text{GOF}=\sqrt{\text{average (commonality)}\times\text{average}\left(R^2\right)}=0.644 \quad (1)$$

Commonality=0.595

$\overline{R}^2$=0.698

Finally, the results showed that although most factors and sub-factors had a very high impact on achieving all-inclusive sustainability and development, the assessment of the present status of papermaking companies by the self-reported opinions of the statistical population revealed that there is a long distance to achieve sustainability. By defining and implementing development-based programs to strengthen the current status of all factors and sub-factors affecting manufacturing sustainability, more reliable steps can be taken to accomplish this goal.

The model proposed for manufacturing sustainability of the papermaking industry

According to the results and a comparison with other researchers (Tseng *et al.* 2009; Joung *et al.* 2012; Tseng 2013), the model depicted in Fig. 1 is proposed for manufacturing sustainability and sustainable production development in the papermaking industry.

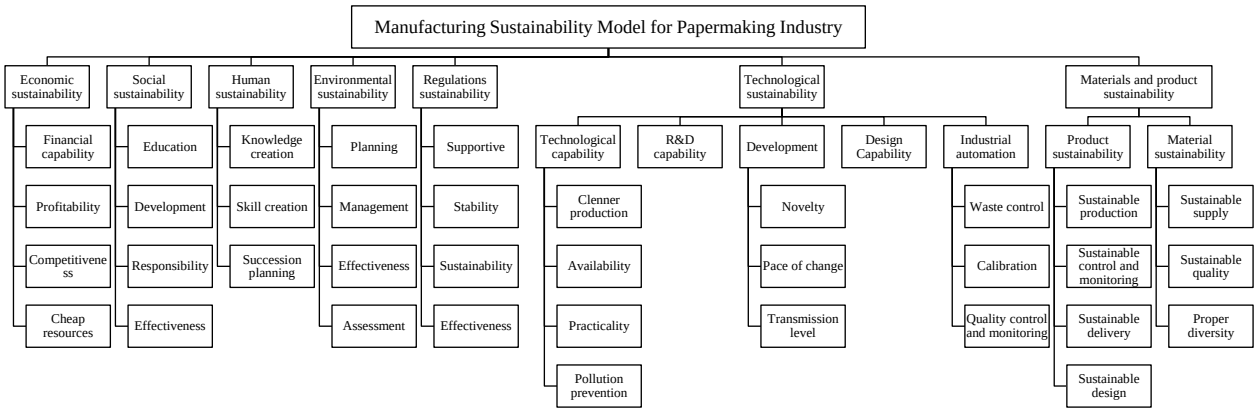

Fig. 1. Proposed model of manufacturing sustainability in the papermaking industry

The proposed model cannot be assumed to completely match other researchers' opinions, but it is generally similar to other models. This model can be applied in all factories in all countries with slight modifications.

CONCLUSIONS

Based on the results, the conclusions can be summarized as follows:

1. To achieve manufacturing sustainability, factors other than economic, social, and environmental sustainability are important. These can include technological sustainability, human resource sustainability, sustainability of regulation supports, sustainable access to proper materials, and product sale.
2. Environmental sustainability requires the designing and implementation of environmental systems through environmental planning, management, assessment, and effectiveness, which have their own details and definitions.
3. Access to proper raw materials and the possibility of product sales complied with standard guidelines are important challenges for manufacturing sustainability in the papermaking industry.
4. In most countries that lack the technical knowledge for designing and manufacturing proper equipment and technology for manufacturing sustainability, if there are no facilitating regulations, it will be very difficult to achieve manufacturing sustainability.

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