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Abstract

Purpose-Quality 4.0 represents the integration of quality management principles with digital technologies to drive continuous improvement and innovation in organizations. The purpose of this paper is to explore the essential Organizational Variables (OVs) for the successful implementation of Quality 4.0 in the Indian furniture industry.

Design/methodology/approach-Through a broad literature review, data from the Indian furniture industry, and experts' judgments a list of nineteen OVs have been recognized and classified into four major categories of Digitalization, Design, Continuous Improvement, and Employee training and up-skilling. The analytic hierarchy process (AHP) has been used to give comparative importance and prioritize the identified nineteen OVs of Quality 4.0 in the context of the Indian furniture industry.

Findings-The results of this study reveal that the identified variables are very important for successful Quality 4.0 implementation and have been supported by empirical evidence from the Indian furniture industry. The variable 'Automation' under the digitalization-related category is a significant variable having a maximum weightage of 26.8% followed by Cloud computing (DI4) having a global weight of 12.8%.

Research limitations/implications-In addition to offering valuable insights and practical recommendations, the study recognizes a few limitations, such as industry-specific, and the limited sample size. To diminish these limitations, future research should believe in conducting similar studies in different industries and extend the scope of the study.

Originality/value-Quality 4.0 is a term that refers to the integration of advanced digital technologies and smart data analytics into quality management systems to implement it considering organizational variables.

Keywords: *Analytic Hierarchy Process, Quality 4.0, Organizational Variables, Multi-Criteria-Decision-Making*

1. Introduction

The business prioritizes growing its market share and profitability (Kumar et al., 2018; Mittal et al., 2023a; Mittal et al., 2021a; Singh et al., 2023). The organizations therefore are concerned

about the quality of their products, customer satisfaction, continuous improvement, and manufacturing costs (Mittal et al., 2021b; Mittal et al., 2023b; Verma et al., 2023; Vadivel et al., 2023). In line with this, the Indian furniture industry is a rapidly growing sector that is expected to continue its growth trajectory in the coming years. The industry is primarily driven by factors such as increasing disposable incomes, rapid urbanization, and changing lifestyles (Menon and Nair, 2022). The market is highly fragmented and dominated by unorganized players, but organized players are gradually gaining ground. Wooden furniture remains the most popular segment of the Indian furniture market, followed by plastic and metal furniture (Mittal et al., 2022). However, there is a growing demand for eco-friendly and sustainable furniture made from materials such as bamboo and cane. The rise of e-commerce has also opened up new avenues for growth for the industry (Yan et al., 2023).

Quality 4.0 in the furniture industry refers to the use of advanced technology and digital tools to improve the quality of furniture products and manufacturing processes (Amat-Lefort et al., 2023; Kaswan et al., 2023a). It is an approach that combines traditional craftsmanship with modern technology to produce high-quality furniture that meets the needs and preferences of consumers. The quality concepts and measures followed in Industry 4.0, are set out in the concept of quality 4.0 (Sánchez-Alegría et al., 2022). The recent studies focused and were based on Industry 4.0, or the fourth industrial revolution to industrial development. Industry 4.0, also known as the fourth industrial revolution, is being ushered in by technologies such as the cloud, and robotics, which are being viewed as the next step for businesses (Zangara et al., 2023).

The ultimate goal of Quality 4.0 is to integrate the entire eminence arrangements and, as an effect, enhance existing quality approaches (Antony et al., 2023). In the regulated production process, innovative industries use cloud-based quality 4.0 advancements (Antony et al., 2022; Kaswan et al., 2023b; Mittal et al., 2022; Yadav et al., 2023). It is used to satisfactorily handle quality problems as they arise, as well as to conduct real-time quality studies to increase competitiveness and exploit those (Antony et al., 2022). At the next level, it needs to manage and supervise the managerial process using quality 4.0. The organizational processes have been changing as a result of digitization today.

Organizations would face some confronts and confusion, whenever trying to implement Quality 4.0 in the context of the Indian furniture industry (Bai and Satir, 2022; Sader et al., 2022). Researchers need to know what OVs are important in the implementation of Quality 4.0

and how they influence and influence organizational performance is essential for researchers and policymakers to effectively and efficiently implement Quality 4.0 (Govindan et al., 2022; Antony et al., 2021). This inspired the authors of this study to investigate fundamental OVs for the implementation of Quality 4.0 from the perspective of the Indian furniture industry.

The implementation of Quality 4.0 OVs in the furniture industry can help manufacturers improve product quality, increase efficiency, enhance customer satisfaction, and better manage their supply chains (Sony et al., 2020). By utilizing these essential OVs of Quality 4.0, furniture manufacturers can collect and analyze large amounts of data to identify potential quality issues early in the production process. In the present study, OVs for the implementation of Quality 4.0 in the context of the Indian furniture industry has been investigated. Initially, a semi-structured interview with industry experts has been used to recognize the fundamental OVs of Quality 4.0. The prioritizing between them is formulated by an AHP MCDM and is discussed in this research study. The findings of this study can facilitate furniture industries to contain a complete acceptance of priority between the essential OVs so that they can bring out the effective organizational performance in the industry.

The winning accomplishment of Quality 4.0 in the furniture industry depends on various OVs that must be carefully considered and addressed. The ranking of the OVs can assist organizations in accomplishing the implementation process of Quality 4.0. This research work will assist Indian furniture industries in the implementation process of Quality 4.0.

In exploring the implementation of Quality 4.0 practices, the present study sought to identify the fundamental OVs of Quality 4.0 from the perspective of the Indian furniture industry. Additionally, this study delves into assessing the success of these identified OVs and their relevance within the circumstances of the Indian furniture industry.

The specific research objectives of this study are to (i) To recognize OVs and the Quality 4.0 elements that make them up (ii) Find the hierarchy of organized variables, and rank them using the MCDM approach.

The rest of the paper is divided into six sections. Section 2 describes literature related to Quality 4.0, OVs for Quality 4.0, Case study, and recognition of OVs for Quality 4.0. Section 3 described the research methodology used to investigate the OVs. The results and Discussion of this study are explained in Section 4. The last section 5 includes Conclusions, Limitations with the future scope of research.

2. Literature Review

A literature review is a critical analysis of existing research and literature on a particular topic. It involves reviewing and summarizing academic articles, books, and other sources of information relevant to a specific research question or topic. A thorough analysis of numerous pertinent literature work on industrial organizations, including OVs for Quality 4.0 extracted in this part of the current research work, is the main goal of this literature review section.

2.1 Quality 4.0

Managing quality in the era of Industry 4.0 is the focus of the business practice known as "Quality 4.0" (Javed et al., 2021). Due to this, the digital transformation and industry 4.0 climates are critically important for quality 4.0. In this study, our main concern is to focus on different OVs of Quality 4.0.

Mittal et al. (2022) provided a comprehensive overview of Quality 4.0, including its background, OVs, key concepts, and application areas. The authors also discussed the challenges and opportunities associated with implementing Quality 4.0, as well as potential future research directions. Chiarini and Kumar (2022) prepossessed a conceptual structure for implementing Quality 4.0 in furniture manufacture-based organizations. The structure included four key elements: quality culture, quality processes, quality technology, and quality data.

The concept of Industry 4.0 and Quality 4.0 are closely interrelated, representing two balancing dimensions of the digital transformation in manufacturing and organizational excellence (Kumar et al., 2023c; Malik et al., 2023). Sisodia and Forero (2020) examined the relationship between Quality 4.0 and Industry 4.0, highlighting how Quality 4.0 can support Industry 4.0 initiatives. The authors also discussed the potential benefits and challenges associated with implementing Quality 4.0 in various industries. Industry 4.0 mainly focuses on the integration of advanced technologies, such as IoT, AI, and automation, to create smart and interconnected production systems (Sharma et al., 2023; Tortorella et al., 2023). Quality 4.0, on the other hand, emphasizes the integration of digital technologies with quality management practices to drive continuous improvement, real-time monitoring, and data-driven decision-making, leading to enhanced product quality and customer satisfaction (Mittal et al., 2022). Prashar (2023) explored the potential impact of Industry 4.0 on quality management, including

the use of advanced analytics and real-time data to get better quality analytics. The authors also discussed the role of leadership and culture in successfully implementing Quality 4.0.

Antony et al. (2021) presented an overview of Quality 4.0, highlighting how it differs from traditional quality management approaches. The authors also discussed the potential benefits of implementing Quality 4.0, including improved efficiency, reduced costs, and increased customer satisfaction.

2.2 OVs for Quality 4.0

An OV for Quality 4.0 refers to the key factors or attributes within an organization that contributes to the effective implementation and success of Quality 4.0 initiatives (Sachan et al., 2023). Quality 4.0 is a term used to describe the integration of digital technologies and data analytics into traditional quality management practices (Antony et al., 2021).

Quality 4.0 is a concept that emerged from Industry 4.0, which refers to the fourth industrial revolution that integrates advanced tools such as AI, big data, and the IOT to create smart factories and interconnected systems (Thekkoote, 2022). Quality 4.0 is the application of these technologies to improve the quality of products and services (Javed et al., 2021). Several studies have been conducted on Quality 4.0, focusing on its potential benefits and challenges. A literature review by Mittal et al. (2022) found that Quality 4.0 can enhance quality control, increase productivity, and reduce costs. The authors emphasized that Quality 4.0 can be applied in various industries, including healthcare, manufacturing, and services. Another literature review by Wu et al. (2021) identified the key technologies that are essential for implementing Quality 4.0, as well as AI, big data analytics, and blockchain. The authors also discussed the challenges and barriers to implementing Quality 4.0, such as data privacy and security concerns and the need for skilled workers to operate these technologies. Similarly, a review by Zonnenshain and Kenett, (2020) highlighted the benefits of Quality 4.0 for supply chain management. The authors argued that Quality 4.0 can enhance the efficiency and transparency of supply chains and improve product quality and safety.

The OVs of quality 4.0 also play a vital role to enhance the organization's performance to its success. Based on the previous studies, various organizational variables are outlined. Sony et al. (2020) discovered eight important OVs for successful Quality 4.0 implementation in manufacturing companies. The eleven quality 4.0 focus areas are identified as Analytics, Data

management, App development, connectivity, scalability, collaboration, competency, leadership, culture, compliance, and management system (Yadav et al., 2021). Jha et al. (2022) proposed eighteen Quality 4.0 applications to enhance eminence in manufacturing organizations. Yadav et al. (2021) identified seven factors related to quality 4.0 technologies.

Overall, the literature suggests that Quality 4.0 has the potential to revolutionize quality management by enabling real-time monitoring and control of production processes, reducing waste and defects, and improving customer satisfaction. However, its successful implementation requires addressing various challenges related to data privacy, cybersecurity, and workforce training.

2.3 Research Gaps

The existing research on Quality 4.0 implementation in the Indian furniture industry is limited, with only a few studies exploring the specific OVs that make possible its successful implementation. There is a lack of comprehensive empirical evidence regarding the critical OVs required for a successful Quality 4.0 implementation in this furniture industry. Moreover, while some general studies on Quality 4.0 and OVs are present, they often do not address the unique variables and opportunities faced by the Indian furniture industry. Therefore, this study aims to bridge this gap by providing in-depth empirical evidence and insights into the critical organizational variables needed for effective Quality 4.0 implementation in the Indian furniture industry.

2.4 Case study

The case industry is one of the leading furniture brands in India, with a rich legacy spanning over 80 years. Established in 1945, the case industry is a subsidiary of the large Group, a conglomerate known for its diverse portfolio of businesses in India. The case industry offers a wide range of furniture products including beds, wardrobes, sofas, dining sets, and office furniture. They cater to both residential and commercial customers and have a strong presence across the country. One of the unique selling points of the case industry is its commitment to sustainability. They have implemented several initiatives such as using eco-friendly materials, reducing waste, and promoting energy-efficient practices across their manufacturing and distribution processes. The case industry has also embraced technology to enhance its customer

experience. They have a dedicated website and mobile app where customers can browse and purchase their products. Additionally, they have a network of physical showrooms across the country where customers can touch and feel the products before making a purchase.

2.5 Classification of OVs of Quality 4.0

Extensive literature has been studied to identify the essential OVs for the implementation of Quality 4.0 in the context of the Indian furniture industry. The literature survey above discussed thoroughly covered the Quality 4.0 concept and its OVs. To achieve the first research objective of the present study, a semi-structured interview with the taken industry experts has been used. Concerning the literature discussed semi-structured interviews with furniture industry experts a total of nineteen essential OVs of Quality 4.0 in the context of the furniture industry in India. The list of identified necessary OVs for Quality 4.0 is: a. Automation, b. Digital twins, c. Digital skills training, d. Agile methodologies, e. Change management training, f. Digital literacy training, g. Cloud computing, h. Sensor technology, i. Data-driven design, j. Blockchain technology, k. Design thinking, l. Data Analytics, m. Process optimization, n. Root cause analysis, o. Digital prototyping, p. Quality management training, q. Simulation modeling, s. Rapid iteration, and r. Constant upgrading.

The flourishing accomplishment of Quality 4.0 in the furniture industry depends on various OVs that must be carefully considered and addressed. In recent years, mostly the furniture industry in India understands the real meaning of OVs. That is why, ranking the OVs is very important for the implementation of Quality 4.0.

3. Research Methodology

The present study aims to investigate the essential OVs for the implementation of Quality 4.0 in the context of the Indian furniture industry. To investigate the essential OVs, this research study considered an AHP multi-criteria decision-making tool that combines two qualitative and quantitative approaches. To resolve complicated and unstructured situations, the chosen MCDM methodology is a global judging method as well as a qualitative technique (Saaty, 1988). AHP was used to break down a multilevel issue into various transitional levels of the hierarchical system and is based on a mathematical framework of well-defined matrices (Saaty, 1980). The rankings between all the accountable hurdles are determined using the opinions of specialists and

academicians. Pair-wise assessment findings based on expert and professional panel judgment have been compared to couples of homogenous criteria (Saaty, 1980). This approach is frequently utilized for a variety of objectives in various contexts. The step-by-step detail of the research methodology chased by this study is presented in Figure 1.

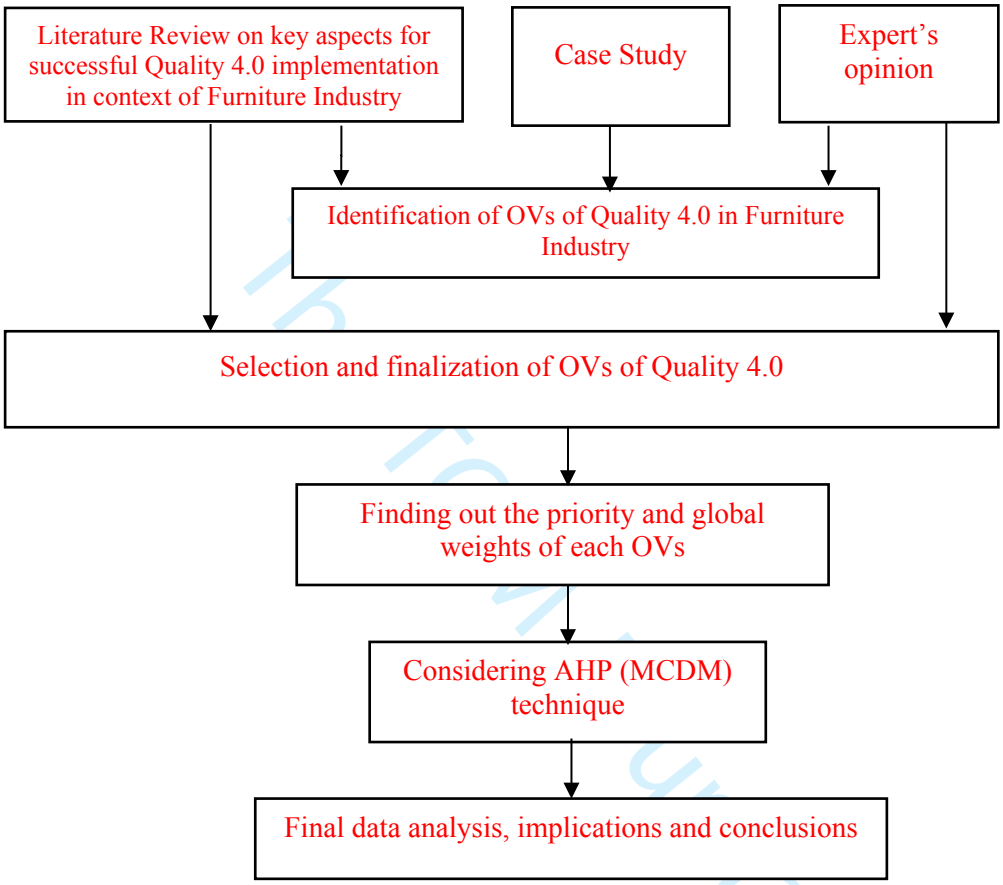

Figure 1. Research Methodology

Following are the many AHP technique steps.

Step-1: Define the objective cum purpose of the study.

Step-2: In line with step-1, i.e. objective a framework based on the expert's judgment is constructed.

Step-3: Assemblage of observed data during the collective judgment of experts.

Step-4: Formulate pair-wise comparisons (PWC) (to evaluate priority weights of components) by using Saaty's 1-9 range.

Step-5: Normalize the column of numbers by dividing each entry by the sum of all entries in the column.

$$r_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

The estimated priority weight (W1, W2,…….Wj) for every element is calculated as:

$$W_j = \frac{1}{n} \times \sum_{i=1}^{n} a_{ij}$$

Here,
n = Number of elements;
a = Cell value

Step-6: Calculate the consistency of formulated pair of norms

$$CI = \frac{\lambda_{max} - n}{(n-1)}$$

Here,
CI = Consistency index;
λ_{max} = Maximum eigenvalue

Step-7: Evaluate the Consistency Ratio (CR).

$$\text{CR} = \frac{\text{CI}}{\text{RCI}}$$

Table 1 Random Consistency Index (RCI) (adopted from Saaty 1985).

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RCI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Where n: number of components

Generally, if CR = < (0.1) 10% Consistent & satisfactory
> (0.1) 10% Inconsistent & Incorrect

Generally, if CR = < (0.1) 10% Consistent & Acceptable
> (0.1) 10% Inconsistent & Revised

4. Results and Discussion

After identifying a list of nineteen OVs, based on data collected and analyzed from relevant literature, a hierarchical structure of these OVs has been created as shown in Figure 1. Using these variables, a questionnaire has been developed to gather opinions from decision-makers working in the Indian furniture industry. The purpose of this questionnaire was to evaluate the OVs related to Quality 4.0 in the context of furniture manufacturing industry. A total of 17

decision-makers from various departments in the furniture industry have been approached to participate in the survey. All eleven decision-makers have been familiar with quality 4.0, and they were requested to provide their judgments using linguistic variables to create a pair-wise comparison matrix. The demographic details of the participants can be found in Table 2.

Table 2 Participants' details

Profile	Classification	Count	Percentage
Respondents	Male	11	64.7%
	Female	6	35.29%
	Total	**17**	
Age	21-30 years	6	35.29%
	31-40 years	4	23.52%
	41-50 years	4	23.52%
	Above 50 years	3	17.64%
	Total	**17**	
Work experience	0-5 years	6	35.29%
	6-10 years	4	23.52%
	11-15 years	5	29.41%
	16 and above years	2	11.76%
	Total	**17**	
Designation of the respondents	Manager	5	29.41%
	Supervisor	6	35.29%
	Senior manager	4	23.52%
	Executive	2	11.76%
	Total	**17**	
Education	Bachelors	12	70.58%
	Post Graduate and above	5	29.41%
	Total	**17**	
Department of respondents	Operations Management	5	29.41%
	Production Management	4	23.52%
	Product Quality Department	3	17.64%
	R&D	2	11.76%
	Sales and Marketing	1	5.88%
	HR	2	11.76%
	Total	**17**	

A hierarchy structure between the OVs has been developed with this objective in mind using the opinions of industry experts. The hierarchy composition has '3' levels, as shown in Figure 2, with level-1 representing the primary aim of this MCDM approach, level-2 representing the major levels of OVs, and level-3 representing sub-levels.

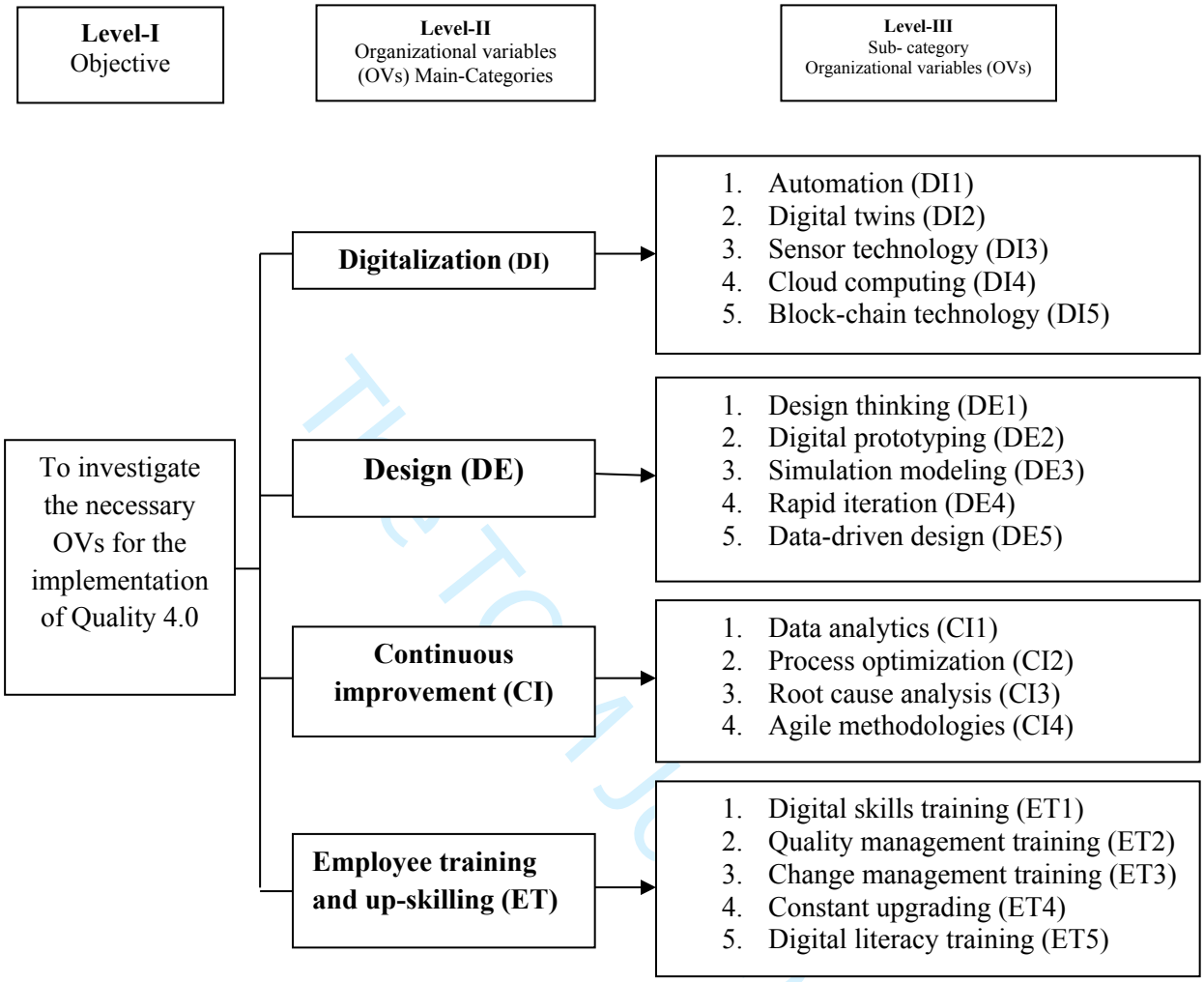

Figure 2 Hierarchy structure of encountered associated barriers in the home appliances industry

To translate linguistic judgments into numbers, the scale of preference has been assigned to the pair-wise judgments of associated OVs on a '1' to '9' range (Saaty, 1988). Where '1'replicates equivalent significance and '9' replicates excessive weightage as presented below in Table 6.

Table 3 Pair-wise comparison scale

Degree of preference	Judgment
1	equivalent weight
3	Moderate weight of one over another
5	necessary weight
7	Very strong importance
9	Extreme weight-age

2,4,6,8	transitional assessments among two adjacent judgments

Each sub-category associated with OV is calculated using a PWC matrix designed for the main-level associated OVs for the adoption of Quality 4.0. Table 4 displays the PWCM for organizational factors linked to the main categories.

Table 4 Pair-wise comparison matrix for the main-category OVs

S. No.	OVs Categories	DI	DE	CI	ET
1.	DI	1	4	5	8
2.	DE	0.25	1	2	3
3.	CI	0.2	0.5	1	3
4.	ET	0.125	0.33	0.333	1
	Sum	1.575	5.833	8.33	15

Based on priority values associated with the main category of OVs, digitalization (DI) is the mainly impacting category of OVs, having a priority value (PV) of '0.61' followed by design (DE) related (PV= 0.19), after that continuous improvement related (CI) (PV = 0.13), then employee training and up-skilling (ET) (PV = 0.06), respectively as presented in Table 5.

Table 5 Normalized matrix with priority values of the main-category OVs

S. No.	OVs Categories	DI	DE	CI	ET	Sum	Priority Weights (W)
1.	DI	0.63	0.69	0.60	0.53	2.45	0.61
2.	DE	0.16	0.17	0.24	0.20	0.77	0.19
3.	CI	0.13	0.09	0.12	0.20	0.53	0.13
4.	ET	0.08	0.06	0.04	0.07	0.24	0.06

Additional, relative values (δ), is evaluated by means of the method: $A \times W_j = \delta$,

$$\begin{vmatrix} 1 & 4 & 5 & 1 \\ 0.25 & 1 & 2 & 0.25 \\ 0.2 & 0.5 & 1 & 0.2 \\ 0.125 & 0.33 & 0.333 & 0.125 \end{vmatrix} \text{ X } \begin{vmatrix} 0.61 \\ 0.19 \\ 0.13 \\ 0.06 \end{vmatrix} = \begin{vmatrix} 2.54 \\ 0.79 \\ 0.53 \\ 0.25 \end{vmatrix}$$

A= Pair-wise comparison matrix; where j = 1, 2,…n

The Eigen vector 'λ':

$$\lambda = \frac{ithenteryinrelativeweight\ (\delta)}{ithentryinpriorityweight}$$

Eigenvalue maximum, $\lambda_{max} = 4.13$,
CI (consistency index) = 0.043 and
CR (Consistency Ratio) = 0.047.

Similarly, Table 6-9, shows the pair-wise comparison matrix for sub-category OVs.

Table 6 PWC matrix for digitalization (DI) OVs

S. No.	OVs sub-category (DI)	DI1	DI2	DI3	DI4	DI5
1.	DI1	1	7	4	2	3
2.	DI2	0.14	1	0.25	0.5	0.5
3.	DI3	0.25	4	1	0.5	2
4.	DI4	0.50	2	2	1	2
5.	DI5	0.33	2	0.50	0.5	1
	SUM	2.23	16	7.75	4.5	8.5

Table 7 PWC matrix for Design (DE) OVs

S. No.	OVs sub-category (DE)	DE1	DE2	DE3	DE4	DE5
1.	DE1	1	9	3	3	4
2.	DE2	0.11	1	0.25	0.25	0.125
3.	DE3	0.33	4	1	0.5	2
4.	DE4	0.33	4	2	1	2
5.	DE5	0.25	8	0.50	0.5	1
	SUM	2.03	26	6.75	5.25	9.125

Table 8 PWC matrix for continuous improvement (CI) OVs

S. No.	OVs sub-category (CI)	CI1	CI2	CI3	CI4
1.	CI1	1	3	3	9
2.	CI2	0.33	1	2	5
3.	CI3	0.33	0.5	1	2
4.	CI4	0.11	0.2	0.5	1
	SUM	1.78	4.7	6.5	17

Table 9 Pair-wise comparison matrix for employee training and up-skilling (ET) OVs

S. No.	OVs sub-category (ET)	ET1	ET2	ET3	ET4	ET5
1.	ET1	1	5	3	2	2
2.	ET2	0.20	1	0.5	0.25	0.25
3.	ET3	0.33	2	1	0.5	2
4.	ET4	0.50	4	2	1	3
5.	ET5	0.5	4	0.50	0.33	1
	SUM	2.533	16	7.00	4.08	8.25

Table 10-13, presents the priority values of the sub-category OVs.

The priority values and comparative significance of related OVs associated with the digitalization (DI) related groups are as Automation (DI1) showed the most important

organizational variable with an assigned value of '0.44'. Cloud computing (DI4) is the next mainly important organizational variable (PV = 0.21). Sensor technology (DI3) has PV is 0.17 and is the third important OV under this group. Blockchain technology (DI5) is the 4th most important OV and Digital twins (DI2) last positioned OV under the digitalization group with a priority weight of '0.07'.

Table 10 Normalized matrix with priority values for digitalization (DI) OVs

S. No.	OVs sub-category (DI)	DI1	DI2	DI3	DI4	DI5	SUM	Priority weights
1.	DI1	0.45	0.44	0.52	0.44	0.35	2.20	0.44
2.	DI2	0.06	0.06	0.03	0.11	0.06	0.33	0.07
3.	DI3	0.11	0.25	0.13	0.11	0.24	0.84	0.17
4.	DI4	0.22	0.13	0.26	0.22	0.24	1.07	0.21
5.	DI5	0.15	0.13	0.06	0.11	0.12	0.57	0.11

Eigen value maximum, λ_{max} =5.31, CI = 0.077 and CR = 0.069

Under the Design (DE) category the associated organizational variable Design thinking (DE1) is a prominent OV with a priority weight of '0.46'. Rapid iteration (DE4) is the second most important OV with a priority weight of '0.20'. Simulation modeling (DE3) has the priority weight'0.16' and is the third most important OV. Data-driven design (DE5) is the 4th most significant OV with a priority weight'0.14' and Digital prototyping (DE2) is the last OV that received '0.04' as a priority weight.

Table 11 Normalized matrix with priority values for Design (DE) OVs

S. No.	OVs sub-category (DE)	DE1	DE2	DE3	DE4	DE5	SUM	Priority weights
1.	DE1	0.49	0.35	0.44	0.57	0.44	2.29	0.46
2.	DE2	0.05	0.04	0.04	0.05	0.01	0.19	0.04
3.	DE3	0.16	0.15	0.15	0.10	0.22	0.78	0.16
4.	DE4	0.16	0.15	0.30	0.19	0.22	1.02	0.20
5.	DE5	0.12	0.31	0.07	0.10	0.11	0.71	0.14

Eigen value, λ_{max} = 5.43, CI = 0.1075 and CR = 0.095.

Under the Continuous improvement related (CI) category, the OV Data analytics (CI1) is significant and top-positioned OV with a priority weight of '0.55'. Process optimization (CI2) is the second most important OV with a priority weight of '0.25'. Root cause analysis (CI3) has a

priority weight 'of 0.14' which is the third most important OV and the Agile methodologies (CI4) OV with a priority weight of '0.06' is last under this group.

Table 12 Normalized matrix with priority values for continuous improvement (CI) OVs

S. No.	OVs sub-category (CI)	CI1	CI2	CI3	CI4	SUM	Priority weights
1.	CI1	0.56	0.64	0.46	0.53	2.19	0.55
2.	CI2	0.19	0.21	0.31	0.29	1.00	0.25
3.	CI3	0.19	0.11	0.15	0.12	0.57	0.14
4.	CI4	0.06	0.04	0.08	0.06	0.24	0.06

Eigen value λ_{max} =4.13, CI =0.043 and CR =0.048

The ranking of sub-category OV under Employee training and up-skilling (ET): Digital skills training (ET1) is a prominent OV by getting a maximum value of priority (0.37). Constant upgrading (ET4) is the second most important sub-OV with a priority weight of '0.27'. Moreover, Change management training (ET3) holds the third position within this group (PV=0.15). The fourth OV under this group with a priority weight of '0.14' is Digital literacy training (ET5). The final OV under this group is Quality management training (ET2) which received priority weights of 0.06.

Table 13 Normalized matrix with priority values for employee training and up-skilling (ET) Ovs

S. No.	OVs sub-category (ET)	ET1	ET2	ET3	ET4	ET5	SUM	Priority weights
1.	ET1	0.39	0.31	0.43	0.49	0.24	1.87	0.37
2.	ET2	0.08	0.06	0.07	0.06	0.03	0.30	0.06
3.	ET3	0.13	0.13	0.14	0.12	0.24	0.76	0.15
4.	ET4	0.20	0.25	0.29	0.24	0.36	1.34	0.27
5.	ET5	0.20	0.25	0.07	0.08	0.12	0.72	0.14

Eigen value, λ_{max} =5.377, CI =0.0942 and CR = 0.084

Further, global weights are calculated by multiplying the priority weights of sub-category OVs by their consequent main category OVs values of priority. For instance, the value of priority for the digitalization (DI) related category is 0.61, and in support of the sub-category Automation (DI1) OV the value of priority (PV = 0.44). Consequently, the global value for this OV is 0.61*0.44 = 0.268. In the same way, the global values and the position of all subcategory OVs are presented in Table 14.

Table 14 Global weights of essential OVs for Quality 4.0

S. No.	Organizational variables	Categories of Organizational variables (Local Weights)				CI	CR	Global Weights	Rank
		Digitalization (DI) (0.61)	Design (DE) (0.19)	Continuous Improvement (CI) (0.133)	Employee Training And Up-Skilling (ET) (0.067)				
1.	Automation (DI1)	0.44				0.077	0.069	0.268	1
2.	Digital twins (DI2)	0.07						0.043	7
3.	Sensor technology (DI3)	0.17						0.104	3
4.	Cloud computing (DI4)	0.21						0.128	2
5.	Block-chain technology (DI5)	0.11						0.067	6
6.	Design thinking (DE1)		0.46			0.107	0.095	0.087	4
7.	Digital prototyping (DE2)		0.04					0.008	18
8.	Simulation modeling (DE3)		0.16					0.030	10
9.	Rapid iteration (DE4)		0.20					0.038	8
10.	Data-driven design (DE5)		0.14					0.027	11
11.	Data analytics (CI1)			0.55		0.043	0.048	0.073	5
12.	Process optimization (CI2)			0.25				0.033	9
13.	Root cause analysis (CI3)			0.14				0.019	13
14.	Agile methodologies (CI4)			0.06				0.0085	16
15.	Digital skills training (ET1)				0.37	0.094	0.084	0.025	12
16.	Quality management training (ET2)				0.06			0.004	19
17.	Change management training (ET3)				0.15			0.010	15
18.	Constant upgrading (ET4)				0.27			0.018	14
19.	Digital literacy training (ET5)				0.14			0.009	17

Based on Table 5, shows the main category OVs priority value and reveals the order between main categories as DI-DE-CI-ET (digitalization-design-continuous improvement-employee training and up-skilling). To start with the main category of OVs, 'digitalization' (DI) is the most influencing category of OVs (PV = 0.61). It suggests that variables under digitalization are very crucial while planning for the implementation of quality 4.0 in the context of the furniture industry. In implementing any type of quality initiative in the digital era digitalization is very crucial.

There is a total of five linked OVs under this group. Along with this 'Automation' (DI) showed the most important OV with a priority weight of '0.44'. Automation ensures that the same procedures and processes are followed every time, resulting in consistent quality output. In the case of the second positioned 'Design' (DE); Design thinking (DE1) is a prominent OV by getting a maximum priority value of '0.46'. In the case of third positioned Continuous Improvement-related OV category; Data analytics (CI1) is significant and top-positioned OV

with a priority weight of '0.55'. By analyzing data, businesses can identify trends, patterns, and correlations that may not be apparent otherwise. In the case of Employee training and the up-skilling category of associated OVs; Digital skills training (ET1) is a prominent OV by getting a maximum priority value of '0.37'. OVs can provide the necessary resources and support to drive the initiative forward. They can also communicate the importance of Quality 4.0 to employees, which can help to create buy-in and support for the initiative.

The rankings provide critical insights into the most influential OVs that organizations should prioritize during their Quality 4.0 implementation journey. By understanding the significance of these variables, organizations can make informed decisions and allocate resources effectively, fostering a culture of continuous improvement and innovation in a new advanced era of technology (Kumar and Sharma, 2016; Kumar et al., 2023a; Kumar et al., 2023b).

4.1 Implications

The present study has some implications for practitioners as well as for academicians. By identifying and prioritizing essential OVs specific to the Indian furniture industry, the research enriches the understanding of how these variables influence the success of Quality 4.0 implementation. From a managerial perspective, this study provides a roadmap for organizations to navigate their Quality 4.0 journey effectively. Managers can leverage this knowledge to make informed decisions, allocate resources efficiently, and formulate tailored strategies for the successful Quality 4.0 implementation. By embracing Quality 4.0, furniture companies can enhance their competitiveness, efficiency, and product quality, leading to greater customer satisfaction.

5. Conclusion, Limitations, and Future Scope

This study aims to investigate the essential OVs for the implementation of Quality 4.0 in the context of the Indian furniture industry. The implementation of Quality 4.0 OVs in the furniture industry can help manufacturers improve product quality, increase efficiency, enhance customer satisfaction, and better manage their supply chains. By utilizing these essential OVs of quality 4.0, furniture manufacturers can collect and analyze large amounts of data to identify potential quality issues early in the production process. Furniture manufacturers must embrace digital technologies in the design process to optimize the production process, reduce waste, and improve quality. Furniture manufacturers must implement digital quality management systems that can

collect and analyze data in real-time to identify quality issues, track quality metrics, and improve quality performance. This includes using digital tools for tracking and managing inventory, scheduling production, and managing supplier relationships. Success in adopting Quality 4.0 for furniture manufacturers hinges on their commitment to employee training and up-skilling. It is imperative to equip employees with the essential competencies to navigate digital technologies, proficiently analyze data, and confidently make data-driven decisions. By investing in workforce development, organizations can foster a culture of innovation and adaptability, positioning themselves at the forefront of the Quality 4.0 era. Furniture manufacturers must embrace a continuous improvement culture that encourages employees to identify opportunities for improvement, test new ideas, and implement changes. This requires a culture of experimentation, data analysis, and rapid prototyping.

Through a broad literature review, experts' judgments of nineteen OVs have been recognized and classified into four major categories of Digitalization, Design, Continuous Improvement, and Employee training and up-skilling. The analytic hierarchy process (AHP) has been used to give comparative importance and prioritize the identified nineteen OVs of Quality 4.0 in the context of the Indian furniture industry. In line with this, a hierarchy framework between the decisive OVs has been formulated and the pair-wise comparisons between them are calculated. The relative rank of identified main categories of OVs is DI-DE-CI-ET (digitalization-design-continuous improvement-employee training and up-skilling). The results of this study reveal that Automation under the digitalization-related OV category is a significant variable having a maximum weightage of 26.8% followed by Cloud computing (DI4) with a global weight of 12.8%. Further, the present study is purely based on the judgment of experts from the industry. In future research work more MCDM techniques like fuzzy AHP, DEMETAL, TOPSIS, and ISM-based may be used to analyze the identified barriers. The proposed AHP-based hierarchy framework may also be enlightened to another dimension of organization.

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