Technology-Assisted Inclusive Employment Framework for Persons with Hearing and Speech Impairment in Corrugated Packaging Manufacturing MSMEs

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Abstract: *The Indian corrugated packaging industry, a significant component of the Micro, Small and Medium Enterprise (MSME) sector, continues to face challenges related to skilled manpower shortages, workforce instability, and employee retention. Traditionally, manufacturing operations in this sector have relied heavily on manual labor and verbal communication, limiting employment opportunities for persons with hearing and speech impairment. However, the increasing adoption of automation, digital technologies, and Human-Machine Interface (HMI)-based systems is gradually transforming the nature of manufacturing work. This study explores the potential of technology-assisted manufacturing to create more inclusive employment opportunities within corrugated packaging MSMEs. Drawing upon disability and employability literature, vocational education frameworks, policy analysis, and industry observations, the paper proposes an inclusive employment framework supported by assistive technologies, visual communication systems, and competency-based vocational training aligned with National Skills Qualifications Framework (NSQF) principles. The framework emphasizes accessible learning methods, visual operating systems, simplified machine controls, and structured workplace participation. Existing research and workplace observations suggest that people with hearing and speech impairment often demonstrate strengths in visual attention, concentration, observation-based activities, and task consistency when supported by appropriate workplace accommodations. Such characteristics are highly relevant to several manufacturing activities involving inspection, monitoring, counting, and process compliance. The proposed framework seeks to bridge the gap between policy objectives, vocational training systems, and employment opportunities through collaboration among industry, government agencies, training institutions, and disability support organizations. The study concludes that technology-assisted manufacturing can serve as an effective pathway for improving workforce inclusion while simultaneously addressing labour challenges faced by MSMEs. By integrating accessibility, skill*

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development, and workplace adaptation, the proposed framework contributes to both inclusive economic growth and sustainable employment generation for persons with hearing and speech impairment.

Keywords: Corrugated Packaging, MSME Manufacturing, Inclusive Employment, Hearing and Speech Impairment, Skill Development, NSQF, Assistive Technology, HMI.

Introduction

The Micro, Small and Medium Enterprise (MSME) sector plays a significant role in India's economic development through its contribution to manufacturing output, employment generation, and industrial growth. Among the various MSME-driven industries, the corrugated packaging sector occupies a critical position by supplying packaging materials to a wide range of industries including food processing, pharmaceuticals, consumer goods, electronics, logistics, and e-commerce. Corrugated boxes have become one of the most widely used packaging materials due to their low cost, light weight, recyclability, ease of transportation, and environmental sustainability (Kirwan, 2013).

Despite its growing importance, the corrugated packaging industry continues to face several operational challenges. One of the most significant concerns reported by manufacturing MSMEs is the shortage of skilled manpower and the difficulty of retaining a stable workforce. Many factories rely heavily on informal learning, on-the-job experience, and the transfer of knowledge through senior workers rather than structured training systems. High labour turnover, inconsistent work practices, and limited access to skilled personnel often result in quality variations, productivity losses, increased wastage, and higher operating costs.

At the same time, India has a large population of persons with disabilities who continue to face barriers in accessing education, vocational training, and employment opportunities. According to the Census of India 2011, approximately 2.68 crore persons with disabilities reside in the country, representing one of the largest disability populations in the world. Although various policy initiatives have been introduced to improve inclusion, employment participation among persons with disabilities remains significantly lower than that of the general population. The Rights of Persons with Disabilities (RPwD) Act, 2016 and the National Education Policy (NEP) 2020 emphasize equal opportunity, accessibility, skill development, and workforce participation; however, a considerable gap continues to exist between policy objectives and practical implementation within industrial workplaces.

Historically, manufacturing environments have been characterized by physically demanding operations, machine noise, verbal instructions, and auditory warning systems. Such conditions often limited employment opportunities for persons with hearing and speech impairment. Traditional training approaches relied heavily on spoken communication, making workplace learning and participation difficult for individuals who could not effectively access auditory

information. Consequently, many employers perceived the inclusion of hearing-impaired workers as operationally challenging.
The emergence of Industry 4.0 technologies is gradually transforming this situation. Human-Machine Interfaces (HMIs), sensor-based monitoring systems, digital displays, visual communication tools, and automated process controls are reducing dependence on manual intervention and verbal communication. Information that was previously conveyed through spoken instructions can increasingly be communicated through visual interfaces, graphical displays, digital alerts, and assistive technologies. Such developments create new opportunities for workplace accessibility and inclusive employment.

Theoretical perspectives also support the use of accessible learning and communication systems. Cognitive Load Theory suggests that learning becomes less effective when individuals must expend excessive effort processing inaccessible information rather than focusing on the task itself (Sweller, 1988). Similarly, the Universal Design for Learning (UDL) framework advocates the presentation of information through multiple accessible formats to accommodate diverse learner needs (CAST, 2018). Together, these approaches provide a useful foundation for designing technology-assisted vocational training and workplace systems for persons with hearing and speech impairment.

The corrugated packaging industry presents a particularly relevant context for such initiatives. Many manufacturing activities involve visual inspection, counting, monitoring, process observation, material verification, and compliance with standard operating procedures. With appropriate workplace adaptations and technology-assisted communication systems, several of these activities can potentially be performed effectively by persons with hearing and speech impairment. This creates an opportunity to address two important challenges simultaneously: workforce shortages within manufacturing MSMEs and limited employment opportunities for persons with disabilities.

Against this background, the present study explores the potential of technology-assisted manufacturing as a pathway for inclusive employment within the corrugated packaging industry. The study proposes a framework that integrates assistive technologies, accessible training methodologies, stakeholder collaboration, and workplace adaptation to improve employment opportunities for persons with hearing and speech impairment. The objective is not only to promote social inclusion but also to provide a practical and sustainable approach that can support workforce stability and operational efficiency within manufacturing MSMEs.
By examining the intersection of disability inclusion, vocational training, and technology-enabled manufacturing, this study contributes to the growing discussion on inclusive industrial development. The proposed framework seeks to demonstrate how accessibility, skill development, and workplace participation can be integrated to create mutually beneficial outcomes for both industry and persons with hearing and speech impairment.

Literature Review

The present study is reviewed as per : (a) vocational rehabilitation for persons with hearing and speech impairment, (b) assistive technology in manufacturing, and (c) NSQF-based skilling in India.

2.1 Disability & Employment

According to the Census of India (2011), approximately 2.68 crore persons with disabilities (PwDs) were recorded by the Office of the Registrar General and Census Commissioner of India. Despite constituting a significant segment of the population, the employment rate among persons with disabilities remains considerably lower than that of the general population. A major shift from a charity-based approach to a rights-based approach occurred with the enactment of the Rights of Persons with Disabilities (RPwD) Act, 2016 by the Ministry of Law and Justice, Government of India. Section 19 of the Act emphasizes vocational training, skill development, and employment support for persons with disabilities. However, despite progressive legislative provisions, the effective implementation of these measures continues to face challenges across different regions of the country, and the intended employment outcomes have not yet been fully realized. According to 2011 census of India, following is the distribution of disabled persons. (Divyangs) in the Indian population as in Fig-1.

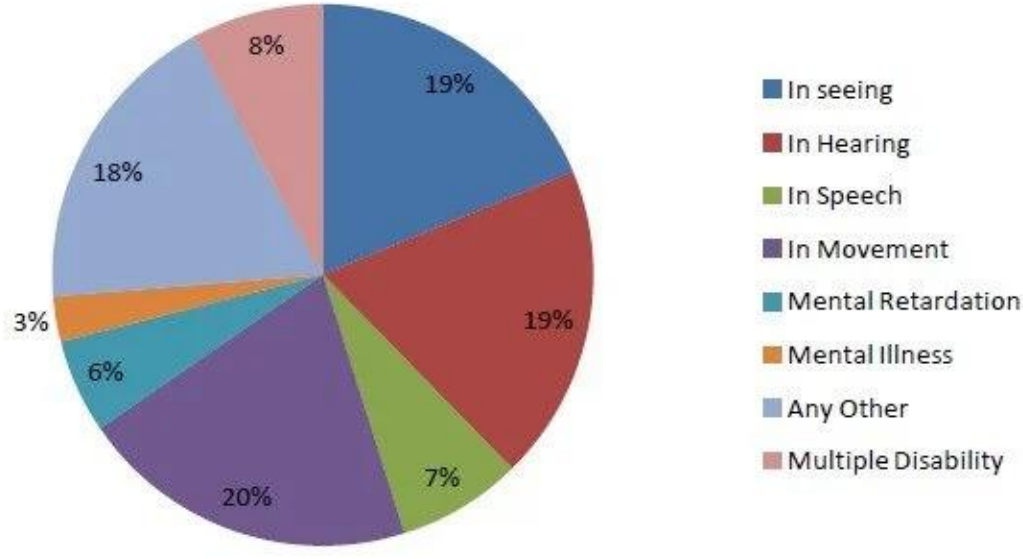

Fig-1: Different-forms-of-Disability-as-per Source: Authors' compilation based on Census of India 2011.

The employment data of Diyvangs has been studied by Farhana Khatoon (2018). The study demonstrates following realities of Persons with Disabilities (PWDs) or Divyangs.

Source: Authors' compilation based on National Statistical Office (2019).

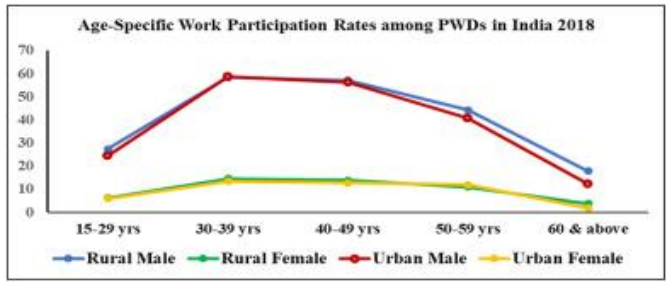

Fig-2: Age Specific Work Participation among PWDs in India Source: Authors' compilation based on National Statistical Office (2019).

In manufacturing industries, a significant proportion of operational instructions, safety alerts, and process-related communications are traditionally conveyed through verbal interaction. Consequently, employment opportunities for persons with hearing and speech impairment on the shop floor remain comparatively limited when compared with some other disability groups. In an integrative review of literature covering the period 2004–2016, Punch (2016) reported that Deaf and Hard of Hearing (DHH) adults encounter multiple workplace barriers, facilitators, and sources of occupational stress. The study highlighted that communication difficulties, inadequate workplace accommodations, and limited social interaction often contribute to higher levels of stress among DHH workers. Safety concerns also emerge when critical instructions, alarms, or emergency warnings are communicated primarily through auditory means.

These findings support the Social Model of Disability proposed by Oliver (1990), which argues that disability is not solely the result of an individual's impairment but is significantly influenced by barriers present within the environment. From this perspective, many workplace challenges experienced by hearing-impaired employees arise from inaccessible communication systems rather than from the impairment itself. Therefore, the adoption of visual communication tools, assistive technologies, pictorial standard operating procedures (SOPs), and Human-Machine Interface (HMI)-based systems can play a vital role in improving workplace accessibility, safety, and participation within manufacturing environments.

The Ministry of Skill Development and Entrepreneurship (MSDE), in its National Policy for Skill Development and Entrepreneurship (2015), recognized that the lack of accessible training materials and appropriate learning support mechanisms constitutes a major barrier for persons with disabilities in acquiring technical and vocational skills. The policy emphasized the need for inclusive training systems, accessible infrastructure, adapted learning resources, and equal opportunities for skill development.

However, available empirical evidence suggests that the progress achieved at the implementation level has been limited. Despite the policy emphasis on inclusion, many skill development centers continue to face challenges in providing accessible learning environments for deaf and hard-of-hearing trainees. This indicates the existence of a persistent gap between policy objectives and practical implementation. Studies examining PMKVY training centers in Uttar Pradesh have reported relatively low participation of persons with disabilities and limited

adoption of disability-specific accommodations within training programs. Such findings suggest that the availability of policy provisions alone may not be sufficient unless accompanied by appropriate infrastructure, trainer preparedness, assistive technologies, and accessible instructional methods.

Marschark, Spencer, Adams, and Sapere (2017) argue that deaf and hard-of-hearing individuals possess cognitive strengths that are often overlooked in conventional educational and workplace settings. Their research suggests that when appropriate accommodations, communication support systems, and accessible learning environments are provided, deaf individuals can perform at levels comparable to or, in some cases, better than their hearing peers in visual-spatial and observation-based tasks. These findings challenge traditional deficit-oriented views and support a strengths-based approach to disability inclusion.

Similarly, Punch (2016), in a review of employment experiences of deaf and hard-of-hearing adults, reported that although significant barriers continue to exist in workplace communication, training, and social integration, many employers have observed enhanced visual attention, concentration, and task focus among deaf employees. Such characteristics make them particularly suitable for activities requiring continuous observation, visual inspection, monitoring, counting, and quality control. These attributes are highly relevant in manufacturing environments where operational accuracy and process discipline are critical.

The findings of Marschark et al. (2017) and Punch (2016) collectively suggest that hearing and speech impairment should not be viewed solely from the perspective of limitations. When appropriate accommodations, accessible communication systems, and visual learning methods are provided, deaf and hard-of-hearing individuals can effectively perform tasks requiring sustained concentration, visual observation, procedural compliance, and quality monitoring. These characteristics are particularly relevant to manufacturing environments, where many operational activities depend on accuracy, repetition, visual inspection, counting, monitoring, and process control. Such evidence supports the need for industry-specific vocational frameworks that focus on individual strengths while addressing workplace accessibility barriers through appropriate training and assistive technologies.

Chithrangathan (2022), in a study on vocational activity training in India, observed that although several policy frameworks and legislative provisions support disability inclusion, sector-specific models that translate these mandates into practical training protocols remain limited. The gap is particularly evident in industrial and manufacturing trades, where structured vocational pathways for persons with hearing and speech impairment are still inadequately developed.

Recognizing this challenge, the Rights of Persons with Disabilities (RPwD) Act, 2016, under Section 19, places responsibility on the government to promote vocational training, skill development, self-employment, and employment opportunities for persons with disabilities. The Act further encourages the formulation of schemes and programs to facilitate access to concessional loans, entrepreneurship support, and employment-related assistance. However, the successful realization of these objectives requires the development of industry-specific

training frameworks, accessible learning systems, workplace accommodations, and collaborative partnerships among government agencies, industries, training institutions, and civil society organizations.

The reviewed literature indicates that persons with hearing and speech impairment face significant employment barriers despite possessing strengths in visual attention, concentration, and observation-based activities. While policy frameworks and vocational initiatives have attempted to improve inclusion, substantial gaps remain in translating these provisions into practical, industry-specific training and employment models, particularly within manufacturing MSMEs.

.**2.2 Technology-Assisted Inclusive Learning and Workplaces** Industry 4.0 technologies—including Human-Machine Interfaces (HMI), Internet of Things (IoT) systems, visual alert mechanisms, and haptic feedback devices—are increasingly being recognized as enablers of inclusive employment for persons with hearing impairment. Punch (2016) reported that the use of visual alerts and signed instructions in workplace environments can significantly improve communication and safety outcomes. Such findings are particularly relevant to manufacturing sectors where machine alarms, process warnings, and operational instructions are traditionally communicated through auditory means. In industries such as corrugated packaging, where worker safety and process compliance are critical, technology-assisted communication systems offer significant potential for improving accessibility and workplace participation.

The theoretical foundation for these interventions can be explained through Cognitive Load Theory (CLT), proposed by Sweller (1988). CLT distinguishes between intrinsic cognitive load associated with task complexity, extraneous cognitive load caused by ineffective instructional design, and germane cognitive load that contributes directly to learning and skill acquisition. For deaf and hard-of-hearing (DHH) learners, conventional training methods that rely heavily on verbal explanations, auditory instructions, and spoken demonstrations may create unnecessary extraneous cognitive load. As a result, learners must devote additional mental effort to interpreting inaccessible information rather than focusing on the skill being taught.

Marschark et al. (2017) further observed that written language frequently functions as a second language for many DHH individuals. Consequently, text-heavy instructional materials may not always provide an effective learning medium unless supported by visual demonstrations, sign-language interpretation, or pictorial representations. These findings suggest that accessible instructional design plays a crucial role in improving learning outcomes for hearing-impaired trainees.

Assistive technologies can help transform inaccessible instructional content into meaningful learning experiences by presenting information through alternative communication channels. The Universal Design for Learning (UDL) framework developed by CAST (2018) provides a practical approach for achieving this objective. UDL advocates the use of multiple means of representation, enabling information to be communicated through visual, tactile, and auditory formats according to learner requirements. Within manufacturing environments, this may include the use of Indian Sign Language (ISL) videos, pictorial standard operating procedures

(SOPs), visual tower lights, vibration-based alert systems, and simplified HMI interfaces. Such adaptations improve accessibility without altering the required competency standards or performance expectations.

Evidence from the Indian context also supports the value of adapted vocational training approaches. Chithrangathan (2022), in a study conducted in Kerala, reported that activity-based and visually structured vocational training methods significantly improved skill acquisition among persons with disabilities. The study highlighted the importance of task breakdown, visual learning, and structured instructional support in enhancing employability outcomes. Although the study was not conducted in a manufacturing environment, its findings demonstrate the potential benefits of adapting vocational training methods to suit diverse learner needs.

A strengths-based perspective further supports the adoption of technology-assisted learning systems. Marschark et al. (2017) argue that educational and vocational interventions for DHH individuals should focus on individual capabilities rather than limitations. Their research indicates that many DHH learners demonstrate strong visual-spatial processing abilities, attention to detail, and observation skills. Such characteristics are particularly relevant to manufacturing activities involving visual inspection, quality monitoring, counting, process observation, and pattern recognition. These competencies closely align with several operational activities performed within corrugated packaging manufacturing units.

Recognizing the importance of accessibility, the NCVET Guidelines for Training of Divyangjan (2021) recommend the use of assistive technologies, accessible content, and reasonable accommodation within vocational training systems. However, despite these policy provisions, the literature reveals a significant implementation gap. While assistive technologies have been discussed in educational and training contexts, very limited evidence exists regarding their integration with NSQF-aligned vocational training for hearing-impaired youth in manufacturing MSMEs. Furthermore, sector-specific frameworks demonstrating how HMI, IoT, visual communication systems, and competency-based training can be combined within industries such as corrugated packaging remain largely unexplored. This gap provides the foundation for the present study.

2.3 NSQF, NCVET and Inclusive Skill Development in India

India has progressively strengthened its vocational education and skill development ecosystem through policy initiatives aimed at improving employability, workforce participation, and lifelong learning opportunities. The National Skills Qualifications Framework (NSQF), introduced by the Ministry of Skill Development and Entrepreneurship (MSDE), provides a competency-based structure for skill development across different sectors and occupations. The framework seeks to standardize vocational qualifications, promote mobility between education and employment pathways, and ensure alignment between training outcomes and industry requirements. By focusing on measurable competencies rather than purely academic credentials, the NSQF has created a foundation for inclusive and industry-relevant skill development.

To strengthen governance and quality assurance within the vocational education system, the National Council for Vocational Education and Training (NCVET) was established as the apex regulatory body for vocational training in India. NCVET is responsible for regulating awarding bodies, approving qualifications, and promoting quality standards across vocational education and training programs. Recognizing the importance of inclusion, NCVET has issued guidelines for training persons with disabilities (Divyangjan), emphasizing the need for accessible infrastructure, adapted instructional methods, appropriate assessment practices, and reasonable accommodation during training and certification processes.

The Rights of Persons with Disabilities (RPwD) Act, 2016 further reinforces the commitment towards inclusive skill development and employment. The Act recognizes vocational training, skill enhancement, self-employment, and employment support as important mechanisms for improving the socio-economic participation of persons with disabilities. It places responsibility on governments and institutions to promote accessible training opportunities and facilitate equal participation in economic activities. These provisions reflect a shift from welfare-oriented approaches towards a rights-based framework that emphasizes empowerment, participation, and equal opportunity.

The National Education Policy (NEP) 2020 also highlights the importance of inclusive and technology-enabled learning. The policy advocates the integration of vocational education into mainstream education and encourages the development of accessible educational content, flexible learning pathways, and assistive technologies to support diverse learners. Special emphasis has been placed on the development of learning resources in Indian Sign Language and the use of digital technologies to improve access to education and skill development for persons with disabilities.

Despite the existence of these progressive policy frameworks, several studies indicate that challenges remain in translating policy intentions into practical implementation. While national policies emphasize accessibility, inclusion, and reasonable accommodation, vocational training programs often face difficulties related to infrastructure, trainer preparedness, availability of assistive technologies, and development of sector-specific implementation models. As a result, the participation of persons with disabilities in vocational education and employment continues to remain below desired levels. This gap between policy objectives and workplace implementation highlights the need for practical frameworks that can effectively connect vocational training, industry requirements, accessibility provisions, and employment opportunities.

Table 1 summarizes the principal findings emerging from the reviewed literature and highlights their relevance to the present study.

Author	Area	Key Finding
Punch (2016)	Employment	Barriers and workplace stress
Marschark et al. (2017)	Learning	Visual-spatial strengths
Sweller (1988)	CLT	Accessible learning
CAST (2018)	UDL	Multiple representations
Chithrangathan (2022)	Vocational Training	Visual training effectiveness

2.4 Research Gap

The review of literature reveals three significant and interconnected gaps that limit the effective inclusion of persons with hearing and speech impairment within manufacturing industries.

First, a sector-specific gap exists in the current body of research. While considerable attention has been given to disability inclusion, vocational education, and employment outcomes, extremely limited research has examined the application of these concepts within manufacturing MSMEs. Existing studies largely focus on education, information technology, retail, hospitality, and service sectors, with minimal attention to industrial manufacturing environments. Furthermore, no structured studies were identified that specifically address inclusive workforce participation within the corrugated packaging sector despite its suitability for process-oriented and visually driven work activities.

Second, a technology implementation gap is evident in literature. Assistive technologies such as visual communication systems, Human-Machine Interfaces (HMI), digital displays, visual alerts, and Industry 4.0 tools have been widely discussed as mechanisms for improving accessibility and workplace participation. However, most studies focus on conceptual discussions or large industrial settings. Limited evidence is available regarding the practical integration of low-cost assistive technologies within resource-constrained manufacturing MSMEs, particularly in developing economies such as India.

Third, a policy-to-practice gap continues to persist despite the availability of progressive legislative and vocational frameworks. The RPwD Act 2016, NSQF, NCVET guidelines, and the National Education Policy 2020 collectively advocate inclusive skill development, reasonable accommodation, and equal employment opportunities for persons with disabilities. However, the literature indicates a shortage of validated implementation models demonstrating how these policy objectives can be translated into accessible, industry-relevant vocational training and employment systems without compromising competency standards.

The present study seeks to address these gaps by proposing a technology-assisted inclusive employment framework for manufacturing MSMEs. The framework integrates assistive technologies, accessible training methodologies, competency-based skill development, workplace adaptation, and stakeholder collaboration to enhance employment opportunities for persons with hearing and speech impairment. By focusing on the corrugated packaging sector, the study contributes to the emerging literature on inclusive manufacturing while supporting

broader objectives related to workforce participation, economic inclusion, and sustainable employment.

Corrugated Packaging Industry: Challenges and Opportunities for Inclusive Employment

The corrugated packaging industry forms a critical component of the manufacturing sector and supports a wide range of industries including food, consumer goods, electronics, pharmaceuticals, e-commerce, and logistics. A sizable proportion of corrugated box manufacturing units operate as Micro, Small and Medium Enterprises (MSMEs), which contribute substantially to employment generation and local economic development. However, these enterprises continue to face persistent workforce-related challenges including labor shortages, high employee turnover, limited formal training systems, and increasing pressure to maintain productivity and quality while operating under cost constraints.

One of the major concerns reported by MSME owners is the difficulty in attracting and retaining a stable workforce for repetitive shop-floor activities. Many manufacturing operations involve routine tasks such as counting, stacking, inspection, bundling, material movement, quality checking, and machine observation. Although these activities are essential for maintaining production efficiency, they often experience high labor turnover and low worker retention. As a result, MSMEs frequently face disruptions in productivity and increased training costs.

At the same time, several operational activities within corrugated box manufacturing rely heavily on visual observation, concentration, process compliance, and diligence rather than extensive verbal communication. Quality inspection, defect identification, counting, monitoring of machine operations, inventory verification, and packaging-related activities are examples of tasks where visual skills play a significant role. Research by Punch (2016) and Marschark et al. (2017) indicates that many deaf and hard-of-hearing individuals demonstrate strengths in visual attention, observation, and task concentration. These characteristics suggest a potential alignment between the requirements of certain manufacturing activities and the capabilities of hearing-impaired workers.

Table 2 illustrates how existing workforce challenges can be converted into opportunities through appropriate workplace adaptations and inclusive employment practices

Workforce Challenge	Inclusive Employment Opportunity
Labor shortage	Access to an underutilized workforce
High employee turnover	Improved workforce stability and retention
Communication barriers	Visual communication and assistive technologies
Safety concerns	Visual alerts and technology-assisted monitoring
Limited training systems	Accessible and technology-assisted learning

Productivity pressures	Structured and process-oriented work practices

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Despite this potential, the participation of persons with hearing and speech impairment in manufacturing MSMEs remains limited. Communication barriers, safety concerns, lack of accessible training systems, and limited awareness among employers continue to restrict employment opportunities. In many cases, employers perceive disability primarily as a limitation rather than recognizing the possibility of adapting workplaces through visual communication systems, assistive technologies, and structured training methods.

The increasing availability of digital technologies, visual standard operating procedures, Human-Machine Interfaces (HMI), visual alert systems, and assistive communication tools presents an opportunity to bridge this gap. Such technologies can improve workplace accessibility while maintaining productivity and safety standards. From an industry perspective, inclusive employment can contribute to workforce stability and improved employee retention. From a social perspective, it can create meaningful livelihood opportunities and greater economic participation for persons with hearing and speech impairment.

Therefore, the corrugated packaging industry represents a promising environment for exploring technology-assisted inclusive employment models. By combining accessible training systems, assistive technologies, and workplace adaptation measures, manufacturing MSMEs can simultaneously address workforce shortages while creating meaningful employment opportunities for persons with hearing and speech impairment. Such an approach has the potential to generate both economic and social benefits, contributing to sustainable industrial growth and greater workforce inclusion.

Proposed Technology-Assisted Inclusive Manufacturing Framework

The literature review and industry analysis indicate that the limited participation of persons with hearing and speech impairment in manufacturing environments is primarily influenced by communication barriers, inaccessible training methods, workplace adaptation challenges, and employer perceptions rather than a lack of capability. Previous studies have highlighted both the barriers faced by deaf and hard-of-hearing individuals in employment settings (Punch, 2016) and their strengths in visual attention, concentration, and observation-based activities (Marschark et al., 2017). Similarly, research on accessible learning systems emphasizes the importance of visual communication, assistive technologies, and adapted instructional methods in improving skill acquisition and workplace participation (Sweller, 1988; CAST, 2018).

At the same time, the increasing adoption of digital technologies within manufacturing MSMEs has created new opportunities for workforce inclusion. Traditional manufacturing activities that previously relied heavily on physical strength and verbal communication can now be supported through visual interfaces, sensors, counters, and digital monitoring systems. The proposed framework illustrates how assistive technologies can support accessible vocational training, facilitate industrial participation, and ultimately contribute to workforce inclusion, productivity improvement, and dignified livelihood generation for persons with disabilities. Existing policy

frameworks, including the RPwD Act 2016, NSQF, NCVET guidelines, and NEP 2020, provide an enabling environment for such initiatives.

The framework consists of four interconnected stages: Assistive Technologies, Process-Oriented Training, Industrial Participation, and Employment & Livelihood Generation.

The first stage focuses on the deployment of assistive technologies that improve workplace accessibility and communication. These include visual standard operating procedures (SOPs), Human-Machine Interfaces (HMIs), digital displays, visual alert systems, pictorial work instructions, and other accessible communication tools. Such technologies reduce dependency on verbal instructions and help create a more inclusive learning and working environment.

To address this gap, a Technology-Assisted Inclusive Manufacturing Framework is proposed, as illustrated in Figure 3

Figure 3. Technology-Assisted Inclusive Manufacturing Framework

The second stage involves process-oriented training delivered through visual demonstrations, activity-based learning, structured repetition, and accessible instructional methods. The objective is to enable trainees to acquire workplace competencies using approaches that align

with their learning strengths. This stage is consistent with the principles of Universal Design for Learning and competency-based vocational education.

The third stage focuses on industrial participation through practical exposure, workplace observation, apprenticeship opportunities, and supervised engagement in manufacturing activities. Interaction with real industrial environments allows trainees to apply acquired skills while enabling employers to assess workplace suitability and performance requirements.

The final stage leads to employment and livelihood generation. By combining accessible technologies, structured training, and industry participation, the framework aims to improve workforce inclusion, employee retention, productivity, and long-term economic participation of persons with hearing and speech impairment. The framework is intended to serve as a practical bridge between policy objectives, vocational training systems, and employment opportunities within manufacturing MSMEs.

Rather than viewing disability as a limitation, the framework adopts a capability-oriented approach that emphasizes individual strengths, workplace accessibility, and supportive learning environments. It seeks to create a mutually beneficial model in which industries gain access to a motivated and stable workforce while persons with hearing and speech impairment gain opportunities for meaningful employment, economic independence, and social inclusion.

Collaborative Ecosystem for Inclusive Employment

The successful inclusion of persons with hearing and speech impairment within manufacturing industries requires the participation of multiple stakeholders. While vocational training institutions play an important role in skill development, sustainable employment outcomes depend upon coordinated efforts involving government agencies, industries, training providers, disability support organizations, and community stakeholders. The literature reviewed in earlier sections indicates that policy provisions alone are insufficient unless they are supported by practical implementation mechanisms and industry participation. Figure 4 presents the proposed collaborative ecosystem for promoting inclusive employment within manufacturing MSMEs.

Figure 4. NGO–Industry–Government Collaboration Model for Inclusive Manufacturing
Source: Developed by Authors

Government institutions provide the policy framework, regulatory support, certification mechanisms, and financial assistance necessary for promoting workforce inclusion. Initiatives under the Rights of Persons with Disabilities (RPwD) Act 2016, National Skills Qualifications Framework (NSQF), National Council for Vocational Education and Training (NCVET), and National Education Policy (NEP) 2020 collectively establish a foundation for inclusive vocational development. These frameworks encourage skill development, accessibility, reasonable accommodation, and equal participation in economic activities.

Table 3 Role of stakeholders

Stakeholder	**Primary Role**
Government Agencies	Policy support, certification, incentives, accessibility guidelines
NCVET / NSQF Ecosystem	Skill standards, competency frameworks, certification pathways
NGOs and Disability Support Organizations	Candidate identification, counselling, communication support, placement facilitation
Training Institutions	Skill development, workplace readiness, accessible learning
Manufacturing Industry	Apprenticeship, workplace exposure, employment opportunities
Persons with Hearing and Speech Impairment	Skill acquisition, workplace participation, continuous learning

Disability-focused organizations and non-governmental organizations (NGOs) serve as important intermediaries between potential trainees and employers. Organizations such as the Skill Council for Persons with Disability (SCPwD), Sounds of Silence (SOS), VAANI Deaf Children's Foundation, and other regional disability support organizations have demonstrated the importance of counselling, communication support, skill training, and employment facilitation. Such organizations can assist in identifying suitable candidates, preparing trainees for workplace participation, and supporting communication between employers and employees.

Industry participation remains central to the success of the ecosystem. Manufacturing enterprises provide practical learning opportunities through industrial visits, apprenticeship programs, on-the-job training, workplace exposure, and employment opportunities. Employers also play an important role in creating inclusive work environments through the adoption of visual communication systems, accessible operating procedures, and reasonable workplace accommodations.

Training institutions act as the connecting link between policy objectives and industrial requirements. By aligning training content with competency-based vocational standards and workplace expectations, training providers can improve the employability and workplace readiness of trainees. Collaboration with industry partners further ensures that training remains relevant to actual job requirements.

The proposed ecosystem is based on the principle that workforce inclusion should not be viewed solely as a social responsibility initiative. Rather, it should be considered a collaborative development model that generates mutual benefits for all stakeholders. Industries gain access to a stable and motivated workforce, training institutions improve placement outcomes, disability support organizations achieve their social objectives, and persons with hearing and speech impairment obtain opportunities for meaningful employment and economic independence.

The collaborative ecosystem therefore functions as an enabling mechanism that links policy support, vocational training, workplace adaptation, and employment generation into a single integrated framework. Such an approach can contribute to both inclusive economic development and sustainable workforce participation within manufacturing MSMEs.

Implementation Strategy and Recommendations

The proposed framework can be implemented through a phased and low-cost approach so that MSMEs are not overburdened financially or operationally. The objective is not to redesign the entire factory system at once, but to identify suitable tasks, prepare candidates, adapt communication methods, and gradually integrate persons with hearing and speech impairment into selected manufacturing activities.

The first step should be identification of suitable candidates through NGOs, disability support organizations, vocational institutions, and local skill development agencies. Candidate selection should consider basic work readiness, visual learning ability, discipline, interest in repetitive tasks, and willingness to work in a shop-floor environment.

The second step should involve pre-vocational orientation. Before placing trainees directly on machines or shop-floor activities, they should be introduced to workplace safety, factory discipline, basic material flow, machine surroundings, visual signs, emergency signals, and simple production terminology. This orientation can reduce fear and improve confidence.

The third step should focus on technology-assisted training. Training should use visual SOPs, pictorial instructions, demonstration videos, HMI screens, digital counters, colour-coded signals, and visual safety alerts wherever possible. Such methods reduce dependency on verbal instructions and make the learning process more accessible for hearing- and speech-impaired trainees.

The fourth step should involve supervised industrial exposure. Trainees may initially be placed in selected activities such as counting, bundling, inspection, label checking, barcode verification, quality observation, machine-status monitoring, and material tracking. These activities should be performed under the guidance of a trained supervisor or mentor.

The fifth step should involve employment placement and follow-up support. NGOs and training institutions should remain connected with both the worker and employer during the initial

employment period. This support can help resolve communication issues, family concerns, workplace adjustment problems, and employer hesitation.

Table 4. Implementation Roadmap for Inclusive Employment in Corrugated Packaging MSMEs

Phase	Key Activity	Expected Outcome
Phase 1	Candidate identification	Selection of suitable trainees
Phase 2	Pre-vocational orientation	Workplace readiness
Phase 3	Technology-assisted training	Accessible skill development
Phase 4	Supervised industrial exposure	Practical work confidence
Phase 5	Employment placement	Workforce participation
Phase 6	Follow-up support	Retention and stability

The implementation strategy should begin with small pilot projects rather than large-scale deployment. A few selected trainees may be placed in suitable activities and their performance, retention, safety, and comfort level may be observed. Based on these observations, the training content, workplace adaptation, and supervisory methods can be improved.

Industries should also sensitize supervisors and co-workers. Inclusive employment cannot succeed only through technology; it also requires patience, communication discipline, and a respectful workplace culture. Simple practices such as written instructions, visual job cards, common signs, and fixed work routines can create a much more inclusive environment.

The expected benefits of the proposed approach are summarized in Table 5.

Table 5 Expected benefits of the framework

Stakeholder	Expected Benefit
Persons with disabilities	Dignified livelihood and economic independence
MSME industries	Stable and disciplined workforce
NGOs	Better placement and rehabilitation outcomes
Training institutions	Practical industry-linked skilling
Government agencies	Improved implementation of inclusion policies
Society	Greater social and economic participation

Therefore, the proposed implementation model should be viewed as a gradual, practical, and partnership-based approach. It can help MSMEs address labour shortages while creating meaningful employment opportunities for persons with hearing and speech impairment.

6.1 Limitations and Future Scope

The present study is conceptual in nature and is based on literature review, policy analysis, observations from the manufacturing sector, and the development of a proposed framework for inclusive employment. The framework has not yet been validated through large-scale field

implementation or longitudinal assessment involving multiple industries and training institutions. Consequently, the practical effectiveness of the proposed model in terms of productivity improvement, employee retention, workplace safety, and long-term employment outcomes remains to be empirically evaluated.

Another limitation of the study is its focus on persons with hearing and speech impairment within the context of manufacturing MSMEs, particularly the corrugated packaging sector. The findings and recommendations may therefore require adaptation before being applied to other disability groups or industrial sectors with different operational requirements.

The study also recognizes that successful implementation depends upon factors such as employer willingness, availability of assistive technologies, trainer preparedness, accessibility of training materials, and institutional support. Variations in these factors across regions and organizations may influence implementation outcomes.

Future research may focus on pilot implementation of the proposed framework within manufacturing units and vocational training centers. Comparative studies involving different industrial sectors, disability groups, and technology-assisted training approaches may provide additional insights. Further research may also evaluate the impact of Human-Machine Interfaces (HMI), visual communication systems, and Industry 4.0 technologies on skill acquisition, workplace performance, safety, and employee retention. Such studies would help establish evidence-based models for scaling inclusive employment initiatives across manufacturing MSMEs.

Conclusion

Employment remains one of the most significant challenges faced by persons with hearing and speech impairment despite the existence of progressive legislative, educational, and vocational development initiatives. At the same time, manufacturing MSMEs continue to experience workforce shortages, high labour turnover, and difficulties in recruiting and retaining trained personnel. These parallel challenges present an opportunity to explore inclusive employment models that can generate mutual benefits for both industry and persons with disabilities.

The literature reviewed in this study indicates that many barriers experienced by deaf and hard-of-hearing individuals arise not from limitations in capability but from inaccessible communication systems, unsuitable training methodologies, and inadequate workplace accommodations. Research also highlights the strengths of hearing-impaired individuals in areas such as visual attention, observation, concentration, and process compliance. Advances in assistive technologies, Human-Machine Interfaces (HMIs), visual communication systems, and technology-enabled learning environments provide practical mechanisms for reducing these barriers and improving workplace participation.

The study further examined the role of policy frameworks including the Rights of Persons with Disabilities Act 2016, National Skills Qualifications Framework (NSQF), National Council for Vocational Education and Training (NCVET), and National Education Policy 2020. While

these frameworks provide strong policy support for inclusive skill development, the literature reveals a continuing gap between policy intent and practical implementation, particularly within manufacturing MSMEs.

To address this gap, the study proposed a Technology-Assisted Inclusive Manufacturing Framework supported by a collaborative ecosystem involving government agencies, training institutions, industry partners, and disability support organizations. The framework integrates accessible learning methods, assistive technologies, workplace adaptation, industrial participation, and employment generation into a structured pathway for workforce inclusion. The proposed implementation strategy emphasizes practical, low-cost, and scalable interventions suitable for resource-constrained MSMEs.

The study contributes to the emerging discourse on inclusive manufacturing by demonstrating how technology, vocational training, and stakeholder collaboration can be combined to create employment opportunities for persons with hearing and speech impairment. The proposed approach seeks to transform workforce inclusion from a welfare-oriented initiative into a sustainable development strategy that benefits both employers and employees.

As industries continue to adopt digital technologies and inclusive workplace practices, opportunities for meaningful participation of persons with disabilities are likely to expand. The success of such initiatives will depend upon continued collaboration among policymakers, training providers, NGOs, and industry stakeholders. By creating accessible pathways to skill development and employment, manufacturing MSMEs can contribute not only to economic productivity but also to the broader goals of social inclusion, dignity, and equal opportunity.

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