

# Workforce diversity and ergonomic challenges for sustainable manufacturing organizations

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## **ABSTRACT**

Demographically, it is evident that the composition of the workforce is becoming more diversified and this trend is very significant in most developed countries such as the US, UK, Canada and Australia. Workforce diversity covers a wide range of dimensions like age, gender, culture, ability, background, level of skill, marital status etc. Because of this, workers share different attitudes, working behaviors, needs, desires and values. Workforce diversity management needs the development and management of such an environment where all individuals with these differences can perform at their full potential, so that any organization can draw an optimum benefit from its diversified workforce. Like many others, manufacturing organizations are also facing the issue of workforce diversity where it affects work performance capabilities. Organizational sustainability can only be ensured by workplace safety, employee satisfaction and retention along with health and well-being. In spite of highly automated systems, manufacturing activities like manual assembly tasks with sustained high quality requirements demand highly repetitive movements with high physical demands at the highest level of work pace. Ergonomics plays a vital role in the development of work environments that ensure a healthy, safe, risk-free and productive use of human capital. Yet there has been little investigation of workforce diversity management with reference to ergonomic issues, challenges, opportunities and strategies. This paper reveals the need for an ergonomics-based 'design for all' approach to address the issues of a diversified workforce. This approach is based on the use of a digital human modeling system where an individual's actual working capabilities along with coping strategies are used at a pre-design phase for any design assessment. A database of 100 individuals

belonging to different age groups and working capabilities provides an opportunity to assess any workplace, product, and process or environment design at an early design phase. In this way, it provides design solutions that are equally acceptable for a broad range of humans belonging to different backgrounds, age groups and levels of ability to do the work. Current ongoing research is focusing on capturing working strategies of a diversified workforce in the furniture manufacturing industry where workers belonging to different age groups, backgrounds, experience and levels of skill will be analyzed. Subsequently this data will be used in a digital human modeling system called HADRIAN providing designers and ergonomists with the ability to access and address the design needs of a more diversified workforce. This strategy helps in addressing global workforce challenges where organizations can effectively utilize their human capital by providing them with a healthy and safe working environment.

**Keywords:** Workforce diversity, organizational sustainability, ergonomics, inclusive design

## **1 INTRODUCTION**

Workforce diversity has become a primary concern of many organizations. It is demographically well-evident that future organizations will be facing a challenge of a more diversified workforce and this trend is very prominent in developed countries like US, UK, Canada and Australia. Workforce diversity covers a wide range of dimensions like age, gender, culture, ability, background, level of skill, marital status etc. Because of this, workers share different attitudes, working behaviors, needs, desires and values. This clear global demographic trend demands a working environment where people with different working capabilities, attitudes, behaviors, age and gender can co-exist effectively within the same organization. Diversity management accentuates the development and implementation of specific skills, policies and practices that aim to get the best from every employee. The ultimate objective of these strategies is to win a competitive advantage for the organization by recognizing the importance of each employee. So, a proper understanding of differences that exist among workers belonging to different age groups, levels of skills, working capabilities, gender and ethnic backgrounds becomes vital for the achievement of effectiveness and productivity. There is a need to implement an inclusive design strategy that can overcome workplace design difficulties by promoting design practices where a maximum proportion of the workforce, with their existing differences, is considered at some earlier design stage.

## **2 WORKFORCE DIVERSITY AND ORGANIZATIONAL PERFORMANCE**

Diversity is typically referred to as differences between individuals that may lead to the perception that other persons are different. Diversity mainly focuses

on the differences in gender, age, functional capability, ethnic and cultural background, and education (Knippenberg, 2007, Williams, 1998).

Workforce diversity management is not so straight forward as diversity is a double-edged sword which comes with potential benefits and challenges. The literature clearly shows that the relationship between work group diversity and work performance on individual and organizational levels is inconsistent. As mentioned above, diversity has different dimensions like age, race, ethnicity, cultural background, gender, disability etc; so different dimensions of diversity might have positive as well as negative effects (Knippenberg, 2004, Shore, 2009). Evidence suggests that effective workforce diversity management can contribute to organizational performance in terms of improved group performance, friendlier attitudes, better cooperation, innovation and better decision-making as people from different backgrounds, cultures, experiences and knowledge provide a larger pool of novel and diverse problem solutions. Moreover, it also helps organizations in winning desirable work behaviors from the employees which contributes to organizations in achieving their goals. It adds value to the organization and contributes a competitive advantage to firms. Richard (2000) also concluded that a positive impact of diversity management will depend on the context and absence of diversity context may lead to negative outcomes. Diversity management can increase coordination and control costs of the organization (Mamman, 2012, Richard, 2000, Williams, 1998). On the other hand, evidence also shows that failure to manage a diverse workforce can lead to a perception of injustice among the members which may lead to an environment of conflicts, frustration and odd behaviors that can have very serious consequences for the organization. Results show that these experiences ultimately promote behaviors like absenteeism, high turnover and job dissatisfaction, lower work commitment and withdrawal from organizational citizenship behaviors (Shore, 2009, Mamman, 2012).

The above discussion reveals the complexity of diversity management and demands strategies that might foster positive aspects and prevent negative outcomes. It requires the exploration of diversity from a new positive and proactive standpoint. Recently, researchers have already started working on new ideas like diversity climate and inclusiveness (McKey, 2007, Roberson, 2006)

### **3 ORGANIZATIONAL SUSTAINABILITY**

Much has been written on the concept of sustainability in the last few years and debate is still going on. This might be due to the varying conceptual roots of defining the term 'sustainability'. Indeed, the sustainability concept has inherent positive meanings that can appeal to everybody at individual and organizational levels. There are two very common perspectives of sustainability mentioned in the literature. The first concept is based on Brundlandt's definition of sustainability, where sustainability is defined as, "meeting the needs of the present generation without compromising the ability of future generations to meet their needs" (WCED, 1987). Later on, Dyllick and Hockerts (2002) conceptualized the definition again in organizational stakeholder's perspective, when they defined it as, "meeting the needs of firm's direct and indirect stakeholders (such as employees,

shareholders, clients, pressure groups, communities etc.) without compromising its ability to meet the needs of future stakeholders as well” (Dyllick, 2002). The second popular concept of sustainability was defined by Elkington (1997), where the triple-P perspective was introduced. The Ps stand for people, planet and profit. An organization might be considered sustainable, if a certain minimum performance can be achieved in these areas. In practical terms, organizational sustainability can be achieved by finding and achieving a balance between financial or economic goals (profit), social goals (people), and ecological or environmental goals (planet) (Elkington, 1997). The core of the organizational sustainability concept lies in the understanding of the fact that multiple stakeholders share different objectives of sustainability as it is directly related to their needs and the extent to which these needs are fulfilled. Moreover, it is a continuous process where the relative needs of different stakeholders might change with the passage of time.

As mentioned previously, the organizational workforce is becoming diversified with every passing day. Here it becomes important for organizations to understand the changing needs of their future diverse workforce, so that they can retain their experienced, skilful and committed workforce. Organizational sustainability can be promoted by achieving a safe, friendly, productive and healthy working environment. As we know, diversity management demands a working environment where people with different backgrounds, races, age, working capabilities, behaviors etc. can co-exist happily in the presence of all these differences. So, the objective of organizational sustainability in workforce diversity management can only be achieved by achieving an environment where differences among the workers are recognized and their job needs are fulfilled according to their capabilities. Workforce dissatisfaction results in higher turnover, lack of interest and absenteeism. Removal of an experienced worker is not simply a loss of a person but it is the drainage of skills, relations and knowledge and regaining these will need resources such as money, time and commitment (Dychtwald, 2004).

#### **4 FUTURE ERGONOMIC CHALLENGES**

The International Ergonomics Association (IEA) states “Ergonomics (or human factors) is a scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well-being and overall system performance. It is broadly divided into three main domains; physical, cognitive and organizational ergonomics which shows its multi-disciplinary nature” (IEA). A multi-disciplinary ergonomics approach provides an option to understand differences in human beings that leads to the addressing of the workforce diversity issue for the achievement of organizational sustainability. Ergonomics has contributed well in the recognition of the mismatch between human work capabilities and work demands. In spite of all this, still there are many areas like understanding human differences that directly or indirectly affect work performance and need the urgent attention of ergonomists, planners, managers and designers. Unlike many other workforces, a manufacturing organization’s workforce is still supposed to complete their work manually where

high work demands with repetitive motions creates many difficulties for the workers. On the other hand, the globally competitive market forces organizations to develop strategies like 'doing more with less' so that they may sustain themselves in the market. For example, it is demographically very clear that the global workforce is ageing and this trend is seen in nearly all parts of the world. United Nations statistics show that there were 378 million people aged 60 or above in 1980 and that figure had approximately doubled to 759 million in 2010. It is further projected that the people in the world aged 60 or over will be increasing to 2 billion by 2050 (U.N.O., 2009). Age affects humans in different ways that directly or indirectly affect human work performance. Functional capacity mainly depends on the musculoskeletal strength of the body, which starts declining after the age of 30 (Wanger, 1994). Moreover, decline in many other functions like joint mobility, balance, visibility, and higher reaction time have been described in the literature (Chung, 2009, Hultsch, 2002, Sue, 2008, Sturnieks, 2008). As age diversity is increasing, such issues are becoming more serious as variations in human capabilities due to age directly influence work performance. For example, most manual assembly tasks require fast and accurate movements of different parts of the body whereas the decline in joint mobility decreases flexibility. Similarly, manual material handling requires muscular strength to safely handle heavy weights but a person 50 years of age is surely less capable of handling such tasks as compared to a 25 year old person. These variations in human capabilities that relate to work performance demand such design solutions that can accommodate a wide range of the worker population. Usually designers and planners target fully capable and young people when they set their organizational goals and ignore these variability issues that create problems for the workers at some later stage.

Like age, skill variation is also an important area that must be considered at a pre-design phase so that skill variability issues might be addressed properly. Human working skills might be influenced by work experience, age, level of education, background etc. An experienced and skillful worker is supposed to perform tasks in the least possible time by adopting less physically strenuous, safe and easy working methods. Conversely, less experienced and younger workers normally go for the strategies that expose them to a number of risk elements.

In future, ergonomists, designers, managers and planners will be facing many problems linked to human variability and its impact on an individual's work performance. More realistic design decisions will be needed to accommodate a diverse workforce so that retention of experienced and skillful workers might be assured. Ergonomics plays a vital role in the designing of workplaces where we can proactively assess the suitability of any product, process and environment design. It would be challenging to understand differences due to human variability, their impact on individual's and organizational work performance and adoption of the strategies that can materialize effectively the benefits of workforce diversity.

## **5 AN INCLUSIVE DESIGN METHOD**

Inclusive design is an approach used to address the design needs of the broader range of the population. The inclusive design approach aims to understand

and address design requirements proactively at some pre-design phase so that any product, environment, service, equipment or tool can be designed in such a way that it could be used by a broad range of population. It takes notice of human variability in shape, size, age, working capabilities and behaviors and uses this data for the assessment of why some people are excluded from any design and how they can be accommodated. Keeping in view the aim of the inclusive design method, it is proposed that the approach can be used for addressing the challenges faced by a diversified workforce. One established way of evaluating the suitability of any design or environment is to use digital human modeling (DHM) tools together with the CAD model of the product, workplace or environment. As the use of DHM tools allows the designers and planners to evaluate any design at an early stage of design against a variety of potential users, so the problems can be addressed early on, when changes are less costly and easier to implement. However, challenges lie in the understanding of differences that exist among the potential users and transformation of this valuable information into a format where it can be used for design recommendations.

To address these issues discussed above, an inclusive design tool called HADRIAN (Human Anthropometric Data Requirements and Analysis) was developed. It is a software database of 103 people consisting of more realistic information about sizes, shapes, working capabilities like joint range of motion and behaviors that influence task performance. It is integrated with a digital human modeling tool SAMMIE (System for Aiding Man Machine Interaction Evaluation); where a task analysis tool was developed to support designers. Any task can be broken down into basic task elements such as look at the screen, reach to the card slot etc. where its automated evaluation process facilitates the users by providing details of those who experienced difficulties in task performance and what was the reason for that. Then user can explore the individual and get exact information about capabilities and behaviors of the individuals designed out and try new design solutions by modifying the computer model of the products or workplaces (Gyi et al., 2004, Marshall, 2010, Case, 2001). Previously, the HADRIAN design evaluation system has been used for a variety of applications including the use of ATMs by wheelchair users, wheelchair access to trains and road vehicles and task performing strategies in kitchen and transport activities (Figure 1 and 2).

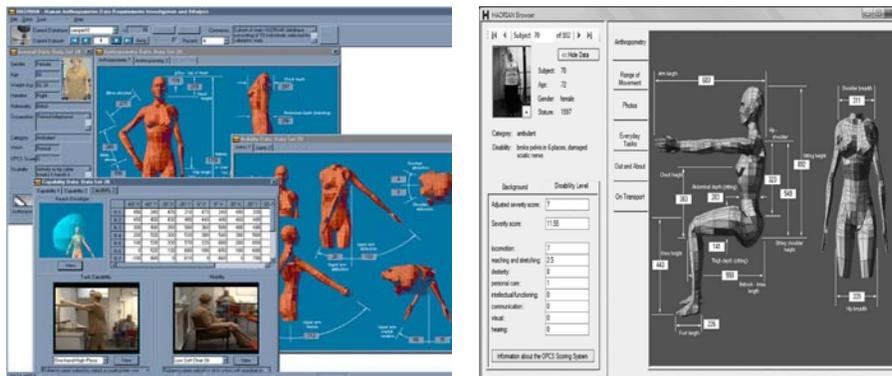


Figure 1. Screenshot of a part of HADRIAN data presentation

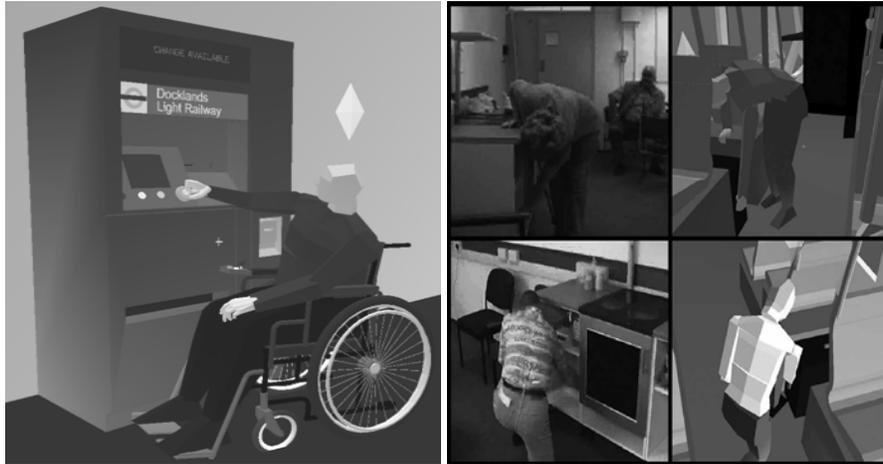


Figure 2. Screenshot of HADRIAN task driven evaluation

The above discussion highlights that the HADRIAN inclusive design approach can address human variability issues and a task evaluation system might be useful for this purpose. However, the HADRIAN automated task evaluation strategy still needs data about task performing strategies for a wide range of workers so that designers can recommend workplace design solutions for a diverse workforce. The next section discusses how this inclusive design approach can be used to capture working strategies of workers having different working strategies, behaviors, levels of skill and experience in a manufacturing industry context. Finally, there is a discussion on how this data might be used in the HADRIAN task evaluation system where upcoming challenges that relate to workforce diversity in manufacturing industries can be addressed.

## 6 MANUFACTURING INDUSTRY PERSPECTIVE

Industrial workforces are becoming more diversified with people from different races, backgrounds, experiences and skills work together for the same organization. Manufacturing industrial tasks, especially manual assembly activities, are greatly influenced by these differences as physical, physiological and cognitive variations among the workers affect task performance. These variations need to be understood by the designers and planners so that organizations can draw optimum benefit from their human capital. Therefore, it is proposed that the HADRIAN inclusive design approach might be equally applicable to workplace design, especially manual assembly tasks. It is believed that through the provision of more applicable and realistic data about task performing strategies of a diverse workforce this can be a good source for the promotion of optimum and effective utilization of organizational workforce diversity.

Recently, research has started where task performing strategies and behaviors of a diverse workforce have been studied for a variety of manual assembly tasks. At present, these strategies have been video recorded and their

ergonomic assessment underway. Subsequently, this data will be used to define basic assembly task elements and assessments will be made against the HADRIAN database where individual's specific data about anthropometry, shape, size, joint range of motion etc. will be utilized in a digital human modeling environment. As mentioned, the HADRIAN database is representative of a more diverse population where data about their capabilities can be exploited to prevent any design exclusion.

For example, Figure 3 shows two different activities performed during sofa assembly, where the worker is using different parts of his body for the completion of the two tasks. Both of these tasks show different joint mobility requirements for successful completion (Table 1).

**Table 1. Typical task completion requirements in sofa assembly process**

Task	Critical joint mobility requirements
Task 1	Upper arm flexion Upper arm abduction
Task 2	Upper arm flexion Upper arm abduction Wrist flexion



Figure 3. Recording individual's capabilities and behaviors performing manual assembly tasks

The HADRIAN database contains joint range of motion data for many older people and evidence shows that age is responsible for a significant decrease in joint range of motion values, especially for arm abduction and wrist flexion. Using these preliminary findings, designers can generate the same kind of scenarios where they can validate these findings by using joint mobility data of older individuals. The HADRIAN design exclusion process can, for example, give feedback that individual 10, aged 55 is unable to perform this assembly task because of joint

constraints. The database provides an opportunity for designers to access detailed data about name, nationality, background, age, anthropometry, joint constraints etc. and this helps designers in understanding why this particular individual was excluded and what kind of design changes can allow that individual to use that product, workstation or environment comfortably. In this way, we might understand potential differences among the workers and design a more inclusive work environment where workers from different age groups, levels of ability, background and experience can work together. Future research will be focusing on using working strategies data of a diverse workforce in a manufacturing assembly environment and using this data for an automated task evaluation method within HADRIAN.

## 7 Conclusion

Demographic changes and economic considerations require the attention for global workforce diversity management so that organizational performance sustainability can be sustained. An inclusive design method is considered useful as its aim of designing products, services, workstations or environment for a broad range of population is well-suited to diversity management issues. A digital human modeling based HADRIAN database is considered helpful where its automated task evaluation approach helps designers and ergonomists to address the design needs of a diverse population. Current ongoing research is focusing on the use of the HADRIAN tool to address the design requirements of a diverse workforce in manufacturing industries, especially manual assembly activities where most of the work is completed physically. Design recommendations achieved through the HADRIAN system can be very helpful in addressing the issues related to workforce diversity. This strategy will ultimately give benefits to the organization by providing safe, healthy, productive and progressive environments for the workers where they might happily co-exist and perform well. Workforce satisfaction leads to an organizational citizenship behavior that positively affects individual and overall organizational performance.

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