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Proactive Ergonomic Assessment for a New Product Development Program in Virtual Environment

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Abstract: Ergonomic projects tend to be highly reactive and often triggered by injuries, occupational hazards, accidents etc. It becomes a costly affair when organizations fail to anticipate the ergonomic issues at preliminary stage of product development. Hence it is not only important to foresee ergonomic concerns but also to take proactive actions to minimize damage. This paper suggests a framework to identify risks in advance to eliminate or mitigate the risk to acceptable level. With the aid of Digitalization, sub-tools have been employed to further investigate the identified risks in early stage to improve efficiency and visualization.

Keywords: Ergonomics, Digitalization, Manufacturing, Proactive, Safety

1. Introduction

In automotive industry, an operator is subjected to occupational risk hazards due to the nature of work. An operator performs repetitive work in various postures, handling heavy weights and applying excessive forces. They are also subjected to noise and vibrations from the use of percussion or power tools.

The National Safety Council (NSC) estimated the total injury related costs in 2019 at $171 billion[1]. As per the Bureau of Labor Statistics, workers in automotive industry have nonfatal injury and illness rate twice as high as private industry.

This paper focuses on impact of early ergonomic assessment using virtual tools to identify and mitigate the risks before it could reach the factory shop floor. The idea is to assess operator reach, posture, part handling forces, frequency, accessibility, and visibility using multiple ergonomic assessment tools. All identified high risks items are documented and ergo risks are either mitigated or evaluated further during the initial phases of development.

2. Research Background

Poor ergonomic conditions lead to ergo injuries, which is mainly MSD (Musculoskeletal Disorder). Huge cost is involved for compensation of these ergonomic injuries. Compensation of ergonomic injury is just direct cost, but there are other indirect costs as well which are huge[2)-4)]. In this section the focus is on research related to compensation cost of ergonomic injuries and different analysis methods being used for ergonomic assessments[5)-16)].

Table 1. List of Evaluation Tools and Focus Areas.

Evaluation Tools	Reference	Focus Area
RULA	McAtamney and Corlett, 1993	Upper limb assessment
HAL	Wurzelbacher et al, 2010	Hand activity
Strain Index	Moore and Garg, 2010	Distal upper extremity disorders
OCRA Index	Occhipinti, 2010	Repetitive tasks
REBA	Hignett and McAtamney, 2010	Entire body assessment
ALLA	Kong et al, 2010	Agricultural lower limb assessment
OWAS	Karho et al, 2008	Working postures
PATH	Richardson et al, 2004	Ergonomic job analysis

A literature review has been conducted to identify ergonomic evaluation tools as shown in Table 1. The focus areas of these assessment tools are also reviewed. These evaluation tools are mainly reactive in nature. One limitation of past studies is a focus on reactive approach and its overall ergonomic performance. This research paper suggests proactive approach to reduce ergonomic concerns.

Good ergonomics adds value to organizations in numerous ways. One of the most commonly cited benefits of good ergonomics is the reduction in musculoskeletal disorders (MSDs) and the reduction in worker's injury related compensation & other costs associated with these injuries. Below diagram shows the percentage of direct and indirect cost for ergonomic injuries.

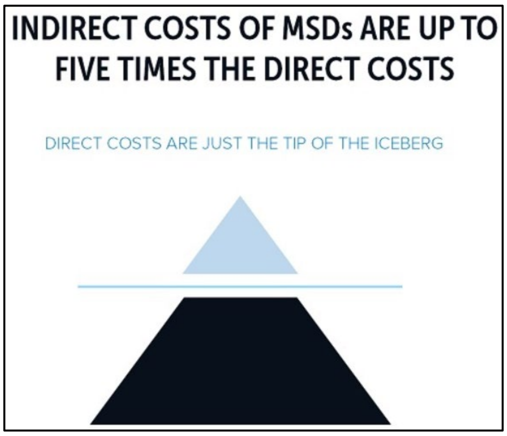


Fig. 1: Cost Distribution of Ergonomic Injuries[2].

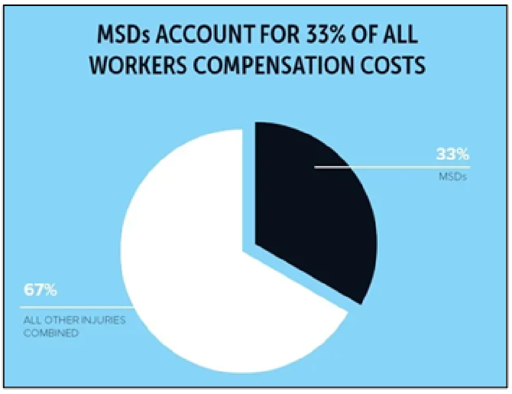


Fig. 2: Musculoskeletal Disorders Cost Distribution[2].

3. Problem Description

Musculoskeletal disorders are very common injuries in the workplace today[17)-23)], representing 33% of workers compensation costs as shown in Fig. 2. To minimize injury costs, companies need to reduce number of ergonomic injuries. The key reason for high number of ergonomic injuries is reactive approach companies usually have. This leads to high compensation cost. Factors which make companies follow reactive approach includes absence of virtual ecosystem, assessment tools, defined organizational safety and ergonomic priorities, lack of leadership support, demographics of workforce. To minimize number of injuries and its costs, companies need to change their approach from reactive to proactive.

It is always cheaper to identify issues in early stages when product and process are still in development. Due to corrective action taken early, the cost to resolve the issue will also be very less. Proactive approach helps to anticipate the ergonomic risk and provide ability to react in timely manner.

Digital manufacturing brings in a lot of power to take actions proactively. We have created a framework which helps companies to become proactive and assists in identifying ergonomic issues at initial stages of product development.

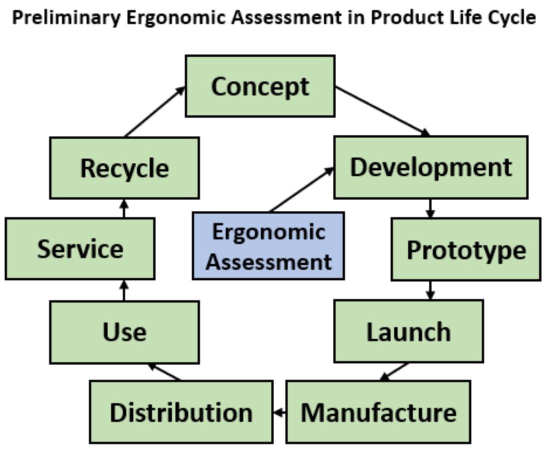


Fig. 3: Positioning of Preliminary Ergonomic Assessment in Product Life Cycle.

4. Framework: Preliminary Ergonomic Assessment

Preliminary ergonomic assessment is for identifying ergonomic risks in very early phases of new product development program. The proposed framework can be utilized for any product development program wherever there are potential ergonomic concerns. This framework has been deployed for multiple new product development programs for Tractor, Turf, Construction and Forestry platforms. A cross-functional team was put together to create this assessment tool. Team members valuable perspective and past experiences led to the framework developed. Fig. 4 shows the process flow for developed framework to conduct Preliminary Ergonomic Assessment.

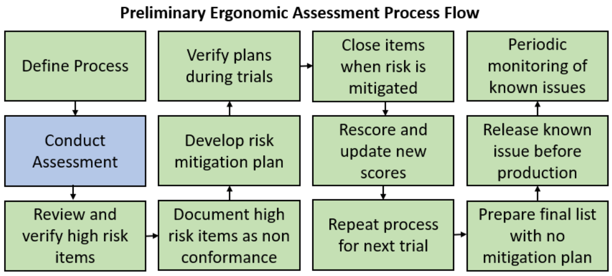


Fig. 4: Preliminary Ergonomic Assessment Process Flow.

In Preliminary Ergonomic assessment, we analyse seven parameters and provide ratings to those parameters. Vertical Height (VH), Horizontal Reach (HR), Part Weight/Forces (PW), Part Handling (PH), Frequency (F), Clearance (C) and Visibility (V) are seven important parameters in Preliminary Ergonomic Assessment.

Rating guidelines are defined for each parameter on the scale of 1 to 4, where 1 is lowest and 4 is the highest ergonomic risk. For any given item, total Risk Priority Number (RPN) would vary from 7 to 28. RPN 7 is desired whereas 28 is the worst score for which immediate action shall be taken.

In Preliminary Ergonomic Assessment, every task gets RPN score. If RPN score is equal or more than defined threshold value, then action shall be taken to mitigate that risk. As per capacity of the factory, threshold value may vary from 11 to 13. The ratings are derived from past experiences and John Deere Ergonomics and Safety document. The document refers to ACGIH (American Conference of Governmental Industrial Hygienists), AMT Standards (Association for Manufacturing Technology), ANSI Standards (American National Standards Institute), ISO Standards (International Organization for Standardization), etc. for defining the ratings.

The ratings are defined conservatively with the aim of capturing all potential ergonomic issues before the start of production.

Below example illustrates Preliminary Ergonomic Assessment done for Wheel Installation task.

Table 2. Example of Preliminary Ergonomic Assessment.

Task	VH	HR	PW	PH	F	C	V	RPN
Install Left Hand Rear Wheel	3	1	3	2	1	1	2	13

Vertical Height – Given rating is 3 because work being done above shoulder level.

Part weight - Given rating is 3 because wheel weight is falling in the range of 10 – 15 kg.

Part Geometry - Given rating is 2 because the shape of wheel is difficult to hold/handle.

Frequency - Given rating is 2 because operator has to work in awkward posture along with multiple hardware to install.

In above example of wheel installation task, RPN score is 13. As total score is more than threshold value, immediate action shall be taken to mitigate ergo risk associated with wheel installation task.

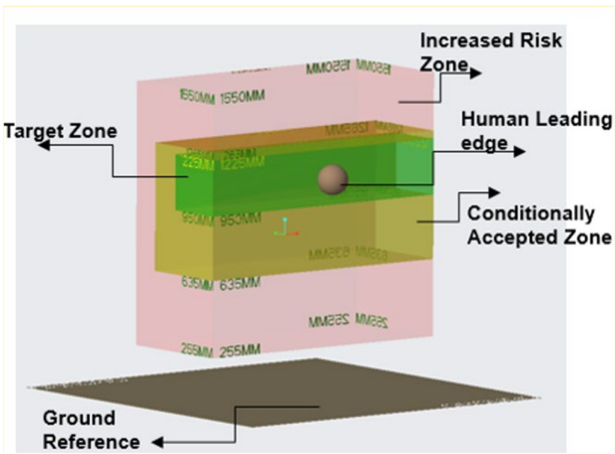
Manufacturing/Ergonomic engineer will prepare a mitigation plan and it will be reviewed and checked during physical build. If proposed mitigation plan works well during physical build, then rescoring of this task would be done and expected RPN score would be below defined threshold value.

While conducting Preliminary Ergonomic Assessment we developed and leveraged assessment tools like Reachability Check Block and Ergonomic dashboard to make the process accurate and efficient.

4.1 Reachability Check Block

Reachability check block helps to provide quick ratings for first two parameters in preliminary ergonomic assessment. Through this block we get quick ratings for Vertical Reach & Horizontal reach. The scores can be provided by simply coinciding the reachability check block ground level with operator's ground level. Rating will be more if the object lies beyond target zone. All the dimensions mentioned in block are in mm.

This check block improves the accuracy and efficiency of doing Pre-ergonomic Assessment. This check block can also be used for checking ergo risk for reachability while developing new fixtures, workstations etc.



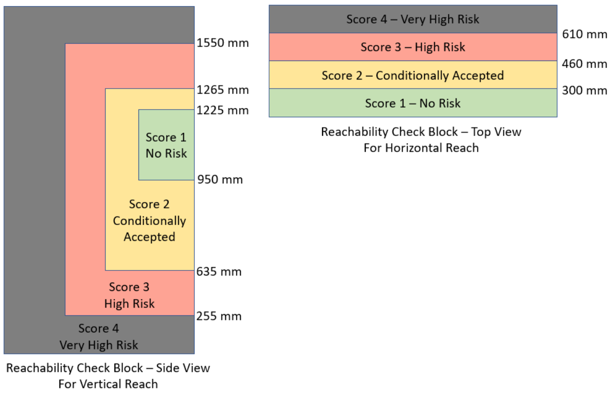


Fig. 5: Reachability Check Block

4.2 Virtual Tools

With availability of 3D product geometry at the development phase, virtual assessment for accessibility, visibility and posture is being done at the early stages[24]. Virtual tools like Industrial Path Solution (IPS), Siemens Classic Jack, Vis-jack are utilized for virtual study.

These tools help in identifying the reachability, operator visibility, clearance, operator strain, fatigue calculation and any other ergonomic concerns[25]. The output is then used to make changes in design, process, procurement of special tooling/fixture or further assessment in the real environment. For items that cannot be completely evaluated for lack of inputs are then documented for review during the early physical builds.

4.3 Ergonomic Dashboard

A dashboard has been created to visually demonstrate the stress level of operators. The real time stress level helps in determining probable injuries and assist in taking proactive actions. Visual representation led to the prioritization of risk and safety issues. Power BI based dashboard also enables the Industrial Engineer to think beyond conventional line balancing. Conventional line balancing depends on demand scenario and often overlooks ergonomic aspect. Hence it is crucial to consider stress level of on operator while work assignment. The dashboard shows the current condition and provide guideline to balance operations ergonomically which results in less injuries.

5. Result

By application of this framework, we were able to document all ergonomic risks for a new product development program. The proposed assessment has been carried out for 15 new products with more than 11,000 processes. 8-10% of these processes had ergonomic concerns which were addressed much before the production.

For one of our John Deere factories, 60% issues were resolved before it hits the shopfloor. Other John Deere units are also adopting this framework due to benefits that unit has gained. From the outcome of the initial programs, this framework has become a standard practice across factories.

American and European factories with aging workforce are highly vulnerable to ergonomic related injuries and are benefitted by this approach. Ergonomic dashboard is helping John Deere factories in optimizing workload distribution based on operator demographics.

6. Conclusion

This paper focuses on injuries and compensation cost associated with ergonomics due to reactive approach. The proposed preliminary ergonomic assessment framework benefits in reduction of injuries and cost. This also improves morale, productivity, quality of product and customer satisfaction. Corrective actions become cheaper due to early identification of ergonomic risks. Tools like Reachability check block, Ergonomic dashboard, Virtual tools are also leveraged for analysing ongoing ergonomic issues on the floor.

In an era of digitization and Industry 4.0, speed and efficiency become an important factor. Inclusion of wearable technology and video analytics will improve efficiency and accuracy of entire process[26]. Further study will focus on automation of preliminary Ergonomic assessment framework to act proactively towards ergonomic risks.

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