Ergo Value Network Map for Multi-Model Automobile Assembly Line

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Value Stream Mapping (VSM) is a widely employed approach within lean manufacturing for practicing system level Kaizen. However, analysing a value stream becomes complex when multiple streams converge at various points within the production flow. This is particularly evident in assembly lines, where numerous raw materials, subassemblies, and final assemblies are processed across multiple stages. Such complexity poses challenges for accurately mapping and optimizing the value stream. The Muda, Muri and Mura (3Ms) of assembly line is mainly affected by the ergonomic factors since assembly activities are carried out by pre dominantly operators. Therefore, to address the ergonomic waste a novel Ergonomic Value Network Map (EVNM) with Ergonomic Index (EI), is developed for a multi-model automobile assembly line based on cognitive, posture, physical, and environmental considerations. This Ergonomic Value Network Map (EVNM) was used in the automobile manufacturing plant in south India and Over Line Efficiency improved from 82% to 85% also, an artificial intelligent (AI) based. Video analytical tool named cerebrum edge was used to capture and analyse ergonomic of each element activity work posture. This study offers valuable insights for both academics and practitioners by demonstrating how the integration of ergonomic considerations through the Ergonomic Value Network Map (EVNM.) can enhance operational efficiency and operator well-being in lean manufacturing environments. This study highlights the importance of integrating ergonomic considerations into value network map to improve operational efficiency and operator well-being.

Keywords: Ergonomic Value Network Map, Multimodel Assembly Line, Ergonomic Index

1. Introduction

The increased human interaction with different equipment, tools, and simple and sophisticated systems in recent years has led to a demand for ergonomics, (Patnaik & Hovgaard, 2017) which continues to be important in enhancing the health of workers across a range of occupations. Ergonomics is "the design of work so that human competencies can be employed in the most suitable feasible way without devastating human limitations," according to international societies. Efficiency is one of the important Key Performance Indicator (KPI) for an automotive industry, most of the Indian automotive sector portfolios are economic segment vehicles. Cost of the vehicle decide the market leader. Employees (workers) on the assembly line move with the moving conveyor to finish the task and then return to their starting positions to work on the next vehicle, which may have reached the upstream stage. Numerous elements influence the assembly line's production. The intricacy of the assembly line and the involvement of several variables make mathematical modeling and analysis extremely time-consuming, and line redesign that encourages reinvestment is also a challenge (Pérez-Lechuga et al., 2021). As a result, the companies are attempting a traditional strategy based on industry demand, literature analysis, and conversations with subject matter experts (management, staff, and assembly-line managers) The objective of the present paper is to propose a methodology ‘‘To improve vehicle assembly line OLE(Over all Line Efficiency) performance” within the imposed cost constraints.

The main objective of this paper is to understand the gaps in the in existing Value Stream Mapping that is being practiced and mainly conducted with different assembly aspects. In assembly line new metric required to identify hidden efficiency losses like ergonomic related losses capturing difficult, Manual work study (REBA) time consumption more and the result get vary based on observer knowledge, Environmental factor not considered in efficiency loss identification. Ergonomic issue has serious repercussions for employees, including the development of psychological issues like burnout and depression, as well as being a major contributor to absenteeism difficulties. This paper aims to develop a novel integrated Ergonomic Index & VNM assessment in the workplace based on physical, cognitive, and environmental components in two-wheeler automotive assembly line.AI based cerebrum edge video analytical tool is a digital ergo study tool support for real-time Monitoring & capturing of individual element activity work posture

2. Methodology

2.1 Identify Current Condition of Assembly Line

In the automobile industry, the vehicle assembly line is an essential section where repetitive tasks are performed sequentially at different workstations. The assembly line is complex and involves the assembly of numerous components received from vendors and other departments. At all workstations, the work pattern is repetitive in nature, leading to boredom and fatigue. Additionally, common issues such as higher cycle time, lengthy changeover time, unnecessary buffers, bottlenecks, and inadequate resource utilization are observed (Rane & Sunnapwar, 2017).OEE (Overall Equipment Efficiency) serves as a benchmark for world-class discrete manufacturing, with a target of 85% achieved through Availability (90%), Performance (95%), and Quality (99.90%) contributions (Vivek Patel & Hemat R. Thakkar, 2014). This same guideline is referred to for the Overall Line Efficiency (OLE) improvement plan, focusing on non-equipment-related losses. Assembly line losses are classified into availability, performance, and quality rates. Further, performance losses are analyzed department-wise and through minor stoppages, categorized by stop switch, using bar charts. In the automotive assembly line, the current OLE stands at 82%. The target plan aims to reduce performance efficiency loss from 6% to 3% and improve OLE from 82% to 85%. In this background value stream mapping become essential to improve line efficiency and inclusion of Erognomic element for assembly line operation in the value stream map aids to enhance OEE.

2.2 Development of Erog-Value Network Map (EVNM) for Assembly Line Operation

Achieving efficiency targets and operational excellence in an assembly line becomes challenging when multiple value streams converge at various points within the production flow. This complexity is particularly evident in assembly lines, where numerous raw materials, subassemblies, and final assemblies are processed across multiple stages. Accurately mapping and optimizing the value stream in such scenarios can be difficult. Value network mapping plays a crucial role in addressing these challenges by identifying the sequence of operations (considering precedence, succeeding activities, and activity dependencies), tracking inventory in work-in-progress, and evaluating the Ergonomic Index Score for "hard-to-do" .operations. To address the ergonomic waste a novel Ergonomic Value Network Map (EVNM) with Ergonomic Index (EI), see figure 1 , is developed for an automobile assembly line. The important parameters and indicators in each of the Ergonomic Index element are includes physical ergonomics, environmental ergonomics, and cognitive ergonomics using literature survey, brainstorming with Cross Functional Team including suppliers.

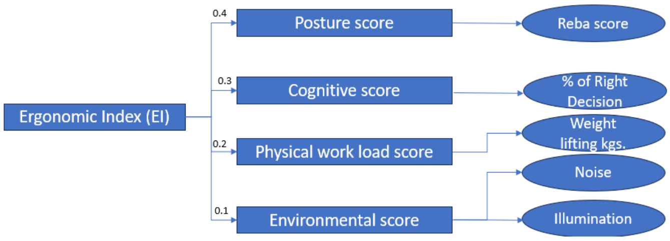

Figure 1 *Ergonomic Index Scoring*

Posture Score:

Posture focuses on the physiological characteristics of individuals and examines how physical characteristics impact their performance. To evaluate this component, physical postures are assessed using the REBA (Rapid Entire Body Assessment) study.

Cognitive Score:

This ergonomic component examines the interactions between individuals and the workplace from a cognitive perspective. The goal of cognitive ergonomics is to design human-work interactions that align with the user's mental constraints. Cognitive ergonomics evaluates sensory-motor activities (such as typing), core cognitive processes (including decision-making, problem-solving, and memory), and perceptual processes (like pattern recognition). The percentage of correct decision-making is used as an indicator to evaluate this component in the automotive assembly line.

Physical Workload Score:

This score considers activities such as part or material lifting, part holding time, and the handling and transferring of materials by individuals.

Environmental Score:

The environmental score evaluates the adverse physical elements of the workplace and their impact on human performance. Indicators such as workplace noise and illumination levels are used to assess this component.
Ergonomics Index = Posture Score+ Cognitive Score Physical Workload Score+ Environmental Score

EI = PS+CS+PWS+ES

Where,
EI (EI: Ergonomic index; PS: Posture score; Cs: Cognitive score; EE: Environmental score;

Table 1 *Guideline for Ergonomic Index*

Guideline for ergonomic Index		
Range of score	**Risk level**	**Control measures**
0-0.2	Acceptable(Low)	Negligible risk ,adequate control measures in place
0.3-0.4	Tolerable and Recoverable(Moderate)	Need for control measures
>0.4	Not acceptable(High)	Urgent demand for control measures

3. Solution Implementation

3.1 Current state EVNM for MML Assembly Line

Considering a continuous flow multimodal assembly line conveyor-based operation, conveyor both side LH and RH side activities, sub assembly and individual assembly operation current state EVNM map of is created as shown in figure 2

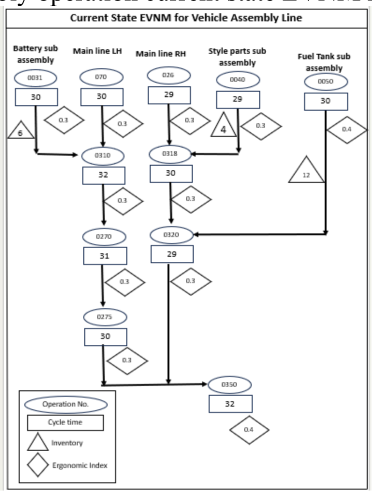

Figure 2 *Current EVNM*

3.2 Future state EVNM for MML assembly line

After brainstorming, Lean future Ideal state map with Kaizen burst and Ergonomic Kaizen of EVNM for vehicle assembly line is arrived as shown in figure 3.

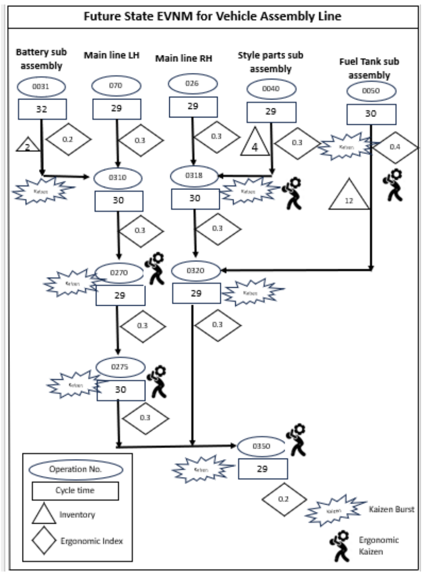

Figure 3 *Future ideal EVNM*

From EVNM &Process flow of Battery sub assembly stage, number of rehandling was more 6 times per component for single vehicle. Inventory (WIP) more 6 components

For Battery sub assembly Ergonomics Index = Posture Score+ Cognitive Load Score+
Physical Workload Score+ Environmental Score

EI = PS+CS+PWS+ES
PS =0.2(REBA score)
CS =0.1(Battery Voltage checking ok/not ok manual confirmation)
PWS =0 (Part/material Weight lifting 0kgs)
ES =0(Illumination level >300Lux; Noise level <80db)
EI =0.2+0.1+0+0 =0.3

Ergonomic index score for scanning stage is 0.3, due to cognitive score was high (manual battery voltage confirmation) from the guideline criteria this stage having moderate risk level and required control measures. Cerebrum edge is an AI powered Ergonomics Risk Assessment tool. The greatest AI-powered tool for estimating a worker's risk of musculoskeletal disorders (MSDs) is Ergo Edge. The solution is made for data-driven, real-time injury risk assessments. Enhancing safety and health at work. A safer workplace is now mostly dependent on AI-powered Environmental, Health, and Safety (EHS) solutions. From EVNM- EI score found high 0.4 due to posture score was high (from REBA study cerebrum edge -AI video analytical tool) from the guideline criteria this stage having moderate risk level and required control measures.

4. Results and Discussions

Results achieved through integrated EVNM approach, through implementing identified Kaizen, minor stoppage in battery assembly stage and scanning stage got reduced. Through this performance efficiency loss reduced by 3% and Overall Line Efficiency improved from 82% to 86%. As Intangible benefit TGW (Things Gone Wrong) First service battery related Customer compliant got eliminated from 0.43 def/100 veh to zero, Ontime delivery improved, and color model service level improved, Operator fatigue reduced,12 square feet Space saved, 3840 watts Energy saved, 5S improvement. Operational excellence through waste reduction EVNM required to achieve business objectives which are the key targets of the any manufacturing company. Based on literature survey and organizational CFT feedback, conducted survey across eight different companies integrated EVNM is developed. By converting offline to online process, static to dynamic operation skill developed for operator is helpful to develop multiscale operator competence to overcome line setting loss reduction in assembly operation as shown in Figure 4.

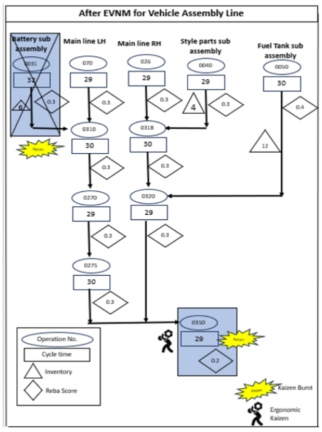

Figure 4 *EVNM for Assembly Line*

After EVNM for vehicle assembly line shown in figure 4 Identified Kaizen burst, ergonomic kaizen implemented as per plan for the identified operation number stages.

After EI score ,

For Battery assembly stage Ergonomics Index= Posture Score+ Cognitive Load Score+ Physical Workload Score+ Environmental Score

EI = PS+CS+PWS+ES

PS =0.2(REBA score)

CS =0.0(Battery Voltage checking ok/not ok interlocked with conveyor Can't flow defect)

PWS =0 (Part/material Weight lifting 0kgs)

ES =0(Illumination level >300Lux;Noise level <80db)

EI =0.2+0.0+0+0 =0.2

Guideline for ergonomic Index

Range of score	Risk level	Control measures
0-0.2	Acceptable(Low)	Negligible risk ,adequate control measures in place
0.3-0.4	Tolerable and Recoverable(Moderate)	Need for control measures
>0.4	Not acceptable(High)	Urgent demand for control measures

Ergonomic Index score for Scanning stage is reduced from 0.3to 0.2

For Scanning stage Ergonomics Index = Posture Score+ Cognitive Load Score+ Physical Workload Score+ Environmental Score

EI = PS+CS+PWS+ES

PS =0.1(REBA score)

CS =0.1(model verification against SKU, chances of vehicle wrong scan 0.2%)

PWS =0 (Part/material Weight lifting 0kgs)

ES =0(Illumination level >300Lux;Noise level <80db)

EI =0.1+0.1+0+0 =0.2

Guideline for ergonomic Index

Range of score	Risk level	Control measures
0-0.2	Acceptable(Low)	Negligible risk ,adequate control measures in place
0.3-0.4	Tolerable and Recoverable(Moderate)	Need for control measures
>0.4	Not acceptable(High)	Urgent demand for control measures

Ergonomic Index score for Scanning stage is reduced from 0.4 to 0.2

5. Conclusions

In the automobile industry, enhancing efficiency while safeguarding workers' health is crucial, particularly in two-wheeler assembly lines where repetitive tasks pose significant ergonomic risks. This paper introduces an innovative Integrated Ergonomic Value Network Mapping (EVNM) approach, incorporating an Ergonomic Index Scoring Factor developed using a Cross-Functional Team (CFT) approach. By engaging suppliers and drawing insights from existing literature, the EVNM provides a streamlined and efficient alternative to traditional ergonomic assessments, such as manual REBA worksheets, which are often time-consuming and labor-intensive. The AI-powered "Cerebrum Edge" tool enables real-time monitoring and automated posture analysis, resulting in measurable improvements in assembly line efficiency. This approach increased the overall line efficiency from 82% to 85%. The proposed integrated EVNM, developed using the CFT approach and enhanced by supplier collaboration and a literature review, addresses ergonomic challenges specific to two-wheeler automotive assembly lines.

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