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Design approach for redesigning of manual material handling devices in automobile industry

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Abstract
The main purpose on any assembly line is to assign work elements so as to minimize the number of workstations without violating the preset constraints and without having the work element time at any individual station exceed the cycle time. Even though most assembly work has been found not to be physiologically taxing, the different work elements of sequential workstations of fixed durations as mentioned impose restrictions on the processes and completion of each task element for the worker. Keeping the above facts in mind the present study was planned to redesign the manual handling devices used by assembly workers during the performance of the activities. For the present study, Bajaj Auto Limited SIDCUL, Pantnagar was purposively selected. The results reveal that the standing eye height revealed that 1538±42 and 1197-1835 was the mean±SD and the range of the respondents, with 5th and 95th percentile value of 1394 and 1764 mm respectively. While calculating the cervical mean±SD, range and 5th and 95th percentile were found to be 1397±25, 1094-1679, 1296 and 1494 mm respectively. It was concluded that by redesigned kit bin and flag can increase the production and reducing the energy and time requirement.

Keywords: Anthropometry, assembly units, ergonomics, workplace, environment

Introduction
There are many workplaces and tasks in existence which place constraints on a worker, such as maintenance, repair and assembly work (Haslegrave *et al.*, 1997) [1]. Assembly in the automotive industry still relies heavily on physical manpower and manual assembly despite the many advances in mechanization; hence the need to examine all aspects of the working conditions (Nussbaum, 2001) [2] as workers are required to adopt awkward working postures and handle loads (Chung *et al.*, 2001) [3].

The work involves the manufacturing of a final product through the process of subassemblies, manufactured parts and components (Dimitriadis, 2006) [4], utilizing precise and sometimes complex equipment, and the organization of thousands of parts. The tasks are characterized as having highly repetitive demands, requiring multiple, dynamic movements which need to occur within a complex time pattern and organizational context, and these processes are thought to increase the likelihood of incurring MSDs and cumulative trauma disorders (CTDs). The main objective on any assembly line is to assign work elements so as to minimize the number of workstations without violating the preset constraints and without having the work element time at any individual station exceed the cycle time. The total work element time at a specific station less the cycle time is known as the workstation’s idle time, which is meant to be kept at a minimum. Even though most assembly work has been found not to be physiologically taxing (Dimitriadis, 2006) [4], the different work elements of sequential workstations of fixed durations as mentioned, impose restrictions on the processes and completion of each task element for the worker. As identified by Chung *et al.* (2001) [3], automotive assembly tasks are one of the most labour intensive industries, where workers are required to perform these tasks repetitively in poor working postures due to the constrained work place, placing large amounts of strain on the musculoskeletal system. Keeping this in view, an attempt was made to redesign the manual handling devices used by assembly workers during the performance of the activities.

Materials and Methods
Selection of Locale
For the present study, Bajaj Auto Limited SIDCUL, Pantnagar was purposively selected. BAL industry was established in 2007 in Pantnagar and area covered by the industry is approx 60 acres. This industry is basically an assembling plant and is established in 2 parts i.e. phase I and phase II.

The phase I was established in the year of 2007 and phase II was established in the year of 2010. Phase I of Bajaj Auto Limited, Pantnagar was established with the consideration of improvement point taken from other 3 plants situated at Maharashtra and Phase II was established on the basis of improvement point from phase I. The whole plant was divided into 11 departments from which 3 departments are basically involved in production processes i.e. vehicle assembly, engine assembly and paint shop. In the assembling plant of Bajaj Auto Limited, there are two Vehicle Assembly (phase I and Phase II), two engine assembly (phase I and Phase II) and single Paint shop.

Designing of Manual Material Handling Devices

The design of any tool/ equipment or machinery should be considered in relation to both the body dimension of individual who are expected to use the implement and movement that can be making without difficulty or strain while using tools. Hence the variation of the individual body dimensions should be given the emphasis when a design problem is tackled. It is widely agreed that use of 5^{th} and 95^{th} percentile value of various body measurement is more logical in design considerations. However it is desirable to use 94^{th} percentile of the body dimension user to establish minimum equipment dimensions involving clearance so that smaller user group will not be affected. An example of application of the anthropometric data on tool design is illustrated taking the case of kit bin redesigning. This is an operation which requires length, diameter, weight, shape, adequate clearance, grip surface.

In the present investigation the objective was to analyze an existing assembly unit tools used by the workers to perform manual handling task with a view to redesigning the tool in order to meet usability and efficiency such as:

- Ease of use
- Useful for majority of workers
- Check unnecessary movement of risk
- Fitting for the 5^{th} and 95^{th} percentile of the population
- Avoid physical injuries

Functional requirement of assembly equipments and tools

In vehicle assembly the body movement is high for martial pickup rather than its fitment. At the conveyor, assembly components are supplied by 4 types of manual material handling devices.

1. **Through Kit bin:** In this system material comes in front of the workstation and very easy to pick and fit in bike.
2. **Online:** Material is been provided in front of workplace in small bins. These components are of very small size.
3. **Through Flag:** Various components are hanged over the flag. From flag material pickup is easy but here assembly workers frequently adopt the overhead working posture at various workstations to pick the components.
4. **Through Trolley:** Materials are supplied through the trolleys from the back side of the conveyor and assembly workers. Body postures like overhead work, twisting and stooping is frequently adopted by the workers to pick the components from the trolley.

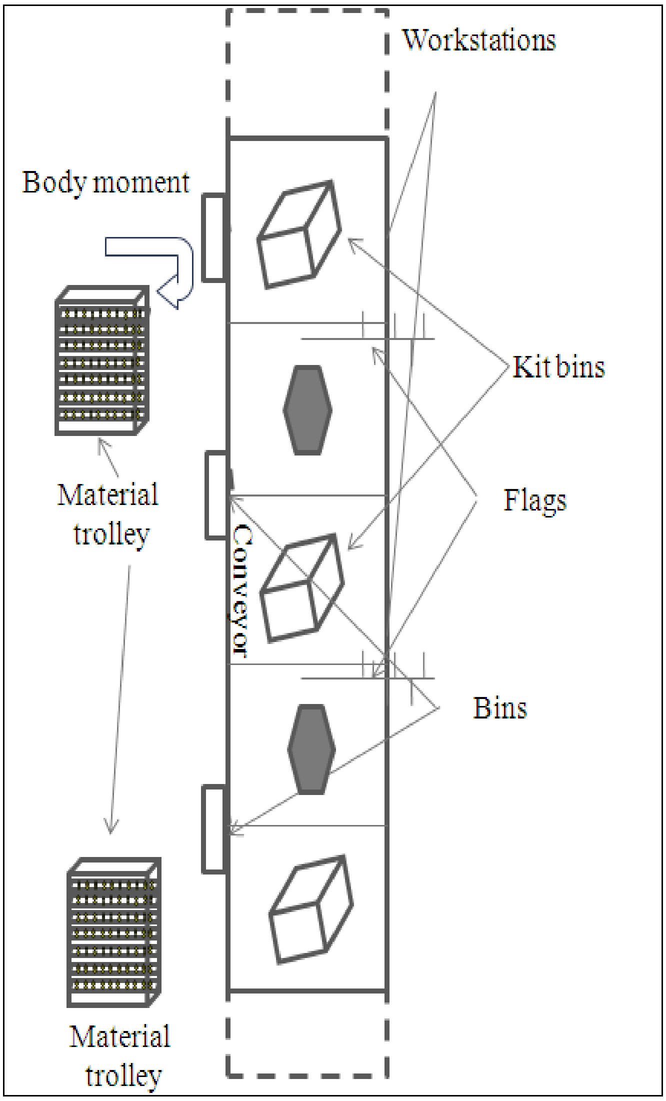

Fig 1: Conveyor of vehicle assembly

Anthropometric Measurements

Anthropometric rod is used for anthropometric measurement of the respondents while working. Obtaining anthropometric measurements was of importance in this study. These measurements provided a quantitative means of describing the sample that was investigated. More importantly however, by making use of anatomical landmarks, these measurements served as reference points for defining the postures that were tested, and aided in translating these into tangible dimensions for the workstation. Standardization of posture was a necessity and would allow for comparisons of responses to be made between the different postures and subjects. With the exception of stature, all other anthropometric measurements were taken from the right hand side using an Anthropometer held perpendicular to the floor. For all these measurements (except the seated positions) subjects had to stand in the anatomical position looking straight ahead and where appropriate measurements were taken from the right hand side. Arm length of the dominant (right) arm was measured using a measuring tape.

Results and Discussion

Table 1: Anthropometric measurement of the workers

S. No.	Measurement	Range (mm)	Mean± SD	Percentile (mm)	
				5th	95th
1	Weight	53- 85	62±31	49	63
2	Normal Standing	1328-1958	1765±20	1437	1769
3	Stature	1431-1986	1694±54	1632	1869
4	Standing eye height	1197-1835	1538±42	1394	1764
5	Cervical	1094-1679	1397±25	1296	1494
6	Mid shoulder	1061-1668	1361±74	1174	1502
7	Elbow	685-1365	957±52	856	1274
8	Waist	884-1237	1089±22	811	1185
9	Span	1378-2096	1789±15	1524	1964
10	Vertical upward arm reach, from floor	1964-2541	2394±67	2037	2397
11	Mid position length, forward arm reach (leaning)	741-1543	1375±57	853	1429
12	Forward mid position grasp reach length (leaning forward)	804-1472	1256±16	937	1324
13	Sideways mid position grasp reach length from body spine	654-1134	896±24	701	937

Anthropometric measurement

Anthropometry data of the respondents were collected in the Phase I and phase II of vehicle assembly and paint shop and it was found that in terms of weight, 62±31 and 53- 85 kg was the calculated mean± SD and range (min.-max) with 5th and 95th percentile (49 and 69 kg.). Further the data about normal standing height revealed that1765±20 was calculated mean± SD value of the respondents and it varied from 1328-1958 mm, with 5th and 95th calculated percentile value of 1437 and 1769 mm respectively. Anthropometry data of stature showed that 1694±54 mm was the recorded mean and SD value, with 5th and 95th percentile value of 1632 and 1869 mm respectively, while the calculated range was 1431-1986 mm (min.-max).

Whereas the standing eye height revealed that 1538±42 and 1197-1835 was the mean± SD and the range of the respondents, with 5th and 95th percentile value of 1394 and 1764 mm respectively. While calculating the cervical mean± SD, range and 5th and 95th percentile were found to be 1397±25, 1094-1679, 1296 and 1494 mm respectively. Mid shoulder measurement revealed that 5th and 95th percentile was 1174 and 1502 mm, with the mean± SD and range of 1361±74 and 1061-1668 mm respectively. The 5th and 95th percentile of elbow of respondents was found to be 856 and 1274 mm, while the mean± SD and the range was 957±52 and 685-1365 mm respectively. Similarly waist measurement showed that the calculated mean± SD and range was found to be 957±52 and 685-1365 mm with the 5th and 95th percentile value of 856 and 1274 mm respectively (Table 4.10).

Span height varied from 1378-2096 mm with the mean± SD value of 1789±15 mm, whereas the 5th and 95th percent value had been calculated to be 1524 and 1964 mm respectively. Data showed that the Vertical upward arm reach, from floor mean± SD value was found to be 2394±67 mm, with the 5th and 95th percentile value of 2037 and 2397 mm respectively, with the range variability of 1964-2541 mm respectively. Furthermore, mean± SD and range of mid position length, forward arm reach (leaning) was found as 1375±57 and 741-1543 mm with the 5th and 95th percentile of 853 and 1429 mm respectively.

Forward mid position grasp reach length (leaning forward) measurement revealed that the mean± SD and range was calculated as 1256±16 and 804-1472 mm, with the 5th and 95th percentile value of 937 and 1324 mm respectively. While the 5th and 95th percentile value of sideways mid position grasp reach length from body spine was found at 701 and 937 mm, with the range and mean± SD of 654-1134 mm and 896±24 mm respectively.

Evaluation of characteristics of material handling devices used by the assembly workers

While analyzing the existing material handling devices and assembling processes in vehicle assembly over the one month, it was noted that the workers were performing their task in un – ergonomic way, mainly due to the poor design of material handling devices and lack of ergonomic knowledge and its principles. With this fact, some of the tools were analyzed for design and performance and these were:

Kit bin

It is used for supplying the components for assembling on the conveyor and made up of plastic. With this system material comes in front of the workstation and very easy to pick and fit in the bike. Various dimensions of the kit bin were measured i.e. length 14.04 inches, width- 22.3 inches and depth- 3.8 inches.

Flag

It was made up of mild steel in hanger shape with the height of 48 inches and width of 22 inches. Various components for assembling i.e. grab handle, fuel tank, side panel, front fender and seat cowl are supplied on the conveyor through the flag.

Design and development of improved material handling devices for enhancing the productivity of assembly workers

On the basis of evaluation of existing material handling devices need was felt to redesign and develop new devices especially for workers to improve health, safety and productivity. Besides this, core aim of redesigning and modification of kit bin and flag was to reduce body moments i.e. bending, twisting and overhead work which was the major cause of postural discomfort among the assembly workers. The design was based on the existing basic design of material handling devices of assembly units, which was poorly designed and not found suitable according to need of users. These were causing to high work load during activities when used for longer duration and its operation demands more energy and time. During the redesign and development phase it was observed that there was tremendous scope of improvement to get best output.

The development of an ergonomically redesigned tool was based upon the existing problem; it was found that workers used to adopt almost awkward postures. In addition to the open observation, interviews were carried out to get the feedback of the following material handling devices.

Kit bin and flag
On the basis of need analysis the ergonomically redesigned material handling devices, initially the idea generated to place trolley material either in kit bin or in flag. After that it was observed that number plate of Bajaj Discover 105 model which is supplying through trolley can be shifted in kit bin by using the spare place and re-layout the bin mould and without removing any kit bin material. Same way the design of flag was modified to add some more components of assembling in the flag to reduce body movements and awkward postures of the assembly workers.

Redesigning of kit bin
Main purpose of modifying the kit bin was to reduce frequent body moments like bending and twisting. For this, idea generated to place trolley material either in kit bin or in flag. After analysis it has been observed that number plate which was supplied through trolley can be shifted in kit bin by using the spare place and re-layout the bin mould and without removing any kit bin material. The length of proposed kit bin was 10.04 inch and width was 22.3 inch. Some parts like number plate can be added in the proposed kit bin to reduce awkward body postures and body movements.

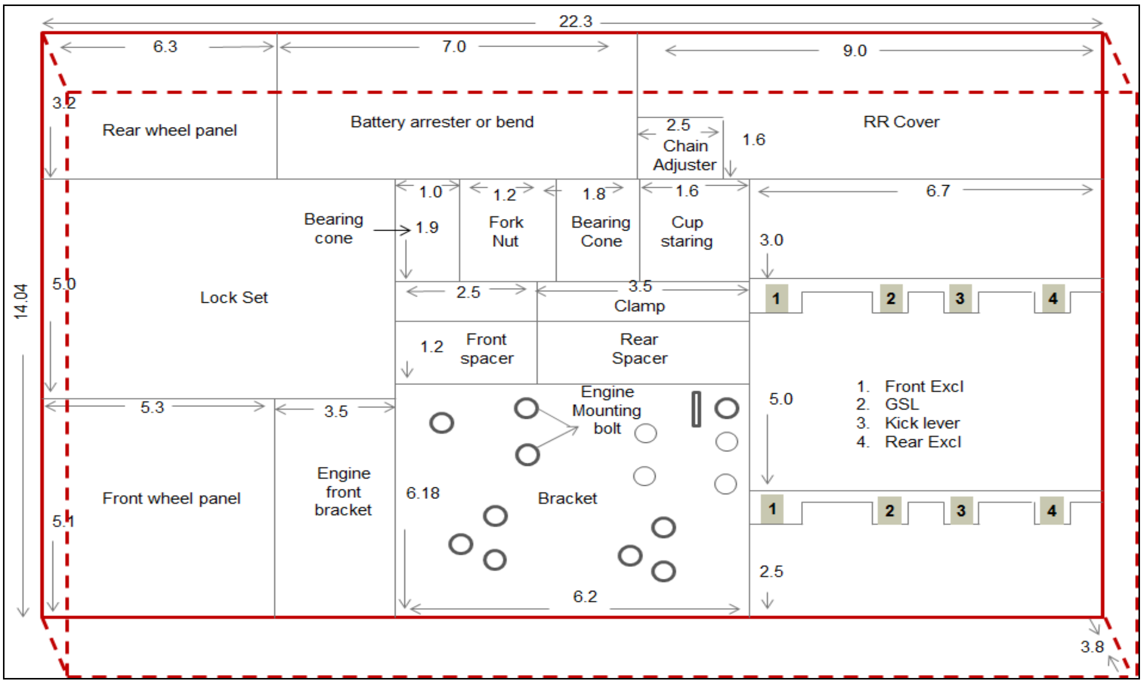

Fig 2: Existing Kit Bin

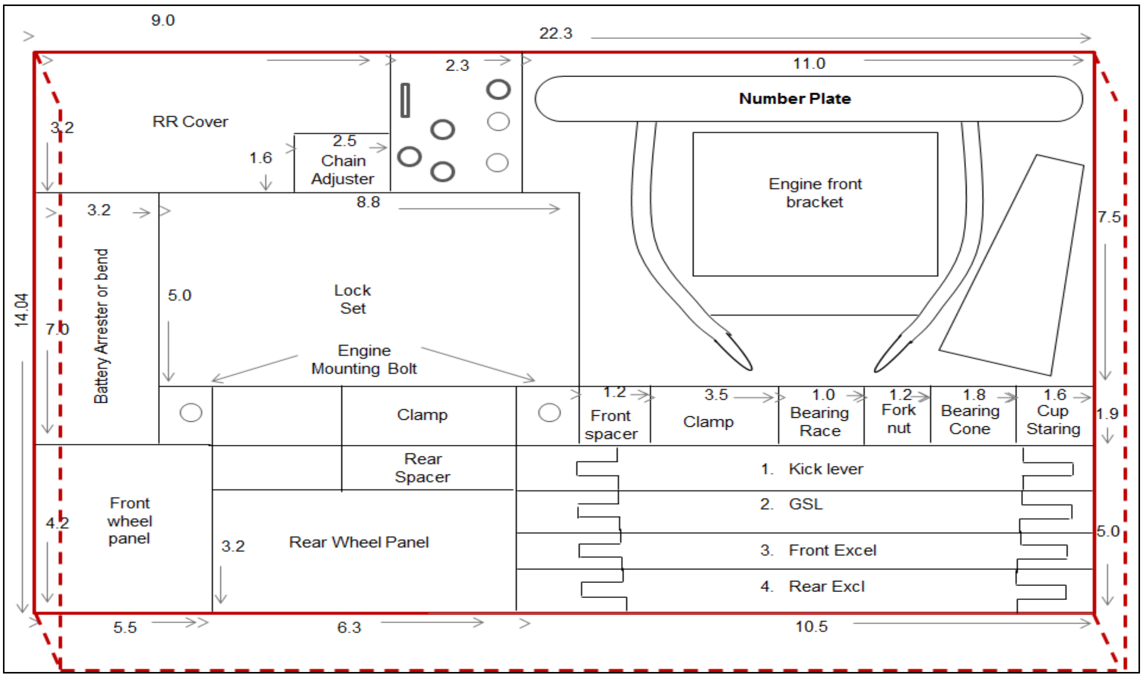

Fig 3: Redesigned Kit Bin

Redesigning of flag
After redesigning, the length of the flag remain same i.e. 48 inches but the width of the flag has been shifted to the 30 inches to add more assembly components like battery, carburetor, rider step and RR unit. These assembly components were also supplied through trolley and kit bin and because of this workers were compelled to adopt awkward body postures. So after supplying of these components with flag and Kit bin the time, motion and energy of the workers can be saved and the productivity can be increased.

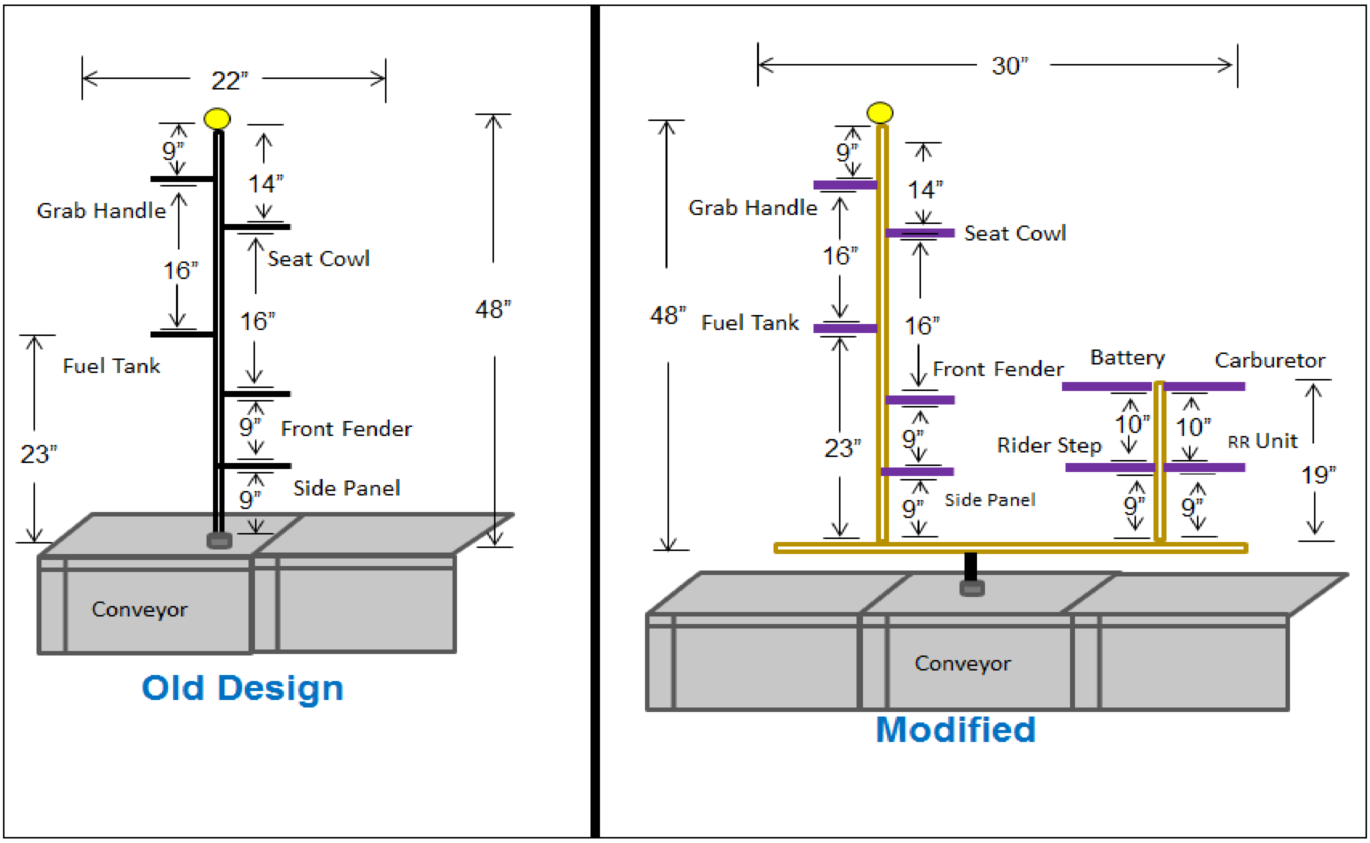

Fig 4: Layout of old and modified flag

Conclusion: The length and width of the kit bin remain same and there is no change in the size of kit bin whereas by redesigning of the kit bin the number plate can be adjusted in the kit bin by which 2 assembling stages can be reduced which will save 15.39% time of the total production. Similarly by redesigning the flag one stage out of 57 stages can be reduced. Therefore, redesigned kit bin and flag can increase the production and reducing the energy and time requirement to manufacture the motor cycle.

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