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Accessibility Index of Selected Combine Harvesters of Chhattisgarh Region

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Abstract

Combine harvesters have become more popular with an increase in harvested area in Chhattisgarh. It must be ensured that the workplace of the combine harvesters must fulfill the anthropometric criteria of agricultural workers of Chhattisgarh. Incorporating anthropometric criteria into the design of combine harvesters is essential for improving the comfort, efficiency, and safety of agricultural workers in Chhattisgarh. In addition to supporting the operators, this strategy likewise enhances the region's agricultural practices' general sustainability and efficiency. In order to assess the accessibility of the controls of the selected combine harvesters, the quantitative method proposed by Banks and Boons in 1981, followed by Shrivastava et al. in 2010 has been used. The study was conducted on 13 self-propelled combine harvesters in workplaces for similar controls of different makes and model to determine the accessibility indices. The location of the controls and accessibility with reference to seat reference point was determined by using ranked frequency of the control during harvesting of paddy and wheat crops. It was found that the accessibility indices were ranged negative between 1.18 and 0.702 while the value of Pearson's coefficient for the given combine harvesters ranges from –0.334 to –0.812. It interprets that arrangement of the controls were not properly located and at par for the agricultural workers of Chhattisgarh. Therefore, it may be concluded that positioning frequently operated controls within the optimal reach of combine harvester operators based on anthropometric data and ergonomic principles is crucial for creating an ergonomic workplace.

Keywords: Combine harvester, workplace, seat reference point, ranked frequency, accessibility index, ergonomics

INTRODUCTION

India boasts the world's largest rice-growing area at 42.75 million hectares, making it the second-largest rice producer globally, trailing only China (105 million tons in 2013). India's rice production accounts for 22.34% of the global total [1]. Harvesting methods in the country involve both manual and mechanical techniques. Mechanical harvesting often employs the combine harvester, a versatile machine that streamlines the entire grain harvesting process by combining reaping, threshing, and winnowing into one operation [2].

During the Green Revolution in India, combine harvesters were introduced and have since seen significant growth. Their numbers surged from 800 in 1971–1972 to over 40,000 today, with over 50 manufacturers, most of them located in Punjab and Haryana. India adds 900 to 1000 combine harvesters to its farms annually [3, 4]. Originally used in Punjab, Haryana, and western Uttar Pradesh, these machines have now spread across the country due to labor shortages, high manual harvesting wages,

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low efficiency, and unpredictable weather conditions. Combine harvesters have become a source of income for private companies, agro-industries, and large farmers, as they offer custom-hiring services. Key players in the Indian combine harvester market include CLASS India Ltd., Balkar Combines, Vishal Combines, Standard Combines, and Kartar Agro Industries Private Ltd [5, 6].

However, the concept of incorporating the application of human factors to the system design is “human machine system”. The system involves the study of human abilities and the characteristics of the system that affect the design of the machinery. The main is to improve the efficiency, comfort and safety of operators. Machinery that is intended to be used by people must be designed and/or selected according to the anthropometric principles if it is to function satisfactorily [7].

Since almost most of the combine harvesters were manufactured in the north Indian states, while designing the anthropometric parameters of those states have been considered. However, penetration of combine harvesters across the country, having different anthropometric characteristics make the task challenging for the operators for working in the same space of the machinery. Thus, it is crucial that the designers should involve in the design of the “people equipment” and understand the use of anthropometric techniques in their design.

As a result, combine harvester manufacturers must address the considerable variation among users and strive to accommodate a broad range of operators. The goal is not only to ensure a spatial fit in the workplace but also to enable operators to perform tasks freely and comfortably. Incorporating dynamic and functional body dimensions into the design process is essential to achieve an “exact fit” for individuals within the combine harvester’s workspace [8].

Anthropometric data for foreign countries are readily accessible for machinery workplace design. However, within the country, there is a lack of available data for design considerations. Therefore, it is crucial to gather anthropometric parameters from various states and regions, given the variations across the nation. This ensures that the combine harvesters control placement accommodates operators dimensions nationwide, not just in manufacturing states. The study’s goal is to assess the feasibility of these controls for the entire user population within combine harvesters’ workplaces.

To design the operator’s seat for combine harvesters, parameters such as seat height, seat pan height, backrest height, and anthropometric dimensions of Chhattisgarh's population were considered. This allows us to compare the interaction between Chhattisgarh user’s population and the existing combine harvester workplace design. This interaction significantly affects worker productivity and the comfort-discomfort aspect of the seat. It has been found that adjusting the controls is easier than modifying the combine harvester seat. There is a notable mismatch between seat dimensions and user anthropometric data, indicating improper seat design, which can have adverse health effects and potentially lead to accidents if left unaddressed.

Moreover, there is limited information available regarding the compatibility of combine harvester operators in Chhattisgarh. Consequently, there is a clear need to adapt combine harvester workplaces to accommodate individuals of varying shapes and sizes. This underscores the importance of designing the operators’ workplace in combine harvesters based on the anthropometric dimensions of Chhattisgarh’s population.

MATERIAL AND METHODS

Permission was taken from both the combine harvester manufacturer and the landowner prior to conducting observations. Measurements of the workplace, including its controls, were taken from all three directions for the existing combine harvester. Three-dimensional distance values were recorded and subsequently analyzed using descriptive statistical analysis in Microsoft Excel software. A total of 13 Indian combine harvesters, varying in makes and models, were randomly chosen from a specific district for assessing the accessibility index. These 13 distinct combine harvester designs were labeled as C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, and C13.

For calculating accessibility index equation below can be used:

$$r = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2][N\Sigma Y^2 - (\Sigma Y)^2]}} \quad (1)$$

$$\mathrm{I} = \mathrm{r} - \sum_{\mathrm{i}=0}^{\mathrm{s}} \left[\frac{\sum_{\mathrm{i}=0}^{\mathrm{n}} \hat{\mathrm{f}}}{\sum_{\mathrm{i}=0}^{\mathrm{N}} \mathrm{f}}\right] \div \mathrm{s} \quad (2)$$

Where,
I = accessibility index,
r = (Pearson) co-relation between distance between distance from the operator to control (X) and the ranked frequency of use (Y),
n = number of controls outside the reach envelope,
N = total number of controls,
f = rank of each control within the envelope,
$\hat{f}$ = rank of each control outside the envelope, and
s = number of operators used to collect the data

RESULTS AND DISCUSSION

Operator's discomfort and safety of operation is based on the arrangement of controls in the workplace of the harvesters. Accessibility index shows the overall suitability of workplace of combine harvester. Distance of controls from the seat reference point (SRP) in all the three axes was taken. The distance from SRP to controls was taken horizontally, vertically, and laterally in *X*, *Y*, *Z* axes, respectively [1].

According to the subjective evaluation of the operators of self-propelled combine harvester, total number of controls either outside (n) or inside the reach of the operator was taken and seen varying from one combine to another combine. Such that controls on left hand side are usually found to be present outside the reach of the operator, that is, whole assembly control lever, threshing control lever, header engagement lever and grain unloading control lever. Rank of these controls are 8, 9, 10, and 11, respectively. Although these controls are not too far from operator but are placed below the center line of the operator and in backside of the operator seat and operator has to attain awkward posture for the function of the same. Therefore, through subjective evaluation it was considered that these four controls are out of the reach of the operators.

Accessibility index for each of the existing self-propelled combine harvester is calculated separately. *X*-axis shows horizontal distance of controls from SRP, *Y*-axis gives vertical distance of controls from SRP, *Z*-axis provides lateral distance of controls from SRP. All dimensions are in millimeters unless otherwise specified.

It was found that the value of Pearson's coefficient for the given combine harvesters ranges from –0.334 to –0.812. Pearson's coefficient is calculated using Equation 1. The accessibility index (I) of the combine harvester is calculated using Equation 2. The accessibility index of the combine harvester was found to range from –0.702 to –1.18.

Highest negative value was found for combine harvester C1 of value negative 1.18 followed by combine C3 of –1.179. Since accessibility ranges from –2 to +1, the more accessibility index moves towards negative poorer the workplace of combine harvester. Lowest negative value was observed for combine harvester C2 of value –0.702 less negative value shows better workplace of combine harvester in comparison with the other existing. The value of index for any of the combine is not approaching zero. Zero indicates that arrangement of controls for this combine harvester is better situated in comparison to the others combines. Distribution of accessibility index of all 13 existing self-propelled combine harvesters is shown in Figure 1.

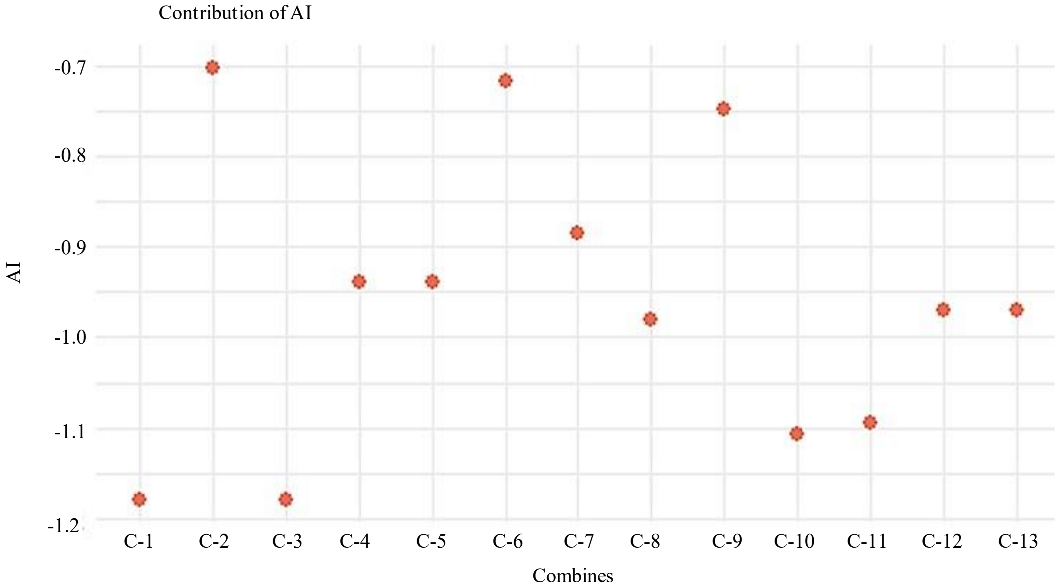

Figure 1. Distribution of accessibility index for all 13 existing combine harvesters.

Figure 2. Workplace of combine harvester (left to right): left side, central controls, and right side.

The results might show the fact that combine harvesters' workplace was designed based on ISO (International Organization for Standardization) standards, that also satisfy BIS (Bureau of Indian Standards) requirements. Still the indices show that workplace of self-propelled combine harvesters are not comfortable for the population of Chhattisgarh.

That proves that the workplace design does not satisfy the requirement of the users' population of Chhattisgarh (Figure 2). Most of the operators does not feel comfortable while operating the controls. They have to move forward, bend side-wise, sometimes stand on the platform to see the crop during harvesting operation. Sometimes to operate clutch they need to stand while harvesting, as clutch is found to be far for fifth percentile operator in most of the cases for Chhattisgarh agricultural workers. Also, it was observed that in most of the existing combine harvesters, lower ranked frequency control is not within the easy reach of the operators.

The value of accessibility index varied from –0.702 to –1.18 Therefore, it was concluded that the workplace for working in combine harvester and operating the controls was not within easy reach of the Chhattisgarh population. The reason for the same is that most of the manufacturers opted the design parameters for designing of combine harvester from the ISO, which may satisfy the requirements for

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BIS but not all percentile of population from every region were considered. Therefore, it may be concluded that higher ranked frequency controls should be within easy reach of the operators. Controls that were located outside the optimum reach of the operators will be difficult for the operators to operate. It was also observed that the anthropometric dimension varies largely from ISO to BIS. Therefore, it is necessary to design workplace based on the BIS anthropometric dimensions. The anthropometric dimension should be taken from all the regions of Indian population keeping all the percentile people in view. Adjustments in the workplace controls including seats should be given to attain more comfortable zone for every percentile operator (Figure 3).

To move the accessibility index more towards positive, it was required to increase the length of infrequently operated controls towards the front of combine harvester's operators' seat and pull it in upward direction such that the controls should be in almost aligned position with the operator [9, 10]. Also, if switches are provided instead of manual movement of those non-frequent levers, it will reduce the physical effort of the operator for the same operation (Tables 1 and 2).

Figure 3. Three-dimensional measurements of controls from seat reference point (SRP).

Table 1. Horizontal distances from operator to controls.

Name of controls	C1 (X)	C2 (X)	C3 (X)	C4 (X)	C5 (X)	C6 (X)	C7 (X)	C8 (X)	C9 (X)	C10 (X)	C11 (X)	C12 (X)	C13 (X)	Rank
Header assembly control lever	496	343	490	347	347	321	333	493	339	489	488	349	320	1
Clutch pedal	496	343	490	347	347	321	333	493	339	489	488	349	320	2
Ground speed control lever	400	604	459	608	608	593	581	161	604	592	632	633	583	3
Gear shift lever	336	255	331	259	259	247	232	335	254	353	351	401	320	4
Brake pedal	614	604	519	608	608	593	581	611	604	592	632	638	593	5
Horn	296	75	289	181	181	176	177	204	196	209	201	352	353	6
Engine speed variation lever	214	343	204	349	349	341	321	214	341	209	219	190	283	7
Threshing control lever	223	285	219	192	192	189	283	221	281	251	237	208	273	8
Header engagement control lever	223	285	219	192	192	189	283	221	281	251	237	208	273	9
Grain unloading control lever	223	285	219	192	192	189	283	221	281	251	237	208	273	10
Whole assembly control lever	223	285	219	192	192	189	283	221	281	251	237	208	273	11

Table 2. Distance from operator to controls in three dimensional axes.

Name of controls	Header assembly control lever	Clutch pedal	Ground speed control lever	Gear shift lever	Brake pedal	Horn	Engine speed variation lever	Whole assembly control lever	Threshing control lever	Header engagement control lever	Grain unloading control lever
C1 (X,Y,Z)	496, 230.8, 140	496, 170.4, 140	400, 159, 169	336, 26, 97	614, 519, 619	296, 187, 38	214, 206, 86	223, 129, 366	223, 132, 366	223, 159, 366	223, 184, 366
C2 (X,Y,Z)	343, 648, 254	343, 608, 184	604, 254, 304	255, 391, 75	604, 254, 34	75, 524, 68	343, 732, 300	285, 422, 115	285, 478, 132	285, 503, 132	285, 582, 132
C3 (X,Y,Z)	490, 18.8, 151	490, 169, 138	459, 162, 162	331, 134, 103	519, 612, 612	289, 183, 42	204, 194, 83	219, 131, 354	219, 157, 354	219, 192, 354	219, 204, 354
C4 (X,Y,Z)	347, 652, 249	347, 612, 183	608, 258, 309	259, 394, 72	608, 258, 309	181, 527, 64	349, 738, 292	192, 427, 128	192, 453, 128	192, 506, 128	192, 542, 128
C5 (X,Y,Z)	321, 641, 246	321, 601, 180	593, 243, 319	247, 388, 61	593, 243, 319	176, 503, 56	341, 703, 281	189, 594, 319	189, 492, 319	189, 417, 319	189, 573, 319
C6 (X,Y,Z)	333, 640, 243	333, 601, 183	581, 234, 309	232, 381, 67	581, 234, 309	177, 513, 58	321, 693, 288	283, 429, 309	283, 463, 309	283, 509, 309	283, 548, 309
C7 (X,Y,Z)	345, 643, 250	345, 610, 18	614, 254, 314	258, 393, 73	614, 254, 314	348, 731, 300	291, 528, 64	241, 564, 114	241, 503, 114	241, 421, 104	241, 589, 104
C8 (X,Y,Z)	493, 231, 139	493, 173, 139	161, 158, 159	335, 123, 96	611, 518, 701	204, 186, 32	214, 205, 85	221, 323, 289	221, 178, 289	221, 131, 289	221, 204, 289
C9 (X,Y,Z)	339, 640, 252	339, 609, 180	604, 256, 309	254, 395, 72	604, 256, 309	196, 519, 63	341, 731, 299	281, 572, 110	281, 510, 110	281, 432, 110	281, 591, 110
C10 (X,Y,Z)	489, 234, 131	489, 178, 151	592, 100, 174	353, 100, 174	592, 161, 95	209, 208, 81	209, 191, 30	251, 171, 288	251, 132, 281	251, 201, 275	251, 231, 275
C11 (X,Y,Z)	488, 213, 133	488, 175, 146	632, 149, 91	351, 93, 172	632, 151, 103	201, 195, 79	219, 182, 36	237, 191, 278	237, 129, 271	237, 204, 263	237, 251, 283
C12 (X,Y,Z)	349, 658, 259	349, 615, 19	633, 251, 318	401, 391, 81	638, 251, 81	352, 752, 81	190, 432, 81	208, 531, 81	208, 427, 81	208, 589, 81	208, 623, 81
C13 (X,Y,Z)	320, 640, 243	320, 600, 179	583, 231, 309	320, 324, 63	593, 213, 309	353, 703, 271	283, 503, 53	273, 482, 327	273, 409, 327	273, 532, 327	273, 566, 327

CONCLUSIONS

It has been observed that accessibility index of all 13 combine harvesters were negative and values of indices were 1.18, 0.702, 0.939, 0.717, 0.884, 0.98, 0.748, 1.101, 1.095, 1.107, 0.97, and 0.97 for C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, and C13, respectively. It was found that the accessibility indices implies that the controls arrangement of self-propelled combine harvesters was not in the easy reach of the user population of Chhattisgarh. The accessibility indices for all current combine harvesters have been determined to have a standard deviation of 16%.

Therefore, all the selected combine harvester's workplace are related to each other. The values of accessibility indices show that reachability of workplace of self-propelled combine harvesters is not in the easy reach of the user population of Chhattisgarh; however, frequently used controls like brake, clutch pedal, and steering were located within the reach in all 13 combine harvesters. It has been observed that about 61% of selected combine harvesters were at par with the standard norms while 39% of the combine harvesters partially satisfied the standard norms.

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