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COBOT in The Construction Sector: Increasing Safety, Productivity and Speed

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Abstract: Buildings have progressed from antiquated instruments to contemporary machinery, with an increasing tendency toward automation. Automation may boost the accuracy, safety, and efficiency of construction. Collaborative robots represent a new automation breakthrough. A sophisticated robot with integrated sensors is called a collaborative robot. It enables the ideal fusion of efficient robot operation with human perception. When paired with human intelligence and adaptability, collaborative robots' strength, endurance, and precision can create workstations that are more ergonomically friendly, more productive, and better than typical manual workstations. Applications for construction automation are numerous and include everything from preliminary planning and design to building, operating, and maintaining facilities as well as the final demolition and recycling of engineering buildings Among other construction equipment, COBOT stands out because of its more accurate level of safety. Due to its ease of use, adaptability, and operation, COBOT is quickly gaining acceptance in the construction industry, both among larger companies and smaller, mid-sized organizations. Owing to its versatility, and convenience of use, COBOT is becoming more and more popular among businesses that manufacture construction products. As a result, various machines can be employed in the construction sector to boost production while lowering labor costs, time, and human effort. More usage of automation in buildings is necessary in India, where there is demand for infrastructure expansion.

Keywords: COBOT, Automation, Collaborative robots, Construction industry, Infrastructure projects.

1. INTRODUCTION

1.1 General

Automation is developing over time, and it does gradually. The definition of automation clarifies that a certain part of the production or even the whole production is transferred to one machine. It is also mentioned that the development of automation has different types of levels. The first step is focusing on how manual work is replaced by machines, which implies mechanization. The second step implies that the machine is also given in man's controlling functions; these controlling functions are called automatic or numerical control. The last and final step is completely automated manufacturing where items are produced directly from raw materials, without being involved with human control or effort. Construction automation has a wide range of applications, from initial planning and design to facility construction, operation and maintenance, and the ultimate demolition and recycling of engineering structures. Recent advancements in the domains of computer science and robotics have aided in the creation of new construction technologies. Japan, a world leader in robotics and automation, has produced a slew of innovative technologies and tools that have aided the construction sector in reducing human labor, lowering construction costs, and shortening project timelines while increasing productivity.

1.2 Areas of Automation in Construction

Based on applications, the primary research efforts in the construction industry are divided into two major categories: House construction and Civil infrastructure. Common civil infrastructure uses include earthwork and the building of roads, tunnels, and bridges. House construction includes the erection and assembly of building skeletons as well as applications such as interior finishing and concrete compaction. Roads Construction & Runways Construction, Engineering Structures, Construction Industry, Ports, Tunnels.

1.3 COBOT – A Collaborative Robot

COBOT is a derivative of the word collaborative robots. COBOTs are the more approachable and successful advancement in classic industrial robots. They're smaller, less expensive, and easier to program for non-experts because of intuitive software. Built-in safety features extend the types of activities they can do and enable them to operate with humans on complex procedures. They can even be reprogrammed to change functions within the same facility, making them versatile and cost-effective. An intelligent COBOT is one that responds to changes to its environment through sensors connected to its controller. One of the most important considerations to use COBOT in a workplace is human safety. When a COBOT with sensory devices senses that there is a human worker or an obstruction in its workspace, it may automatically shut down to protect both the human worker and itself from injury.

Figure1.1: COBOT

The main goal of Cobotization is to optimize a process. In other words, achieving the maximum goal at minimum cost. Because of COBOT errors are minimized, employees have more time for other things, productivity increases, and ultimately results in better operating. Setting up COBOT naturally requires an investment, but in the long run, it saves money and even makes more profit. Unlike humans, COBOTs are very accurate. A COBOT is designed to work with people and not to replace people. COBOTs, also known as people-focused robots, assist individuals in simplifying and improving their tasks. Dirty, unsafe, boring, monotonous or repetitive tasks can be performed by the COBOT so that employees can concentrate on other tasks. Not only quality checks and maintenance but also the assembly of a product could take place in cooperation with a COBOT. For example, the COBOT is screwing a product, so that the employee completes the product one step further in the process.

2. LITERATUREREVIEW

In today's construction industry scenario, the shortage of skilled labour is one of the major problems. It not only affect the quality of work but also creates disruption in project timeline leading to delay in completion of project in time. This chapter discusses the literature under the following heads: Human COBOT Collaboration, Successful collaboration of COBOTS among themselves, Safety approach by using COBOT, Design Guidelines of COBOT, Framework for Workstation, Developing a Prototype, Educating operators as well as students about COBOT, Review on COBOT programming, Industry 4.0 and Future Trends.

2.1 Human COBOT Collaboration

Andrea Cherubini and David Navarro-Alarcon (2021) present a systematic review of existing sensor-based control methodologies for applications that involve direct interaction between humans and robots, in the form of either physical collaboration or safe coexistence. To this end, the researcher first introduces the basic formulation of the sensor-servo problem, and then, presents its most common approaches: vision-based, touch-based, audio-based, and distance-based control. **Tobias Kopp et al (2020)** describe a revolution in Automation Industry. Automation using industrial robots has been a driver in enterprises during the last decades, leading to an ever-increasing number of industrial robots being implemented in factories. However, the research agenda in the past few years has focused on developing smaller lightweight robots that enable direct interaction with humans without the need for physical separation. This Research focuses on practically relevant factors to guide HRI (Human-Robot Interaction) research, inform COBOT development, and support companies in overcoming apparent barriers. **Andrea Cherubini et al (2017)** present results on the development of a collaborative human-robot manufacturing cell for homo-kinetic joint assembly. The robot alternates active and passive behaviors during assembly, to lighten the burden on the operator in the first case, and to comply with his/her needs in the later. Their approach successfully manages direct physical contact between robot and human and between robot and environment.

2.2 Successful collaboration of COBOTS among themselves

Vivekananda Shanmuganatha, Lad Pranav Pratap, Pawar Mansi Shailendra Singh (2017) prepared a human-robot collaboration framework do independent and performing table-best protest object manipulation with humans and actualized two different activity models to trigger robot activities. The idea here is to explore collaborative systems and to build up a plan for them to work in a collaborative environment which has many benefits to a single more complex system. Here two robots that cooperate among themselves are constructed. The participation linking the two robotic arms, the torque required, and the parameters are analyzed. The purpose of this paper is to demonstrate a modular robot system that can serve as a base on aspects of robotics in collaborative robots using haptics.

2.3 Safety approach by using COBOT

Tsukiyama Kazunari and Taketa Saori (2021) suggested a new method for the efficient safety design of an interactive manufacturing system is studied and its effectiveness is verified. First, applications of the interactive manufacturing system were analyzed and a new concept of consecutive application was created. Then, by applying this concept, a method was devised to select the most appropriate safety criteria as a basis for safety design. Furthermore, a method for systematic hazard identification and determination of the need for risk reduction was studied and its effectiveness was confirmed. Because of Research of these methods, designers can demonstrate safety of the interactive manufacturing system that adequate cost and user-friendly system. **A. Adriaensen, F. Costantino et al (2021)** examines current approaches to COBOT safety by showing that these approaches can additionally benefit from systems thinking methods. This explorative research dimension is expected to overcome an overly narrow interpretation of safety issues, anticipating the challenges ahead in ever more complex COBOT applications. The safe operation of COBOT applications can only be achieved through alignment of design, training, and operation of such applications. These methods each provide interesting extensions to complement the traditional understanding of risk as required by current and future industrial COBOT implementations. The power of systemic methods for safer and more efficient COBOT operations lies in revealing the distributed and emergent result from joint actions and overcoming the reduction view from individual failures or single agent responsibilities. **Ying Lu et al (2021)** propose a novel method of quantitative construction safety risk assessment for building projects at thed esign stage. This method consists of three indexes: Likelihood, consequence, and exposure. These indexes are calculated using occupational injury, fatality, and specific construction planning data which are accurate and objective. A plug-in that links building information modeling (BIM) with safety risk data is developed in Autodesk Revit, which can automatically calculate construction safety risk to help architects and structural designers quickly select design alternatives. A case study is presented to demonstrate the feasibility and effectiveness of the proposed method.

2.4 Design Guidelines of COBOT

Joseph E Michaelis et al. (2020) described most COBOT applications as only low-level interactions with little flexible deployment, and experts felt traditional robotics skills were needed for collaborative and flexible interaction with COBOTs. The paper concludes with design recommendations for improved future robots, including programming and interface designs, and educational technologies to support collaborative use. **Helena Anna Frijns et al (2021)** propose a set of design guidelines for COBOTs based on existing literature on heuristics and COBOT UI design. The guidelines were further developed on the basis of modified heuristic evaluations by researchers with robotics expertise, as well as interviews with COBOT Experience design experts. The resulting design guidelines are intended for identification of usability problems during heuristic evaluation of the UI (User Interfacing) design of COBOT systems. This paper is concerned with the design of robots and associated UIs that are part of collaborative industrial robot systems COBOTs. COBOT saresystems that are intended for collaborative operation, i.e. the concurrent execution of tasks by human and robot in the collaborative workspace. **Chen Feng et al (2015**) created the design of the structure in which the algorithms automatically determine the assembly sequence. Furthermore, if a 3D camera is mounted on the manipulator, 3D point clouds can be readily captured and registered into the same reference frame through our marker-based metrology and the manipulator's internal encoders, either after construction to facilitate as built Building Information Model (BIM) generation, or during construction to document details of the progress. Implemented using a 7-axis KUKA KR100 robotic manipulator, the presented robotic system has successfully assembled various structures and created as-built 3D point cloud models autonomously, demonstrating the effectiveness of the designed algorithm in autonomous on-site construction robotics applications.

2.5 Framework for Workstation

Ana Colim, Carlos Faria (2021) prepared a framework that follows four main steps, (i) the characterization of the initial condition, (ii) the risk assessment, (iii) the definition of requirements for a safe design, and (iv) the conceptualization of the hybrid workstation with all the normative implications it entails. The applied methodology to a case study in an assembly workstation of a furniture manufacturing company. Results show that the methodology adopted sets an adequate foundation to accelerate the design and development of new human-centered collaborative robotic workstations.

2.6 Developing a Prototype

David Bitonneau et al (2017) focus on a human-centered approach to improve the introduction of collaborative robots in the industry. Several industrial applications are studied within Safran and Airbus Safran Launchers. In this paper, the researcher presents the first application of work on a pyrotechnic tank cleaning workstation. The approach is illustrated with the design of a solution through several simulation steps involving the workstation's operators. In particular, the current design of a prototype based on a teleoperated robot is introduced. Industrials are starting to deploy collaborative robots as new solutions to improve workstations. **Ernesto Gamboa and Miguel Hernando(2021)** designed a modular flexible collaborative robot prototype has been designed and developed as a demonstration of the proposed new generation of material handling methodology. This technology supposes a break with traditional paradigms regarding flexibility, cost, accessibility, and applicability of high-tech handling solutions as well as conventional human-machine interaction. The control system is based on hierarchical order control block architecture. Since a collaborative robot is characterized by real cooperation between human workers and intelligent assist devices, an elaborate safety system has been developed.

2.7 Educating operators as well as students about COBOT

Titanilla Komenda et al (2021) give a new approach required for technological and organizational preconditions as well as prior knowledge of the industrial engineering domain, the paper presents a hands-on educational concept for flexible task allocation in human-COBOT teams. Upon analysis of required competencies and identification of deficits in existing teaching approaches - based on evaluation criteria such as innovation content, human-COBOT team suitability, industrial relevance, and reusability - a teaching concept in addition to three hands-on demonstrators was developed. Thus, by working and evaluating the demonstrators hands-on, not only professionals, but also children and the public can explore the potential benefits, consequences, and necessary preconditions within potential use cases.

2.8 Review on COBOT programming

Shirine El Zaataria, et al (2019) gives an overview of collaborative industrial scenarios and programming requirements for COBOTs to implement effective collaboration. Then, detailed reviews on COBOT programming, which are categorized into communication, optimization, and learning, are conducted. Additionally, a significant gap between COBOT programming implemented in industry and in research is identified, and research that works towards bridging this gap is pinpointed. Finally, the future directions of COBOTs for industrial collaborative scenarios are outlined, including potential points of extension and improvement. **Alejandro Grisales Pachon (2017)** analyzed some of these existing automated (fully or partially) construction sites and by exploring new ways of conceiving and managing the processes and safety, it is possible to detect and highlight common parameters and the strategies that they have used to overcome the main difficulties in on-site automation. **Lucija Ivancac and Dalia Susa (2019)** aim to investigate how the academic community defines Robotic Process Automation (RPA) and to what extent has it been investigated in the literature in terms of the state, trends, and application of RPA. Moreover, the difference between RPA and business process management is also addressed. In order to do so, a systematic literature review (SLR) based on the Web of Science and a Scopus database has been conducted. The paper provides the results of the conducted SLR on RPA providing an overview of the RPA definitions and practical usage as well as benefits of its implementation in different industries.

2.9 Industry 4.0 and Future Trends

Smit Rangani1 and Jayraj Solanki (2020) focus on how much amount of Automation is utilized in current construction industry and its future trends, and study which barriers are highly affect to apply in construction and how it can be minimized. Intelligent and integrated control over all construction processes to optimize resource value. To improve and achieve an ideal optimum value of construction quality, safety, profitability, and productivity. **Andrea Pazienza et al (2019)** aim to use AI in the field of robotics. From robots that replace workers to robots that serve as helpful colleagues, the field of robotic automation is experiencing a new trend that represents a huge challenge for component manufacturers. The contribution starts from an innovative vision that sees an ever-closer collaboration between COBOT, able to do a specific physical job with precision, the AI world, able to analyze information and support the decision-making process, and the man able to have a strategic vision of the future. **Eloise Matheson et al (2019)** give an introduction to human-robot collaboration, presenting the related standards and modes of operation. An extensive literature review of works published in this area is undertaken, with particular attention to the main industrial cases of application. The paper concludes with an analysis of the future trends in human-robot collaboration as determined by the authors.

3. RESEARCH METHODOLOGY

3.1 Methodology

From literature found that the increasing complexity of infrastructure projects and the environment, within which they are constructed, place greater demands on construction managers to deliver projects on time, within the planned budget, and with high quality. However because of frequent changes of project managers, the appointment of staff in the site who are not experienced, non-sequential progress of works, etc. problems occurred. Additionally, work was not followed as per procedure instead it was followed as per the availability of resources causing delays in the construction project. By using/operating advanced technology (Application of COBOT) at construction projects many problems will be solved such as a reduction in delay of transporting material, increased efficiency of work, and good quality of product that ultimately reflect saving in time and cost of construction project.

In the dissertation following methodology has been decided to measure and manage the outcome.

1. **Literature review:**
   Literature review of different papers related to Automation and COBOT to collect relevant research knowledge in the field, to identify areas of prior scholarship to prevent duplication, to identify the research gap.
2. **Real problem identification and Problem statement:**
   In this step after finding the research gap, the actual problem on the construction site is identified and focusing on factors causing problems. It will provide a clear and concise roadmap for research and help to ensure that the research is well-designed.
3. **Primary data collection and Preparation of questionnaires:**

A study of the present scenario of the site and the willingness of labour to adopt automation is carried out in this step. Also, the awareness among the labours about automation in construction is checked in this step.

A questionnaire and personal interviews are formed based on this research. Questionaries are prepared to identify awareness among the labour about the COBOT technology and their opinion about COBOT models and automation on construction sites. The format of questionaries is based on Yes, No, or Other opinions for each question.

4. **Analysis of data:**
   Data obtained from questionaries are analyzed with the help of SPSS software. The rating given for each question is evaluated based on the rating 1 to 3. 1 represents Yes, 2 represents No, and 3 represents Other.
5. **Response from Analysis of data:**
   (a) Positive response: If the response is positive then suggesting different ways of using COBOT.
   (b) Negative response: If the response is negative then again starting from primary data collection to find out reason why labours are not ready for automation on site.

6. **Result and Designing of Pick and place model:**
   According to the results, the necessary action required to solve the problem by using COBOT is suggested.
   Designing the Pick and Place Cobot model along with technical aspects to reduce human efforts, to have intelligent control, and to make it safer to work along with labours.

Figure 3.1: Flow of Methodology

4. DATA ANALYSIS

4.1 SPSS Software

IBM SPSS software was used for the questionnaire analysis. A statistical analysis software program is called SPSS Statistics. In keeping with the initial market, the software's name was originally SPSS, or Statistical Package for the Social Sciences. It is a Windows based program that can be used to perform data entry and analysis and to create tables and graphs. It can handle massive volumes of data, execute every analysis discussed in the book, and much more. It is a widely used program for statistical analysis in social science. In addition, data miners, government agencies, market research firms, health research centers, government agencies, education researchers, and others use it. All the responses obtained from the questionnaires are entered in to the software. First, the variables or the questions are entered in the data view, then, the responses are entered into the software from the various data entered into the software, frequency can be found which is used to determine the relative importance factor.

4.2 SPSS Data View

The Excel file contains the results of the questionnaire survey. After opening data, SPSS displays them in a spreadsheet-like fashion as shown in below figure 5.1. The Excel file was exported in Data View to check the values and other information in a spreadsheet.

4.3 SPSS Variable View

An SPSS data file always has a second sheet called variable view. It shows the metadata associated with the data. Data values and variable meanings are described in metadata. In Variable View, different columns are displayed. Each line corresponds to a variable. A variable can be defined as any quantity that varies and can be measured, including height, weight, the number of children, gender, educational attainment, and so on. You can choose the variable's name, but it must make sense. Also, SPSS will not accept names that begin with digits or symbols. Moreover, you cannot use spaces in the name. The name of variable was used such as EMI, Construction material, etc. The figure below displays the variable view spreadsheet.

4.4 SPSS Data Analysis

Any type of data can be opened by SPSS, and its Data Editor window can display the data along with their meta-data in two sheets. In our data contain a variable holding respondents' on ferrocement related question, we can compute the frequency by navigating to Descriptive Statistics. For better understanding and detailed study pie charts option is also selected.

4.5 SPSS Data Output View

After clicking Ok, a new window opens up, SPSS output viewer window. It contains an excellent table with all the statistics for every variable we selected. The Data Editor window we previously saw is not the same as the Output Viewer window in terms of organization and design. Unlike Excel, which uses separate windows for data and research outputs based on that data, SPSS does not alter our data in any way when creating an output.

4.6 Frequency Table

The distribution of observations based on the choices in the variable is displayed in the frequency table. Frequency tables are helpful in understanding which alternatives occur more or less frequently in the dataset. This aids in improving comprehension of each variable and determining whether recoding of the variables is necessary or not.

4.7 Questionnaire Survey

The questionnaires are designed on a communication basis. It was divided into categories based on the responder profile and other factors influencing the time and cost for finishing a certain task using automation. Inquiries about the respondent's position in the company, professional expertise, locations of past and/or present employment, and contact details were included in the questionnaire. These questions in the survey are of great importance to the research by analyzing personal qualification concerns from a variety of different profiles from different regions. The set of questions was prepared and targeted the factors/sources affecting cost saved in the Automation Industry. The responses were expected to be specific to the project at hand and based on the respondents' understanding, expertise, and practice.

This straightforward and uncomplicated approach was used to create a list of the variables influencing time and cost. A three-point scale of 1 to 3 was considered for evaluating the impact of each factor. Questions are attached to the annexure page.

The rating of the respondents is correlated with these numerical impact values:

1: Yes

2: No
3: Other

4.8 Questionaries development

Since questions are thought to be the foundation of any survey activity, considerable effort is made to create an appropriate questionnaire: The questionaries should be framed by considering the following factors:

- The general information about the organization should always be the first section of the questionnaire.
- Some factors that are not related to construction should be removed or modified.
- It is necessary to reorganize certain components in order to get better consistency and suitability.
- Some factors should be revised with additional information.
- Factors repeated with similar meanings should be removed.
- Some factors should be changed to give clearer importance and understanding.

Questionnaire Survey Related to the Automation Industry (Cabot Technology)

Table 4.1: List of Questions

Sr.No.	Questions
1	Is cobotic technology required in the construction industry?
2	Are you aware of cobotic technology in construction?
3	Is cobot useful for rainy season?
4	Do you believe that project delay factor can be eliminated by using cobot?
5	Is cobot very friendly to human beings?
6	Do you believe that using advanced construction techniques like Cobot to build a high-rise structure is the best option?
7	Do you think that in pandemic Situation cobot will be useful for construction work?
8	Do you believe that errors in layout caused by incorrect data in drawing can be found by using cobot application?
9	Do you believe that Cobot will reduce the number of accidents as compared to Robot?
10	Is automation is useful for construction work?
11	Do you think that project cost will be reduced by using cobot in construction works?
12	Do you believe that the Construction Industry suffers during Pandemic situation because of labour shortage?
13	Do you think that quality of the work would suffer as a result of the fast-track construction using Cobotic Technology?
14	Do you think that use of advanced building techniques is required in the construction industry?
15	Do you believe that by using Cobots in project activities increases the quality of work?
16	In summer season, do you think that cobot can bear high temperature?
17	Does cobot is affordable for small-scale businesses?
18	Are workers ready to share the same workplace with COBOTS?
19	Do you believe a cobot can be a one-time purchase with multiple uses?
20	Is your site's labour dedicated to various software upgrades aimed at increasing productivity?
21	Do you use any advanced construction methods on your construction site?
22	Do you believe that including a cobot in a project will reduce the overall cost?
23	Will the ideal time for project completion be achieved by the use of cobots?
24	Does the use of cobot technology have an influence on the environment as a whole?
25	Do you believe the project will be delayed as a result of the site, drawings, and materials being released late?
26	Does improper material management affect total project cost and time required for completion of the project?

27	Do you think that the employment of labourers will get reduced because of Cobot?
28	Do you prefer cobots over robots?
29	Is it true that heavy rain causes building activity to slow down?
30	Do you believe that cobot can reduce errors?
31	Do you think COBOT is economical for construction industry?
32	Do you think that cobot increases quality and productivity in construction?
33	Do you think the speed of construction is improved by cobotic technology?
34	Do you think the speed of construction get increased as compared to man power?
35	Do you think the fastest speed of cobot technology maintains the quality of construction?
36	Is the material shifting speed from floor to floor faster than labour?
37	Is labour required knowledge to handle the cobot?
38	Do you think the cobot increases the profit of company?
39	Do you feel Cobot is easy to adopt?
40	Do you think wastage is reduced by using cobot technology?
41	Do you think the speed of manufacturing will get improved using the technology?
42	Do you believe that cobot technology increases profitability and less quality inspection?
43	Do you think using human resource management improves performance of a project?
44	Do you think human resource management reduces time and cost required for production?
45	Does the installation of Cobot require changes in designing of the workplace?
46	Do you think giving the proper training to employee increase the productivity of work and decreases the loss of work?
47	Do you think absolute use of resources or machine affect the project construction cost?
48	Does the training improve skill of employees more than the cobot machine?
49	Do you think Cobot is capable of performing On-site construction work?
50	Are climatic conditions in Maharashtra favorable enough for advanced technology?

5. RESULT AND DISCUSSION

5.1 General

Data collected from the questionnaire survey is arranged in an Excel sheet for overall view. Then the results are obtained with the help of SPSS Software.

5.2 Analysis of data and results

Data analysis is done with the help of SPSS software. Firstly, the data arranged in an Excel sheet is transferred to SPSS software. Then criteria for collected responses are set for all questions. After that for analysis of data, structure is created such as what to calculate, and in which format the result is required. Then with the help of analysis command results are obtained for each question. All responses are then checked and suggestions are made for using COBOT in the Construction industry based on results.

6. DESIGN CALCULATION OF COBOT MODEL

6.1 Hardware

1. ATmega328P
2. Motor Driver(L293D)
3. Buzzer
4. Dc Motor
5. Power Supply
6. Temperature Sensor
7. Ultrasonic Sensor

8. Touch Sensor

6.2 Application

6.2.1 ATMEGA328P:

- Used in ARDUINO UNO, ARDUINO NANO and ARDUINO MICRO boards.
- Industrial control systems.
- SMPS and Power Regulation systems.
- Digital data processing.
- Analog signal measuring and manipulations.
- Embedded systems like coffee machines, and vending machines.
- Motor control systems.
- Display units.
- Peripheral Interface system

6.2.2 L293D (Motor Driver):

- Separate Input-Logic Supply
- Internal ESD Protection
- High-Noise-Immunity Inputs
- Output Current 600 mA Per Channel
- Peak Output Current 1.2 A Per Channel
- Output Clamp Diodes for Inductive Transient Suppression
- Operation Temperature 0°C to 70°C.
- Automatic thermal shutdown is available

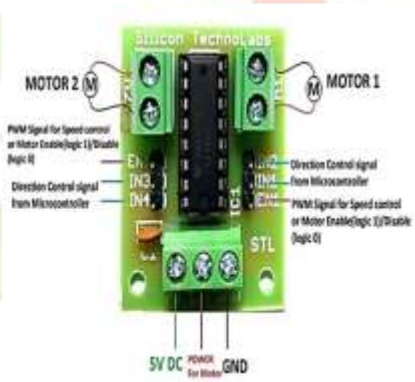


Figure 6.1: Motor Driver

6.2.3 Buzzer:

An Active Buzzer Alarm Module for Arduino is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric. Just like what you are viewing now, it is 3.3V-5V DC Electronic Part Active Buzzer Module. Using top quality material, it is durable in use. An active buzzer rings out as long as it is electrified. Compared with a passive buzzer, it is a bit expensive but easier to control. Typical uses of buzzers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke.

Figure 6.2: Buzzer Unit

6.2.4 DC Motor

A direct current (DC) motor is a type of electric machine that converts electrical energy into mechanical energy. DC motors take electrical power through direct current, and convert this energy into mechanical rotation. The output torque and speed depend upon both the electrical input and the design of the motor.

Figure 6.3: DC Geared Motor

6.2.5 Power Supply

Table 6.1: Power Supply Specifications

<table>
<tr><td>Brand</td><td colspan="3">VGS MARKETINGS</td></tr>
<tr><td>Model Number</td><td colspan="3">12V 7 Ah SMF UPS-Emergency Battery UPS battery Lead Acid Battery Solar Battery</td></tr>
<tr><td>Type</td><td colspan="3">AGM</td></tr>
<tr><td>Voltage</td><td colspan="3">12 V</td></tr>
<tr><td>Capacity Rating</td><td colspan="3">7</td></tr>
<tr><td>Weight</td><td colspan="3">2 Kg</td></tr>
<tr><td rowspan="2">Dimensions</td><td>Width</td><td>Height</td><td>Depth</td></tr>
<tr><td>15 cm</td><td>6.5 cm</td><td>6.5 cm</td></tr>
</table>

Figure 6.4: Power Supply

6.2.6 Temperature Sensor

The MAX31820 ambient temperature sensor provides 9-bit to 12-bit Celsius temperature measurements with ±0.5°C accuracy over a +10°C to +45°C temperature range. Over its entire -55°C to +125°C operating range, the device has ±2.0°C accuracy

Specifications

1. Breadboard Friendly: Yes
2. Sensor Type: Temperature
3. Typical Input Voltage: 3.3VDC
4. Operating Current: 1.5mA
5. Interface: Digital
6. Communication Protocol: Dallas 1-Wire

Figure 6.5: Temperature Sensor

6.2.7 Ultrasonic Sensor

- HC-SR04 is an ultrasonic sensor mainly used to determine the distance of the target object.
- It measures accurate distance using a non-contact technology – A technology that involves no physical contact between sensor and object.

Figure 6.6: Ultra-Sonic Sensor

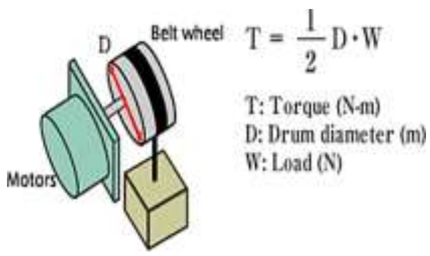
6.3 Testing on Cobot

Scope of Cobots in testing Industry domains of testing applications:

- ✓ **Functional testing:** Testing of physical action-based features of a device or module
- ✓ **Performance testing:** Consistent and rigorous testing of device inputs and responses
- ✓ **User testing:** Limitation of maximum possible user actions to cover DUT functionality
- ✓ **System testing:** Testing in tough or hazardous environment for end usage
- ✓ **Assisted testing:** Robot assisting human to perform repetitive tasks
- ✓ **Aerospace:** Cockpit operation,
- ✓ **User testing Medical:** Bench-top instrument testing, motion profiling for robotic surgery Industrial
- ✓ **Automation:** Machine tending, quality inspection
- ✓ **CPRD:** User testing of DUT, performance testing, GUI testing.

6.4 Design Calculation

The Motor Calculations



T = 1/2. D. W
D = 5MM
W = 1KG = 9.81 N

T = 1/2 X 5 X 9.81 = 24.525 NMM^2
= 0.024525 NM^2

GEARED MOTOR

Number Of Motors Are Required = 3
Assume the RPM of Motor To be 60 RPM
Torque of the motor calculated = 0.024 N/MM^2

$$
\begin{aligned}
P &= 2 \times \pi \times N \times \frac{T}{60} \times \text{No. of Motors} \\
&= 2 \times 3.14 \times 60 \times \frac{0.024}{60} \times 3 \\
&= 0.150 \times 3 \ \text{WATTS} \\
&= 0.452 \ \text{WATTS}
\end{aligned}
$$

6.5 Robotic Arm 3d Model

Figure 6.7: Front Top View of Arm

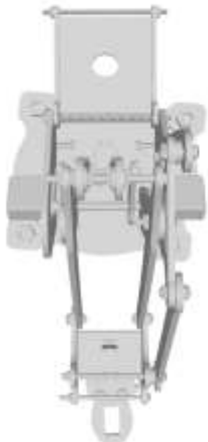


Figure 6.8: Back Top View of Arm

Figure 6.9: Bottom View of Arm

Figure 6.11: Left Side View of Arm

Figure 6.12: Right Side View of Arm

CONCLUSION

7.1 Conclusion

The major goal of this study is to discover how automation is now used in construction and how to boost the productivity, safety, and speed of the construction industry by using COBOT applications. From this study, we can say that automation can improve the current construction industry scenario. The application of COBOT not only increases the productivity and speed of construction but also increases the safety of labours to a higher extent. The barriers in the construction industry will be reduced by developing technologies like COBOT that are easier to operate and understand. Also, the labours can be easily trained by arranging training programs at workplaces. The high-performing low-maintenance work structure can be achieved even for small and medium-sized businesses.

The most important factor i.e. safety of labours increases drastically as the cobot is designed to work along with labours also the built-in sensors attached to the COBOT help to reduce accidents due to the collision of COBOT and labour while sharing the same workplace. COBOT is a very human-friendly solution to modern construction problems also it is very easy to operate and adjust according to need which makes it very trustworthy among operators. Its ability to get modified according to need makes it stand out among other machineries. COBOT can be modified to do different functions according to the nature of work which makes it more profitable in the long run not only for larger firms but also for small-medium-size firms.

COBOT is very easy to program and modify, it is capable of doing all the tasks allotted to it. By using the design considerations provided in this study, one can create a prototype model of the pick-and-place activity. The design considerations may vary for different functions based on the COBOT design. Furthermore, one can design COBOT to perform heavy tasks by modifying it according to an industrial product-based model. So, from this study, it can be concluded that the use of COBOT leads to enhancement in productivity, safety, and speed in the construction industry.

APPENDIX

Table 1: Are you aware of Cobotic technology in construction?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	98	65.3	65.3	65.3
	No	28	18.7	18.7	84.0
	Others	24	16.0	16.0	100.0
Total		150	100.0	100.0	

Table 2: Is cobot useful for rainy season?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	110	73.3	73.3	73.3
	No	21	14.0	14.0	87.3
	Others	19	12.7	12.7	100.0
Total		150	100.0	100.0	

Table 3: Do you believe that project delay factor can eliminated by using cobot?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	103	68.7	68.7	68.7
	No	26	17.3	17.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 4: Is cobot very friendly to human beings?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	94	62.7	62.7	62.7
	No	28	18.7	18.7	81.3
	Others	28	18.7	18.7	100.0
Total		150	100.0	100.0	

Table 5: Do you believe that using advanced construction techniques like Cobot to build a High rise

structure is the best option?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	100	66.7	66.7	66.7
	No	29	19.3	19.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 6: Do you think that in pandemic Situation cobot will be useful for construction work?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	94	62.7	62.7	62.7
	No	32	21.3	21.3	84.0
	Others	24	16.0	16.0	100.0
Total		150	100.0	100.0	

Table 7: Do you believe that errors in layout caused by incorrect data in drawing can find out by cobot application?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	109	72.7	72.7	72.7
	No	20	13.3	13.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 8: Do you believe that Cobot will reduce the number of accidents as compared to Robot?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	103	68.7	68.7	68.7
	No	26	17.3	17.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 9: Is automation is useful for construction work?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	99	66.0	66.0	66.0
	No	29	19.3	19.3	85.3
	Others	22	14.7	14.7	100.0
Total		150	100.0	100.0	

Table 10: Do you think that project cost will be reduced by using cobot in construction works?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	107	71.3	71.3	68.7
	No	22	14.7	14.7	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 11: Do you believe that the Construction Industry suffers during Pandemic situation because of labour shortage?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	51	34.0	34.0	34.0
	No	86	57.3	57.3	91.3
	Others	13	8.7	8.7	100.0
Total		150	100.0	100.0	

Table 12: Do you think that quality of the work would suffer as a result of the fast-track construction using Cobotic Technology?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	81	54.0	54.0	54.0
	No	58	38.7	38.7	92.7
	Others	11	7.3	7.3	100.0

Total	150	100.0	100.0	

Table 13: Do you think that use of advanced building techniques is required in the construction industry?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	91	60.7	60.7	60.7
	No	51	34.0	34.0	94.7
	Others	8	5.3	5.3	100.0
Total		150	100.0	100.0	

Table 14: Do you believe that by using Cobots in project activities increases the quality of work?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	113	75.3	75.3	75.3
	No	30	20.0	20.0	95.3
	Others	17	4.7	4.7	100.0
Total		150	100.0	100.0	

Table 15: In summer season, do you think that cobot can bear high temperature?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	103	68.7	68.7	68.7
	No	35	23.3	23.3	92.0
	Others	12	8.0	8.0	100.0
Total		150	100.0	100.0	

Table 16: Does cobot is affordable for small-scale businesses?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	99	66.0	66.0	66.0
	No	29	19.3	19.3	85.3
	Others	22	14.7	14.7	100.0
Total		150	100.0	100.0	

Table 17: Are workers ready to share the same workplace with COBOTS?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	105	70.0	71.9	71.9
	No	36	24.0	24.7	96.6
	Others	5	3.3	3.4	100.0
	Total	146	97.3	100.0	
Missing System		4	2.7		
Total		150	100.0		

Table 18: Do you believe a cobot can be a one-time purchase with multiple uses?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	99	66.0	66.0	66.0
	No	29	19.3	19.3	85.3
	Others	22	14.7	14.7	100.0
Total		150	100.0	100.0	

Table 19: Is your site's labour dedicated to various software upgrades aimed at increasing productivity?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	92	61.3	63.0	63.0
	No	43	28.7	29.5	92.5
	Others	11	7.3	7.5	100.0
	Total	146	97.3	100.0	
Missing System		4	2.7		
Total		150	100.0		

Table 20: Do you use any advanced construction methods on your construction site?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	99	66.0	66.0	66.0
	No	29	19.3	19.3	85.3
	Others	22	14.7	14.7	100.0
Total		150	100.0	100.0	

Table 21: Do you believe that including a cobot in a project will reduce the overall cost?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	90	60.0	61.6	61.6
	No	46	30.7	31.5	93.2
	Others	10	6.7	6.8	100.0
	Total	146	97.3	100.0	
Missing System		4	2.7		
Total		150	100.0		

Table 22: Will the ideal time for project completion be achieved by the use of cobots?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	99	66.0	66.0	66.0
	No	29	19.3	19.3	85.3
	Others	22	14.7	14.7	100.0
Total		150	100.0		

Table 23: Does the use of cobot technology have an influence on the environment as a whole?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	90	60.0	61.6	61.6
	No	46	30.7	31.5	93.2
	Others	10	6.7	6.8	100.0
	Total	146	97.3	100.0	
Missing System		4	2.7		
Total		150	100.0		

Table 24: Do you believe the project will be delayed as a result of the site, drawings, and materials being released late?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	99	60.0	61.6	61.6
	No	46	30.7	31.5	93.2
	others	10	6.7	6.8	100.0
	Total	146	97.3	100.0	
Missing System		4	2.7		
Total		150	100.0		

Table 25: Does improper material management affect total project cost and time required for completion of the project?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	107	71.3	71.3	71.3
	No	22	14.7	14.7	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 26: Do you think that the employment of labourers will get reduced because of Cobot?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	90	60.0	61.6	61.6
	No	46	30.7	31.5	93.2
	Others	10	6.7	6.8	100.0
	Total	146	97.3	100.0	

Missing	System	4	2.7		
Total		150	100.0		

Table 27: Do you prefer cobots over robots?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	107	71.3	71.3	71.3
	No	22	14.7	14.7	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 28: Is it true that heavy rain causes building activity to slow down?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	109	72.7	72.7	72.7
	No	20	13.3	13.3	86
	Others	21	14.0	14.0	100.0
Total		150	100.0		

Table 29: Do you believe that cobot can reduce errors?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	107	71.3	71.3	71.3
	No	22	14.7	14.7	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 30: Do you think cobotic is economical for construction industry?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	109	72.7	72.7	72.7
	No	20	13.3	13.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 31: Do you think that cobot increases quality and productivity in construction?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	107	71.3	71.3	71.3
	No	22	14.7	14.7	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 32: Do you think the speed of construction is improved by cobotic technology?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	109	72.7	72.7	72.7
	No	20	13.3	13.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 33: Do you think the speed of construction get increased as compared to manpower?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	109	72.7	72.7	72.7
	No	20	13.3	13.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 34: Do you think the fastest speed of cobot technology maintains the quality of construction?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	107	71.3	71.3	71.3
	No	22	14.7	14.7	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 35: Is the material shifting speed from floor to floor is faster than labour?

	Frequency		Percent	Valid Percent	Cumulative Percent
Valid	Yes	109	72.7	72.7	72.7
	No	20	13.3	13.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 36: Is labour required knowledge to handle the cobot?

	Frequency		Percent	Valid Percent	Cumulative Percent
Valid	Yes	109	72.7	72.7	72.7
	No	20	13.3	13.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 37: Do you think the cobot increase the profit of company?

	Frequency		Percent	Valid Percent	Cumulative Percent
Valid	Yes	94	62.7	62.7	62.7
	No	32	21.3	21.3	84.0
	Others	24	16.0	16.0	100.0
Total		150	100.0	100.0	

Table 38: Do you feel Cobot is easy to adopt?

	Frequency		Percent	Valid Percent	Cumulative Percent
Valid	Yes	109	72.7	72.7	72.7
	No	20	13.3	13.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 39: Do you think wastage is reduced by using cobot technology?

	Frequency		Percent	Valid Percent	Cumulative Percent
Valid	Yes	110	73.3	73.3	73.3
	No	20	13.3	13.3	86.7
	Others	20	13.3	13.3	100.0
Total		150	100.0	100.0	

Table 40: Do you think the speed of manufacturing will get improved using the technology?

	Frequency		Percent	Valid Percent	Cumulative Percent
Valid	Yes	94	62.7	62.7	62.7
	No	32	21.3	21.3	84.0
	Others	24	16.0	16.0	100.0
Total		150	100.0	100.0	

Table 41: Do you believe that cobot technology increases profitability and less quality inspection?

	Frequency		Percent	Valid Percent	Cumulative Percent
Valid	Yes	109	72.7	72.7	72.7
	No	20	13.3	13.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 42: Do you think using human resource management improves performance of project?

	Frequency		Percent	Valid Percent	Cumulative Percent
Valid	Yes	110	73.3	73.3	73.3
	No	20	13.3	13.3	86.7
	Others	20	13.3	13.3	100.0
Total		150	100.0	100.0	

Table 43: Do you think human resource management reduce time and cost required for production?

	Frequency		Percent	Valid Percent	Cumulative Percent
Valid	Yes	94	62.7	62.7	62.7
	No	32	21.3	21.3	84.0
	Others	24	16.0	16.0	100.0

Total	150	100.0	100.0	

Table 44: Does the installation of Cobot require changes in designing of the workplace?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	109	72.7	72.7	72.7
	No	20	13.3	13.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 45: Do you think the giving the proper training to employee increase the productivity of work and decreases the loss of work?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	94	62.7	62.7	62.7
	No	32	21.3	21.3	84.0
	Others	24	16.0	16.0	100.0
Total		150	100.0		

Table 46: Do you think absolute use of resources or machine affect the project construction cost?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	110	73.3	73.3	73.3
	No	20	13.3	13.3	86.7
	Others	20	13.3	13.3	100.0
Total		150	100.0	100.0	

Table 47: Does the training really improve skill of employee than the cobot machine?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	109	72.7	72.7	72.7
	No	20	13.3	13.3	86.0
	Others	21	14.0	14.0	100.0
Total		150	100.0	100.0	

Table 48: Do you think Cobot is capable of performing On-site construction work?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	110	73.3	73.3	73.3
	No	20	13.3	13.3	86.7
	Others	20	13.3	13.3	100.0
Total		150	100.0	100.0	

Table 49: Are climatic conditions in Maharashtra favourable enough for advanced technology?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	94	62.7	62.7	62.7
	No	32	21.3	21.3	84.0
	Others	24	16.0	16.0	100.0
Total		151	100.0	100.0	

Table 50: Is cobotic technology required in the construction industry?

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	Yes	110	73.3	73.3	73.3
	No	20	13.3	13.3	86.7
	Others	20	13.3	13.3	100.0
Total		150	100.0		

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