Design, Fabrication, and Performance Analysis of an Ergonomically Designed Self-Cleaning Dining Table

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Abstract

Traditional cleaning processes in restaurant, wedding, and event settings often involve manual labor, resulting in time-consuming and labor-intensive tasks. Additionally, conventional sterilization and hygiene practices are not upheld. In this paper, an innovative solution is proposed to address the challenge of time-consuming and labor-intensive cleaning processes in restaurant, wedding, and event settings by introducing an automated self-cleaning dining table. The development process has included the creation of an ergonomic machine prototype, the selection of suitable materials and machining techniques, and a comprehensive cost-benefit analysis. This research explores the concept and potential benefits of this automated dining table, offering a promising solution for simplifying and improving the cleanliness of dining environments while enhancing efficiency and hygiene standards in a very short time.

Keywords:

Self-Cleaning Table, Ergonomic Design, Hygienic, Time-saving, Automation.

Introduction

Restaurants, weddings, and other events require manual table cleaning, which takes a lot of time. The required decontamination and hygiene standards are not always perfect as it is performed manually. In the USA, the FDA does not currently have any standards regarding the hygiene of dining areas (FDA, 2017) . The repetitive cleaning process along with the disposal of leftovers can also be unpleasant and tiring. Considering these facts, our goal was to develop a dining table cleaning system that would get rid of all of these complexities of the cleaning process. We wanted to design a system that has the optimum ease of use for its customers. Following this, we went for a background check of similar types of projects. However, there has not been much work done in manufacturing or updating an automated self-cleaning dining table. Sokoot Jahromi et al. (2021) suggested a table with a moving component (chariot) that would automatically gather food waste and direct it to a garbage can placed next to the table. The table's moving component collects food trash as it moves along and uses alcohol spraying to sanitize the table as it returns to the starting place.

To get a much better idea about how the structure of an automated dining table should be, the research of Duan et al. (2021) demonstrated how a dining table includes three functional modules, an inventive structure, various uses, and dependable performance. Tabletops and a cam-link combination mechanism make up the folding extension module. The desktop cleaning module comprises the friction wheel trolley, parallel four-bar, scraper, and space linkage mechanism. The waste collection module comprises a hinged four-bar mechanism, a trash container, and an ultrasonic cleaning tank.

The cleaning mechanism of the self-cleaning dining table is a major issue to look into. Yin et al. (2020) showed robot employment in the cleaning procedure. But for an automated table, different mechanisms need to be implemented. Hu and Wei (2016) recommended an automatic cleaning device for dining tables that consists of a waste recycling bin, a cleaning system with cleaning brushes, and tabletop sterilizing lamps.

To take the leftovers out of the table surface, we have considered using rolls of clean sheets for our proposed design. Zhou et al. (2015) have proposed a system that is based on a smart tablecloth equipped with a fine-grained pressure textile matrix and a weight-sensitive tablet. It can determine how many pieces are cut on the main dish

plate, how many are taken from the side dish, how many sips are taken from the drink, how fast the food is being consumed, and how much weight is taken overall.

Comfort is a major issue in using any type of table. From a rehabilitation and physiotherapy view, the most prominent spinal problems in Iran result from immobility, long sitting, and standing (Faraji and Daeechian 2014) . So the table should be ergonomic so that it can provide necessary body support to the users.

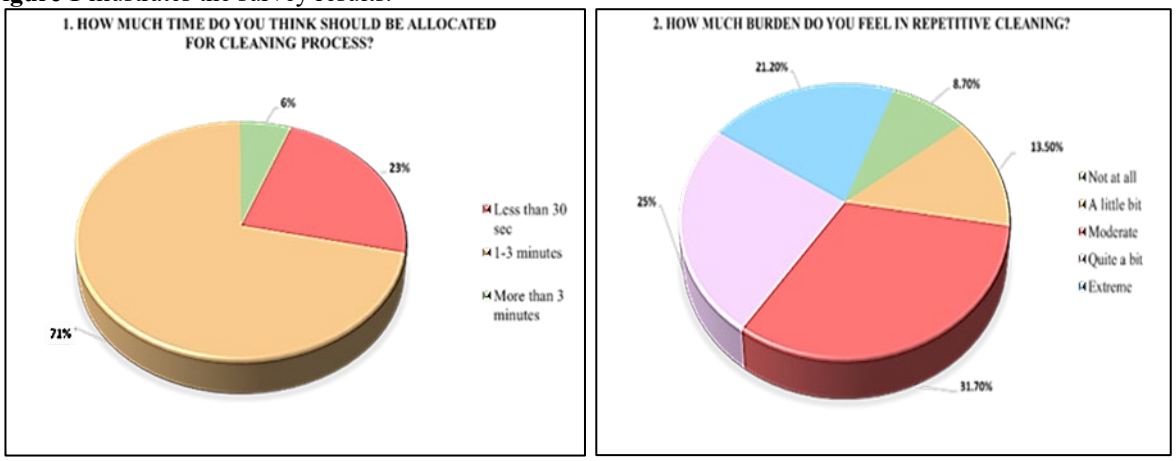
We can infer from the examination of numerous research publications that some effort has been made to improve self-cleaning dining tables and automate the cleaning procedure. The product we will be introducing shares some characteristics with the goods discussed in these publications. Our main goal is to make a self-cleaning dining table that will give much better performance with much less structural complexity; requiring a little human involvement to control it.

1. Methodology

The Self-Cleaning Dining Table's innovative approach to dining furniture is sure to take off in the market. Its innovative characteristics satisfy the hygienic and convenient needs of today's consumers. Its simplicity of usage is its main draw. The automated trash collection system on the table eliminates the need for ongoing supervision and post-meal cleanup. Another important selling factor is its emphasis on hygiene. By keeping the surface of the table continually clean, the self-cleaning system lowers the possibility of bacteria and germs. Moreover, the single-use sheets offer an extra degree of cleaning guarantee. These disposable sheets appeal to people who value cleanliness and ease of maintenance since they make washing easier and ensure a spotless, fresh surface for each use. The market is likely to be captivated by the overall efficiency of this innovative product.

2.1 Survey Findings

Businesses that understand customer needs are likely to outperform their competitors and it is the easiest way to position our product smartly in the market as the keystone of any successful business is addressing customers. Customer satisfaction has been discussed extensively by several researchers as a central element of a firm's marketing concept during the past two decades. Any business can move on to the upper level of advantage by achieving customer satisfaction in an intensely competitive market (Leninkumar 2017). Understanding customer needs is the key to giving good services in this advanced world. To bring a new dimension to our product and make it acceptable to our customers, we contacted them directly and took their opinion to meet their needs.
Figure 1 illustrates the survey results.



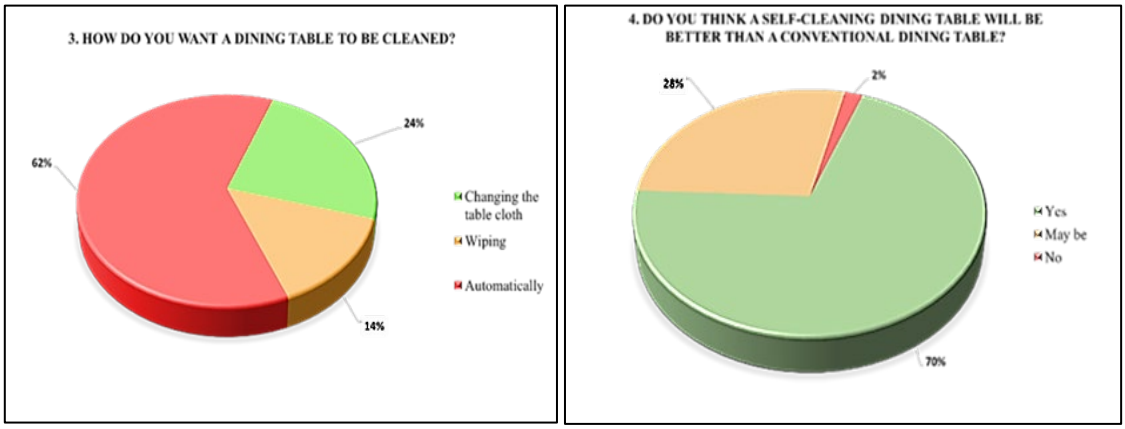


Figure 1. Survey Findings

We shared our product ideas during our survey with restaurant owners and employees. Most of them had a positive view regarding our product. Through this survey, we got to know that the conventional cleaning process is a burden for most of the workers. Additionally, they believed that the cleaning procedure would be considerably simpler if it could be automated. A few of them had doubts about the garbage box being at the bottom of the table which may cause a bad smell. Our prime target is to consider all the reviews and to provide the highest customer satisfaction.

2.2 Quality Function Deployment

Knowing what the customer wants is essential before producing a high-quality product. As a result, it is essential to know what customers expect from items. A method and toolset known as Quality Function Deployment (QFD) is used to clearly define customer needs and combine them into precise technical specifications and plans for constructing the products that meet those criteria. House of Quality (HOQ) is one of the matrices of an iterative process called Quality Function Deployment (QFD). The foundation of the HOQ is the belief that products should be designed to reflect customers' desires and tastes (Temponi et al. 1999). The HOQ of the self-cleaning dining table is demonstrated in **Figure 2**.

HOQ is designed to deploy customer input throughout the design, production, marketing, and delivery facets of a given product or service (Ariza-Lopez et al. 2005). In **Figure 2**, some general requirements for self-cleaning dining tables, such as automation, consecutive waste collection, moderate sitting arrangement, and longer product life, are contrasted with some technical concepts, such as rolling mechanism, efficiency, power consumption, maintenance, dustbin volume, and so on. In a typical QFD application, a cross-functional team creates and analyzes a matrix linking customer wants and needs to a set of product and service design metrics that the company can then measure and control. Determining the correct importance weights for the CNs and DRs is essential because they significantly affect the target values set for the engineering characteristics (Büyüközkan et al. 2004) . So the importance rating, weight, and customer requirements that were determined through group discussions and market research are also displayed here. Square is defined as strong, the circle as weak, the triangle is defined as moderate and the ratings of the Likert Scale of 9-7-5-3-1, accordingly, are the relationships of several symbols.

Consecutive waste collection is strongly related to rolling mechanism, efficiency, and dustbin volume. At the same time, features are only moderately related to design because the design of a product is influenced by its features. The relationship between fundamental and technical customer requirements is also established in this manner. Then, using a few symbols, technical correlations are also demonstrated. For example, the relationship between the Rolling Mechanism and Power Consumption is strongly positive, thus if we choose the rolling mechanism, the power consumption will increase. The same theory also applies to other relationships.

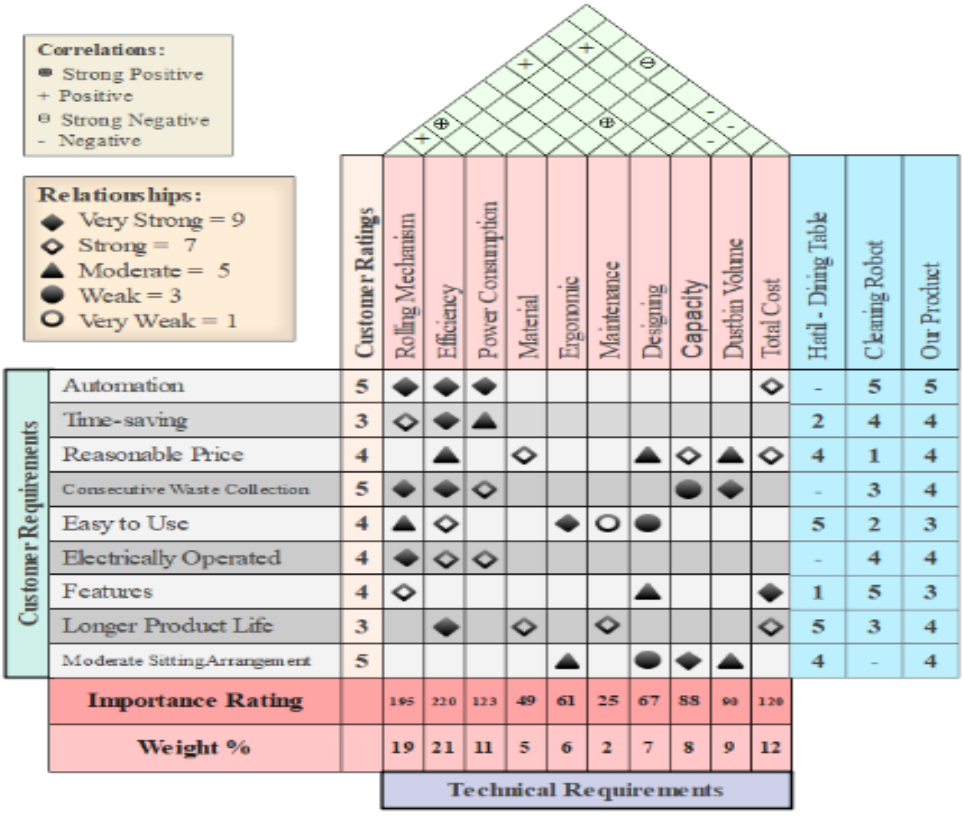


Figure 2. House of Quality for Self-Cleaning Dining Table

2.3 Component Hierarchy

Component hierarchy refers to the categorization of the various parts or elements that make up a system, device, or product. It provides a structured representation of how different components relate to each other.

2.3.1 Main Body Parts

The main body parts of the self-cleaning dining table consist of a customized wooden table, a sheet holder, and a roll of sheets. This table is different from a normal dining table because one side is specially designed to hold a box that will collect the waste from the table. To facilitate effortless opening and closing of the box, four caster wheels have been affixed underneath. Additionally, a sheet holder is mounted beneath the table's top surface to securely hold the clean sheet roll in place.

2.3.2 Energy Conversion

Electrical Energy will be required to run both the motor which will convert electrical energy to mechanical energy and rotate the pinion and sprockets. The pinion will convert mechanical rotational energy from the Stepper motor shaft. The stepper motor can be used to convert the digital signal into the position angle of the rotor (Huy et al. 2017). Similarly, the Sprocket will convert mechanical rotational energy from the DC motor shaft.

2.3.3 Working Principle

The primary objective behind the creation of a self-cleaning dining table is to provide an automated and hygienic solution for table maintenance. To operate this function seamlessly, two key mechanisms are required: the rolling mechanism and the waste collection mechanism. When electrical power is supplied, the process begins with the stepper motor initiating clockwise rotation. Utilizing the rack and pinion mechanism, the waste collection box opens. Subsequently, the DC motor is powered, and via the sprocket and chain mechanism, the roller starts to rotate, causing the tablecloth to fold into it. The DC motor halts automatically when a specific length of the sheet is folded into the roller. The smooth rotation of the roller is ensured by two ball bearings attached at its ends. As the soiled sheet is folded into the roller, any waste on the table is directed into the storage bin inside the box. This results in a clean table surface and waste containment within the box. Once the rolling process concludes, the stepper motor reverses its rotation to a counterclockwise direction. The box is automatically closed as the rack

and pinion mechanism operate in reverse. This entire sequential process is meticulously controlled by a Microcontroller, specifically the Arduino UNO, through computer programming. As the entire process is automated, it requires no human intervention apart from activating the power switch.

Figure 3 demonstrates the circuit diagram of the overall procedure.

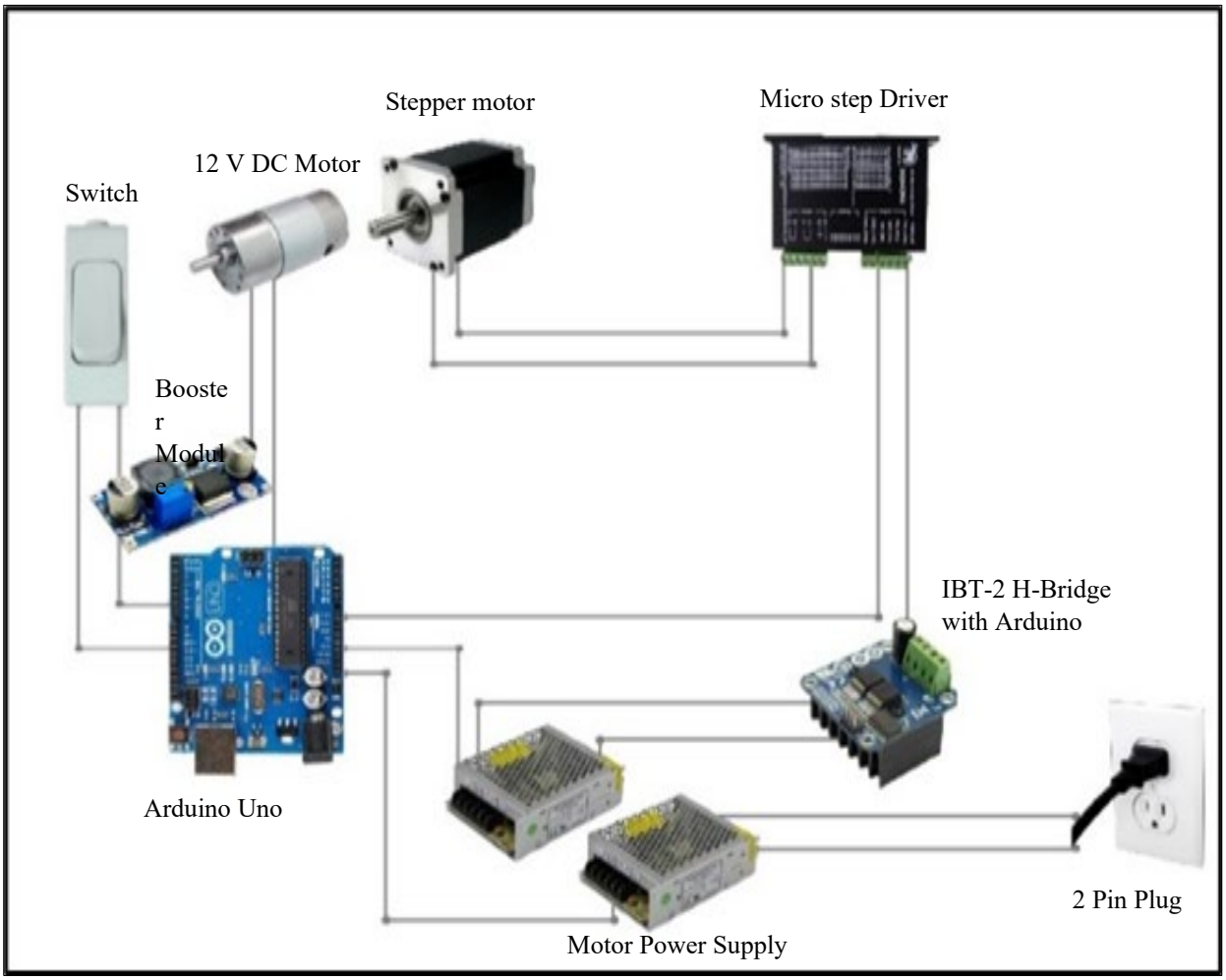


Figure 3. Circuit Diagram Self-Cleaning Dining Table

All Components of the Self-Cleaning dining Table are classified into three categories. Such as Main body Parts, Energy conversion, and mechanisms. Wooden table, sheet holder, castor wheel, and sheet are the components that are included in the Main Body Parts. Energy conversion is classified as Electrical, mechanical, and rotational energy. Mechanisms are classified as waste collection mechanisms and Rolling mechanisms. Components included in the waste collection mechanism are a bin, steeper motor, Rack & pinion, switch microcontroller, and power supply. DC motor, power supply, bearing, sprocket, roller, and chain, motor mounting bracket are the components included in the Rolling mechanism. The component Hierarchy of the Self-Cleaning Dining Table is shown in **Figure 4**.

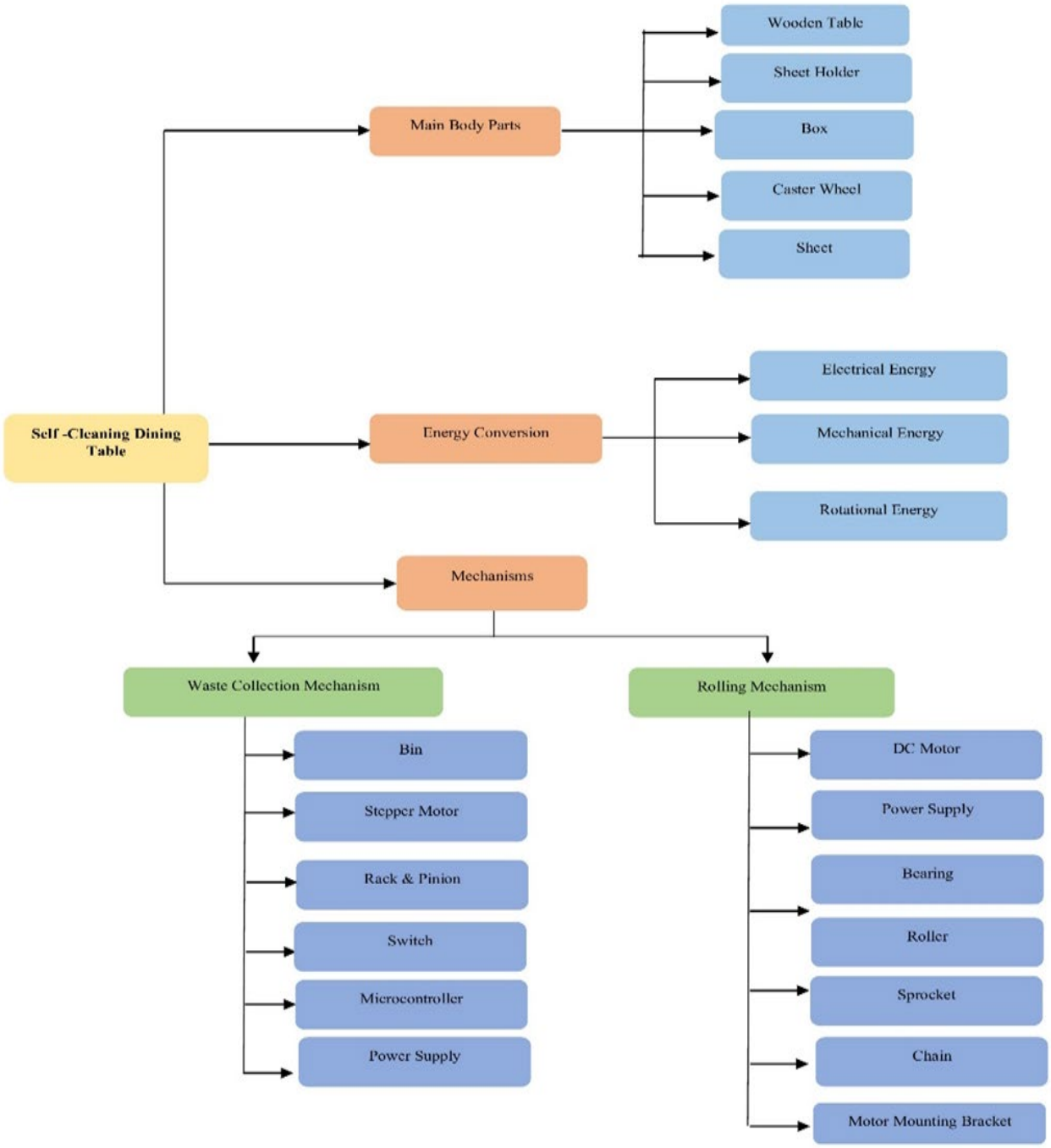


Figure 4. Component Hierarchy of Self-Cleaning Dining Table

2.3.4 Cluster Function Structure

Figure 5 depicts the overall functionality of the Self-Cleaning Dining Table. Using three arrow types, it illustrates energy, material, and information flows. The Waste Collection Mechanism orchestrates bin opening and closing, driven by electrical and mechanical energy. In contrast, the Rolling Mechanism, powered by a DC motor, facilitates seamless sheet replacement. This succinct structure showcases the dynamic interplay of components, optimizing the cleaning process.

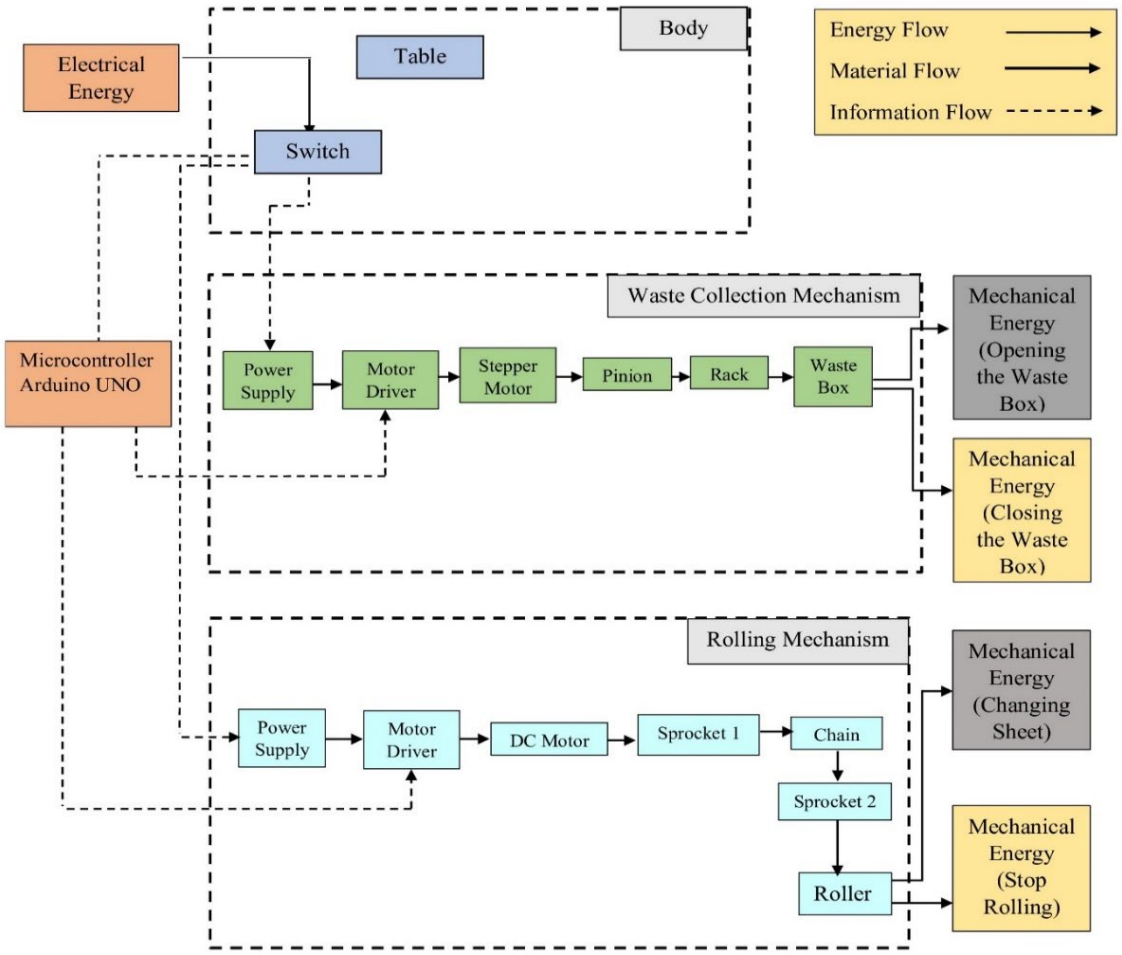


Figure 5. Cluster Function Structure of Self-Cleaning Dining Table

2. Design Analysis

Product design serves as a link between entrepreneurship and advanced new technology; nevertheless, in addition to product quality, design concepts are more competitive in the marketplace (Liu 2014). **Figure 6** shows the design we have performed using SolidWorks software. The dimensions of the table were taken considering the ergonomic measurements of the traditional dining tables. We were able to replicate our product using design analysis, which helped us identify its flaws (Mourtzis and Dimitris 2019)

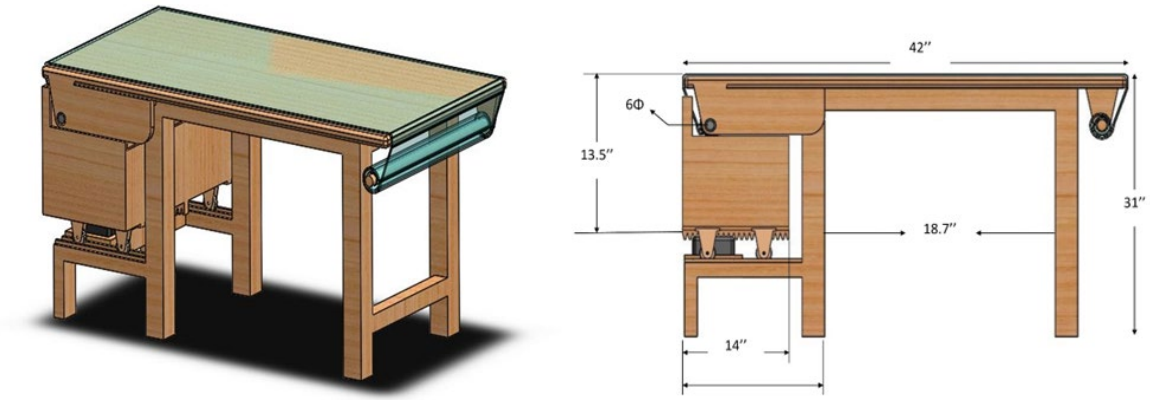


Figure 6. SolidWorks Model of Self-Cleaning Dining Table

The table stands at a comfortable 31 inches in height, stretching 42 inches in length, with a leg-to-leg spacing of 18.7 inches. The waste box, seamlessly integrated, boasts dimensions of 13.5 inches in height and 14 inches in width ensuring both functionality and aesthetic appeal.

3. Result & Discussions

Figure 7 shows the outcome of the product after manufacturing.

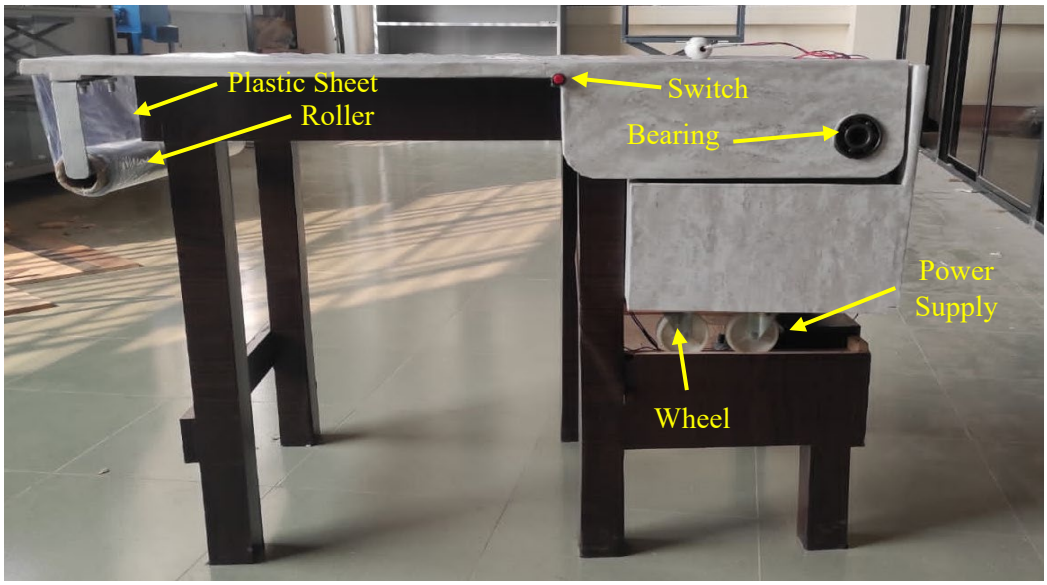


Figure 7. Self-Cleaning Dining Table

This table is designed to make the cleaning process efficient and hygienic. The waste material situated on the tabletop is systematically removed and securely stored in a designated garbage box. It is important to note that the waste materials are relatively lightweight. **Table 1** shows some observations that were taken to investigate the potential impact of varying waste weights on cleaning time.

Table 1. Observations on cleaning time across different waste weights

Observation No	Weight of the wastes(gm)	Cleaning Time (Sec)
1	400	13.5
2	600	15.05
3	800	17.7
4	1000	19.1
5	1200	20.8

Through performance testing, we assessed the cleaning time of our table under various weights. The observations indicate a direct correlation between the applied weights and the cleaning time. On average, the data reveals that cleaning a tabletop with an 800-gram waste load takes approximately 17.23 seconds. This underscores the efficiency of the cleaning process, showcasing consistent time effectiveness when managing waste of this specific weight

4. Conclusion

Our suggestion of a Self-cleaning Dining Table presents a promising answer to the labor- and time-intensive cleaning procedures at dining establishments, wedding venues, and event venues. We sought to streamline cleanliness, improve hygiene, and reduce human participation in our design by reviewing many prior efforts on related issues. This innovative approach could fundamentally alter how we approach sanitation and hygiene in typical eating spaces. It focuses on decreasing structural complexity and minimizing human participation, ultimately resulting in safer and more pleasurable dining experiences for everyone. To create a significantly improved version of our model, we believe that future researchers will find our ideas to be of tremendous use.

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Biographies

Syed Md Naieem, a dedicated BSc student in Industrial and Production Engineering at MIST, embarked on his academic journey from Ideal School and College to Dhaka College, laying a solid foundation for his current pursuits. Demonstrating a keen interest in engineering, Naieem has achieved notable success with a published paper at the International Conference on Industrial and Data Analytics (ICIDA) 2023. Currently undertaking his undergraduate thesis under the guidance of Dr. Ferdous Sarwar, he explores the complexities of supply chain management, showcasing not only theoretical understanding but also practical problem-solving skills. Naieem's commitment to academic excellence, research endeavors, and real-world applications positions him as a promising contributor to the dynamic fields of Industrial and Production Engineering and supply chain management.

Samina Rahman Shuchi, a dedicated student pursuing a degree in Industrial and Production Engineering at the Military Institute of Science and Technology, seamlessly transitioned from Bogura Cantonment Public School

and College to Govt. Azizul Haque College. Beyond excelling in coursework, she has made a significant contribution to the field through a paper published in the International Conference on Industrial and Data Analytics (ICIDA) 2023, highlighting her commitment to advancing knowledge. Samina is presently working on her supply chain management thesis, which involves maintaining the complexities of maximizing the flow of information and goods in the business sector. Her endeavors reflect a vision of making impactful contributions to the fields of Industrial and Production Engineering and supply chain management, underscoring her potential as a promising professional in the evolving landscape of technology and analytics.

Farhan Rahat Shaiket, currently in the final semester of pursuing an undergraduate degree in Industrial and Production Engineering (IPE) at the Military Institute of Science and Technology (MIST) in Dhaka, Bangladesh, is poised to graduate in 2024. Throughout his academic journey, Farhan has distinguished himself with a passion for innovative engineering solutions. Leading a dynamic team, he played a key role in the design and development of an autonomous self-cleaning dining table as part of a product design project. Proficient in SOLIDWORKS software, Farhan applied ergonomic principles to create a salon in another project, emphasizing a commitment to user-centric design. Currently engrossed in his undergraduate thesis focusing on Cold Supply Chain Logistics, Farhan envisions a future in the dynamic field of data science. While venturing into his first academic conference at the 6th Industrial Engineering and Operations Management Conference in Dhaka, Bangladesh, he eagerly anticipates the opportunity to contribute and learn. Despite not yet having published research findings or established professional affiliations, Farhan Rahat Shaiket approaches his academic pursuits with dedication, showcasing a commitment to growth within the realms of industrial engineering and operations management.

Parsha Mohsina Promi is an industrious Industrial and Production Engineering student at the Military Institute of Science & Technology. With a stellar academic record and a passion for process optimization and quality control, Parsha stands out in the field. Actively engaged in research initiatives, she consistently demonstrates a commitment to advancing manufacturing practices. With a vision for innovation and efficiency in industrial processes, Parsha is positioned to make a significant impact in the dynamic realm of Industrial and Production Engineering.

Jahanara Akter Trina is a BSc student in Industrial and Production Engineering at MIST, with a background from Dhaka Cantonment Girls Public School and College and Adamjee Cantonment College. Her current focus is a thesis on the "Processing and Applications of Metal Matrix Composite: Recent Advancements and Future Trends," reflecting her commitment to staying updated in the field. Trina aspires to contribute to the evolving landscape of industrial engineering, particularly in metal matrix composites.

Adib Bin Rashid has completed his MSc and BSc in Mechanical Engineering from the Military Institute of Science and Technology (MIST) and the Islamic University of Technology respectively. He is currently working as an assistant professor in the Industrial and Production Engineering Department of the Military Institute of Science and Technology, Dhaka, Bangladesh. His main research interests are thermal hydraulics, renewable energy, advanced material science, and additive manufacturing. He is a member of the Institute of Engineers, Bangladesh.