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THE DEVELOPMENT OF AUTOMATIC SPRAYING ROBOT FOR WALL PAINTINGS

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ABSTRACT

This study identifies two methods for painting building walls which are a traditional method and a modern method. The major problems for this study include different amounts of paint, impractical procedures and safety and health issues that can create hazards for the labour. There are several objectives for this study. The objectives are to create the automatic spraying robot for wall painting design idea, to assemble from improvise the design of automatic spraying robot for wall painting productivity, to demonstrate the performance of this innovation project and lastly to identify the target markets for this innovation project. Therefore, this study used desk study, design thinking and three-dimensional software to collect and gather all data related to this innovation project. To achieve the objectives of this study, the design for this innovation project has been developed based on the issues that have been identified, while assembling the components for this innovation project is step by step by using suitable and quality materials. Thus, the operational process of this innovation project is divided into three phases which are before, during and after. The target market for this innovation project is builder and contractor companies that work on residential or one-storey building construction projects. In conclusion, this innovation project was developed to solve several issues related to painting works.

Keywords: *painting, innovation, method, worker's health, risk*

INTRODUCTION

 In the construction industry especially for painting works, several issues have been identified. First of all, the major problem was the amount of paint. In the construction industry, there are 2 types of methods for interior painting building walls which are traditional methods and modern methods. The traditional method of painting walls for the interior involves physically applying paint by using brushes or rollers, and hydraulic lifts or ladders. Additionally, using the traditional method of painting walls can result in different amounts of paint. Therefore, this type of technique yields inconsistent and uneven painting quality because the painter's movement and unstable working position can make it difficult to achieve constant quality, productivity varies greatly depending on the competence skill of workers (Asadi et al., 2018). In other words, the traditional method can create lower quality. This is because the traditional method still demands labour to perform the painting works for the interior wall which means labour can create mistakes during the painting procedure. Additionally, when labourers make mistakes during the painting procedure, it can create defects in the future. If defects happen, it can cause an increase in the cost of the project.

The second problem was the impractical procedure. In the construction industry, there are a variety of machine that has been used to perform the painting works for interior finishing works such as spray paint machine. However, the major problem for this existing painting machine was an impractical procedure. This is because this existing machine was demanded skilled labour (Zaki et al., 2012). This existing product demanded skilled labour to operate it. It cannot operate by itself. This is because this existing product still needed help from workers to perform the painting work. Meanwhile, Malaysia also currently facing a skilled labour shortage due to the difficulty in retaining skilled and experienced labourers. The construction industry has been forced to rely on foreign labour to meet the demand for skilled labour (Zaki et al., 2012). In contrast, the construction industry in Malaysia was forced to hire foreign labour which can cause the increasing cost of the project expenses.

Nevertheless, injury. Safety and health issues are quite important issues. This is because safety and health play an important role in the project. Painting building walls is one of the most dangerous, dirty, and difficult works. It is easy to see but difficult to perform. Furthermore, painting building walls can create hazards for the labour. On the other hand, the labour is exposed more to hazards. This happens because paint can affect workers' safety and health such as eye injury, skin irritation breathing problems, etc (Patil et al., 2022).

 In paint, several types of chemicals are harmful to workers' safety and health and the human body system. The particles of the chemicals could get into the human body through the respiratory route. For example, by nose or mouth. Thus, the liquid chemical which is paint is also easily separated into a vapour that workers can breathe

in. Meanwhile, liquid chemicals which as the paint is also can be absorbed by the skin which can cause instant skin irritation or skin damage. The liquid chemical passes through the skin and directly into the human's bloodstream. It can spread into human's body system. When the particles get into the human body, it can cause internal and external injury. This is because when painting building walls, workers may exposed to paint's chemicals. When humans are exposed to chemical containment it will result in the presence of dangerous diseases (Wolf & Vicker, 2012). On the other hand, a chemical contained in paint is not safe for the human body system. As a result, chemical and physical hazards in painting works can create accidents and injury to labourers during painting. While it can affect the safety of labour.

LITERATURE REVIEW

Definition and History of Paint

In this era, construction projects are becoming larger and more complex. The use of automation in construction projects can allow for the reduction of labourintensive procedures, which can improve product quality, increase accuracy, improve safety and health, and reduce the construction period. Hence, in the construction industry painting is the process of putting paint, pigment, colour, or any other solvent on the wall surface of the building.

According to Talbert (2007), the purpose of paint is to improve appearance and to protect the substrate material. Meanwhile, according to (Johnson et al., 2009) paint is any liquid, liquefiable, or mastic material that when applied to a surface in a thin layer, transforms into an opaque solid film is referred as paint. They also stated that paint is a pigmented coating that is applied to an object or surface to protect, decorate, or enhance functioning. Moreover, they also stated that paint is used to hasten drying, boost durability, keep surfaces looking new, and fend off corrosioncausing moisture.

In addition, the history of paints. According to Lambourne & Strivens (1999), they said in their book, the first paint was invented about 25,000 years ago by prehistoric man. The prehistoric men were hunters and cave dwellers (Lambourne & Strivens, 1999). Therefore, the principle of pigments employed by Palaeolithic artists was based on iron and manganese oxides. Thus, according to chemical analyses of cave paintings at Altamira and Lascaux in Spain and France, there are three pigments of paint were found around the cave, which are black, red, and yellow (Lambourne & Strivens, 1999). Nonetheless, in Lascaux, there are no traces of white pigment whose bright background was created by using the colour of the rock itself. But some prehistoric African cave paintings were found to contain white pigments (Lambourne & Strivens, 1999).

Apart from this, according to Lambourne (1999), hollowed stones are thought to have been used as mortars and bones as pestles for instance, there is an article found that is stained with pigments on it. On top of that, the Egyptians also developed the art of

paint-making. They developed various colour ranges of pigments. However, during the thirteenth century, the protective value of drying oils began to be recognized in Europe (Lambourne, 1999). Subsequently, lead and zinc-based paints were developed to fulfil the need for anti-corrosive primers in the construction industry. The anti-corrosive primers can delay or prevent from rusting or corrosion. It can be clarified that the simplest paints based upon red lead dispersed in linseed oil are still probably one of the best anti-corrosive primers for structural steel.

Composition of Paint

Paint is produced from a combination of several types of chemical mixtures. Paints are made up of a variety of components that vary based on the manner of application, intended qualities, substrate to be coated, and ecological, and economic boundary conditions. Paint can have a wide variety of components such as water, organic solvents, and flocculants for example volatile paint components, binders, resin, plasticizers, colourants, dyes, pigments, and extenders are examples of nonvolatile substances (Stoye & Freitag, 2008).

The important benefits like improved flow behaviour, better wetting of pigment substrates, and catalytic acceleration of curing are produced by low concentrations of additives (Stoye & Freitag, 2008). The binder is the most crucial component in the paint composition. The application procedure, drying and curing behaviour, substrate adherence, mechanical qualities, chemical resistance, and weather ability is essentially all determined by the binder.

Binder and resin

The binder that binds the pigment particles together and provides adherence of the coating to the substrate. Most coatings are named for the generic resin composition type utilised, such as phenolic, epoxy, polyurethane, acrylic, polyester, alkyl, and so on. The majority of a coating's chemical and physical qualities, such as abrasion, hardness, weather resistance, chemical resistance, cohesion, and adhesion, are determined by the resin. The curing mechanism of the coating is also determined by the type of resin used. Nowadays, rosin is the most often used natural resin as a binder, and it is frequently chemically modified to suit specific uses (Stoye & Freitag, 2008). Hence, hard resin binders can enhance the surface hardness, lustre, and adherence while increasing the solid content (Stoye & Freitag, 2008). Furthermore, the majority of synthetic binders are softer and more malleable rather than hard resin.

Plasticizers

Plasticizers are an organic liquid with lower volatility and high viscosity (Stoye & Freitag, 2008). The binder is softening, and film-forming temperatures are reduced by plasticizers. It is also can help with flow, flexibility, and adhesion. Plasticizers are chemically mostly inert and do not react with binder components.

Pigments and Extender

Pigments and extender in paints are responsible for colour and opacity and sometimes improves the corrosion resistance of the paint film (Stoye & Freitag, 2008). In general, pigment's major function is to offer colour and opacity to the coating layer, as well as weathering, durability, and protection to light-sensitive resins. Other than that, extenders are to increase the mechanical strength of the coating film, reduce settling, control viscosity, improve film build, and control gloss. However, pigments are divided into two types which are organic pigments and inorganic pigments (Abdullah Youssef, 2019). The organic pigment is used in decorative paints while the inorganic pigment is merely used in protective paints. Table 1 below shows a few types of organic pigment and inorganic pigment that have been identified and used in several colours.

Table 1: Colour and its pigments

Colour	Inorganic Pigment	Organic Pigment
White	Titanium Dioxide Zinc Oxide Zinc Sulphide Antimony Oxide	-
Black	Carbon Black Black Iron Oxide	Aniline Black
Brown	Iron Oxide Brown	Benzimidazole
Yellow	Lead Chromate Yellow Iron Oxide	Acrylamide Di arylide
Red	Cadmium Red Red Iron Oxide	Metallized Azo Red Perylene
Blue	Ferric Potassium Ferrocyanide Cobalt Blue	Copper Phthalocyanine Blue
Green	Chrome Green Chromium Oxide Hydrated Chromium Oxide	Copper Phthalocyanine Green

Source: (Abdullah Youssef, 2019)

In short, in paint, there are a lot of compositions that have been used such as binder and resin, plasticizers, pigments and extenders etc. Each of the compositions has its function in painting. The function of a binder or resin is to bind the particles together while pigment and extender are to give colour to paint.

Type of Paint

In the construction industry, several types of paint have been identified. Besides, there are 2 main purposes of paint which are protection and decoration. Paint acts as protection and prolongs the life of the material while paint that used as decoration to decorate the surface. Therefore, paint also can increase the value of the product.

Epoxy paint

Most epoxy paint are two-component system that is utilised for a variety of purposes, including covering concrete, steel structures, and timber grounds as a primer and finish, as well as coating metal surfaces such as petrol pipes and tanks. Coating pipes and tanks for water and oil is a significant coating duty. Epoxies are part of the "thermoset" resin family, which also includes polyester, silicones, urethanes, melamine, acrylics, and phenolics (Sukanya Pradhan et al., 2015).

Polyurethane paint

Polyurethane paint is an epoxy. It is works often based on the 2K system, which has great washability, and chemical resistance, making it appropriate for use on steel, wood, and concrete surfaces. Polyurethanes are a very significant class of polymers with many desired properties for their wide range of uses in coatings, adhesives, and sealants (Sukanya Pradhan et al., 2015).

Varnish

Varnish is a colourless paint that is used as protection and to conceal the prepped surface beneath it (Agrawal & books, 2022). Therefore, there are various varieties of varnish. It is determined by the solvent used.

In short, various types of paint are usually used in the construction industry. Each of them has its function and appearance such as varnish and polyurethane paint. Varnish is often used on timber surfaces meanwhile polyurethane paint is used on steel and concrete surfaces.

As a summary for the literature review, paint was invented by a prehistoric man 25,000 years ago. Despite this, paint has various compositions in it which have their function and characteristics. Also, the construction industry uses various types of   paint such as epoxy paint, polyurethane paint, and varnish. Figure 1 below shows the summary of the paint
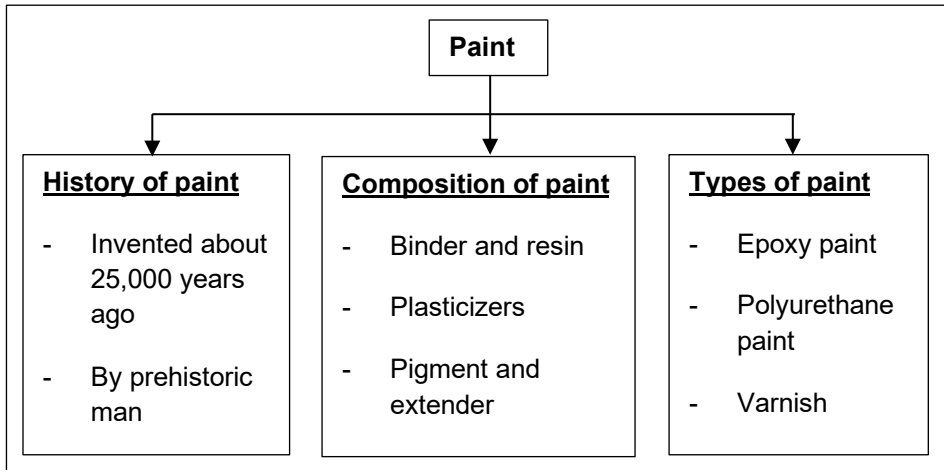
Figure 1: Summary of paint

DATA COLLECTION METHOD

Data collection is the process of acquiring and measuring information on variables of interest in a systematic manner that allows people to answer the stated research questions (Kabir, 2016). Subsequently, this study used 3 types of data collection methods as depicted in Figure 2 below. This study used a desk study to collect and gather all the data related to this innovation project by using existing articles. Moreover, this study also used a design thinking process to collect data to design the innovation project. Furthermore, this innovation project also uses 3dimensional modelling such as Sketchup software to illustrate and demonstrate this innovation project in simulation and animation. Last but not least, this innovation project has no testing due to limited sources and data.
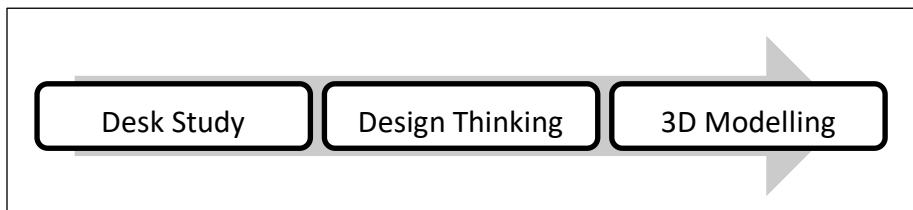

Figure 2: Data collection method used

FINDINGS

The Development of Automatic Spraying Robot For Wall Painting Design Idea

Several existing painting wall products have been identified in this construction industry. Each of these, existing products its advantages and disadvantages. This study aims to develop an automatic spraying wall painting robot that can perform the task of painting building walls by using the spray technique. This innovation project is important in the construction industry to improve the productivity of painting building walls. Plus, it is important to reduce the defects of the building wall in the future.

First and foremost, the existing product is roller-based interior wall painting. Roller-based interior wall painting is a painting robot that consists of a painting arm with an end effector roller that scans the walls vertically and a mobile platform that provides a horizontal feed to paint the entire area of the building walls comprising the robot (Sorour et al., 2011). The advantage of this product is this robot can perform the painting works by itself. This is because this robot has a painting arm that can paint the building wall by using roller techniques vertically. Besides, this robot also has wheels. As a result, this robot can move freely without help from workers or labourers. This robot operates by itself by using the painting arm to perform the painting wall vertically, it does not expose workers or labour to potentially dangerous coating chemicals. In other words, workers or labourers are safe from chemical hazards that can cause internal injury. The disadvantage of this product is the robot requires routine maintenance. To avoid any kind of problems, that happen during the process of painting a building wall, this robot requires frequent maintenance. Therefore, this robot also may raise the cost of construction projects. This is because the cost of hiring robotic machines in construction projects is high. Therefore, the expenses of the project may rise based on the quantity of the robotic machine used.

Other than that, is automatic wall painting. An automatic wall painting robot is an automatic robotic machine made out of an arm that can scan the wall vertically and horizontally while the arm is outfitted with infrared sensors (Monika, 2018). Additionally, this automatic wall painting robot uses spray guns to paint the wall as shown in Figure 3 below. It will determine the distance between the wall and the spray guns. The microcontroller unit is intended to control the direct current motor's movement.

Figure 3: Automatic wall painting robot (Source: Keerthanaa et al., 2013)

Thus, is painting brush or roller tools. Painting a building wall by using a brush or roller is a traditional method of painting building walls (Patil et al., 2022). There are several types and sizes of brush to paint the building walls. Every size and type of brush has its uses and has a different function to use. The advantage of painting building walls by using a brush or roller is this tool is perfect for painting details, or creating a textured impression compared with other machines or painting robots. Therefore, by using this tool, workers can easily get into tight corners and recesses.

The disadvantage of painting building walls by using a brush or roller is time consuming. This is because this method only covers a small area of painting building walls. Therefore, this kind of method of painting building walls demands high numbers of manpower. The workers or labour required to perform the painting building works by using the brush can cause wastage in terms of manpower. As a result of hiring a lot of skilled workers, will cause an increase in the unnecessary cost of the construction project. Apart from that, by performing the task of painting a building wall using this method, it can create defects, mistakes, or human error. This is because this method uses humans to perform the task which means humans can create errors even though they do the task carefully. If the mistake or error happens, it can cause defects in the future. In other words, the quality of the productivity is not good. Defects also can cause increasing costs and extension of time of the project.

Last but not least, is the spray-painting machine. A spraying painting machine is a machine that performs the task of painting a building wall by using the spray techniques depicted in Figure 4 below. The advantage of a spray-painting machine is the quality of the productivity is higher compared with the traditional method. This is because this machine sprays the wall with the same amount of paint layer by layer consistently.

Figure 4: Spraying painting device (**Source:Helen, 2018**)

The disadvantage of this machine is it requires a labourer to operate. This machine can operate with help from humans. Thus, this machine is time-consuming.
This is because this product size is small. As a result, it only covers small areas. Table 2 below shows the comparison of an existing product.

Table 2: The comparison of existing product

Types of Existing Products	Pricey	Required Manpower	Time Efficiency
Roller-Based Interior Wall Painting	/		/
Automatic Wall Painting Robot	/		/
Brushes or roller tools		/	
Spraying Painting Machine	/		/
Pictobot	/	/	/

Table 2 above shows the comparison between the existing product in terms of price, required manpower to handle the product and time saving or time efficiency. As a result, roller-based interior wall painting, automatic wall painting robot and spraying painting machine is quite pricey compared with brushes and roller tools of painting. It is due to this existing product is a robot or machine. While brushes or roller is not a robot or machine. It is a tool that is used for painting building walls. Therefore, roller-based interior wall painting, automatic wall painting robots and spraying painting machines do not require manpower to operate them. It is due to these existing products can operate it by itself. Meanwhile, brushes and roller tools required manpower or skilled labour to operate it. That is why, brushes and roller tools are cheaper compared with other existing products for wall painting.

In summary, the idea of creating of automatic spraying robot for wall painting is based on several factors that have been researched based on the existing products. There

are several modifications and improvements have been added to this innovative product to produce a better-quality product.

Development of Automatic Spraying Robot for Wall Painting

Ideas are important for developing the initiative solution concept. As a result, ideas that are generated through drawing or simple sketches to aid in the model design process emerge.

The idea of this research study is to invent an automatic spraying robot for painting building walls as illustrated in the figure below. Based on a combination of machine and robotic systems. The idea behind this product is that the machine's movement will be entirely controlled by the computer system. As a result, the product does not require manpower or skilled labour to operate it.
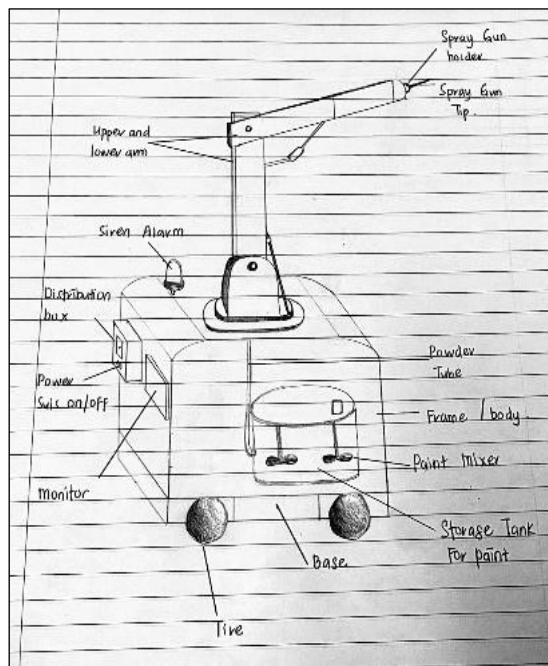
Figure 5: Raw sketch of innovation product

Proposed material and components

Selecting the right material is based on a set of criteria that are derived from the specifications. Identify the most appropriate material for enhancing the product's functionality and dependability. The quality of a product's components has a significant bearing on its final performance. Therefore, the materials used to install the product are also critical to the overall quality and performance of the product. Table 3 below shows the list of components used for this innovation project
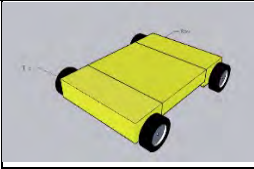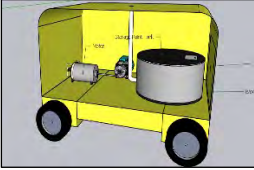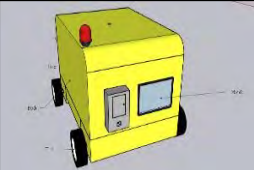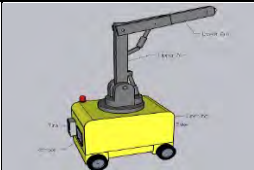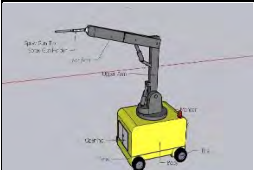
Table 3: List of components used.

Component	Description
Monitor	• Monitor is an output device that can display all information in the form of images and text. • It is including a screen and circuitry.
Spray gun	• Integrated at the tip of the gun.
Lower and upper arm	• The material used is aluminium alloy. • It is a lightweight material.
Powder tube	• It is a tube that permits the powder pump to quickly transport powder through the tube to the gun.
Paint mixer	• A high-speed mixing device. • Consists of the rotating blade that is fixed with the shaft.
Base	• Foundation to the robot. • To carry and support the load from the robot. • The material used is structural steel.
Tire	• Material used is steel and rubber.
Storage tank	• Used to store paint. • Large capacity.
Siren Alarm	• As a security feature.
Gun holder	• Used to hold the spray gun.
Distribution box	• Designed to distribute electrical power.

Assembly of product

In this innovation project, various components need to be installed step by step correctly and properly. It is due, to maintain the functionality of the components. Despite it also can affect the productivity and the performance of the innovation product. The procedure of assembling the components to develop the innovative product that has been designed is as follows. Table 4 below shows the procedure of assembly of the innovation product step by step.

Table 4: Procedure of assembly innovation product

No.	Assembly of component	Image	Description
1	Install tire and base		First of all, several components were assembled to develop this invented product. The tire was attached to the base to develop a rigid and stable base for this invented product.
2	Install body of innovation product		Next, the body of the product was assembled. However, inside the body of the product, there were several components were assembled too such as a storage tank for paint which has mixer paint inside the storage tank, a pump, and a motor.
3	Install a siren alarm, distribution box and monitor		After the body and components inside the body of the product had been assembled, the monitor, distribution box and siren alarm were assembled. The monitor and distribution box were designed and attached to the front of the invented product. However, the siren alarm also was attached to the corner of the body of the invented product.
4	Install arm		Then, install and assemble the arm which consists of the shoulder joint, and the lower and upper arms were assembled. The position of the lower and upper arm was at the top and centre of the body of the invented product.
5	Install spray holder and spray gun tip		Plus, a spray gun holder was attached to the lower arm. The spray gun holder was designed to hold the spray gun tip. Last but not least, the spray gun tip was attached to the spray gun holder.

Operational Process

To operate this innovative product few operational processes, need to be done. Table 5 below show the list of operational process for this innovation product as follows.

Table 5: List of operational process

No.	Operational Phase	Description
1.	Preparation of surface	• Wall surface must be thoroughly prepared. • The robot must be configured to analyse the wall's condition.
2.	Preparation of paint	• Prepared the desired paint. • Pour the desired paint into the storage tank for paint.
3.	Setup the robot path and route	• Switch on the key in the wall's dimension, route and texture. • The function is to smoothen the process of painting a building wall and avoid obstacles.
4.	Start painting	• Painting works mat begin from above to below vertically. • Robot moves its arm along a predetermined course.
5.	Finish	• Robot moves on to the next portion of the wall. • The Robot returns to its starting place after completing the painting works.

In summary, the operation process for this innovation product was divided into five operational phases. In the first phase, before conducting the painting works, the wall surface must be thoroughly prepared. the second phase is the preparation of paint. Third, set up the robot path. The robot path must be keyed into the robot system. After setting up the robot path, it will start the painting work. Last, the robot will return to the starting point.

Performance of Product

This innovative product's performance is very critical in establishing its marketability and reach in the marketplace. It is commonly acknowledged that the ability for this innovation endeavour is crucial to a company's long-term success. With the improvement of performance-based characteristics in this innovation project, it will remain relevant and help project players in the construction sector in particular. Hence, this innovative product is precision. This is because it has been designed to apply a high level of precision that can ensure a consistent and even amount of paint. Additionally, this innovative product can perform painting tasks much faster which can improve productivity and 4 times faster than the brushing and rolling technique. Moreover, it is also a consistent product. It is because this innovative product can apply painting consistently and can eliminate human error during the painting works. Last but not least, in terms of safety, it is safer working environments by reducing the need for workers to be exposed to hazardous chemicals and eliminating workers working in high-risk environments.

In short, the performance of this innovative product can prevent workers from being exposed to chemicals and work in a dangerous area or high-risk area. Also, this innovative product can shorten the period of painting work. Subsequently, it also can solve the issues of uneven quality paint and can eliminate defects or human error.

Marketability Potential of The Development of An Automatic Spraying Robot for Wall Painting

The marketability of a product may be used to assess how quickly and profitably it can be sold and purchased by customers. As a result, the marketability of a proposed innovation project is established by identifying the intended audience as well as the strengths and weaknesses of the proposed innovation project. Thus, a new product's economic viability cannot be presented to the market if it lacks acceptable traits and features for its clients. The builders and contractors will be the target market for this innovative product. This is because this innovative product is suitable for undergoing construction for painting works. However, it is only targeted for a 1-storey building or residential project. Apart from that, by implementing this technology in construction it gives more benefits to the users, especially since this innovation product was invented to solve issues regarding safety and health issues. Lastly, it also can reduce the duration of the construction project.

CONCLUSION

The method of painting building walls involves using brush rollers which can lead to mistakes and human error. This method is impractical due to the shortage of skilled labour in Malaysia. On the other hand, the method of painting building walls by using robotic or machines can be dangerous and pose risks to workers' safety and health. Chemical hazards and physical hazards in painting work can also cause injuries and accidents. This study aims to create an automatic spraying robot for painting building walls using a combination of machine and robotic systems. The machine's movement will be entirely controlled by a computer system, eliminating the need for manpower or skilled labour. The chosen material is based on criteria derived from specifications, to ensure the product's functionality and dependability. Nevertheless, this innovative product's performance is crucial for establishing its marketability and reach in the construction sector. Its precision, speed, consistency, and safety features make it a more suitable solution for builders and contractors. Last but not least, its implementation can provide more benefits to users, especially in terms of safety and health issues. In conclusion, this innovative product can have greater impacts on its users or consumers, such as contractors and workers. It also shortens the time of construction projects.

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Tarikh : 20 Januari 2023

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PEJABAT REKTOR

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Rektor
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Perkara di atas adalah dirujuk.

2.   Adalah dimaklumkan bahawa pihak kami ingin memohon kelulusan tuan untuk mengimbas (*digitize*) dan memuat naik semua jenis penerbitan di bawah UiTM Cawangan Perak melalui Repositori Institusi UiTM, PTAR.

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Sekian, terima kasih.

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