Tanzania Journal of Engineering and Technology 2023, **42(1)**:213-227
OPEN ACCESS articles distributed under Creative Commons Attribution Licence [CC BY-ND]
Websites: https://www.ajol.info/index.php/tjet; https://tjet.udsm.ac.tz

ISSN 1821-536X (**print**); ISSN 2619-8789 (**electronic**)
DOI: 10.52339/tjet.v42i1.900

Special Issue – Seventh International Conference on Mechanical and Industrial Engineering (MIE) 2022 Conference, 20 – 21, October 2022, University of Dar es Salaam New Library, Dar es Salaam, TANZANIA

A Mathematical Algorithm Approach for Estimating Water-Based Paint Requirements for a Given Wall

Costance P. Gambi and Ismail W.R. Taifa*

Department of Mechanical and Industrial Engineering, College of Engineering and Technology, University of Dar es Salaam, Dar es Salaam, Tanzania

*Corresponding email: taifaismail@yahoo.com; itaifa@udsm.ac.tz

ABSTRACT

The research aimed to improve the accuracy of estimating water-based paint requirements for a given wall using mathematical algorithms. The approach used in this study included a survey and document review to obtain details concerning paint. The study focused on water-based paints, including silk, weather guard, emulsion hi-cover and polyvinyl acetate (PVA) roof paint used in Tanzania's building and construction industry. Data collected from the field study were analysed systematically. It was observed that there is a high level of familiarity in improving the accuracy of estimation of the required water-based paints, namely silk, weather guard, emulsion hi-cover and PVA roof paint for a given wall. The algorithm validation was performed by benchmarking the pre-established algorithms. Validation involved conducting five experiments: the physical study by applying two paint coats on a wall and recording the results. The percentage errors of a painting by approximating the paint using the algorithm developed gives better results than that from the different projects held in Tanzania, which was taken as a sample. The novelty of this study is based on the developed mathematical algorithm. In fact, this is among the fewer studies that mainly improve the accuracy of estimating the paint required for a given wall using a mathematical algorithm in Tanzania. There are limited studies of that nature as the majority use experience, which result in higher discrepancies.

ARTICLE INFO

Submitted: **Aug. 17, 2022**

Revised: **Sept. 17, 2022**

Presented: **Oct 21-22, 2022**

Accepted: **Dec. 15, 2022**

Published: **Feb. 25, 2023**

Keywords: *Improving estimation accuracy; Quantity estimation; Wall painting; Water-based paint; Mathematical algorithm.*

INTRODUCTION

Paint is known as a pigmented solution. When applied on the surface, it dries and forms a thin layer to decorate and protect (Sharma, 2016; Oladipo *et al*., 2013; Almansoori *et al*., 2021). Paint is commonly used to protect, colour, or provide objects' texture (NPCS, 2015). Paint has three main purposes: decorating, protecting and texture-giving. In our daily life, paint cannot be easily separated from us, from where we store our products in containers, the houses we live in and even cars for oil-based paint (Standeven, 2011; James and Taifa, 2022). Paint is one of the highest-selling products in the construction market, and its price is generally high. So, being unable to know the amount needed for a building is really frustrating. Many paint producers are available in Tanzania, including Coral paints, Goldstar paints, Billion paints, Galaxy paints, Sadolin paints, Rabiallac paints, and Crown paints, among others.

Paint consists of pigments, solvent, binder or resin, additives and extenders or fillers. Among the paint components, pigment is responsible for providing the shade of the paint. There are several shades in every kind of paint; these include white, pale blue, and black, among others. Solvents are responsible for providing the flow ability of paint, solvent aid in reducing cost, and completing the formulation (Youssef, 2019). The world's demand for paint has been increasing day by day. This is mainly because of the increased building construction but also the need for woodwork finishing for a shiny appearance (Jain and Sharma, 2016).

Paint approximation can be in terms of the required temperature, time to complete the task, the colour that matches the wall or surface, quantity in terms of kilograms or volume needed in litres, etc. However, most paint approximation focuses on the volume of paint before purchasing or procuring. The issue of poor quantity or volume of paint approximation in most of the building materials, including paint, has been discouraging sponsors from financing the project as the project seems to cost high (Acharya *et al.*, 2004). The question to be asked is whether someone can say the amount of paint needed to complete a certain wall or building; of course, the accuracy is inferior for most scenarios (Joseph, 2010). Paint is highly demanded for decorative and industrial use. For example, in the case of India, the decorative sector accounts for about 73% of the total paint demand and 23% accounts for industrial demand (Jain and Sharma, 2016). In comparison, the world market is 50% for decoration and 50% for industrial use (Jain and Sharma, 2016). An accurate approximation is necessary for an ongoing project to ensure the client's budget meets the expected output of the project. There is no 100% efficiency in approximating the amount of paint required, as painting is more an art and not a direct science (Ugochukwu *et al.*, 2020).

Estimating the volume of paint is currently performed just by approximating with experienced painting experts who observe the area to be painted (wall surface), windows, doors, and ceiling boards, among others. However, estimating the required paints for different construction projects is challenging. Thus, this study focuses on the wall surface. The approximation has been a custom for many days, which is also a problem in the documentation of the project cost.

So, estimating the quantity of paint required for a given wall surface, basically for water-based paint, has been a problem for a couple of years. This is because the painters only estimate manually without knowing the expected paint, which raises quarrels between painters and building owners. They both think there is some cheating, while it might be just poor paint estimation of the amount required (Ugochukwu *et al.*, 2020).

Several researchers have performed studies to estimate the required paints and the cost estimation of the paint required. For example, Kiil *et al.* (2010) researched approximating the amount of paint but was based on polishing paints such as varnish and Hi-gloss paints. Naticchia *et al.* (2006) set up a robotised system for interior wall painting. Naticchia *et al.'s* (2006) study involved the following issues: paint flow was set to 0.3 g/s via the adoption of a small aerography spraying on a circle having a 0.06 m long diameter; distance from the wall, equals to 0.08 m; air pressure, set at 3×10^5 Pa; paint type, i.e., water-based; trajectories, that is, a two-coat paint was applied on the internal surface of plaster walls; and spraying type, which is aerography. Likewise, Naticchia *et al.* (2007) set up an automated multi-colour system for interior wall painting in Italy. When developing an algorithm or any mathematical approach for estimating the volume of the required paint, the aim should be to have minimal errors. Thus, developing an application (algorithm) that accurately approximates or estimates the quantity of paint required for a given wall surface is important. In fact, reducing such errors while estimating the quantity for a given wall of the surface contribute to saving costs and align with the budgeting issues. As over-estimation or underestimation are costly, the effectiveness and accuracy in approximating the required paint quantity can encourage project completion on time. This study thus focuses on establishing how the estimation can be completed for the painted with two coats.

THEORETICAL BACKGROUND

Paint

Paint is a pigmented solution that, once applied on the surface, dries and forms a thin layer to protect, decorate or symbolise (Sharma, 2016; Youssef, 2019; Almansoori et al., 2021). Paint can originate from coloured rocks since ancient times, but several improvements have been performed to date as it can be obtained in paste form. Paint is important in multiple ways (Rudd, 2017); for example, MoW (2020) highlighted the importance of painting walls and types of machinery, thus being to prevent corrosion, prolonging the weld's life, etc. The basic concern is household paint, which has some characteristics, such as being easily applicable and plasticity in nature (Standeven, 2011). In addition, the paint should be resistant to heat and weather changes (Standeven, 2011). Painting sometimes reflects the process of delivering information to the community issues like values, norms, and customs can be presented in paintings (Silva *et al.*, 2021). Paint application needs to be performed on a clean surface and free of contamination between the surface to be painted and the paint.

Area of the wall to be painted

Paint is applied on a surface or material, and the different components that can be painted include building walls, metal works, vehicles, and different properties. The study's concentration is on estimating the paint to be painted on the building walls. Paint coverage is what gives the relation between paint and the area to be painted (Standeven, 2011). According to Pandey and UV (2020), the area of the wall is directly related to the paint quantity required and the coat's thickness; as long as the coat is one, the quantity of paint will be minimal. The area in consideration is the one that is to be painted, so windows and doors can be removed from that area (Ugochukwu *et al.*, 2020). Figure 1 shows how painters execute the painting job. The paint volume must be estimated appropriately because without knowing how much it costs and the accuracy required, it may result in huge errors, thus delaying the project. In fact, material consumption contributes hugely to the performance of the particular project (Taifa and Lushaju, 2020; Taifa *et al.*, 2021).

Figure 1: Painter working in Dar es Salaam, Tanzania.

Estimation accuracy

Estimation is defined as the rough calculation of the value, number or quantity of something. Estimation is the most complex issue for both clients and painters, and the complexity comes from many individuals being involved in estimating the paints (Leung *et al.*, 2007). In construction activities, estimation accuracy is one of the drawbacks for the construction project to succeed. Most government construction activities can increase costs for several reasons, including poor estimation of the construction materials and finishing products such as paints (K'Akumu, 2007). For the case of accurate approximation of paint for a wall, it is challenging in all construction projects. An estimation of the required paints during the construction phase directly affects the project budget in terms of financial matters, which encourages or discourages clients and investors from carrying on their projects. In the cost estimation of the painting, the labour cost should be directly added to the painting cost. It should be noted that in estimating the cost, the cost increases with the area to be painted and the nature of the wall (Ugochukwu *et al.*, 2020).

Paint application

Paint applications consider a lot of factors. All factors add up to get the final surface with smoothness finish. These factors include the surface to be painted, the type of applicator, and the thickness of the coat being painted. Other factors include temperature, tools used for paint application, and pre-preparations of walls, such as skimming. Paint application needs experts who are well experienced in mixing to obtain the flowing nature of paint to be applied to the walls (NPCS, 2015). For the case of mixing, it is concerned with the solvent that is being used to dissolve the paint, on which for water-based paint, it is water which requires an appropriate ratio. The ratio depends on the specific gravity of the paint, which differs from one paint type to another.

The algorithm

A mathematical algorithm is an algorithm that deploys the mathematical concept in solving the problem, that is, achieving a goal. An algorithm is a step-by-step procedure designed to achieve a certain objective in a finite time, often with several steps that repeat or "loop" as many times as necessary (Wright Group, 2001). An algorithm can be direct or indirect, with inputs to feed on it to obtain the pertinent output. Therefore, an algorithm is a set of procedures designed to be performed step by step to achieve a certain objective, often with a loop repeated for the number of activities. Ugochukwu *et al.* (2020) reported the algorithm that aids paint application and general cost. Ugochukwu *et al.'s* (2020) study, the algorithm came up with the results in which equation (1) describes the algorithm that was developed by Ugochukwu *et al.* (2020).

$$U_p = YA_m \times C_p + YL_p \tag{1}$$

where: *Up*= Unit cost of painting; *Y*= Area to be painted; *Am*=Average quantity of the material per square meter; *Cp*=Cost of material per metre square; and *Lp*= Cost of labour per square meter.

This equation (1), the algorithm developed from the research and studies, included the cost of paint and the labour cost per square meter where the paint was required to be applied. From the developed algorithm, the coverage was found to be different depending on the type of paint. So, the coverage based on the Nigerian paint market was analysed as per Table 1, which summarises the results from the algorithm.

Table 1 Painting material per square meter

S/N	Paint brand	Paint type	Average paint per square meter (L/M^2)
1	Dulux	Emulsion	0.2602
		Matte	0.1735
		Silk	0.1735
2	Intercolour	Emulsion	0.2602
		Matte	0.1735
		Silk	0.1735
		Texcoat	0.7806
3	Homepride	Emulsion	0.7806
		Texcoat	0.2602
4	Sharon	Emulsion	0.5204
		Matte	0.2606
		Silk	0.2606
		Texcoat	0.7806
5	Finecoat	Emulsion	0.5204
		Matte	0.1735
		Silk	0.1735
		Texcoat	0.7806

Source: **(Ugochukwu *et al.*, 2020)**

Proper systematic and procedural painting processes can result in an accurate paint approximation. Paint estimates are accomplished with experts locally. So, researchers, including Närman et al. (2011), have performed the study on accuracy in estimating. Närman et al. (2011) explained how improvements in the approximation of construction give an advantage to project success. To improve the process, the necessary components include a tape measure, paint, roller or brush (applicator), proper surface for paint application, water, a device for mixing paint and solvent, and a bucket. Närman *et al.* (2011) deployed an architecture analysis technique. The approach employs the Probabilistic Relational Model formalism and ArchiMate to model and analyse data accuracy.

Related studies and the research gap

There are some studies on paint. Acharya *et al.* (2004) studied the use of deltamethrin as it is harmless to mammals and human beings and is less toxic compared to organ phosphorus, organochlorines and carbamate insecticides, which have been used in the previous technology. Paints are used to decorate wood and protect buildings; additional pesticides create an environment that does not allow insects to harm it (Zailani *et al.*, 2016). For a long time now, different studies and researches have been conducted on construction delay; these are divided into two sections: the factors that cause delay and the effect of delay on the project (Zailani *et al.*, 2016). GEOMET Technologies Inc (2001) developed the Wall Paint Exposure Model (WPEM). So, these studies encourage more studies to ensure effective and efficient estimating for construction activities. This makes a need to study the paint quantity estimation of a given wall.

Most current studies attempted to approximate the quantity or volume of paint required without considering the technological change. Most concentrate on oil-based paints (Kiil *et al.*, 2010). This brings a gap concerned with water-based paint, which is mostly used daily. This is because the community's economy is moderate (middle class), and water-based paint is related to this economy. These water-based paints include silk, weather guard, Hi cover, and roof paint. The theoretical underpinnings indicate that the focus should be on water-based paint that is silk, weather guard and emulsion hi-cover. The approximation and coverage of paint are always affected by the following factors: the condition of the surface to be painted, the thickness of coats, the number of coats, the method of application (using brush or roller) and environmental conditions. All these factors determine the outcome of approximation, and the approximation obtained can be converted to monetary value. The research conducted at the end of the algorithm should provide the desired outputs.

RESEARCH METHODOLOGY

Study area

This study was conducted in Dar es Salaam, Tanzania, which has the highest population, and most of the construction activities in Tanzania use water-based paints. The study area was chosen due to the abundance of painting works where painting professionals are widely available: painters, quantity surveyors, paint supplies, and paint manufacturers. This is achieved easily as the region has people with different skills and knowledge of paints. In addition to that, all types of paint from different companies are readily available, and it is also an industrial and commercial city. In addition to that, different bills of quantities (BOQs) are available for the case of paint building works.

Methods

This study adopted different research approaches to achieve the specific objectives, including surveys, experiments and focus group discussions. These approaches are suited for developing mathematical algorithms for estimating the required quantity of paint.

Sample size and population

The study population included building professionals (architects, engineers, quantity surveyors, and experienced painters), paint manufacturers, and suppliers. For data reliability and cost reduction, the purposive sampling technique was employed. The factors studied were experience, skills level, capacity and ability. Different categories were derived from these factors, and the respondents were painters, quantity surveyors and civil engineers. Twenty-two semi-structured interviews were employed with the respondents based on their skills in the referred study area.

Paint coverage per square meter

Paint coverage per square meter consisted of different calculations and dimensions with high accuracy. This increases the percentage of accuracy of the developed mathematical algorithm. Different materials and equipment were used to access the final formula, including a tape measure, paint, roller or brush, proper surface for application, buckets for paint mixing, weigh balance, calculator, pen and notebook. The following procedures assisted in calculating the coverage with the following assumptions (equations 2 to 4).

$$Room\ dimensions\ =\ 3.6 \times 3.6 \times 2.8\ m \tag{2}$$

$$Window\ dimensions\ =\ 1.2 \times 1.2m \tag{3}$$

$$Door\ dimensions\ =\ 0.9 \times 2.1m \tag{4}$$

The following are procedures to calculate the coverage area and other related dimensions.

i. Calculate the area of the wall to be painted (room excluding window and doors), call it **A**
ii. Add all weights of the properties to be used in the application by weighing balance; call it $\mathbf{W_0}$
iii. Apply the paint to the wall
iv. Add all properties' weight after application and call it $\mathbf{W_1}$
v. Find out the difference in weight in step two and step four
vi. Calculate the spreading capacity of the paint

The above procedures yield equation (5).

$$Weight\ of\ paint\ used\ (W)\ =\ W0 - W1 \tag{5}$$

Now, since we had the area to be painted then, from the formula of Specific Gravity (S.G) (equation 6);

$$Volume\ of\ paint\ used\ = \frac{Weight\ of\ paint\ used}{Specific\ gravity} \tag{6}$$

The volume obtained here is in a cubic centimetre (cc), called **V**cc; thus, after obtaining the volume of paint used **V**cc from equation (7), then we conversed as follows;

$$\boldsymbol{A}\ sq.meter\ =\ \boldsymbol{V}cc;\ X\ = 20 \times 1000\ cc \tag{7}$$

Then, we obtained the paint coverage for a 20L bucket, and from it, we came up with the coverage for one square meter (equation 8).

Defined as:

$$X = \frac{((20{\times}1000cc) \times (A\ sq.meter))}{\boldsymbol{V}\ cc} \tag{8}$$

Now the coverage differs from one type of paint to another, so for every type of water-based paint, the coverage differs from the other as materials (content) differ from one type of paint to another.

Algorithm

This is a step-by-step procedure designed to achieve a certain objective in a finite time. Many steps generate a loop and are executed as many as necessary until the accuracy has been attained. Basically, the algorithm describes how the problem can be solved (Wright Group, 2001). The common algorithms we are familiar with are the basic four that is multiplication, division, additional and subtraction.

Different types of algorithms available include the following recursive algorithm, divide and conquer algorithm, dynamic programming algorithm, Greedy algorithm, Brute force algorithm and backtracking algorithm. Now, all these algorithms depend on the nature of the problem, from where someone may determine which type of algorithm fits the problem being solved. The following are basic steps followed up to develop the algorithm.

Step 1. Obtain details of the problem comprehensively

Step 2. Analyse the problem

Step 3. Develop a high-level algorithm

Step 4. Refine the algorithm via additional details

Step 5. Review the model (algorithm) as many as necessary

Step 6. Validation of the model.

Data collection method

In order to collect data, both primary sources and secondary sources were deployed. Primary data comprised real physical observation, semi-structured interviews, market survey and work-study. All these resulted in details on developing a mathematical algorithm. Secondary data included the review of the bills of quantities (BOQ) for past buildings based on the painting section. Additionally, online sources and theoretical underpinnings were used to gather different literal works. This study also involved different stakeholders, e.g., painters, clients, paint suppliers, quantity surveyors, and paint manufacturers.

Data analysis technique

Most of the collected data were obtained from experienced experts. For the case of data analysis, simple arithmetic computation was used to describe and analyse the data collected. In addition, description and content analysis methods were imposed and carried out by experts in painting works. Some data were collected by applying paint on the building walls (vertical walls).

Ethical consideration

This study considered all ethical issues, analysing all norms and customs of society. The study was executed in cooperation with community members such as painters, paint suppliers and construction professionals. This enabled compliance with the community ethics as we have community members in for this study.

Data reliability and viability

The quality of the research was assessed by checking the accuracy and consistency of the data measured and collected. Regarding reliability, the concern was on the way the algorithm shows consistency in the data being obtained. This was achieved by performing several experiments while developing the algorithm. In the case of data viability, the concern was on ensuring the accuracy of the measured measurement. This includes wall measurements, the quantity of paint, and the wall applicator (brush or roller) issue. Achieving data reliability and viability provided the research's quality (Nchalala *et al.*, 2022).

RESULTS AND DISCUSSIONS

Data collection

The data of this research were collected from different stakeholders. These stakeholders include painters, paint sellers, quantity surveyors, and companies estimating building materials. A discussion was conducted, where different individuals and experts in the paint industry contributed their ideas. From the conducted discussion, different data were obtained.

Table 2 shows the distribution of how the respondents were numbered according to their professions. This includes both skilled labour and unskilled, while well-experienced individuals are classified as semi-skilled labourers.

So, the respondents were classified as per Table 2, consisting of three organisations concerned with building and painting: Suma JKT, National Housing and JPC Quantity surveyors. So, the total number of respondents for the questionnaire was 57, and the answers from these questionnaires provided the way through for the research.

Table 2: Distribution of respondents on the questionnaire

S/N	Organisation	Painters	Quantity surveyors	Engineers	Total
1.	Suma JKT	5	10	5	20
2.	National Housing	7	10	4	21
3.	JPC Quantity surveyors	_	12	4	16
Total		12	32	13	**57**

Tabulation of actual paint used to approximate paint (expected paint)

There are a number of techniques and methods being in the application by different organisations to approximate the amount of paint that would be required for a given wall. The organisations with these data being studied are NHC, TBA, JPC quantity surveyors and SUMA JKT. They deal with the approximation of building materials and also building. These data are from different organisations holding construction projects dealing with building materials' approximations. They are from the currently completed project located in different areas of Tanzania's mainland from early 2020 to February 2022 (Table 3). From Table 3, the paint quantity was recorded and measured in kilograms (kg).

Table 3: Construction project and their approximation quantity and actual quantity

S/N	Organisation	Project	Category (ownership	Approximated paint (kg)	Actual paint used (kg)	% Errors
1.	TBA	Magomeni kota (644	Overnment	95953	120756	20.44
2.	TBA	Helvetas Dodoma	Private	11920	9760	22.13
3.	NHC	NHC Dodoma	Government	89934	76000	18.33
4.	SUMA JKT	VP office	Government	52080	43400	19.99
5.	JPC QS	China civ	Private	26800	28700	6.62

Additionally, Table 3 indicates the distribution of actual paint used in the client's painting project. This is the amount of paint that was realised to be used on the project; from the figure, Magomeni kota 644 is the maximum amount of paint used, amounting to 120956 kg of paint. This highest amount of actual paint is due to the project scale, and the project is large. Helvetas Dodoma accounts for the smallest actual paint quantity used, which was 1960 kg of paint.

The paint quantity used or applied always depends on the scale of the project; large and complex buildings will account for a large amount of paint. Project complexity will increase the counting error as the point of application is not easy; for example, painting on the roof accounts for more paint than the building. Figure 2 shows the variation of percentage errors by different projects held by different organisations, which developed from the details of the actual paint used and the approximated paint quantity (kg).

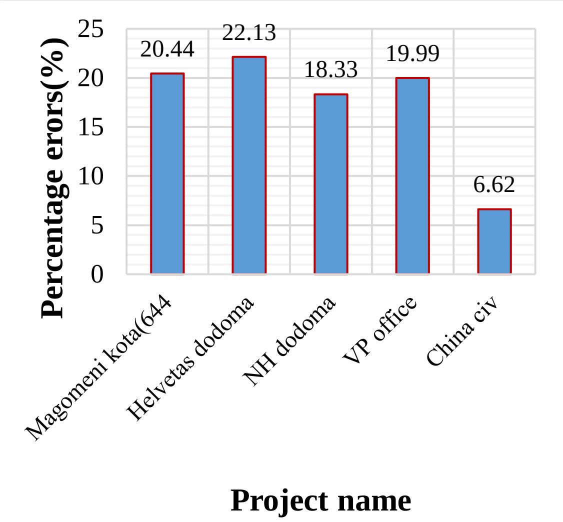

Figure 2: The percentage errors for different project

From Figure 2, most of the projects yield a percentage error which is greater than 10%; from the document review, the tolerated error for most of the building activities, including wall painting, is 10%, but for the data of 5 projects, only one has a percentage error which is less than 10%. The expectation for a high percentage of errors is for roof painting which accounts for the high level of counting errors, on which 10% to 20% is a tolerated error for roof painting, including ceiling board. This is because roof painting faces the direct force of gravity, which pulls the paint down. Helvetas Dodoma amounts the large percentage error among all accounting to 22.13%, which is high and shows poor approximation, and accuracy is generally low for the method used. A high percentage error means a loss to the customer; this is because having a positive error means a client has more paint than required. When having a negative percentage error, the client's budget can be altered as s/he is supposed to buy more paint to fulfil the project's needs.

Identification and categorisation of common types of paints under study area

Content transcription from semi-structured interviews of skilled and semi-skilled labour revealed different types of paints in Tanzania. Paints in the Tanzania market and worldwide, in general, are categorised into two types: water-based paint and oil-based paint. This research is concerned with water-based paint. The walls of most buildings tend to use both water-based and oil-based paint. This study focused on water-based paint. Under physical observation, work-study and semi-structured interviews, the following category were analysed.

Oil-based paint, from this category, also paints under different forms and structures are detailed as follows.

- NC paints; this paint is commonly used in furniture and woodwork. This paint has protection against insects and is highly gross in nature.
- 2k paints; this paint has a high percentage of long oil alkyd and is commonly used in automobile painting. This paint has high level of gross, and the coating thickness is big.
- Road marking paints; this paint is used in drawing the markings on the road, and it is common in two shades that are white and yellow.
- Other oil-based paints available in Tanzania are high gross, bituminous, and epoxy paint.

Water-based paint; similarly, different water-based forms are available depending on the use and condition of the place where the application would take place. So, with water-based paints, the classes are as follows.

- PVA paint: Polyvinyl Acetate is commonly used in roof painting because it is aggressive towards corrosion, tear and wears out of the roof.

- Hi cover paint: this is the economy class of paint since its price is relatively low, and it is available in most of the Tanzania's regions. It is commonly used to paint walls of the building. To some industries, it is called "budget paint"; this name is due to its price, while others call it emulsion hi-cover paint.
- Silk paint: having a high binder concentration makes this paint aggressive in terms of cost. It is the first choice in government buildings and public apartments, but also this paint has a high gloss among all water-based paint. It has been a choice for the buildings that need to last long, maybe for 20+ years.
- Weather-guard paint: this type of paint is good for protecting the building from the weather effects such as humidity, sunrays and rain. It is in three basic forms: weather guard white, weather guard base N and weather guard base P. These two bases, N and P, are used for tinting to get different shades out of the white shade, which is produced independently. Weather guard is commonly applied for exterior paint, matt finish, and larger film thickness, protecting weather conditions such as rain.

From the identification of the paint category, our concern is water-based paint in 3 different categories: silk painting, weather guard and emulsion Hi cover. Now, in the case of silk, its content is highly concentrated in the binder, also termed glue. For the case of weather guard, the concentration of binder is high but not as much as that of silk. Emulsion Hi cover has the lowest amount of binder among all, and this even makes it economically sweet, but in terms of quality, it is the lowest in the row. Furthermore, identification and categorisation of common types of paints under study can be of much importance should it be shown how the paints categories make them different when estimating the quantity to be used.

Determination of the average paint quantity required per square meter of a wall

Different methods are used to approximate the paint required for a given wall; now, worldwide, details and studies tell us that the rate of paint volume per square meter, also termed as the coverage for water-based paint in exceptional PVA roof paint, is 1.587 (Jain and Sharma, 2016). For our case, to obtain these details, a standard room with dimensions [(3.5m×3.5m×2.7m high)], a door of [(0.9m×2.1m] and a window of [(1.2m×1.2m sides)] was used and paint was applied, and the following details were yielded (see equations 9 to 13);

$$Area\ to\ be\ painted\ is\ as = area\ width \times length \tag{9}$$

Width =3.5m and Length =2.7m

Length =2.7m

The number of sides is 4. Then;

$$Area = 3.5m \times 2.7m \times 4m = 37.5m\ square \tag{10}$$

Area of the openings, i.e., window + door

$$Area = 1.2m \times 1.2m + 0.9m \times 2.1m \tag{11}$$

$$Area = 3.3m\ square \tag{12}$$

To obtain the area to be painted, subtract the openings from the area of the room, i.e., the area to be painted of a standard room is 37.5 square meters. Keeping in touch,

$$1bucket = 20\ litres\ of\ paint \tag{13}$$

The amount of 2 saddles of 4 litres covered the room. We deduce the coverage by dividing the area by a unit square meter (equation 14).

= (37.5 - 3.3) =34.2 square meter and the volume taken is 4×2 = 8 liters

$$Coverage = \frac{8\ litres}{34.2\ square\ meter} \quad (14)$$

Coverage = 0.2339 litres per square meter; this is the coverage from the field study.

Figure 3(a) indicates different tools, accessories and materials used in the paint application process in a standard room. Likewise, Figure 3(b) shows the ready-prepared paint.

Figure 3: (a) paint and brush on preparation for painting (b) ready prepared paint for application

The field study analysed the coverage as 0.2339 litres of paint per square meter. These results have been established after the application of paint to the building walls of a standard room.

Development of a mathematical algorithm equation for estimating the paint quantity

Some factors could not be considered in the model's development since they cannot be easily assessed. The assumptions are as follows:

- Constant temperature and pressure (environmental constant).
- Two coats are accounted for.
- Hand rollers and brushes are the applicators being used.
- Do not use the compressor
- One paint type is applied at a time.
- The primer has been smoothly applied.
- Qualified painter is required

Once the paint coverage has been attained for the desired paint, then, equations (15) to (18) were used to get the required algorithm.

$$volume = \big((A - G) \times Coverage\big) - e \quad (15)$$

$$Coverage = \frac{weight\ of\ paint\ used\ in\ kg}{specific\ gravity} \quad (16)$$

But ***G*** stands for the area that will not be painted and is calculated, as per equation 17, as follows.

$$G = w + d + g \quad (17)$$

whereby, A = Area of the wall such as room, W = window area if any, d = door area if any, g = area of places not to be painted, and e = counting error.

Counting error accounts for the amount of paint lost during the application, on which the error is about 5% of the total volume of paint applied (GEOMET Technologies Inc, 2001). This includes the paint flowing down during the application; we call it floor paint. The applicators also absorb the paint.

As some amount of paint falls at the point of application, this might be due to roller condition or brush. Now, all these data are for the walls that have been applied and yield similar results. For the 20 litres as the volume of paint, the error would be as shown by equation 18. So, the actual volume would be 19 litres of paint because the 1 litre would be expected as an error.

$$e = 5\% \times 20litre = 0.05 \times 20litre = 1\ liter \quad (18)$$

Validation of the algorithm (model)

Various methods can be used to evaluate, analyse and validate the developed model. One of the validation techniques that can be used is benchmarking to the pre-established algorithm that different scholars developed. By referring to equation (1) for establishing painting cost in Nigeria, with equation (15) developed from this study, they offer a similar approximation of paint quantity. Table 4 indicates the data that were obtained from the field study, and the data for the paint approximation of a given project was recorded. The project names are virtual due to confidentiality purposes. The algorithm in the application is in equation (15).

Table 4: Paint approximation of a given project

S/N	Project name	Ownership	Area to be painted (m^2)	Company name	Paint type	Approximated paint (Liters)
1.	Project V	Private	756.72	Kiboko paints	Hi-cover	157.94
2.	Project W	Private	912.00	Kiboko paints	Silk	167.72
3.	Project X	Private	98.88	Coral paints	Silk	18.18
4.	Project Y	Private	17.53	Gold star	Weather guard	3.22
5.	Project Z	Private	1578.97	Gold star	Hi cover	29.05

The amount of actual paint used in these projects was recorded immediately after applying paint on the wall with two coats. Table 5 indicates the amounts of actual paint used at the end of the paint application and the paint company name.

Table 5: Project name and the actual paint used

S/no	Project name	Ownership	The area painted (m^2)	Company name	Paint type	Actual paint (litres)
1.	Project V	Private	756.72	Kiboko paints	Hi-cover	147.90
2.	Project W	Private	912.00	Kiboko paints	Silk	168.43
3.	Project X	Private	98.88	Coral paints	Silk	22.32
4.	Project Y	Private	17.53	Gold star	Weather guard	3.54
5.	Project Z	Private	1578.97	Gold star	Hi cover	29.05

The study came up with the details and information that aid in developing the mathematical algorithm for estimating the paint quantity required for a given wall. So. the algorithm developed here and marked as equation (15) aids in approximating the paint for wall painting. From the percentage error view, the percentage error is reduced by approximating the paint required using the developed algorithm. The results from this study linked the approximation of water-based paint for a building wall which was the gap analysed; thus, the study has covered the gap. The data presented in Table 6 indicates the percentage error encountered from these five projects to be under 10%, which is the desired percentage error. For these projects, only one has a high percentage error above 10%, which shows the developed algorithm's accuracy.

Table 6: Project name and the percentage error encountered

S/N	Project name	Ownership	Area painted (m^2)	Company name	Paint type	Percentage error encountered (%)
1.	Project V	Private	756.72	Kiboko paints	Hi-cover	6.79
2.	Project W	Private	912.00	Kiboko paints	silk	0.42
3.	Project X	Private	98.88	Coral paints	silk	18.55

4.	Project Y	Private	17.53	Gold star	Weather guard	9.04
5.	Project Z	Private	1578.97	Gold star	Hi cover	9.22

From the study's results (Table 6), the observed percentage error in project X (NPCS, 2015) seems abruptly high, counting to 18.55%. This is due to various factors that were not pre-established in the early stage of wall painting, and with this, the condition of the wall was not good; the wall had a lot of holes and was highly rough. This uses a higher amount of paint than the approximated amount by the algorithm (equation 15).

CONCLUSION AND RECOMMENDATION

Paint is one of the building materials that cannot be avoided during construction mainly because it is one of the factors of concern for visualisation. Speaking of paint, this is the final product that a client will see and comment on it; it differs directly from bricks. The brick errors can be hidden by the plaster and, finally, the paint. The developed mathematical algorithm would aid the estimators in conducting their work properly. Likewise, the client can see how much it might cost in terms of paint. The approximation accuracy of the water-based paint of a building wall was successfully improved, and the algorithm was developed. Compared to the percentage errors of five projects presented in Table 3, the algorithm's approximation results were better.

The percentage errors of a painting by approximating the paint using the algorithm developed from this study gives better results than that from the different projects held in Tanzania, which was taken as a sample. The algorithm was validated by conducting five experiments: the physical study by applying two paint coats on a wall and recording the results. Its procedures included approximating the paint required and recording by using the algorithm-developed, then applying the paint, recording the actual paint used, and calculating the error percentage that arose.

Limitations and Future Studies

From different points of view, some activities and scenarios were the constraints and drawbacks towards the accomplishment of the research study. Some limitations arose as the study was in progress. These limitations include the following:

i. This study has focused only on water-based paint, namely silk, weather guard and emulsion hi-cover, while there are other types of water-based paints.
ii. Paint coverage of one shade differs from one to another, and this research has not gone through each shade; for example, two shades of black would be enough to cover the wall, but for white, at least three to four coats can ensure coverage.
iii. The specific gravity of paint differs from one company to the other; now, these differences would provide different approximations of the same paint from two production companies. For example, Kiboko silk paint S.G is different from that of Goldstar silk paint; hence even the approximation will be different

It is recommended to perform further studies and technology involvement that could develop an application for the approximation of paint required for a wall and even increase the scope to furniture and automobiles. This can be done to all types of paint, basically oil-based paints and water-based paint in all types that are available globally. Developing the application would be more efficient and accurate in approximating, though in terms of cost, it will be high. For better results, more studies and research need to be performed to ensure accuracy, consistency and quality work.

REFERENCES

Acharya, B.N., Nivsarkar, M., Saxena, C. and Kaushik, M.P. (2004), "Effects of the process of the incorporation of deltamethrin on slow release property of insecticidal paint", *Pigment and Resin Technology*, **33**(1): 21–25.

Almansoori, N., Aldulaijan, S., Althani, S., Hassan, N.M., Ndiaye, M. and Awad, M. (2021), "Manual spray painting process optimization using Taguchi robust design", *International Journal of Quality and Reliability Management*, **38**(1): 46–67.

GEOMET Technologies Inc. (2001), Wall Paint Exposure Model (WPEM) Version 3.2 - User's Guide, available at: https://www.epa.gov/sites/default/files/2015-05/documents/wpemman_0.pdf.

Jain, A.K. and Sharma, V. (2016), "A Study of Paint Industry With Special Reference to India-2016", *International Journal of Scientific Research*, **5**(9): 222–224.

James, J.M. and Taifa, I.W.R. (2022), "Quality improvement of long oil alkyd (LOA) resin requirements in the formulation of Hi-gloss paints", *International Journal of Quality and Reliability Management*, available at:https://doi.org/10.1108/IJQRM-08-2022-0247.

Joseph, R. (2010), "Painting problem solver", *Metal Finishing*, **108**(9): 23–24.

K'Akumu, O.A. (2007), "Construction statistics review for Kenya", *Construction Management and Economics*, **25**(3): 315–326.

Kiil, S., Dam-johansen, K., Weinell, C.E., Pedersen, M.S., Kiil, S., Dam-johansen, K., Weinell, C.E., et al. (2010), "Estimation of Polishing and Leaching Behaviour of Antifouling Paints Using Mathematical Modelling: A Literature Review", *Biofouling*, **19**(S1): 37–43.

Leung, M.Y., Skitmore, M. and Chan, Y.S. (2007), "Subjective and objective stress in construction cost estimation", *Construction Management and Economics*, **25**(10): 1063–1075.

MoW. (2020), Design, Construction Supervision, Operation and Maintenance (DCOM) Manual, Ministry of Water (MoW), Dodoma, Tanzania, available at: https://www.maji.go.tz/uploads/publications/sw1640159401-28. Design, Construction Supervision, O&M of Water Projects Manual Vol. IV.pdf.

Närman, P., Holm, H., Johnson, P., König, J., Chenine, M. and Ekstedt, M. (2011), "Data accuracy assessment using enterprise architecture", *Enterprise Information Systems*, **5**(1): 37–58.

Naticchia, B., Giretti, A. and Carbonari, A. (2006), "Set up of a robotized system for interior wall painting", 2006 Proceedings of the 23rd International Symposium on Robotics and Automation in Construction, ISARC 2006:194–199.

Naticchia, B., Giretti, A. and Carbonari, A. (2007), "Set Up of an Automated Multi-Colour System for Interior Wall Painting", *International Journal of Advanced Robotic Systems*, **4**(4): 407–416.

Nchalala, A., Alexander, T. and Taifa, I.W.R. (2022), "Establishing standard allowed minutes and sewing efficiency for the garment industry in Tanzania", *Research Journal of Textile and Apparel*, doi: 10.1108/RJTA-09-2021-0112.

NPCS. (2015), "Formulation and Manufacturing Process of Paints Pigments Varnishes and Enamels", Niir Project Consultancy Services (NPCS), available at: https://www.entrepreneurindia.co/blog-description/347/formulation+and+manufacturing+process+of+paints+pigments+varnishes+and+enamels (accessed 21 September 2022).

Oladipo, G.O., Eromosele, I.C. and Folarin, O.M. (2013), "Formation and Characterization of Paint Based on Alkyd Resin Derivative of Ximenia americana (Wild Olive) Seed Oil", *Environment and National Resources Research*, **3**(3): 52–62.

Pandey, P. and UV, K. (2020), "Solvent based paint and its impact on environment and human beings environment and society", Government P.G. College Saidabad, Prayagraj (U.P.):198-207.

Rudd, A. (2017), "Why Painting Matters: Some Phenomenological Approaches", *Journal of Aesthetics and Phenomenology*, **4**(1): 1–14.

Silva, J.M., Pratas, D., Antunes, R., Matos, S.

and Pinho, A.J. (2021), "Automatic analysis of artistic paintings using information-based measures", *Pattern Recognition*, **114**: 1–13.

Standeven, H.A.L. (2011), House Paints, 1900-1960: Histroy and Use, 1st ed., Getty Conservation Institute, California, United States.

Taifa, I.W.R. and Lushaju, G.G. (2020), "Establishing basic requirements for textile and garment mass production units in the Tanzanian context", *Research Journal of Textile and Apparel*, **24**(4): 321–340, doi: 10.1108/RJTA-11-2019-0054.

Taifa, I.W.R., Twaha, I. and Mwakibambo, M.A. (2021), "Critical analysis of material consumption and cost reduction techniques for the apparel cutting processes", *Tanzania Journal of Science*, **47**(5): 1689–1700, doi: 10.4314/tjs.v47i5.17.

Ugochukwu, S.C., Ogunsina, O., Udoka, O.E. and Enenmoh, R.C. (2020), "Cost Estimation of Painting Works in Nigeria Using Algorithmic Equations", *Archives of Current Research International*, **20**(1): 29–39.

Wright Group. (2001), Algorithms in Everyday Mathematics, Home Connection Handbook, McGraw-Hill.

Youssef, A.M.A. (2019), Paints Industry: Raw Materials & Unit Operations & Manufacturing & Quality Tests, Higher Technological Institute-10Th of Ramadan City, Egypt, available at:https://doi.org/10.13140/RG.2.2.22793.60007.

Zailani, S., Ariffin, H.A.M., Iranmanesh, M., Moeinzadeh, S. and Iranmanesh, M. (2016), "The moderating effect of project risk mitigation strategies on the relationship between delay factors and construction project performance", *Journal of Science and Technology Policy Management*, **7(**3): 346–368.