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The Role of Value Engineering Job Plan in Prioritizing Finishing Flooring Selection Criteria

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Finishing flooring criteria- Value Engineering- Life cycle cost- performance- Value Index

Abstract
The selecting criteria of finishing flooring materials affects the future performance of learning spaces, especially drawing halls. Value engineering is an analytical process that aims to obtain creative alternatives for any project. The research aims to raise the efficiency of the finishing floor material of the largest drawing halls in the Annex Building at the Modern Academy of Engineering and Technology in Maadi, by measuring the value of each alternative considering the value engineering job plan. The proposed approach provides a comprehensive evaluation system based on the functional requirements of floors that are further divided into 26 sub-criteria. The floor finishing material's functions have been evaluated according to the needs of users using an electronic questionnaire. The analytical Hierarchy Process (AHP) is used as a multi-criteria decision-making technique that helps to measure the relative weight of each function. Then using the life cycle cost technique, the life cycle cost of each finishing floor alternative was calculated. Finally, the extent of achieving these functions by the suggested alternatives was measured related to its life cycle cost in the final steps. The research concluded that Imported HDF is the optimum solution that achieves the highest value. Relying on performance evaluation or evaluation of LCC alone is not a true reflection of the optimal solution during the selection process. This highlights the role of value engineering in getting desired balance.

1. **Introduction**

The drawing halls or "studios" is the main zoning component of any Faculty of Architecture. It is a multi-activity educational space that union multiple educational actions. These special types of spaces need floor specifications that are characterized by being attractive, inspiring, strong, withstand continuous operation and cleaning. And certainly, do not conflict with various forms of furniture organization, and are cost-effective. Most of the used flooring materials include marble, porcelain, wood, rubber, and epoxy [1]. The selection of inappropriate materials will affect the performance and future maintenance work of the drawing hall. Floor finishing represents 4 to 5 % of the cost

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percentage breakdown in construction projects [2]. It attracts users and makes designers pay special attention to this item and do great efforts to select it in proportion to the dimensions, proportions, and uses of spaces.

Value engineering (VE) is one of the most basic topics in project management. It is a tool to improve quality, increase reliability, availability, and customer satisfaction [3]. The research objective is to raise the efficiency of the finishing floors material of the largest drawing halls on the third floor (DHN 8,9,10,11) in the annex building Modern Academy of Engineering and Technology in Maadi, by measuring the value of each finishing floor alternative for the case study by using value engineering job plan which consists of 5 phases [4]: Informative & Function Analysis Phase, Speculative (Creative) Phase, Evaluation Phase, development phase, and final report phase. The life cycle cost analysis technique aims to cover all the building's future costs over its lifetime [5]. A value engineering job plan is applied to adopt a clear formulation of the functional and different criteria and requirements for the selection of flooring type in learning spaces, especially, drawing halls.

2. Literature Review

In educational buildings, from nurseries to colleges, the internal environment quality is important. lighting and ventilation in classrooms for example are fundamental for students' concentration and development [6]. Sitting criteria, internal colors, and finishing materials are other basic elements.

Compared to students in typical lecture rooms who have mild classical activities, architectural students spend a long time in their design studios. It's about six to eight hours per week to perform designing, drawing, physical model making, and research organizing, in addition to other gathering and brainstorming or experimentation activities [7].

Value engineering (VE) is one of the most basic topics in project management. It is a systematic approach to analyzing the functionality of projects and providing key performance at the lowest total cost by removing unnecessary costs [8]. VE is applied in various investment projects and physical or moral products, as well as policies for companies and institutions to ensure that the required quality is maintained at the lowest possible costs [9]. This research is an attempt to answer several important questions. When we need to renovate the existing drawing hall flooring system, is it wise to choose the same type of flooring or not from the value engineering point of view? What alternatives could be? What is the most suitable type, which satisfies the needs of the users and the functions of the floors.

2.1 Finishing flooring for educational spaces

Learning spaces are classified into Formal and Informal learning spaces [10]. The first one is spaces that contain classroom activities related to a specific curriculum. It is not related to the design characteristics of the educational space like classrooms and lecture halls [11]. While informal learning spaces are not related to regular classroom activities in terms of non-compliance with a specific curriculum and depend on non-actual achievement behaviors that are associated with skills and social activities and are affected by the characteristics of the educational space to achieve efficient behavioral and creative performance, Such as in drawing rooms, meeting rooms, multi-purpose halls and the library [12].

The drawing hall "studios" is the main zoning component of the Faculty of Architecture. It is a multi-activity educational space that union multiple educational actions as shown in Fig. 1, varied according to curriculum educational objectives of the academic year, and students' behavioral needs [13]. These special types of spaces need floor specifications that are characterized by being attractive, inspiring, strong, withstand continuous operation and cleaning, do not conflict with various forms of furniture organization, and are cost-effective. Most used flooring materials include marble, porcelain, wood, rubber, and epoxy [15]. A brief about these materials is summarized in Table 1 with examples of application in different drawing halls in varied universities.

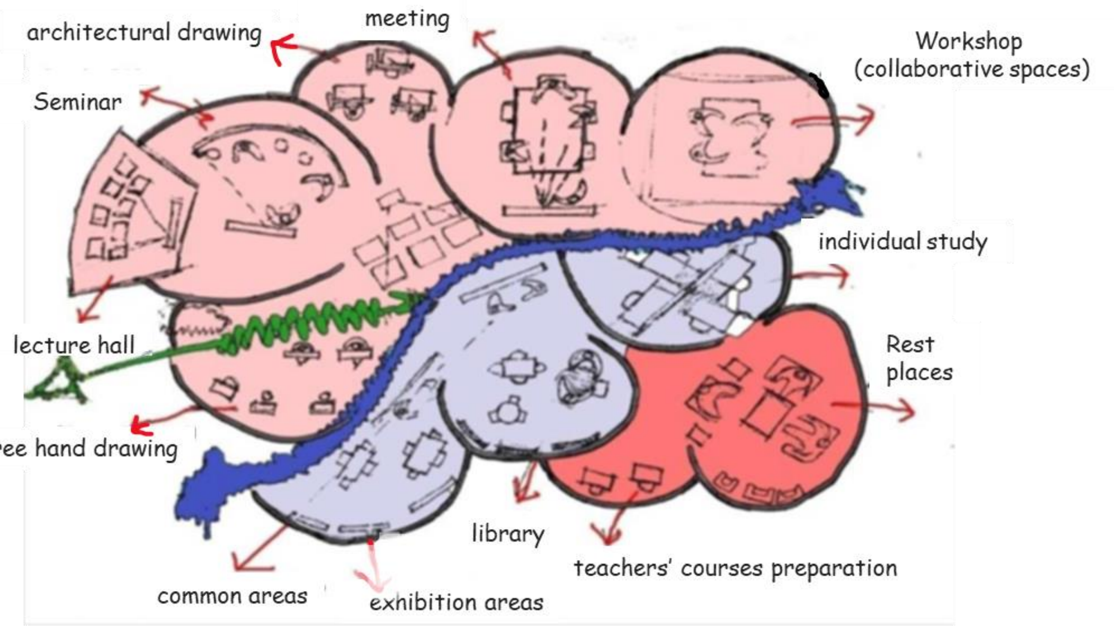
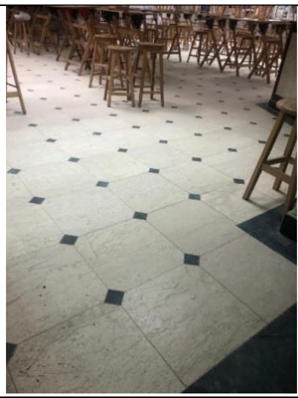
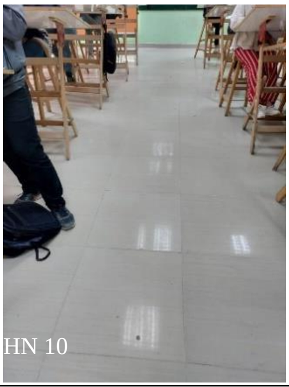
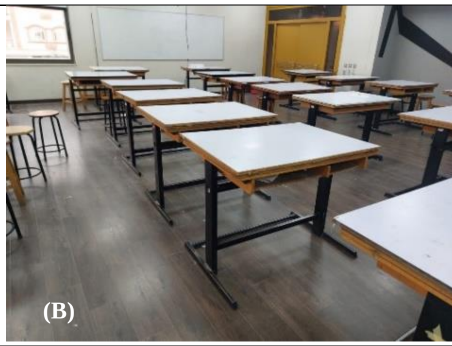
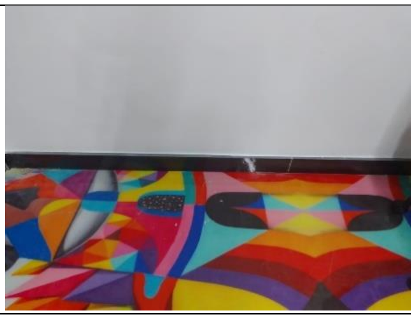
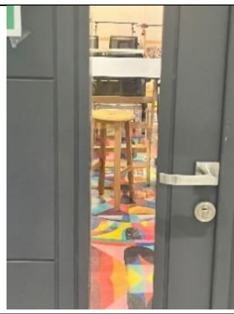
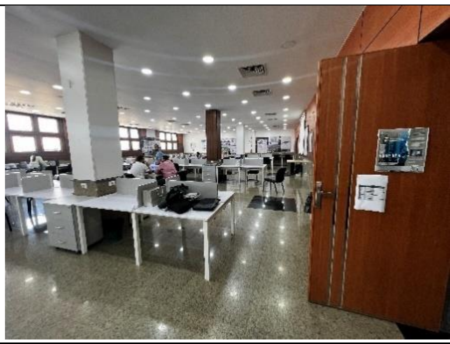
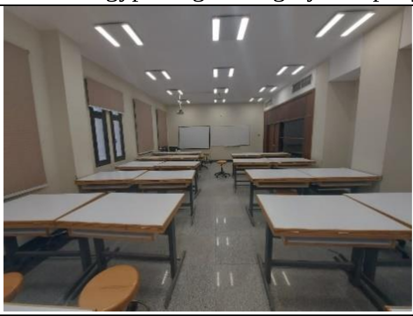
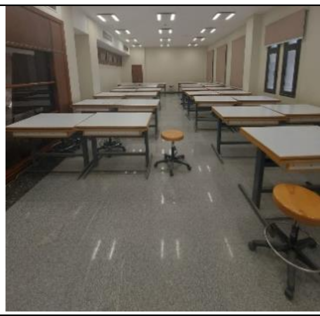


Fig. 1: Various activities inside the architectural drawing halls [14]

Table 1: Most prominent finishing floor in educational spaces.

Floor-type	**floor specifications**
Marble [16]	Marble is a metamorphic rock formed over time as sedimentary rocks, such as limestone, are transformed under pressure and heat. Marble flooring has long been the material of choice in custom homes and buildings because of its natural elegance and luxurious aesthetic. There are a lot of benefits of marble flooring as it looks gorgeous, highly durable material, is hardwearing and resistant to break, is an excellent insulator, reflects light, it is easy to clean, has colour variety, has good heat conduction, and is easy to maintain.
Modern Academy of Engineering and Technology – Drawing halls on the first floor	
Type	Egyptian Galala Marble (Galala Karimi) ≈ 50x50cm, with small tiles (10x10 cm) of Indian green marble
 	
Porcelain [17]	It is a compact material, made by blending clay-like ceramic tiles. It is popular for large spaces. It resists acids, chemicals, and thermal shock, and is durable and easy to clean. There are some benefits for porcelain tiles wear-resistant, low maintenance, suitable for high traffic areas, highly durable, moisture resistant, and simple to clean.
Modern Academy of Engineering and Technology (Case study)	
Type	Porcelain 60x60cm in DHN 10, Ceramic tiles 42x42cm in DHN 8,9,11

  	
HDF [18]	***High-Density Fibreboards*** Wood flooring has been in style for hundreds of years. It is a long-lasting, aesthetically pleasing, and affordable interior floor covering. The benefits of wood flooring are aesthetics- durability cost-effectiveness - ease of restoration - ease of maintenance and cleaning - styles, shapes, and colours.
The British University in Egypt – BUE, (A) **Arab Academy for Science, Technology & Maritime Transport – Heliopolis Branch- AAST- Sheraton, (B).**	
Flooring Type	Imported heavy-duty HDF flooring, with 20x140cm plank size, installed over mosaic floors
  	
Rubber [19]	It is a flooring type that is quickly gaining popularity. This type of flooring has a wide range of uses. Rubber flooring has a lot of benefits such as durability, resiliency, ease of maintenance, good slip resistance, eco-friendly and recycled, sound-static and moisture insulation, and heavy impact resistance, and available in different colours and designs.
Arab Academy for Science, Technology & Maritime Transport - Heliopolis Branch- AAST- Sheraton,	
Flooring Type	Imported Interlocking Rubber Floor Tiles, 50x50cm adherent to mosaic floors
  	
Epoxy [20]	It is made with a resin mixed with a hardening chemical. It is a hard floor that is very resistant to other types of flooring. For that epoxy flooring is popular usage. The epoxy floor is durable, easy to maintain, unique and impressive, economical, slip-resistant, and low-cost.
University of Hertfordshire	
Flooring Type	Epoxy

  	
Granite [21]	Granite is a coarse-grained igneous rock that is made up of quartz and feldspar. Most granite is white, pink, or gray, though there are multiple other color variations. It is also a hard and tough rock. Its color and strength have been prized and used in building projects and decoration for thousands of years.
Ain Shams University-Faculty of Engineering, Architecture department	
Flooring Type: Granite Verdy - Galaxy tiles, 60x60cm -	
 	
Arab Academy for Science, Technology & Maritime Transport - South Valley Branch- Aswan. AAST-Aswan	
Egyptian granite grey company, with Aswan black granite, 50x50 cm	
  	

2.2 Finishing floor material selection criteria

The selection of buildings' finishing materials is one of the major challenging duties of building professionals. The choice is the mental process of judging the advantages of multiple options and the selection of the preferred one, which is subjected to many selection criteria [22]. The selection of inappropriate materials will affect the performance and future maintenance work of the building. There are no ultimate flooring materials to be convenient for all circumstances and different functional requirements [23]. Flooring performance requirements can be gathered in six main principles as shown in Table 2.

Table 2: Finishing flooring performance requirements [24].

N	FF. Performance Requirements	Descriptions
1	**Aesthetic requirements**	The statement "beauty is more than skin deep" applies to the floor finish more than one might think when considering decorative flooring options. Getting the right look means understanding the desired aesthetics, in addition to creating the visual and ability to maintain its appearance and functionality.

N	FF. Performance Requirements	Descriptions
2	**Functional & Maintenance requirements**	This item deals with the provision of floors to protect against slipping, fire, and electric charges with the availability of strength and endurance for the current activities that take place in the architectural space.
3	**Environmental requirements**	This item represents the contribution of the floor type to achieve the principle of sustainability and its impact on acoustics, lighting, energy consumption, and thermal comfort.
4	**Safety requirements**	This item deals with the provision of floors to protect against slipping, fire, and electric charges with the availability of strength and endurance for the current activities that take place in the architectural space.
5	**Construction requirements**	This item deals with the provision of floors to protect against slipping, fire, and electric charges with the availability of strength and endurance for the current activities that take place in the architectural space.
6	**Cost requirements**	Financial capabilities are among the first questions asked when choosing the type of floor finish. Flooring work has a large contribution to the grand total of the project cost. It includes material cost, meeting the budget limitation, life cycle cost, quality level, and … etc.

2.3 Definition of Value Engineering

Value Engineering is an analytical process that aims to obtain creative alternatives for any project [25]. There are a lot of definitions for value engineering. It can be defined as a systematic approach for analyzing the functional requirements of projects to provide the main performance with the lowest total cost and aims to reduce overall project cost by removing unnecessary costs [26]. In addition, value engineering can be described as a process that eliminates unnecessary costs by identifying alternatives that obtain the same function but with a lower cost [27]. By Dell'losla (1997) value engineering was defined as the process that identifies opportunities to remove unnecessary costs while assuring that quality, reliability, performance, and other critical factors will meet the customer's needs. Value engineering is a creative and teamwork method to solve problems, decrease costs and improve the function and quality of projects [28].

Value engineering is used to identify the best design alternatives for projects, processes, products, or services. In addition to its importance in reducing costs by removing unnecessary expenses and providing the optimum value for the budget program cost. It is used to improve quality, increase reliability, availability, and customer satisfaction. VE is a powerful tool for identifying problems and improving overall organizational performance [29]. Function, Cost, and Value are the three poles of value engineering, considering maintaining the required quality. They are combined by the following formula [30].

$$Value = Function / Cost,$$

where:

The Function is the specific work that a design/item must perform. It is classified according to the nature of function into (work functions and sell functions) and according to the weight of the importance into (basic function, and secondary function). Functions include two main issues, Performance and Quality. Performance refers to the owner's or user's needs, while Quality refers to the level of achievement.[31], [32]. ***Cost*** refers to the Life Cycle Cost (LCC) [33]. And finally, ***Value*** is the ratio of performance to cost, and it has more than one alternative to increase [34]. As the following equation the value increases in many cases, when function increases and cost reduce, when function increase with maintaining the cost function value increases, and when maintaining function with reducing cost.

$$\frac{F\uparrow}{C\downarrow} \quad \frac{F\uparrow}{C\rightarrow} \quad \frac{F\rightarrow}{C\downarrow} \quad \frac{F\uparrow\uparrow}{C\uparrow}$$

$\downarrow$ Reduction $\uparrow$Increase $\rightarrow$ Maintain.

2.4 Value Engineering Stages and The Job Plan

There are three stages of VE related mainly to project timelines, as shown in Fig. 2. They are the Pre-workshop stage, Workshop stage, and post-workshop stage. The job plan is the heart of the system that includes the pivotal work. It comes in the middle stage of VE and has a sequence of phases, as follows [35]:

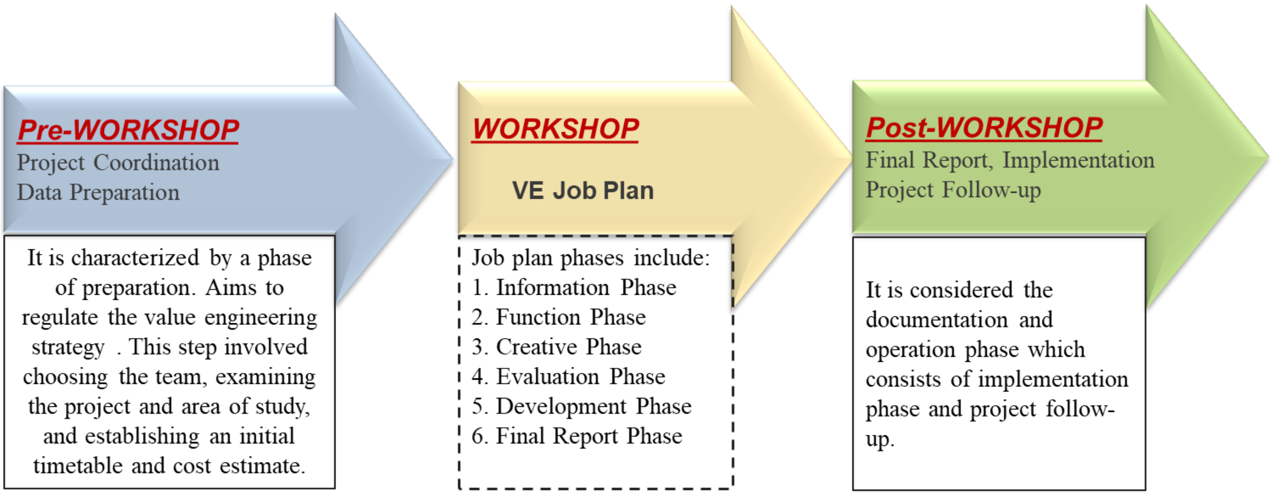


Fig. 2: Value Engineering Stages. [35] [Designed by authors]

- ***Information phase***: in this phase, the objective is understanding and defining the aim of the project and the limitations influencing the results of the project.
- ***Function phase***: this phase aims to functionally understand the project, which is, what the project should do instead of how the project is now. Some activities necessary to achieve this objective in the project as determining the project functions, classifying the project functions, developing the function model by tools like the function analysis system technique (FAST), evaluating mode by cost parameters, performance characteristics, and user behavior to select functions, and estimating functions' cost.
- ***Creative phase***: in this phase, explore effective alternative designs required to answer the identified functions through the brainstorming session. The purpose of this phase is to present several ideas.
- ***Evaluation phase***: this phase aims to decrease the number of ideas and present a short list of the most potential ideas to improve and actualize the project functions concerning qualitative requirements and resource limitations.
- ***Development phase:*** it investigates and develops a short list of ideas and properly develops them to select alternative values.
- ***Final Report phase:*** presentation is made, and the final report is to those who are interested.

2.5 Life cycle cost analysis

Life cycle cost (LCC) is the summation of the expenses needed by an item during its life cycle/life span [36]. Life cycle cost (LCC) can be divided into a lot of types of expenses as [37]:

The initial cost: includes purchasing and installation prices or construction.

Operation Cost: including cleaning and maintenance, repair costs, removal costs, and replacement costs.

Finally, ***Salvage Value is calculated at*** the end of the project lifetime including disposal.

The Life cycle cost analysis (LCCA) technique is used to calculate life cycle cost (LCC). It is a technique used for evaluating the economic performance of a project considering its lifetime. It aims to cover all the building's future costs over its lifetime. It can select the optimum alternative among different competing alternatives [38].

This technique calculates the initial cost, and present value PV during the project lifetime [39]. Numerous studies approved that the most economical initial cost is not associated with the lowest project life cycle cost for most flooring systems. Present value can be defined as the time value of any present, past, or future at a certain point (present time) and it is calculated by summation of the PV of (year 1) + PV (year 2) + PV (year 3) + ………………. + PV (year N). To adjust the value of money in the present time, we use the inflation rate and discount/interest rate and specify the time in which the costs are being paid or earned [40].

3. Methodology

The study was divided into two sections:

The First section: the literature review which Includes finishing flooring in educational spaces, floors functional requirements in buildings, value engineering applications, and case study selection.

The Second section includes applying Value Engineering Job Plan (JP.) phases to the selected case study. These phases include the Informative & Function Analysis Phase, Speculative (Creative) Phase, and the Evaluation Phase, as shown in Fig. 3

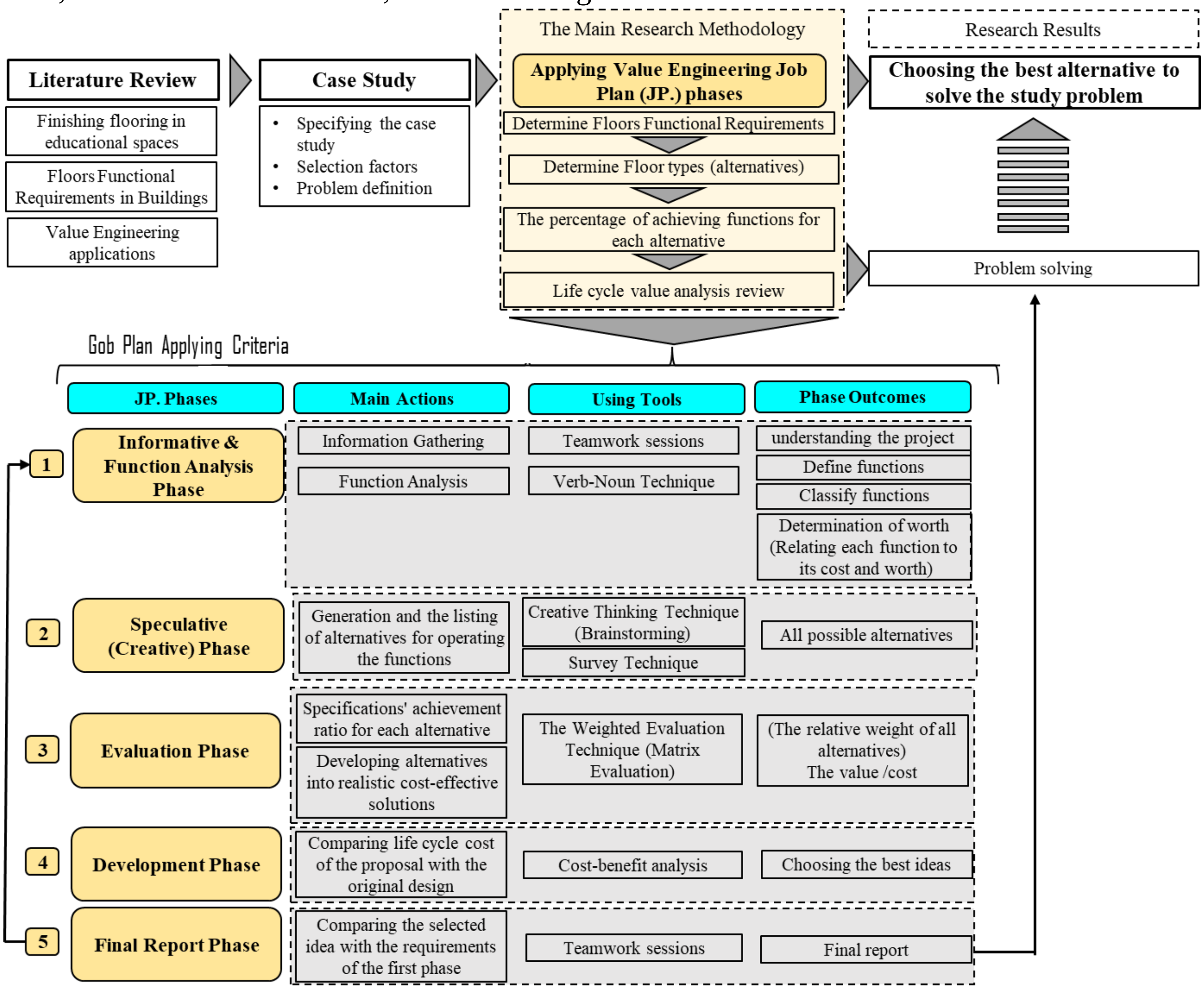


Fig. 3: Research methodology.

Informative & Function Analysis Phase

Information Gathering

The Modern Academy of Engineering and Technology in Maadi is in the middle plateau area of Mokattam. It is 700 meters away from the ring road. The academy includes two separate buildings, the main building, and the annex building. The annex building consists of a basement, ground floor, and four other floors. It has a plot of land with 3,540 square meters, with a total built-up area equal to 12,000 square meters.

The academy annex building contains 15 architectural drawing halls for the Department of Architecture only varied in their area. The area of windows is about 15% of the floor area of the halls. All the halls depend on artificial ventilation through central air conditioning except the drawing hall on the third floor (DHN15) which is air-conditioned with ٨ spit units. Each of them is equipped with wooden drawing tables and chairs according to the capacity of each. They are also equipped with a whiteboard, a high counter, or a wide desk with chairs for staff members.

Drawing halls are located on the first, third, and fourth floors, while the ground floor contains the stands, and the third floor is for laboratories as shown in Fig. 4.

- **Problem definition:** It is required to raise the efficiency of the finishing floors material of the largest drawing halls on the third floor (DHN 8,9,10,11) due to the emergence of some defects that pose a danger to users, represented in the breakage and separation of some floor tiles as shown in Fig. 5.
- **Description of the study area:** The large drawing halls on the third floor occupy about 30% of the floor area, the floor types differ from 42x42 cm ceramic tiles in drawing halls 8,9,11, and 60x60 cm porcelain tiles in drawing hall 10. The wooden engineering drawing tables with wooden highchairs represent the main furniture with a capacity as shown in Table 3. In addition to a wooden office and a chair for the lecturer.

Fig. 4: Plan of the drawing halls' floors. (a) First Floor, (b)Third Floor, (c) Fourth Floor.

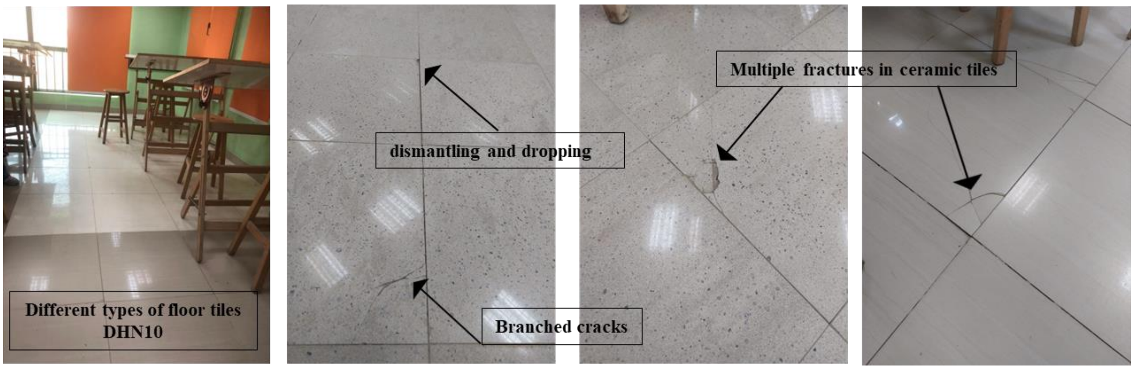


Fig. 5: Some floor finishing defects in the case study.

Table 3: Fourth floor largest drawing halls area and capacity.

	Dimensions	Area	Capacity (students)
Drawing Hall (DHN8)	15.4x 10.80	166.32	٦٠
Drawing Hall (DHN 9)	10.80x 13.8	184.66	٦٠
Drawing Hall (DHN 10)	14.0x 13.80	184.66	٦٠
Drawing Hall (DHN 11)	15.4x 10.80	166.32	٦٠

Function Analysis

There are a lot of techniques to analyze the functions of any product or service. Some of these techniques that suit value engineering process are Verb-Noun Technique, Function Analysis System Technique FAST [27], [28]. The Verb-Noun Technique is used to describe each function and classify them into basic, secondary, and neglected functions as shown in Table 4. An interview was conducted with expertise in various fields such as construction and finishing materials, project management, and building technology in addition many brainstorming sessions were done and many questions and discussions were raised to several architecture students, staff members, and other site engineering to classify these functions. Cost requirements have been excluded because the research topic focused primarily on the life cycle cost analysis. So other determinants were only discussed.

Table 4: Finishing flooring requirements using Verb-Noun Technique.

N	Finishing flooring requirements/ criteria	Function		Classification
		Verb	Noun	
1.	Aesthetic requirements	Design / provide	Luxury / beauty	Basic
		Appear	Good	Basic
		Provide	Comfort	Basic
		Reflect	Light	Basic
		Achieve	Resilient	Secondary
		Colour	Good	Basic
2.	Functional & Maintenance requirements	Can / be	Refinishing	Basic
		Provide / protect	Durability	Basic
		Clean	Easy	Basic
		Resist	tinctures	Secondary
3.	Environmental requirements	Insulate	Sound	Basic
		Insulate	Thermal	Secondary
		Achieve	Leed	Secondary
		Lose/save	Energy	Secondary
4.	Safety requirements	Resist	Damp	Basic
		Achieve	Smoothness	Secondary
		Work	Hardness	Basic
		Resist	Fire	Basic
		Offer	Warranties	Basic

N	Finishing flooring requirements/ criteria	Function		Classification
		Verb	Noun	
		Resist	Slip	Basic
		Resist	Static	Secondary
		Provide	Strength and stability	Basic
6.	**Construction requirements**	Achieve	Quality	Basic
		Install / Fix	Easy	Basic
		Prepare	Layers / easy	Basic
		Finish	methods	Basic

According to table 4, finishing flooring material requirements and performance can be summarized in the following Table 5.

Table 5: Finishing flooring material requirements and performance.

N	FF. Requirements	FF. Materials Performance
1.	**Aesthetic Requirements**	1.1 Floor Pattern Design. Appropriate and distinctive floor pattern design with endless design options.
		1.2 Attractive Appearance. Due to overall consistency (design, colour, material)
		1.3 Comfort Feelings. Especially because of the long working hours.
		1.4 Light Reflection Level. Moderate reflection level commensurate with natural and artificial lighting percentage.
		1.5 Providing Resilience. Indicates to the ability to achieve the desired design.
		1.6 Colour and Gloss Level. Matching with the floor area and type of current activities.
2.	**Functional & Maintenance Requirements**	2.1 Refinishing Capability. The ability to renew and polish the outer surface
		2.2 Durability. Including providing rigidity, stability, and shock resistance.
		2.3 Cleanliness. Low cleaning frequency with less sensitivity to detergents and disinfectants
		2.4 Resistance to tinctures. Whether resulting from spillage of liquids or being affected by detergents or changing the colour of the joints.
		2.5 Smoothness. Easy to walk on and easy to clean, without protrusions or roughness cause injury when falling.
		2.6 Corrosion resistant. Caused by persistent friction
		2.7 Damp Resistance. To withstand accidents of liquids spillage and periodic cleaning (mostly under warranties offered)
3.	**Environmental Requirements Including LEED Aspects**	3.1 Soundproofing. Refers to Sound Insulation to Dampen Noise by the surface type or underlayment addition
		3.2 Thermal Insulation. Including applying Insulated decking in damp floors such as basement or to resist solar radiation in roofs.
		3.3 low-emission materials. To achieve high rated air quality.
		3.4 Sustainable materials including: • locally sourced materials. • Recycled content materials. • Materials that have been salvaged or reused. • Maintenance savings. • Renewable energy generation.
4.	**Safety Requirements**	4.1 Slip Resistance. Resulting from excessive surface smoothness
		4.2 Electrical Resistance (Static floors). The ability to resist, or stop, the flow of electricity to ground or path to ground.
		4.3 Fire Resistance. Including resistance to ignition, continuous burning and highly flame retardant.
		4.4 Surface flatness, avoid sudden or hidden levels.

N	FF. Requirements	FF. Materials Performance
5.	**Construction Requirements**	5.1 Easy to install (supply & apply). Include the availability of raw materials and suppliers.
		5.2 Low wastage percent. According to space proportions and pattern design.
		5.3 Short installation time. Refers to the ease of application and the availability of space for supplies and temporary storage, and Labor.
		5.4 Easy to remedy various defects.
		5.5 Conforming final quality expectations.

Speculative (Creative) Phase

A survey about drawing halls at different universities and academic institutions was conducted. A collection of the most common alternatives for flooring finishing materials that are observed at these locations are summarized as mentioned in previous table 1. In addition, conducting several brainstorming sessions with several architecture students who were considered the main users of the halls, and some teaching staff, which added several ideas that were characterized by innovation and creativity. For example, students suggested sustainable energy floors at the entrance of the drawing hall, movable stepped raised floors (by using interlocking portable modular floors installed over any existing floor type) were either proposed as a means of changing the interior design or stacking the drawing tables with flexibility as shown in Fig. 6. But with the limitation of the net area and absence of accurate supply and installation price, these suggestions have been excluded. Micro-cement flooring has been suggested as a trendy type that offers the same stunning finish as polished concrete. It uses innovative hybrid epoxy resin technology in all colours, ideal for rapid renovations and residential transformations, spaces samples are shown in Fig. 7.

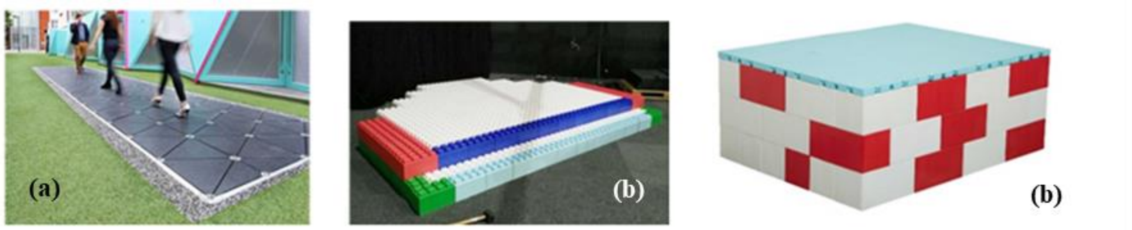


Fig. 6: (a) Sustainable Energy Floors. (b) Movable stepped raised floors.

Fig. 7: Microcement flooring .

Specifications of the selected materials proposed by experts in the construction and finishing materials field are shown in Table 6, which is included the initial cost that was divided into 3 parts, Recurring Cost (Operation Cost), and salvage cost. Also, it is included the prices of supply and installation, as well as cracking or implementing of subflooring.

Table 6: Selected materials specifications and costs.

		Initial Cost			Recurring Cost (Operation Cost)		Salvage cost	
	Cost destinations / Item Description	Breaking and removing the existing flooring (Porcelain) /m^2. including lifting and moving	lump sum, replacement of defective and broken tiles by any substrate flooring with the same size (22 tiles).	Supply and installation price including skirting installation/m^2	Cleaning cost & rate	Repair/ maintenance costs & rate	Breaking and removing	Disposal of material
F1	**Terista Marble** Flooring tiles ≈ 60x60, 2 cm thickness, with 10 cm marble skirting	70	-	800	24000/year	Surface polishing 90/ m^2 every 5 years	75	
F2	**Egyptian granite Grey company,** ≈ 60x60, 2 cm thickness tiles, with 10 cm same type skirting	70	-	850	24000/year	-	75	
F3	**Imported HDF** water resistance flooring (Turkish/Chinese) class 32, 8 mm. installed over the existing porcelain floors as a subflooring with skirting.	-	4150	480	20000/year	By m^2, replacing affected tiles after accidents	30	
F4	By square meter supply and apply a layer of **Self-leveling epoxy** 2mm thickness by using master-top 0203 from Basif or equivalents as specs of approved colour. Items include mechanical grinding of the substrate and using epoxy putty (2 layers) including filling the joints, primer epoxy coating master-top 1200 or equivalents.	-	4150	750-850	24000/year	Renewal of the polyurethane coat layer every year 120-150	-	No disposals of epoxy
	By square meter supply and apply a water transparent poly urethane coat overlay the self-leveling epoxy as a protection coat not less than 150 microns.	-		120-150			-	
F5	**Microcement flooring** By square meter supply and apply a layer of **Microcement** 3mm thickness. Item include mechanical grinding of the substrate and using epoxy putty (2 layers) including filling the joints, and all Microcement system preparation steps.	-	4150	1000-1300	24000/year	Renewal of the top layer every 3 years 120-150	-	No disposals
F6	By square meter supply and apply **Imported Interlocking Rubber Floor** Roll, 1.0X10.00m, 2mm thickness. Flooring is adhesive over existing floors directly, and wooden skirting is installed.	-	4150	1150	20000/year	By m^2, replacing affected parts after accidents	30	All Recycled
F7	Heavy-duty **porcelain tiles**, 60x60 cm. with 10 cm porcelain skirting.	70	-	700	24000/year	By m^2, replacing affected parts after accidents	60	

Note: Prices are collected in June 2023.
The prices include all necessary materials for installation as per the specifications, drawings, and approved samples.

Evaluation Phase

The main objective of this phase is to measure the value of each finishing floor alternative in the previous step. This phase is divided into ۳ steps as follows:

Step 1: Measure the relative weight (RW.) of each function (Quality). From the literature review, (Five) main requirements (Main functions) and (twenty-six) (sub-functions) have been categorized, and by using the Analytical Hierarchy Process (AHP) [41], the weights of these factors were determined as shown in Appendix (1).

An electronic questionnaire was designed to determine the level of achievement of the specified flooring types(performance, P.) (from F1-F7) for the functions and sub-functions by using a 1-10 scale. The questionnaire was distributed among students and staff members in the architecture department at Modern Academy and in other architecture colleges, in addition to other workers in the field of interior design, as illustrated in Table7. Subsequently, the results of the electronic questionnaire were collected and analyzed. Weighed evaluation technique (Evaluation Matrix) has been applied by measuring the function of each FF type calculated by summation of the performance (P) of the floor type (the mean values of questionnaire results) multiplied by the relative weight calculated by the AHP, as illustrated in Table 8.

Table 7: The distribution of the electronic questionnaire to the experts

Participant	**Number**
students	10
staff members	10
interior designers	10
Total	30

Table 8: Evaluation matrix of floor types related to achieving functions.

N	**Finishing flooring Functions**	**RW.**	**(F1)**		**(F2)**		**(F3)**		**(F4)**		**(F5)**		**(F6)**		**(F7)**	
			P	W*P	P	W*P	I	W*P	P	W*P	P	W*P	P	W*P	P	W*P
1. Aesthetic requirements		0.233	9	2.097	9	2.097	9	2.097	9	2.097	9	2.097	9	2.097	9	2.097
1-1	Floor Pattern Design	0.082	8	0.655	8	0.655	2	0.164	9	0.736	2	0.164	3	0.245	7	0.573
1-2	Attractive Appearance	0.047	7	0.329	8	0.376	6	0.282	8	0.376	4	0.188	5	0.235	6	0.282
1-3	Comfort Feelings	0.032	7	0.227	7	0.227	9	0.292	8	0.259	8	0.259	6	0.194	3	0.097
1-4	Light Reflection Level	0.038	8	0.305	8	0.305	8	0.305	6	0.229	6	0.229	8	0.305	8	0.305
1-5	Providing Resilience	0.024	7	0.166	7	0.166	5	0.118	9	0.213	9	0.213	6	0.142	5	0.118
1-6	Color and Gloss Level.	0.011	8	0.085	8	0.085	5	0.053	9	0.096	4	0.043	7	0.075	8	0.085
2. Functional & Maintenance Requirements		0.425	10	4.250	10	4.250	10	4.250	10	4.250	10	4.250	10	4.250	10	4.250
2-1	Refinishing Capability	0.084	9	0.760	3	0.253	1	0.084	8	0.676	8	0.676	2	0.169	3	0.253
2-2	Durability.	0.087	9	0.784	9	0.784	6	0.523	8	0.697	8	0.697	8	0.697	7	0.610
2-3	Cleanliness.	0.072	9	0.647	9	0.647	7	0.503	9	0.647	9	0.647	6	0.431	8	0.575
2-4	Resistance to tinctures.	0.045	8	0.360	9	0.406	6	0.270	9	0.406	9	0.406	8	0.360	8	0.360
2-5	Smoothness	0.040	9	0.356	9	0.356	9	0.356	9	0.356	9	0.356	6	0.238	9	0.356
2-6	Corrosion resistant	0.020	9	0.177	9	0.177	4	0.079	6	0.118	9	0.177	8	0.157	8	0.157
2-7	Damp Resistance	0.023	9	0.206	9	0.206	4	0.092	9	0.206	9	0.206	9	0.206	9	0.206
3. Environmental Requirements/ LEED		0.163	8	1.304	8	1.304	8	1.304	8	1.304	8	1.304	8	1.304	8	1.304
3-1	Soundproofing	0.059	7	0.412	7	0.412	8	0.471	8	0.471	8	0.471	8	0.471	4	0.235
3-2	Thermal Insulation	0.062	8	0.494	8	0.494	8	0.494	8	0.494	8	0.494	8	0.494	4	0.247

N	Finishing flooring Functions	RW.	(F1)		(F2)		(F3)		(F4)		(F5)		(F6)		(F7)	
			P	W*P	P	W*P	I	W*P	P	W*P	P	W*P	P	W*P	P	W*P
3-3	low-emission materials	0.033	9	0.299	9	0.299	8	0.266	7	0.233	7	0.233	6	0.199	8	0.266
3-4	Sustainable materials	0.008	9	0.076	9	0.076	9	0.076	3	0.025	3	0.025	9	0.076	4	0.034
4. Safety Requirements		0.119	8	0.952	8	0.952	8	0.952	8	0.952	8	0.952	8	0.952	8	0.952
4-1	Slip Resistance	0.051	6	0.306	2	0.102	9	0.458	9	0.458	9	0.458	9	0.458	2	0.102
4-2	Electrical Resistance	0.037	6	0.224	6	0.224	8	0.299	8	0.299	8	0.299	9	0.336	8	0.299
4-3	Fire Resistance	0.026	6	0.156	6	0.156	2	0.052	7	0.182	9	0.234	6	0.156	8	0.208
4-4	Surface flatness	0.020	9	0.184	9	0.184	9	0.184	9	0.184	9	0.184	7	0.143	8	0.163
5. Construction Requirements		0.060	6	0.360	6	0.360	6	0.360	6	0.360	6	0.360	6	0.360	6	0.360
5-1	Easy to install	0.022	4	0.087	4	0.087	9	0.195	9	0.195	9	0.195	8	0.173	3	0.065
5-2	Low wastage percent	0.012	9	0.106	9	0.106	6	0.071	9	0.106	9	0.106	7	0.083	3	0.035
5-3	Short installation time	0.008	4	0.032	4	0.032	9	0.072	8	0.064	8	0.064	7	0.056	4	0.032
5-4	Easy to remedy various defects	0.006	5	0.032	5	0.032	8	0.051	5	0.032	7	0.045	9	0.058	7	0.045
5-5	Conforming final quality expectations	0.009	8	0.070	8	0.070	7	0.062	8	0.070	7	0.062	8	0.070	7	0.062
Floors Function			**16.2801**		**16.4737**		**15.1867**		**16.5800**		**16.0923**		**15.1861**		**14.1760**	

Notes: - The highest weight of alternatives (floor types) indicates the best alternative according to the needed function.

Step 2: to calculate the life cycle cost of each finishing floor alternative in the previous step by using the life cycle cost analysis technique, the following steps were taken:

1- Assumed that lifetime span for flooring is 30 years.
2- Based on the World Bank, calculated the average of the last 30 years for interest rate (*i*), and inflation rate (*f*) as: $i = 8.64\%$, $f = 9.32\%$ [42] .
3- Divided flooring lifetime into 3 phases: construction phase, operation and maintenance phase and salvage phase.
4- Based on current market prices, determined / collected the prices of each phase for flooring, as previously illustrated in table 6.
5- Calculated future value (*FV*) by using the following formulas (1), (2), (3), (4) [43]:

$$f = \left[\frac{cost_n}{cost_{now}}\right]^{\frac{1}{n}} - 1 \qquad (1)$$

$$f + 1 = \left[\frac{cost_n}{cost_{now}}\right]^{\frac{1}{n}} \qquad (2)$$

$$[f + 1]^n = \left[\frac{cost_n}{cost_{now}}\right] \qquad (3)$$

$$cost_n = \frac{[f + 1]^n}{cost_{now}} \qquad (4)$$

Where: *cost n*= the future value (*FV)* at year n, *f* = inflation rate and *n*= number of interest period lifetime span.

6- Then, calculated present value (*PV*) for each year of flooring lifetime span by using the following formula (5) [44]:

Present Value $PV = FV/(1+i)^{n}$ **(5)**

Where: *PV*= present value, *FV*= Future Value, *i* = interest rate and *n*= number of interest period lifetime span.

7- After that, present value (*PV*) of flooring life cycle using the following formula (6) [45]:

Present Value $PV = \sum_{t=0}^{n} \frac{Ct}{(1+i)^{t}}$ **(6)**

Where: *PV*= present value of life cycle cost, *Ct*= sum of all relevant costs occurring in year *t*, *i* = interest rate and *n*= number of interest period lifetime span.

***Ct* = initial cost + operation cost + salvage cost** **(7)**

8- Finally, calculated the life cycle cost (LCC) for each flooring type, as illustrated in Table 9.

9-

Table 9: The total life cycle cost for all finishing floor alternatives

Code	Flooring Type	Total Life Cycle Cost
F1	Terista Marble	1,755,417.63 $
F2	Egyptian Granite Grey Company	1,445,462.77 $
F3	Imported HDF	980,134.82 $
F4	Self-leveling epoxy	4,416,643.06 $
F5	Micro-cement flooring	4,383,718.31 $
F6	Imported Interlocking Rubber Floor	1,405,949.65 $
F7	porcelain tiles	1,327,550.79 $

Step 3: estimating the value of each finishing floor alternative analyzed in the previous step, by using **the following formula (8) [46]:**

Value = Function / Life Cycle Cost **(8)**

Then, the final value results are illustrated in Table10.

Table 10: The value index.

Finishing floor type	(F1)	(F2)	(F3)	(F4)	(F5)	(F6)	(F7)
FF Functions	**16.2801**	**16.4737**	**15.1867**	**16.5800**	**16.0923**	**15.1861**	**14.1760**
Cost $	1755417.63	1445462.77	980134.82	4416643.06	4383718.31	1405949.65	1327550.79
Value Index VI. (function/ Cost)	**9.27×10^{-06}**	**1.14×10^{-05}**	**1.55×10^{-05}**	**3.75×10^{-06}**	**3.67×10^{-06}**	**1.08×10^{-05}**	**1.07×10^{-05}**

4. Results and Discussion

Applying a value engineering job plan for selecting the optimum solution for finishing floor types is divided into 5 phases. The ***first*** is the Informative and Function Analysis Phase, which includes information gathering about the case study defining the problem. Then, function analysis by using verb& noun techniques is applied to conclude 26 finishing flooring performance requirements (Functions in value engineering). The ***second*** is the Speculative or Creative Phase. Where a survey about drawing halls at different universities and academic institutions was conducted and collecting of the most common alternatives for floor finishing materials was observed. In addition, several brainstorming sessions were conducted and suggested 7 different finishing floor alternatives. The ***third phase*** is for evaluation which is the main phase in this study aimed to measure the value of each finishing floor alternative to help to select the optimum one. This phase is divided into 3 parts which are: measuring the relative weight of each function requirement by using the Analytical Hierarchy Process (AHP), categorizing the alternatives according to these weights, calculating the life cycle cost of each finishing floor alternative by using the life cycle cost technique, and estimating the value of each finishing floor alternative.

Results of the previous 3 phases were represented as ***the fourth and fifth*** phases which are the development phase and final report phase.

As illustrated in Table 11**,** alternative ranking according to function (performance & quality) shows that Self-leveling epoxy (F4) achieved the highest performance, and the second highest one is Teresta Marble (F1), as configured in Fig. 8. While alternatives ranking according to LCC shows that Self-leveling epoxy (F4) achieved the lowest LCC and the second lowest one is porcelain tiles (F7), as shown in Fig. 9. Finally, alternative ranking according to value analysis by using the value formula shows that imported HDF (F3) achieved the highest value, and the second highest value is Egyptian granite grey company (F2), as shown in Fig. 10.

More specially, by applying value engineering phases, imported HDF (F3) is the first choice and optimum solution, and the second one is the Egyptian granite grey company (F2).

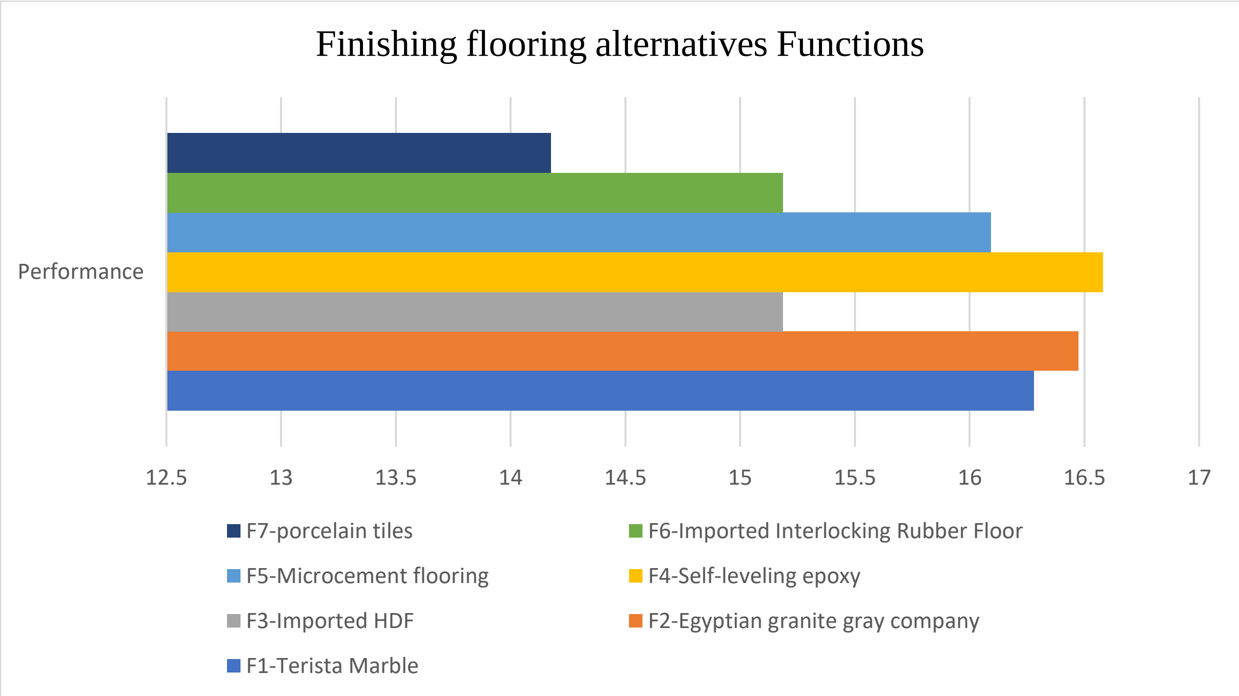


Fig. 8: Finishing flooring alternative functions

Table 11: The value index.

Flooring Type	Initial cost	Operation cost	Salvage cost	**Total cost**	**Ranking to cost**	Performance	**Ranking to function**	VI.	**Ranking to VI.**
F1-Terista Marble	610705	1081623	63090	1755418	**5**	16.280112	**3**	$9.27421x10^{-6}$	**3**
F2-Egyptian granite grey company	645803	736570	63090	1445463	**4**	16.4737	**2**	$1.13968\ x10^{-5}$	**6**
F3-Imported HDF	341091	613808	25236	980135	**1**	15.186718	**5**	$1.54945\ x10^{-5}$	**7**
F4-Self-leveling Epoxy	663992	3752651	0	4416643	**7**	16.58	**1**	$3.75398\ x10^{-6}$	**2**
F5-Microcement flooring	846502	3537216	0	4383718	**6**	16.092254	**4**	$3.67091\ x10^{-6}$	**1**
F6-Imported Interlocking Rubber	811404	593669	877	1405950	**3**	15.186082	**6**	$1.08013\ x10^{-5}$	**5**
F7- porcelain tiles	540509	736570	50472	1327551	**2**	14.176022	**7**	$1.06783\ x10^{-5}$	**4**

Table 11 shows a convergence in the function values of various flooring types. This reflects that despite the different opinions of specialists about them, each type has its own characteristics. This causes great dependence on the LCC in calculating the value index, making it somewhat in control of the arrangement of the proposed alternatives.

The reduction percentage is calculated by subtracting any two types of flooring according to the comparison scheme (function, life cycle cost or value engineering) as illustrated in Table 11, as well as Figures from 8 to10. Then comparing the difference by the highest value (the lower LCC.) as a percentage. Table 12 shows the percentage of reduction according to LCC. values compared to The Imported HDF flooring type, which has the highest LCC. value.

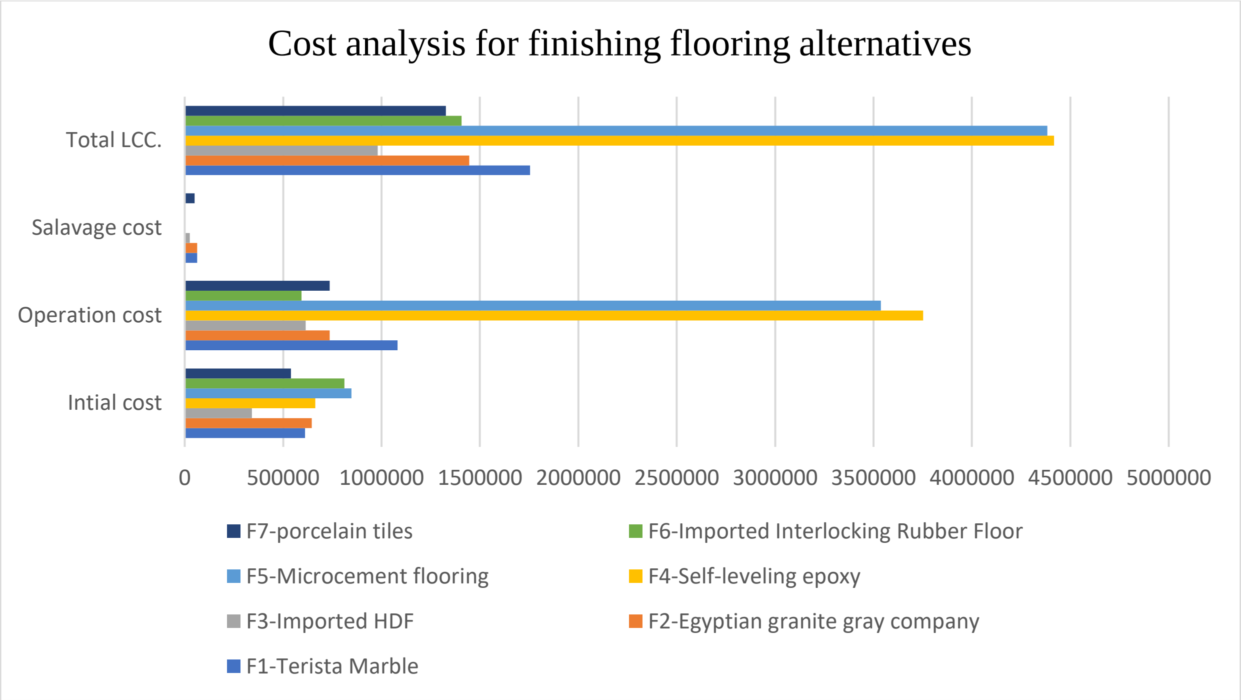


Fig. 9: Cost analysis for finishing flooring alternatives

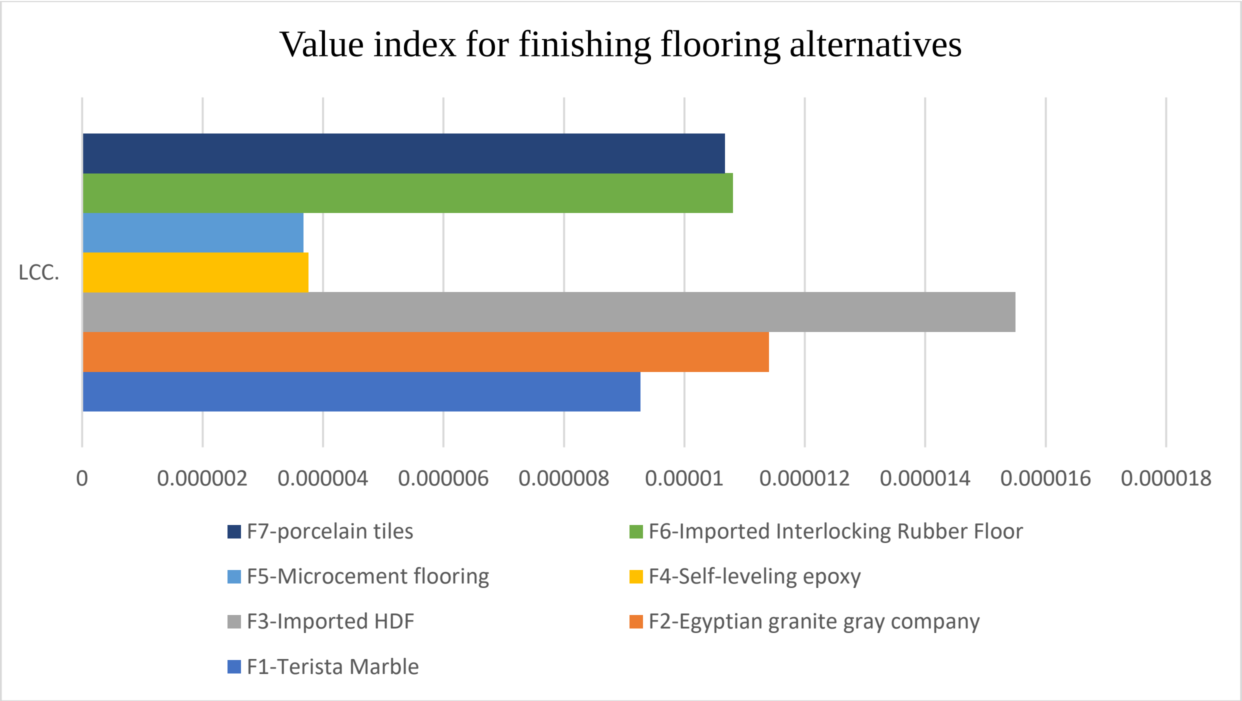


Fig. 10: Value index for finishing flooring alternatives

Table 11: Reduction rate of LCC. Values.

Flooring Type	**Reduction rate**
F1-Terista Marble	40.15 %
F2-Egyptian granite grey company	26.45 %
F3-Imported HDF	
F4-Self-leveling Epoxy	75.77 %
F5-Microcement flooring	76.31 %
F6-Imported Interlocking Rubber	30.29 %
F7- porcelain tiles	31.08 %

5. Conclusions

The choice is the mental process of judging the advantages of multiple options and the selection of the preferred one, which is subjected to many selection criteria. Flooring performance requirements can be gathered in six main principles which are: (1) Aesthetic requirements, (2) Functional & Maintenance requirements, (3) Environmental requirements, (4) Safety requirements, (5) Construction requirements, and (6) Cost requirements.

Value Engineering is a systematic approach for analyzing the functional requirements of projects to provide moderate performance with the lowest total cost and aims to reduce overall project costs by removing unnecessary costs.

The research aims to raise the efficiency of the finishing floors material of the largest drawing halls on the third floor (DHN 8,9,10,11) in the annex building of the Modern Academy of Engineering and Technology in Maadi, by measuring the value of each finishing floor alternative for the case study by using value engineering job plan.

The value engineering job plan is divided into 5 phases. The Evaluation Phase is the main phase in this study which aimed to measure the value of each finishing floor alternative in 3 steps which are measuring the relative weight of each function requirement by using the Analytical Hierarchy Process (AHP), and categorizing the alternatives according to these weights, calculating the life cycle cost of each finishing floor alternative by using life cycle cost technique, and estimating the value of each finishing floor alternative.

The research concluded that Imported HDF (F3) is the optimum solution that achieves the highest value. Finally, the suggested evaluation approach based on a value engineering job plan is considered a primary action in obtaining creative alternatives for finishing floor materials. The research methodology can be applied on any flooring type after determining the following variables:

Finishing flooring type, the percentage of achieving functions (described in Table 5), the selected materials specifications and costs including the Initial, recurring (operation) and salvage costs. Thus, life cycle cost can be calculated and compared. Whenever it is possible to determine the specifications of the materials and the details of the implementation costs accurately, with a focus on the basic functions, the greater the success of the application of value engineering).

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Conflicts of Interest

There are no ethical issues applied to this research and no conflict of interest.

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Appendix (1): Measuring the relative weight (RW.) of each function.

To calculate relative weights these steps were applied:

- Square reciprocal matrices were created, and a pair-wise comparison was conducted. Matrices are of ***n*** order, and its elements are determined by the a_{ij}, where $a_{ij} = 1/a_{ji}$ for $i \neq j$ and $a_{ii} = 1$.
- Al the matrices were filled by **(10)** experts in architecture design. The pair-wise comparison was determining the relative importance between two compered elements using the AHP 1-9 scale where:

  1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).
- By repeating matrices for each main function and sub-functions, the relative weight can be calculated. Then checking consistency for the matrices were also applied by calculating the consistency ratio (CR).

Relative weights of each element are calculated by getting the Eigen Vector **(ω).** Eigen Vector = **[***Geometric Mean /Σ (Geometric Means)***].** And to check the consistency ratio (CR), consistency Index (CI) was calculated using equation (1), and then (CR) calculated using equation (2) and (Table **A1)**. It shouldn't exceed 0.1, Thus, the matrix is valid.

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

Where, *CI* is the consistency index, ***n*** is the order of the comparison matrix and λ_{max} = (multiplying matrix A with the Eigen Vector**)**.

$$CR = \frac{CI}{RI} \quad (2)$$

Where, *CR* is the consistency ratio, *CI* is the consistency index and *RI* is the random consistency index obtained from (Table**.7).**

Table A1: Average random consistency index

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

- Global weight is then calculated for the sub-functions by multiplying the relative weight for each sub-function by the relative weight for its main function.

The following is the application of the previous calculations on the Main Functions and the sub-functions of the Aesthetic requirements function.

Table A2: Pair-wise comparison matrix for the Main Functions.

	Aesthetic requirements (A)	Functional & Maintenance requirements (B)	Environmental requirements (C)	Safety requirements (D)	Construction requirements (E)
A	1	1	2	1	3
B	1	1	4	6	5
C	0.5	0.25	1	4	2
D	1	0.166666667	0.25	1	5
E	0.333333333	0.2	0.5	0.2	1
Sum	3.833333333	2.616666667	7.75	12.2	16

Table A3: Eigen Vector Calculation (relative weights for Main Functions).

	Geometric Mean (nth root of Product) (A*B*C*D*E)^(1/5)	**Eigen Vector (ω)** = Geometric Mean/ Σ (Geometric Means)	**Aω** Matrix A * Eigen Vector	**λ_{max} = Aω/ω**
A	1.430969081	**0.233**	**1.103**	**4.729**
B	2.605171085	**0.425**	**2.025**	**4.768**
C	1	**0.163**	**0.862**	**5.290**
D	0.730721276	**0.119**	**0.464**	**3.895**
E	0.367097772	**0.060**	**0.328**	**5.479**
Sum	**6.133959213**	**1.000**		**λmax =4.67019368655382 (Average)**

Table A4: Pair-wise comparison matrix for Aesthetic requirements functions.

	1.1	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**
1.1	1.00	2	5	1	4	7
1.2	0.5	1.00	2	2	1	5
1.3	0.2	0.5	1.00	1	2	5
1.4	1	0.5	1	1.00	1.00	5
1.5	0.25	1	0.5	1	1.00	1.00
1.6	0.143	0.2	0.2	0.2	1	1.00
Sum	**3.093**	**5.2**	**9.7**	**6.2**	**10**	**24**

Table A5: Eigen Vector Calculation (relative weights for Aesthetic requirements functions).

	Geometric Mean (n^{th} root of Product) (A*B*C*D*E*F)^(1/6)	**Eigen Vector (ω)** Geometric Mean / Σ (Geometric Means)	**Aω** Matrix A * Eigen Vector	**λ_{max} = Aω/ω**
1.1	2.557759297	**0.354**	**2.320**	**6.549**
1.2	1.467799268	**0.203**	**1.302**	**6.404**
1.3	1	**0.138**	**0.892**	**6.441**
1.4	1.164993051	**0.161**	**1.077**	**6.679**
1.5	0.707106781	**0.098**	**0.665**	**6.792**
1.6	0.323344386	**0.045**	**0.294**	**6.564**
Sum	**7.221002782**	**1.000**		**λ_{max} = 6.57152(Average)**

Table A6: Eigen Vector Calculation (relative weights for Aesthetic requirements functions).

Sub-Functions	**Global weight**
1.1 Floor Pattern Design.	0.081825
1.2 Attractive Appearance.	0.046947
1.3 Comfort Feelings.	0.032415
1.4 Light Reflection Level.	0.038176
1.5 Providing Resilience.	0.023667
1.6 Color and Gloss Level.	0.01067
2.1 Refinishing Capability.	0.084452
2.2 Durability.	0.087135
2.3 Cleanliness.	0.071899
2.4 Resistance to tinctures.	0.045057
2.5 Smoothness.	0.039599
2.6 Corrosion resistant.	0.019629
2.7 Damp Resistance.	0.02289
3.1 Soundproofing.	0.058823

Sub-Functions	Global weight
3.2 Thermal Insulation.	0.061767
3.3 low-emission materials.	0.033231
3.4 Sustainable materials including:	0.00848
4.1 Slip Resistance.	0.050928
4.2 Electrical Resistance	0.037317
4.3 Fire Resistance.	0.02602
4.4 Surface flatnessز	0.020428
5.1 Easy to install	0.02163
5.2 Low wastage percent	0.011819
5.3 Short installation time.	0.008019
5.4 Easy to remedy various defects.	0.006412
5.5 Conforming expectations.	0.008803

Global weights of sub-functions = relative weight of the sub-function* weight of the main function