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Engineering Economics and Life Cycle Cost Analysis of Green Building

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Abstract: ***Green Building promotes the efficiency of buildings with regards to the use of water, renewable energy and materials while reducing the structure's impact on individual's health and the environment through its better design, construction, operation, maintenance system. Hence Green Building is all about the complete building life cycle Life-cycle cost analysis (LCCA) is an evaluating mechanism to evaluate the total financial/resource requirements for total ownership of a building for a pre-determined service period of the building. LCCA is highly helpful for project options that accomplishes the same task demands, having different initial/ construction costs and operational costs, needs to be examined in order to execute the option that optimizes financial requirements. Green building related expenses can be classified as 1) Non-Recurring Cost: Initial Costs, Residual Values, Finance Charges and 2) Recurring cost: Operation, Maintenance, and Repair Costs, Replacement Costs, Non-Monetary Costs. This article mainly emphasizes on the Maintenance and Repair cost analysis of green building materials; giving plausible trends for next 25 years for various essentials using DISTRICT SCHEDULE RATE (DSR), WHOLESHALE PRICE INDEX (WPI) and CONSUMER PRICE INDEX (CPI). These trends are only applicable for the whole of Mumbai city and suburban district.***

Keywords: Life Cycle Cost, Maintenance and Repair cost, Green Buildings

1. Green Building

A building which can function using an optimum amount of energy, consume less water, conserve natural resources, generate less waste and create spaces for healthy and comfortable living, as compared to conventional buildings, is a green building.

Green building design is a sensible and climate compliant approach to building design. Different factors, like geographical location, existing climatic conditions, use of locally available and low embodied energy materials and design consideration significant to the type of usage of the building are normally taken into consideration. Such an approach ensures minimum damage to the environment, while constructing and using the building.

1.1 Advantages of Green Building over Conventional Building

Reduced operating costs by increasing productivity and using less energy and water, Improved public and occupant health due to improved indoor air quality, Reduced environmental impacts by, for example, reducing storm water runoff and the heating effect.

Conventional methods of building use tremendous quantities of material, many of them non-renewable and toxic, and pay little attention to the impact the building has on the environment. Green buildings not only reduce these impacts but are also healthier and consume less energy saving money in the long run.

Using green building materials and products promotes conservation of dwindling nonrenewable resources internationally. In addition, integrating green building materials into building projects can help reduce the environmental impacts associated with the extraction, transport, processing, fabrication, installation, reuse, recycling, and disposal of these building industry source materials.

2. Life Cycle Cost Analysis (LCCA)

LCCA is "an economic estimation considering all agreed projected significant and relevant cost flows over a period of analysis expressed in financial value. The projected costs are those needed to achieve defined levels of performance, including reliability, safety and availability".

Broadly, life cycle costs are those associated directly with constructing and functioning of the building; while whole life costs include other costs such as land, income from the building and support costs related with the activity within the building.

2.1 Importance of LCCA

LCCA brings all costs of each substitute to a common point in time to attain a fair judgment. LCCA can readily make out the option with the lowest total cost based on present value of all preliminary and future costs. The most reasonable option in the long term is not always the option with the lowest capital or initial costs. When whole-life cost of an asset or alternative must be considered, an LCCA should be performed to determine the most cost-effective route.

3. Maintenance and Repair

Building revamp and maintenance mainly consists of conserving proper state of a building, its functions and utilities in routine use the types of building maintenance are:

- Day to day repairs service facilities
- Annual repairs
- Unpredictable repairs
- Additions and alterations
- Preventive maintenance

4. Research Methodology

The maintenance and repair costs are found for various elements that are subjected to maintenance and repairs. The costs of these elements are gathered from the DISTRICT

SCHEDULE OF RATES OF MUMBAI AND SUBURBAN AREA over the last 15 years i.e. from year 2001. Since DISTRICT SCHEDULE OF RATES OF MUMBAI AND SUBURBAN AREA is used, these trends are only applicable to Mumbai district. These rates are considered as the basis for the projected cost over the next 25 years i.e. till year 2040. Basic rates for cistern fittings and labor wages have been collected from the WHOLESALE PRICE INDEX and CONSUMER PRICE INDEX respectively corresponding forecast is developed. Forecasts are developed with the help of trend lines characterized by specific curve equations thereby giving projected rates.

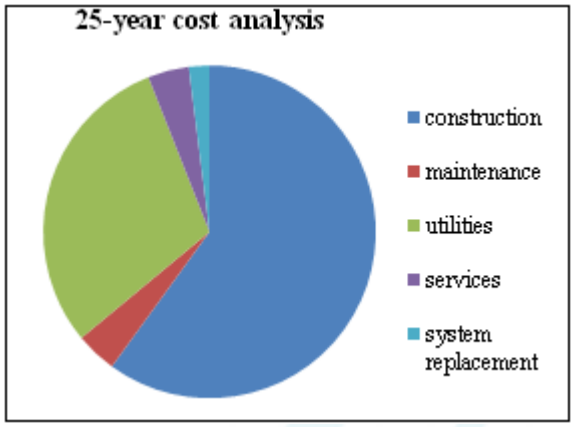

Chart 1: 30-Year Analysis

Since the maintenance and repair cost is 3rd highest for a super structure thus this article mainly emphasizes on it.

5. Elements Considered for Maintenance

Next 25 years of cost projections for following maintenance elements have been determined:

1) Internal Plastering
2) External Plastering
3) Zero Voc Internal Painting
4) Cistern Fittings
5) Dado Tiling
6) Flooring
7) Water Proofing
8) Green Glass
9) AAC Blockwork

The main reason behind selecting these elements lies in the fact that these maintenance and repair parameters are the most common and most widely subjected in reference to maintenance and repair works.

5.1 Internal Plastering

DESCRIPTION: The analysis considers internal plastering being undertaken in single coat, having 12 mm thickness. The plaster is prepared in fly ash cement to water ratio 1:5. Cost of neeru finish has been neglected in this analysis. The cost of scaffolding required and curing provided has been considered

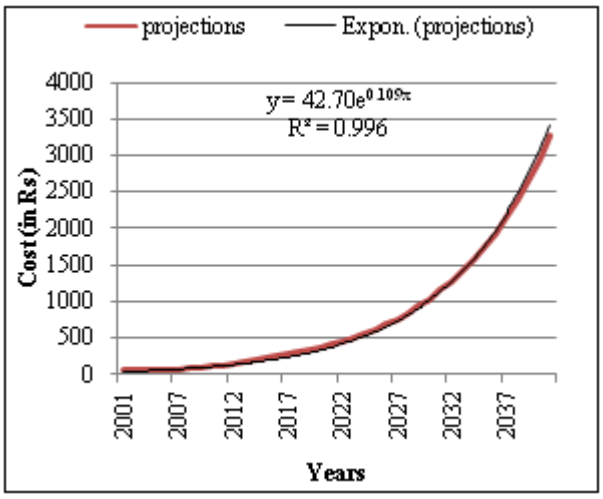

Chart 2: Cost Projections for Internal Plastering

Table 1: Cost Projections for Internal Plastering

Years	Projected COST(Rs/Sqm)	Years	Projected COST(Rs/Sqm)
2016	263.5237	2029	1030.573
2017	292.6699	2030	1144.556
2018	325.0397	2031	1271.146
2019	360.9897	2032	1411.737
2020	400.9158	2033	1567.878
2021	445.2579	2034	1741.288
2022	494.5042	2035	1933.878
2023	549.1973	2036	2147.768
2024	609.9395	2037	2385.315
2025	677.3999	2038	2649.135
2026	752.3216	2039	2942.135
2027	835.5297	2040	3267.54
2028	927.9408		

5.2 External Plastering

DESCRIPTION: Rough cast cement plaster is considered for external plastering. The plastering is provided in two coats to concrete, stone or brick masonry. The analysis also includes preparing the base and watering the surface. The base coat is 12 to 15 mm thick, prepared in cement to water ratio of 1:4. The analysis also considers water proofing of the surface using water proofing compound at the rate of 1 kg per 50 kg of fly ash cement. Rough cast treatment provided is 12 mm thick and in proportion 1:1.5:3 (cement: sand : coarse aggregate). The cost of scaffolding required and curing provided for 14 days has been considered.

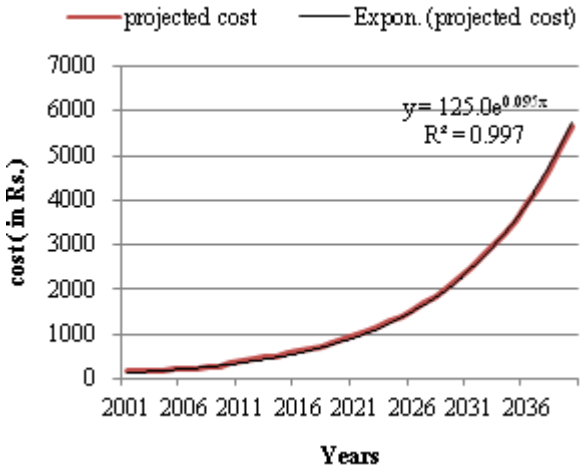

Chart 3: Cost Projections For External Plastering

Table 2: Cost Projections for External Plastering

Years	Projected COST(Rs/Sqm)	Years	Projected Cost(Rs/Sqm)
2016	263.5237	2029	1030.573
2017	292.6699	2030	1144.556
2018	325.0397	2031	1271.146
2019	360.9897	2032	1411.737
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2026	752.3216	2039	2942.135
2027	835.5297	2040	3267.54
2028	927.9408		

5.3 Cistern Fittings with Labor Wages

5.3.1 Cistern Fittings

DESCRIPTION: Under cistern fittings only considerations regarding the regular taps that are used are made. Taps ranging from kitchen taps to toilet and bathroom taps and basin taps are considered here. The costs considered are average cost of taps in household. The base costs are gathered from the WHOLESALE PRICE INDEX.

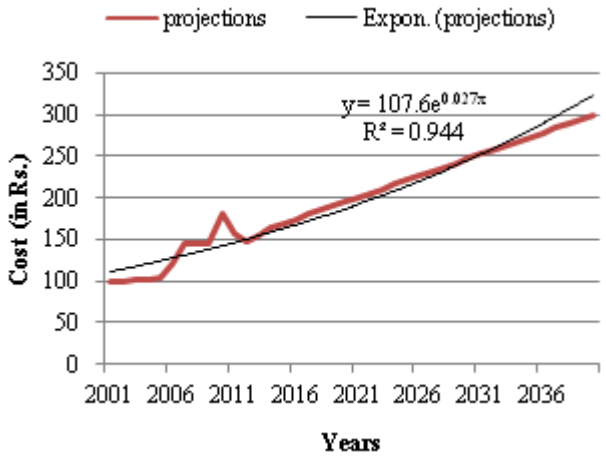

Chart 4: Cost Projection for Cistern Fittings

Table 3: Cost Projection for Cistern Fittings

Years	*Projected Cost*	*Years*	*Projected Cost*
2016	175.0323	2029	242.0623
2017	180.1885	2030	247.2185
2018	185.3446	2031	252.3746
2019	190.5008	2032	257.5308
2020	195.6569	2033	262.6869
2021	200.8131	2034	267.8431
2022	205.9692	2035	272.9992
2023	211.1254	2036	278.1554
2024	216.2815	2037	283.3115
2025	221.4377	2038	288.4677
2026	226.5938	2039	293.6238
2027	231.75		
2028	236.9062		

5.3.2 Labour Requirement for Fittings

Description: Skilled labour is considered for the fitting of taps since time requirement for the fixation of tap is nominal, generally unskilled labour wages are considered here. Since the base wages of the unskilled labour is collected from the Consumer Price Index references.

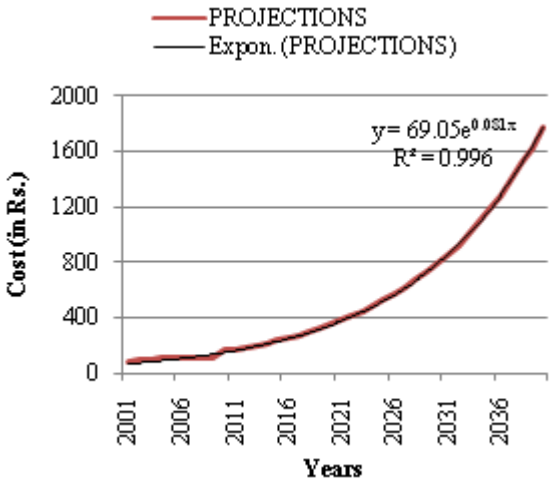

Chart 5: Cost Projection for Labour Wages

Table 4: Cost Projection for Labour wages

YEARS	PROJECTED COST(Rs/Hr)	YEARS	PROJECTED COST(Rs/Hr)
2016	252.9275	2029	727.1442
2017	274.331	2030	788.6773
2018	297.5457	2031	855.4176
2019	322.7249	2032	927.8056
2020	350.0349	2033	1006.319
2021	379.6559	2034	1091.477
2022	411.7835	2035	1183.841
2023	446.6298	2036	1284.021
2024	484.425	2037	1392.679
2025	525.4185	2038	1510.532
2026	569.8809	2039	1638.357
2027	618.106	2040	1777
2028	670.412		

5.4 Dado Tiling

Description: The analysis consists of providing and fixing plain ceramic tiles of size 300 mm X 200 mm. The plaster used is cement mortar ratio of 1:4. The forecast includes filling of joints with neat cement flurry or cement paste. The cost also includes curing and cleaning after dado tiling is done.

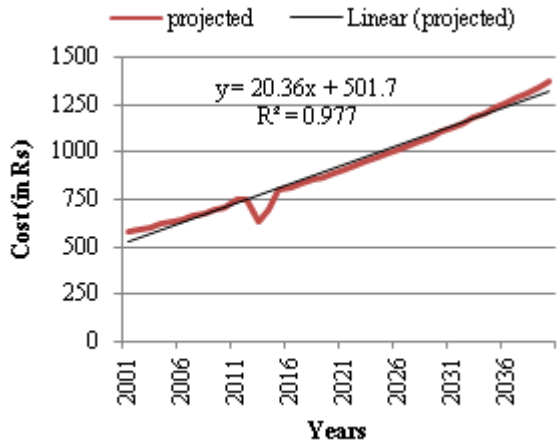

Chart 6: Cost Projection for Dado Tiling

Table 5: Cost Projection for Dado Tilings

YEARS	PROJECTED COST(Rs/Sqm)	YEARS	PROJECTED COST(Rs/Sqm)
2016	813.9379	2029	1079.762
2017	831.8262	2030	1103.492
2018	850.1075	2031	1127.744
2019	868.7907	2032	1152.529
2020	887.8844	2033	1177.859
2021	907.3978	2034	1203.745
2022	927.34	2035	1230.2
2023	947.7205	2036	1257.237
2024	968.5489	2037	1284.867
2025	989.8351	2038	1313.105
2026	1011.589	2039	1341.964
2027	1033.821	2040	1371.457
2028	1056.542		

5.5 Flooring

Description: The analysis consists of providing and laying of marble mosaic that is 10 mm thick. This flooring is made of marble chips of white or any other colour. These chips are preferably of 6 mm size. Coloured cement is more suitable for flooring. It also includes an under layer of cement concrete 1:2:4.Providing aluminium strips for panels, leveling, compacting, curing, polishing, rubbing and cleaning are considered in the analysis.

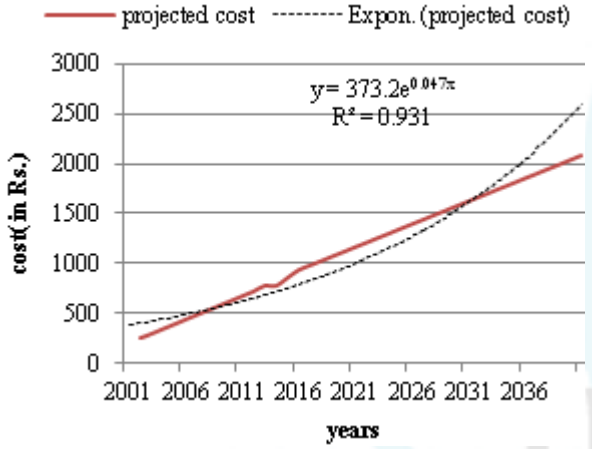

Chart 7: Cost Projection for Flooring

Table 6: Cost Projection for Flooring

YEARS	PROJECTED COST(Rs/Sqm)	YEARS	PROJECTED COST(Rs/Sqm)
2016	989.7752	2029	1584.853
2017	1035.55	2030	1630.628
2018	1081.326	2031	1676.403
2019	1127.101	2032	1722.178
2020	1172.876	2033	1767.954
2021	1218.651	2034	1813.729
2022	1264.426	2035	1859.504
2023	1310.202	2036	1905.279
2024	1355.977	2037	1951.054
2025	1401.752	2038	1996.83
2026	1447.527	2039	2042.605
2027	1493.302	2040	2088.38
2028	1539.078		

5.6 AAC Blocks

The analysis consists of providing autoclaved aerated concrete block masonary conforming to IS 2185(Part-3) of size 200*240*650 mm in cement mortar 1:4 in superstructure including bailing out water manually, striking joints on unexposed faces, racking out joints on exposed faces and watering etc, complete

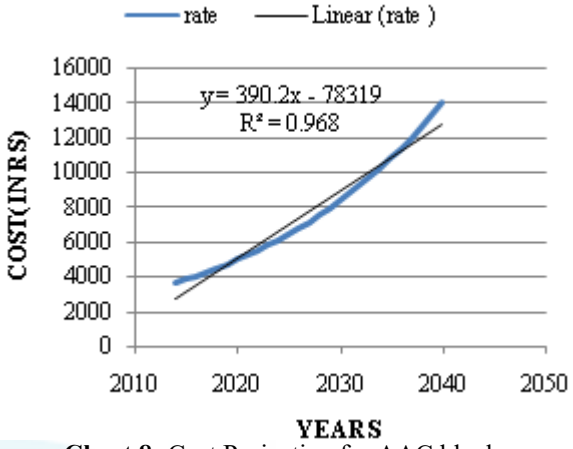

Chart 8: Cost Projection for AAC blocks

Table 7: Cost Projection for AAC blocks

Years	*Projected Cost*	*Years*	*Projected Cost*
2014	3635.767	2028	7528.894
2015	3829.809	2029	7930.714
2016	4034.208	2030	8353.978
2017	4249.515	2031	8799.833
2018	4476.31	2032	9269.483
2019	4715.215	2033	9764.198
2020	4966.867	2034	10285.32
2021	5231.951	2035	10834.25
2022	5511.182	2036	11412.47
2023	5805.315	2037	12021.56
2024	6115.147	2038	12663.16
2025	6441.514	2039	13338.99
2026	6785.3	2040	14050.9
2027	7147.433		

5.7 Aluminium Double Glazed Window Glass

Providing and fixing in position extruded modular aluminium fixed double glazed low e-value, low U-value (solarban) glass panel window having frame made out of extruded tubular section mechanically assembled at corners with glazing, beading of angle 25mmx25mm x 1.6 mm thick including plain sheet glass 5.5 mm thick with rubber gasket and wooden encasement wherever necessary etc. as per approved drawing and specification etc. complete

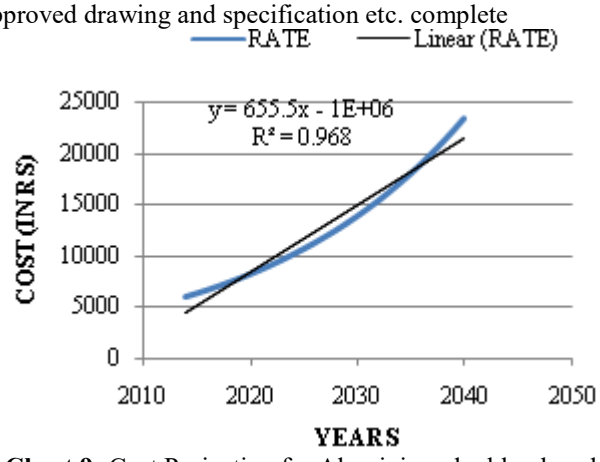

Chart 9: Cost Projection for Aluminium double glazed window glass

Table 8: Cost projection for Aluminium Double glazed window glass

Years	Projected Cost	Years	Projected Cost
2014	5992.475	2028	12506.87
2015	6315.833	2029	13181.75
2016	6656.64	2030	13893.04
2017	7015.838	2031	14642.72
2018	7394.418	2032	15432.86
2019	7793.427	2033	16265.63
2020	8213.966	2034	17143.33
2021	8657.198	2035	18068.4
2022	9124.347	2036	19043.38
2023	9616.704	2037	20070.98
2024	10135.63	2038	21154.03
2025	10682.56	2039	22295.51
2026	11258.99	2040	23498.6
2027	11866.54		

5.8 Zero Voc Paint

DESCRIPTION: Applying of zero VOC, odour less, solvent free, non toxic paint having anti-bacterial and anti-fungal property and complying with all the GREEN product standard with coverage of up to 12 m2 /litre of surface area of required shade to the building and workshop's plastered surface has been considered including scaffolding, surface preparation and cleaning.

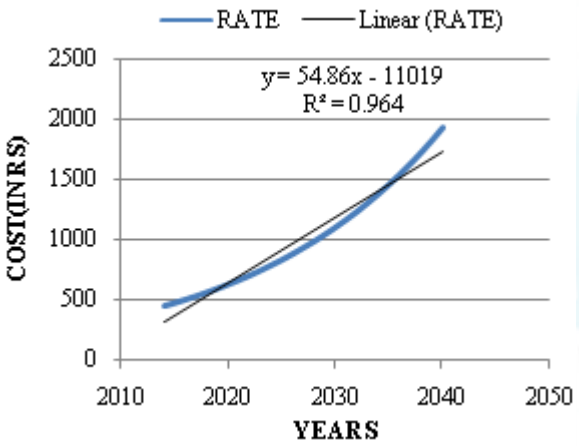

Chart 10: Cost Projection for Zero VOC paint

Table 9: Cost projection For Zero VOC paint

Years	Projected Cost	Years	Projected Cost
2014	5992.475	2028	12506.87
2015	6315.833	2029	13181.75
2016	6656.64	2030	13893.04
2017	7015.838	2031	14642.72
2018	7394.418	2032	15432.86
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2024	10135.63	2038	21154.03
2025	10682.56	2039	22295.51
2026	11258.99	2040	23498.6
2027	11866.54		

5.9 Waterproofing

Providing and laying waterproofing treatment of 112mm average thickness consisting of 12 m thick layer in cement mortar 1:3 with water proofing compound and jute fiber at the rate of 1 kg, each per bag of cement as base, constructing and laying brick bat coba in cement mortar 1:5 with waterproofing compound at the rate of 1 kg per bag of cement and having average thickness of 80 mm and finishing with 20mm thick cement plaster layer in cement mortar 1;3 with waterproofing compound at the rate of 1kg per cement bag, including all lead, lifts and laid to proper slope to drain off water entirely preparing bell mouth including watta, beveled or champhered portion at the junction of parapet and work up to height 300 mm or as directed and including finishing the top layer of water proofing treatment with false marking of 30 cm x 30 cm, curing

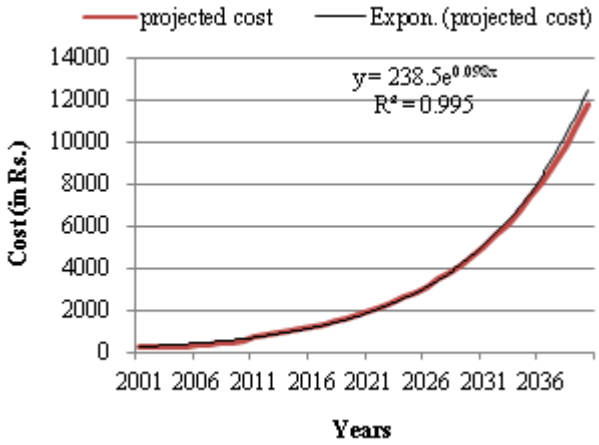

Chart 11: Cost Projection for waterproofing

Table 10: Cost projection for waterproofing

Years	*Projected Cost*	*Years*	*Projected Cost*
2014	697.6	2028	1056.542
2015	796.4344	2029	1079.762
2016	813.9379	2030	1103.492
2017	831.8262	2031	1127.744
2018	850.1075	2032	1152.529
2019	868.7907	2033	1177.859
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2025	989.8351	2039	1341.964
2026	1011.589	2040	1371.457
2027	1033.821		

6. Conclusion

Thus based on the cost projections and trends of different activities/ process it can be conferred that the maintenance and repair costs of green building are bound to increase with time. Some tend to increase linearly while some tend to increase exponentially. These graphs will help the financial controllers and economy managers to predict the cost of specific repair maintenance work in the future years. These predictions will assist to plan and manage the finances according requirement.

7. Acknowledgement

We would like to thank and acknowledge the hard work and perseverance of Dr. Shagufta Sayed in guiding us and showing the correct path during the entire research period.

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