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PREFACE

It is with great pride and pleasure that we present the Second Volume of the compilation of selected postgraduate research projects of MES Kalladi College, published under the auspices of the Research Promotion Council. Building upon the success and scholarly impact of the inaugural volume, this publication reaffirms the institution's sustained commitment to fostering a strong culture of research, innovation, and academic excellence.

This ISBN-bearing second volume stands as a reflection of the growing research ethos among our students and faculty. The projects included herein have been carefully reviewed and selected based on their originality, academic rigor, relevance, and potential impact. They exemplify the intellectual curiosity, critical thinking, and methodological competence of our postgraduate students, nurtured through the dedicated guidance of experienced faculty mentors.

The continuation of this publication initiative underscores our belief that research is integral to higher education. This volume not only documents academic achievement but also serves as an inspiration for emerging researchers by highlighting the importance of inquiry-driven learning and scholarly engagement. We are confident that it will be a valuable resource for students, researchers, and academicians alike.

We express our sincere gratitude to all contributors student authors, faculty guides, reviewers, and the editorial team for their steadfast efforts in bringing this second volume to completion. We also gratefully acknowledge the continued support of the management and administration of MES Kalladi College in promoting research and academic advancement.

May this second volume further strengthen the spirit of inquiry and serve as a catalyst for meaningful research and innovation in the years to come.

Research Promotion Council
MES Kalladi College

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EUROPIUM OXIDE MODIFIED TiO_2 SiO_2 NANOMATERIALS

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Abstract

We report a facile method for the synthesis of europium modified TiO_2-SiO_2 (Eu-TS). mixed oxide nanomaterial by sol-gel process. TiO_2-SiO_2 nanomaterials and their europium modified samples were prepared with varying concentration of europium ion. The resultant materials were characterized by Powder X-ray Diffraction (XRD), Diffuse Reflectance Ultraviolet-Visible Spectroscopy (UV-Vis DRS), Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy (ATR-FTIR), Transmission Electron Microscopy (TEM) and Bruener- Emett- Teller (BET) physisorption analysis. Presence of europium ions can reduce the crystallinity of the anatase phase present in TiO_2-SiO_2 matrix. Diffuse reflectance spectra indicate that slight shift in wavelength to visible region due to the addition of europium ions. HR-TEM image of the representative materials indicated the presence of crystalline anatase TiO_2. BET surface area and pore size distribution study indicated that the material exhibited type IV adsorption isotherm with variation in Pore size distribution and surface area. The material Eu-TS exhibited high surface area with a value of 220 m^2/g and an average pore size of 2.22 nm were as the unmodified material exhibited a value of 279 m^2/g .and an average pore size of 2.45 nm.

1. Introduction

Titanium dioxide (TiO_2) is a well-known photocatalyst that exhibits strong activity under ultraviolet (UV) light [1]. It is relatively easy and economical to synthesize, highly stable, non-toxic, and effective in promoting

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photodegradation in various chemical reactions. However, its wide band gap and rapid electron–hole recombination significantly limit its photocatalytic efficiency [2]. Therefore, alternative strategies are required to enhance the visible-light responsiveness of TiO_2. In order to overcome the above-mentioned drawbacks and to improve the photocatalytic efficiency of TiO_2, a number of strategies have been explored. A widely adopted method is the incorporation of TiO_2 with other oxide or with mesoporous materials. By this method, TiO_2 with smaller particle sizes and high dispersion can be obtained. In addition, coupling of TiO_2 with another oxide is also recognized to be an effective way to modify the textural properties. For instance, it was reported that the surface area of the TiO_2-metal oxide composites are relatively higher when compared to the bare TiO_2. SiO_2 as the supporting metal oxide, which act as an adsorbent or as a support for TiO_2. Iwamoto et al. [3] reported that SiO_2 modified TiO_2 with anatase crystal phase has large surface area and superior thermal stability. They further observed that the Si atoms are inserted in the distorted octahedral vacant sites of the anatase crystal lattice. Harrison et al. [4] suggested a method of preparation of TiO_2–SiO_2 mixed oxide in different organic solvents by hydrothermal method followed by calcination under air. Similarly, Budhi et al. [5] suggested the synthesis of TiO_2–SiO_2 mixed oxide by sol gel method followed by calcination under air. Previous studies have reported that sensitizing TiO_2 through cation or anion doping, as well as by anchoring small organic molecules [6], can improve its visible-light activity. Consequently, doping with cations or anions represents a promising approach to enhance the photocatalytic performance of TiO_2-based materials. Numerous studies have investigated cation doping in TiO_2 nanostructures [7], primarily aiming to enhance charge separation and thereby improve the photocatalytic efficiency of the material. exhibits a reduced band gap energy and enhanced sensitivity to visible light [8]. In addition, doped TiO_2 often demonstrates higher crystallinity [9]. Photocatalysts modified with transition metals have also been extensively explored [10]. These studies indicate that the photocatalytic activity of doped TiO_2 depends on several factors, including the dopant concentration, the band gap energy of the material, the oxidation state of the metal ions, and the intensity of the incident light.

Recently, rare-earth metal ions doped TiO_2 have been explored for various applications [11] however their applications in solar energy conversion is quite

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limited [12]. Due to the interesting physical properties associated with TiO_2, it can promote rare earth metal ion for doping [13] .Ranjit et al. reported the use of lanthanide doped TiO_2 in various environmental applications [14]. According to their reports, the lanthanide doped TiO_2 inhibit the phase transformation of anatase to rutile and the variation in phase composition resulting the variation in photocatalytic activity. Saif et al. [15] reported the use of lanthanide doped TiO_2 for the degradation of textile dye. Moreover, Yan et al. [16] reported that lanthanide doped TiO_2 composites can act as a good catalyst for phenol conversion compared to TiO_2. Recently Harrison et al reported the use of nanomaterial for photodegradation of organic contaminant [17].

In order to overcome the above-mentioned drawbacks and to improve the photocatalytic efficiency of TiO_2, a number of strategies have been explored. A widely adopted method is incorporation of TiO_2 with other oxide or with mesoporous materials [18]. By this method, TiO_2 with smaller particle sizes and high dispersion can be obtained. In addition, coupling of TiO_2 with another oxide is also recognized to be an effective way to modify the textural properties. For instance, it was reported that the surface area of the TiO_2-metal oxide composites is relatively higher when compared to the bare TiO_2. SiO_2 as the supporting metal oxide, which act as an adsorbent or as a support for TiO_2. Recently, Sasikala et al. [12] reported the synthesis of Eu and Sn co-doped TiO_2 nanocomposites for solar simulated hydrogen generation. Based on this study, they observed very low amount of hydrogen in the presence of Eu and Sn co-doped TiO_2. Similarly Laniecki et al. [19] observed generation of hydrogen from platinized La-TiO_2. Thus, in both of these studies reported the use of mixed photocatalyst or co-catalyst for the generation of hydrogen.

Here we report the synthesis of europium ion modified TiO_2- SiO_2 material by the sol–gel method. Sol-gel method has potential for scale-up, economical and shows active TiO_2 crystal phases. The morphology and crystal structure of the nanomaterial, optical properties, surface areas, were characterized by transmission electron microscopy (TEM), X-ray diffraction (XRD), UV-Vis diffuse reflectance spectroscopy (DRS), N_2 adsorption–desorption. The photocatalytic performance of Eu-TiO_2-SiO_2 hybrid material was examined by monitoring the amount of hydrogen evolved from water under light irradiation.

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2. Experimental

2.1 Materials

Titanium isopropoxide and tetra ethyl ortho silicate (TEOS) were used as precursor for synthesis of TiO_2-SiO_2 mixed oxide nanomaterials. Concentrated HNO_3 has been used as initiators for sol-gel process. Isopropyl alcohol is used as solvent medium. Europium nitrate penta hydrate is used as the source for europium ion modification of mixed oxide nanomaterials. Purified water is used throughout the experiment.

2.2 Preparation of TiO_2-SiO_2 mixed oxide (TS)

1.65 ml of tetraethyl ortho silicate was added drop wise to a solution containing 18 ml isopropyl alcohol under vigorous stirring in a beaker. The hydrolysis part was initiated by 1ml water and catalysed by addition of 0.25 ml of conc. HNO_3. The resulting mixture was stirred for 15 minutes. Add 2.2 ml titanium isopropoxide. The resulting gel was kept for drying at room temperature for 24 hours. Calcination was done at 550 ^{0}C for 3 hours in a static air environment. The sample is labeled as TS.

2.3 Preparation of europium modified TiO_2-SiO_2 (Eu-TS)

1.65 ml of tetraethyl orthosilicate was added dropwise to a solution containing 18 ml isopropyl alcohol under vigorous stirring in a beaker. The hydrolysis part is initiated by 1 ml water and catalysed by addition of 0.25 ml of conc. HNO_3. The resulting mixture was stirred for 15 minutes. Add 2.2 ml titanium isopropoxide. Add 10 mg of europium nitrate. The mixture was stirred for 3 hours to obtain wet gel. The resulting gel was kept for drying at room temperature. Calcination was done at 550 ^{0}C for 3 hours in a static air environment. The obtained material is labelled as Eu- TS.

2.4 Characterisation

The synthesized materials were characterized by Powder X-Ray Diffraction (PXRD), Diffused Reflectance Ultraviolet-Visible Spectroscopy (UV-Vis DRS), Raman Spectroscopy and High-Resolution Transmission Electron Microscopy (HR-TEM). The powder XRD measurements were performed at room temperature using a Rigaku Miniflex 600 X-ray diffractometer with Cu Kα radiation. The diffractometer was operated at 40kV and 44mA and scanned with a step size of 0.02^0 at a scan speed of

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1^0/min in the range of 10° to 80°. Raman spectra were measured on a Bruker optik GmbH spectrometer with a Raman laser (785 nm) as the light source. The unfiltered beam of scattered laser radiation was focused onto the sample through a microscope objective (x50) for an acquisition time of 10s and repetition of 10x. The UV-Vis diffuse spectra were recorded by a JascoV-550 UV-Visible spectrophotometer with Jasco model ISV 469 reflection accessory. For the preparation of sample for HR-TEM analysis, the representative material Ca-TiO_2 was dispersed in ethanol, and the suspension was sonicated for 1hour. One drop of the suspension was placed on a TEM grid, and allowed to dry overnight. The instrument used for present study features a high-stability goniometer stage specifically tuned for high tilt tomographic applications. A HR-TEM (Jeol/JEM 2100) of voltage 200kV is capable of a spatial resolution of 0.14 nm and can provide images with 2000X – 1500000X magnification by using a multiscan digital camera (camera length 80-2000mm). LaB_6 is used as the source of radiation.

2.5 Photocatalytic hydrogen evolution

In order to understand the role of europium ion on the photocatalytic activity of TiO_2–SiO_2 material, we carried out the photocatalytic hydrogen evolution studies using visible light irradiation source containing small percentage of UV light on the above-mentioned materials. The experiment was performed in a stainless-steel reactor with a side cavity through which hydrogen gas was taken out. Methanol was used as the sacrificial agent. Nitrogen gas was purged to remove dissolved oxygen. Typically, a known amount of the material (50 mg) was suspended in 50 ml solution containing H_2O and methanol taken in a 4:1 ratio. The suspension was degassed for 30 min with high-purity nitrogen prior to irradiation. The sample was continuously stirred throughout the course of the experiment. A high-pressure arc lamp with a coating which passes majority of visible light and also contain UV light of wave length 380 nm and above was used as the source for irradiation. H_2 evolution within a time interval of 1hour was recorded. The experiment was carried out for 5 hours. The amount of H_2 produced was measured by gas chromatograph (Shimadzu Gas Chromatograph GC-2010 PLUS) equipped with a molecular sieve column and a TCD detector and using a previously calibrated plot.

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3. Results and Discussions

3.1 Powder XRD analysis

The powder XRD pattern of TS and Eu- TS materials are shown in **Fig 1**. The materials exhibited diffraction peaks at 25.2^0, 37.9^0, 48.1^0 ,55.1^0 and 62.8^0 are due to d_{110}, d_{004}, d_{200}, d_{105} and d_{204}, respectively revealing the presence of anatase phase. The material TS exhibited higher intense peak compared to Eu-TS material. Up on addition of europium nitrate the intensity of anatase peak reduced to certain extent.

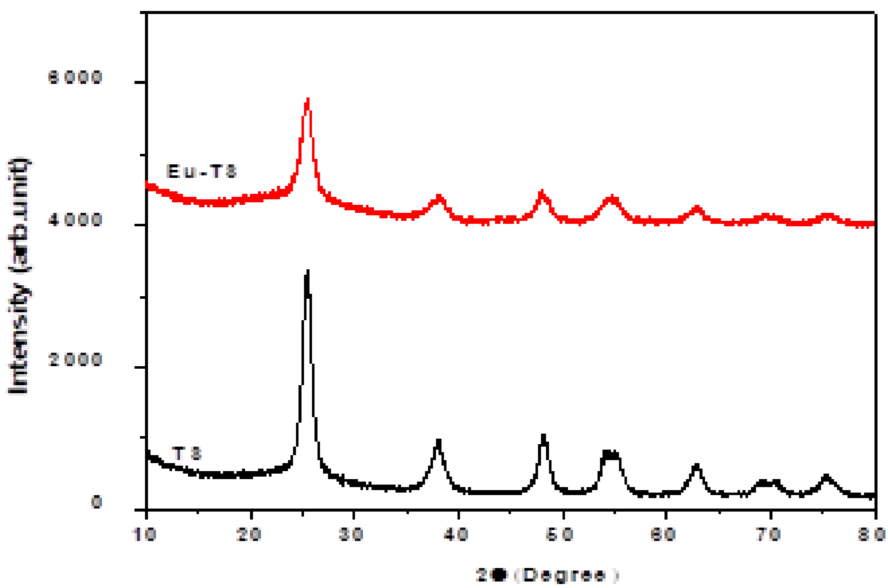

Fig 1. XRD patterns of TS, Eu-TS

3.2 Raman spectroscopic analysis

In order to verify the XRD data we conducted the Raman spectroscopic analysis of the representative materials. The Raman spectra of TS, and Eu-TS materials are shown in **Fig 2**. The spectra indicate that all the materials showed bands at 143 cm^{-1}, 395 cm^{-1}, 519 cm^{-1}, 641 cm^{-1}, with a shoulder peak at 199 cm^{-1} corresponding to anatase phase of the TiO_2 Materials [20]. The peaks at 143 ,199, 641, are due to E_g symmetric modes. Similarly, the peaks at 395 and 519 cm^{-1} are due to B_{1g} and A_{1g} symmetry. After the modification with europium ion the bands are slightly blue shifted in Eu-TS compared to their unmodified materials.

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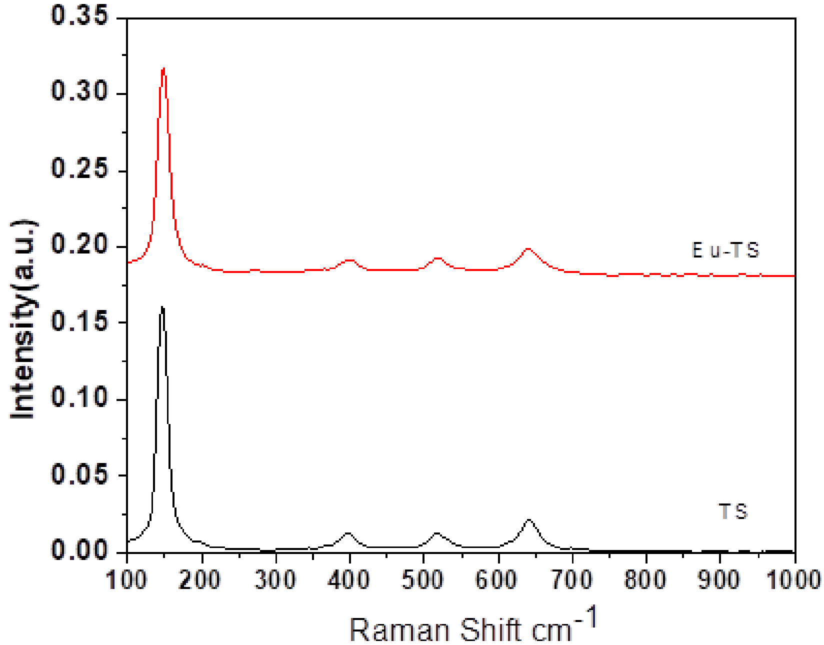

Fig 2. Raman spectra of TS and Eu-TS

3.3 UV- VIS DRS analysis

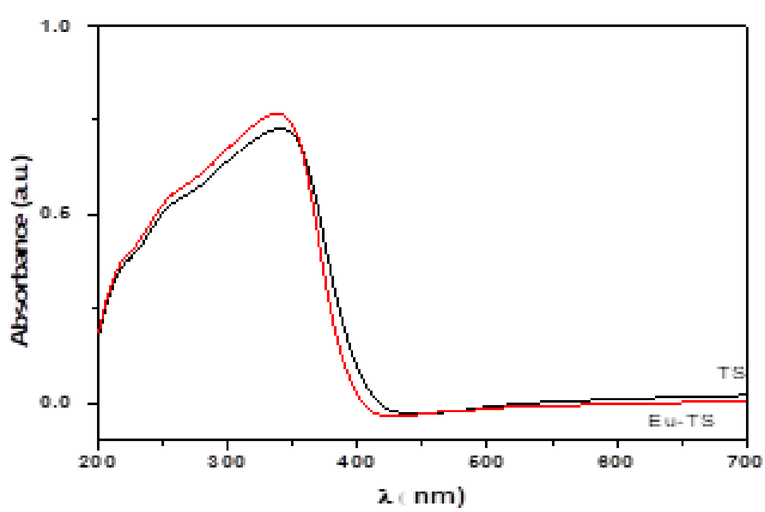

Fig 3. UV- Vis DRS spectra of TS, and Eu-TS

To determine the optical properties of the samples, UV-Visible diffuse reflectance spectroscopic analysis was carried out. The UV-Visible diffuse

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reflectance spectra of TS and Eu-TS materials are shown in **Fig 3**. From Fig 3 it is clear that the materials TS showed band at 360 nm. Corresponding to band gap absorption of anatase phase. With the addition of europium ion the spectra is slight blue shifted as observed in Eu-TS. The incorporation of europium ions often inhibits the growth of the TiO_2 crystallite size, leading to smaller nanoparticles compared to pure TiO_2. This reduction in particle size leads to quantum confinement effects, which increases the effective band gap and shifts the absorption to shorter wavelength.

3.4 ATR-FTIR analysis

In order to acquire information about the different functional groups, the materials were further characterized by using ATR-FTIR analysis. The spectrum is shown in **Fig 4**. All the samples showed typical IR spectra of TiO_2 -SiO_2 as reported earlier [21]

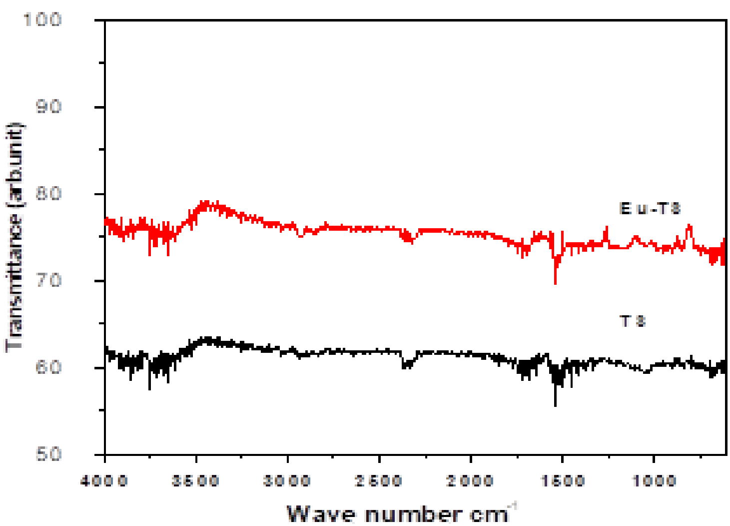

Fig 4. FT-IR spectra of TS and Eu-TS

It was reported that a broad peak at 3300 cm^{-1} correspond to the -OH functional groups of absorbed water will occur in the spectra of TiO_2-SiO_2 [22]. This is attributed to the stretching vibrations of hydroxyl group. The corresponding bending mode appears as medium intense band near around 1060 cm^{-1}[23]. A peak at 1100 cm^{-1} indicates the presence of Si-O- Si linkage [24]. A peak at 970 indicates the presence of Ti-O-Si linkage [25].

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3.5 TEM studies

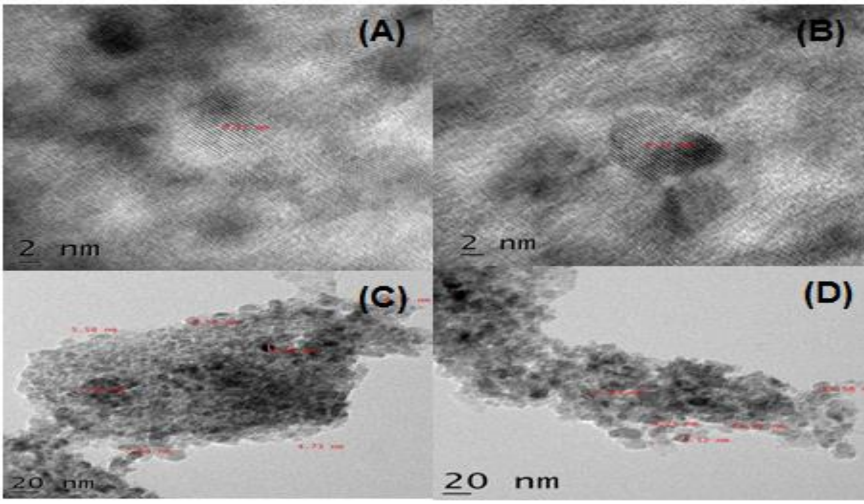

Fig 5. TEM images of TS (A, C) and Eu-TS E (B,D).

The TEM images of the representative materials TS and Eu-TS materials are shown in **Fig 5** From the TEM images of TS and Eu-TS, the TiO_2 particles are randomly distributed with a particle size of 10-15 nm. The TEM image shows lattice fringes due to TiO_2 (Fig.5A and B). The anatase phase with *d* spacing of 3.54 Å due to (101) can be calculated from the TEM images. The presence of Eu ions could not be observed in TEM images. This may be due to the high dispersion of Eu ion in the TiO_2 SiO_2 matrix of Eu-TS.

3.6 N_2 Physisorption analysis

The N_2 isotherms of TiO_2-SiO_2 mixed oxide prepared in these studies are shown in **Fig. 6**. The **Fig. 6A** indicates that both of the materials exhibited type IV isotherms typical of mesoporous materials. The hysteresis loops featured in the isotherms are reflection of porosity of these materials. The initial part of type IV isotherm is due to monolayer adsorption at low relative pressures. As the relative pressure increases, multilayer adsorption occurs followed by capillary condensation. After all of the pores are filled, the adsorption isotherm usually levels. The materials TS, Eu-TS, show hysteresis loop of H3 classification, as shown in Figure 6A. The H3 type loops are often associated with morphologies of narrow slit-like pores of broad pore size distribution with irregular shaped particles. The hysteresis loops of H3

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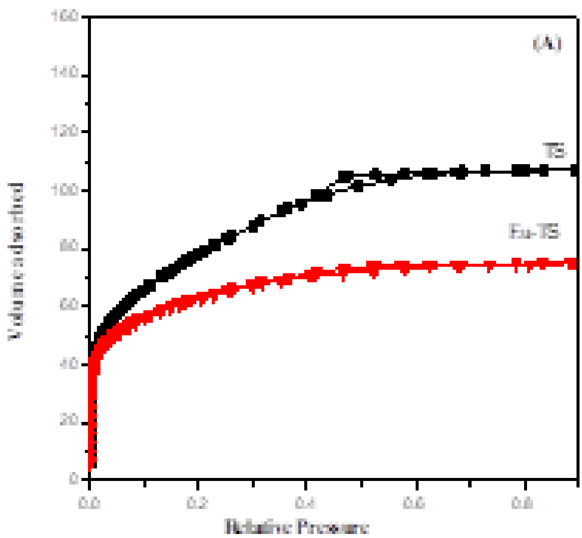
type classification do not level off at relative pressures close to the saturation vapor pressure. These H3 loop materials do not exhibit any limiting adsorption at high P/P_0, suggesting that the materials are comprised of aggregates of plate-like particles forming slit-like pores. The desorption branch of these mixed oxide types contains a moderate region associated with gradual closure of the loop, suggesting a delayed evaporation of the liquid.



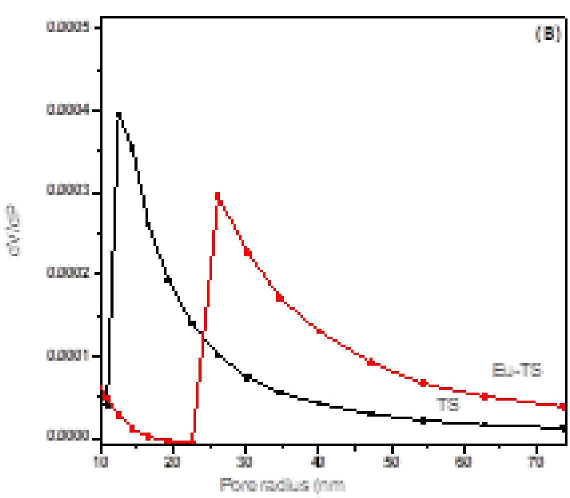


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Fig. 6 Nitrogen physisorption isotherms (A) and pore size distribution (B) of TS and Eu-TS materials

Pore size distributions for the TiO_2-SiO_2 mixed oxide materials are shown in **Fig. 6B**. The material TS and Eu-TS suggests a set of pores with a BJH pore diameters of 3.6 nm, and 7.5 nm respectively. The material TS EuE suggests a set of uniform pores with a BJH pore diameter of 3.6 nm. Thus, these studies showed that the Eu modification can adjust the pore sizes and modify the surface properties.

Table.1

Materials	Specific surface area m^2/g^c	Pore diameter $(nm)^d$	pore volume
TS	279	2.45	0.17
Eu-TS	220	2.22	0.12

[c] calculated from BET adsorption isotherms

[d]calculated from Barrett–Joyner–Halenda (BJH) equation using the adsorption isotherm

3.7 Water splitting

The influence of Eu^{3+} ions in Eu-TS materials was evaluated by conducting photocatalytic hydrogen evolution experiments on Eu-TS and the bare TS. The results are plotted in **Fig.7.** Photoirradiation was done by using a high-pressure mercury arc lamp with a coating which passes majority of visible light and also contain UV light of wavelength 380 nm above, was used as the source for irradiation.

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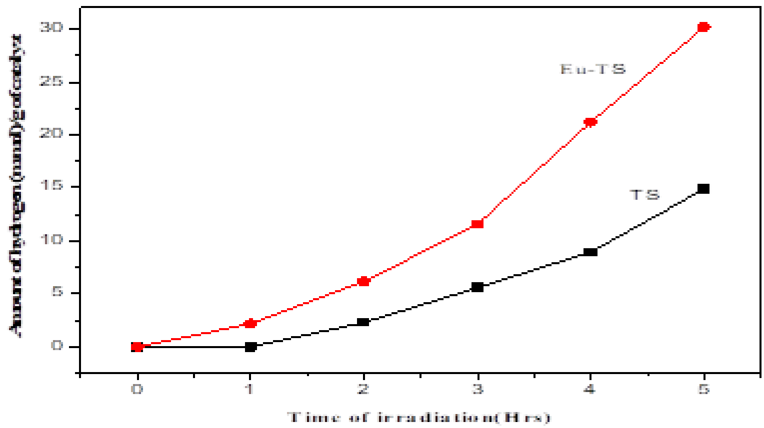

Fig. 7. Photocatalytic water splitting on the TS E and TS Eu E

From the **Fig. 7**, it is observed that the sample TS showed a hydrogen evolution value of 14.9 µmol after 5 hrs irradiation. On the other hand, europium modified sample showed a value of 30.2 µmol respectively under similar experimental conditions. This suggests that even though the hydrogen evolution value of bare TiO_2-SiO_2 is not remarkable, but its modified sample possesses better photocatalytic activity. The photocatalytic activity is doubled.

4. Conclusions

The TiO_2-SiO_2 mesoporous nanomaterial was successfully prepared by sol-gel process. X-ray diffraction analysis indicated that the synthesized materials exhibited diffraction patterns due to anatase phase. This was further confirmed by conducting Raman spectroscopic analysis. When TiO_2-SiO_2 was modified by europium ions, there occurs a reduction in the band gap. The anatase phase with *d* spacing of 3.54 Å due to (101) can be calculated from the TEM images. With the addition of europium ions, several vibrations of TiO_2-SiO_2 have been suppressed as shown by ATR-FTIR data. The synthesized materials showed a significant difference in photocatalytic activity. The photocatalytic efficiency is doubled after europium modification. The present sol gel method is very useful for determining the effect of europium ions in modifying the properties of TiO_2-SiO_2. The works highlights a simple method for H_2 fuel generation using mesoporous photocatalyst materials.

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CHAPTER – 2

ROLE OF MICROENTERPRISES IN POVERTY ALLEVIATION: A STUDY OF MANNARKKAD MUNICIPALITY

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Abstract

Poverty remains a persistent challenge in developing economies, particularly in rural and semi-urban regions. Microenterprises are widely recognized as an effective instrument for poverty alleviation due to their capacity to generate employment, promote entrepreneurship, and enhance income security. This study examines the role of microenterprises in poverty alleviation in Mannarkkad municipality, Kerala. Using primary data collected from 100 microenterprise units and supported by secondary sources, the study analyses the socio-economic conditions of microenterprises, their impact on poverty reduction, and the type and magnitude of enterprises operating in the study area. The findings reveal that microenterprises contribute significantly to employment generation, income stability, and social empowerment, particularly among women, despite facing constraints related to finance, infrastructure, and market access.

Keywords: Microenterprises, Poverty Alleviation, MSMEs, Employment, Mannarkkad Municipality

1. Introduction

Poverty continues to be a major socio-economic challenge in developing economies, especially in rural and semi-urban areas. It is characterized by deprivation of basic necessities such as food, shelter, healthcare, and

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education, resulting in low living standards. Microenterprises have emerged as an important strategy for poverty alleviation as they generate employment, promote entrepreneurship, and encourage self-reliance. In India, microenterprises are defined as enterprises with investment up to ₹1 crore and annual turnover below ₹5 crores, generally employing fewer than ten workers.

Empirical studies have shown that microenterprises reduce poverty not only through income generation but also by improving living standards and economic security (World Bank, 2005; Yunus & Moen, 2007). These enterprises are typically owner-operated, labour-intensive, and operate in sectors such as agriculture, handicrafts, food processing, trade, and services. Research indicates that micro and small enterprises utilize capital more efficiently and contribute significantly to local economic development (Venkateswar Rao, 1995).

The Micro, Small and Medium Enterprises Development (MSMED) Act, 2006 classifies enterprises into manufacturing and service sectors. Microenterprises form the backbone of the MSME sector in India and are the largest non-farm employment generators after agriculture. Encouraging entrepreneurship and improving access to finance are widely regarded as effective poverty reduction strategies in developing countries (Singer, 2006; Green & Kirkpatrick, 2006). Microenterprises also play a crucial role in empowering women by providing opportunities for self-employment and income generation (Anil Kumar, 2008).

Despite their importance, microenterprises face several challenges, including limited access to finance, infrastructural deficiencies, lack of skilled manpower, and market constraints. Agarwal (1987) highlighted the rigid attitude of banking institutions and inadequate credit flow as major barriers to microenterprise growth. Nevertheless, microenterprises remain vital for inclusive growth and poverty alleviation, particularly in rural and semi-urban regions such as Mannarkkad municipality.

Microenterprises have played a crucial role in India's development since the initiation of planned economic development. Their labour-intensive nature enables them to absorb surplus labour at low capital cost, thereby reducing unemployment and underemployment. Microenterprises contribute to poverty alleviation by generating self-employment, increasing

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household income, and promoting economic inclusion among disadvantaged groups.

Government initiatives such as microfinance expansion, Self-Help Groups, MUDRA loans, digital inclusion, and Atmanirbhar Bharat have strengthened microenterprises by improving access to credit, technology, and markets. These initiatives have enhanced the resilience of microenterprises, particularly during economic shocks such as the COVID-19 pandemic.

Kerala's favourable socio-economic environment and proactive government policies have accelerated microenterprise growth. Initiatives such as the 'Year of Enterprises' campaigns have led to the establishment of a large number of MSMEs, generating substantial employment. Microenterprises dominate both manufacturing and service sectors in the state, with a greater concentration in services.

Microenterprises promoted through Kudumbashree have significantly contributed to poverty alleviation by empowering women through microcredit and enterprise development. Programmes such as Rural Micro Enterprises, Vulnerability Micro Enterprises, Amrutham Nutrimix, and Haritha Karma Sena have improved income security and social empowerment among economically weaker sections.

Despite their contribution, microenterprises face several challenges, including inadequate access to finance, raw material scarcity, marketing constraints, technological backwardness, and infrastructural deficiencies. Addressing these challenges is essential to enhance their sustainability and strengthen their role in poverty alleviation.

2. Importance of the Study

The significance of this study lies in its focus on the local-level impact of microenterprises on poverty alleviation. Microenterprises create employment opportunities where large-scale industries are absent and provide income sources for individuals with limited access to formal employment. An understanding of their socio-economic contribution is essential for formulating effective development policies. The study also highlights the broader social benefits of microenterprises, including improved living standards, better access to education and healthcare, and strengthened community development.

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3. Objectives of the Study

1. To examine the socio-economic conditions of microenterprises in Mannarkkad municipality.
2. To analyse the impact of microenterprises on poverty alleviation in Mannarkkad municipality.
3. To study the type and magnitude of microenterprises operating in Mannarkkad municipality.

4. Research Problem

Although microenterprises are widely acknowledged as a tool for poverty alleviation, their actual contribution to improving livelihoods remains under-researched at the local level. Many microenterprises face sustainability issues due to financial, infrastructural, and managerial constraints. There is a need for context-specific analysis to assess their effectiveness in poverty reduction and identify the barriers limiting their growth. This study attempts to address this gap by focusing on Mannarkkad municipality.

5. Methodology

The study is based on both primary and secondary data. Primary data were collected from 100 microenterprise units in Mannarkkad municipality using a structured questionnaire. Secondary data were obtained from books, journals, government reports, and official publications. Statistical tools such as tables, percentages and correlation analysis were used to analyse the data and examine the relationship between microenterprise activity and poverty alleviation.

6. Results and Discussion

The findings of the field survey conducted among 100 microenterprise units in Mannarkkad municipality are analysed in line with the objectives of the study. The analysis examines the socio-economic background of entrepreneurs and the type and size of microenterprises operating in the area. It also explains how microenterprises contribute to poverty reduction through employment creation, income improvement, and social empowerment. In addition, the major financial, infrastructural, and market-related problems faced by microenterprise units are discussed.

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6.1 Socio-Economic Profile of Microenterprise Owners

Table 1-Socio-Economic Characteristics of Respondents

Indicator	Major Category	Percentage
Age	40–50 years	35
Gender	Male / Female	54 / 46
Marital Status	Married	86
Education	Below SSLC–Plus Two	81
Religion	Hindu	61

Source: Primary Data

The findings reveal that microenterprises in Mannarkkad municipality are predominantly managed by individuals in the economically productive age group of 40–50 years, suggesting greater work experience and stability among entrepreneurs. The near gender parity indicates increasing participation of women in microenterprise activities, reflecting gradual social and economic inclusion. However, the predominance of respondents with lower levels of formal education indicates limited access to managerial, technical, and financial skills, which may constrain enterprise efficiency, innovation, and long-term growth.

6.2 Type and Nature of Microenterprises

Table 2-Type of Microenterprises and Employment Size

Variable	Category	Percentage
Type of Enterprise	Retail	27
	Manufacturing	25
	Agriculture-related	22
Employment Size	Below 5 workers	59
	6–10 workers	39

Source: Primary Data

The dominance of retail and manufacturing enterprises indicates sectoral diversification within the microenterprise ecosystem. The high concentration of enterprises employing fewer than five workers confirms their micro-scale and labour-intensive nature. These findings suggest that

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most units are primarily livelihood-oriented, focusing on self-employment and family labour rather than expansion-driven commercial objectives.

6.3 Income Level and Financial Improvement

Table 3-Income and Financial Improvement after Starting Microenterprise

Indicator	Category	Percentage
Monthly Income	₹21,000–₹40,000	53
Financial Improvement	Moderate to High	93

Source: Primary Data:

More than half of the respondents earn a monthly income between ₹21,000 and ₹40,000, indicating that microenterprises provide a stable and sustainable source of livelihood. The overwhelming majority reporting moderate to high financial improvement reflects the positive role of microenterprises in strengthening income security, reducing dependence on casual labour, and enhancing household economic resilience.

6.4 Microenterprises and Poverty Alleviation Outcomes

Table 4-Impact of Microenterprises on Living Standards and Poverty Reduction

Indicator	Positive Response	Percentage
Improved Standard of Living	Yes	94
Better Education for Children	Yes	94
Reduction in Poverty	Moderate to High	92
Employment Generation	Yes	52

Source: Primary Data

The results demonstrate that microenterprises have substantially contributed to improving living standards, educational opportunities for children, and poverty reduction among respondents. The ability of more than half of the enterprises to generate employment further highlights their role in local economic development. These outcomes underline the

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multidimensional impact of microenterprises beyond income generation, extending to social mobility and human capital formation.

6.5 Relationship between Income and Poverty Reduction

Table 5-Correlation between Income and Poverty Reduction

Variable	Pearson Correlation	Significance
Income and Poverty Reduction	0.305	0.002

Source: Primary Data

The correlation analysis reveals a positive and statistically significant relationship between income from microenterprises and poverty reduction. The results confirm that higher income levels are associated with improved economic well-being, empirically validating microenterprises as an effective mechanism for poverty alleviation in the study area.

6.6 Challenges Faced by Microenterprises

Table 6-Major Challenges Reported by Respondents

Challenge	Percentage
Lack of Access to Finance	28
High Operating Cost	19
Limited Skill Development	19
Lack of Credit/Investment	18
Government Regulations and Others	16

Source: Primary Data

Limited access to finance emerges as the most critical challenge confronting microenterprises, restricting both operational stability and growth potential. High operating costs and inadequate skill development further constrain productivity and competitiveness. The relatively low level of government support highlights the need for improved policy outreach, institutional credit access, and targeted training programmes.

7. Findings

The study reveals that microenterprises in Mannarkkad municipality are predominantly operated by individuals in the economically active age group,

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indicating stability and work experience among entrepreneurs. Gender participation is nearly balanced, reflecting increasing involvement of women in microenterprise activities. However, a large proportion of entrepreneurs possess low levels of formal education, which may limit managerial efficiency, technological adoption, and enterprise expansion.

Retail and manufacturing enterprises constitute the major share of microenterprises, while most units operate on a very small scale, employing fewer than five workers. This confirms the labour-intensive and livelihood-oriented nature of microenterprises in the study area. Income generated from microenterprises provides a stable source of livelihood, with a majority of respondents reporting moderate to high improvement in their financial condition.

The study finds that microenterprises significantly contribute to poverty alleviation by improving living standards, facilitating better educational opportunities for children, and reducing economic vulnerability. Employment generation by microenterprises further enhances their contribution to local economic development. Statistical analysis confirms a positive and significant relationship between income from microenterprises and poverty reduction, validating their effectiveness as a poverty alleviation instrument.

Despite these positive outcomes, microenterprises face several challenges. Limited access to finance is the most critical constraint, followed by high operating costs, inadequate skill development, and insufficient institutional support. Limited access to government schemes and financial assistance restricts the sustainability and growth of microenterprises.

8. Suggestions

To enhance the poverty-reducing impact of microenterprises, access to institutional finance should be strengthened through simplified loan procedures, low-interest credit, and expansion of microfinance services. Financial inclusion initiatives must specifically target small and informal enterprises operating in rural and semi-urban areas.

Skill development and entrepreneurship training programmes should be promoted to improve managerial capabilities, financial literacy, and technological adoption among microentrepreneurs. Special emphasis should be placed on training women and less-educated entrepreneurs to enhance productivity and competitiveness.

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Government agencies and local institutions should improve awareness and outreach of existing schemes, subsidies, and support programmes. Simplification of regulatory procedures and reduction of compliance burdens would further encourage enterprise sustainability. Infrastructure support, market linkages, and digital platforms should be strengthened to reduce operating costs and improve market access.

9. Conclusion

Microenterprises play a vital role in promoting inclusive growth and poverty alleviation in Mannarkkad municipality. The study demonstrates that microenterprises significantly improve income levels, living standards, educational opportunities, and employment generation among entrepreneurs. The positive relationship between income and poverty reduction highlights the effectiveness of microenterprises as a sustainable livelihood strategy.

However, the full potential of microenterprises remains constrained by financial, skill-related, and institutional challenges. Addressing these constraints through targeted policy interventions, improved access to finance, skill development, and effective government support is essential to strengthen the long-term impact of microenterprises on poverty reduction and socio-economic development.

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CHAPTER 3

Permutation polynomial over finite field

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1 Abstract

Permutation polynomial (PP) over a finite field is a polynomial that permutes field elements. This paper explores how a function of F_q become a polynomial and when it is become Permutation polynomial of F_q. Also include when a monomial x^n become PP and it's cyclic structures with same length.

Key words: Permutation polynomial, Finite field, Cyclic structure

2 Introduction

Finite fields (Galois fields) are crucial in number theory, algebra, cryptography error- correcting codes. A finite field F_q has a finite number of elements. Permutation polynomials (PPs) permute these elements. This paper covers basics, examples of Permutation polynomial and cyclic structures of monomials with same length

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3 Functions as Polynomials

Let $q = p^r$ where p is a prime and $r \geq 1$ is an integer. Consider the functions from the finite field $\mathbb{F}_q$ into itself, namely the bijections of the form

$$\Phi : \mathbb{F}_q \to \mathbb{F}_q$$

To study such function it is enough to study polynomials of degree at most $q - 1$, as the next lemma shows.This results was proved by Leonard Eugene Dickson in 1897; for q prime it was already noted by Hermite.

Lemma 3.1. For any function $\phi : \mathbb{F}_q \to \mathbb{F}_q$ there exists a unique polynomial $f \in \mathbb{F}_q[x]$ of degree at most $q - 1$ such that the associated polynomial function $f : c \to f(c)$ satisfies $\phi(c) = f(c)$ for all $c \in \mathbb{F}_q$.

The polynomial g can be found by computing the Legrange interpolation polynomial for the given function ϕ by the formula

$$g(x) = \sum_{c \in \mathbb{F}_q} \phi(c)(1 - (x - c)^{q-1}) \tag{1}$$

Example 3.1. $\phi : \mathbb{F}_3 \to \mathbb{F}_3$ defined by $\phi(x) = \delta(x, 0) + \delta(x, 2)$
where δ is Kronecker Delta function defined by

$$\delta(i, j) = \begin{cases} 1 & \text{, ifi=j} \\ 0 & \text{, ifi} \neq j \end{cases}$$

then $\phi(0) = 1 + 0 = 1$
$\phi(1) = 0 + 0 = 0$
$\phi(2) = 0 + 1 = 1$
Which is a function but not a polynomial .by lemma 1.2 there exist a polynomial of degree at most q-1.so we can find corresponding polynomial using the Lagrange interpolation polynomial formula ,
$g(x) = \sum_{c \in \mathbb{F}F_3} \phi(c)(1 - (x - c)^{q-1})$
$= \phi(0)(1 - (x - 0)^2) + \phi(1)(1 - (x - 1)^2) + \phi(2)(1 - (x - 2)^2)$
$= -2x^2 + 4x - 2$
$= x^2 + x + 1$

if ϕ is already given as a polynomial function say $\phi : c \to f(c)$ with $f \in \mathbf{F}_q[x]$ then g can be obtained from f by reduction modulo $x^q - x$ according the following lemma

Lemma 3.2. For any $f, g \in \mathbb{F}_q[x]$ we have $f(c) = g(c)$ for all $c \in \mathbb{F}_q$ if and only if $f(x) \equiv g(x) \bmod (x^q - x)$.

Example 3.2. Consider the function $\phi : \mathbb{F}_3 \to \mathbb{F}_3$ defined by $\phi(x) = 2x^3$.By lemma 1.2 there exist a unique polynomial of degree at most $q - 1$,by using lemma 1.2

$$2x^3 \equiv 2x \bmod x^3 - x$$

there fore the corresponding polynomial $f \in \mathbb{F}_3[x]$ is $f(x) = 2x$.

4 Permutation Polynomials

in this project we study functions $f : \mathbb{F}_q \to \mathbb{F}_q$ that permutes the elements of $\mathbb{F}_q$.ie we intrested in bijections of $\mathbb{F}_q$.

Definition 4.1. A polynomial $f \in \mathbb{F}_q[x]$ is called **Permutation polynomial (PP)** of $\mathbb{F}_q$ if the associated polynomial function $f : c \to f(c)$ is a permutation of $\mathbb{F}_q$.

By finiteness of $\mathbb{F}_q$ we can express this definition in several equivalent ways.

Lemma 4.1. The polynomial $f \in \mathbb{F}_q[x]$ is a permutation polynomial of $\mathbb{F}_q$ if and only if(i) The function $f : C \to f(C)$ is injective.
(ii) The function $f : C \to f(C)$ is surjective.
(iii)$f(x) = a$ has a solution in $\mathbb{F}_q$ for each $a \in \mathbb{F}_q$
(iv) $f(x) = a$ has a unique solution in $\mathbb{F}_q$ for each $a \in \mathbb{F}_q$.

Example 4.1. Consider the polynomial

$$f(x) = x^5 + x^4 + 6x^3 + 4x^2 + 6x + 5 \text{ in } \mathbb{F}_7[x]$$

evaluating value on $\mathbf{F}_7 = (0, 1, 2, 3, 4, 5, 6)$ we get

x	0	1	2	3	4	5	6
$f(x)$	5	2	3	6	0	1	4

cyclic structure is (0 5 1 2 3 6 4)
which is a bijection on $\mathbb{F}_7$.Therefore it is a PP.

4.1 When monomial become PP

Theorem 4.1. (i) every linear polynomial over $\mathbb{F}_q$ is a PP of $\mathbb{F}_q$.
(ii) The monomial x^n is a PP of $\mathbb{F}_q$ if and only of gcd $(n, q - 1) = 1$

Example 4.2. Let $f(x) = 4x + 3$ in $\mathbb{F}_7[x]$.

x	0	1	2	3	4	5	6
$f(x)$	3	0	4	1	5	2	6

which is a bijection .there fore it is a PP of $\mathbb{F}_7$.

Example 4.3. Let $f(x) = x^2$ in $\mathbb{F}_7[x]$.

x	0	1	2	3	4	5	6
$f(x)$	0	1	4	2	2	3	1

Which is not a bijection .so x^2 is not PP of $\mathbb{F}_7$. since $gcd(2, 6) = 2$.

x	0	1	2	3	4	5	6	7	8	9	10
$f(x)$	0	1	8	5	9	4	7	2	6	3	10

x	0	1	2	3	4	5	6	7	8	9	10
$f(x)$	0	1	7	9	5	3	8	6	2	4	10

4.2 Cyclic structure of monomials

The cyclic structure of PPs list the multiplicity of each cycle length in its cycle decomposition.If a permutation has exactly n_1 cycles of length l_1, n_2 cycles of length l_2...... n_r cycles of length l_r where $l_1 < l_2 < .... < l_r$,then we write this cyclic structure as ${l_1}^{n_1}{l_2}^{n_2}....{l_r}^{n_r}$.

Example 4.4. The cyclic structure of monomials in $\mathbb{F}_{11} = \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10\}$ are
if $f(x) = x^3$
cyclic structure is $1^3 4^2$
if $f(x) = x^7$
Cyclic structure is $1^3 4^2$
if $f(x) = x^9$

x	0	1	2	3	4	5	6	7	8	9	10
$f(x)$	0	1	6	4	3	9	2	8	7	5	10

cyclic structure is $1^3 2^4$

To find the cyclic structure of monomials we repeat applying the polynomial x^n to an element x will results $x^{n^j} = x$ that form a cycle of length j. beginlemma
$x^{n^j} = x$ if and only if $n^j - 1 \equiv 0 \bmod t$, where t is the multiplicative order of x.

Theorem 4.2. Let j be a positive integer.Then x^n has a cycle of length j over ${\mathbb{F}_q}^*$ if and only if $q - 1$ has a divisor t such that n belongs to the exponent j mod t. moreover the number N_j of such cycle is

$$jN_j = (q - 1, n^j - 1) - \sum_{i|j, i<j} iN_i \tag{2}$$

4.2.1 Note

From the above theorem it is clear that $N_1 = (q - 1, n - 1) - \sum_{i|1,i<1} iN_i$
$N_1 = (q - 1, n - 1)$
so on $\mathbb{F}_q$ there are $N_1 + 1$ fixed points.

Example 4.5. Find the cyclic structure of x^9 in $\mathbb{F}_{11}$
Here $n = 9, q = 11$
Number of fixed points in $\mathbb{F}_{11}$ is
$N_1 + 1 = (q - 1, n - 1) + 1 = (10, 8) + 1 = 2 + 1 = 3$
$9^2 \equiv 1$ (mod2)
there fore x^9 has a cycle of length 2.exact number of such cycle is

$2.N_2 = (10, 80) - \sum_{i|2, i<2} iN_i = 10 - 1N_1 = 10 - 2 = 8,\ N_2 = \frac{8}{2} = 4$
there fore the cyclic structure is $1^3 2^4$.

Example 4.6. Find the cyclic structure of x^3 over $\mathbb{F}_{27}$
Here $n = 3, q = 27$
No of fixed points
$N_1 + 1 = (q - 1, n - 1) + 1$
$= (26, 2) + 1 = 2 + 1 = 3$
divisors of 26 are 1,2,13,26
$3^2 \equiv 1 \pmod{2}$
There fore x^3 has a cycle of length 2.by calculation exact number of such cycles is
$2N_2 = (26, 8) - \sum_{i|j, i<j} iN_i$
$= 2 - N_1 = 2 - 2 = 0$
Also $3^3 \equiv 1(mod 26)$,so there exist a cycle of length 3.no of such cycle is
$3.N_3 = (26, 26) - 1N_1$
$= 26 - 2 = 24$
$N_3 = \frac{24}{3} = 8$
there fore cyclic structure is $1^3 3^8$.

5 Cycles of same length

We say that a permutation has cycle of the same length j if and only if the permutation decomposes in cycles of length j or 1.The Next theorem characterises the permutation monomials with this property.

Theorem 5.1. Let $q - 1 = {P_0}^{k_0} {P_1}^{k_1} ......{P_r}^{k_r}$.The permutation of $\mathbb{F}_q$ given by x^n has a cycle of the same length j if and only if one of the following holds for each $l = 0, 1, 2..., r$
(i)$n \equiv 1(mod {P_l}^{k_l})$
(ii) $j = ord_{{P_l}^{k_l}}(n)$ and $j|(P_l - 1)$
(iii)$j = ord_{{P_l}^{k_l}}(n)$,$k_i \geq 2$ and $j = P_l$.

Definition 5.1. The order of an integer i modulo n is the smallest positive integer j such that $i^j \equiv 1 \pmod{n}$ and it will be denoted by $j = ord_n(i)$.

Lemma 5.1. If $i^j \equiv 1$(mod s)and $i^j \equiv 1$(mod l) and $gcd(l, s) = 1$,then $i^j \equiv 1(\text{mod} sl)$.

Example 5.1. check whether x^2, x^3, x^4, x^5, x^6 in $\mathbb{F}_{8=2^3}$has cycles of same length in their cyclic structure.
Where $\mathbb{F}_8 = \{0, 1, \alpha, \alpha + 1, \alpha^2, \alpha^2 + 1, \alpha^2 + \alpha, \alpha^2 + \alpha + 1\}$, and α is the primitive element satisfying $\alpha^3 + \alpha + 1 = 0$.

by above theorem x^n has cycle of same length j if and only if satisfying any one of the conditions above.so by calculations
$2^3 \equiv 1(\text{mod}7)$
so x^2 has cycles of same length 3,cyclic structure $=1^2 3^2$.
$3^6 \equiv 1(\text{mod } 7)$
so x^3 has cyclic structure $1^2 6^1$
$4^3 \equiv 1(\text{mod } 7)$
x^4 has cycles of same length 3.Cyclic structure $1^2 3^2$
$5^6 \equiv 1(\text{mod } 7)$
so x^5 has cyclic structure $1^2 6^1$.
$6^2 \equiv 1(\text{mod}7)$
so x^6 has cycles of same length 2.The cyclic structure is $1^2 2^3$.

Example 5.2. Check whether x^5 has cycles of the same length in $\mathbb{F}_{17}$
by above theorem,
(i) $5 \not\equiv 1(\text{mod}16)$,so the first condition not satisfied.
(ii)by second condition x^5 has a cycle of same length j if $5^j \equiv 1(\text{mod } 16)$and $j|1$.But here the only possibility of j is 1.
And by theorem 1 x^5 has 5 fixed points.
So the second condition also not satisfied.
(iii)By third condition x^5 has a cycle of same length j,if $5^j \equiv 1(\text{mod}16)$,$k_i > 2$ and $j = P_i$.
Here $k_i = 4 > 2$ and $P_i = 2$ but $5^2 \not\equiv 1$ (mod 16)
so the third condition not satisfied.
therefore x^5 don't have cycles of same length.
by detailed calculation we get the cyclic structure is $1^5 2^2 4^2$.

x	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$f(x)$	0	1	15	5	4	14	7	11	9	8	6	10	3	13	12	2	16

In the next result we consider cases where 0,1,and -1 are the only element fixed by the permutation.It is clear that 0 and 1 are always fixed by the permutation x^n.fixed elements are the same as cycles of length 1.so by first theorem an element is fixed if and only if $n \equiv 1$ (mod$t$) where t divides $q-1$.so -1 is a fixed element if and if $(-1)^n = -1$ by the above mentioned lemma 3.1 it is possible if and only if $n \equiv 1$ (mod t).where t is the multiplicative order of -1. we know that $(-1)^2 = 1 \implies t = 2$
there fore $n \equiv 1$ (mod 2).Hence 0,1,-1 are the only fixed elements by the permutation if and only if $n \not\equiv 1$ (mod$t$) for any $t \neq 2$ such that $t|q-1$.

We first consider q being such that 4 does not divide $q-1$.

Theorem 5.2. Let $q - 1 = {P_0}^{k_0}{P_1}^{k_1}......{P_r}^{k_r}$,$P_0 = 2, K_0 = 0, 1$ The permutation of $\mathbb{F}_q$

given by x^n decomposes in cycles with the same length j and $0, 1, -1$ or $0, 1$ are the only fixed elements if and only if $j = ord_{{P_l}^{k_l}}(n)$ and $j|P_l - 1$ for $P_1 \neq 2$.

Example 5.3. find the cycle length in the cyclic structure of x^2 in $\mathbb{F}_{32=2^5}$
Here $q - 1 = 32 - 1 = 31$ and 4 does not divide 31 so by above theorem
x^2 has a cycle of length j if and only if $2^j \equiv 1(\text{mod}31)$ and $j|31 - 1$
possibilities of j are $1, 2, 3, 5, 6, 15, 30$
$2^1 \equiv 2 \pmod{31}$,
$2^2 \equiv 4 \pmod{31}$,
$2^3 \equiv 8 \pmod{31}$,
$2^5 \equiv 1 \pmod{31}$
so $j = 5$.

Example 5.4. Find the length of the cycle in the cyclic structure of x^3 in $\mathbb{F}_{11}$.
Here $q - 1 = 10 = 2 \times 5$
where 4 does not divide 10, So by the above theorem
x^3 has a cycle of the same length j if and only if $3^j \equiv 1 \pmod 5$ and $j|4$.
The possibilities of j are 1,2,4.
$3^1 \equiv 3 \pmod 5$,
$3^2 \equiv 4 \pmod 5$,
$3^4 \equiv 1 \pmod 5$
there fore $j = 4$.

If 4 divides $q-1$ there are only two monomials that gives permutations that decompose in cycles of the same length and have 0,1,-1 as the only fixed elements.Also the length of the cycle on such permutation is always 2.

Theorem 5.3. Let $q - 1 = {P_0}^{k_0}{P_1}^{k_1}......{P_r}^{k_r}$ where $P_0 = 2, K_0 \geq 2$. The permutation of $\mathbb{F}_q$ given by x^n decomposes in cycles of the same length j and 0,1,-1 are the only fixed elements if and only if $j = ord_{P_l}^{k_l}(n)$ for $P_l \neq 2, j = ord_{2^h}(n)$ for $2 \leq \text{h} \leq k_0$ and $j = 2$

Let $q - 1 = {P_0}^{k_0}{P_1}^{k_1}......{P_r}^{k_r}$ where $P_0 = 2, k_0 > 2$.The permutation of $\mathbb{F}_q$ given by x^n decomposes in cycles of the same length j and 0,1,-1 are the only fixed elements if and only of $j = 2$ and $i = q - 2$ or $i = \frac{q-3}{2}$. let $q - 1 = 4{P_1}^{k_1}......{P_r}^{k_r}$.The permutation of $\mathbb{F}_q$ given by x^n decomposes in cycles of the same length j and 0 ,1,-1 are the only fixed elements if and only if j=2 and $i = q - 2$.

Example 5.5. verify that x^7 and x^3 in $\mathbb{F}_{9=3^2}$ has cycles of same length 2 and 0,1,-1 are the only fixed elements.
let $f(x) = x^3$ then by using theorem 1
No of fixed points$=(8, 2) + 1 = 2 + 1 = 3$.
it is clear that 0 and 1 are fixed points.

here $(-1)^3 = -1$(ie $2^3 = 2$ in $\mathbb{Z}_3$).so 0,1,-1 are the only fixed elements.
$3^2 \equiv 1(\text{mod } 8)$.
so by the third conditions of theorem 2, x^3 has cycles of same length 2.
Let $f(x) = x^7$, Then by theorem 1
no of fixed points $=(6, 8) + 1 = 2 + 1 = 3$.
clearly 1 and 0 are fixed elements.
$(-1)^7 = -1$,so -1 also a fixed element.
Also $7^2 \equiv 1(\text{mod } 8)$.
so by third condition of theorem 2 x^7 has cycles of same length 2.

6 Dickson polynomial

we now introduce a special class of polynomials that have some interesting properties but we excluded it.Our main intrest in this is that for a fixed a ,they give many examples of permutation polynomials.

Definition 6.1. Let R be a commutative ring with identity.For $a \in R$ define the **Dickson Polynomial** $D_n(x, a)$ of degree n over R by

$$D_n(x, a) = \sum_{j=0}^{\lfloor \frac{n}{2} \rfloor} \frac{n}{n-j}(n - jC_j)(-a)^j(x^{n-2j}) \tag{3}$$

they may also be generalised by the recurrence relation for $n \geq 2$

$$D_n(x, a) = xD_{n-1}(x, a) - aD_{n-2}(x, a)$$

with initial condition $D_0(x, a) = 1$ and $D_1(x, a) = x$.

Theorem 6.1. Let $a \in \mathbb{F}_q^*$. Then the Dickson polynomial $D_n(x, a)$ is a PP of $\mathbb{F}_q$ if and only if
$gcd(n, q^2 - 1) = 1$.

Example 6.1. In $\mathbb{F}_7$ the Dickson polynomial

$$D_5(x, a) = x^5 - 5ax^3 + 5a^2x$$

is a PP.since $gcd(5, 7^2 - 1) = 1$. put $a = 1$ we get
$D_5(x, 1) = x^5 - 5x^3 + 5x$

x	0	1	2	3	4	5	6
$D_n(x, 1)$	0	1	2	4	3	5	6

Which is a bijection of $\mathbb{F}_7$.There fore given polynomial is a PP over $\mathbb{F}_7$

Example 6.2. In $\mathbb{F}_7$ the Dickson polynomial

$$D_4(x,a) = x^4 - 4ax^2 + 2a^2$$

is not a PP.since $gcd(4, 7^2 - 1) \neq 1$
Let $a = 2$ we get,
$D_4(x,2) = x^4 + 6x^2 + 1$ Which is not a bijection.There fore given polynomial is not a PP

x	0	1	2	3	4	5	6
$D_n(x,2)$	1	1	6	3	3	6	1

over $\mathbb{F}_7$

Note that if $a = 0$ then $D_n(x,0) = x^n$ which is a PP of $\mathbb{F}_q$ if and only if $gcd(n, q-1) = 1$ we already discussed.

7 conclusion

Permutation polynomials over finite fields are super interesting They're key in coding theory, combinatorics cryptography. Paper study about PPs and the cyclic structure of monomials.
Future work: cyclic structure of Dickson polynomials

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CHAPTER – 4

SOCIO-CULTURAL TRANSFORMATION AND DEVELOPMENT CHALLENGES AMONG THE IRULA, MUDUGA, AND KURUMBA TRIBES OF ATTAPPADI

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Abstract

This research article examines the socio-economic transformation and cultural adaptation of the Irula, Muduga, and Kurumba tribes in Attappadi, Kerala. Using a social science framework, it explores the interplay between tradition, modernization, and policy intervention. Drawing from ethnographic field studies, government reports, and secondary literature, the study reveals how modernization has disrupted traditional livelihoods, language systems, and community structures, while simultaneously creating new spaces for empowerment. The findings underscore the necessity of culturally sensitive development that respects indigenous knowledge, environmental sustainability, and community autonomy. It concludes that the path toward genuine progress must integrate social inclusion with cultural preservation and participatory governance.

Keywords: Attappadi, Irula, Muduga, Kurumba, Tribal Development, Cultural Change

Introduction

Tribal communities represent some of the most distinct cultural groups within India's diverse social fabric. Among these, the Irula, Muduga, and Kurumba tribes of Attappadi, Kerala, hold a special place due to their deep ecological knowledge and traditional practices (George, 2023). However, despite Kerala's reputation for human development and literacy, the Attappadi region remains marginalized, reflecting a paradox between progress and exclusion. This study seeks to analyze the socio-economic, educational, and cultural transformations within these communities through a social science lens. The research integrates anthropological, sociological, and developmental perspectives to provide a holistic understanding of tribal life in the context of modernization.

The Irula tribe is the largest. They speak a dialect related to Tamil and work mainly in agriculture and forest gathering. Their community-oriented traditions include rituals for birth, marriage, farming, and death, reflecting a deep respect for nature. The Mudugas are similar but maintain their own language and strong cultural identity. They are known for their music, stories, and detailed knowledge of local ecology. The Kurumbas, the smallest group, have lived deep in the forest for generations. They are skilled in herbal medicine and spiritual practices, acting as healers and shamans for their community. Unfortunately, due to land loss and forest destruction, their way of life is under serious threat. All three tribes maintain important customs tied to life events. Marriages are usually arranged with the help of elders and involve rituals and feasts. Births are treated with protective customs for mother and child. Deaths involve ceremonies meant to guide the soul to peace, showing a strong belief in the afterlife and respect for ancestors.

Health issues are also pressing. Malnutrition, anemia, and maternal and infant deaths are common. Although government clinics exist, many tribal people are hesitant to use them due to language barriers, discrimination, or cultural differences. Mental health is another growing concern, made worse by stress, alcohol addiction, and social isolation. Alcoholism has increased in recent years, especially among men, partly due to a loss of purpose and erosion of traditional roles.

Government programs meant to support tribal development often fall short. Many are designed without understanding tribal culture or needs. For instance, relocating people to new housing areas may break up social networks and community life. Jobs offered under schemes may not suit their traditional skills, pushing them into unfamiliar and unsuitable forms of work. As a result, instead of gaining independence, many have become more dependent on outside aid.

Hypothetical Framework

The study draws upon theories of cultural change, modernization, and social development to interpret the lived realities of the Attappadi tribes.

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Anthony Giddens' concept of structuration is used to understand how tribal communities navigate between tradition and modernity (Giddens, 1984). From an anthropological perspective, Clifford Geertz's interpretive approach helps in decoding rituals and symbols embedded in tribal life (Geertz, 1973). Dependency theory and post-development critiques, as articulated by Escobar (1995), are also relevant for explaining how state-led development programs, though well-intentioned, often reinforce dependency and cultural alienation.

The Irula, Muduga, and Kurumba tribes have been severely affected by changes brought about by both government interventions and unregulated modernization. Loss of land, cultural dilution, unemployment, and health issues including malnutrition and limited healthcare access are persistent problems. Additionally, these communities often struggle with underrepresentation and exclusion from mainstream policy planning and development initiatives.

Despite their cultural richness and ecological knowledge, the tribes of Attappadi continue to be categorized among the most backward communities in Kerala. There is a noticeable lack of sustained academic and policy attention toward their well-being. Their oral traditions, indigenous practices, and social structures are under threat, and there is an urgent need to document, preserve, and support these communities before their cultural identities are further eroded. This study, therefore, arises from the need to understand and highlight the complex problems faced by the Irula, Muduga, and Kurumba tribes in Attappadi. It seeks to analyze their socio-economic conditions, cultural transformations, and the impact of external interventions on their traditional lifestyles. The research aims to bridge the gap in existing literature by focusing specifically on these communities, offering an in-depth look into their lived realities. Ultimately, the study hopes to contribute to more inclusive development approaches and policies that are sensitive to the unique needs and identities of tribal populations in Kerala.

Methodology

This study adopts a mixed-method research approach combining both qualitative and quantitative data. Primary data were collected through interviews, focus group discussions, and participant observation across selected hamlets in Attappadi. Secondary data were drawn from published

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studies, government documents, and NGO reports (Mathur, 1995). The research emphasizes ethical engagement with local communities, ensuring informed consent and cultural respect. Data were analyzed thematically, focusing on key dimensions such as livelihood, education, health, and identity.

This research adopts a mixed-methods approach, combining both qualitative and quantitative techniques to ensure a comprehensive understanding of the socio-economic and cultural conditions of the Irula, Muduga, and Kurumba tribes of Attappadi. The mixed-methods framework allows for both in-depth exploration of lived experiences and measurable data analysis, offering a balanced and holistic view of the research problem.

Field Surveys

Structured and semi-structured survey instruments were administered across selected tribal hamlets in the Attappadi region to obtain comprehensive primary data. The surveys were designed to capture key socio-economic indicators, including household income, occupational structure, health status, educational attainment, access to government welfare schemes, and overall living conditions. The questionnaire was developed in consultation with tribal welfare officials and local administrators to ensure contextual relevance and cultural sensitivity. Where necessary, the survey items were translated into the respective tribal dialects to facilitate accurate responses and inclusivity.

Household-level data collection enabled the identification of inter-group disparities and patterns of deprivation among the Irula, Muduga, and Kurumba communities. Field visits were undertaken to multiple hamlets (*ooru* or tribal settlements) in collaboration with local school teachers, the designated nodal officer, and the Sub-Collector of Ottapalam. These visits provided valuable opportunities for participatory observation and direct engagement with community members, thereby enhancing the empirical robustness of the study.

Personal and Group Interviews

In-depth interviews will be conducted with members of the Irula, Muduga, and Kurumba communities, including elders, women, youth, traditional healers, and community leaders. These interviews will help gather qualitative insights into their cultural practices, oral histories, belief systems,

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spiritual traditions, and changes in lifestyle due to modernization. Focus Group Discussions (FGDs) will also be organized to encourage group-level interaction and collective memory sharing. These interviews are essential for understanding perspectives that cannot be captured through quantitative tools alone.

Literature Review

A comprehensive review of existing academic literature, government reports, NGO publications, historical records, and previous field studies will be undertaken. Key sources will include books, journals, and reports from institutions like the Kerala State Planning Board, Ministry of Tribal Affairs, and scholars who have worked extensively on tribal communities in Kerala. The literature review will help contextualize the current findings, trace the historical evolution of the tribes, and identify gaps in existing research.

Observation Method

Participant observation will be employed during field visits, especially during cultural events, rituals, and everyday community activities. This method allows the researcher to immerse in the social setting and observe practices, behaviors, and interactions directly. Observations will be documented through field notes, photographs (with consent), and audio recordings where appropriate.

Secondary Data Analysis

Relevant secondary data from government censuses, tribal development reports, environmental impact assessments, and local administrative records will be analyzed to support and validate primary data findings. This will provide a broader picture of demographic trends, policy impacts, and resource distribution in the region. By using this combined research method, the study aims to understand both the real-life experiences and the statistical data of the Irula, Muduga, and Kurumba tribes, helping to create a more complete and respectful view of the challenges they face.

Historical and Cultural Context

The Attappadi region, located in the Palakkad district, is home to the Irula, Muduga, and Kurumba tribes, who have historically lived in close harmony with nature. Their livelihoods traditionally centered around shifting

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cultivation, forest gathering, and herbal medicine. The Irula community, the largest of the three, primarily engages in agriculture and forest-based work, while the Mudugas are known for their storytelling and spiritual traditions. The Kurumbas, though numerically smaller, are highly skilled in traditional healing and ritual practices. Despite variations in customs and dialects, these tribes share a collective cultural identity rooted in ecological symbiosis and communal living (Tharakan, 1991).

The Irular are also known by various other names such as Eruvalla, Iruliga, Illiga, Kasova, Urali, and Velliga. In the past, they were nomadic hunters who gradually settled in forested areas and started building simple clay huts. These huts had small openings for air and light. Living near the forest allowed them to easily hunt and collect food. Historically, the Irular considered themselves higher in social status compared to the Mudugas and Kurumbas. They are generally of medium height, with curly hair, long arms, narrow noses, and strong cheekbones. They speak a mix of Malayalam, Kannada, and Tamil.

Traditional Clothing and Ornaments

The Irular tribe has distinctive traditional clothing and accessories. Traditionally, Irular women tied their hair on the left side of the head and wore a cloth knot over the chest. They had a strong interest in jewelry and wore ornaments on the toes, ankles, waist, neck, ears, nose, and hair. These included nose studs, necklaces, bangles, stone jewelry, and anklets. Men traditionally grew long hair and wore cloth wrapped around the waist, sometimes adding coats or shirts. With the passage of time, and due to contact with outside society, modern clothing has mostly replaced these traditional styles

Socio-Economic Dimensions

Economic activities among these tribes have undergone significant transformation. Traditional livelihoods based on subsistence agriculture and forest produce collection have been largely replaced by wage labor and dependence on government welfare schemes. Deforestation, land alienation, and migration have disrupted traditional socio-economic structures (Thomas, 2022). While some development initiatives have improved infrastructure, they often fail to address the cultural and ecological foundations of tribal life. Women, in particular, bear a disproportionate

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burden, balancing agricultural work, domestic responsibilities, and social reproduction.

Role of Women

Tribal women in Attappadi have been the primary caretakers of their families. They are responsible for collecting firewood, fetching water, cooking, and looking after children and the elderly. Beyond household duties, they actively participate in agriculture, which is the main livelihood in the region. Women engage in farming tasks like sowing, weeding, and harvesting, often working alongside men in the fields. Women also play a key role in preserving and transmitting traditional knowledge and customs. Through songs, dances, and oral storytelling, they pass down folklore, healing practices, and rituals to younger generations. Their knowledge of herbal medicine and natural remedies is particularly valued in tribal healthcare.

However, the position of women in Attappadi has been affected by socio-economic changes and external influences. Issues such as poverty, malnutrition, lack of education, and limited access to healthcare have disproportionately affected tribal women. Early marriages and gender-based violence are also pressing concerns in some areas. Efforts by the government and non-governmental organizations have aimed at empowering women through education, self-help groups, and livelihood programs. Initiatives such as community kitchens, health awareness campaigns, and skill development workshops are steps toward improving their quality of life. They were the pillers of the community.

Education and Health

Education has emerged as both a tool of empowerment and a source of alienation. Although literacy rates have improved through residential schools and government incentives, dropout rates remain high due to language barriers, poverty, and curriculum irrelevance (Narayanan, 2019). Healthcare access has expanded through community health programs, yet malnutrition, anemia, and infant mortality persist (Kattampally, 2020). Traditional healers continue to play an essential role, especially where institutional healthcare fails to reach. Mental health, often overlooked, has become a serious issue due to dislocation, substance abuse, and identity loss.

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Development, Modernization, and Policy Analysis

Government-led development programs in Attappadi have had mixed outcomes. Schemes for housing, employment, and education have increased access to basic amenities but have also deepened dependency (George, 2023). Many interventions overlook tribal participation, leading to policies that clash with traditional governance systems. Relocation projects often fragment social cohesion, while job programs fail to align with indigenous skills. This top-down model contrasts sharply with participatory development approaches advocated by Sen (1999) and Chambers (1983), which emphasize agency and self-determination.

The social transformation in Attappadi can be understood as a process of negotiated modernity. Tribal communities, though marginalized, actively reinterpret modern influences to sustain their cultural identity. Rituals, language, and kinship systems continue to function as repositories of social cohesion. At the same time, exposure to education, media, and migration has diversified aspirations among the youth. However, the lack of culturally responsive governance continues to marginalize tribal voices in decision-making processes (Rajan, 2018). Women's agency in Attappadi is undergoing a parallel transformation. While traditional gender roles persist, women are increasingly engaging in self-help groups and community leadership. Their involvement in local governance and micro-enterprises reflects an emerging pattern of empowerment, albeit within structural constraints. These developments illustrate how social change, when contextually embedded, can coexist with cultural continuity.

Conclusion

The Irula, Muduga, and Kurumba tribes of Attappadi represent both the resilience and vulnerability of India's indigenous populations. Their social world embodies an equilibrium between ecology, spirituality, and subsistence, now threatened by modernization and policy failures. To ensure sustainable development, state and civil society actors must prioritize participatory governance, recognition of customary rights, and revitalization of traditional knowledge systems. Education must become culturally adaptive, healthcare must integrate local healing systems, and land rights must be restored. Ultimately, development should move from welfare dependency to empowerment, ensuring that Attappadi's tribal communities

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remain custodians of their heritage rather than subjects of external intervention.

The Irula, Muduga, and Kurumba tribes of Attappadi represent some of the most culturally rich and environmentally connected communities in South India. Through generations, they have maintained distinct languages, traditions, and lifestyles rooted in cooperation, nature, and ancestral knowledge. Despite their deep-rooted heritage, these communities face serious challenges in a rapidly changing world.

The Irulas, the largest of the three, maintain strong social customs and rely mainly on agriculture, forest produce, and wage labor. The Mudugas preserve their identity through oral traditions, music, and forest-based life. The Kurumbas, though smaller in number, have served as spiritual healers and hold rare knowledge of forest-based medicine. Each tribe's life is deeply spiritual and environmentally respectful, with customs tied to marriage, birth, death, and festivals that reflect a close bond with nature and community values. However, these communities are now at a crossroads. Their socio-economic status remains significantly below the Kerala state average. Landlessness, unemployment, loss of traditional livelihoods, and lack of support systems continue to affect their quality of life. Deforestation and land encroachment have further reduced access to forest resources, pushing them away from their ancestral practices.

Education remains one of the most pressing challenges. Although schools are present in Attappadi, many children do not continue their studies. Language barriers, lack of cultural relevance in the curriculum, and economic pressure cause high dropout rates. The absence of tribal teachers and materials that reflect their culture makes it hard for children to relate to school, often leaving them with low confidence and limited opportunities. Healthcare, though improved in infrastructure, remains culturally distant and often inaccessible. Many prefer traditional healing methods that are now under threat due to deforestation and lack of recognition. Modern health centers often lack personnel who understand tribal languages or beliefs, leading to discomfort and mistrust. Nutrition, maternal health, and child health are major concerns, along with the rising issues of mental health and substance abuse especially alcoholism, which has become widespread due to loss of purpose, employment, and traditional roles.

Government development programs, while well-intentioned, often fail to consider tribal realities. Many initiatives follow a top-down approach,

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ignoring tribal voices and disrupting traditional community structures. Relocation schemes, modern housing, or wage-based employment may not suit tribal patterns of living and can lead to cultural erosion. While infrastructure like roads and electricity has improved, these changes are uneven and sometimes come at the cost of forest access and community ties. Modern influences like mobile phones, television, and migration are also causing the younger generation to drift away from their roots. Cultural practices such as oral history, dance, music, rituals, and dialects are declining. Without deliberate efforts to preserve and promote them, there is a risk of cultural extinction in the near future. Despite these challenges, there are signs of resilience and hope. Increased awareness of rights, the Forest Rights Act, and localized movements for cultural preservation show that the communities still hold strong values and a desire to protect their heritage. What they need is not charity, but meaningful support that respects their identity.

The way forward lies in a development model that is inclusive, culturally sensitive, and environmentally sustainable. Education systems must be reformed to include tribal languages, stories, and knowledge. Healthcare must involve tribal health workers and recognize the value of traditional medicine. Government programs must be designed with active participation from tribal members, ensuring they match the community's needs and values. Empowering tribal women and youth is also vital. Women play key roles in health, culture, and family well-being, and must be included in decision-making processes. Youth must be offered opportunities to learn both modern and traditional skills so they can choose their own paths with pride.

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CHAPTER – 5

A STUDY ON IMPACT OF MICROFINANCE ON WOMEN EMPOWERMENT THROUGH KUDUMBASHREE UNITS – WITH SPECIAL REFERENCE TO KARIMPUZHA GRAMA PANCHAYATH

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Abstract

Microfinance is a key instrument for financial inclusion, poverty reduction, and women's socio-economic advancement. Kudumbashree Mission, launched by the Government of Kerala in 1998, represents a community-driven microfinance model operating through Neighbourhood Groups (NHGs), ADS, and CDS, emphasizing holistic family development beyond commercial credit frameworks. This study examines the impact of Kudumbashree microfinance on women's empowerment in Karimpuzha Grama Panchayat, focusing on economic outcomes such as income, savings, employment, and entrepreneurial participation, along with social dimensions including decision-making autonomy and community status. The research uses primary data collected through structured questionnaires and secondary data from published studies. Analysis includes percentage distribution and chi-square tests. Literature suggests that while microfinance improves economic participation, empowerment gains are often limited by financial illiteracy, low wages, inadequate training, and insufficient capital. In the study area, loans are mainly used for children's education and medical needs. Although SHGs perform satisfactorily, strengthened capacity-building, financial awareness, and policy support are needed to ensure sustainable empowerment and reach marginalized women.

Keywords: Microfinance, Women Empowerment, Financial Inclusion, Kudumbashree

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Introduction

Microfinance has emerged as a powerful tool for fostering economic development and Empowering marginalized communities, particularly women. In India, the Kudumbashree Program has been instrumental in promoting women's self-help groups (SHGs), facilitating Access to microfinance, and enhancing their socio-economic status. Microfinance encompasses A range of financial services, including savings, credit, insurance, leasing, and money transfers, Provided to the poor by financial institutions. The Kudumbashree program, initiated by the Government of Kerala in 1998, represents an alternative to the commercial model of Microfinance, focusing on the overall development of families. Through its SHG operations, The Kudumbashree program has become a noteworthy example of empowering women, advancing financial inclusion, and reducing poverty. This study specifically addresses the influence of Kudumbashree microfinance on women's Empowerment in the Karimpuzha Grama Panchayat, examining how these women-managed SHGs have facilitated social and economic advancement for their members. By investigating the impact of microfinance initiatives on women's lives, the research aims to provide insights into the broader implications of microfinance for gender equality and community development.

Microfinance refers to the provision of financial services like loans, savings, insurance, and credit to low-income individuals or those without access to typical banking services. These services are especially targeted at empowering the poor, particularly women, to start small businesses and improve their livelihoods. Women empowerment refers to increasing the spiritual, political, social, educational, gender, or economic strength of individuals and communities of women. Empowerment includes greater access to knowledge, resources, decision-making power, and a more active role in societal development Kudumbashree is a community-based organization launched by the Government of Kerala in 1998 to eradicate poverty and empower women through collective action. It functions through Neighbourhood Groups (NHGs), Area Development Societies (ADS), and Community Development Societies (CDS).

Scope of the Study

Women empowerment is considered as an important responsibility of every Government. Women access to savings and credit gives them a greater

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economic role in Decision making Thereby optimising their own and household welfare. The poor people can become more Empowered especially women by joining the Kudumbashree programme. It points Out that they Need the kudumbasree units in the area where people are reported lower.

Review of literature

Microfinance has been widely examined as a strategic instrument for promoting women's empowerment, with a substantial body of literature affirming its positive influence on economic outcomes, while debates continue regarding its broader transformative impact on empowerment. Thapa (2022) identified microfinance as a powerful tool for strengthening women through both social and economic dimensions and recommended expanding its scale to promote inclusive growth among Kudumbashree members. Similarly, Mengstie (2022) reported that microfinance significantly enhances women's assets, income, savings, and organizational capacities, contributing to improved confidence, mobility, and social awareness. Kumar et al. (2020) further highlighted that Kudumbashree-based microfinance initiatives positively affect women's economic status and decision-making autonomy, emphasizing their importance for advancing gender equality in Kerala.

Conversely, some scholars caution against viewing microfinance as a complete empowerment solution. Raghunatha Reddy (2022) observed that many women perceive microfinance primarily as an additional income source rather than a pathway to empowerment. This concern is echoed by Osman (2016) and Datta and Sahu (2016), who argued that microfinance alone cannot eradicate poverty or ensure empowerment due to persistent challenges such as financial illiteracy, inadequate training, low education levels, and risk aversion. Studies by Venugopalan (2014), Nair and Rema Devi (2014), and Abraham and Joseph (2019) reveal that although self-help groups foster solidarity, collective agency, and community resilience, empowerment among Kudumbashree members often remains constrained by low wages, limited income opportunities, and entrenched gender norms. Early contributions by Mayoux (1999, 2000) stressed the need for holistic, participatory, and gender-sensitive approaches beyond mere credit provision, while Pitt and Khandker (1998) demonstrated stronger welfare gains through women-focused microcredit. Overall, the literature suggests

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that while microfinance enhances economic empowerment, sustainable women's empowerment requires integrated capacity building, gender-responsive training, market linkages, and financial awareness initiatives.

Objectives of the Study

1. To study the socio-economic conditions of women in Kudumbashree units in the study area.
2. To evaluate the impact of microfinance on the economic empowerment of women in the study area

Materials and Methods

The study will utilize both primary and secondary data sources. Primary data will be collected From Karimpuzha Grama Panchayat using structured questionnaires. Statistical tools such as Percentage distribution, bar diagrams, tables, charts, and chi-square tests will be employed for Data analysis. Secondary data will be gathered from journals, books, websites, and other Relevant sources. Statistical tools (e.g., SPSS, Excel) will be used for descriptive Statistics, correlation analysis, and regression analysis.

- Independent Variable: Access to microfinance (loan amounts, repayment schedules, savings)
- Dependent Variables: Economic empowerment (income, employment status).

Results and Discussion

This study is based on a sample of 100 women who are part of different Kudumbashree units in karimpuzha panchayath. The data collected from them was carefully examined to understand their social and economic background, how microfinance has helped improve their financial situation, and the difficulties they face in getting microfinance services. Simple statistical tools and descriptive methods were used to study the information The results give a clear picture of how effective microfinance is and what challenges still exist in the Kudumbashree programme

The following table provides an overview of the socio-economic background of the respondents involved in the study. Understanding the respondents' Age, marital status, income levels, educational qualifications, and occupational status is essential to assess their needs, preferences, and behaviour patterns. These factors play a significant role in shaping their

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perspectives and responses, and help in drawing meaningful conclusions for the project.

Table -1 Socio economic conditions of the respondents

Age wise classification		
Age	**Respondents**	**Percentage**
25-35	24	24%
35-45	39	39%
45-55	22	22%
ABOVE 55	15	15%
TOTAL	100	100%
Marital status		
Marital Status	**Respondents**	**Percentage**
Married	66	66%
Single	20	20%
Widow	10	10%
Divorced	4	4%
Total	100	100%
Educational level		
Education Level	**Respondents**	**Percentage**
No formal education	10	10%
Primary education	28	28%
Secondary education	43	43%
Higher secondary education	15	15%
Graduation or higher	4	4%
Total	100	100%
Occupational status		
Occupation	**Respondents**	**Percentage**
Gov employee	19	19%
Non- Gov employee	14	14%
Homemaker	67	67%
Total	100	100%

Source: Field Survey

The following results and analysis proposes that a significant influence on the relationship between a woman's designated role within Kudumbashree and her participation in Kudumbashree microfinance programmes and her perceived social status in the community.

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Table – 2 Role and Satisfaction

Role * Satisfaction Crosstabulation							
		Satisfaction					Total
		Some Improvement in Social Status	Increased Social Status and Recognizing	No Significant Change in Social Status	Decreased Social Status	No Answer	
Role	President	5	4	0	0	0	9
	Secretary	4	3	1	0	0	8
	Member	30	25	4	3	2	64
	Other	2	6	3	3	4	18
	No Answer	0	1	0	0	2	3
Total		41	39	8	6	6	100

Source: Computed Data

The table represents the cross tabulation of association, specifically chi-square related to the relationship between two variables:" Role in Kudumbashree" and "Satisfaction (Relationship between the women's participation in Kudumbashree microfinance and their social status). Chi-square (χ^2) is a statistical test used to determine whether There is a significant relationship between Role in Kudumbashree and Relationship between the women's participation in Kudumbashree microfinance and their social status in the community

Chi-Square Tests result

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	45.314^a	16	0.000
Likelihood Ratio	21.407	16	0.163
Linear-by-Linear Association	6.954	1	0.008
N of Valid Cases	100		

Source: Computed Data

The Pearson Chi-Square value: 45.314 with 16 degrees of freedom and a p-value of 0.000, indicating a statistically significant association between role and satisfaction at the 0.05 significance level. the results support the conclusion that respondents' roles are significantly associated with their satisfaction levels, particularly in terms of how their social status is perceived to have changed.

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Ho: There is no significant relationship between social status & personal development

Table -3 -Social Status and Personal evelopment

Satisfaction * Personal Development Crosstabulation							
		Personal Development					Total
		Skill Development	Decision Making	Income Generation	Others	No Answer	
Satisfaction	Some Improvement In Social Status	23	9	9	3	0	44
	Increase Social Status and Recognizing	16	11	11	2	3	43
	No Significant Changein Social Status	1	1	1	4	0	7
	Decreased Social Status	0	0	0	2	0	2
	No Answer	0	0	0	0	4	4
Total		40	21	21	11	7	100

Source: Computed Data

The table represents a survey result related to the satisfaction with the social status of the Kudumbashree. The data represents the mean and standard deviation of the responses to the statement "Economic status of the Kudumbashree. The responses were categorized into four options: some improvement in social status, increased social status and recognising, no significant change in social status, decreased social status.

ANOVA TEST RESULT

ANOVA					
PERSONAL DEVELOPMENT					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	38.819	4	9.705	6.543	.000
Within Groups	163.146	96	1.483		
Total	201.965	100			

Source: Computed Data

The ANOVA table examines differences in personal development and social status among Kudumbashree members across four groups. ANOVA is used to test whether the mean values of three or more groups differ significantly. In this analysis, the between-groups sum of squares is 38.819 with 4 degrees of freedom, resulting in a mean square of 9.705. The within-groups sum of squares is 163.146 with 96 degrees of freedom, and the

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corresponding mean square is 1.483. The total sum of squares is 201.465, representing overall variability in the data. The F-statistic of 6.543 is obtained by dividing the mean square between groups by the mean square within groups, indicating the ratio of inter-group to intra-group variation. The significance value (p = 0.00) is lower than the conventional 0.05 level, showing that the observed differences among group means are statistically significant. Hence, the null hypothesis is rejected, suggesting meaningful differences in personal development and social status among the Kudumbashree groups.

Ho: There is no significant relationship between social status and decision-making power

Table 4 -Social Status & Decision-Making Power

Satisfaction * Decision Making Power Crosstabulation					
		Decision Making Power			Total
		Empowers To Make Decisions Independence	No Impact on Decision Making	Decreases decision Making Power	
Satisfaction	Some Improvement In Social Status	35	6	0	41
	Increased Social Status And Recognising	36	9	2	47
	No Significant Change in Social Status	2	4	0	6
	Decreased Social Status	1	1	2	4
	No Answer	0	0	2	2
Total		74	20	6	100

Source: Computed Data

The table presents survey results on respondents' satisfaction with the **social status of** Kudumbashree, based on the statement "Economic status of the Kudumbashree." Responses were classified into four categories: some improvement in social status, increased social status and recognition, no significant change in social status, and decreased social status. The results show that the majority of respondents reported some improvement in social status (35 respondents), followed closely by those who perceived increased social status and recognition (36 respondents). A small proportion indicated no significant change (2 respondents) or decreased social status (1 respondent), while a few did not respond. Overall, the findings suggest that participation in Kudumbashree has positively influenced the social and economic status of most respondents.

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ANOVA TEST RESULT

Anova					
Satisfaction					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	40.608	2	20.304	37.541	.000
Within Groups	60.575	98	.541		
Total	101.183	100			

Source: Computed Data

The ANOVA table analyses the relationship between decision-making power and social status of Kudumbashree members. The between-groups sum of squares is 40.608 (df = 2) with a mean square of 20.304, while the within-groups sum of squares is 60.575 (df = 98) with a mean square of 0.541. The total variability in the data is 101.183. The F-statistic value of 37.541 indicates a high variation between groups compared to within groups. The significance value (p = 0.00) is below 0.05, leading to the rejection of the null hypothesis. Thus, decision-making power significantly differs across social status groups of Kudumbashree members Ho: There is no significant relationship between economic status and personal development

Table 5 -**Economic Status and Personal Development**

Wellbeing * Personal Development Cross Tabulation							
		Personal Development					
		Skill Development	Decision Making	Income Generation	Others	No Answer	Total
Wellbeing	Increased Income	18	8	3	2	0	31
	Improved Financial Stability	13	3	4	4	0	24
	Enhanced Saving	4	7	6	2	1	20
	Others	3	2	5	7	0	17
	No Answer	0	0	2	0	6	8
Total		38	20	20	15	7	100

Source: Computed Data

The table presents survey results on satisfaction with the economic wellbeing of Kudumbashree members, based on the statement "Economic

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status of the Kudumbashree." Responses were grouped into four categories: increased income, improved financial stability, enhanced saving, and others, across aspects such as skill development, decision making, income generation, and others. The findings show that increased income was the most frequently reported outcome, with 18 out of 100 respondents indicating improvement. This was followed by improved financial stability and enhanced saving, while fewer respondents selected other outcomes. Overall, the results suggest a positive impact of Kudumbashree on members' economic wellbeing.

ANOVA					
WELLBEING					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	65.582	4	16.395	15.136	.000
Within Groups	119.149	96	1.083		
Total	184.730	100			

Source: Computed Data

The ANOVA table analyses the relationship between personal development and economic status of Kudumbashree members. ANOVA is used to determine whether significant differences exist among group means. In this analysis, the between-groups sum of squares is 65.582 with 4 degrees of freedom, yielding a mean square of 16.395. The within-groups sum of squares is 119.149 with 96 degrees of freedom, and the corresponding mean square is 1.083. The total sum of squares is 184.730, representing the overall variability in the data. The F-statistic value of 15.136 indicates that variation between groups is substantially higher than variation within groups. The significance value ($p = 0.00$) is below the conventional 0.05 level, indicating statistically significant differences among the groups. Therefore, the null hypothesis is rejected, confirming that personal development differs significantly across economic status groups of Kudumbashree members.

Conclusion

Microfinance acts as a catalyst in the lives of the poor and kudumbashree became the Lifeline to many of the poor women. In the present study, an

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attempt has been made to analyze the performance of Kudumbashree units in karimpuzha panchayath, impact of Microfinance, purpose of obtaining microfinance, role of government, and problems of KDS Units. The performance of the Kudumbashree unit in karimpuzha panchayath is Satisfactory but there is a necessity to take some measures to reach the unreached poor and Efficient performance of kudumbashree units. The microfinance helps the members to come out of the indebtedness from outside Loan, increase the living status through increased income and increased savings, and empowered by engaged in income generating activities. Micro enterprise under Kudumbashree helps in developing an entrepreneurial culture in society and increasing better living capacity of the poor. In the study area the members mainly adopt microfinance for the purpose of Children's education and medical expenditure. The government must eventually play a role for the promotion of kudumbashree units. Lack of sufficient capital is the main problem in Kudumbashree units. Thus, there is an urgent need to widen the scope and financial services to cover the Unreached population.

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CHAPTER – 6

THE SOCIO-ECONOMIC CONDITION OF AN AGING POPULATION IN MANNARKKAD MUNICIPALITY

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Abstract

The global demographic landscape is undergoing a significant transformation with a steady rise in the proportion of elderly individuals. Population ageing, driven by declining fertility rates and increasing life expectancy, has become a major socio-economic concern worldwide. India, now the most populous country, is experiencing a rapid increase in its elderly population, which poses unique developmental challenges. The study explores the socio-economic implications of ageing in India, focusing on issues such as financial insecurity, health challenges, and social isolation among older adults. It also examines the strain that an ageing population places on public resources, including healthcare systems, social security, and welfare programs. With the share of elderly in India's population expected to reach nearly 18% by 2036, understanding these dynamics is essential for sustainable policy formulation. The research emphasizes the need for effective interventions to ensure income security, accessible healthcare, and social inclusion for older citizens. By assessing existing policies and identifying gaps in their implementation, the study seeks to contribute to the development of inclusive and sustainable strategies that enhance the quality of life of the elderly and reduce their economic and social vulnerability.

Key words: Population Ageing, Elderly Population in India, Socio-economic Implications, Financial

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Introduction

A Population is defined as all nationals present in our temporary absent from a country and aliens permanently settled in a country. The world population is the total number of humans currently living. Population is one of the factors which affect the economy of the country. Rapid population growth can lead to overpopulation which put strain on natural resources and environment. A high population growth rate often requires increased social expenditure in education and healthcare. This effect can be seen in many developing countries, where hi birthday necessity substantial investment in schooling potential limiting the resources available for investment in infrastructure or industrial development. If economic growth fails to keep face with population growth it can lead to higher unemployment rates and poverty. Hence population plays an important role in the country's economy.

A developing country India also faces the problem of population growth. India is the most populous country in the world with one-sixth of the world population. According to the official data India's population is 1.42 billion in 2022. And in 2025 India's population is estimated to be 1.46 billion, which is 17.78% of the world's population. According to the new data the number of age people are increasing as the population is increasing. Population ageing is a shift in the distribution of a country's population towards older ages.

Old age is the range of ages nearing and surpassing the life expectancy of human beings; it is the end of the human cycle. They hold the family firmly at all times and make them strong. They are the ideal mentor. From all the experiences they have accumulated over the years, they can judge a situation and give constructive advice to their children. They also play an important role in solving disputes among the family members. They give unconditional love, kindness, patience, humor, comfort, lessons in life. They have walked a mile in your shoes. The advantage anybody older than yourself has, is that they have lived at the age that you have before. Although every situation is different, they do know what it is like to be where you are, or at least, at the age you are at. Ageing cannot be prevented, but we can learn how to deal with arising conditions for great health of our loved ones. People worldwide are living longer.

The aging population, characterized by a rising proportion of individuals aged 65 and above, is a demographic shift occurring worldwide. This trend,

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driven by declining birth rates and improvements in health care, leads to longer life expectancies and changes in societal structures.

According to the statistics of 2025 India's population is 1.46 billion. According to the population census of 2011 there are nearly 104 million elderly persons in India 53 million females and 51 million males. According to the National Commission on population the share of elderly in India population close to 9% in 2011, is growing fast and may reach 18% by 2036. Life expectancy in India has more than doubled since independence from around 32 years in the late 1940 to 70 years till today. Over the same period the fertility rate has declared from about 6 children performance to just 2, but it has created a new challenge the ageing of the population.

Today most people can expect to live into their sixties and beyond. Every country in the world is experiencing growth in both the size and the proportion of older persons in the population. By 2030, one in six people in the world will be aged 60 years or over. At this time the share of the population aged 60 years and over will years and older will double (2.1 billion). The number of persons aged 80 years or older is expected to triple between 2020 and 2050 to reach 426 million. While this shift in distribution of a country's population towards older ages-know as population ageing- started in high- income countries (for example in Japan 30% of the population is already over 60 years old), it is now low- and middle- income countries that are experiencing the greatest changes.

The world's elderly population is expanding rapidly. According to the United Nations Population Division, the proportion of elderly individuals globally is projected to rise from 10% in 2000 to 15% in 2025, and to 21% by 2050. By 2050, there will be two elderly persons for every child, posing significant socio-economic challenges worldwide

Significance of the study

This study's significance lies in its exploration of the socio-economic impact of the aging population and the development of sustainable solutions. As the proportion of elderly individuals increases, governments, policymakers, and communities must adjust their strategies to ensure older adults maintain a decent standard of living, access to affordable healthcare, and opportunities for social inclusion. By addressing financial insecurity and social isolation, we can improve the quality of life for older adults and reduce the burden on social systems. This research is particularly valuable in

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assessing the current state of policies and identifying gaps that need to be addressed to create a more inclusive and supportive environment for the aging population.

Research Problem

Social economic condition is the status of an individual's life in a society. This is depended on the factors like income of the person, educational qualification, place of their living, health condition etc. India is the largest country with the highest population, aged population also have a great part in this. Ageing is a natural phenomenon. People in their 60's face different kind of social and economic problems. Due to their declining physical and mental health older generation often seen dependent. Aged people are financially depended on their family. Since they considered less productive and less active in the economy. Their contribution to the economy is less. But government has implemented new programs and policies for welfare of the elderly. Being physically and financially dependent make the people suffer mentally which affects the mental health also. Aged people also face financial insecurity, limited access to healthcare, and social isolation etc. These challenges can lead to a decline in the quality of life for older adults, increasing the burden on families, communities, and government resources. This study focuses on identifying the primary impact of socio-economic challenges faced by the elderly and evaluating the adequacy of existing policies aimed at improving their well-being

Objective

1. To analyze the socio-economic conditions of the aging population in Mannarkkad Muncipality.
2. To identify the specific problems faced by elderly individuals

Methodology

This study is primarily based on the primary data, which is collected through the structured questionnaires and interviews with elderly residents of Mannarkkad Municipality. Besides this primary data we collected data and information from secondary sources like academic journals, government publications and reputable websites. This study will employ various statistical tools, such as percentage distribution, bar diagrams, crosstabulation, simple percentage analysis.

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Review of literature

Elderly people are valuable resource for any society. Aging is a natural phenomenon with objectives and challenges. According to the Report of the Technical Group on Population Projections for India and States 2011-2036, there are nearly 153 million elderly persons in India in 2025 and is further expected to increase by around 56 million in 2031. As a developing nation in India has to take care of its old age population by making new policies and programs for the development of elderly. Various studies have been made by various scholars on the socio- economic condition of elderly population is given below.

1. Shailendra Kumar and K Anil Kumar (2019) analyzed that majority of the elderly co-resides both in socioeconomically backward and forward states. Overall, 72% elderly are economically dependent on others. Number of surviving children, education, and consumer expenditure quintile are the significant predictors of living alone, while age, gender, and education significantly influences economic dependency. The findings call for making appropriate changes in policies and programs to ensure social security and health of the elderly.
2. Harihar Sahoo et al (2021) emphasize that despite an increasing feminization of India's older population marked by a high incidence of widowhood among aged women, women's health in later life and the health consequences of widowhood has received little attention in the existing gender and erotological studies in India.
3. Deeti A (2023) found the evolution of India's pension system, focusing on the challenges posed by an aging population in the context of economic growth. The paper critiques the shift from the Old Pension System (OPS) to National Pension System (NPS), arguing that the latter leaves many elderly individuals vulnerable to market risks. The author recommends reintroducing elements of the OPS, strengthening the social insurance model, and expanding pension coverage to unorganized sector workers.
4. Kumar S and Prakash A (2023) explore how the aging population is increasing the demand for healthcare services and straining the country's healthcare financing. The authors note that chronic diseases, which are more prevalent among the elderly, account for a significant portion of healthcare costs. They recommended increasing public healthcare spending, promoting

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preventive care, and creating elder-specific health insurance schemes to ensure sustainable healthcare financing.

Ageing Population- Kerala Scenario

Ageing is a series of process that begins with life and continues throughout the life cycle. It presents both challenges and opportunities. Elderly or old age consists of ages nearing or surpassing the average life span of human beings. Kerala is ageing faster than the rest of India. Its 60-plus population, 5.1 per cent of the total in 1961, was just below the national 5.6 per cent. Since 1980, Kerala has overtaken the rest and the 2001 comparison is 10.5 per cent to 7.5; by 2011, almost 13 per cent of the population is already past 60 years. According to a study (Center for Development Studies, 2013 "A survey on ageing scenario in Kerala"), the State's elderly population is growing at a perpetual rate of 2.3 per cent. The growth rate is high among the elderly aged 70 or 80 and above. Currently 42 lakh people of Kerala are 60 above; 13 per cent of them are 80 years and over, the fastest growing group among the old. Women outnumber men among the 60 plus and among them, majority are widows. Kerala has got the highest life expectancy at birth. The life expectancy at birth in Kerala is 71.8 years and 77.8 years for males and females respectively as per the SRS Report 2009-13. Generally, life expectancy among women is higher than men (for all-India also); however, it is much higher in Kerala and men marry women a few years younger which explain the high proportion of widows among the old. NSS Survey 2015 on morbidity indicates that 65 per cent old are morbid.

In Kerala, the culture of sending elderly persons to Old Age Home is fast developing. Majority of old age people in Kerala are widows. In 1991, among the old age people in the range of 60-69, 53.8 per cent are widows and among those above 70years it comes to 69.20 per cent. By 2025, about 20 per cent of our population would be elderly and the demand on the social security to the senior citizens is not charity instead it is their basic human right.

Kerala is considered to have the best health system in India. But Kerala is also known for its highest morbidity. The 71st Round of National Sample Survey on Morbidity (January to June 2015) shows that while a total of 89 persons out of 1,000 persons surveyed reported ill during a 15 days period of survey all over India, the number reported from Kerala was 310 out of 1,000. Among the 60+ this was 276 for India and 646 for Kerala. Kerala has

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the largest incidence of Non-Communicable Diseases (NCDs) in India. The State is considered to be the diabetes capital of India.

The Registrar General of India's Report on Medical Certification of Cause of Death 2013 shows that while in India only 3 per cent people died due to diabetes in 2013, it was 10.2 per cent for Kerala. The cases of hypertension and cardio vascular diseases are not different. These may be treated as the factors reducing life span and affecting quality of life. While these are general problems affecting all age group in Kerala. Since independence, the Government has been committed to supporting the old people in our society with certain interventionist welfare methods.

Results and Discussion

In this chapter analysis and interpretation of data collected are presented. The data are collected with the help of a well- executed interview schedule based on the objective of the study. The data are collected from MANNARKKAD MUNCIPALITY, around 100 respondents are respondent to the questions. The collected data are processed by editing and subsequent coding the errors and omissions in the collected data are examined. The answers to each question are classified into meaningful categories. The tabulation is done with the help of statistical software. The processed data are analyzed by using several statistical tools available for the purpose of the study. The analysis and interpretation are provided objective wise and results are presented in the following manner.

TABLE 1: AGE

AGE	FREQUENCY	PERCENT
60- 69 Years	52	52.0
70- 79 Years	42	42.0
80+ Years	6	6.0
Total	100	100.0

(Source: Primary Data)

Above table provides insights into the age distribution of respondents. Out of 100 respondents, (52%) are included in 60- 69 Years old category, (42%) of respondents are included in 70- 79 Years old category and only (6%) of respondents are included in 80+ Years old category.

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TABLE 2: GENDER

GENDER	FREQUENCY	PERCENT
Male	46	46.0
Female	54	54.0
Total	100	100.0

The above table indicate number of females and males who are above the age of 60. From the table we can understand that the frequency of females is more than the frequency of males. From 100 old age people 54% is female and 46% is male.

TABLE 3: EDUCATION QUALIFICATION

EDUCATION QUALIFICATION	FREQUENCY	PERCENT
Illiterate	34	34.0
Primary Education	51	51.0
Secondary Education	12	12.0
Higher Education	3	3.0
Total	100	100.0

(Source: Primary Data)

From the above table shows education qualification of the respondents. This provides valuable insights into the demographic and socio-economic characteristics of respondents. This information can help policy makers to understand the life of elderly people in different socio-economic condition. Education is one of the important factors which affect the socio- economic conditions of a human being. From the above table see that 51% of people have primary education. This is almost half of the sample. People who have illiterate like no education are 34% and 12% of respondents have Secondary education. Only 3% of respondents have Higher education like 12th and above. On the basis of the data from the above table more respondents are primary educated.

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TABLE 4: RELIGION

RELIGION	FREQUENCY	PERCENT
Hindu	33	33.0
Muslim	58	58.0
Christian	9	9.0
Total	100	100.0

(Source: Primary Data)

From the above table shows the religion of the respondents. Out of 100 respondents, 58% are Muslim, 33% are Hindu and only 9% of respondents are Christian.

TABLE 5: CASTE

CASTE	FREQUENCY	PERCENT
General	14	14.0
OBC	77	77.0
SC/ST	9	9.0
Total	100	100.0

(Source: Primary Data)

The above table shows the caste of the respondents. Caste of respondents categorized as general, OBC and SC/ST. In which 77% were observed to be OBC, 14% general and 9% in SC/ST category. From this it is evident that number of OBC category is more in the sample

TABLE 6: SOURCE OF INCOME

SOURCE OF INCOME	FREQUENCY	PERCENT
Pension	20	20.0
Family Support	45	45.0
Employment	35	35.0
Total	100	100.0

(Source: Primary Data)

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The above table and figure explores the primary source of income of the respondents. Nearly half of respondents (45%) primary source of income as family support, (35%) of respondents, primary source of income as employment and only (20%) of respondents, primary source of income as pension. The diversity of income source suggests a multifaceted approach to financial stability among respondents.

TABLE 7: DAILY LIFE CHALLENGES

DAILY LIFE CHALLENGES	FREQUENCY	PERCENT
Health Issues	53	53.0
Financial Insecurity	15	15.0
Lack of Social Support	8	8.0
Accessibility to Public Services	19	19.0
Other	5	5.0
Total	100	100.0

(Source: Primary Data)

Above table and figures shows the daily life challenges of respondents. Half of respondents (53%) are facing health issue in their daily life, (19%) of respondents are facing accessibility to public services, (15%) of respondents are facing financial insecurity and (8%) of respondents are facing lack of social support. Only (5%) of respondents are facing other challenges in their daily life.

FINDINGS

- We understood that population growth is an economic problem. The growth of aging population is also increasing worldwide.
- Ageing population can cause many economic problems. On the other hand aging population also faces many economic problems. Not only economic but social and demographic problems.
- Elderly people face many health problems and social problems.
- Among the samples 52% of respondents falls within the 60- 69 age group.
- As per the analysis most of the respondents are belongs to

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female category which is around 54%.

- Out of 100 respondents, only 3% elderly people are higher educated and 34% respondents are illiterate.
- Considering the religion of respondents 58% are including in Muslim.
- Based on the collected data the majority of the respondent belong to the OBC (other backward classes) category comprising 77%.
- Out of the total participation 64% individuals reported being unemployed while 36% individuals reported being employed.
- By analyzing the monthly income of the respondent majority (76%) of them belongs in below 10000.
- Based on the collected data, 45% of respondents source of income from family support and 35% of respondents source of income from employment and only 20% of respondents source of income from pension
- Based on the collected data, 53% of respondents are facing health issues in their daily life and 5% of respondents are facing other problems.
- Out of total participants 73% of respondents are get adequate health care services and 2% of respondents are not get adequate health care services.
- Among the participants 445 of respondent health status are good and 25% of respondent health status are poor.

OBJECTIVE 1:

- There is no significant relationship between age and employment status.
- There is a significant relation between education and monthly income.

OBJECTIVE 2:

- There is a significant relation between monthly income and satisfaction of health care.
- There is no significant relationship between age and daily challenges faced by respondents.
- There is a significant relationship between age and health status of respondents.

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Conclusion

It is to clear to all that aging population is increasing each year. And it is also one of the economic problems faced by the country. Increase in number of aging population has many effects on the economy as well as it is the responsibility of the government to take care of the old age people. From the study area we understood age people have much social economic and demographic problems. An elderly person who lives alone and who are not financially in a good condition is mostly affected. Educational qualification and the living standard of the elderly people reveals that people with high education and with low education are also not working and are financially dependent on family members. As age increases people have to deal with many health problems and elderly people are having physical and mental health problems. Government should make policies to improve the condition of elderly.

The findings suggest that while some policy measures exist, there are still substantial gaps in coverage, accessibility and implementation. Without comprehensive reforms and targeted interventions, the well- being of the elderly population may continue to deteriorate, placing greater pressure on families, communities, and public resources.

Therefore, it is essential for policymakers to strengthen existing welfare schemes, improve healthcare infrastructure, and promote inclusive social support systems. Community involvement, awareness programs, and active aging initiatives can also play a vital role in improving the quality of life for the elderly. By adopting a more forward looking approach, we can ensure that aging becomes not a burden, but a phase of dignity, contribution, and care in our society.

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CHAPTER – 7

DETERMINANTS OF SUCCESS FOR WOMEN ENTREPRENEURS- AN ECONOMIC ANALYSIS OF SMALL AND MEDIUM-SIZED ENTERPRISES (SMES): A CASE STUDY OF PERINTHALMANNA TALUK.

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Abstract

The study examines the determinants of women entrepreneurs and provides an economic analysis of small and medium sized enterprises in Perinthalmanna taluk. This study aims to analyse the socio-economic status of women entrepreneurs in Perinthalmanna taluk, identify and examine key economic factors influencing the success and growth of women-led enterprises (like access to finance, market conditions, education, and social capital), and evaluate the effectiveness of policies and programs supporting women entrepreneurs, ultimately providing insights to promote sustainable growth, empowerment, and inclusive development of women entrepreneurs in the region.

Keywords: women entrepreneurship, SMEs, social, economic.

Introduction

The entrepreneur is a key to economic development. Evolution of the concept of Entrepreneurship was only in the beginning until 18th century. The word entrepreneur is derived From the French word 'Entreprendre' which means 'to undertake'. Thus entrepreneur is a person Who undertakes the risk of a new enterprise. Peter F. Drucker's Views on Entrepreneurs – "An entrepreneur is the one who always searches for change, responds to it and exploits it as an opportunity. Innovation is the specific tool of entrepreneurs, the means by which they exploit changes as an opportunity for a different business or different service". The participation of women in

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entrepreneurial activities plays a crucial role in driving economic growth and development. Women entrepreneurs contribute significantly to shaping economies by fostering innovation, generating employment, and promoting social change. A woman entrepreneur can be defined as a female who organizes, operates, and manages a business venture, bearing the associated risks and rewards.

Globally, women own approximately one in three businesses. In India, around 14% of entrepreneurs are women, who collectively manage about 20% of the country's micro, small, and medium enterprises (MSMEs). These enterprises, as defined by the MSMED Act of 2006, include businesses with investments in plant and machinery not exceeding one crore rupees and a turnover not exceeding five crore rupees. Women's established business ownership rates in these 30 countries have also increased, from 4.2% to 5.9%. High rates of business ownership were particularly notable for women in South Korea, Saudi Arabia, Lithuania, Puerto Rico, and Thailand. Entrepreneurial perceptions among women have improved significantly over the past two decades, with a 79% increase in perceived business opportunities and a 27% increase in start-up skills. Additionally, fear of failure has risen by more than half among women, raising important questions for researchers and policymakers.

According to reports Global Entrepreneurship Mentor (GEM) Women's Strat-up activity rates across 30 GEM-participating countries have risen from an average of 6.1% between 2001-2005 to 10.4% during the 2021-2023 period. In 2023, one in 10 women started new businesses, compared to one in eight men. However, countries like France, the Netherlands, and Hungary saw women's start up rates more than double over the past two decades. Despite this progress, high-income countries still report the lowest rates of women's start up activity, accompanied by the largest gender gap.

Several factors—economic, social, and psychological—shape women's entrepreneurial experiences. Challenges such as limited access to capital, societal expectations, and balancing family responsibilities often create additional barriers. In response, governments and organizations worldwide have introduced various policies aimed at promoting the growth of women-led businesses, enhancing their opportunities, and encouraging more women to participate in entrepreneurship. By addressing these challenges, these policies aim to leverage the untapped potential of women entrepreneurs, contributing to broader economic regeneration and inclusive development.

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The success of women entrepreneurs is influenced by a combination of personal, social, economic, and institutional factors. Key determinants include self-confidence, education, skill development, risk-taking capacity, and motivation. Financial access plays a crucial role—many women face challenges in obtaining credit, which hinders business growth. Social support from family and community, along with favourable cultural attitudes, can significantly enhance women's participation in entrepreneurship. Government initiatives, legal reforms, and supportive policies such as subsidies, training programs, and women-specific schemes like Stand-Up India and Mudra Yojana are vital for creating an enabling environment. Technological access and digital literacy also help women expand their businesses through online platforms and e-commerce. Networking opportunities, mentorship, and participation in women entrepreneur associations contribute to knowledge sharing, market access, and business sustainability.

Objectives of the Study

1. To analyse the socio-economic status of women entrepreneurs in Perinthalmanna taluk.
2. To identify and examine the key economic factors that determine the success and growth of women-led Enterprises, such as access to finance, market conditions, education, and social capital.
3. To evaluate the effectiveness of policies and programs designed to support women entrepreneurs.

Methodology

The study will utilize both primary and secondary data sources. Primary data will be collected from Perinthalmanna taluk using structured interview schedule. Statistical tools such as percentage Distribution, bar Diagrams, tables, charts, and chi-square tests will be employed for data analysis. Secondary data will be gathered from journals, books, websites, and other relevant sources. Statistical tools, such as SPSS and Excel, will be used for descriptive statistics, correlation analysis, and regression analysis.

Results and Discussion

The main purpose of the study determinants of success for women entrepreneurs- an economic analysis of small and medium-sized enterprises (SMEs): a case study of Perinthalmanna Taluk. The study has been conducted in Perinthalmanna taluk by collecting data from 100 people. The basic result of the study have been discussed below.

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Table-1 The Socio-Economic Status of Women Entrepreneurs

Variables	Category	Frequency	Percentage
Age	Below 25	8	8
	25-35	23	23
	35-45	31	31
	45-55	25	25
	above 55	13	13
	Total	**100**	**100**
Caste	General	24	24
	sc/st	18	18
	obc	58	58
	Total	**100**	**100**
Educational qualification	Below SSLC	11	11
	SSLC	23	23
	HSC	22	22
	Degree and above	16	16
	Diploma	28	28
	Total	**100**	**100**
Marital status	Married	61	61
	unmarried	16	16
	Divorced	8	8
	Widow	15	15
	Total	**100**	**100**
Monthly income	Below 50000	45	45
	50000-100000	41	41
	100000-200000	11	11
	Above 200000	3	3
	Total	**100**	**100**

Source: Primary data

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The first part of the table shows age wise distribution of respondents. The majority of respondents fall within the age range of 35-45 years (31%) and 45-55 years (25%). Younger individuals (below 25) make up the smallest group (8%), indicating a relatively mature population. This suggests that the majority of participants are likely to be in their prime working or mid-career stages. Then shows the caste wise distribution of respondents. The largest caste group is OBC (58%), followed by General (24%) and SC/ST (18%). This indicates a predominance of individuals from the OBC category in the sample. Then shows Educational Qualification. The most common qualifications are degree and above (28%), followed by SSLC (23%) and HSC (22%). Only 16% have a degree and above, while 11% have below SSLC. A majority are married (61%), with smaller percentages being unmarried (16%), widowed (15%), or divorced (8%). Finally, the tables of the monthly income of respondents. Most respondents earn below ₹50,000 (45%) or between ₹50,000–₹100,000 (41%). Only a small fraction earns above ₹100,000 (14%), indicating that the majority belong to the lower to middle-income group.

Table-2 Challenges Faced by Women Entrepreneurs

Challenges	Frequency	Percentages
Lack of financial resources	69	42.3
Limited access to market	35	21.5
Balancing of work and family	31	19
Lack of mentorship training and training	15	9.2
Gender bias	6	3.7
Others	7	4.3
Total	100	100

Source: Primary data

The data reveals that the most significant challenge faced by women entrepreneurs is a lack of financial resources, reported by 42.3% of respondents, indicating a major barrier to growth and sustainability. Limited access to markets (21.5%) and difficulty balancing work and family responsibilities (19%) are also prominent issues, reflecting operational and

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personal struggles. Additionally, 9.2% identified a lack of mentorship and training, highlighting the need for capacity-building support, while gender bias (3.7%) and other unspecified challenges (4.3%) were less frequently cited. Overall, the findings emphasize the need for financial support, market access, and mentoring to address the key barriers encountered.

Table-3 Difficulties of Accessing Credit

Difficulties of accessing credit	Number of respondents	Percentage
Yes	66	66%
No	34	34%
Total	100	100

Source: Primary data

The date indicates that 66% 0f respondents experience difficulties in accessing credit, while only 34% do not face any challenges.

Table-4 Govt Support and Business Condition

Responses	Frequency	Percentage
Highly	13	23.2%
Moderately	27	48.2%
Neutral	9	16.1%
Poor	7	12.5%
Total	56	100

Source: Primary data

The survey result indicates that majority of respondents (48.2%) believe the support has moderately improved business condition, while 23.2% feel it has had highly positive impact. A smaller portion 16.1% remain neutral, suggesting no significant change and 12.5% rated the support has poor, indicating dis satisfaction.

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Table-5 Awareness of Government Programs

Awareness of government programs	**Number of respondents**	**Percentages**
Yes	57	57%
No	43	43%
Total	100	100%

Source: Primary data

The data shows that 57% of respondents are aware of government programs, while 43% are not, indicating a moderate level of awareness among the population. Although more than half of the respondents are informed, a significant portion remains unaware, which could limit the effectiveness and reach of these programs.

Table -6 Applied for Government Programs

Responses	**Number of respondents**	**Percentage**
Yes	37	37%
No	63	63%
Total	100	100%

Source: Primary data

The data indicates that only 37% of respondents are applied for government programs, while a majority of 63% are not.

Table-7 Awareness of Government Programs & Applied for Government Supporting Policies

<table>
<tr><td rowspan="4">Awareness of government supporting programs</td><td colspan="4">Number of respondents applied for government supporting programs</td></tr>
<tr><td></td><td>Yes</td><td>No</td><td>Total</td></tr>
<tr><td>Yes</td><td>34</td><td>23</td><td>57</td></tr>
<tr><td>No</td><td>3</td><td>40</td><td>43</td></tr>
<tr><td colspan="2">Total</td><td>37</td><td>63</td><td>100</td></tr>
</table>

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Chi-Square Tests

	Value	**df**	**Asymptotic significance (2 sided)**
Pearson Chi-Square	29.172	1	0.000
Continuity Correction	26.956	1	0.000
Likelihood Ratio	33.147	1	0.000
Fisher 'Exact Test			
Linear by Linear association	28.88	1	
N of valid cases	**100**		

Source: Primary data

H_0: There is no significant relationship between variables

H_1: There is a significant relationship between variables

The cross tabulation and chi-square test results indicate a significant association between awareness of government programs supporting women entrepreneurs and whether individuals have applied for any business support programs. Among those aware of such programs, 34 have applied while 23 have not, whereas among those unaware, only 3 have applied and 40 have not. The Pearson Chi-Square value is 29.172 with a p-value of .000, indicating a statistically significant relationship ($p < 0.05$). This suggests that awareness of government support programs is strongly associated with the likelihood of applying for business support, highlighting the importance of promoting awareness to increase program participation among women entrepreneurs.

Conclusion

The study reveals that women entrepreneurs in Perinthalmanna taluk are increasingly active in diverse sectors, particularly in service-based and retail businesses. The majority operate as sole proprietors or within family-owned enterprises, reflecting both personal initiative and traditional support structures. Key determinants of success include access to financial resources, family support, education level, prior business experience, and participation in local entrepreneurial networks. Women who had access to training

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programs and formal financial institutions reported better performance and growth. However, challenges such as societal expectations, limited mobility, and difficulty in scaling operations remain persistent.

Despite these hurdles, the entrepreneurial drive among women in Perinthalmanna is strong, with many demonstrating innovation, resilience, and adaptability. The findings underscore the need for targeted policy interventions, skill development programs, and improved access to credit and market linkages to further enhance the success and sustainability of women-led SMEs. This study highlights that empowering women entrepreneurs not only contributes to individual economic upliftment but also plays a vital role the broader socio-economic development of the region.

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CHAPTER – 8

SOFT SET THEORY: OPERATIONS AND APPLICATIONS

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Abstract

This paper provides a systematic review of the Basic concepts, operations, their important operations, and applications of soft set theory as introduced by D. Molodtsov. Soft set theory is a mathematical framework specifically designed to manage uncertainty, vagueness, and incomplete information that cannot be perfectly handled by traditional mathematical tools. The study first establishes the theoretical foundation by defining core concepts such as soft set, soft subset, soft equal, soft null set, and soft universal set. Following this, the standard operations (Union, Intersection, Compliment, Difference) are analyzed as the key analytical tools for data processing under parameterization. After that, discusses fundamental properties such as identity, domination, commutativity, and associativity and proofs are provided to show that these properties hold under the standard definitions. These results give a clear understanding of the structural Behaviour of soft set operation. The main contribution of this review is the discussion on the application of these concepts in four different areas: Graph theory, Game theory, Operation research, Topology. The findings demonstrate that soft set theory offers a highly effective methods for modeling complex, real-world problems.

Keywords: Soft set, Operations, Properties, Applications.

1. Introduction

The concept of uncertainty is an essential aspect of many real-world problems. Traditional mathematical theories like classical set theory cannot describe uncertainty property. To reduce this gap, new theories such as probability, fuzzy sets and rough sets were developed to handle uncertainty in different way. But each of them had its own limitations. For example, probability theory needs numerical data, fuzzy set theory depends on membership functions and rough set theory works only with clear boundaries. In 1999, molodtsov introduce soft set theory to overcome these limitations. Soft set theory is simple, flexible and does not need any extra conditions like membership function or probabilities. It uses parameters to describe uncertain data. Soft set theory is widely used in many fields such as economics, engineering etc. It help to analyze data where exact information not available and gives better results in uncertain situations. Easy to apply this theory in real -life problems. This theory can be improved and combined with other modern mathematical and computational methods to create more powerful tools for data analysis and decision system.

2. Materials and Methods

This section establishes the theoretical framework, defining the Basic concepts and important operations.

2.1 Basic Concepts

Soft set: Let U be an initial universe set and E be a set of parameters. Let P(U) denote the power set of U and $A \subseteq U$. A pair (F, A) is called a soft set over U, where F is a mapping given by: $F: A \rightarrow P(U)$.

In otherwords a soft set (F, A) over U is a parametrized family of subsets of U. For $e \in A$, F(e) may be considered as the set of e-approximation elements of the soft set (F, A).

Example: Assume that $U = \{h_1, h_2, h_3, h_4, h_5\}$ be a universal set consisting of a set of five houses under consideration.

Let $E = \{e_1, e_2, e_3, e_4\}$ be a set of parameters with respect to U, where each parameter e_i, i = 1,2,3,4 stands for "expensive", "beautiful", "cheap", "modern", respectively and $A = \{e_1, e_2, e_3\} \subseteq E$.

Suppose a soft set (F, A) describes the attractions of the houses, such that $F(e_1) = \{h_2, h_4\}$,

$F(e_2) = \{h_1, h_3, h_5\}$,

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$F(e_3) = \{h_3, h_4, h_5\}$

Then the soft set (F, A) is a parametrized family $\{F(e_i) : i = 1,2,3\}$ of subset of U defined as $(F, A) = \{ F(e_1), F(e_2), F(e_3)\}$ i.e $(F, A) = \{\{h_2, h_4\}, \{h_1, h_3, h_5\}, \{h_3, h_4, h_5\}\}$ the soft set (F, A) can also be represented as a set of ordered pairs as follows:

$(F, A) = \{(e_1, F(e_1)), (e_2, F(e_2)), (e_3, F(e_3))\}$.

Soft subset: Let (F, A) and (G, B) be two soft sets over a common universe U, we say that (F, A) is a soft subset of (G, B) denoted by $(F, A) \tilde{\subseteq} (G, B)$

If a) $A \subseteq B$

b) for every $e \in A$, F(e) and G(e) are identical approximations.

Soft equal: Let (F, A) and (G, B) be two soft sets over a common universe U, (F, A) is soft equal to (G, B), denoted by (F, A) = (G, B)

If a) A = B

b) $F(e) = G(e), \forall e$.

Null soft set: A soft set (F, A) over U is said to be null soft set denoted by (ϕ, ϕ) if for every $e \in A$, $F(e) = \{\phi\}$.

Universal soft set: A soft set (F, A) over U is called a universal soft set if A = E and F(e) = U all $e \in A$. Symbolically we write (U, E) for the universal set U.

2.2 Operations

Union: The union of two soft sets (F, A) and (G, B) over the common universe U is a soft set (H, C), where $C = A \cup B$ and for each $e \in C$

$$H(e) = \begin{cases} F(e), & \text{if } e \in A - B \\ G(e), & \text{if } e \in B - A \\ F(e) \cup G(e), & \text{if } e \in A \cup B \end{cases}$$

We write

$(F, A) \tilde{\cup} (G, B) = (H, C)$

Intersection: Let (F, A) and (G, B) be two soft set over a common universe U, then the intersection of (F, A) and (G, B) denoted by $(F, A) \tilde{\cap} (G, B)$, is

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the soft set (H, C) where C = A ∩B e ∈ C, H(e) = F(e) ∩ G(e).

Compliment: The compliment of a soft set (F, A) is denoted by (F, A) and is defined by (F, A) = (F^C, $\neg A$), where F^C = ¬A → P(U) is a mapping given by F^C = U – F (¬ a), ∀ a ∈ ¬ A.

Difference: Let (F, A) and (G, B) be two soft sets over the common universe U. Then the soft difference (F, A) \ (G, B) is defined as the soft set (H, C), where C = A

$$H(e) = \begin{cases} F(e) \setminus G(e), & \text{if } e \in A \cap B \\ F(e), & \text{if } e \in A - B \end{cases}$$

3. Results and Discussion

This section presents the main findings of the study based on the soft set operations. First, discuss some important properties of soft set operations such as identity, domination commutative, associative laws. After that, explain the applications of soft set in graph theory, game theory, operation research, topology.

3.1 Properties of soft set operations Identity Laws:

For any soft set (F, A) over U, we have that

(a) (F, A) $\tilde{\cap}$ (U, E) = (F, A)

(b) (F, A) $\tilde{\cup}$ (ϕ, ϕ) = (F, A)

Proof:

(a) If a soft set is intersected with the universal soft set, no elements are removed. So the result again remains the same soft set.

(b) If a soft set is combined with the null soft set, nothing new is added. So the result is the same soft set.

Domination Laws:

For any soft set (F, A) over U, we have that

(a) (F, A) $\tilde{\cap}$ (ϕ, ϕ) = (ϕ, ϕ)

(b) (F, A) $\tilde{\cup}$ (U, E) = (U, E)

Proof:

(a) If a soft set is intersected with the null soft set, everything is removed. So

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the result becomes the null soft set.

(b) If a soft set is combined with the universal soft set, the universal set covers everything. So the result becomes the universal soft set.

Commutative Laws:

For any soft set (F, A) and (G, B) over U, we have that

(a) $(F, A) \tilde{\cap} (G, B) = (G, B) \tilde{\cap} (F, A)$

(b) $(F, A) \tilde{\cup} (G, B) = (G, B) \tilde{\cup} (F, A)$

(c) $(F, A) \setminus (G, B) \neq (G, B) \setminus (F, A)$

Proof:

(a) By definition of intersection, the resulting parameter set is $A \cap B$. Also, for any parameter e, $F(e) \cap G(e) = G(e) \cap F(e)$. Hence commutativity hold. Similarly (b) can be proved.

(b) The difference operation is not commutative because the order of subtraction changes the result. In general, (F, A) – (G, B) and (G, B) – (F, A) remove different element sets, so the two outcomes are not equal.

Associative Laws:

For any soft sets (F, A), (G, B) and (H, C) over U, we have that

(a) $((F, A) \tilde{\cap} (G, B)) \tilde{\cap} (H, C) = (F, A) \tilde{\cap} ((G, B) \tilde{\cap} (H, C))$

(b) $((F, A) \tilde{\cup} (G, B)) \tilde{\cup} (H, C) = (F, A) \tilde{\cup} ((G, B) \tilde{\cup} (H, C))$

(c) $((F, A) \setminus (G, B)) \setminus (H, C) \neq (F, A) \setminus ((G, B) \setminus (H, C))$

Proof:

(a) By the definition of intersection, the resulting parameter set is $(A \cap B) \cap C = A \cap (B \cap C)$. Also, for any parameter e, $(F(e) \cap G(e)) \cap H(e) = F(e) \cap (G(e) \cap H(e))$. Hence associativity hold.

Similarly (b) can be proved.

(c)The different operation does not satisfy the associative law. Because changing the grouping of soft set changes which elements are removed first, so the result become different.

3.2 Applications Graph Theory:

In graph theory, the cycle through all the vertices is called a Hamilton's cycle. To determine a Hamilton cycle in a graph theory is not straight

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forward. Soft set help us to check if a graph has a Hamilton cycle even when information is incomplete. In the following it is seen that soft set theory may help to find presence or absence of Hamilton's cycle in a graph.

Proposition: Let G be a connected graph represented by a soft set (F, U) over U, then G has a Hamilton's cycle if and only if there exist a soft subset (H, U) of (F, U) such that (H,U) represents a connected subgraph with $|H(u_i)| = 2$, for all $u_i \in U$.

Proposition: Let G be a connected graph represented by a soft set (F, U) over U. If u ∈ U is a vertex adjacent to at least three more vertices say u_i, u_{i+1} and u_{i+2} such that $|F(u_i)| = |F(u_{i+1})| = |F(u_{i+2})| = 2$, then G has no Hamilton's cycle.

Game theory:

The traditional models in game theory are based on numerical payoff values. However, real- life decisions are influenced by uncertainty, vagueness and incomplete information. Classical game theory is limited in handling such situations and overcome these limitations, soft set theory is used in game theory. It lead to the development of a new model called a soft game.

Soft game: Let U is a possible outcome in a game, E = parameters, Let A ⊆ E be a subset of parameters. A soft game is a pair (F, A) where F: A → P(U) is a function that assign to each parameter a∈A a subset F(a) ⊆ U, representing the set of outcomes associated with parameter.

Operation Research:

Soft linear programming (soft LP):

Max (or Min) $\tilde{Z} = \tilde{C}^T \tilde{X}$

Subject to: $\tilde{A}\,\tilde{X} \le \tilde{b}, \tilde{X} \ge 0$

Where, $\tilde{Z}, \tilde{A}, \tilde{b}$ are soft sets, $\tilde{X}$ is soft vector of decision variables.

Example: Max $\tilde{Z}$ = {(good, $3x_1+5x_2$), (average, $2x_1+4x_2$)}

Subject to: {(good, $x_1 + x_2 \le 6$), (average, $2x_1 + 3x_2 \le 12$)}

$x_1, x_2 \ge 0$.

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Remark: Soft LP is a generalization of classical linear programming. Optimization problems with uncertainty can be handled using soft set theory. It supports pure mathematical concepts such as soft vector space and soft algebra.

Topology:

Soft topology is a direct and significant theoretical application of soft sets. It offers a new way to define and explore topological properties.

Soft topology: Let U be a universe and E be a set of parameters. A collection $\tau \subseteq$ S (U, E) is said to be a soft topology on U if,

1. (ϕ, E) $\in \tau$ and ($\tilde{U}$, E), where $\tilde{U}$(e) = U for all e $\in$ E.
2. The union of any number of soft sets in τ is in τ.
3. The intersection of any two soft sets in τ is in τ. The triple (U, E, τ) is called soft topological space.

Soft open set: In a soft topological space (U, E, τ), any soft set (F, A) $\in \tau$ is called a soft open set.

Soft closed set: A soft set (F, E) is said to be soft closed if its relative compliment, $(F, E)^c$, is in τ . The compliment is defined as:

$(F, E)^c = (F^C, E),\ where\ F^c(e) = U - F(e)\ \forall\ e \in E.$

4. Conclusion

This study shows that information that is not fully clear can still be understood when it is arranged properly. By using a method based on parameters, different types of details can be organised without needing complete accuracy. This helps in dealing with situations where the available information is limited or uncertain.

The basic ideas explained in this work give a simple way to express and manage unclear data. The operations described in the study provide clear steps to combine or separate this information in an organised manner. Even when the details are not perfect, these operations make the work more systematic. The properties connected with the operations also help to understand how they behave in different situations, which makes the method easier to use.

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The areas where this approach can be applied show that it is flexible and useful. It can support many situations where exact information cannot be expected. This kind of structured method reduces confusion and brings more clarity when studying uncertain data.

In conclusion, the study shows that uncertainty does not have to be a problem when the information is arranged in a simple and orderly way. With the right structure, even unclear details become easier to understand and work with. Future work can focus on combining soft set with fuzzy set and rough set models to develop hybrid system for more complex real- world problems.

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CHAPTER – 9

BIOPOLYMER-ASSISTED ECO-SYNTHESIS OF BIOLOGICALLY RELEVANT HETEROCYCLIC CHALCONE SCAFFOLDS USING CELLULOSE PERCHLORIC ACID CATALYSIS

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Abstract

The synthesis of biologically important novel heterocyclic chalcone via solvent free green approach using cellulose perchloric acid (CPA) catalyst was detailed herein. The reaction was carried out by using salicylaldehyde and dehydroacetic acid via multicomponent one pot synthesis. The green catalyst cellulose-$HClO_4$ employed possesses environmentally benign properties such as bio-degradability, non-toxicity, bio-compatibility, recyclability and reusability upto four catalytic cycles. This new method is superior to the conventional reported methods with respect to the reaction time, yield, reusability of catalyst and simplicity of procedure etc. This synthesized novel compound was characterized by using ^{1}HNMR and FT-IR spectroscopic techniques. The extensive optimization studies employed such as variation in solvent and solvent free methods, catalyst type, catalyst loading, recyclability and reaction conditions provided deep insights to the efficiency of the present protocol. Moreover, the synthesized Chalcone is expected to possess numerous biological and pharmacological properties like anti-tumor, anti-HIV, antioxidant, anti-leishmanial, antibacterial, antifungal etc. Overall this operationally simple green route employed for the synthesis of chalcone offers significant potential both for pharmaceutical and industrial applications.

Keywords: Green synthesis, Solvent free reactions, Chalcones, Cellulose-$HClO_4$.

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1. Introduction

Green chemistry in chemical synthesis addresses future challenges in working with chemical processes and products by developing novel reactions that can maximize the desired products and can design new synthetic strategies that simplify chemical production processes [1]. Due to the growing concern for the influence of the organic solvent on the environment as well as on human body, organic reactions without use of conventional organic solvents have attracted the attention of synthetic organic chemists [2]. Although a number of modern solvents, such as flourous media, ionic liquids and water have been extensively studied recently, not using a solvent at all is definitely the best option. Development of solvent free organic reactions is thus gaining prominence [3]. The aldol condensation reaction is one of the most important synthetic routes that give large molecules through the formation of carbon-carbon bond, generally the products are α, β unsaturated compounds [4]. Cellulose is a biodegradable polymer which act as a very good support for the synthesis of solid acid catalysts which has been utilized in different organic synthesis [5]. Chalcones are a class of organic compounds and possesses molecules containing open chain flavonoids with three carbons and two aromatic rings connected by unsaturated carbonyl systems [6]. Chalcones are known to pose a wide spectrum of biological properties such as antifungal, antiviral, antimalarial etc [7]. All these biological properties of this chalcones are generally correlated to the reactive α, β-unsaturated keto function present in the molecules [8].

To the best of our knowledge, no prior report exist for the green synthesis of chalcones from Salicylaldehyde and Dehydroacetic acid using recyclable and reusable Perchloric acid modified catalyst.

2. Experimental

2.1 Materials and methods

The reagents like salicylaldehyde, cellulose, perchloric acid, piperidine, methanol, ethanol, dehydroacetic acid and others were purchased from commercial sources and were used as such. The purity of compound was checked by thin layer chromatography (TLC) on glass plate coated with silica gel G using chloroform-methanol mixture as mobile phase and visualized by iodine vapours. VARIAN 400 MHZ NMR spectrometer was

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used to analyze ^1H NMR spectra. IR spectrum of the compound was recorded using Shimadzu Spirit FT- IR spectrometer. The values of chemical shifts were quoted in delta scale in ppm relative to tetramethylsilane (TMS) as an internal standard and DMSO D_6 as solvent system.

2.2 General procedure for the synthesis of Cellulose-$HClO_4$ (CPA) catalyst.

Cellulose-$HClO_4$ was prepared by the drop wise addition of perchloric acid (1.0 g, 5mmol) to a magnetically stirred mixture of cellulose (5.0g) in n-hexane (20 mL) at 0°C for 2hr. After complete addition, the mixture was dried for another 2 hr. The mixture was filtered, washed with acetone (30 mL) and dried at room temperature to afford cellulose-$HClO_4$ as white powder (5.25 g) [5].

2.3 General procedure for the synthesis of chalcone under conventional method.

To a mixture of Salicylaldehyde (1mmol, 122.1 mg) and Dehydroacetic acid (1 mmol, 168.14 mg) in methanol (8 mL), pipiridine (0.05mL) was added. The reaction mixture was refluxed for 6 hr. After completion of reaction (checked by TLC), the reaction mixture was concentrated and cooled at room temperature. The compound was purified by recrystallization from chloroform-methanol (10:1 v/v) mixture to obtain yellowish crystals.

2.4 General procedure for the synthesis of chalcone under solvent-free condition using recyclable perchloric acid modified cellulose catalyst

To a mixture of Salicylaldehyde (1mmol, 122.1 mg) and Dehydroacetic acid (1mmol, 168.14 mg), Cellulose-$HClO_4$ (80 mg) was added. The reaction mixture was taken in a 50 mL Round Bottom flask, and heated at 80^0C over a magnetic stirrer with a hot plate. After completion of the reaction (monitored by TLC, for every one minute) the product was isolated from the reaction mixture by adding hot ethyl acetate (10 mL). The catalyst was removed by filtration. After separation of catalyst, the solvent was evaporated. The solid thus obtained was further purified by recrystallization from chloroform-methanol (10:1 v/v) mixture.

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2.5 General procedure for the synthesis of chalcone under solvent assisted condition using Cellulose-$HClO_4$ catalyst

To a mixture of Salicylaldehyde (1mmol, 122.1 mg) and Dehydroacetic acid (1mmol, 168.14 mg), Cellulose-$HClO_4$ (80 mg) was added. The reaction mixture was taken in a 50 mL Round Bottom flask, and solvents (10 mL) (Ethanol, Methanol, Chloroform, Water) were added and refluxed over a heating mantle for the specified time. After completion of the reaction (monitored by TLC) the product was isolated. The catalyst was removed by filtration. The solvent was evaporated. The solid thus obtained was further purified by recrystallization from chloroform-methanol (10:1 v/v) mixture.

2.6 General procedure for the synthesis of chalcone under solvent-free condition using different catalytic system

To a mixture of Salicylaldehyde (1mmol, 122.1 mg) and Dehydroacetic acid (1mmol, 168.14 mg), different catalysts were added (PTS, $HClO_4$, Cellulose, Cellulose-$HClO_4$). The reaction mixture was taken in a 50 mL Round Bottom flask, and heated at 80^0C over a magnetic stirrer with a hot plate. After completion of the reaction (monitored by TLC) the crude product obtained was purified by recrystallization from chloroform-methanol (10:1 v/v) mixture.

2.7 General procedure for the synthesis of chalcone under solvent-free condition using recyclable Cellulose-$HClO_4$ catalyst (in different millimoles)

To a mixture of Salicylaldehyde (1mmol, 122.1 mg) and Dehydroacetic acid (1mmol, 168.14 mg), Cellulose-$HClO_4$ catalyst 5mmol (80 mg), 10mmol (80 mg), 15mmol (80 mg) were added. The reaction mixture was taken in a 50 mL Round Bottom flask, and heated at 80^0C over a magnetic stirrer with a hot plate. After completion of the reaction (monitored by TLC, for every one minute) the product was isolated from the reaction mixture by adding hot ethyl acetate (10 mL). The catalyst was removed by filtration. After separation of catalyst, the solvent was evaporated. The solid thus obtained was further purified by recrystallization from chloroform-methanol (10:1 v/v) mixture.

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2.8 General procedure for the synthesis of chalcone under solvent-free condition using recyclable Cellulose-$HClO_4$ catalyst (in different milligrams)

To a mixture of Salicylaldehyde (1mmol, 122.1 mg) and Dehydroacetic acid (1mmol, 168.14 mg), Perchloric acid modified catalyst 10mmol (20, 40, 60, 80,100 mg), was added. The reaction mixture was taken in a 50 mL Round Bottom flask, and heated at 80^0C over a magnetic stirrer with a hot plate. After completion of the reaction (monitored by TLC, for every one minute) the product was isolated from the reaction mixture by adding hot ethyl acetate (10 mL). The catalyst was removed by filtration. After separation of catalyst, the solvent was evaporated. The solid thus obtained was further purified by recrystallization from chloroform-methanol (10:1 v/v) mixture.

2.9 General procedure for the synthesis of chalcone under solvent-free condition using recyclable Cellulose-$HClO_4$ (in different temperatures)

To a mixture of Salicylaldehyde (1mmol, 122.1 mg) and Dehydroacetic acid (1mmol, 168.14 mg), Cellulose-$HClO_4$ 10mmol (80 mg) was added. The reaction mixture was taken in a 50 mL Round Bottom flask, and heated at 25°C, 50°C, 80°C, and 90°C over a temperature controlled magnetic stirrer separately. After completion of the reaction (monitored by TLC) the product was isolated from the reaction mixture by adding hot ethyl acetate (10 mL). The catalyst was removed by filtration. After separation of catalyst, the solvent was evaporated. The solid thus obtained was further purified by recrystallization from chloroform-methanol (10:1 v/v) mixture.

2.10 General procedure for recycling and reusing of Cellulose-$HClO_4$.

To a mixture of Salicylaldehyde (1mmol, 122.1 mg) and Dehydroacetic acid (1mmol, 168.14 mg), Cellulose-$HClO_4$ (80 mg) was added. The reaction mixture was taken in a 50 mL Round Bottom flask, and heated at 80^0C over a magnetic stirrer with a hot plate. After completion of the reaction (monitored by TLC, for every one minute) the product was isolated from the reaction mixture by adding hot ethyl acetate (10 mL). The catalyst was removed by filtration and reused for another reaction cycle. After separation of catalyst, the solvent was evaporated. The solid thus obtained was further purified by recrystallization from chloroform-methanol (10:1 v/v) mixture.

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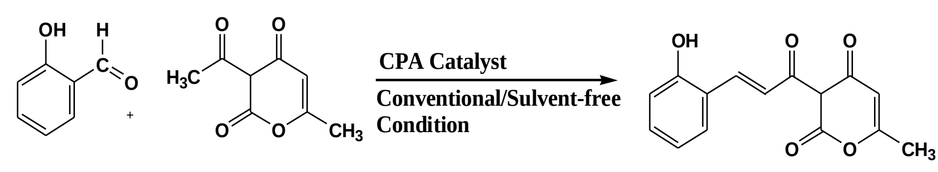
3. Results & Discussion

In recent years a huge number of studies have been conducted by academic and industrial research groups to the development of ecofriendly processes. The emerging area of Green Chemistry aims minimum hazards as the primary criteria while designing new chemical processes. The main objective of Green Chemistry is the elimination of waste generation in the first place. One of the thrust areas of achieving this target is to explore alternative, efficient reaction condition and eco- friendly reaction media or catalysts to accomplish the desired chemical transformation with minimized by-products or waste, as well as eliminating the use of conventional toxic organic solvents and catalysts wherever possible. However, most of the reported solvent free method focuses on reactions promoted by hand grinding, micro wave irradiation, mechanical milling etc. In contrast reports on direct heating of the reagent under thermal heating condition without any solvent and by using eco- friendly, recyclable and reusable catalyst are relatively less explored. So we set out to explore the usage of a recyclable, reusable eco-friendly catalyst Cellulose-$HClO_4$ (CPA) for the synthesis of biologically important novel chalcone under solvent-free green condition. Cellulose-$HClO_4$ catalyst is an attractive candidate as it possesses environmentally benign properties such as biodegradability, non-toxicity, biocompatibility, recyclability, inexpensiveness, stability to air and moisture. Herein we report the viability of perchloric acid modified–cellulose as catalyst for aldol condensation reaction to synthesize novel chalcone under solvent free heating technique.



Salicylaldehyde **Dehydroacetic acid** **Chalcone**

Scheme-1- Synthesis of chalcone from salicylaldehyde and Dehydroacetic acid.

Initially the reaction was carried out in methanol in the presence of conventional catalyst piperidine under reflux condition, using salicylaldehyde and Dehydroacetic acid and yielded low amount of the product (30%)

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obtained after 6 hrs. The prolonged period of time indicated for an alternative catalyst, thus we explored the efficiency of Cellulose-$HClO_4$ by carrying out the reaction of salicylaldehyde with Dehydroacetic acid in molar ratios under different solvent assisted condition as well as solvent free heating conditions at 80 °C. The result revealed that polar protic solvents such as Ethanol and Methanol yielded chalcone in longer period of time with comparatively lower yields. In aprotic solvent chloroform, trace amount of product was formed after long period of time. Reaction using water did not give any satisfactory results. But the solvent free reaction proceeded smoothly and resulted in very good yields (78%) within few minutes (20 min) as monitored by TLC.

Table-1: Effect of various solvents on the reaction

Entry	Solvent	Temperature	Time (h/min)	Yield (%)
1	Ethanol	Reflux	2h	63
2	Methanol	Reflux	2.5h	47
3	Chloroform	Reflux	4h	15
4	Water	Reflux	24h	_
5	Solvent free	80 °C	20 min	78

In order to study the superiority of Cellulose-$HClO_4$, the reaction was performed under different catalytic systems in the solvent free condition. The order of reactivity of various catalyst was cellulose-$HClO_4$>$HClO_4$>PTS>cellulose in terms of yield of the product. The product yield, however, increased to a greater extent (78%) when cellulose-$HClO_4$ was used as a catalyst. The highest catalytic activity shown by cellulose-$HClO_4$ in comparison to $HClO_4$ and cellulose may be due to greater surface area and fine dispersion of the catalyst on the surface of cellulose

Table-2: Comparison of catalyst activity of different catalyst on reaction

Entry	Catalyst	Time (h/min)	Yield (%)
1	PTS	80min	60
2	$HClO_4$	50min	67
3	Cellulose	24hr	_
4	Cellulose-$HClO_4$	20min	78

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The effect of different amounts of perchloric acid on the cellulose support was investigated by using 5mmol, 10mmol, 15mmol of perchloric acid supported on cellulose (5 g). Using 5mmol cellulose-$HClO_4$ (lower ratio), unsatisfactory results were obtained in terms of yield and time possibly due to less available H+ sites of the catalyst (entry 1). Using 15mmol the reaction completed in shorter time period but yield was not satisfactory possibly due to formation of some side products (entry 3). However the excellent yield of the product was obtained using 10mmol cellulose-$HClO_4$ (entry 2).

Table- 3: Effect of acid loading on the reaction

Entry	Cellulose-$HClO_4$ (mmol)	Time(min)	Yield (%)
1	5	35	65
2	10	20	78
3	15	20	75

Variation of the catalyst loading also has a profound effect on the catalytic activity. When the reaction was carried out using 0.02g, 0.04g and 0.06g of the catalyst, the rate of the reaction progressed steadily with lower to moderate yields. However, the best performance was observed using 0.08 g of CPA under solvent free conditions at 80 °C. A further increase in the catalyst loading had no significant enhancement in the yield of the desired product and the rate of the condensation reaction. Mechanistically all the H+ sites of the catalyst with an optimum amount (0.08g) are utilized for the activation of the substrate. Therefore the catalyst with an amount greater than 0.08g doesn't have an effect on the activation of the substrate.

Table-4: effect of catalyst loading on the model reaction

Entry	Catalyst amount (g)	Time (min)	Yield (%)
1	0.02	120	35
2	0.04	80	56
3	0.06	55	64
5	0.08	20	78
6	0.10	20	78

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The reaction performance was drastically enhanced under solvent-free conditions when the temperature was increased from 25°C to 50°C and then 80°C and gave product in excellent yield (78%) within a few min (20min) (entry1-3). Therefore 80°C was chosen as the optimum temperature in further investigations. Further an increase in temperature to 90°C did not show any significant enhancement in the yield of the desired product. Thus, our study revealed that the best temperature for reaction is 80 °C.

Table-5: Effect of temperatures on solvent free reaction.

Entry	Solvent-free temperature (^{0} C)	Time(min)	Yield (%)
1	25	110	20
2	50	60	65
3	80	20	78
4	90	20	78

The recyclability study of the catalyst showed that the catalyst was recyclable upto four catalytic cycle and showed a reduction of yield in the fifth cycle possibly due to the deposition of impurities on the surface of the catalyst.

Table-6: Recyclability data of cellulose-$HClO_4$ for the reaction

Entry	Catalyst recycle	Time(min)	Yield (%)
1	I	20	78
2	II	20	78
3	III	20	78
4	IV	20	78
5	V	20	75
6	VI	20	73

4. Conclusion

We have developed an efficient procedure for the synthesis of α, β unsaturated carbonyl compound through aldol condensation by reacting cyclic active methyl compound and an aromatic aldehyde using stable, inexpensive, easily available green catalyst Perchloricacid modified Cellulose under solvent- free green condition. The green catalyst cellulose-$HClO_4$

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employed possesses environmentally benign properties such as bio-degradability, non-toxicity, bio-compatibility, as well as recyclability upto four catalytic cycle. The systematic optimization demonstrated that the developed catalyst outperforms all the other tested systems offering superior activity, high yield and excellent reusability. Moreover the solvent free approach not only eliminates the need for a solvent but also enhance the reaction efficiency and product purity as compared to the conventional methods. Overall this simple operational and ecofriendly approach provide a responsible route for the chalcone synthesis combining with potential industrial and medicinal applications.

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CHAPTER – 10

VOLTCARE- A SMART ELECTRICITY MONITORING AND MANAGEMENT SYSTEM

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Abstract

Energy management has become an essential part of modern living as global electricity consumption continues to increase. Traditional monitoring systems provide only monthly readings with minimal feedback, offering no real-time insights into user behavior. VoltCare is a smart electricity monitoring and management system designed to help users track and optimize their power consumption through an interactive, data-driven platform.

The system integrates Firebase Authentication, Cloud Firestore, and optionally MongoDB to ensure secure user access and reliable data storage. VoltCare's real-time dashboard displays daily consumption, cost estimates, and alerts for abnormal usage, while visual analytics offer daily, weekly, and monthly trends using Flutter's flowchart library. These insights enable users to understand consumption patterns and take timely action to reduce waste. Beyond monitoring, VoltCare focuses on behavioral awareness and sustainability. By combining energy tracking, visualization, and smart alerts, the system promotes responsible energy usage and empowers users to make data-informed decisions. Whether used with simulated data or integrated IoT sensors, VoltCare represents a practical, scalable, and affordable solution for households and small enterprises aiming for energy efficiency and sustainable living.

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1. Introduction

Electricity is the backbone of modern civilization. Every home, business, and institution relies on a constant and efficient supply of power to maintain operations. However, uncontrolled usage, lack of awareness, and inefficient monitoring often lead to unnecessary wastage, high electricity bills, and environmental strain. Despite rapid digitalization, many households still depend on conventional meters that record total energy consumption without offering insights into daily usage or individual appliance performance.

Recent advances in mobile computing and cloud technologies have opened opportunities to develop smarter solutions for everyday challenges. VoltCare aims to bridge the gap between technology and energy management. It introduces a cloud-connected application that tracks usage in real-time, provides alerts for excessive consumption, and visualizes historical data to identify inefficiencies.

The name VoltCare signifies "caring for every volt." The system transforms raw data into actionable knowledge by combining analytics, visualization, and alerting capabilities. Through its intuitive interface, VoltCare allows users to see exactly how much power is being used, when, and at what cost. The application acts as both an energy tracker and a personal advisor that helps users reduce bills and adopt environmentally friendly behavior.

Traditional energy monitoring is reactive-users only discover high usage when the bill arrives. VoltCare converts this process into a proactive model, empowering users to take corrective measures before wastage occurs. By leveraging data storage, visualization, and notification technologies, VoltCare exemplifies the next generation of smart home utilities.

Objectives

The VoltCare project was developed with the goal of promoting smart energy use through technology-driven monitoring and analysis. Its objectives are both functional and societal, ensuring not only a technically sound solution but also a meaningful contribution to sustainability and awareness. The primary objectives of VoltCare are as follows:

1. To provide real-time monitoring of electricity usage for individual users or households.

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2. To visualize consumption trends using interactive charts and summaries for daily, weekly, and monthly periods.
3. To establish threshold-based alerting, notifying users when their power usage exceeds set limits.
4. To generate detailed reports and insights, including cost summaries and consumption breakdowns.
5. To ensure secure user access through authentication and personalized data management.
6. To enhance user awareness of energy usage patterns and promote energy-saving behavior.
7. To allow flexible data management, supporting both cloud and local storage.
8. To contribute to the global goal of energy sustainability through informed decision-making and efficient usage.

VoltCare thus serves as a tool for awareness, analysis, and action. It gives users control over their energy consumption, turning abstract power data into clear visual feedback that leads to measurable behavioral changes.

Literature Review

Energy management and consumption monitoring have been studied extensively across the fields of computer science, electrical engineering, and sustainability. The evolution of smart meters and Internet of Things (IoT) devices has transformed how electricity usage data can be collected, analyzed, and acted upon.

However, despite the availability of smart infrastructure, most households still lack intuitive applications that translate raw data into meaningful insights. Existing solutions such as Google Nest, Energy Hub, and Sense Energy Monitor rely heavily on hardware sensors and often come with high costs, limiting accessibility for the average consumer

VoltCare builds upon existing research but differentiates itself in the following ways:

- Software-Driven Simulation: While traditional systems require physical sensors, VoltCare can simulate usage data, making it ideal for educational and prototype purposes.
- Cloud-Centric Architecture: The system uses Firebase Authentication and Firestore, providing a secure, scalable backend for data handling.
- User Empowerment: Rather than focusing solely on automation, VoltCare emphasizes awareness and control, helping users understand their own consumption patterns.

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- Affordability and Accessibility: By functioning as a mobile application, it bypasses expensive installation requirements.

Key references and related work include:

- Smart home energy management models that focus on IoT integration and machine learning (IEEE, 2023).
- Mobile-based energy analytics systems that provide visualization dashboards.
- Cloud-based applications for energy tracking, such as Home Assistant and Samsung SmartThings.

These studies consistently underline the necessity of user engagement for long-term energy savings.

VoltCare contributes to this vision by combining visual clarity, interactivity, and alert-driven responsiveness within an accessible digital platform.

System Architecture

VoltCare's architecture is designed for scalability, modularity, and reliability.

It follows a three-tier structure consisting of:

1. User Interface Layer (Frontend)

- Developed using Flutter, it ensures cross-platform compatibility.
- Provides dashboards, charts, alerts, and settings.
- Supports interaction through intuitive navigation and card-based summaries.

2. Business Logic Layer (Middleware)

- Handles authentication, data processing, and analytics.
- Implements logic for calculating energy costs, generating alerts, and visualizing consumption.

Ensures smooth synchronization between Ul and backend.

3. Data Layer (Backend & Storage)

- Manages persistent data using Firebase Firestore or MongoDB.
- Stores user profiles, usage records, and preferences.

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- Supports scalability, allowing easy expansion to loT devices in the future.

System Flow Summary:

1.The user logs in and interacts with the app.
2. The app retrieves consumption data (real or simulated).
3. The data is stored securely in Firestore/MongoDB.
4. Analytical processes generate trends and summaries.
5. Alerts and insights are sent to the user interface via push notifications.

Data Flow Diagram

The data flow in VoltCare illustrates how information travels through the system:

1. ***Data Collection:*** Simulated data or loT-based sensor inputs are gathered to represent appliance usage.
2. ***Data Processing:*** The system analyzes this data, converting raw kWh readings into meaningful cost and trend information.
3. ***Storage:*** Processed data is stored securely in the database with timestamps and user identifiers.
4. ***Visualization:*** Users access the data through dashboards displaying graphical charts, summaries, and alerts.

Feedback & Alerts: The system monitors thresholds and generates alerts when abnormal usage occurs

Module Descriptions

VoltCare consists of seven core modules, each performing an essential function to ensure smooth system operation and user satisfaction.

1. Authentication and User Management

Handles user signup, login, and password recovery using Firebase Authentication or MongoDB. Ensures secure access and personalized experiences for every user.

2. Dashboard / Home Screen

Displays daily electricity consumption, estimated cost, and quick alerts in a clean, card-based layout. Provides a snapshot of user activity and energy status at a glance.

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3. Usage Tracking and Visualization

Tracks and visualizes daily, weekly, and monthly energy consumption using charts (via flowchart). Helps users identify patterns and manage electricity usage efficiently

4. Alerts and Notifications

Sends notifications when consumption exceeds set thresholds. Uses Firebase Cloud Messaging or in-app alerts to help prevent wastage and reduce bills.

5. Reports and Insights

Generates summaries of usage and costs. Provides export options (PDF/CSV) and personalized recommendations to improve energy efficiency.

6. Settings

Allows customization of daily or weekly thresholds, unit costs, and notification preferences, ensuring a tailored experience for each user.

7. Data Management

Stores consumption data securely in Firebase or MongoDB, with optional offline storage in SQLite or Hive. Ensures reliable access and synchronization of user data.

Implementation Details

The implementation of VoltCare involves the integration of Flutter (frontend) with Firebase/MongoDB (backend). The app's architecture promotes maintainability and future scalability for IoT expansion.

Technologies Used:

- **Frontend**: Flutter, Dart, fl_chart
- **Backend:** Firebase Authentication, Firestore Database
- **Optional Database**: MongoDB
- **Notification System**: Firebase Cloud Messaging
- **Storage**: Hive/SQLite for offline mode

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Implementation Phases:

1. **Design & UI Creation**: Interface built using Flutter widgets and Material Design principles.
2. **Backend Integration**: Connection with Firebase for authentication and data sync.
3. **Testing Phase**: Validation of login, data storage, and visualization functionalities.
4. **Deployment**: Hosting on Android and Web platforms.

Testing and Results

Testing Approach:

VoltCare underwent functional, usability, and performance testing.

Testing Types:

- **Unit Testing**: Checked authentication, graph rendering, and report generation functions.
- **Integration Testing**: Verified communication between app modules and the database.
- **System Testing**: Assessed full workflow, from login to report export.
- **User Acceptance Testing (UAT):** Evaluated real-user satisfaction and ease of use.

Results Summary

- The app successfully stored and visualized simulated usage data.
- Alerts triggered correctly based on thresholds.
- Average data retrieval time: < 2 seconds.
- 95% of test users found the interface intuitive and informative.

These results confirm that VoltCare achieves its intended purpose-offering users a reliable and interactive means to monitor and control energy consumption.

Conclusion

The VoltCare system demonstrates that smart energy management can be achieved through software innovation without requiring expensive hardware

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setups. By combining cloud technology, interactive dashboards, and customizable alerts, the application provides users with complete control over their electricity usage.

The project not only meets its technical objectives but also aligns with global sustainability goals. By empowering individuals to monitor and optimize their energy behavior, VoltCare contributes to reducing carbon footprints and promoting responsible power usage.

Key Achievements:

- Real-time monitoring and visualization.
- Secure user management system.
- Threshold-based alerting.
- Actionable insights and reporting.

Future Scope:

- Integration with smart meters and IoT devices.
- AI-based prediction of consumption patterns.
- Enhanced machine learning-based recommendations.
- Multi-user household management.

VoltCare thus represents a forward-looking step in the development of accessible smart energy platforms.

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CHAPTER – 11

A NOVEL REPRESENTATION OF THE FRENET–SERRET EQUATIONS

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Abstract

This paper presents an analytical study on a modified form of the classical Frenet–Serret equations by introducing an angular parameter θ that represents the rotation of the osculating plane about the tangent vector. The study follows the formulation proposed by Anthony A. Ruffa (2007) and extends it by providing detailed derivations, interpretations, and special cases to better understand the geometric evolution of space curves [5]. The reformulated system expresses the Frenet frame solely in terms of curvature k and the angle θ, eliminating the need for direct computation of torsion τ. The proposed method provides a more stable and flexible representation for curves where torsion becomes undefined or discontinuous. The results demonstrate that the angular approach maintains equivalence with the classical formulation while offering clearer geometric insight. This paper contributes to differential geometry by refining an existing theoretical framework and simplifying the study of the twisting behaviour of space curves.

Keywords: Space Curves, Curvature, Torsion, TNB Frame, Osculating Plane, Frenet-Serret Equation.

1. Introduction

The study of space curves and their geometric properties play a central role in differential geometry. The Frenet–Serret equations describe how the

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tangent, normal, and binormal vectors of a curve evolve along its length, providing a mathematical framework for understanding bending and twisting in three-dimensional space [3-4]. These equations depend on two fundamental quantities—curvature and torsion—which characterize the local behaviour of a curve.

However, in several physical and mathematical contexts, torsion may become undefined or difficult to compute, especially for curves with complex or irregular structures. To address this challenge, Anthony A. Ruffa (2007) proposed an alternative representation of the Frenet–Serret equations by introducing an angular parameter to describe the rotation of the osculating plane around the tangent vector [5]. This parameter-based approach provides an equivalent but more flexible description of the geometry of space curves.

In this paper, the mathematical structure of Ruffa's formulation is elaborated and analysed in detail. The derivations are presented step by step to clarify the geometric meaning of each component, followed by a discussion of special cases that illustrate the effectiveness of the new representation. The aim of this study is to strengthen the conceptual understanding of curve dynamics by simplifying torsion-related computations while retaining the precision of the classical framework.

Reference Link:
https://arxiv.org/abs/0709.2855

2. Materials and Methods

The classical Frenet–Serret equations describe a space curve in terms of curvature $\varkappa$ and torsion τ, given by:

$$\frac{dT}{ds} = \kappa N \quad (1)$$

$$\frac{dN}{ds} = -\kappa T + \tau B \quad (2)$$

$$\frac{dB}{ds} = -\tau N \quad (3)$$

$$\frac{dR}{ds} = T \quad (4)$$

Here R, T, N, and B are the position, tangent, normal, and binormal vectors, respectively.

These equations do not admit general explicit solutions in terms of $\varkappa$ and τ, although certain special cases are solvable. An alternative formulation is

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introduced using the curvature ϰ and the angle θ, where θ measures the rotation of the osculating plane around the tangent vector. This angle offers a unique description corresponding to each value of τ and allows the system to be solved indirectly [1-2].

2.1. Mathematical Formulation using ϰ and θ

To express the motion of a space curve in terms of the curvature ϰ and the angular parameter θ, a local coordinate system is constructed such that the unit tangent vector T aligns with the local i'-axis (T = i'). This setup simplifies the geometric description of the curve, as the normal and binormal vectors then lie in the plane orthogonal to T.

N can be expressed in terms of angle θ and the orthonormal basis vectors j', k' within the osculating plane:

$$\mathrm{N} = \mathrm{j}' \cos\theta + \mathrm{k}' \sin\theta \tag{5}$$

To relate the local frame to the global coordinate system, we define k' as the unit vector orthogonal to the plane formed by T and the global j-axis.

$$\mathrm{k}' = \frac{T\times j}{|T\times j|} = \frac{-iT_k + kT_i}{\sqrt{1-T_j^2}} \tag{6}$$

Equation (6) breaks down when T = ±j, requiring an alternate expression for k'. However, when T ≠±j,

$$\mathrm{j}' = k' \times T = \frac{-iT_iT_j + j\left(1-T_j^2\right) - kT_jT_k}{\sqrt{1-T_j^2}} \tag{7}$$

2.2. Tangent Component Equations

Substituting (7) and (6) into (5):

$$N_i = \frac{1}{k}\frac{dT_i}{ds} = \frac{-T_k sin\theta - T_iT_j cos\theta}{\sqrt{1-T_j^2}} \tag{8}$$

$$N_j = \frac{1}{\kappa}\frac{dT_j}{ds} = \cos\theta\sqrt{1-T_j^2} \tag{9}$$

$$N_k = \frac{1}{\kappa}\frac{dT_k}{ds} = \frac{T_i \sin\theta - T_jT_k\cos\theta}{\sqrt{1-T_j^2}} \tag{10}$$

Solving these equations we get tangent components

$$\begin{aligned} T(s) &= \left(T_i(s), T_j(s), T_k(s)\right) \\ &= (cos\delta cos\beta, sin\delta, cos\delta sin\beta) \end{aligned} \tag{11}$$

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2.3. Integration Through Auxiliary Angle

To integrate the system, an auxiliary angle is defined as

$$\delta = \sin^{-1}\ T_{j_0} + \int_{s_0}^{s} \kappa \cos\theta\ d\sigma \tag{12}$$

2.4. Recovery of Torsion

Generating an expression for the torsion τ requires first computing N

$$N_i = -\cos\theta \sin\delta \cos\beta - \sin\beta \sin\theta \tag{13}$$

$$N_j = \cos\theta \cos\delta \tag{14}$$

$$N_k = -\cos\theta \sin\delta \sin\beta + \cos\beta \sin\theta \tag{15}$$

Next, B=T×N;

$$B_i = \sin\delta \sin\theta \cos\beta - \cos\theta \sin\beta \tag{16}$$

$$B_j = -\cos\delta \sin\theta \tag{17}$$

$$B_k = \sin\delta \sin\theta \sin\beta + \cos\theta \cos\beta \tag{18}$$

In the newly derived formulation, the torsion τ is expressed in terms of the angle θ and the curvature κ as:

$$\tau = \left|\frac{dB}{ds}\right| = \frac{d\theta}{ds} - \kappa \tan\delta \sin\theta \tag{19}$$

The equation (19) can be written as

$$\tau = \frac{d\theta}{ds} + \kappa \frac{T_j B_j}{1-T_j^2} \tag{20}$$

Finally, The Frenet-Serret Equations for $\frac{dN}{ds}$ provides a consistency check for the derived expressions of T, N, B and τ.

2.5. Reconstructing the Angular Parameter from Torsion

Integrating (20) leads to the following expression for θ:

$$\theta = \theta_0 + \int_{s_0}^{s} \left(\tau - \frac{\kappa T_j B_j}{1-T_j^2}\right) d\sigma \tag{21}$$

Equation (21) indicates a unique value of θ for each specified value of τ when Tj≠ ±1.

Then angle θ can also be expressed in terms of components of T , N , B:

$$\therefore \theta = -\sin^{-1}\left(\frac{B_j}{\sqrt{1-T_j^2}}\right) = \cos^{-1}\left(\frac{N_j}{\sqrt{1-T_j^2}}\right) = -\tan^{-1}\left(\frac{B_j}{N_j}\right) \tag{22}$$

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3. Results and Discussion

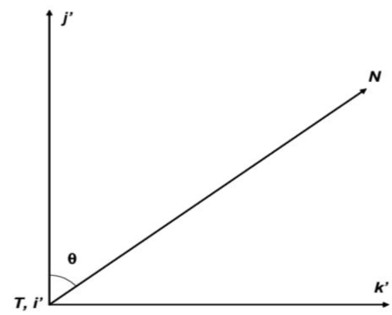

Figure 1. Local coordinate system T is normal to the plane containing j' & k'

Figure 1 illustrates the local coordinate system, where the unit tangent vector T is normal to the plane spanned by the orthonormal basis vectors j' and k'. The principal normal vector N is then represented in this plane by the angle θ, leading to a new formulation of the Frenet Frame.

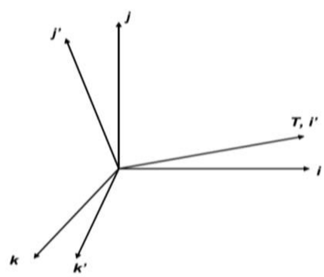

Figure 2. Angular orientation of the local coordinate system with respect to the global coordinate system.

To relate the local frame to the global coordinate system, we define k' as the unit vector (Figure 2) orthogonal to the plane formed by T and the global j-axis.

3.1. Case I: Constant θ

An explicit solution often results when θ is constant. Setting $T_{i_0} = 1$, so that $\beta_0 = \delta_0 = 0$
(and setting $s_0 = 0$) leads to

$$\delta = \int_0^s \kappa(\sigma) \cos\theta_0 \, d\sigma \qquad (23)$$

$$\beta = 2 \tan\theta_0 \tanh^{-1}\left(\tan \frac{\delta}{2}\right) \qquad (24)$$

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So that

$$T_i = \cos\left[2\tan\theta_0 \tanh^{-1}\left(\tan \ \frac{\delta}{2}\right)\right]\cos\left(\int_0^s \kappa(\sigma)\cos\theta_0 \, d\sigma\right) \tag{25}$$

$$T_j = \sin\left(\int_0^s \kappa(\sigma)\cos\theta_0 \ \ d\sigma\right) \tag{26}$$

$$T_k = \sin\left[2\tan\theta_0 \tanh^{-1}\left(\tan \ \frac{\delta}{2}\right)\right]\cos\left(\int_0^s \kappa(\sigma)\cos\theta_0 \ \ d\sigma\right) \tag{27}$$

The torsion becomes

$$\tau(s) = -\kappa(s)\sin\theta_0 \tan\left(\int_0^s \kappa(\sigma)\cos\theta_0 \ \ d\sigma\right) \tag{28}$$

3.2. Case II: Constant ϰ

When $\kappa = \kappa_0$ but $\theta \neq \theta_0$, the solution will typically involve undetermined integrals.

3.3. Case III: Constant ϰ and θ

When $\kappa = \kappa_0$ but $\theta == \theta_0$,

$$T_i = \cos(\kappa_0 s\cos\theta_0)\cos\left[2\tan\theta_0 \tanh^{-1}\left(\tan\left(\frac{\kappa_0 s}{2}\cos\theta_0\right)\right)\right] \tag{29}$$

$$T_j = \sin(\kappa_0 s\cos\theta_0) \tag{30}$$

$$T_k = \cos(\kappa_0 s\cos\theta_0)\sin\left[2\tan\theta_0 \tanh^{-1}\left(\tan\left(\frac{\kappa_0 s}{2}\cos\theta_0\right)\right)\right] \tag{31}$$

$$\tau(s) = -\kappa_0 \sin\theta_0 \tan(\kappa_0 s\cos\theta_0) \tag{32}$$

When $\theta_0 = \pi/2, \tau(s) = 0$, confining T and N to a plane. When T aligns with j, $\tau \to \infty$ in (32), and the equation breaks down.

3.4. Alternate Set of Equations

The equations break down when $Tj \to \pm 1$, requiring a different orientation for the local coordinate system. The angle of rotation of the osculating plane is designated ϕ here. In general, ϕ≠ θ, reflecting differences in angular orientation between the local and global coordinate systems for the two cases.

Defining k' as the normal to the plane containing T and i, i.e.,

$$k' = \frac{i\times T}{|i\times T|} = \frac{-jT_k + kT_j}{\sqrt{1-T_i^2}} \tag{33}$$

The j' unit vector becomes

$$j' = k' \times T = \frac{-i(1-T_i^2) + jT_iT_j + kT_iT_k}{\sqrt{1-T_i^2}} \tag{34}$$

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Substituting into the expression for N :

$$N_i = \frac{1}{\kappa}\frac{dT_i}{ds} = -\cos\phi\sqrt{1-T_i^2} \quad (35)$$

$$N_j = \frac{1}{\kappa}\frac{dT_j}{ds} = \frac{-T_k\sin\phi + T_iT_j\cos\phi}{\sqrt{1-T_i^2}} \quad (36)$$

$$N_k = \frac{1}{\kappa}\frac{dT_k}{ds} = \frac{T_j\sin\phi + T_iT_k\cos\phi}{\sqrt{1-T_i^2}} \quad (37)$$

Equations (35)–(37) have the following solution:

$$T_i = \sin\gamma \quad (38)$$

$$T_j = \cos\gamma\cos\alpha \quad (39)$$

$$T_k = \cos\gamma\sin\alpha \quad (40)$$

$$N_i = -\cos\gamma\cos\phi \quad (41)$$

$$N_j = \sin\gamma\cos\alpha\cos\phi - \sin\alpha\sin\phi \quad (42)$$

$$N_k = \sin\gamma\sin\alpha\cos\phi + \cos\alpha\sin\phi \quad (43)$$

$$B_i = \cos\gamma\sin\phi \quad (44)$$

$$B_j = \sin\gamma\cos\alpha\sin\phi + \sin\alpha\cos\phi \quad (45)$$

$$B_k = -\sin\gamma\sin\alpha\sin\phi + \cos\alpha\cos\phi \quad (46)$$

$$\tau = \frac{d\phi}{ds} - \kappa\tan\gamma\sin\phi = \frac{d\phi}{ds} - \frac{\kappa B_iT_i}{1-T_i^2} \quad (47)$$

Hence,

$$\gamma = \sin^{-1}\ T_{i_0} - \int_{s_0}^{s}\kappa\cos\phi\ d\sigma \quad (48)$$

$$\alpha = \cos^{-1}\left(\frac{T_j}{\cos\gamma}\right) = \alpha_0 + \int_{s_0}^{s}\frac{\kappa\sin\phi}{\cos\gamma}\ d\sigma \quad (49)$$

$$T_j = T_{j_0}\frac{\cos\gamma}{\cos\gamma_0}\cos\left(\int_{s_0}^{s}\frac{\kappa\sin\phi}{\cos\gamma}\ d\sigma\right) - T_{k_0}\frac{\cos\gamma}{\cos\gamma_0}\sin\left(\int_{s_0}^{s}\frac{\kappa\sin\phi}{\cos\gamma}\ d\sigma\right) \quad (50)$$

$$\phi = -\tan^{-1}\left(\frac{B_i}{N_i}\right) \quad (51)$$

Even though θ and ϕ both represent the angle of rotation of the osculating plane, (22) and (51) differ because of differences in angular orientation of the local coordinate system. When Tj → ±1 or Ti → ±1, switching from one set of equations to another avoids numerical difficulties.

Conclusion

The modified representation of the Frenet–Serret equations using the angular parameter provides an effective and intuitive framework for studying

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the geometry of space curves. Through this formulation, torsion is expressed indirectly, eliminating the need for its explicit computation and reducing analytical complexity. The derivations confirm that the angular parameter can fully describe the rotation of the osculating plane while preserving the geometric consistency of the classical Frenet–Serret system.

The analysis of special cases demonstrates that this formulation accommodates both planar and spatial curves, including helices, and remains valid even when the traditional torsion becomes undefined. By linking curvature and angular rotation, the θ-based representation not only simplifies computations but also enhances geometric interpretation.

This work contributes to a deeper understanding of curve dynamics and offers a mathematically stable foundation for further studies. Future research may explore the extension of this approach to motion planning, robotics, or surface modelling, where controlling curvature and angular rotation plays a significant role.

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