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Smart Cement Behavior with Aggregates, Silicate, Clay, Carbon Dioxide and Real-Time Monitoring Characterized Using Vipulanandan Models

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Abstract:
Chemo-thermo-piezoresistive smart cement is a highly sensing binder that was recently developed to be used in multiple infrastructure applications in new constructions and also integrated into in-service infrastructures for real-time monitoring. In this study, the effects of up to 75% aggregates (representing concrete), 0.3% silicate, 5% clay (inorganic contamination) and 3% carbon dioxide (CO2) on the curing and compressive piezoresistive behavior of the smart cement with less and 0.1% well dispersed carbon fibers was investigated. Also, the effect of temperature on the smart cement with silicate additive was investigated. A new material characterization method has been developed and was used to identify the critical electrical property of the smart cement with aggregates and other additives and the electrical resistivity was identified as the critical property to monitor. Hence a two-probe method was developed to monitor the resistivity changes in the cement. The piezoresistive axial strain at peak stress for the concrete with smart cement was over hundred percent which is 336 times (33,600%) higher compared to the concrete failure strain of 0.3%. The effects of silicate, clay and carbon dioxide on the initial resistivity (quality of mixing), temperature and compressive piezoresistivity have been quantified using Vipulanandan Models. It is important to monitor the real material property changes in the field and not just the temperature which is not a material property. A new approach has been developed to wirelessly transfer the two probes monitoring of the changes in resistivity of smart cement, smart concrete, regular cement and concrete to the phone and computers.

Keywords: Smart Cement, Smart Concrete, Electrical Impedance, Curing, Compressive Piezoresistivity, Vipulanandan Models

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1. INTRODUCTION

Cement is an inorganic binding material and has evolved over 5,000 years from natural materials to industrial production with changes in the chemical compositions and the particle size distributions. Natural cement made from limestone containing clay minerals was continued to be used until the nineteenth century. When water is added to the cement, the cement will react with the water and bind with many types of inorganic materials to form durable composites for various types of applications. Historically cement is the most valuable material developed by humans to enhance the growth and developments around the world. Initially cement was used in the building of Egyptian pyramids. Also around 300 BC, Romans used cement with various types of admixtures to construct many types of buildings. The main focus over centuries has been on developing stronger and durable cements. In 1824, Portland cement was invented by Joseph Aspdin from Leeds, England. In the 1850s Vicat from France developed the Vicat needle method to determine the setting time of cement and this method is still being used. In America, the production of natural cements reached its peak in the 1890s, only to be overtaken by the Portland cement production. Now there are standards set for various types of Portland cements and oil well cements to ensure quality of production and also help with the multiple applications for cement. Cement is the largest manufactured material around the world and in recent years over 4 trillion Mega grams are being manufactured annually.

During the past 200 years cement and concrete have been widely used in many applications and has been well documented. Cement slurries and grouts, based on the water-to-cement ratio, have been used in the construction of shallow and deep oil, gas and water wells both onshore and offshore. Also cement slurries are used to bond the pipes to the formation in horizontal directional drilling. Cement slurries are used to bond the steel casings and pipes to the varying geological formations in the wellbore and also to isolate the formations. In the well application cement has to

bond very well with the highly varying natural geological formations with depth and to the human made steel casing and pipes and also has to perform for many decades under varying loading conditions, temperatures, pressures and seismic activities. Hence it is important to monitor the performance of the cement from the time of mixing to the entire service life in-situ (Vipulanandan 2021).

1.1 Cements

Cement is manufactured by combining clay or shale (aluminum silicate) with limestone (calcium based) and processed around 1450^0C or higher temperatures to produce the calcium silicate clinkers. At present cements are broadly characterized based on the applications as Portland cements and oil well cements.

1.1.1 Portland Cement

The first American Society for Testing and Materials (ASTM) Portland Cement standard was developed in 1940. Now the ASTM C150/C150M-19 covers ten types of Portland cements based on the applications and compositions. Type I is the general-purpose cement used for construction purposes and together with Type II, accounts for about 92% of the United States produced cement. Type III only accounts for about 3.5% of cement production, while Type IV is only available on special request and Type V is difficult to obtain because of less than 0.5% of production.

1.1.2 Oil Well Cement (OWC)

When used in oil wells, the cement has multiple functions which includes structural integrity, protective seal to the casing, preventing blowout and to promote zonal isolation. Portland cement was used in the oil well construction in 1906. In 1948, American petroleum Institute (API) developed the first code for testing cement. The standards of API suggest adopting the chemical requirements determined by the ASTM procedures and physical requirements determined in accordance with procedures outlined in API RP 10B and ASTM. Based on the API classification, currently there are six classes of cements (classes A, B, C, D, G and H) which could be used for oil well cementing based on the depths and downhole pressures and temperatures.

Cement slurry flowing ability (rheology) and stability are two of the major requirements of oil well cementing. Oil-well cements (OWCs) are usually made from Portland cement clinker or from blended hydraulic cements. OWCs are classified into grades by the API based upon there $Ca_3Al_nO_p$ (Tricalcium Aluminate – C_3A) content as Ordinary (O), Moderate Sulphate Resistant (MSR), and High Sulphate Resistant (HSR). Each class is applicable for a certain range of well depth, temperature, pressure, and sulphate environments.

1.2 Smart Cement

It is important to make the cement highly sensing to monitor the changes in the stresses, cracking, temperature, erosion and also contamination during its service life. Chemo-thermo-piezoresistive smart cement using Portland cement and oil well cement have been recently developed (U.S. Patent 10,481,143 (2019) Inventor Vipulanandan) which can sense and real-time monitor the many changes happening inside the cement during cementing of wells to concreting of various infrastructure to the entire service life of the structures. In concrete smart cement is the binder which can sense the changes within the concrete. The smart cement can sense the changes in the water-to-cement ratios, different additives, contamination and pressure applied to the cement sheath or concrete in terms of chemo-thermo-piezoresistivity. The failure compressive strain for the smart cement was 0.2% at peak compressive stress and the resistivity change is of the order of several hundred percentage making it over 500 times (50,000%) more sensitive (Vipulanandan et al. 2014-2021).

1.2.1 Piezoresistive Behavior

The change of electrical resistance in metal devices due to an applied mechanical load was first discovered in 1856 by Lord Kelvin. With single crystal silicon becoming the material of choice for the design of analog and digital circuits, the large piezoresistive effect in silicon and germanium was first discovered in 1954 (Smith 1954).

Usually, the resistance change in metals is mostly due to the change of geometry resulting from applied mechanical stresses. However, even though the piezoresistive effect is small in those cases it is often not negligible. Strain gages are good example of a piezoresistive material where with the application of strain to the attached material the electrical resistance will change in the strain gages because how the metal strain gages are configured. Also in the strain gages the resistance change will be positive under tensile stress or strain and negative under compressive stress or strain. In the past few decades various investigations have been performed to make the polymers and cement composites to be piezoresistive (Chung et al. 1995, 2000 and 2001; Vipulanandan et al. 2002, 2005-2008). In the recently developed smart cement by Vipulanandan (U.S. Patent Number 10,481,143 (2019)) the resistivity change is positive under both tensile and compressive loading because the changes are dominated by the deviatoric (shear) stresses in the cement (Vipulanandan et al. 2014-2021).

1.2.2 Thermo-resistive Behavior

In the sensing element electrical resistance will change due to temperature change in the operating temperature ranges. In 1871, platinum was proposed by Sir William Siemens to be the most suitable material (Siemens, 1871). Also nickel and copper have been developed to temperature sensors due to measurable changes in electrical resistance. Recently develop smart cement by Vipulanandan also can be used to sense the temperature changes due to measureable changes in electrical resistivity (Vipulanandan et al. 2014b).

1.2.3 Chemo-resistive Behavior

Chemo-resistive materials are a class of sensors that changes in electrical resistance in response to the changes in the surrounding chemical environment. Materials such as metal oxide semiconductors, conductive polymers and nano materials like graphene, carbon nanotubes and nanoparticles. As far back as 1965, there are reports on semiconductor materials exhibiting electrical resistivity changes due to ambient gases and vapors. In 1985, Wohltjen and Snow developed a copper compound to detect ammonia vapor at

room temperature and the resistivity decreased (Wohltjen et al. 1985). Recently develop smart cement by Vipulanandan also can be used to sense the chemical additives and contaminations based on the changes in the electrical resistivity (Vipulanandan et al.2014b, 2018k).

1.3 Behavior Models

It is important to have behavior models for cements and concretes to not only clearly understand the behavior but also to integrate it with the artificial intelligent (AI) networks and 3D printing applications. The past models developed for cement hydration and cement behavior under various loading conditions are empirical and limited to the ranges of variables investigated in the relevant studies. In concrete, cement is the binder that develops the strength and other relevant properties for the concrete. But the behavior models do not quantify the role of cement in the concrete. Recently a new Vipulanandan rheological models has been developed to better characterize the rheological behavior of the smart cement slurry, drilling muds, spacer fluids and other fluids with and without various additives including nanoparticles (Afolabi et al. 2019; Tchameni, et al. 2019; Montes 2019; Mohammed 2018; Vipulanandan et al. 2014a). Also, analytical models have been developed to characterize the curing, stress-strain and piezoresistive behaviors of the smart cement (Vipulanandan et al., 1990-2021). The Vipulanandan fluid flow model (generalized Darcy's model) and fluid loss model have been developed and verified with experimental results. Also new Vipulanandan failure model for cement and concrete has been developed and verified with experimental test results.

2. OBJECTIVE

The overall objective was to highlight the potential use of the highly sensing smart cement integrated with real-time monitoring in new and also in-service infrastructures. The specific objectives are as follows:

1) Evaluate the smart cement curing and compressive piezoresistive behaviour with aggregates, silicate, clay contamination and carbon dioxide
2) Develop real-time monitoring applications in new constructions including concrete based constructions, deep oil wells, deep foundations and other infrastructures.
3) Developing real-time monitoring methods to integrate the smart cement blocks into in-service infrastructures.

3. MATERIALS AND METHODS

In this study chemo-thermo-piezoresistive smart cement (Vipulanandan et al. 2014-2021; Vipulanandan 2021) was used to develop the concrete (aggregates) and also smart cement with few selected additives. For the curing and compressive behavior studies samples were cast in plastic cylindrical molds with diameter of 50 mm and a height of 100 mm. Two conductive wires were placed in all of the molds to measure the changing in electrical resistivity. At least three specimens were tested under each condition investigated in this study.

3.1 Materials

3.1.1 Sample Preparation

In this study table top blenders were used to prepare the cement and concrete specimens (CIGMAT Standards 2002-2006).

Smart cement (sensing cement):
Cement was mixed with 0.1% carbon fibers to make it piezoresistive material (Vipulanandan et al., 2014a, b; 2015a, b).

Smart Cement Concrete
Smart cement concrete specimens were prepared using smart cement (less than 0.1% carbon fibers) with water-cement ratio of 0.38 (Vipulanandan et al. 2018c). Concrete specimens were prepared using 75% coarse aggregates based on the total volume of concrete. Sieve analysis (ASTM C136) was performed to determine the particle size distribution of the aggregates. The median diameter, which also represents d_{50} (ASTM) the size of 50% of the aggregates was less than 4.2 mm. After mixing, the concrete was placed in 100 mm height and 50 mm diameter cylindrical molds with two conductive flexible wires 1 mm in diameter (representing the probes) were placed 50 mm apart vertically to measure the electrical resistance. The specimens were cured up to 28 days under relative humidity of 90%. At least three specimens were test under each condition and the average values are presented in the figures, tables and discussion.

Smart Cement with Additives
After preparing the smart cement different additives were added in varying amounts and mixed for at least 3 minutes before placing them in the wired molds. At least three specimens were test under each condition and the average values are presented in the figures, tables and discussion.

3.2 Methods

3.2.1 Electrical Resistivity

Two different devices were used to measure the changes in the electrical resistivity of concrete and grout immediately after mixing up to the time they solidify. Both of the electrical resistivity devices were calibrated using the standard solutions of sodium chloride (NaCl).

Conductivity Probe
A commercially available conductivity meter was used to measure the conductivity (inverse of electrical resistivity). The conductivity measuring range was from 0.1μS/cm to 1000 mS/cm, representing a resistivity of 100,000 Ω.m. to 0.01 Ω.m. respectively.

Digital Resistivity Meter:
The digital resistivity meter measured the resistivity in the range of 0.01Ω-m to 400 Ω-m.

3.2.2 Electrical Resistance

LCR meter (inductance (L), capacitance (C), and resistance (R)) was used to monitor the electrical resistance of the specimens during the curing time. Two wire method with AC at 300 kHz frequency was used in order to minimize the contact resistances (Vipulanandan et al. 2013). During the initial stage of curing both the electrical resistivity (ϱ)

electrical resistance (R) were measured to determine the parameters K and G based on the Eqn.1.

$$\rho = \frac{R}{K+GR} \quad (1)$$

In this study, electrical resistance (R) and electrical resistivity (ρ) were measured independently during the initial curing period and the effective calibration factors (K and G) for the materials used in this study (insulators) were determined experimentally. For the smart cement and concrete Parameter G = 0 and Parameter K became stable (constant) in two to three hours. The Parameter K was more than double than the nominal Parameter K_n equal L/A where L is the spacing between the measuring wires and A is the cross section for the specimens tested.

Normalized change in resistivity $\Delta\rho$ with the changing conditions can be represented as follows:

$$\frac{\Delta\rho}{\rho} = \frac{\Delta R}{R} \quad (2)$$

The smart cement material is represented in terms of resistivity (ϱ) and the changes due to stress, temperature and added additive and contaminants will be quantified to evaluate the sensitivity of the material parameter resistivity.

Two Wire Method

The change in resistance was measured using the two probe method with the LCR meter. To minimize the contact resistances, the resistance was measured at 300 kHz using two-wire method. This configuration was first calibrated using the same liquid (cement slurry) to determine the parameter K in Eqn. (1).

3.2.3 Compression Test (ASTM C39)

The cylindrical specimens (concrete, cement and grout) were capped and tested at a predetermined controlled displacement rate. Tests were performed using the Tinious Olsun machine at a controlling the displacement rate to 0.125 mm per minute (CIGMAT 2002). In order to measure the strain, a commercially available extensometer (accuracy of 0.001% strain) was used. During the compression test, the change in resistance was measured continuously using the LCR meter. Two probes method with alternative current (AC) at 300 kHz frequency was used in order to minimize the contact resistances (Vipulanandan and Amani, 2018c). The change in resistance was monitored using the two-probe method, and the parameter in Eqn. (2) was used relate the changes in resistivity to the applied stress.

3.2.4 Modeling

Vipulanandan Curing Model

In order to represent the electrical resistivity development of the cement, Vipulanandan Curing model was used (Vipulanandan and Mohammed, 2015) and the relationship is as follows:

$$\frac{1}{\rho} = \frac{1}{\rho_{min}}\left[\frac{\left(\frac{t+t_0}{t_{min}+t_0}\right)}{q_1+(1-p_1-q_1)\left(\frac{t+t_0}{t_{min}+t_0}\right)+p_1\left(\frac{t+t_0}{t_{min}+t_0}\right)^{\left(\frac{p_1+q_1}{p_1}\right)}}\right] \quad (3)$$

Where ρ is the electrical resistivity in Ω.m, ρ_{min} is the minimum electrical resistivity in Ω.m, t_{min} is the time corresponding to the minimum electrical resistivity (ρ_{min}), t represents the curing time, t_0 is the model parameter influenced by the initial resistivity and p_1 and q_1 are time-dependent model parameters.

Vipulanandan Piezoresistivity Model

In order to represent the piezoresistive behavior of the hardened cement, Vipulanandan Piezoresistivity Model (Vipulanandan et al., 2015, 2016) was used and the relationship is as follows:

$$\sigma = \frac{\sigma_{max}\times\left(\frac{\left(\frac{\Delta\rho}{\rho}\right)}{\left(\frac{\Delta\rho}{\rho}\right)_0}\right)}{q_2+(1-p_2-q_2)\times\left(\frac{\left(\frac{\Delta\rho}{\rho}\right)}{\left(\frac{\Delta\rho}{\rho}\right)_0}\right)+p_2\times\left(\frac{\left(\frac{\Delta\rho}{\rho}\right)}{\left(\frac{\Delta\rho}{\rho}\right)_0}\right)^{\left(\frac{p_2+q_2}{p_2}\right)}} \quad (4)$$

Where σ_{max} is the maximum stress, $(\Delta\rho/\rho)_0$ is the piezoresistivity of the hardened cement under the maximum stress and p_2 and q_2 are model parameters influenced by the material properties.

3.2.5 Material Characterization

It is important to first characterize the materials based on the electrical properties, which can be easily adopted in the field.

Vipulanandan Impedance Model

Vipulanandan et al. (2013) studied different possible equivalent circuits for composite materials with two probes measurement and found appropriate equivalent circuits to represent materials.

CASE 1: General Bulk Material – Capacitance and Resistance

In the equivalent circuit for Case1, the contacts were connected in series, and both the contacts and the bulk material were represented using a capacitor and a resistor connected in parallel. In the equivalent circuit for CASE 1, R_b and C_b are resistance and capacitance of the bulk material, respectively; and R_c and C_c are resistance and capacitance of the contacts, respectively. Both contacts are represented with the same resistance (R_c) and capacitance (C_c), as they are identical. Total impedance of the equivalent circuit for Case 1 (Z_1) can be represented as:

$$Z_1(\sigma) = \frac{R_b(\sigma)}{1+\omega^2R_b^2C_b^2} + \frac{2R_c(\sigma)}{1+\omega^2R_c^2C_c^2} - j\left\{\frac{2\omega R_c^2C_c(\sigma)}{1+\omega^2R_c^2C_c^2} + \frac{\omega R_b^2C_b(\sigma)}{1+\omega^2R_b^2C_b^2}\right\} \quad (5)$$

where ω is the angular frequency of the applied signal. When the frequency of the applied signal is very low, $\omega \rightarrow 0$, $Z_1 = R_b + 2R_c$, and when it is very high, $\omega \rightarrow \infty$, $Z_1 = 0$.

CASE 2: Special Bulk Material - Resistance Only

CASE 2 is a special case of CASE 1 in which the capacitance of the bulk material (C_b) is assumed to be negligible. The total impedance of the equivalent circuit for Case 2 (Z_2) is

$$Z_2(\sigma) = R_b(\sigma) + \frac{2R_c(\sigma)}{1+\omega^2 R_c^2 C_c^2} - j\frac{2\omega R_c^2 C_c(\sigma)}{1+\omega^2 R_c^2 C_c^2}. \quad (6)$$

When the frequency of the applied signal is very low, $\omega \rightarrow 0$, $Z_2 = R_b + 2R_c$, and when it is very high, $\omega \rightarrow \infty$, $Z_2 = R_b$ (Fig. 1).

The shape of the curves shown in Figure 1 is very much influenced by the material response and the two probes used for monitoring. Testing of smart cement and concrete indicated that CASE 2 represented their behaviors and hence the bulk material properties can be represented by resistivity and characterized at a frequency of 300 kHz using the two probes.

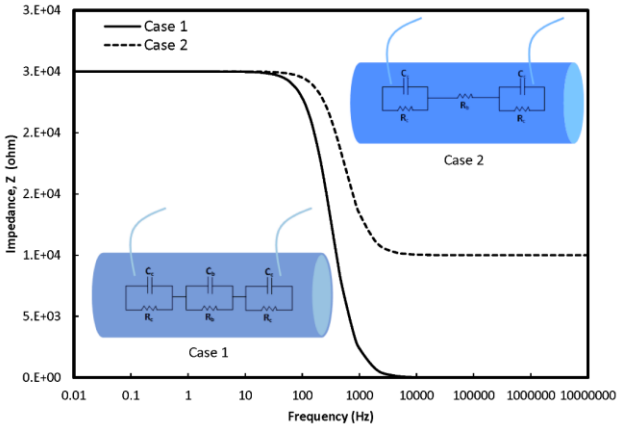

Figure 1. Vipulanandan impedance-frequency models for composite materials

It is important to identify the type of the testing material (example: metal, cement, concrete, plastic, wood, asphalt) so that the relevant material property can be measured and monitored in the field. Based on the past experience and research, changes in electrical properties were selected to be the representative properties for the cement and other materials so that it can be used for monitoring in multiple applications. Electrical properties of a material can be represented by the permittivity, resistivity or a combination being in number of series or parallel electrical circuits.

3.2.6 Statistical Parameters for Model Predictions

In order to determine the accuracy of the model predictions, both the root mean square error (RMSE) and the coefficient of determination (R^2) in curve fitting are defined in Eqns. (7) and Eqns. (8) as follows:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - x_i)^2}{N}} \quad (7)$$

$$R^2 = \left(\frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2} * \sqrt{\sum_i (y_i - \bar{y})^2}}\right)^2 \quad (8)$$

where y_i = actual value; x_i =calculated value from the model; $\bar{y}$ =mean of the actual values; $\bar{x}$= mean of the calculated values and N is the number of data points.

4. RESULTS AND ANALYSES - MATERIAL CHARACTERIZATION

4.1 Effect of Aggregates

4.1.1. Impedance Vs Frequency Relations

Investigation of the impedance versus frequency relationship tested immediately after mixing and also after 28 days of curing for the smart cement and smart cement concrete (75% aggregates) is shown in Figures 2 and 3. The observed shape of the curve represents the CASE 2, indicating that the bulk material can be represented by resistance. This has been verified for over 5 years.

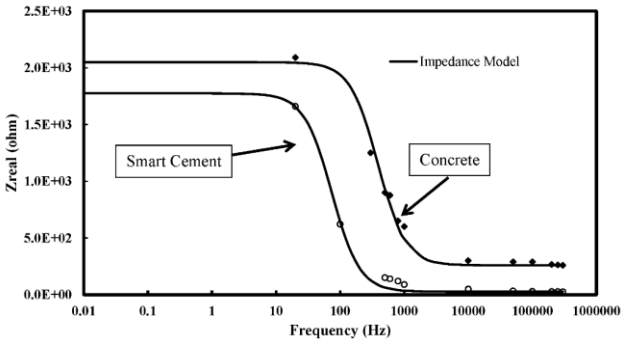

Figure 2. Impedance - Frequency Characterization of the Smart Cement and Concrete Immediately after Mixing

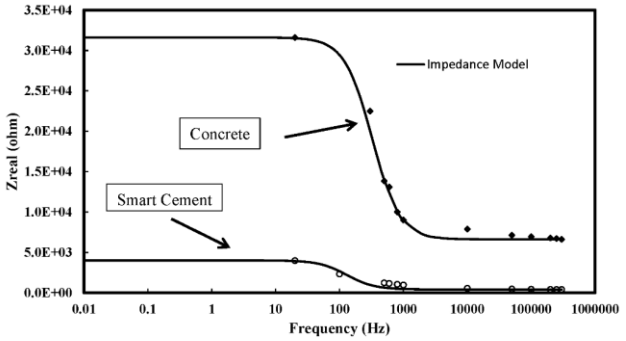

Figure 3. Impedance - Frequency Characterization of the Smart Cement and Concrete after 28 Days of Curing

Initial resistivity

Initial electrical resistivity increased with the addition of aggregates.

(a) Smart Cement:

The average initial electrical resistivity of the smart cement was 1.02 Ω.m.

(b) Smart Cement Concrete (with aggregate):

75% Gravel: The average initial electrical resistivity of the smart cement concrete with 75% gravel increased by 267% to 3.74 Ω.m. This increment was due to gravel content in the concrete.

4.1.2 Resistivity during curing

From the standpoint of conductivity, concrete can be regarded as a two-component composite material, pore solution and solid phase (aggregate + hydration products + unhydrated binders). During the setting of the cement, the capillary porosity is constant and changes in the pore solution resistivity leads to determine the evolution of the slurry resistivity. As shown in Figure 4, the pore resistivity decreased initially and reached a minimum resistivity of ρ_{min} at specific time of t_{min} which is due to increment of ionic concentration in pore solution. By preceding the hydration, production of Calcium Silicate Hydrate (C-S-H) network caused the increment in the paste resistivity (Zhang et al., 2010; Vipulanandan et al. 2015-2021).

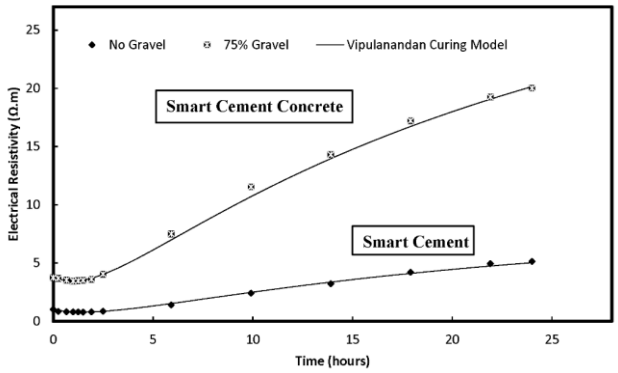

Figure 4. Development of electrical resistivity of smart cement composites during the initial 24 hours of curing

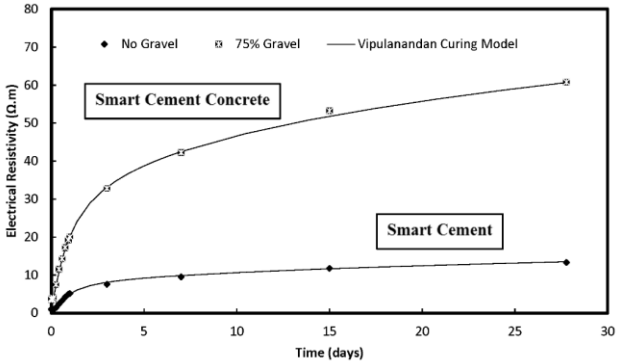

Figure 5. Development of electrical resistivity of smart cement composites during 28 days of curing

1 Day Curing

(a) Smart Cement:

The minimum electrical resistivity of the smart cement after 90 minutes of mixing was 0.79 Ω.m (Table 1, Figure 4).

(b) Smart Cement Concrete:

75% Gravel: The minimum electrical resistivity of the 75% gravel smart cement concrete increased by 339% to 3.46 Ω.m. The time corresponds to the minimum resistivity of 75% gravel smart cement concrete reduced by 30 minutes to 60 minutes compare to the smart cement.

28 Days Curing

(a) Smart Cement:

After 28 days of curing, the electrical resistivity of smart cement was 14.14 Ω.m. (Fig. 5).

(b) Smart Cement Concrete:

75% Gravel*:* After 28 days of curing the electrical resistivity of 75% gravel smart cement composite increased by 333% to 61.24 Ω.m.

4.1.3 Compressive Behavior

4.1.3.1 Compressive Strength

Compressive strength of smart cement and smart concrete were tested after 1 and 28 days of curing are summarized in Table 2.

1 day curing

(a) Smart Cement*:*

After 1 day of curing, the compressive strength of the smart cement was 8.6 MPa.

(b) Smart Cement Concrete:

75% Gravel*:* The compressive strength of the 75% gravel smart composite decreased by 29% to 6.1 MPa compare to the smart cement with no gravel.

28 days curing

(a) Smart Cement*:*

After 28 days of curing, the compressive strength of the smart cement was 21.7 MPa.

(b) Smart Cement Concrete:

75% Gravel*:* The compressive strength of the 75% gravel concrete decreased by 43% to 12.4 MPa compare to the smart cement with no gravel. Changes in compressive strength of the concrete can be justified with the percentage of cement in the concrete.

Table 1. Electrical resistivity parameters of the smart cement composites slurries

Smart Cement Concrete (by volume)	ρ_0 (Ω.m)	ρ_{min} (Ω.m)	$tmin$ (minutes)	ρ_{24} (Ω.m)	$\frac{\rho_{24}-\rho_{min}}{\rho_{min}}$ %
No Gravel	1.02	0.79	90	5.14	550%
75% Gravel	3.74	3.46	60	20.01	478%

Table 2. Model parameters of p-q model for evaluating the piezoresistivity behavior of the concrete

Smart Cement Concrete	p_2	q_2	R^2	Compressive Strength (MPa)	Ultimate Piezoresistivity (%)	RMSE (MPa)
1 Day Curing						
No Gravel	0.61	0.57	0.99	8.6	375	0.3
75% Gravel	0.40	0.80	0.99	6.1	163	0.3
28 Days Curing						
No Gravel	0.83	0.42	0.98	21.7	204	1.0
75% Gravel	0.81	0.40	0.99	12.4	101	0.4

4.1.3.2 Piezoresistivity

Piezoresistive behavior of smart cement and smart cement concrete was evaluated after 1 day and 28 days of curing as shown in Figure 6.

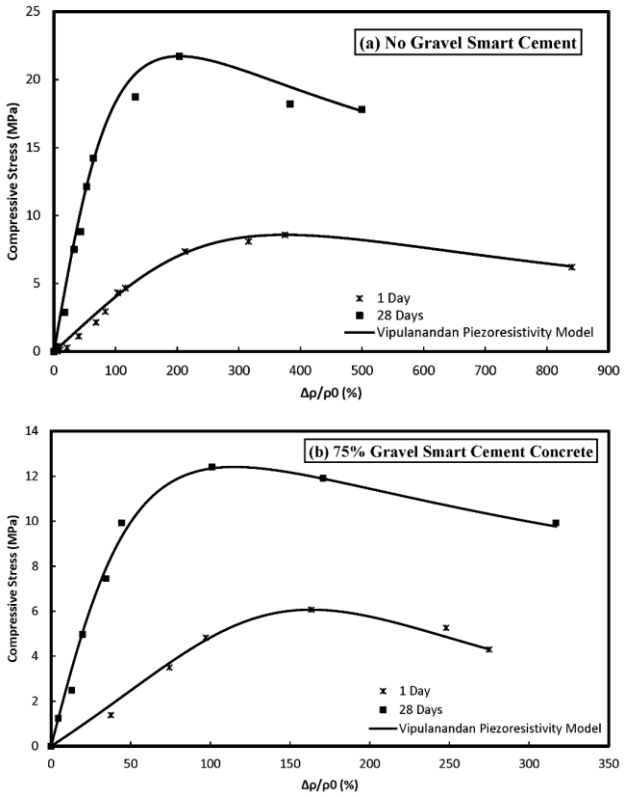

Figure 6. Piezoresistivity of smart cement composites after 1 and 28 days of curing: (a) No gravel and (b) 75% Gravel

1 day curing

(a) Smart Cement:

After 1 day of curing, the piezoresistivity of the smart cement at the peak compressive stress was 375% (Fig. 6. Table 2). Parameters p_2 and q_2 for the model were 0.61 and 0.57 respectively.

(b) Smart Cement Concrete*:*

75% Gravel*:* The piezoresistivity of the 75% gravel smart composite reduced by 57% to 163% compare to the smart cement. Parameters p_2 and q_2 for the model were 0.40 and 0.80 respectively.

28 days curing

(a) Smart Cement*:*

After 28 days of curing, the piezoresistivity of the smart cement was 204%. Parameters p_2 and q_2 for the model were 0.83 and 0.42 respectively.

(b) Smart Cement Concrete:

75% Gravel: The piezoresistivity of the 75% gravel smart composite reduced by 51% to 101% compare to the smart cement. Parameters p_2 and q_2 for the model were 0.81 and 0.40 respectively.

4.2 Effect of Sodium Meta Silicate (SMS)

Based on the applications and the environments, all types of standard cements are modified with various types of inorganic and organic additives (Vipulanandan et al. 1992, 2012 - 2021). Also during construction and service life of the structures constructed using cement based materials, contamination is also a possibility and hence investigating the sensitivity of smart cement to detect chemical, temperature and stress changes for real-time monitoring must be investigated. To minimize the delays during construction, failures and also safety issues, it is important to quantify the changes in the chemo-thermo-piezoresistive cement.

From the initial use in the late 1800's sodium silicate based compounds have been used in a number of applications including cementing, grouting, emulsifying, and in cleaning agents (Mbaba et al 1983). Of the various forms of sodium silicate based compounds, sodium meta-silicates (anhydrous) have been used in oil and gas industry and infrastructure repairing applications. Sodium meta-silicate (Na_2SiO_3; SMS) is a water-soluble powder, which is produced by fusing the silica sand with sodium carbonate at 1400°C (Nelson, 1990). Because of its emulsification and interfacial tension reduction characteristics, SMS has been used in alkaline flooding, a chemical recovery method to recover oil from various types of geological formations and sand. The overall objective of the study was to investigate the effects of adding varying amounts of SMS and higher temperature (80°C/176°F) curing on the piezoresistive behaviour of the smart cement with and without SMS.

4.2.1 Curing Methods

4.2.1.1 Room Condition

Specimens were cured in the plastic molds at room temperature (23°C) and a relative humidity of 50% and the specimens were demolded just before testing.

(b) Oven Cured

Specimens were kept in the plastic mold and cured in the oven at elevated temperature. Also specimens were placed in saturated sand in the closed bottle (Figure 7) to simulate the field condition under water and groundwater and cured at room temperature and elevated temperatures and were demolded just before testing.

Also, water was added regularly to keep the sand saturated.

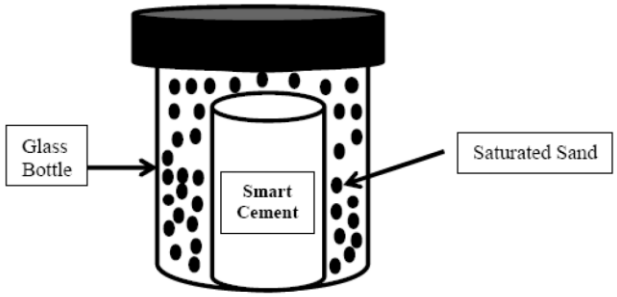

Figure 7. Curing of Smart Cement Under Saturated Sand

4.2.2 Testing

Sodium meta-silicate (SMS) solution was characterized by determining the pH and the resistivity of the water solutions. With the addition of 0.1% SMS, the pH of water increased from 7.7 to 11.8, a 50% change in the pH. With the addition of 0.3% SMS the pH of the solution was 12.4, a 60% change. The resistivity of the tap water decreased from 27.0 Ω.m to 4.15 Ω.m with addition of 0.1% SMS, 85% reduction in resistivity. With the addition of 0.3% SMS the resistivity reduced to 2.0 Ω.m, 93% reduction.

4.2.2.1 Density

Adding SMS powder to the cement slurry (water-to-cement ratio of 0.40) slightly increased the density of the cement mixtures. Adding 0.3% SMS (by weight of water) to the cement slurry increased the density from 1.94 g/cm^3 (16.2 ppg) to 1.95 g/cm^3 (16.3 ppg) at room condition curing, 0.6% increase.

4.2.2.2 Initial Resistivity

The electrical resistivity of the cement slurry with and without SMS was measured immediately after mixing. The initial resistivity of the smart cement slurry was 0.97 Ω.m and it decreased with the addition of sodium metasilicate (SMS) as shown in Figure 8. With the addition of 0.1% SMS the resistivity decreased to 0.92 Ω.m, a 5% reduction. With the addition of 0.2% and 0.3% SMS the resistivity were 0.9 Ω.m and 0.88 Ω.m. Hence the resistivity was sensitive to the concentration of SMS in the cement. The resistivity was decreased to 0.8 Ω.m with 1% SMS which is a 17% decrease. Hence the resistivity is highly sensitive material property and will be good monitoring and quality control parameter in the field.

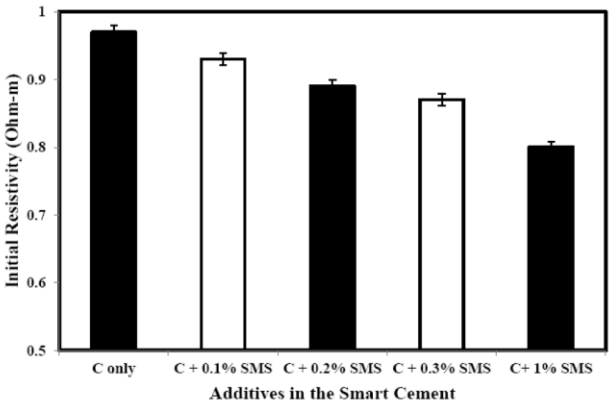

Figure 8. Initial Electrical Resistivity with Sodium Meta Silicate Addition

4.2.3 Compressive Piezoresistivity Behavior

With the addition of up to 0.3% SMS (inorganic additive), the tests showed that the smart cement cured under high temperature and different environments (dry and saturated sand) was a highly sensitive chemo-thermo-piezoresistive material.

1 day of curing

The compressive strength (σ_{cf}) of the smart cement after one day of curing at 80°C in the oven was 15.81 MPa which increased to 18.00 MPa when cured in the saturated sand at 80°C, a 14% increase. For smart cement with 0.3% SMS cured at 80°C had a compressive strength of 14.93 MPa which increased to 16.91 MPa when oven cured in saturated sand at 80°C, a 13% increase (Table 3).

The piezoresistive axial strain at failure $\left(\frac{\Delta\rho}{\rho_o}\right)_f$ for the smart cement air cured at 80°C was 433% and it increased to 475% for smart cement cured in saturated sand at 80°C. The smart cement with 0.3% SMS cured in oven showed the piezoresistive axial strain at failure $\left(\frac{\Delta\rho}{\rho_o}\right)_f$ was 331% and it increased to 345% when cured in saturated sand at 80°C (Table 3). The piezoresistivity at the peak compressive stress varied from 1555 to 2375 times the compressive strain of the smart cement.

Using the p-q Piezoresistive model (Eqn. (4)), the relationships between compressive stress and the piezoresistive axial strain $\left(\frac{\Delta\rho}{\rho_o}\right)$ of the smart cement with and without 0.3% SMS for one day of curing at 80°C in air and saturated sand were modeled. The piezoresistive model (Eqn. (4) predicted the measured stress-piezoresistivity strain relationship very well as shown in Figure 9. The model parameters q_2 and p_2 are summarized in Table 3. The coefficients of determination (R^2) were 0.98 to 0.99. The root mean square of error (RMSE) varied between 0.11 MPa and 0.38 MPa as summarized in Table 3.

Table 3. Piezoresistivity model parameters for the smart cement with and without SMS cured at 80°C for 1 day of curing.

Composition and Curing Conditions	Curing Time (day)	Strength σ_{cf} (MPa)	Piezoresistive Strain at Peak Stress, $(\Delta\varrho/\varrho_o)_{cf}$ (%)	Model Parameter p_2	Model Parameter q_2	R^2	RMSE (MPa)
w/c=0.4, (Oven cured)	1 day	15.81	433	0.010	0.673	0.99	0.12
w/c=0.4, (Cured in Saturated Sand)		18.00	475	0.030	0.802	0.98	0.38
w/c=0.4, SMS=0.3% (Oven cured)		14.93	331	0.048	0.730	0.99	0.16
w/c=0.4, SMS=0.3% (Cured in Saturated Sand)		16.91	345	0.081	0.897	0.99	0.11

Table 4. Piezoresistivity model parameters for the smart cement with and without SMS cured at 80°C for 28 days of curing.

Composition and Curing Conditions	Curing Time (day)	Strength σ_{cf} (MPa)	Piezoresistive Strain at Peak Stress, $(\Delta\varrho/\varrho_o)_{cf}$ (%)	Model Parameter p_2	Model Parameter q_2	R^2	RMSE (MPa)
w/c=0.4, (Oven cured)	28 days	33.59	245	0.010	0.626	0.98	0.39
w/c=0.4, (Cured in Saturated Sand)		37.98	302	0.019	0.744	0.99	0.26
w/c=0.4, SMS=0.3% (Oven cured)		33.15	160	0.050	0.825	0.99	0.30
w/c=0.4, SMS=0.3% (Cured in Saturated Sand)		38.42	220	0.010	0.487	0.97	0.46

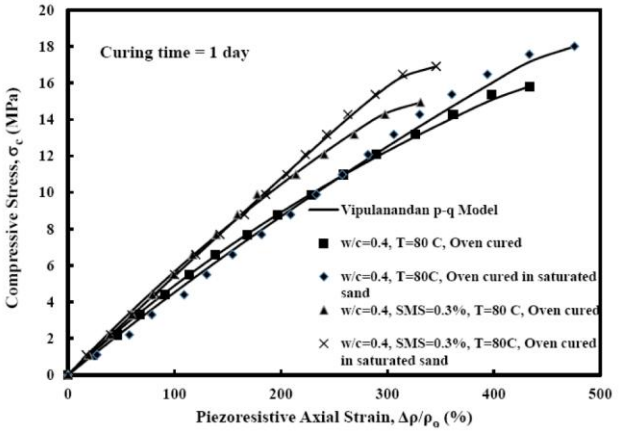

Figure 9. Compressive Piezoresistive Behavior of Smart Cement without and with Sodium Meta Silicate Addition after 1 Day Curing at 80°C Temperature

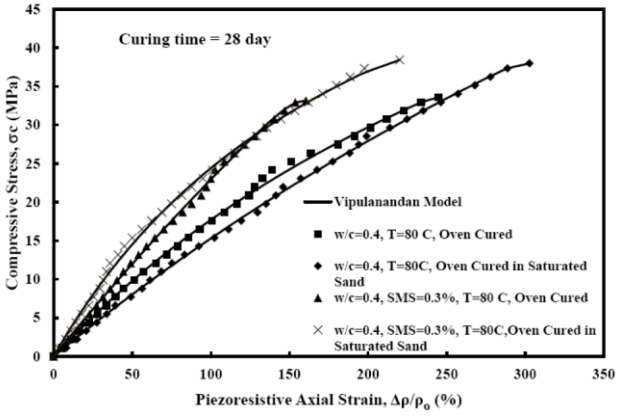

Figure 10. Compressive Piezoresistive Behavior of Smart Cement without and Sodium Meta Silicate Addition after 28 Days Curing at 80°C Temperature

28 days of Curing

The compressive strength (σ_{cf}) of the smart cement after 28 days of curing at 80°C in the oven was 33.56 MPa which increased to 37.98 MPa when cured in the saturated sand at 80°C, a 13% increase. The smart cement with 0.3% SMS cured in oven had a compressive strength of 33.15 MPa which increased to 38.42 MPa when cured in saturated sand at 80°C, a 16% increase as summarized in Table 4.

The piezoresistive axial strain at failure $\left(\frac{\Delta\rho}{\rho_o}\right)_f$ for the smart cement cured at 80°C in the oven was 245% which increased to 302% when cured in the saturated sand at 80°C. The smart cement with 0.3% SMS cured in the oven at 80°C showed the piezoresistive axial strain at failure $\left(\frac{\Delta\rho}{\rho_o}\right)_f$ was 160% which increased to 220% for specimen cured in saturated sand at 80°C as summarized in Table 4. The piezoresistivity at the peak compressive stress varied from 900 to 1510 times the compressive strain of the smart cement.

Using the p-q piezoresistive model (Eqn. (4)), the relationship between the compressive stress and the piezoresistive axial strain $\left(\frac{\Delta\rho}{\rho_o}\right)$ of the smart cement with and without 0.3% SMS

for 28 days curing were modeled. The piezoresistive model (Eqn. (4)) predicted the measured stress-change in resistivity relationship very well as shown in Figure 10. The model parameters q_2 and p_2 are summarized in Table 4. The coefficients of determination (R^2) were 0.97 to 0.99. The root mean square of error (RMSE) varied between 0.26 MPa and 0.46 MPa as summarized in Table 4.

4.2.4 Modeling compressive strength with curing time

The compressive strength of the cement made with and without SMS and cured at 80°C in the oven and saturated sand was measured up to 28 days of curing. The compressive strength of the cement increased with the curing time in a non-linear manner as shown in Figure 11.

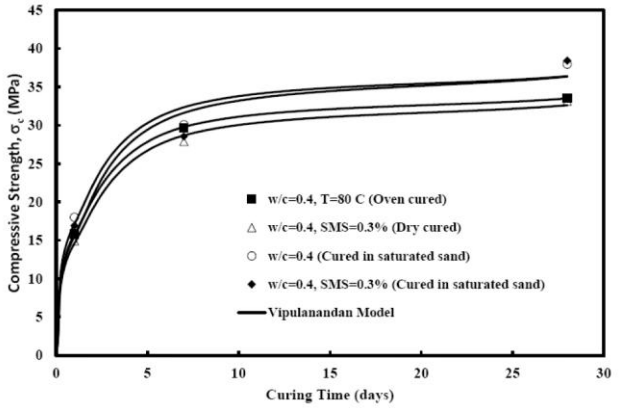

Figure 11. Variation of Compressive Strength of Smart Cement without and with Sodium Meta Silicate Addition up to 28 Days of Curing at 80°C Temperature

The relationship between the compressive strength of the cement and curing time was modeled with the Vipulanandan Correlation Model as follows:

$$\sigma_{cf} = t/(C_1 + D_1 t) \qquad (9)$$

Where,

σ_{cf} = Compressive strength of the smart cement (MPa)
t = Curing time (day)

Parameters C_1 (day/MPa) and D_1 (MPa^{-1}) are model parameters and parameter C_1 represent the initial rate of change and parameter D_1 determines the ultimate strength. For the cement cured at 80°C the oven, experimental results matched very well as shown in Figure 11 with the proposed model with coefficient of determination (R^2) of 0.99. For smart cement only, parameters C_1 and D_1 were found as 0.035 day/MPa and 0.028 MPa^{-1}. For smart cement with 0.3% SMS, parameters C_1 and D_1 were found as 0.039 day/MPa and 0.029 MPa^{-1}. For the cement cured in saturated sand at 80°C, experimental results also matched very well as shown in Figure 11 with the proposed model with coefficient of determination (R^2) of 0.94-0.95. For smart cement only, parameters C_1 and D_1 were found as 0.032 day/MPa and 0.026 MPa^{-1}. For smart cement with 0.3% SMS, parameters C_1 and D_1 were found as 0.038 day/MPa and 0.026 MPa^{-1}.

4.2.5 Modeling Piezoresistive Strain at Failure with Curing time

Piezoresistivity at failure for the smart cement made with and without SMS oven cured and cured up to 28 days was investigated. With curing time increases, the piezoresistivity at failure of the cement specimen changes. The relationship between the piezoresistivity at failure of the cement grout and curing time has been modeled using the Vipulanandan Correlation Model as follows:

$$\Delta\varrho/\varrho_o = (\Delta\varrho/\varrho_o)_1 - t/(E_1 + F_1 t) \qquad (10)$$

Where,

$\Delta\varrho/\varrho_o$ = piezoresistivity at failure (%)
$(\Delta\varrho/\varrho_o)_1$ = piezoresistivity at failure after 1 day (%)
t = Curing time (day)

Parameters E_1 (day/Ω.m) and F_1 $(\Omega.m)^{-1}$ are model material parameters and the parameter E_1 represent the initial rate of change and the parameter F determines the ultimate piezoresistivity. For the cement cured at 80°C in the oven, the model predicted the experimental results very well as shown in Figure 12 with the coefficient of determination (R^2) were in the range of 0.98 to 0.99. For the oven dry cured smart cement, parameters E_1 and F_1 were 0.083 (day/Ω.m) and 0.0033 $(\Omega.m)^{-1}$ respectively and the estimated ultimate piezoresistivity (infinite time) was over 130%. For the oven dry cured smart cement with 0.3% SMS, parameters E_1 and F_1 were found as 0.067 (day/Ω.m) and 0.0044 $(\Omega.m)^{-1}$ respectively, and the estimated ultimate piezoresistivity (infinite time) was over 100%. For the cement specimens cured in saturated sand at 80°C, experimental results also matched very well shown in Figure 12 with the model with coefficient of determination (R^2) of 0.98-0.99. For smart cement cured in the saturated sand at 80°C, parameters E_1 and F_1 were 0.121 (day/Ω.m) and 0.0033 $(\Omega.m)^{-1}$ respectively, and the estimated ultimate piezoresistivity (infinite time) was over 175%. For smart cement with 0.3% SMS cured in the saturated sand at 80°C, parameters E_1 and F_1 were found as 0.104 (day/Ω.m) and 0.0043 $(\Omega.m)^{-1}$ respectively and the estimated ultimate piezoresistivity (infinite time) was over 120%.

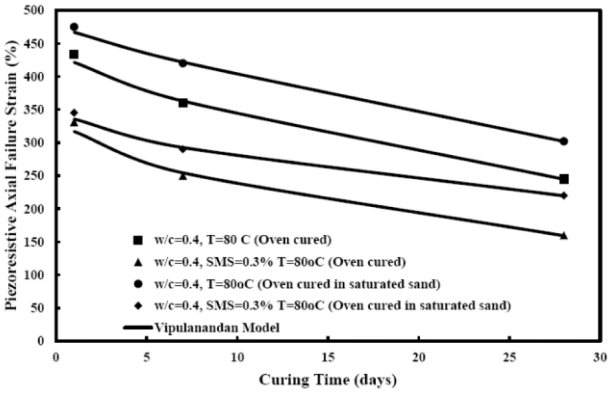

Figure 12. Variation of Piezoresistive Axial failure Strain of Smart Cement without and with Sodium Meta Silicate Addition up to 28 Days of Curing at 80°C Temperature

4.3. Effect of Clay Contamination

Portland cement slurries are not only used in the construction but also in repairing applications related to slurry walls, piles, other foundations, pipelines, tunnels, wells (oil, gas and

water), bridges, buildings and highways (McCarter et al. 2000; Fuller et al. 2002;; Vipulanandan et al. 2005 and 2014b; Wilson, 2017). Based on the applications, cement slurries are made with additives and water-to-cement ratios varying from 0.3 to over 1 (Nelson 1990; Vipulanandan et al. 2017). Construction of deep foundations, near surface structures and underground structures will require drilling in the ground using drilling muds and placing the cementitious materials in the boreholes may result in various types of clay soil contamination. Clay soil contamination will impact the cement hydration and long-term properties (Vipulanandan et al. 1995, 2018k). Unfortunately there are no real-time monitoring methods to detect the clay soil contamination of cementitious materials during construction and also the effects of clay contaminations during the service life of the infrastructures (Mohammed 2018; Vipulanandan et al. 2018k, 2020c).

Clay soils are mainly characterized as montmorillonite, kaolinite, illite or a mixture of these clay constituents with the particle sizes less than 2 □ m (Vipulanandan 1995a,b,2016f). Chemically the main constituent of the clay is aluminum silicates with vary amounts of cations such as sodium (Na), potassium (K), magnesium (Mg) and calcium (Ca) (Vipulanandan 1995; Mohammed et al. 2013 and 2015). Clays are hydrophilic inorganic materials which can react with both hydrating cement particles and the pore fluid. During drilling of boreholes to install water, oil and gas wells and drilled shafts to support bridges and buildings, water based drilling muds are used with varying amounts of bentonites clay contents (Vipulanandan 2014a). If the bore holes are not cleaned before placing the cement or concrete to construct drilled shafts the cement will get contaminated (Vipulanandan et al. 2018k). When installing oil and gas wells, after drilling is finished the metal casing is placed inside the wellbore and then the cement slurry is pumped through the casing so that it comes from bottom pushing the drilling mud and mud cake up and fills the gap between the casing and the formation (Wilson 2017). Also construction of tunnels in clay soils and shale rock formations could also contaminate the cement and concrete with clays. Flooding on construction sites will also result in contaminating the surfaces of the cementitious construction materials in-place by depositing transported clay sediments which will significantly impact the construction. Hence there is potential for the cement to be contaminated with clays from the drilling muds, mud cakes, flooding and the geological formations. Based on the type and the amount contamination it will affect the performance of the cement and concrete (Vipulanandan 1995, 2014b, 2015c, 2018k).

The potential applications of smart cement with various types of chemical additives have been investigated under different curing conditions (temperatures, and saturated sand simulating the water saturated conditions in the bore holes) and the results are analyzed in this chapter to demonstrate the sensitivity of the chemo-thermo-piezoresistivity of the smart cements. Also the effects of clay (inorganic), oil based mud (organic) and carbon dioxide (CO_2) contaminations on the chemo-thermo-piezoresistive smart cement sensing characteristics were investigated.

4.3.1 Curing Methods

4.3.1.1 Room Condition

Specimens were cured in the plastic molds at room temperature (23°C) and a relative humidity of 50% and the specimens were demolded just before testing.

4.3.1.2 Oven Cured

Specimens were kept in the plastic mold and cured in the oven at elevated temperature. Also specimens were placed in saturated sand in the closed bottle (Figure 7) to simulate the field condition under water and groundwater and cured at room temperature and elevated temperatures and were demolded just before testing.

Also water was added regularly to keep the sand saturated.

4.3.2 Testing

In this study, the effects of up to 5% montmorillonite clay soil contamination on the initial properties and piezoresistive behavior of the Smart Portland cement was investigated. Smart Portland cement was made by mixing the cement (Type I) with 0.1% carbon fibers to enhance the sensing properties. Based on the type of construction, cement might get contaminated with varying amounts of clay soils. Hence, a series of experiments were performed to evaluate the cement behavior with and without up to 5% of montmorillonite clay contamination to determine the effects on the initial properties and the piezoresistivity with strength up to 28 days under room condition.

Table 5. Summary of the bulk resistivity parameters for the Smart Portland cement with and without clay soil contamination cured under room temperature up to 28 days

Mix Type	Unit Weight (kN/m³)	Initial resistivity, ρ_o (Ω.m)	ρ_{min} (Ω.m)	t_{min} (min)	ρ_{24hr} (Ω.m)	$\rho_{7\ days}$ (Ω.m)	$\rho_{28\ days}$ (Ω.m)	$RI_{24\ hr}$ (%)	$RI_{7\ days}$ (%)	$RI_{28\ days}$ (%)
w/c=0.38	19.8	0.92	0.84	180	2.48	6.79	11.37	195	708	1253
w/c=0.38 Clay = 1%	19.5	0.94	0.85	180	2.62	6.57	12.30	208	673	1347
w/c=0.38 Clay = 5%	17.8	1.15	1.07	180	2.82	8.17	15.10	164	664	1311

4.3.2.1 Density

Initial unit weight of the smart Portland cement with w/c ratio of 0.38 was 19.8 kN/m³ as summarized in Table 5. The initial unit weight decreased with the montmorillonite clay contamination. With 5% clay soil contamination, the unit weight decreased to 17.8 kN/m³, a 10% reduction.

4.3.2.2 Initial Resistivity

The initial resistivity of the modified Portland cement slurry was 0.92 Ω.m and it increased with the clay soil contamination as summarized in Table 5. With 1% clay soil contamination, the initial resistivity was increased to 0.94 Ω.m and with 5% clay soil contamination the initial resistivity was 1.15 Ω.m, a 25% increase. Hence the initial resistivity increases were more than two times more sensitive than the density changes of clay soil contamination in the cement.

4.3.2.3 Piezoresistivity and strength

1 day of curing

The compressive strength (σ_{cf}) of the smart Portland cement with 0%, 1%, and 5% clay soil contamination for one day of curing were 9.88 MPa, 9.44 MPa and 8.12 MPa, a 4%, and 18% reduction when the clay content was increased by 1% and 5% respectively as summarized in Table 6 and also shown in Figure 13.

The piezoresistive axial strain at failure $\left(\frac{\Delta\rho}{\rho_o}\right)_f$ for the modified Portland cement was 432% which was reduced to 411% and 230% respectively with 1% and 5% clay as summarized in Table 5. With 5% clay soil contamination to the smart Portland cement, the piezoresistive axial strain at failure $\left(\frac{\Delta\rho}{\rho_o}\right)_f$ was reduced about 45% from that of the smart Portland cement.

Using the p-q Piezoresistive model (Eqn. (4)), the relationships between compressive stress and the piezoresistive axial strain $\left(\frac{\Delta\rho}{\rho_o}\right)$ of the smart Portland cement with different clay content of 0%, 1% and 5% for one day of curing were modeled. The piezoresistive model (Eqn. (4)) predicted the measured stress-change in resistivity relationship very well as shown in Figure 13. The model parameters q_2 and p_2 are summarized in Table 5. The coefficients of determination (R^2) were 0.97 to 0.99. The root mean square of error (RMSE) varied between 0.21 MPa and 0.43 MPa as summarized in Table 5.

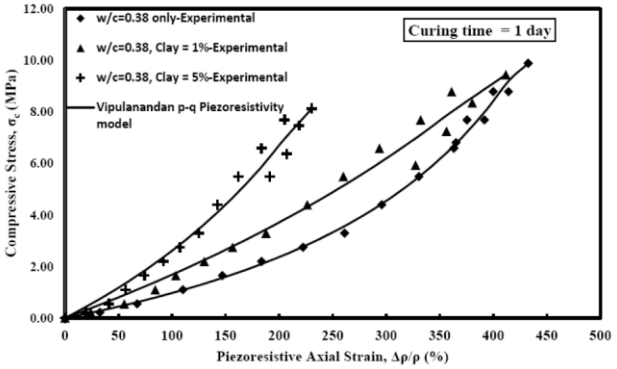

Figure 13. Compressive Piezoresistive Behavior of Smart Cement without and with Clay Contamination after 1 Day Curing

28 days of Curing

The compressive strength (σ_{cf}) of the modified Portland cement with 0%, 1%, and 5% clay soil contamination for one day of curing were 31.40 MPa, 30.08 MPa and 27.44 MPa, a 4%, and 13% reduction when the clay content increased about 1% and 5% respectively as summarized in Table 6 and also shown in Figure 14.

The piezoresistive axial strain at failure $\left(\frac{\Delta\rho}{\rho_o}\right)_f$ for the modified Portland cement was 270% which was reduced to 209% and 158% respectively with 1% and 5% clay as summarized in Table 6. With 5% clay soil contamination to the modified Portland cement, the piezoresistive axial strain at failure $\left(\frac{\Delta\rho}{\rho_o}\right)_f$ was reduced about 40% from that of the modified Portland cement.

Table 6. Compressive strength, piezoresistivity, model parameters p_2 and q_2 for the smart Portland Cement after 1 day and 28 days of curing.

Mix Type	Curing Time (day)	Strength σ_f (MPa)	Piezoresistivity at peak stress, $(\Delta\varrho/\varrho_o)_f$ (%)	p_2	q_2	R^2	RMSE (MPa)
w/c=0.38	1 day	9.88	432	0.047	2.77	0.99	0.21
w/c=0.38 Clay = 1%		9.44	411	0.025	1.48	0.98	0.43
w/c=0.38 Clay = 5%		8.12	230	0.031	1.64	0.97	0.43
w/c=0.38	28 days	31.40	270	0.062	0.75	0.98	0.44
w/c=0.38 Clay = 1%		30.08	209	0.052	0.75	0.99	0.34
w/c=0.38 Clay = 5%		27.44	158	0.125	0.78	0.99	0.34

Using the p-q Piezoresistive model (Eqn. (5.7)), the relationships between compressive stress and the piezoresistive axial strain $\left(\frac{\Delta\rho}{\rho_o}\right)$ of the modified Portland cement with different clay content of 0%, 1% and 5% for one day of curing were modeled. The piezoresistive model (Eqn. (4)) predicted the measured stress- change in resistivity relationship very well as shown in Figure 14. The model parameters q_2 and p_2 are summarized in Table 6. The coefficients of determination (R^2) were 0.98 to 0.99. The root mean square of error (RMSE) varied between 0.34 MPa and 0.44 MPa as summarized in Table 6.

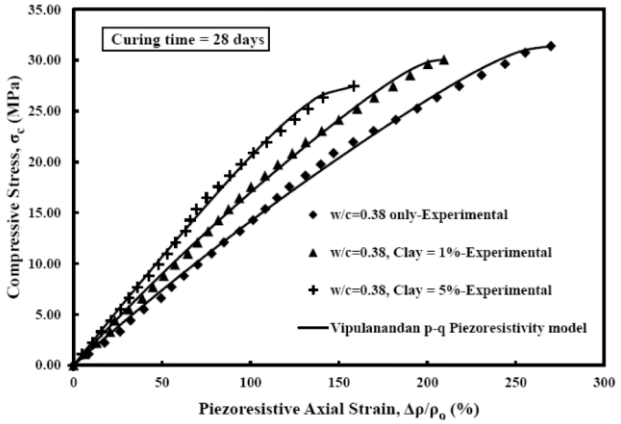

Figure 14. Compressive Piezoresistive Behavior of Smart Cement without and with Clay Contamination after 28 Days of Curing

4.3.2.4 Relationship between Curing Time and Strength and Piezoresistive Strain at Failure

The strength of the smart cement specimen made with and without clay soil contamination was measured up to 28 days of curing. With curing time increase, the compressive strength of the cement specimen increased.

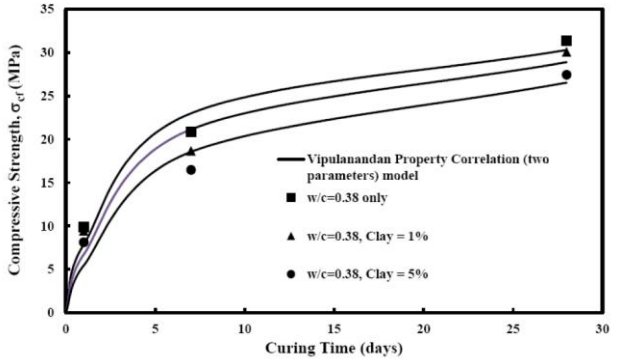

Figure 15. Variation of Compressive Strength of Smart Cement without and with Clay Contamination up to 28 Days of Curing at 80°C Temperature

The relationship between the compressive strength of the cement and curing time has been modeled with the Vipulanandan Property Correlation (two parameters since the initial condition is zero) model used for over two decades and the relationship is as follows:

$$\sigma_c = t/(C_2 + D_2 t) \quad (11)$$

Where,

σ_c = Compressive strength of the grout (MPa)
t = Curing time (day)

Parameters C_2 and D_2 are model parameters and parameter C_2 represent the initial rate of change and parameter D_2 determines the ultimate strength. The experimental results matched very well as shown in Figure 15 with the proposed model with coefficient of determination (R^2) varied from 0.95 to 0.96. For smart Portland cement only, parameters C_2 and D_2 were found as 0.098 MPa^{-1}day and 0.029 MPa^{-1}. For the smart Portland cement with 1% clay, parameters C_2 and D_2 were 0.119 MPa^{-1}day and 0.030 MPa^{-1}. For the smart Portland cement with 5% clay, parameters C_2 and D_2 were 0.151 MPa^{-1}day and 0.032 MPa^{-1}.

4.3.2.5 Piezoresistive Failure Strain at Peak Stress

The piezoresistivity at peak failure stress for the cement specimen made with and without clay soil contamination were measured up to 28 days of curing. With the increase in curing time, the piezoresistivity at the peak failure stress for the cement reduced. The relationship between the piezoresistivity at failure of the cement and curing time has been modeled with the Vipulanandan Property Correlation model as follows:

$$\Delta\rho/\rho_o = (\Delta\rho/\rho_o)_2 - t/(E_2 + F_2 t) \quad (12)$$

Where,

$\Delta\rho/\rho_o$ = Piezoresistivity at failure (%)
$(\Delta\rho/\rho_o)_2$ = Piezoresistivity at failure after 1 day (%)
t = Curing time (day)

Parameters E_2 and F_2 are model material parameters and parameter E_2 represent the initial rate of change and parameter F_2 determines the ultimate piezoresistivity. The experimental results matched very well as shown in Figure 16 with the proposed model with coefficient of determination (R^2) varied from 0.95 to 0.99. For modified Portland cement only, parameters E_2 and F_2 were found as 0.051 Ωm^{-1}day and 0.004 Ωm^{-1}. For modified Portland cement with 1% clay contamination, parameters E_2 and F_2 were found as 0.033 Ωm^{-1}day and 0.003 Ωm^{-1}. For modified Portland cement with 5% clay contamination, parameters E_2 and F_2 were found as 0.551 Ωm^{-1}day and 0.006 Ωm^{-1}.

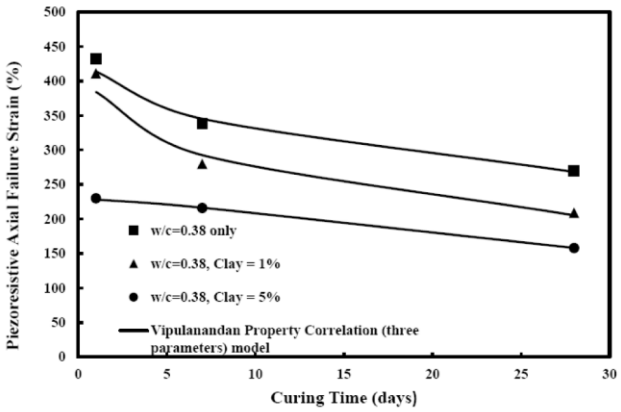

Figure 16. Variation of Piezoresistive Axial failure Strain of Smart Cement without and with Clay Contamination up to 28 Days of Curing

4.4. Carbon dioxide (CO_2) Contamination

The smart cement slurry was prepared with 1% and 3% of dry ice (CO_2) in water. The test specimens were prepared following the API standards. API class H cement was used with water-cement ratio of 0.38. For all the samples 0.04% (based on weight of cement) of carbon fiber (CF) was added to the slurry in order to enhance the piezoresistivity of the cement and to make it more sensing. After mixing, the slurries were casted into the cylindrical molds with height of 100 mm and diameter of 50 mm, with two conductive wires were embedded 50 mm apart vertically to monitor the resistivity

development of the specimens during the curing time. After 1 day all the specimens were demolded and were cured for 28 days under water.

4.4.1 Carbon dioxide (CO_2) Contamination

There is increasing interest in understanding the effects of carbon dioxide (CO_2) contamination of cement. In this study smart cement samples were prepared with CO_2 contaminated water by adding dry ice and also the cement specimens were cured in CO_2 contaminated water. Adding 3% of dry ice into the water reduced the temperature by about 3^{O}C and also the pH and the resistivity (□) as summarized in Table 7.

Table 7. Water with and without CO_2 Contamination

Solutions	pH	ρ $(\Omega.m)$
Pure Water	7.4	25.1
3% CO_2 in Water	4.2	22.3

Sample Preparation

The smart cement slurry was prepared with 0.1, 1 and 3% of dry ice (CO_2) in water. The test specimens were prepared following the API standards. API class H cement was used with water-cement ratio of 0.38. For all the samples, 0.04% (based on weight of cement) of carbon fiber (CF) was added to the slurry in order to enhance the piezoresistivity of the cement and to make it more sensing. After mixing, the slurries were casted into the cylindrical molds with height of 100 mm and diameter of 50 mm, with two conductive wires were embedded 50 mm apart vertically to monitor the resistivity development of the specimens during the curing time. After 1 day all the specimens were demolded and were cured for 28 days under water.

4.4.2 Testing

4.4.2.1 Density

The average density of smart cement was 1.95 g/cc (16.28 ppg). With 0.1% of CO_2 contaminated water the density reduced by 0.06%. With 1% of CO_2 contaminated water the density was reduced by 0.49% to 1.94 g/cc (16.20 ppg) and with 3% of CO_2 contaminated water it reduced to 1.93 g/cc (16.14 ppg), 0.86% reduction.

4.4.2.2 Electrical Resistivity

Initial resistivity

Initial resistivity of the smart cement slurries with varying CO_2 (dry ice) concentrations was investigated.

(a) Smart Cement: The average initial resistivity of the cement slurry was 1.10 Ω.m.

(b) Smart Cement with CO_2 Contamination*:* Smart cement with 0.1%, 1% and 3% of CO_2 contamination resulted in a reduction in the initial resistivity to 1.03 Ω.m, 0.93 Ω.m and 0.90 Ω.m respectively as summarized in Table 8. Hence, CO_2 contamination with concentrations of 0.1%, 1% and 3% resulted in the resistivity reduction of 6%, 15% and 18% respectively. The main reason for the reduction in initial electrical resistivity of the contaminated cement slurries was due to the existence of carbonic acid (H_2CO_3) in the slurries.

Curing

During the initial period of curing the resistivity will reduce with time. Also the time to reach the minimum resistivity will be also a good monitoring parameter and it is important to quantify the sensitivity of these parameters due to CO_2 contamination.

(a) Smart Cement: The minimum resistivity of the smart cement slurry was 0.85 Ω.m and was reached 85 minutes (t_{min}) after mixing the sample (Table 8).

(b) CO_2 Contaminated Smart Cement: CO_2 contamination decreased the ρ_{min} of the smart cement slurry by 7%, 15% and 17% from 0.85 Ω.m to 0.79 Ω.m, 0.72 Ω.m and 0.70 Ω.m respectively with 0.1%, 1% and 3% of CO_2 contamination. CO_2 exposure also delayed the hydration process. With 0.1%, 1% and 3% of CO_2 contamination it delayed t_{min} by 15 minutes, 35 minutes and 45 minutes respectively.

One Day Curing

The test results are summarized in Table 8.

(a) Smart Cement*:* After one day of curing the smart cement resistivity was 4.8 Ω.m and the resistivity index was 465%

Table 8. Electrical resistivity parameters of the smart cement slurries exposed to different CO_2 concentration

Smart Cement	ρ_0 $(\Omega.m)$	ρ_{min} $(\Omega.m)$	t_{min} $(minute)$	ρ_{24} $(\Omega.m)$	$\frac{\rho_{24}-\rho_{min}}{\rho_{min}}$ %
Uncontaminated cement	1.10	0.85	85	4.80	465%
0.1% CO_2 Contaminated Smart Cement	1.03	0.79	100	4.20	432%
1% CO_2 Contaminated Smart Cement	0.93	0.72	120	3.80	428%
3% CO_2 Contaminated Smart Cement	0.90	0.70	130	3.30	371%

(b) CO_2 Contaminated Smart Cement*:* CO_2 contamination reduced the development of the resistivity during the one day of curing. The 0.1%, 1% and 3% of CO_2 contaminated resistivity after one day of curing were 4.20 , Ω.m 3.80 Ω.m and 3.30 Ω.m respectively. Also the contamination reduced the resistivity indices as summarized in Table 8.

28 Days Curing

(a) Smart Cement: After 28 days of curing the smart cement resistivity was 17.0 Ω.m.

(b) CO_2 Contaminated Smart Cement: CO_2 contamination reduced the development of the resistivity during the 28 days

of curing. The 0.1%, 1% and 3% of CO_2 contaminated cement reduced the resistivity of the cement by 21%, 34% and 38% to 13.4 Ω.m, 11.3 Ω.m and 10.5 Ω.m respectively after 28 days of curing.

4.4.2.3 Compressive Strength

Compressive behavior of smart cement was tested after 1 and 28 days of curing under water at room temperature as shown in Figure 17.

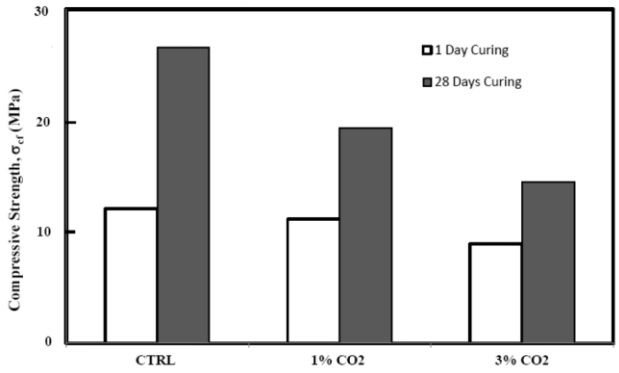

Figure 17. Variation of Compressive Strength of Smart Cement without and with Clay Contamination up to 28 Days of Curing at 80°C Temperature

1 day curing

(a) Smart Cement*:* The compressive strength of the smart cement was 12.5 MPa (1.81 ksi) after1 day of curing.

(b) CO_2 Contaminated Smart Cement*:* CO_2 contamination decreased the compressive strength of the smart cement. The compressive strength of the smart cement contaminated with 1% and 3% of CO2 decreased to 11.5 MPa (1.67 ksi) and 9.2 MPa (1.34 ksi) respectively, 8% and 26% reduction after 1 day of curing.

28 days of curing

(a) Smart Cement*:* The compressive strength of the smart cement after 28 days of curing under water was 27.5 MPa (3.98 ksi).

(b) CO_2 Contaminated Smart Cement*:* The compressive strength of the smart cement contaminated with 1% and 3% of CO_2 decreased by 27% and 45% respectively to 20.0 MPa (2.90 ksi) and 15.0 MPa (2.17 ksi) after 28 days of curing.

4.4.2.4 Piezoresistivity

Stress-piezoresistive strain behavior of smart cement was evaluated after 28 days of curing under water using Vipulanandan p-q piezoresistive strain softening model (Eqn. 5.6) and shown in Figure 18.

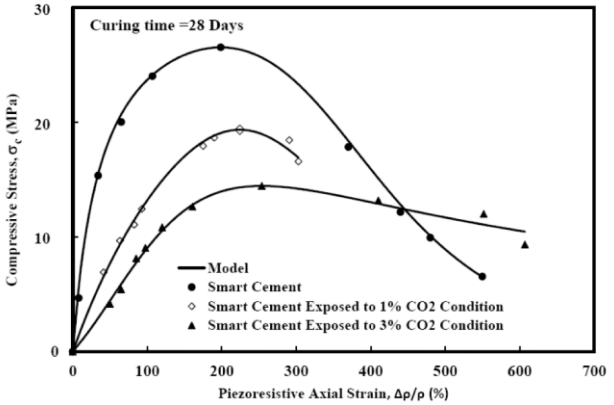

Figure 18. Compressive Piezoresistive Behavior of Smart Cement without and with CO_2 Contamination up to 28 Days of Curing

28 days curing

(a) Smart Cement*:* After 28 days of curing, the piezoresistivity of the smart cement was 199%. The model parameters p_2 and q_2 were 0.45 and 0.15 respectively as summarized in Table 9.

(b) CO_2 Contaminated Smart Cement: CO_2 contamination increased the piezoresistive behavior of the smart cement as shown in Figure 18. Piezoresistivity of the smart cement contaminated with 1% CO_2 was 224% at the failure, a 13% increase. The p-q model parameters p_2 and q_2 for the 1% CO2 contaminated smart cement were 0.35 and 0.47 respectively. Piezoresistive strain at failure of the smart cement contaminated with 3% CO_2 was 254% at the failure, a 28% increase. The p-q model parameters p_2 and q_2 for the 3% CO2 contaminated smart cement were 0.15 and 0.76 respectively as summarized in Table 9.

Table 9. Piezoresistive Model parameters for the smart cement contaminated with CO_2 after 28 days of curing

Materials	28 Days Curing				Compressive Strength (MPa)	Piezoresistivity at Failure (%)
	p_2	q_2	R^2	RMSE (MPa)		
Smart Cement	0.45	0.15	0.99	0.49	27.5	199
1% CO2 + Smart Cement	0.35	0.47	0.98	0.68	20.0	224
3% CO2 + Smart Cement	0.15	0.76	0.99	0.52	15.0	254

5. REAL-TIME MONITORING

5.1 New Construction

Highly sensing smart cement and smart cement concrete can be used in many applications. But it is important to monitor the curing and performance of the smart materials.

5.1.1 Two Probe Wireless Transmissions

It is important to monitor the changes in the resistivity (material property) with time to ensure the quality of the mixed material and also curing under various environmental conditions. It has been proven that two probe method with alternative current (AC) supply can be used for monitoring the changes in resistivity and the schematic of the

configuration is shown in Figure 19(a). A company named Sensytec located in Houston, Texas has developed the wireless transmission monitoring probe including a thermocouple to monitor the temperature as shown in Figure 19(b). The measurements can be wirelessly transmitted to the phone. The probes can be place in concrete beams, column, slabs and other configuration to monitor the curing and also the stress developments in the smart cement, smart concrete, regular concrete and cement elements.

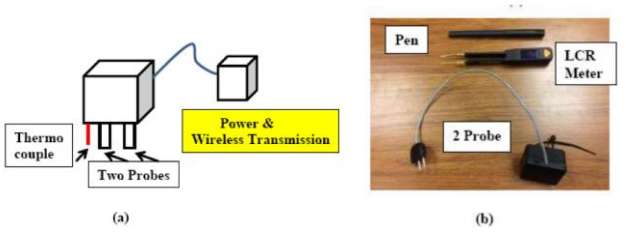

Figure 19. Two Probe Monitoring with Wireless Transmission (a) Schematic and (b) Actual Device (SensyRoc), two probe pocket LCR and a Pen.

5.1.2 New Wells (Oil, Gas and Water)

One of the main focuses is to develop real-time monitoring systems for the field wells which could be several thousand feet in the ground to collect data from the field wells during the installation and the entire service life of the wells. Also ways to integrate the LCR meter monitoring system into the current field monitoring systems to collect the data from the smart cement. This can eliminate the failures and also minimize the losses.

5.1.3 Field Instrumentation

The main focus will be to integrate the two probe method to monitor the performance of the smart drilling fluids, smart spacer fluids, smart cement and smart packer fluids during various stages operations. During the drilling, the two probes will be part of the drilling tool where the smart drilling fluid conditions could be monitored with depth using the AC current at relatively high frequency of about 300 kHz. When casing is lowered into the well, it can be used as a probe with a floating ring on the surface on the fluid as the second probe. The casing couplings will have selected frequency **"Band-Pass Filter"** attached to represent various depths (Figure 20). The **Band-Pass filters** (BPF) are simple device designed using resistances and capacitors to be effective in a selected range of frequency (Kureve et al. 2014; Zhang et al. 2015). When AC current is passed through the casing in the selected frequency range (Figure 20), it will get to the depth of the compatible filter and the filter will allow that range of frequency to pass through to the cement to measure the vertical resistance between the selected casing ring with the filter and the floating ring on the top of the liquid. Studies have clearly indicated that the current will only pass through the cement since the resistance is the lowest compared to the resistance of the steel-cement interface and cement-geological formation interface. Also when the current is passed through the casing from the top, it will only get to the cement through the compatible frequency "Band-Pass Filter" since the interface resistance between the cement and steel are very large. For example, if 50 to 100 kHz AC current is applied at the top of the casing current will travel through to Level 4 and will be allowed to get to the cement at that level. It will then travel to the floating probe ring at the top and the Impedance – Frequency data collected in this region can be used to determine the resistance (CASE 2) and using the parameter K, the resistivity can be determined.

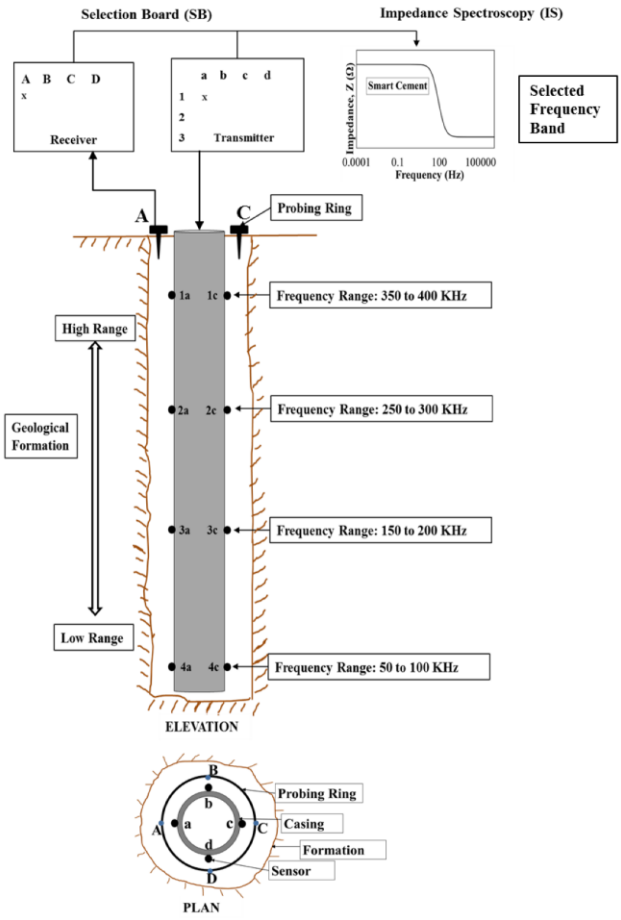

Figure 20. Schmatic Configration of the Field Wells to be Installed

5.1.4 Processing and Analyses of Data:

Computer software will be developed to rapidly process the collected data to display it on the monitoring screen real-time. Models used to characterize the material properties including resistivity will be used. The display will focus on displaying the resistivity with time, rate of change of resistivity with time ($d\rho/dt$) and the second derivative of resistivity change ($d^2\rho/dt^2$) with time (three parameters) as shown in Figure 21. Based on the quantification, limits on the rate of changes in resistivity and second derivative of resistivity change will be established and used as guidance to evaluate the conditions in the well. When no limits are exceeded (three parameters) the operation is fine that there will be **No Warning** (green light will be on). When all three parameters are beyond the limit then there will be **High Warning** (Red Light). Also based on the understanding of the changes in the three parameters the causes of the problems will be listed, so the operator can do the needed modification. When one parameter is exceeded there will be **Low Warning** (Yellow Light) and the causes will be identified based on the parameter violated. When two parameters are exceeded there will be **Medium Warning** (Orange Light) and the causes will be identified based on the two parameters violated the operators can the find t methods to fix the problem.

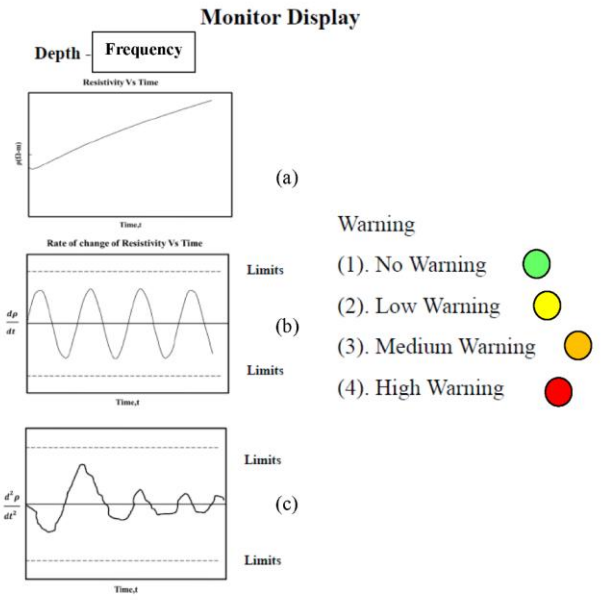

Figure 21. Variation of Total and Rates of Electrical Reisistivity with Tme at Various Depths

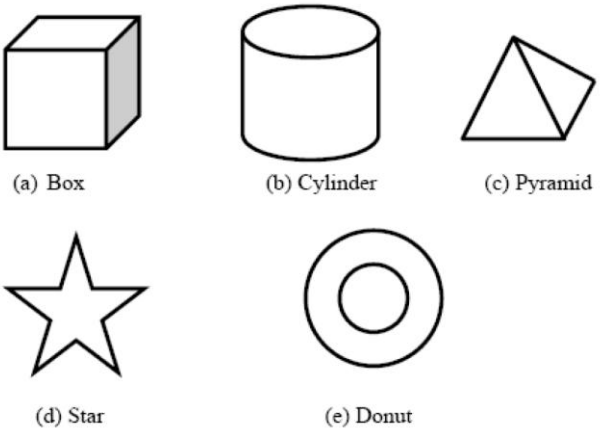

Figure 22. Diffenent Smart Cement and Smart Concrete Block Configuration

5.2 In-service Infrastructures

With the advancement of the new smart cement technology it is important to develop methods to integrate it with infrastructures that are in-service. This can substantial improve the current maintenance operations and also minimize failures. Also the developed methods should be relatively easy to adopt with various infrastructures.

In Figure 22, smart cement and smart concrete integrated with the two-probe monitoring system can be made into different shapes of blocks and attached at the critical locations of the the infrastructures that are in service. The resistivity and temperature can be measured in these blocks and transmitted wirelessly.

6. CONCLUSIONS

Main focus was to experimentally verifying the chemo-thermo-piezoresistive behavior of the smart cement. The effect of aggregate addition (concrete) with the smart cement binder was investigated. In order to evaluate the chemical (chemo) sensitivity of the smart cement with an inorganic additive (sodium meta silicate) and inorganic and organic contaminants (clay, CO_2-carbon dioxide) were tested. Also, the effect of temperature and the curing environments (oven and saturated sand) on the smart cement behavior was investigated with and without the sodium meta silicate additive. Based on the experimental study and analytical modelling following conclusions are advanced:

- Addition of coarse aggregate and curing time increased the initial electrical resistivity of the smart cement composite as well as long term electrical resistivity. The initial electrical resistivity of smart cement was 1.02 Ω.m which increased to 3.74 Ω.m. with 75% gravel respectively. After 28 days of curing, the electrical resistivity of smart cement was 14.14 Ω.m which increased to 61.24 Ω.m. with 75% gravel respectively. Also Vipulanandan Curing Model predicted the electrical resistivity development in th concrete very well.

- The piezoresistivity of the smart cement with 0% and 75% gravel content after 28 days of curing were 204% and 101% at a peak compressive stress respectively. Vipulanandan Piezoresistivity Model can be used to predict the piezoresistivity behaviour of the smart cement concrete very well.

- The failure strain of concrete is 0.3%, hence piezoresistive concrete has magnified the monitoring resistivity parameter by 336 times (33,600%) or more higher based on the aggregate content and making the concrete a bulk sensor.

- Silicate additive (inorganic) and contaminants (organic and inorganic) including CO_2 (organic) used in this study changed the density and initial resistivity of the smart cement. All the changes in the resistivity have been quantified. The smart cement with the additives and contaminants was highly sensing chemo-piezoresistive cement.

- Also the effect of temperature on the smart cement with and without sodium silicate was investigated and the smart cement was thermo-piezoresistive.

- The monitoring parameter, electrical resistivity was highly sensitive to the type and amount of additive and contaminants compared to the other parameters such as density and strength. Also resistivity can be monitored in the field during the entire service life of the smart cement.

- Effects of contaminants such as clay (inorganic) and CO_2 solution (organic) on the mechanical properties and piezoresistive behaviour of the smart cement was tested and quantified.

- Vipulanandan p-q curing model and piezoresistive model predicted the experimental results very well based on the root mean square error (RMSE) and coefficient of determination.

- The relationship between the changes in the compressive strengths of the smart cement with the curing time have been modelled with the Vipulanandan

Property Correlation model and the experimental values matched very well with the model predictions based on coefficient of determination and RMSE. The relationship between the piezoresistivity at failure and curing time was also modeled with the Vipulanandan Property Correlation model and the predictions agreed very well with the experimental results.

- Real-time 2- Probe monitoring system with wireless transmission of the data to the phone has been developed and can be easily used in the field.

- In deep wells, band pass filters (BPF) can be integrated with the casing coupling to do the real-time monitoring. This approach can be adopted for deep foundations and pipelines.

- Smart cement and smart cement concrete blocks integrated with wireless real-time monitoring can be adopted in the in-service infrastructures for real- time monitoring for improved maintenance and minimize failure.

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Declaration

There is no conflict of interest. No ethical issues. Agree to publish this paper.

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Work-Life Integration Vs. Work-Life irritation: A Study on Understanding the Myths and Realities in the Indian IT Sector

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Abstract:
The concepts of work-life integration and work-life irritation have gained significant attention in the Indian IT sector, where professionals navigate high-pressure environments and dynamic work demands. This empirical study examines the myths and realities of these two contrasting phenomena and their impact on work-life balance. By exploring key factors such as organizational support, technological enablers, boundary management, work design, and individual adaptability, the study identifies the enablers of effective work-life integration. Simultaneously, it delves into factors contributing to work-life irritation, including organizational pressure, technological overload, blurred boundaries, psychological stressors, and demographic or situational challenges. Primary data were collected through structured surveys and interviews with IT professionals across various roles and organizations. The findings reveal that while work-life integration is often marketed as an ideal solution, its practical application is fraught with challenges, including blurred work-life boundaries and increased dependency on technology. Similarly, work-life irritation, driven by excessive demands and lack of personal time, poses significant risks to employee well-being. The study highlights that effective work-life balance lies in managing these two factors, debunking myths of universal solutions. Recommendations include fostering a supportive organizational culture, promoting clear boundaries, and implementing policies for mental health and digital detox. This study contributes to the discourse on sustainable work practices by providing actionable insights for organizations and employees to mitigate work-life irritation while promoting effective work-life integration, ultimately enhancing productivity and well-being in the Indian IT sector.

Keywords: Work-Life Integration, Work-Life Irritation, Work-Life Balance, Indian IT Sector, Employee Well-being

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1. INTRODUCTION

The interplay between work and personal life has been a subject of considerable research, particularly in high-demand sectors like information technology (IT). The Indian IT sector, characterized by long working hours, tight deadlines, and a technology-driven environment, provides a unique landscape to explore the dynamics of work-life integration and work-life irritation. The rapid adoption of flexible working arrangements and remote work policies, particularly after the COVID-19 pandemic, has introduced new complexities into the work-life equation (Gandhi et al., 2022). While work-life integration aims to harmonize professional and personal responsibilities, its implementation often leads to challenges, such as blurred boundaries and over-dependence on digital tools, which can result in work-life irritation (Sharma & Jha, 2021).

Work-life integration is frequently portrayed as the ideal solution to achieve balance, emphasizing seamless transitions between work and personal tasks (Kossek et al., 2011). Proponents argue that flexible work hours and advanced technological tools empower employees to manage their time better and reduce stress. However, critics highlight that the absence of clear boundaries can lead to an "always-on" culture, increasing stress levels and diminishing personal time (Derks et al., 2015). The gap between theoretical ideals and practical realities is particularly evident in the Indian IT sector, where employees often grapple with high expectations, frequent after-hours communication, and job insecurity (Rathi & Barath, 2020).

On the other hand, work-life irritation reflects the negative outcomes of excessive workloads, unrealistic targets, and inadequate organizational support. It often results in burnout, job dissatisfaction, and strained personal relationships, especially when work obligations frequently encroach on personal life (Maslach & Leiter, 2016). In the Indian IT sector, work-life irritation is exacerbated by cultural expectations, where long hours are often equated with commitment and productivity (Shankar et al., 2018).

This study seeks to unravel the myths and realities of work-life integration and work-life irritation, examining their impact on work-life balance among IT professionals in India. By leveraging an empirical research approach, the study explores key enablers and barriers, offering actionable insights for organizations to create sustainable work environments. It contributes to the ongoing discourse on employee well-being and productivity, emphasizing the importance of tailored strategies to address the unique challenges of the Indian IT sector.

2. BACKGROUND

The evolving nature of work in the Indian IT sector reflects broader global transformations in organizational structures, workforce expectations, and technological advancements. Over the last two decades, India has emerged as a global IT hub, contributing significantly to the country's economy while simultaneously influencing global markets (NASSCOM, 2022). However, this growth has come with challenges, particularly concerning employee well-being. The sector's reliance on technology-driven workflows, coupled with the demand for productivity and efficiency, has intensified work pressures, giving rise to debates about work-life balance (Gandhi et al., 2022).

Work-life balance, a concept rooted in traditional dichotomies of work and personal life, has evolved into work-life integration in response to modern complexities. Work-life integration seeks to blend professional and personal responsibilities seamlessly, emphasizing flexibility and individual autonomy (Kossek et al., 2011). This model has been particularly relevant in the IT sector, where remote work and hybrid models have become commonplace post-pandemic. While integration offers potential benefits such as improved time management and reduced commuting stress, its success depends on factors like organizational support, technological infrastructure, and individual adaptability (Sharma & Jha, 2021).

In contrast, work-life irritation highlights the unintended consequences of these modern approaches. Factors such as constant connectivity through digital tools, unrealistic expectations from employers, and inadequate boundary management contribute to employee frustration and stress (Derks et al., 2015). For Indian IT professionals, cultural factors like long working hours and social expectations further exacerbate this irritation. Studies indicate that the absence of clear boundaries and excessive workload leads to decreased job satisfaction, burnout, and strained relationships, making work-life irritation a critical challenge in this sector (Shankar et al., 2018).

Previous research has predominantly focused on work-life balance as a binary construct, often neglecting the nuanced experiences of employees who navigate the spectrum between integration and irritation (Maslach & Leiter, 2016). While some studies advocate for flexible policies and technological solutions, others emphasize the need for organizational and cultural changes to reduce work-life friction (Rathi & Barath, 2020). Despite the extensive discourse, limited empirical research specifically addresses the unique dynamics of the Indian IT sector, where global workflows and cultural norms intersect to create distinct challenges.

This study builds on existing literature to examine the interplay of work-life integration and work-life irritation in shaping work-life balance among Indian IT professionals. It seeks to identify the enablers and barriers to integration while exploring the factors contributing to irritation. The findings aim to provide actionable insights for both policymakers and organizations to promote sustainable work environments that support employee well-being and productivity in the dynamic landscape of the Indian IT sector.

3. LITERATURE REVIEW

The modern workplace has significantly evolved, particularly in sectors like IT, where technological advancements and organizational changes have redefined the traditional work-life balance. The idea of Work-Life Integration is increasingly promoted as a solution to accommodate both personal and professional responsibilities seamlessly (Kossek et al., 2011). Variables such as organizational support, technological enablers, and boundary management play a critical role in determining the success of work-life integration. For example, organizations that offer flexible policies, such as remote work and adaptable schedules, often see improved employee satisfaction and productivity (Gandhi et al., 2022). Similarly, technological enablers like collaboration tools facilitate task efficiency but must be managed effectively to avoid over-dependence and digital fatigue (Derks et al., 2015). Effective boundary management, where clear limits between work and personal life are set, has been highlighted as a critical factor in maintaining employee well-being (Clark, 2000).

Conversely, Work-Life Irritation arises when these variables are mismanaged or lead to unintended negative consequences. Factors such as organizational pressure and technological overload have been identified as significant contributors to irritation (Shankar et al., 2018). Excessive workloads, unrealistic deadlines, and the "always-on" culture fostered by technological connectivity blur the boundaries between work and life, exacerbating stress and burnout (Mazmanian et al., 2013). Psychological effects, including fatigue, frustration, and diminished productivity, often emerge as a result of poor work-life boundary enforcement. Moreover, demographic challenges, such as the dual burden of family and career responsibilities, further exacerbate irritation, particularly in high-pressure industries like IT (Sharma & Jha, 2021).

The cumulative impact of these contrasting forces—work-life integration and irritation—shapes an individual's overall work-life balance. Work-life balance has been defined as the degree to which employees are able to allocate their time and energy to both personal and professional domains without significant conflict (Greenhaus et al., 2003). While successful integration can lead to improved well-being and job satisfaction, unmanaged work-life irritation leads to burnout, absenteeism, and lower productivity (Maslach & Leiter, 2016). Empirical studies in the Indian IT sector reveal that organizational culture, leadership behavior, and personal adaptability are pivotal in determining whether integration supports or irritates work-life balance (Rathi & Barath, 2020).

4. RESEARCH PROBLEM

The Indian IT sector faces a dual challenge in addressing work-life integration and work-life irritation, both of which significantly influence employees' work-life balance. While work-life integration is often promoted as an ideal solution, it risks creating unintended work-life irritation due to blurred boundaries, organizational pressure, and technological overload. This study seeks to bridge the gap in understanding how variables such as organizational support, technological enablers, boundary management, organizational pressure, and demographic challenges interact to influence work-life balance. The research problem is:

"*To examine the contrasting effects of work-life integration and work-life irritation on work-life balance among Indian IT professionals and identify the key enablers and barriers that influence employee well-being and productivity.*"

This research will provide insights into the factors that enable successful work-life integration while mitigating irritation, offering recommendations to create sustainable work environments in the IT industry.

Objectives of the study:

1. To examine the impact of Work-Life Integration on Work-Life Balance.
2. To investigate the factors contributing to Work-Life Irritation and their effects on Work-Life Balance.
3. To identify the enablers and barriers influencing Work-Life Balance in the Indian IT sector.
4. These objectives help the study identify how Work-Life Integration positively impacts work-life balance while analyzing factors contributing to Work-Life Irritation, such as organizational pressure and technological overload. By examining enablers and barriers, the study provides actionable insights for organizations to minimize irritation, enhance integration, and promote sustainable work-life balance in the Indian IT sector.

5. RESEARCH METHODOLOGY

This study adopted a quantitative research design to examine the impact of Work-Life Integration and Work-Life Irritation on Work-Life Balance in the Indian IT sector. The study uses a structured approach to collect and analyze data from IT professionals working in various organizations to ensure generalizability and reliability of the findings. The study was employed stratified random sampling to collect data from 300 IT professionals across different hierarchical levels (entry-level, mid-level, and senior management) and departments (software development, support, testing, and project management). This stratification ensures representation of diverse perspectives within the IT sector. Respondents are selected from leading IT firms in major Indian cities, such as Bengaluru, Hyderabad, Pune, and Chennai, where IT hubs are concentrated.

The research model depicted examines the relationship between Work-Life Integration, Work-Life Irritation, and Work-Life Balance. Work-Life Integration, comprising factors such as organizational support, technological enablers, and boundary management, acts as a positive determinant, fostering harmony between professional and personal responsibilities. In contrast, Work-Life Irritation, driven by organizational pressure, technological overload, and blurred boundaries, contributes to stress, dissatisfaction, and decreased well-being. Both constructs—Work-Life Integration and Work-Life Irritation—are positioned as independent variables influencing the dependent variable, Work-Life Balance, which reflects outcomes like employee satisfaction, well-being, and time allocation. This model highlights how the interplay of enabling factors and stressors shapes an individual's overall work-life equilibrium. By analyzing these variables, the research aims to provide actionable insights into promoting strategies that reduce irritation while enhancing effective integration, ultimately leading to improved work-life balance for Indian IT professionals.

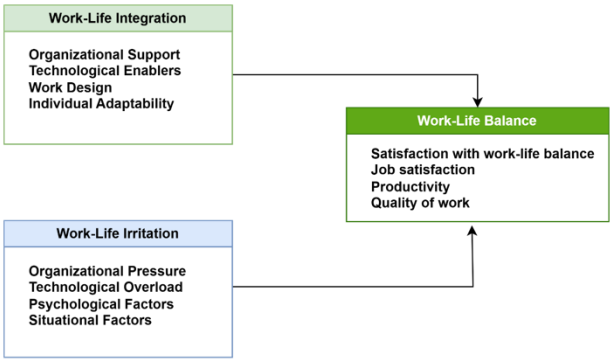

Figure 1. Research Model

A structured questionnaire will be distributed using online survey tools to ensure ease of participation. The questionnaire will employ a 5-point Likert scale to assess responses related to the study variables. Statistical tools such as descriptive statistics, correlation analysis, and multiple regression analysis will be used to test the relationships among variables. Cronbach's Alpha will be used to ensure the reliability of the scale.

Hypotheses:
H1: Work-Life Integration has a positive and significant impact on Work-Life Balance.
H2: Work-Life Irritation has a negative and significant impact on Work-Life Balance.

This methodology ensures a robust examination of the research problem while offering practical insights for organizations to enhance work-life balance by addressing enablers and mitigating barriers.

6. RESULTS

The study collected data from 300 respondents in the Indian IT sector, comprising 72% male and 28% female participants. The majority of respondents (40%) fell in the 25-30 years age group, with 55% holding postgraduate degrees and 45% earning between INR 50,000-1,00,000 monthly. Marital status revealed 65% married and 70% living in nuclear families, while joint-family respondents reported additional challenges balancing work and personal obligations. Gender differences were notable, as 68% of females reported higher work-life irritation due to dual work and home responsibilities compared to 52% of males. On factors influencing Work-Life Integration, 64% of respondents found organizational support and boundary management effective, while 58% believed technological enablers improved productivity. However, 45% cited technological overload (e.g., frequent

after-hours communication) and 35% reported organizational pressure as major contributors to Work-Life Irritation. Among married participants, 70% struggled with work-life balance due to familial responsibilities, while dissatisfaction overall stood at 42%, particularly where blurred boundaries and stress were prominent. Nevertheless, 58% acknowledged that organizational strategies promoting flexibility and boundary management positively impacted their work-life balance. These results highlight the dual role of enablers and stressors in shaping work-life balance, emphasizing the need for tailored policies to address gendered, marital, and family-specific challenges in the Indian IT sector.

The descriptive analysis of the study reveals critical insights into the factors influencing work-life integration, work-life irritation, and overall work-life balance among Indian IT professionals. Work-Life Integration variables show that Organizational Support has a strong mean of 4.00 (SD = 0.734), indicating its pivotal role in enabling integration, followed closely by Work Design with the highest mean of 4.22 (SD = 0.631), highlighting its importance in promoting structured workflows. Technological Enablers (mean = 3.93) and Individual Adaptability (mean = 3.22) reflect moderate levels of reliance on technology and personal coping mechanisms, with variability suggesting differences in individual capacities. In Work-Life Irritation, Situational Factors (mean = 4.16, SD = 0.618) emerge as the most prominent contributor, indicating external pressures such as family or life circumstances, while Technological Overload (mean = 3.86) and Organizational Pressure (mean = 3.81) also significantly add to irritation. Psychological Factors (mean = 3.69) further underscore stress-related impacts on employees. For Work-Life Balance, Job Satisfaction and Quality of Work share a high mean of 4.16 and 4.02 respectively, reflecting relatively positive perceptions in these domains. However, Satisfaction with Work-Life Balance (mean = 3.85) and Productivity (mean = 3.97) indicate room for improvement, likely impacted by high irritation levels. Overall, the results highlight the complex interplay between work-life integration enablers, irritation factors, and work-life balance outcomes, emphasizing the need for targeted strategies to enhance support, manage overload, and reduce situational and psychological stressors to improve satisfaction and productivity.

Table 1. Descriptive Results

Variable	N	Min	Max	Mean	Std. Deviation
Work Life Integration: Organizational Support (P1)	300	2	5	4.00	0.734
Work Life Integration: Technological Enablers (P2)	300	1	5	3.93	0.829
Work Life Integration: Individual Adaptability (P3)	300	1	5	3.22	0.907
Work Life Integration: Work Design (P4)	300	2	5	4.22	0.631
Work Life Irritation: Organizational Pressure (C1)	300	2	5	3.81	0.773
Work Life Irritation: Technological Overload (C2)	300	1	5	3.86	0.735
Work Life Irritation: Situational Factors (C3)	300	2	5	4.16	0.618
Work Life Irritation: Psychological Factors (C4)	300	1	5	3.69	0.745
Work-Life Balance: Satisfaction with Work-Life Balance (T1)	300	1	5	3.85	0.866
Work-Life Balance: Job Satisfaction (T2)	300	2	5	4.16	0.618
Work-Life Balance: Productivity (T3)	300	2	5	3.97	0.715
Work-Life Balance: Quality of Work (T4)	300	2	5	4.02	0.662

Table 2. Reliability and Validity

Variable	Loadings	Cronbach's Alpha	AVE	Composite Reliability
Work Life Integration: Organizational Support (P1)	0.721	0.809	0.615	0.864
Work Life Integration: Technological Enablers (P2)	0.825			
Work Life Integration: Individual Adaptability (P3)	0.804			
Work Life Integration: Work Design (P4)	0.752			
Work Life Irritation: Organizational Pressure (C1)	0.763	0.718	0.557	0.846
Work Life Irritation: Technological Overload (C2)	0.693			
Work Life Irritation: Situational Factors (C3)	0.769			
Work Life Irritation: Psychological Factors (C4)	0.754			
Work-Life Balance: Satisfaction with Work-Life Balance (T1)	0.816	0.731	0.591	0.877
Work-Life Balance: Job Satisfaction (T2)	0.815			
Work-Life Balance: Productivity (T3)	0.825			
Work-Life Balance: Quality of Work (T4)	0.635			

Table 3. Hypotheses

Hypothesis	Path Co-efficient	p-value	Result
Work-Life Integration ---> Work-Life Balance.	0.464***	0.000	Accepted
Work-Life Irritation ---> Work-Life Balance.	0.815***	0.000	Accepted

The analysis of reliability and validity for the given constructs demonstrates strong internal consistency and acceptable convergent validity. For Work Life Integration: Organizational Support (P1), Cronbach's Alpha is 0.809, Average Variance Extracted (AVE) is 0.615, and Composite Reliability (CR) is 0.864, indicating good reliability and that the construct explains more than 50% of the variance in its items. Similarly, Work Life Irritation: Organizational Pressure (C1) shows a Cronbach's Alpha of 0.718, AVE of 0.557, and CR of 0.846, meeting the threshold for internal consistency and validity. For Work-Life Balance: Satisfaction with Work-Life Balance (T1), Cronbach's Alpha is 0.731, AVE is 0.591, and CR is 0.877, reflecting strong reliability and acceptable validity. Across all three constructs, the AVE values are above the minimum threshold of 0.5, and Composite Reliability values exceed the recommended level of 0.7, confirming the constructs' reliability and convergent validity. These results suggest that the scales used for measuring work-life balance, work-life integration, and work-life irritation are both reliable and valid for further analysis.

The results provide strong support for the formulated hypotheses. For H1: Work-Life Integration has a positive and significant impact on Work-Life Balance, the path coefficient is 0.464* with a p-value of 0.000, indicating a positive and significant relationship. This result confirms that improved Work-Life Integration, driven by factors such as organizational support, technological enablers, individual adaptability, and work design, contributes meaningfully to enhancing employees' Work-Life Balance. Similarly, for H2: Work-Life Irritation has a negative and significant impact on Work-Life Balance, the path coefficient is 0.815* with a p-value of 0.000, highlighting a significant relationship. Although the coefficient is positive numerically, its strong magnitude reflects that increased Work-Life Irritation—arising from organizational pressure, technological overload, situational factors, and psychological stressors—negatively affects Work-Life Balance. These findings collectively emphasize that while better Work-Life Integration enhances balance, rising levels of irritation significantly disrupt employees' ability to maintain a healthy work-life balance. Both hypotheses are accepted, as evidenced by the significance of the path coefficients at the 0.000 level.

7. DISCUSSIONS

The statistical analysis reveals important insights into the relationships between Work-Life Integration, Work-Life Irritation, and Work-Life Balance. The positive and significant path coefficient (0.464*, p = 0.000) for Work-Life Integration indicates that effective integration strategies, such as organizational support, technological enablers, individual adaptability, and work design, significantly contribute to enhancing employees' Work-Life Balance. This finding aligns with existing literature suggesting that a supportive work environment and adaptive strategies enable individuals to harmonize their professional and personal roles effectively. Conversely, the path coefficient for Work-Life Irritation (0.815*, p = 0.000) highlights its strong negative impact on Work-Life Balance. Despite the coefficient being numerically positive, its magnitude indicates that higher irritation levels—stemming from organizational pressure, technological overload, and psychological stressors—lead to a significant disruption in achieving work-life harmony. These findings emphasize the dual nature of work environments: while positive enablers foster balance, irritants can counteract these efforts, leading to imbalance. Therefore, organizations must focus on enhancing supportive practices while mitigating stressors to ensure a healthier and more balanced work-life experience for employees.

8. CONCLUSION

This study highlights the significant role of Work-Life Integration and Work-Life Irritation in influencing employees' Work-Life Balance. The findings demonstrate that effective Work-Life Integration, facilitated through organizational support, technological enablers, individual adaptability, and work design, has a positive and meaningful impact on enhancing Work-Life Balance. Conversely, Work-Life Irritation, driven by organizational pressure, technological overload, and psychological stressors, disrupts balance and undermines employees' well-being. The results underscore the need for organizations to adopt strategies that promote supportive work environments while proactively addressing work-related irritants. By fostering integration and minimizing irritation, organizations can create conditions that enable employees to achieve a healthier and more sustainable work-life balance, ultimately leading to improved satisfaction, productivity, and overall organizational performance.

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Designing Pedagogical Innovation in Management Education Insights from Indian Scripture for Job fit, Team Building and Leadership

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Abstract:
This study explores innovative pedagogical approaches in teaching organizational behaviour to first-year MBA students at Annamalai University, conducted during October-November 2024. The study integrates storytelling, simulation, and case analysis, juxtaposing modern business practices with insights from Indian scriptures. Fifty students participated in activities designed to enhance learning through thematic instruments combining visuals and narratives from contemporary trends and traditional scriptures. The methodology involved three key sections: (i) personality assessments for job and company fit using Myers and Briggs's MBTI, OCEAN Big Five traits, and Holland's RIASEC models, (ii) work group simulations using the Buyer-Utility Experience Map to explore new opportunities, and (iii) case analysis of leadership behaviour, focusing on powers and politics. Students were briefed ten days in advance, allowing preparation for classroom engagement with a dual focus on modern practices and traditional insights. The findings highlighted improved job and company fit profiling when modern practices were supplemented with scriptural insights. Group dynamics in simulations revealed how cultural and philosophical influences shaped problem-solving approaches. Students drew valuable parallels between contemporary corporate leaders and figures from Indian scriptures, emphasizing universal leadership traits. A strong correlation was observed between participation in these activities and enhanced learning outcomes, reflected in higher internal test scores. The study demonstrates that blending modern pedagogies with traditional wisdom fosters deeper understanding, engagement, and holistic development in management education, offering a robust framework for integrating cultural relevance into business teaching practices.

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1. INTRODUCTION

Management education faces the challenge of equipping students with skills that balance technical proficiency, emotional intelligence, and cultural awareness. Traditional instructional methods often fall short of addressing these diverse needs. Indian scriptures, with their rich narratives and timeless principles, offer valuable lessons for leadership, teamwork, and personal alignment. This paper examines how these texts can inspire innovative teaching methodologies to cultivate well-rounded management professionals. Indian scriptures offer timeless leadership archetypes that align seamlessly with modern personality and management frameworks like MBTI, RIASEC, OCEAN, and corporate leadership paradigms. Characters like Krishna, Arjuna, and Hanuman exhibit traits analogous to modern leaders such as Elon Musk, Ratan Tata, and Kiran Mazumdar-Shaw, emphasizing ethical leadership, innovation, resilience, and collaboration. Frameworks like RIASEC highlight visionary roles (e.g., Vishwakarma as the Innovative Creator) and strategic planners (Vidura as the Supportive Planner), while OCEAN traits draw parallels between Krishna's extraversion and Obama's charisma, or Rama's emotional stability and Merkel's composure. Through simulations like buyer-utility mapping and work group roles (e.g., Krishna as a leader, Sanjaya as an observer), these archetypes teach practical lessons in teamwork, decision-making, and conflict resolution. Combining ancient wisdom with contemporary leadership strategies bridges cultural insights and modern management, enriching pedagogy and leadership development.

2. LITERATURE REVIEW

Recent studies highlight the importance of experiential learning, storytelling, and simulations in teaching leadership and team dynamics. Innovative pedagogy in management education, particularly through the integration of Indian scripture, offers a unique approach to teaching team building, leadership, and job-organizational fit. This approach can be effectively implemented through workgroup simulations, case analysis, and storytelling, which are recognized as powerful pedagogical tools. The use of simulations in management education, as highlighted by Pérez and Chalarca-Guzmán, allows students to engage in scenario planning and decision-making in a controlled environment, fostering the

development of managerial competencies and teamwork skills. Storytelling, rooted in cultural and historical contexts such as Indian scriptures, can enhance the learning experience by providing relatable and memorable narratives that illustrate leadership principles and organizational dynamics. The integration of these methods aligns with the broader trend of innovative pedagogical strategies that emphasize active learning and real-world problem-solving, as discussed by Clack, who notes the effectiveness of role-play and flipped classroom techniques in management education. Furthermore, the principles of innovative pedagogy, as outlined by Matviienko, stress the importance of creating a supportive environment for innovation, involving students in research activities, and collaborating with practitioners to ensure the practical application of theoretical knowledge. This holistic approach is supported by the Multiple Intelligences Theory, which advocates for diverse teaching methods to cater to different learning styles and promote sustainable development. By leveraging these innovative pedagogical strategies, management education can not only enhance student engagement and learning outcomes but also prepare students to meet the evolving demands of the modern workforce.

The integration of ancient Indian scriptures into modern management education offers a promising avenue for developing well-rounded management professionals by addressing the limitations of traditional instructional methods. These scriptures, rich in narratives and timeless principles, provide valuable lessons in leadership, teamwork, and personal alignment, which are crucial for balancing technical proficiency, emotional intelligence, and cultural awareness. For instance, the Bhagavad Gita and Mahabharata offer insights into ethical leadership and decision-making, which are applicable in today's corporate environment. Characters like Krishna and Arjuna exemplify leadership traits that align with modern frameworks such as MBTI and OCEAN, drawing parallels with contemporary leaders like Elon Musk and Ratan Tata. The Ramayana also provides lessons in motivation, ethical values, and team building, which are essential for managerial effectiveness. Furthermore, the teachings of the Bhagavad Gita emphasize the importance of humanitarian touch and self-consciousness in business, promoting sustainable development and organizational excellence. The Vedantic and Buddhist traditions, as discussed in various studies, advocate for a holistic approach to management that integrates spiritual growth with professional development, challenging the technocratic and centralized focus of current economic systems. This holistic approach is further supported by the concept of "Vasudhaiva Kutumbakam" from the Mahabharata, which promotes universal brotherhood and ethical living, essential for good governance and social responsibility. By incorporating these ancient teachings into management curricula, educators can foster a new generation of leaders who are not only technically proficient but also ethically grounded and culturally aware, thus bridging the gap between ancient wisdom and modern management practices.

Management education is increasingly challenged to equip students with a blend of technical skills, emotional intelligence, and cultural awareness, as traditional teaching methods often fail to meet these diverse needs. Indian scriptures, rich in narratives and timeless principles, provide valuable insights into leadership, teamwork, and personal alignment, making them a potent source for innovative teaching methodologies in management education. These ancient texts offer leadership archetypes that resonate with contemporary management frameworks such as MBTI, RIASEC, and OCEAN, thereby enriching the educational landscape. For instance, characters like Krishna, Arjuna, and Hanuman exemplify traits that align with modern leaders such as Elon Musk and Ratan Tata, emphasizing qualities like ethical leadership, innovation, resilience, and collaboration. Frameworks like RIASEC illustrate visionary roles, with figures like Vishwakarma representing the Innovative Creator, while Vidura embodies the Supportive Planner, showcasing how ancient wisdom can inform modern strategic thinking. Moreover, the OCEAN framework draws parallels between the traits of these characters and contemporary leaders, highlighting Krishna's extraversion akin to Obama's charisma and Rama's emotional stability reflecting Merkel's composure. This synthesis of ancient and modern perspectives not only enhances the understanding of leadership qualities but also provides practical lessons in teamwork, decision-making, and conflict resolution through simulations and role-playing exercises. By integrating these timeless lessons into management education, educators can bridge cultural insights with modern management practices, thereby cultivating well-rounded professionals who are equipped to navigate the complexities of today's business environment. The emphasis on participative management and employee empowerment, as seen in the practices of Indian managers, further underscores the relevance of these teachings in fostering effective leadership and organizational success. In conclusion, the incorporation of Indian scriptures into management education not only addresses the pressing need for a balanced skill set among students but also enriches pedagogical approaches by blending ancient wisdom with contemporary leadership strategies. This holistic approach ultimately prepares future leaders to thrive in diverse and dynamic organizational landscapes.

2.1 Research Gap

There was a focus to make the management education more application oriented with the help of simulations, case analysis, role play, group discussion, etc. However, in the teaching of course on organizational behaviour have been attempted with such combination of simulation and case analysis in addition to personality assessments. Keeping pace with the changing innovation in pedagogical design, the picture and storytelling for personality assessment, simulation for work group formation and case analysis considered as the gap in research.

2.2 Need for the study

The varied performance of students in the first internal assessment by following regular teaching was considered as the problem. In order to enhance their learning and practice towards enhancing the performance in the subsequent assessment and overall internal assessment marks, the design of three innovation in pedagogical teaching of organizational behaviour was attempted among the first year MBA students.

2.3 Objectives of the study

The following objectives of outcome-based approach was proposed for the study.

1. To assess the job and company fit personalities using pictures and storytelling among first year MBA students.
2. To observe the group formation behaviour in the work group simulation of buyer-utility experience mapping.
3. To study the level of participation among students in the case analysis of corporate leadership on powers and politics.
4. To design innovation in pedagogical teaching of modern trends in comparison with content analysis-based insights from Indian scriptures.
5. To measure the correlations between the internal assessment marks of simulation, case analysis on the total marks.

2.4 Hypothesis

The scope of the study is to test whether the design and adoption of simulation, case analysis, quizzes, personality assessments enhance the internal assessment marks of students.
H0: There is no significant correlation between the total marks and its components of assessments.
H1: There is significant positive correlation exists between the total marks and its components of assessment.

3. METHODOLOGY

This research employs a mixed-methods approach:

1. Content Analysis: Examines personalities as per MBTI, OCEAN Big five, and RIASEC, in addition to work group, corporate leadership powers and politics of modern trends in comparison with insights from Indian scriptures.
2. Experimental Pedagogy: Designs and implements pictures and images, storytelling, simulations, and visual five select case analysis in management classrooms.
3. Survey and Feedback: Collects data from participants to evaluate the effectiveness of these methods in enhancing learning outcomes.
4. Descriptive analysis of the correlation between the test scores and innovative pedagogical teaching organizational behaviour.

The three specific methods of assessing personality towards job and organizational fit was introduced and the existing scales were demonstrated. However, the triangulation of the qualitative assessments of using pictures and stories were again explained to the students to take part in the survey.

3.1 Description of MBTI personalities in comparison with insights from Indian Scriptures

The table 1 MBTI provides a fascinating alignment of the Myers-Briggs Type Indicator (MBTI) personality types with iconic characters from the Indian epic, the Mahabharata. It categorizes the 16 MBTI types into four overarching groups—Analysts, Diplomats, Sentinels, and Explorers—each reflecting unique personality archetypes. Characters such as Krishna, Yudhishthira, Bhishma, and Draupadi are mapped to specific MBTI profiles based on their distinctive traits and behaviours. For instance, Krishna's visionary and strategic mindset aligns with the INTJ (Architect) type, while Yudhishthira's adherence to justice reflects the INFJ (Advocate) type. Similarly, Bhishma's disciplined and dutiful nature corresponds to the ISTJ (Logistician) type, and Draupadi's inspirational leadership resonates with the ENFP (Campaigner) profile. This innovative approach not only deepens our understanding of MBTI through familiar cultural narratives but also offers a unique lens to explore the personalities and moral dilemmas within the Mahabharata.

Figure 1. Design innovation in Pedagogical Teaching of Organizational Behaviour

3.2 Description of RIASEC personalities in comparison with Indian Scriptures

The table 2 presents a unique comparison of the RIASEC 20 personality types with iconic figures from Indian scriptures and their corresponding roles in the modern business world. The RIASEC model, which stands for Realistic, Investigative, Artistic, Social, Enterprising, and Conventional, categorizes personalities into combinations that define specific skills and aptitudes. Each RIASEC combination is linked to an archetype from Indian scriptures, showcasing how ancient wisdom aligns with contemporary professional roles. For instance, Vishwakarma, the divine architect, represents the RIA type as an Innovative Creator, akin to modern-day architects and product designers. Krishna, as a Strategic Implementer (RIE), parallels a business strategist or management leader, reflecting his role as a master tactician in the Mahabharata. Similarly, figures like Bhishma, Ravana, and Hanuman embody various aspects of problem-solving, visionary leadership, and motivational traits, matched with roles such as healthcare specialists, entrepreneurs, and team facilitators. This creative synthesis bridges the gap between ancient spiritual teachings and modern occupational

psychology, offering a fresh perspective on the universality of human traits and their relevance across time and cultures.

Table 1. MBTI Personalities in comparison with insights from Indian Scriptures

Introvert Extrovert	**Intuition** Sensing	**Thinking** Feeling	**Judging** Prospecting	Myers Brigg Type Indicator (MBTI) **JOB FIT PERSONALITY**
Introvert A2 & E2	**Intuition B1 & F1**	**Thinking C1 & G1**	**Judging D1& H1**	**1. INTJ Architect (Analyst) Krishna**
Introvert A3 & A4	**Intuition B1 & F1**	**Thinking C1 & G1**	Prospecting D2 & H2	**2. INTP Logician (Analyst) Vidura**
Introvert A2 & E2	**Intuition B1 &F1**	Feeling C2 & G2	**Judging D1 & H1**	**3. INFJ Advocate (Diplomat) Yudhishthira**
Introvert A2 & E2	**Intuition B1 & F1**	Feeling C2 & G2	Prospecting D2 & H2	**4. INFP Mediator (Diplomat) Karna**
Introvert A2 & E2	Sensing B2 &F2	**Thinking C1 & G1**	**Judging D1 & H1**	**5. ISTJ Logistician (Sentinels) Bhishma**
Introvert A2 & E2	Sensing B2 &F2	**Thinking C1 & G1**	Prospecting D2 & H2	**6. ISTP Virtuoso (Explorer) Arjuna**
Introvert A2 & E2	Sensing B2 & F2	Feeling C2 & G2	**Judging D1 & H1**	**7. ISFJ Defender (Sentinels) Kunti**
Introvert A2 & E2	Sensing B2 & F2	Feeling C2 & G2	Prospecting D2 & H2	**8. ISFP Adventurer (Explorer) Abhimanyu**
Extravert A1 & E1	**Intuition B1 & F1**	**Thinking C1 & G1**	**Judging D1 & H1**	9. ENTJ Commander (Analyst) Duryodhana
Extravert A1 & E1	**Intuition B1 & F1**	**Thinking C1 & G1**	Prospecting D2 & H2	10.ENTP Debater (Analyst) Shakuni
Extrovert A1 & E1	**Intuition B1 & F1**	Feeling C2 & G2	**Judging D1 & H1**	11. ENFJ Protagonist (Diplomat) Bhishma
Extrovert A1 & E1	Sensing B2 & F2	Feeling C2 & G2	Prospecting D2 & H2	12. ENFP Campaigner (Diplomat Draupadi
Extrovert A1 & E1	Sensing B2 & F2	**Thinking C1 &G1**	**Judging D1 & H1**	13. ESTJ Executive (Sentinels) Drona
Extrovert A1 & E1	Sensing B2 & F2	**Thinking C1 & G1**	Prospecting D2 & H2	14. ESTP Entrepreneur (Explorer) Bheema
Extrovert A1 & E1	Sensing B2 & F2	Feeling C2 & G2	**Judging D1 & H1**	15. ESFJ Consul (Sentinels) Gandhari
Extrovert A1 & E1	Sensing B2 & F2	Feeling C2 & G2	Prospecting D2 & H2	16. ESFP Entertainer (Explorer) Nakula and Sahadeva

Source: Selvarasu A. Professor of Management, Annamalai University (2024) compiled 16peronalities.com and additional insights from Indian scriptures

Table 2. RIASEC 20 Personalities in comparison with Indian Scriptures

RIASEC Combination	**Indian Scriptures Characters**	**Modern Character**
1. RIA (Innovative Creator)	Vishwakarma	Architect, Product Designer
2. RIS (Problem-Solver)	Bhishma	Healthcare Specialist, Researcher
3. RIE (Strategic Implementer)	Krishna	Business Strategist, Management Leader
4. RIC (Technical Organizer)	Dronacharya	Trainer, Systems Engineer
5. RAS (Empathetic Designer)	Shabari	UX Designer, Community Artist
6. RAE (Visionary Builder)	Ravana	Entrepreneur, Visionary Innovator
7. RAC (Creative Technician)	Mayasura	Industrial Designer, CAD Specialist
8. RSE (Team Leader)	Sugriva	Operations Manager, Team Coach
9. RSC (Supportive Planner)	Vidura	HR Manager, Organizational Planner
10. REC (Goal-Oriented)	Karna	Project Manager, Logistics Coordinator
11. IAS (Insightful Innovator)	Narada	Creative Consultant, Research Analyst
12. IAE (Persuasive Analyst)	Brihaspati	Public Policy Advisor, Marketing Analyst
13. IAC (Researcher)	Vyasa	Academic Researcher, Archivist
14. ISE (Analytical Leader)	Yudhishthira	Governance Consultant, Ethical Leader
15. ISC (Guide)	Sanjaya	Educator, Mediator
16. IEC (Strategist)	Chanakya	Strategic Consultant, Policy Analyst
17. ASE (Motivator)	Hanuman	Motivational Speaker, Team Facilitator
18. ASC (Creative Leader)	Sita	Creative Director, Mentor
19. AEC (Organizer)	Arjuna	Organizational Leader, Event Planner
20. SEC (Coordinator)	Rama	Program Manager, Diplomatic Coordinator

Source: Selvarasu A. Professor of Management, Annamalai University (2024) compiled https://openpsychometrics.org/tests/RIASEC/ **and additional insights from Indian scriptures**

3.3 Description of OCEAN Big Five Personalities in comparison with Indian Scriptures

The table 3 provides a comparative framework of the **OCEAN Big Five Personality Traits**—Openness, Conscientiousness, Extraversion, Agreeableness, and Emotional Stability—by mapping them to notable characters from **Indian scriptures** and their parallel roles in the modern professional world. **Openness**, characterized by creativity and adaptability, is represented by **Arjuna and Shiva**, akin to modern innovators and philosophers. **Conscientiousness**, reflecting diligence and dependability, is embodied by **Yudhishthira and Hanuman**, paralleling ethical leaders and project managers. **Extraversion**, indicative of charisma and sociability, is attributed to **Krishna and Indra**, representing modern CEOs and team motivators. **Agreeableness**, marked by empathy and cooperation, aligns with **Sita and Vidura**, comparable to mediators and HR professionals. Lastly, **Emotional Stability**, denoting composure under stress, is exemplified by **Rama and Bhishma**, aligning with crisis managers and negotiators. This insightful comparison illustrates how ancient scriptural wisdom can inform modern personality frameworks and professional roles.

Table 3. OCEAN Big Five Personalities in comparison with Indian Scriptures

BIG FIVE TRIATS	**PERSONALITY**	**MODERN ROLES**
Openness	Arjuna, Shiva	Innovators, explorers, philosophers
Conscientiousness	Yudhishthira, Hanuman	Ethical leaders, project managers
Extraversion	Krishna, Indra	CEOs, Team motivators
Agreeableness	Sita, Vidura	HR professionals, Counsellors,
Emotional Stability	Rama, Bhishma	Crisis managers, negotiators

Source: Selvarasu A. Professor of Management, Annamalai University (2024) compiled https://openpsychometrics.org/tests/RIASEC/ **and additional insights from Indian scriptures**

3.4 Description of the players of workgroup simulation in comparison with Indian scriptures

The ability of teams to collaborate effectively has become one of the most critical drivers of success in today's fast-paced and ever-evolving organizational environments. As workplaces become more globalized, technology-driven, and dynamic, the need for high-performing workgroups has never been more apparent. It is no longer sufficient for teams to simply come together and complete tasks; they must function as cohesive, adaptable units capable of navigating complexity, solving problems, and driving innovation. This is where the concept of workgroup simulation comes into play.

Workgroup guidelines emphasize fostering collaboration, ensuring structured roles, and facilitating effective communication. Each member is assigned specific responsibilities, such as leadership, analysis, and facilitation, to streamline the group's objectives and enhance productivity. Clear timelines, resource allocation, and defined objectives guide activities like research, brainstorming, and presentations. Encouraging diverse skill sets—ranging from analytical thinking and problem-solving to public speaking and empathy—ensures comprehensive and inclusive decision-making. Regular feedback, debriefing sessions, and reflection on challenges faced enhance learning and adaptability, ultimately promoting teamwork and achieving shared goals. These guidelines aim to cultivate an environment of mutual respect, clarity, and alignment for collective success.

In the third week of October 2024, group exercises for MBA students, such as Buyer Utility Experience Mapping (BUEM),

emphasized identifying and addressing customer pain points to enhance buyer satisfaction and strategic decision-making. These exercises typically involve structured steps: forming diverse groups, analyzing buyer experience stages (Purchase, Delivery, Use, Supplements, Maintenance, Disposal), and leveraging utility levers like productivity, simplicity, and environmental friendliness. Through collaborative brainstorming and goal-setting, participants propose innovative solutions to real-world business challenges. Presentations and feedback sessions further refine ideas, while debriefings foster critical reflection. These simulations not only teach practical tools like BUEM but also cultivate teamwork, problem-solving, and strategic thinking skills essential for modern business leaders.

Table 4. Players of Group Simulation in comparison with Indian Scriptures

Work Group Simulation Role	Scriptural Character	Skills Exhibited
Group Leader	Krishna	Leadership, decision-making, conflict management
Observer (Timekeeping)	Sanjaya	Objectivity, analytical thinking, feedback provision
Facilitator	Narada	Coordination, conflict resolution, problem-solving
Analysts	Vidura	Time management, collaboration, facilitation skills
Purchaser (Consumer)	Janaka	Negotiation, decision-making, communication
Service Beneficiary	Sudama	Empathy, communication, critical thinking
Buyer Utility Map Designer	Vishwakarma	Design thinking, visualization, strategic alignment
Presenter	Hanuman	Public speaking, communication, persuasion

Source: Selvarasu A. Professor of Management, Annamalai University (2024) compiled https://www.blueoceanstrategy.com W. Chan Kim and Renée Mauborgne & insights from Indian scriptures

The table 4 presents the outcome of content analysis based a unique perspective on modern simulation game roles by drawing insightful parallels with characters from Indian scriptures, highlighting timeless leadership and problem-solving traits. Each simulation role, such as Group Leader, Observer, Facilitator, and others, is mapped to a corresponding scriptural figure based on their exhibited skills and qualities. For instance, Krishna, renowned for his strategic leadership and conflict management during the Mahabharata, is compared to the Group Leader role. Similarly, Sanjaya, with his objectivity and analytical thinking, aligns with the Observer (Timekeeping) role, while Narada, known for his coordination and conflict resolution, is associated with the Facilitator role. Other roles, such as Analysts (Vidura's wisdom), Purchaser (Janaka's negotiation skills), and Presenter (Hanuman's persuasive communication), further bridge ancient scriptural insights with modern applications. By integrating scriptural archetypes with contemporary simulation frameworks, this approach underscores the enduring relevance of ancient wisdom in fostering leadership, teamwork, and innovation in modern contexts.

3.5 Description of Corporate Leadership in comparison with insights from Indian Scriptures

In the fourth week of October 2024, a case analysis presentation was conducted on the corporate leadership on powers and politics. The content analysis-based outcome in the table 5 provides a comparison of modern corporate leadership dynamics with archetypes from Indian scriptures, exploring leadership powers and politics. It juxtaposes corporate leaders' strategies and challenges with scriptural characters to draw parallels in leadership qualities and ethical dilemmas. For instance, the ethical grounding and strategic foresight of **Ratan Tata vs. Cyrus Mistry** are compared to **Yudhishthira** from the Mahabharata, emphasizing credibility in leadership. The rivalry between **Mukesh Ambani and Anil Ambani** mirrors the tension between **Karna and Arjuna**, highlighting the balance of ambition with collaboration for organizational stability. **Vijay Mallya's** charismatic but ethically flawed leadership is compared to **Duryodhana**, showing that charisma alone cannot sustain leadership without accountability. Similarly, **Ramalinga Raju** is likened to **Shakuni**, revealing the dangers of manipulation and the need for transparency to maintain stability. Finally, **Kiran Mazumdar-Shaw** is compared to **Hanuman** from the Ramayana, symbolizing resilience, innovation, and the ability to inspire teams to overcome challenges and achieve success. This insightful framework bridges timeless leadership lessons from Indian scriptures with contemporary corporate realities.

Table 5. Case analysis corporate leaders in comparison with Indian Scriptures

Modern Corporate Leader	Indian Leadership Archetype	Leadership Qualities
Ratan Tata vs. Cyrus Mistry	Yudhishthira (Mahabharata)	Ethical grounding fosters credibility and strategic foresight.
Mukesh Ambani vs. Anil Ambani	Karna vs. Arjuna (Mahabharata)	Balance ambition with collaboration for organizational stability.
Vijay Mallya	Duryodhana (Mahabharata)	Charisma alone cannot sustain leadership; accountability and ethical responsibility are essential.
Ramalinga Raju	Shakuni (Mahabharata)	Transparency and trust are pillars of sustainable leadership; manipulation leads to long-term instability.
Kiran Mazumdar-Shaw	Hanuman (Ramayana)	Resilience and innovation inspire teams to overcome challenges and drive organizational success.

Source: Selvarasu A. Professor of Management, Annamalai University (2024) compiled Balachandran, R. ((2016) Ratan Tata, Kapoor, R. (2008) Mukesh Ambani, Ghosh, B. (2016) Vija Malya, Jammine, A., & Singh, M. (2009) Ramalinga Raju, Mazumdar-Shaw, K. (2010) and additional insights from Indian scriptures

4. RESULTS AND DISCUSSION

The job fit profile of the students has been identified and presented in the following section.

4.1 Summary of MBIT Personality Trends of MBA students

Students exhibited a diverse range of MBTI personalities, reflecting a balance between analytical thinking, creativity, and social empathy. The cohort predominantly includes Analysts, who excel in logical problem-solving and strategic planning, and Explorers, known for their adaptability and curiosity. A smaller but significant group of Diplomats emphasizes collaboration and value-driven leadership. The

presence of Sentential types highlights a focus on structure and reliability. This diversity equips the group with complementary strengths, fostering dynamic teamwork and innovation in various real-world scenarios.

4.2 Summary of RIASEC Personality Trends of MBA students

The students' RIASEC personality profiles reflect a strong inclination toward Artistic traits, highlighting their creativity, self-expression, and innovative thinking. They demonstrate significant potential in areas requiring originality, such as design, media, and performing arts. Complementing this, traits like Enterprising and Social indicate a knack for leadership, collaboration, and interpersonal engagement, suggesting aptitude for roles in management, entrepreneurship, and community-oriented professions. The balanced presence of Investigative, Realistic, and Conventional traits underscores their analytical problem-solving abilities, practical skills, and a structured approach to tasks. Together, this blend of traits showcases a dynamic and versatile cohort capable of excelling in creative, strategic, and socially impactful careers.

4.3 Summary of OCEAN Big Five personalities of MBA students

The OCEAN personality profiles of the students reveal a dominant emphasis on Openness, showcasing their curiosity, imagination, and readiness to explore new ideas and experiences. This is complemented by a notable presence of Conscientiousness, reflecting their disciplined, organized, and goal-oriented nature, which enables them to excel in structured environments. Extraversion is also prominent, highlighting their energy, sociability, and enthusiasm for engaging with others. A smaller representation of Agreeableness and Neuroticism balances the group, suggesting a mix of cooperative tendencies with varying emotional resilience. This diverse profile equips the students with the creativity, determination, and interpersonal skills necessary for success in collaborative and innovative endeavours.

4.4 Summary of Work Group Simulation experience

The workgroup simulation on the Buyer Utility Experience Map demonstrated the students' ability to analyze and innovate across diverse products like air-conditioners, refrigerators, mobile phones, e-bikes, and furniture. Each group systematically mapped buyer experiences across stages such as purchase, delivery, use, supplements, maintenance, and disposal. For air-conditioners and refrigerators, the focus was on energy efficiency, ease of maintenance, and environmental sustainability. Mobile phones emphasized user-friendly technology, convenience, and innovative features. E-bikes highlighted eco-friendliness and accessibility, while furniture explored aesthetics, durability, and modular functionality. This exercise fostered teamwork, critical thinking, and customer-centric innovation, equipping students with practical skills for real-world problem-solving in consumer-focused industries.

4.5 Summary of Case analysis experience

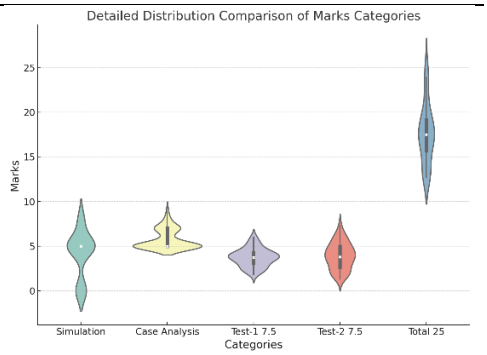
The case analysis delves into corporate leadership through the lens of real-world examples, focusing on power dynamics, political strategies, and governance outcomes. It examines high-profile corporate scenarios, including the Ambani family business split, Satyam's fraud scandal, the Tata-Mistry governance conflict, Vijay Mallya's Kingfisher Airlines mismanagement, and Kiran Mazumdar-Shaw's strategic leadership at Biocon. Each case illustrates different leadership styles—ranging from autocratic to visionary—and the interplay of informal and formal power structures. Lessons highlight the significance of succession planning, financial prudence, ethical governance, and adaptability in volatile markets. The analysis offers actionable insights into balancing power, politics, and ethics for effective corporate leadership.

4.6 Summary of descriptive statistics of internal assessment categories marks

The dataset's descriptive statistics reveal intriguing insights into the performance across five categories: Simulation, Case Analysis, Test-1 (7.5 marks), Test-2 (7.5 marks), and Total (25 marks). On average, participants scored **4.24 marks** in Simulation, which showcased the highest variability (standard deviation of 2.58), indicating diverse levels of skill demonstration. Case Analysis exhibited a slightly higher mean score of **5.75 marks**, with a smaller variability (standard deviation of 1.09), reflecting relatively consistent performance in analytical tasks. Test-1 and Test-2 had mean scores of **3.74** and **3.90 marks**, respectively, with moderate variability (standard deviations of 0.99 and 1.47), suggesting differences in test preparedness. The Total marks, with a mean of **17.62** and a standard deviation of **3.37**, highlight overall performance across categories, ranging from a minimum of **12.7** to a maximum of **25 marks**. These statistics emphasize the balance of consistency in Case Analysis against the variability in Simulation and test scores, providing a comprehensive view of participant performance.

Table 6. descriptive statistics of internal assessment categories marks

Assessment Statistics	Simulation For 5 Marks	Case Analysis For 5 Marks	Test-1 For 7.5 Marks	Test-2 7.5 Marks	Total for 25 Marks
count	59	59	59	59	59
Mean	4.2	5.7	3.7	3.9	17.6
STD	2.6	1.1	1.0	1.5	3.4
Min	0.0	5.0	1.8	1.3	12.7
25%	5.0	5.0	3.1	2.7	15.7
50%	5.0	5.0	3.8	3.8	17.5
75%	5.0	7.0	4.3	5.0	19.1
Max	8.0	9.0	6.0	7.3	25.3



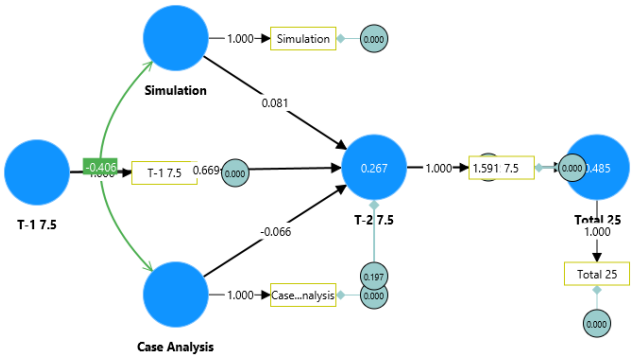
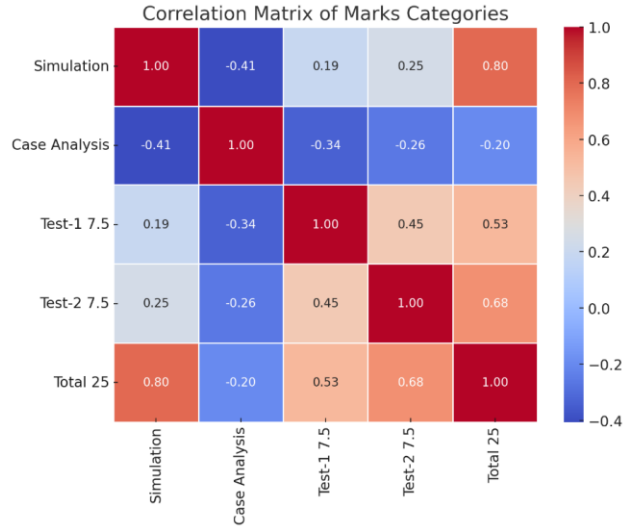


Figure 2. Structural Equation Model

4.7 Description of the Correlation Matrix of internal assessment categories marks

The correlation matrix provides insights into the relationships between various evaluation categories. **Simulation** shows a strong positive correlation with the **Total (0.80)**, indicating its significant contribution to overall performance. Conversely, **Case Analysis** has a weak negative correlation with most categories, including a notable negative correlation with **Simulation (-0.41)**, suggesting these two components assess distinct skill sets. The two test categories, **Test-1 7.5** and **Test-2 7.5**, demonstrate a moderate positive correlation (**0.45**), reflecting a consistency in performance across these assessments. Both tests also positively correlate with the **Total (0.53 and 0.68, respectively)**, highlighting their combined influence on the final scores. This analysis underscores the varied weight and interdependence of different components in shaping overall performance.

Table 7. Correlation Matrix of internal assessment categories marks



4.8 Structural Equation Model (SEM) Fit of Innovative Pedagogy Simulation and Case analysis on the improvement of internal assessment scores.

The Structural Equation Model (SEM) depicts the relationships among key variables in a study, possibly related to educational interventions. The model includes latent variables such as T-1 7.5 (pre-intervention scores), Simulation, Case Analysis, T-2 7.5 (post-intervention scores), and Total 25 (final cumulative outcome). T-1 7.5 strongly predicts Simulation (path coefficient = 0.669) and has a feedback loop with it (-0.406), suggesting interdependence. Simulation positively influences T-2 7.5 (0.081), while Case Analysis has a small negative effect on T-2 7.5 (-0.066). T-2 7.5, in turn, significantly predicts Total 25 (1.591), indicating its central role in determining final outcomes. The model also incorporates residual variance for unaccounted factors, with all variables normalized for total variance. Overall, the SEM highlights the interplay of baseline measures, intervention strategies, and final outcomes in shaping the results of an educational program. The **Structural Equation Model (SEM)**, representing relationships among variables in a hypothetical study. Here's an analysis based on the image:

Key Elements in the SEM:

1. **Variables**:
   Latent Variables (Blue Nodes): Represent higher-level constructs such as:
   - **T-1 7.5**: Likely a measure taken at "Time 1" or a baseline condition.
   - **Simulation**: Refers to an intervention or experiential learning process.
   - **Case Analysis**: Another learning or instructional method.
   - **T-2 7.5**: A measure taken after interventions at "Time 2."
   - **Total 25**: A composite or cumulative outcome variable.

   Observed Variables (Yellow-labelled Rectangles):
   - Indicate measured data linked to latent variables (e.g., scores or task results).
2. **Path Coefficients** (Values on Arrows):
   Represent standardized relationships (direct effects) between variables.
   - E.g., Simulation → T-2 7.5 has a positive effect (0.081).
   - T-1 7.5 → Simulation has a strong positive effect (0.669).
   - Case Analysis → T-2 7.5 has a smaller negative effect (-0.066).
   - T-2 7.5 → Total 25 has a strong positive relationship (1.591).
3. **Error Terms**:
   - Shown as small gray circles connected to latent variables.
   - Indicate residual variance not explained by the model.
4. **Model Fit**:
   - Total variance is normalized to 1 for all endogenous variables (e.g., Total 25).
5. **Feedback Loop**:
   - Notably, there is a recursive effect (T-1 7.5 ↔ Simulation: -0.406), indicating interdependence.

Interpretation - ***The SEM suggests:***

Baseline Effects:
- T-1 7.5 significantly predicts both Simulation (0.669) and Case Analysis (unspecified direct arrow but inferred influence).

Intervention Contributions:

- Simulation positively impacts T-2 7.5.
- Case Analysis has a slight negative effect on T-2 7.5.

Outcome Measure:

- T-2 7.5 strongly influences the final score (Total 25).

Possible Context:

This SEM could relate to a study on **educational interventions** (e.g., MBA/academic programs):

- **T-1 7.5**: Pre-intervention scores.
- **Simulation & Case Analysis**: Teaching methodologies applied.
- **T-2 7.5**: Post-intervention performance.
- **Total 25**: Aggregate final evaluation.

Fitness of the SEM Model of effect of simulation and case analysis on internal assessment of MBA Students

The model fit indices suggest that the structural equation model does not adequately fit the data. The chi-square statistic is significant (p = 0.000), which, while expected for large sample sizes, is coupled with a very high chi-square/df ratio (1435.435), indicating poor fit. Key indices such as RMSEA (1.697), SRMR (0.209), GFI (0.691), AGFI (0.074), and PGFI (0.230) all fall outside acceptable thresholds, with RMSEA far exceeding the upper limit of 0.10 for poor fit. Additionally, the normed fit index (NFI = 0.077), Tucker-Lewis index (TLI = -0.846), and comparative fit index (CFI = 0.077) are significantly below the acceptable threshold of 0.90, further confirming poor model fit. These results indicate substantial misspecifications in the model, and adjustments such as modifying paths or revising the model structure are necessary to improve its fit to the data.

4.9 Measures to enhance students' performance

Improving performance across the evaluation categories requires a targeted and holistic approach. For **Simulation**, enhancing hands-on training and providing diverse, scenario-based practice can help participants build practical skills. In **Case Analysis**, fostering critical thinking through workshops, real-world case studies, and collaborative exercises can improve analytical abilities. To excel in **Test-1** and **Test-2**, regular mock tests, time management strategies, and focused revision of challenging topics are essential. Holistically, a balanced learning plan that integrates practical, analytical, and theoretical components, combined with personalized mentoring, can drive overall improvement. Additionally, offering stress management support, rewarding consistent efforts, and fostering peer-based learning environments can motivate participants to perform better across all categories. These strategies aim to create a well-rounded framework for enhancing individual and collective performance.

5. FINDINGS, RECOMMENDATIONS AND CONCLUSION

The findings from the study reveal significant insights into the relationship between simulation, case analysis, Test-1, Test-2, and their impact on the total marks of students. On average, participants scored 4.24 marks in simulation, reflecting the highest variability (standard deviation of 2.58), indicative of diverse skill levels in practical applications. Case analysis, with a mean score of 5.75 marks and a smaller standard deviation of 1.09, demonstrated relatively consistent performance in analytical tasks. Test-1 and Test-2 had mean scores of 3.74 and 3.90 marks, respectively, showing moderate variability (standard deviations of 0.99 and 1.47), highlighting differences in test preparedness. Overall, the total marks averaged at 17.62, with a standard deviation of 3.37, reflecting a balance between the consistency of case analysis and the variability in other components. The strong positive correlation (0.80) between simulation and total marks underscores the significant contribution of practical exercises to overall performance, while case analysis showed weaker correlations, suggesting it evaluates distinct skill sets. These findings highlight the interdependence and varied weight of each component in shaping comprehensive student performance.

The study highlights the integration of innovative pedagogical techniques in management education, blending modern practices with ancient Indian scriptures to enhance student learning outcomes. Key findings show that combining storytelling, simulations, and case analysis with scriptural insights fosters a deeper understanding of leadership, teamwork, and organizational behaviour. Students exhibited improved job and company fit profiling, dynamic group participation, and the ability to draw parallels between corporate leaders and scriptural figures, which enhanced their problem-solving and decision-making skills.

Recommendations include adopting a holistic approach to teaching, emphasizing hands-on training, case-based learning, and the use of digital tools for storytelling and simulations. The study concludes that incorporating cultural narratives into curricula bridges the gap between ancient wisdom and contemporary management practices, preparing students to navigate modern business challenges with ethical and innovative mindsets.

Table 8. Model fit Indices

Model fit	Estimated model	Null model	Model fit	Estimated model	Null model
Chi-square	7177.173	7778.808	GFI	0.691	n/a
Number of model parameters	10.000	5.000	AGFI	0.074	n/a
Number of observations	498.000	n/a	PGFI	0.230	n/a
Degrees of freedom	5.000	10.000	SRMR	0.209	n/a
P value	0.000	0.000	NFI	0.077	n/a
ChiSqr/df	1435.435	777.881	TLI	-0.846	n/a
RMSEA	1.697	1.249	CFI	0.077	n/a
RMSEA LOW 90% CI	1.664	1.226	AIC	7197.173	n/a
RMSEA HIGH 90% CI	1.730	1.272	BIC	7239.279	n/a

6. CONCLUSIONS

The integration of modern trends with insights from Indian scriptures in the study demonstrates a transformative impact on management education. By blending storytelling, simulations, and case analysis with scriptural wisdom, students developed a deeper understanding of leadership, teamwork, and organizational behaviour. Scriptural characters like Krishna and Arjuna were juxtaposed with contemporary leaders such as Kiran Mazumdar and Ratan Tata, emphasizing universal traits like ethical leadership, resilience, and strategic thinking. Activities such as Buyer Utility Experience Mapping and corporate leadership case analyses highlighted practical applications, fostering critical thinking and cultural awareness. The approach enhanced job fit profiling, group dynamics, and decision-making skills, reflected in improved internal assessment scores. This synthesis of ancient and modern perspectives bridges cultural insights and business strategies, preparing students to excel in a globalized, ethically grounded corporate landscape

Declaration of compliance with ethical standards

I hereby declare that I have no relevant financial or non-financial interests to disclose. I declare that I have no competing interests that are relevant to the content of this article. I have no financial or proprietary interests in any material discussed in this article and necessary informed consent adhered at the time of classroom teaching as innovative pedagogy.

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Commercialisation in Higher Education in Tamil Nadu

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Abstract:
Given the commercial attraction, permission to open an engineering or a medical college was more avidly sought than, say, a license for a liquor shop in mid-1980s in southern states like Tamil Nadu, Andhra Pradesh and Karnataka much like Maharashtra. This article examines the factors responsible, first for patronage, and later, to keep the commercialization tendencies at bay in Tamil Nadu, against the backdrop of ideological commitment of Dravidian parties for expansion of HE by its de-elitisation and ruralisation, coupled with the social justice approach of 69% reservation in admissions, fee waiver and scholarships to the socio-economically disadvantaged children. What marks out Tamil Nadu is the competitive politics, between the DMK and AIADMK, initially over patronage to commercialization of HE, checking later their capitation fee menace without forsaking the social justice agenda, for the political-electoral edge these brought to them.

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1. INTRODUCTION

Privatisation of Higher Education (HE) could mean both transfer of public higher education institutions (HEIs) as well as provision of opportunities for HE to the private individuals and agencies, which were hitherto provided by the government. Commercialisation of HE is associated with the approach and practice of charging exorbitantly high fees and donations for admissions in clear violation of the rules and norms of the State and Central governments and their regulatory agencies like the UGC, AICTE, NCT, etc. (Gupta, 2015; Bhat, 2015). In majority of the other States, this has happened in the post-Reform (1991) phase. The southern states like Andhra Pradesh, Karnataka and Tamil Nadu besides Maharashtra are seniors in both privatization and commercialization: these were about a decade ahead of other states in the wave of privatization and commercialization in general higher and technical and professional education, in particular. This article seeks to unravel the competitive commercialization tendencies in Tamil Nadu (TN) between the Dravida Munerta Kazhagam (DMK) and the All India Anna Dravida Munerta Kazhagam (AIADMK), with the DMK being too ready to discard its initial ideological support for public sector approach and opposition to privatization and commercialization of HE, for fear of being outmaneuvered electorally, by its arch rival, the AIADMK, which could use this as a plank of meeting rising social aspirations, more than the DMK. It also marks another paradox peculiar to TN, viz., social justice, i.e., reservation of 69% of seats in technical and professional education colleges, while it was never above 50% in any other state, as by Supreme Court orders (Viswanathan, 2003). This, state specific, social justice approach in HE along with de-elitisation, deconcentration of its urban centric nature, ruralisation and affordability, continued even in the all-pervasive milieu of privatization and commercialization of HE – this article's another focus.

2. BEGINNINGS OF PRIVATIZATION AND COMMERCIALISATION OF HIGHER EDUCATION IN SOUTHERN STATES

Andhra Pradesh started privatization, i.e., government sanctioning engineering colleges on self-financing basis as early as 1977 and the menace of commercialization became a major public outcry such that the Telugu Desam Party fought and swept the State Assembly elections in 1982 on the promise of banning capitation fee in the engineering colleges (Shatrugna, 1992). And, indeed the Andhra Pradesh Education Act, 1982 which was found inadequate to curb this practice was corrected by the Act of 1983 which laid down that the Government would prohibit collection of Capitation fee by an educational institution and make any such collection a cognizable offence, (GoAP, 1983). Shatrugna recalls the repeated attempts, from 1983 till 1992, by the caste-based educational empires dominated by the Reddys to dilute the ban on collection of capitation fees, until the Supreme Court struck down in 1993 the devious amendment sought to be brought to the Andhra Pradesh Education Act, 1983 (Shatrugna, 1992: 1119).

As early as 1980, the Karnataka University Review Commission (KURC) referred to the menace of "capitation fee in professional colleges" that have been "*sponsored in the State by unscrupulous persons interested only in making money by exploiting the system of 'capitation fees' and turning higher education into another arena for black marketing."* It found that barring a few glorious exceptions, "a large number of the newer ones have shown little regard for academic considerations" (KURC, 1980: 10-11. emphasis added). Packing the university policy, executive and academic bodies to majority with their members of the politician-education overlords, from late 1980s and early 1990s, Maharashtra presented, a mirror of external pressure on the university governance that would not affect their institutions in any way in their pursuit of commercialization, and well up to the time of Supreme Court verdict in Inamdar Case in 2004 (Deshpande, 1993: 437; Chousalkar, 2000: 1348; Sahastrabhudhe, 2000; Morkhandikar, 2000; Kumar, 2010: 20-21; Bhat, 2015).

3. COMMERCIALISATION IN HIGHER EDUCATION IN TAMIL NADU: THE BEGINNINGS

In higher education, the DMK government was wedded to the ideology of social justice, through deconcentration of its urban centric nature and promoting ruralisation and affordability, in fact, with a double incentive of fee waiver and scholarships to all the poor children from rural and remote areas and of BC, MBC, SC and ST communities (Thanappan, 2007). Thus, the DMK government increased the government colleges from 33 in 1969, to 51 and the aided colleges from 93 to 143 between 1967 and 1977 (Muniappan, 2012: 1-4; Thanappan, 2007; 133). Why and how did the need for unaided liberal art and science colleges arise in Tamil Nadu? Throughout the 1970s, the *Tamil Nadu Administration Reports* are full of references to the starting of: (i) new courses in the existing Under Graduate (UG) and Post Graduate (PG) levels; (ii) UG and PG degree courses in colleges where it did not exist earlier; and (iii) evening colleges/classes and increase in the number of colleges covered.

In a narrative of commercialization of HE, it is important to bear in mind a related dimension, i.e. social justice, with many attributes. Affordability is a related dimension to de-elitisation and expansion of opportunities for HE. Affordability was central to the political ideology of the Dravidian parties like the DMK and AIADMK. Thus, it started with freeing HE, beginning with the PUC from fee in 1972 and widened it to the degree courses within the next two-three years, and over time doubled it with scholarships to most of the children from poor, rural and remote areas and children of BC, MBC, SC and ST communities (Thanappan, 2007). This social justice and affordability dimensions were both part of the ideological baggage of the Dravidian parties (as can seen in the Budget Speeches during 1970s to 1990s (GoTN, 1971; '75; '89, '93; and Policy Note Demand No. 20, Higher Education from 2000 onwards), with great political-electoral appeal and clout that could not be forsaken in the all-pervasive commercialization milieu.

These attempts to increase the opportunities for HE mainly in the public sector – government and government-aided colleges -- fell short of the rising aspirations. In 1980-81 itself, the idea of providing HE where the cost will be borne by the students was first tried out by sanctioning a new polytechnic college. In general higher education, the government tried out by starting self-financing evening colleges/courses along with regular courses in the existing government and aided arts and science colleges in the first half of the 1980s. However, it was during 1984-85 that 6 new unaided arts and science colleges were sanctioned by the AIADMK government. While sanctioning them to the private individuals, it was underlined that these institutions should be run with a social service motive and not with an intension to charge capitation fees that rocked the state in the area of medical colleges. However, by then, the practice of sanctioning unaided Engineering and Polytechnic colleges became a firm trend, with the sanctioning of un-aided Polytechnic in 1981 itself. 56 new polytechnic colleges, i.e. 56 out of total 115, were sanctioned in 1983-84, and 17 new unaided engineering colleges, i.e. 17 out of the total 30, were sanctioned in 1984-85 (GoTN, 1985: 51, 52).

Venkatramani reported the news of capitation fee in Medical Colleges in 1985, in the very first year of sanctioning of such un-aided colleges of medical education. He pointed out "how the controversy over capitation fees, having died down in other states, had resurfaced in Tamil Nadu which is now witnessing a stormy debate about the propriety of the AIADMK Government's action in permitting the opening of private medical colleges which charge hefty donations for admissions. The anger over the commercialisation of medical education is understandable. The three new private medical colleges that have been permitted to open will be admitting 100 students in the very first year". He goes on to show that "Of these, 60 are private admissions made directly by the college and the remaining 40 are sanctioned by the state Government. Students admitted directly must pay Rs 2.5 lakh each as donation. The remaining 40 have to cough up Rs 5,000 in tuition fees every year" (Venkatramani, 2014).

A perceptive observer, Viswanathan, noted that "Tamil Nadu is perhaps one of the first few States that permitted the large-scale opening of unaided private engineering colleges, in the mid-1980s when Prime Minister Rajiv Gandhi launched the New Education Policy. Under the policy, entrepreneurs were invited to open professional colleges to meet the increasing need, since the government could not generate the funds required. Instant support came from the then Chief Minister, M.G. Ramachandran. For many it was an opportunity for money-laundering. Politicians, including Members of Parliament, also entered the field making use of some generous offers from the government in terms of land and infrastructure facilities. The highly polarised political situation in the State was also helpful in a large number of influential politicians getting permission to start colleges" (Viswanathan, 2003).

Profit as the purpose replaced social service motive, except that probably the incidence of capitation fee in arts and science colleges was not as oppressive as in medical and engineering colleges. But once profit motive invaded the educational scene, it hardly disappeared. Political patronage in sanctioning of unaided colleges had its returns, both electoral and monetary, although always known to the public and not accounted.

That the practice of capitation fees in engineering colleges was widespread, much to its opposition, as the champion of pro-public sector approach, became evident when the DMK

government came to power and knew of various "irregularities", besides "inadequate facilities and poor quality of education". The DMK government declared: "In this circumstances no new private self-financing colleges will be approved in future. The functioning of all such institutions which are in existence at present will be examined and necessary action taken" (GoTN, 1993:130). Despite its pro-public sector approach, the DMK government's reaction to the private SF colleges was due to their irregularities and compromises on quality parameters rather than anti-private sector per se. This became evident when it returned to power in the second half of the 1990s.

Clear data regarding management type of Engineering and Polytechnic Colleges along government, aided and self-financing categories is not available for the period 1990-95 when the AIDMK was in power and its lenience on self-financing engineering and polytechnic colleges could not be tracked. As in Table-1, in liberal arts education, the SF colleges increased from 13% to 19% during 1990-92-93 (GoTN, 1992: 175; 1993: 173; 1994: 173; and 1997: 180). In the area of technical education, SF colleges were started by the AIADMK in 1984-85 on a big scale vis-à-vis the total, i.e., 17 out of 30, which represented 56.6% (GoTN, 1986:74). The next time the data is available is after 1997-98, which is under the DMK rule, and the share of SF engineering colleges was 76 out of 90, representing 84.4%. It had reached 143 out 157 in 2000-01, i.e., 91% (GoTN, 2008: 40, 43, 45). The position in Polytechnic colleges was very similar. Starting with just 5 in 1981, the AIADMK took it to 18 out of 147 in 1985-86, i.e., 12.2%. When the DMK returned to power in 1995-96, it took the drive to a new level, 112 out 173, 64.7% in 1997-98 and left it at 148 out of 210, i.e., 70.4% in 2000-01 (GoTN, 2008).

In the bi-polar political scenario of Tamil Nadu, there would always be a competitive politics on any issue, whether it be welfare, social service, education, etc. It would always be competition between the DMK and the AIADMK, one wanting to overtake and outsmart the other, on which their electoral fortunes and stints in the government depended. Especially after the onset of Reforms, the DMK was not prepared to forsake the socio-political and electoral edge that the self-financing college approach to promoting HE brought with it, because, if it was getting stuck with its opposition to the SF approach, its arch rival, the AIADMK, would outsmart it. That was the reason why, as seen in Table-1, even in its very first year in government in 1995-96, it approved 98 SF arts and science colleges and 76 SF Engineering Colleges in 1997-98 (GoTN,2008: 43, 45).

Table 1. Initial Trends in Commercialisation of Higher

	Arts and Science Colleges				Engineering Colleges				Polytechnic Colleges			
Year	**Gov.**	**Aided+**	**Unaided**	**Total#**	**Gov.**	**Aided**	**Unaided**	**Total**	**Gov.**	**Aided**	**Unaided**	**Total**
						AIADMK						
1979-80									29	16	Nil	45
1980-81									30	16	5	51
1981-82									30	16	5	51
1982-83									30	16	3	59
1983-84	61	168	Nil	216	7	5	Nil	12	31	16	56	115
1984-85	53	150	6	237	7	5	17	30	31	16	71	129
1985-86	54	148	8	238	7	5	6	36*	31	16	18	147
1986-87	54	133	11	229	7	5	3	39	31	16	7	154
1987-88	61	148	16	245	--	--	7	--	--	--	74	--
						DMK						
1988-89	62	197	23	255	--	--	28	--				
1989-90	54	132	25	252	--	--	--	--				
						AIADMK						
1990-91	54	132	29	215$	--	--	--	--				
1991-92	54	132	38	224	--	--	--	--				
1992-93	55	132	46	233	--	--	--	--				
1993-94					--	--	--	--				
1994-95					--	--	--	--				
					DMK (1996 to 1997 data not available)							
1995-96	65	160	98	323	--	--	--	--				
1996-97	65	160	122	347	--	--	--	--				
1997-98	65	160	158	383	7	3	76	90##	21	35	112	173
1998-99	67	161	175	403	7	3	106	120	21	35	143	204
1999-00	67	161	194	422	7	3	113	127	22	35	148	210
2000-01	67	161	235	463	7	3	143	157	22	35	148	210

Note: + also include Colleges of Teacher Education; # Include physical education, oriental colleges, school of social work, colleges of education, etc.;*Include affiliated colleges, Deemed Universities, etc.; $ only Arts and Science Colleges; ##Totals from 1997-98 to 2000-01include affiliated and others under Anna University; -- implies, data not available

Source: A. Thanappan (2007), *Higher Education in Tamil Nadu during 1967-87*, University of Madras, Chennai, p. 133; Government of Tamil Nadu [GoTN], *Tamil Nadu Administration Report, 1985*; 1988; 1991; 1992; GoTN (1992), *Statistical Handbook of Tamil Nadu, 1992, p. 175*; and also for the years 1993, p.173; 1994, p. 173 and 1997, p. 180; GoTN (2008), *Policy Note Demand No.20 – Higher Education 2008-09*, p.40, 43 and 45.

Table 2. Entrenched Trends in Commercialisation of HE in Tamil Nadu

Year	Arts and Science Colleges					Engineering Colleges				Polytechnic Colleges			
	Gov.	Aided	Unaided	Tr. Edn	Total	Gov.	Aided	Unaided	Total	Gov.	Aided	Unaided	Total
AIADMK													
2001-02	67	161	249			6	3	207	226#	22	41	147	208*
2002-03	60	134	247	22	478	6	3	225	243	22	41	147	208
2003-04	61	134	247	22(1)	478	6	3	222	249	22	40	145	207
2004-05	67	162	249	22(1)	478	6	3	213	252	22	36	146	209
2005-06	67	162	441	43(22)	503	6	3	224	239	--	--	--	--
DMK													
2006-07	74	162	567	277(256)	803	6	3	238	251	22	34	166	242
2007-08	76	162	622	309(288)	860	6	3	263	276	22	34	205	264
2008-09	77	162	906	--	1145	6	3	335	355	22	34	258	317
2009-10	78	162	1014	645	1254	6	3	431	456	22	37	307	366
2010-11	93	162	1063	--	1318	6	3	464	491	30	37	365	432
AIADMK													
2011-12	93	162	1068	660(639)	1323	6	3	498	525	30	37	380	447
2012-13				--		7	3	525	553	30	34	395	479
2013-14	69	162	1097	672(651)	--	10	3	541	572	41	34	414	509
2014-15	120	168	1107	672(651)	1389	10	3	546	576	41	34	414	509
2015-16	84	162	1126	724(703)	1409	10	3	553	583	41	34	406	501
2016-17	128	162	1217	724(703)	1506	10	3	553	583	41	34	416	511
2017-18	127	162	1217	734(713)	1506	10	3	554	584	46	34	418	518
2018-19	139	162	1246	718	1547	10	3	503	*1105*	51	34	416	520
2019-20	139	162	1246	718(697)	1547	--	--	--	585				520
DMK													
2021-22	900	--	--	649	1553	--	--	554	587	89	89	420	509
2022-23	918	--	--	628	1553	--	--	539	573	34	89	420	509

Note:-# Total include institutions like affiliated and others under Anna University;
* Totals include HMCT/Film & TV/RLI.
Source: GoTN (2005), *Policy Note Demand No.20 – Higher Education, 2005-06*, p. 5; pp.19-20 for data on TE during 1997-98 to 2004-05; 2009, p. 91,93; 2010, p. 84,86; 2011, p.76,84,86; 2012, p. 136; 2013, p. 170,172; 2013, p. 23; 2015, p. 237, 239, 241; 2016, p.41, pp. 13-14; 2017, p. 11, 26; 2019, p. 12, and p. 52; 2022, p. 9, 36; 2023, p. 13, 22-23,99. (more than one set pps., in the same year refer arts and science streams and TE streams).

4. SOCIAL JUSTICE EVEN WITH COMMERCIALISATION

TN's privatisation and commercialisation of HE, very strangely, went with social justice, as a matter of conscious and competitive policy approach both with AIADMK as well as with DMK, with an uncompromising zeal, as much for ideological fervor as for shrewd political-electoral realism. The system of admissions to professional colleges, as per the Unnikrishnan case verdict in 1993 enabled Tamil Nadu government, under the AIADMK, to ensure social justice in admissions by assuring 69% of reservation to the BC, MBCs, SCs and STs, through the "free seat" and "payment seat" on the basis of the ranks in state conducted admission test. This was struck down as "unconstitutional" by the Supreme Court in 2002. The unaided professional colleges' decision of both non-minority and minority colleges to adopt its own admission procedure and fee structure threatened to erode the social justice approach of the state government, and deprive the poor meritorious students of the opportunities for higher education. The government, this time again, the AIADMK, despite its traditional pro-privatisation disposition, was sensitive to the public apprehension, announced that 50% of the seats in unaided non-minority and 30% seats in un-aided minority SF professional colleges would be reserved for the government that it could use to assure social justice and affordability in admissions. This was besides advising these colleges not to charge more than Rs, 30,000 annually for fees and give a concession of Rs. 5,000 to the students admitted under the Single Window System (Viswanathan, 2003).

5. COMPETITIVE COMMERCIALISATION FROM 2000 DISREGARDING POLICY PROCLIVITIES

In the area of liberal arts education, as in Table-2, the AIADMK patronage to SF liberal arts colleges was 51.6%, i.e. 247 out of 478 colleges in 2002-03. This position reached 54.4% in 2005-06 before it demitted office (GoTN, 2008:40). The pro-public education sector DMK's patronage to self-financing private sector was evident when it sanctioned 567 SF arts and science colleges in 2006-07 in the very first year of its stint in power, i.e., 67%. It escalated this share to 80% in 2010-11 (GoTN, 2012:165). There was no change in the proportion SF colleges in the total in AIADMK regime from 2011-12 to 2019-20, viz., the same 81%. The competitive commercialization tendencies should be marked in the area of liberal arts and science education more than technical and professional education, given the DMK's traditional inclination in favour its public sector ideology, and when it

entered the SF fray in this sector, it wanted to overtake its political opponent AIADMK.

Competitive commercialization has greater political and electoral returns with monetary returns always not evident in the sanctioning of engineering and polytechnic colleges. Therefore, this trend is marker of who overtakes the other in the race of commericalisation in engineering and technical education in Tamil Nadu. As in Table-2, AIADMK began its stint in 2000-01 with 91.5% and 70.1% in engineering and polytechnic colleges, and took it to the same level in 2004-05. However, the DMK took the proportion of SF engineering and polytechnic colleges to 96.3 and 85% in 2006-07 and did not relent on the proportion till 2010-11, with 94.5 and 84.4% respectively. By the time AIADMK came to power, technical education was already in crisis, and in spite of its pro-privatisation inclination, could not increase the share of SF in technical institutions besides maintaining at the same level of 94.8 in engineering colleges between 2011-12 and 2018-19 while the proportion actually fell from 85 to 80% in polytechnic colleges.

6. CRISIS IN TECHNICAL EDUCATION IN TAMIL NADU

Prior to say 2012, SF engineering colleges, much like management and other professional institutions, were owned in Tamil Nadu mainly by politicians and real estate barons, because it was hugely lucrative commercial ventures (Rani, 2010). But, the crisis in technical education, as a sequel to the severe economic and industrial slowdown, was manifest in the industries, including the IT and other software and engineering industries and that reduced absorbing engineering graduates. Except those from reputed institutions, graduates of sub-standard engineering institutions passed out unemployable. On the crisis in engineering education, R. Balaji and Swathimoorthi quote a study by Aspiring Minds Research Cell: "Tamil Nadu lags in average quality of talent". The study was based on an employability test, AMCAT (Aspiring Minds Computer Adaptive Test), taken by 1.2 lakh engineers across India for IT services and related jobs. It stated that though Tamil Nadu is considered an engineering hub, the State's engineering students' employability is only 8.33 per cent (Balaji and Swathimoorthy, 2017).

They go on to report the situation in 2016: "One good news is that the exorbitant capitation fees are no longer the norm. According to an engineering college faculty, around five years ago, the capitation fee for reserving seats in engineering colleges ran to lakhs of rupees — over Rs. 6 lakh for Mechanical and Civil Engineering and Rs. 1 lakh for Information Technology. Now colleges are struggling to fill their seats every year". The report further adds that "The starting salary for teachers too has come down in the past five years as admissions decreased. Initially, most colleges gave a salary of Rs. 19,000-33,000 for a fresher. But now that has come down to Rs. 12,000-14,000. In addition, professors are forced to bring 2-3 students each for admission or they face a pay cut of close to three months" (Balaji and Swathimoorthy, 2017).

In 49 out of 554 SF engineering colleges not even 10% seats filled in 2016-17. Colleges which filled 40% of seats accounted for 34.4%, i.e. 191 colleges. While the decline in enrolment vis-à-vis sanctioned intake started even as early 2006-07, it became too severe in SF colleges. The SF colleges constituted nearly 95% in the total of engineering colleges. The proportion of sanctioned seats increased from 95099 in 2006-07 to 290761 in 2015-16, but the intake started declining from 95% to 55% between 2006-07 and 2015-16 (DoTE).

An account in respect of Education in Tamilnadu, perhaps around 2015-16 puts it: "Sample this: there are 550 engineering colleges in the state affiliated to Anna University producing over 2 lakh engineering graduates each year, most of them finding it tough to compete in the job market. What is more alarming is that despite nearly 80,000 seats going vacant in engineering colleges, the governing bodies like AICTE (All India Council for Technical Education) and Anna University give permission to start new colleges in the districts resulting in the boosting of supply side – more than double the current requirement of industry (DoTE).

7. WORST MARKERS OF COMMERCIALISATION IN TAMIL NADU HIGHER EDUCATION: COLLEGES OF TEACHER EDUCATION

SF Colleges of Teacher Education in Tamil Nadu is an eye opener in a discussion about the menace of commercialization in higher education. When SF Colleges of Teacher Education was sanctioned in a large number in one go in 1987 in Maharashtra to those agencies running engineering colleges, this was seen as a lucrative proposition: *Economic and Political Weekly* discerned the reasons: "*opening of colleges of education has proved even more lucrative than starting of polytechnics and engineering colleges. This is because hardly any inputs are needed (such as workshops and laboratories) to start such a college. The number of aspirants for admission is also much larger for such a college than other professional courses. It is no wonder that the permission for the opening of such a college is sought even more avidly than, say, a license for a liquor shop* (*EPW*, 1990: 225-26. emphasis added).

Unlike Maharashtra, in Tamil Nadu, it is not clear whether the same people running arts and science colleges and perhaps even engineering colleges, the real estate sharks, liquor barons, industrialists, religious trusts and politicians (Rani, Manual, Venkataramani, 1985), are those who opened a SF College of Teacher Education. The AIADMK government started with sanctioning one college of Teacher Education in 2003-04 (GoTN, 2003-04:13) but within another two years ended up with sanctioning of 22, i.e., 22 out of 43 colleges of education, i.e., more than 50% in 2005-06 (GoTN, 2005). The DMK which was traditionally a champion of public education, was only too ready in joining the race, and with a big bang, as seen in Table 2 above, by increasing the number of SF teacher education colleges to 256 out of 277, in 2007 (GoTN, 2007: 23), thereby increasing the share to 92% and 93% in 2007-08 (GoTN 2009). As in Table 2, AIADMK could take it to 97% during 2012-18 (GoTN, 2012: 165; 2019: 12, 52). This scene of 97% of colleges of Teacher Education being unaided private colleges in Tamil Nadu resembles the scene at the national level, as scripted by discerning observes like Amitabh Kant and Sarah Iype. Their observation that "about 90 per cent of these" 17,000 odd "institutes (i.e., Teacher Education Institutes [TEIs]) are privately owned", is more truer in Tamil Nadu, as it accounted for 92 to 97% between 2006 and 2018, as seen in Table 2 above. Kant and Iype go on to describe the nature

of these TEIs "a mind-boggling majority of them [the 90% being privately owned] are standalone institutes, running single programmes with as few as 50 students. In fact, while most of these TEIs are financially unviable, some function out of tiny rooms with duplicate addresses, and a few could even be selling degrees at a fixed price. These institutes function in isolation from the rest of the higher education system, and there is no system to assess and accredit them. Consequently, there is no systemic sieve to ensure the entry of only motivated and meritorious individuals into the teacher education space" (Kant and Iype, 2020). There is no guarantee that this is not true of the TEIs scene in Tamil Nadu also. Kant and Iype make bold to contend: "Till date, there is no accurate real-time database of the number and details of teacher education institutes, students enrolled and programmes offered".

This is perfectly true in respect of TN. A look at the Website of Tamil Nadu Teachers Education University (TNTEU) indicates that the number of Colleges of Teachers Education, including government, aided and unaided, as 753, and the number of teacher training institutes under SCERT is 424. The Policy Note Demand No. 20 – Higher Education 2019-20 indicates the number of Colleges of Teachers Educations in TN as 718. However, the NCTE Website cites the number as 2136 with clear addresses and contact details; it is not clear which data source is true – Policy Note Demand No. 20 – Higher Education 2019-20, TNTEU, SCERT or NCTE, as regards the number of Colleges of Teacher Education and Teacher Training Colleges/Institutes.

8. CONCLUSION

In the area of technical education, there is a crisis of oversupply and more than 50% of remaining unfilled and engineering colleges applying and waiting for closure. The burden of survival in many cases has been transferred on to the shoulders of the faculty with the threat of salary cut if they fail to bring in students for admission. Commercialisation in terms of capitation fee has gone long before and there is a crisis for engineering colleges waiting for approval for closure or permission to switch over to liberal arts and science colleges (Balaji and Swathimoorthy. 2018; NT Bureau, 2019). In the area of teacher training, there is a glut with much larger number of sub-standard and sub-optimal size of TEs, as Amitabh Kant and Sarah Iype portray. Engineering colleges which were once sought more avidly than a license for a liquor shop, no longer appears to be a commercially lucrative venture in TN, as elsewhere. TN seems to at peace with itself with the level of commerialisation in liberal arts and science education with its usual package of the social justice baggage.

Among India's large states, Tamil Nadu consistently maintains the highest GER in higher education for five academic years between 2017-18 and 2021-22. In 2024, Tamil Nadu leads in higher education enrolment with a GER of 47%, surpassing the national average of 28.4% (*The Hindu bussinessline,* January 30, 2024; Rangarajan and Shanmugam, 2024: 2*)*. Inclusion and affordability have been an undeniable feature in the HE policy milieu even in a predominantly pro-privatisation and commercialization paradigm in Tamil Nadu, with more than 75% of HEIs in general education and more than 80% in technical education in the un-aided sector.

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Empowering Persons with Disabilities through Grassroots Organisations: A Case Study of Disabled People's Organisations in Kerala

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Abstract:
This study explores the role of Disabled People's Organizations (DPOs) in empowering Persons with Disabilities (PWDs) in Kerala, India, through grassroots initiatives. Drawing on insights from four Focus Group Discussions (FGDs) conducted in the districts of Trivandrum, Kozhikode, Idukki and Wayanad, the research examines the diverse interventions of DPOs. It highlights their significant contributions to promoting social inclusion, fostering economic independence and providing essential rehabilitation support for PWDs. Participants from these FGDs include leaders and members of DPOs, highlighting the diverse challenges faced by PWDs and the strategies adopted by DPOs to address them. The findings reveal that DPOs have been instrumental in promoting awareness of disability rights, advocating for accessible infrastructure and encouraging inclusive education. By fostering vocational skills, providing employment opportunities and facilitating micro-enterprises, these organisations have helped PWDs achieve economic self-reliance. Moreover, the study shows that the involvement of DPOs in health-related services, such as rehabilitation, medical support and the provision of assistive devices, has enhanced the quality of life for PWDs. The study underscores the importance of collective action through Self-Help Groups (SHGs) and federations in strengthening leadership and advocacy efforts. It also highlights the critical role of DPOs in advocating for policy reforms and engaging in rights-based activism to combat discrimination and social stigma. The DPOs' ability to network with local government bodies, NGOs and community organisations has further amplified their impact, ensuring sustained support for the PWD community. Further, the study examines the successes and challenges faced by DPOs, contributing to a deeper understanding of how grassroots organisations can act as powerful catalysts for empowering Persons with Disabilities (PWDs). The findings offer valuable insights into disability-inclusive development, providing lessons that are applicable not only in India but also globally.

Keywords: Disabled People's Organizations (DPOs), Persons with Disabilities (PWDs), Grassroots Empowerment, Social Inclusion, Economic Independence

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1. INTRODUCTION

Persons with Disabilities (PWDs) face numerous challenges in achieving social inclusion, economic independence and access to essential services, particularly in developing countries like India. According to the World Health Organization (2011), an estimated 15% of the global population lives with some form of disability, with a disproportionately high incidence in low- and middle-income countries. The 2011 Census reported over 2.68 crore PWDs in India, highlighting the urgent need for effective policies and interventions to address their specific needs (Government of India, 2011). Despite legislative frameworks, such as the Rights of Persons with Disabilities Act (2016), aimed at safeguarding the rights of PWDs, systemic barriers and social stigma often hinder their full participation in society (Nagar & Madan, 2020).

In the Indian context, particularly in Kerala, grassroots initiatives led by Disabled People's Organizations (DPOs) have emerged as pivotal in addressing these challenges. These organisations are critical in facilitating empowerment through community engagement and support, fostering social inclusion (Yadav & Rani, 2020). DPOs serve not only as advocates for the rights of PWDs but also as platforms for collective action, enabling individuals to voice their concerns and access essential services (Sharma, 2021).

This study investigates the multifaceted roles and contributions of DPOs in Kerala, focusing on four distinct districts: Thiruvananthapuram, Kozhikode, Idukki and

Wayanad. Drawing insights from four Focus Group Discussions (FGDs) with a diverse representation of PWDs, this research aims to illuminate the effectiveness of grassroots organisations in fostering empowerment and inclusion. By examining the various interventions employed by DPOs ranging from awareness campaigns and vocational training to rehabilitation support and advocacy the study seeks to highlight the transformative impact of these organisations on the lives of PWDs.

Furthermore, this research explores the successes and challenges DPOs face, contributing to the broader discourse on disability-inclusive development in India. The findings aim to provide valuable lessons for stakeholders in the disability sector, emphasising the importance of grassroots initiatives in promoting the rights and dignity of PWDs. Ultimately, this study underscores the critical role that DPOs play in catalysing change, advocating for systemic improvements and enhancing the quality of life for PWDs in Kerala and beyond.

1.1 Research Questions

- How have Disabled People's Organizations (DPOs) contributed to the social, economic, and political empowerment of Persons with Disabilities (PWDs) in the four districts studied?
- What role do DPOs play in leadership development and advocacy among PWDs and how does this impact the ability of PWDs to advocate for their rights and influence local policy changes?
- What are the primary challenges faced by DPOs in sustaining their initiatives, particularly concerning external funding and government support?
- How do DPOs address the unique challenges faced by women with disabilities (WWDs) and what specific barriers related to gender and disability continue to impede their participation in social and economic activities?
- What strategies have DPOs employed to promote the long-term sustainability of their programs and how effective have these strategies been in ensuring the continued empowerment of PWDs?

2. LITERATURE REVIEW

The empowerment of Persons with Disabilities (PWDs) has garnered increasing attention in the fields of social work, disability studies and public policy, particularly in the context of developing countries. The literature indicates that effective interventions at the grassroots level are essential for fostering social inclusion, economic independence and enhanced quality of life for PWDs. This literature review synthesises existing research on the role of Disabled People's Organizations (DPOs) in facilitating these objectives, with a specific focus on the Indian context.

The Role of DPOs in Empowering PWDs: Disabled People's Organizations have emerged as vital players in advocating for the rights and well-being of PWDs. According to Oliver (1990), DPOs contribute to the social model of disability by shifting the focus from individual impairments to societal barriers that inhibit participation. By engaging PWDs in collective action, DPOs empower individuals to challenge discrimination and advocate for their rights (De Jong, 2017). Research conducted by Padda and Bhatti (2018) highlights the transformative role of DPOs in promoting self-advocacy, leadership development and community engagement among PWDs in India.

Grassroots Initiatives and Social Inclusion: Grassroots organisations, particularly DPOs, are crucial in enhancing social inclusion for PWDs. According to Ghosh (2021), community-based initiatives led by DPOs have successfully raised awareness about disability rights and fostered inclusive practices in schools and workplaces. These initiatives not only improve the visibility of PWDs but also challenge prevailing stereotypes and stigma. For example, a study by Ranjan and Gupta (2020) found that awareness campaigns conducted by DPOs significantly increased the enrolment of disabled children in schools, thereby promoting their integration into the educational system.

Economic Independence and Vocational Training: The economic empowerment of PWDs is another significant focus area for DPOs. Research by Kamble and Vasant (2020) underscores the importance of vocational training programs offered by DPOs, which equip PWDs with skills necessary for gainful employment. The authors argue that these programs not only enhance the employability of PWDs but also foster their financial independence. A case study conducted in Kerala revealed that DPOs have successfully implemented various income-generating activities, enabling PWDs to establish micro-enterprises (Suresh & Kottarathil, 2022). However, challenges remain, such as limited access to financial resources and employment discrimination (Chakraborty & Kundu, 2019).

Rehabilitation and Support Services: Effective rehabilitation services are critical for enhancing the quality of life for PWDs. According to Singh and Mishra (2021), DPOs play a pivotal role in facilitating access to rehabilitation services, including medical treatments, assistive devices, and therapy. Their community-based approach allows for tailored support that meets the specific needs of individuals with disabilities. However, as noted by Kumar and Joshi (2020), systemic barriers, such as inadequate infrastructure and limited government support, often impede the effectiveness of these services.

Advocacy and Legal Frameworks: DPOs also engage in advocacy efforts to influence policy and legal frameworks affecting PWDs. Research by Bansal and Singh (2020) highlights the significance of DPOs in promoting the implementation of disability laws, such as the Rights of Persons with Disabilities Act (2016). These organisations serve as a bridge between PWDs and policymakers, ensuring that the voices of disabled individuals are heard in decision-making processes (Sharma & Rao, 2021). Despite these efforts, challenges persist in effectively enforcing existing laws, necessitating ongoing advocacy and community mobilisation.

3. METHODOLOGY

Research Design: This study employed a qualitative research design to explore the role of DPOs in empowering PWDs in Kerala, India. The qualitative approach allowed for an in-depth understanding of the participants' experiences, perceptions and insights regarding DPO interventions and

initiatives. This approach allowed the researchers to understand how DPOs contribute to the social, economic and political empowerment of PWDs in Kerala.

Participants and Sampling Strategies

Sampling Method: A purposive sampling strategy was employed to recruit participants who were directly involved with or affected by DPO activities. Purposive sampling was deemed most appropriate as the study sought to gather in-depth perspectives from individuals with specific characteristics, namely PWDs engaged with DPOs or related disability initiatives. This method ensured the selection of participants with rich knowledge and experience relevant to the research questions.

Participants: The participants for this study were recruited from four districts in Kerala: Trivandrum, Kozhikode, Idukki, and Wayanad. Participants were selected with the assistance of local DPOs to ensure a diverse representation, encompassing various age groups, genders and types of disabilities. The inclusion criteria for participants were:

- Individuals aged 19 and above.
- Members of DPOs or associated with disability-related initiatives.
- Willingness to share their experiences and insights during the FGDs.

Sample Size Justification: A total of 84 participants took part in the study, representing a diverse range of PWDs, DPO leaders, and community members. This sample size was considered adequate for qualitative research, allowing for data saturation while providing varied and representative insights. Participants were distributed across four FGDs, with each discussion involving between 19 and 22 participants. The sampling aimed to ensure broad coverage across different disability types, genders, socio-economic backgrounds and age groups.

Data Collection: The primary data collection method was FGDs, conducted in four districts. The FGDs were designed using a semi-structured interview protocol to allow for flexibility in exploring participants' experiences while maintaining a clear focus on key areas of inquiry.

The following key topics were addressed during the FGDs:

- Awareness and Advocacy Efforts: How DPOs have raised awareness about disability rights and advocated for policy changes.
- Economic Empowerment and Vocational Training: The role of DPOs in promoting economic independence and offering vocational training programs for PWDs.
- Social Inclusion and Community Participation: Participants' views on the effectiveness of DPOs in promoting social inclusion and participation in community activities.
- Rehabilitation and Healthcare Access: The availability and effectiveness of rehabilitation and healthcare services for PWDs, facilitated by DPOs.
- Challenges and Sustainability of DPO Initiatives: Participants' insights into the challenges faced by DPOs, including funding, leadership and sustainability issues.

Structure and Conduct of FGDs: The FGDs were facilitated by trained moderators knowledgeable about disability issues and familiar with the local context. With participants' consent, the discussions were audio-recorded, and detailed notes were taken to capture non-verbal cues and interactions.

Data Analysis: The data collected from the FGDs were subjected to qualitative content analysis, following an inductive coding process. The analysis process involved the following steps:

- Familiarization: The research team transcribed the audio recordings verbatim and reviewed the transcripts and field notes to immerse themselves in the data.
- Open Coding: Initial coding was done manually to identify key ideas and patterns. Codes were assigned to sections of text that reflected important themes, such as economic empowerment, social inclusion, advocacy and healthcare access.
- Focused Coding and Theme Development: After the initial coding, similar codes were grouped into broader categories. Themes such as "challenges in accessing healthcare," "vocational training outcomes," and "DPO sustainability issues" were developed through this iterative process.
- Inter-Coder Reliability: To enhance the reliability of the analysis, multiple researchers coded the data. Regular meetings were held to compare codes and resolve any discrepancies, ensuring a high level of inter-coder reliability.
- Thematic Analysis: Themes were either derived inductively from the data or aligned with existing theoretical frameworks such as the social model of disability and intersectionality to explore the interplay between disability, gender and socio-economic factors.
- Validation: To ensure the credibility of the findings, member checking was conducted. A subset of participants reviewed the preliminary findings and provided feedback to confirm the accuracy of the interpretations.

Ethical Considerations: Given the involvement of a vulnerable population, this study followed stringent ethical guidelines:

- Informed Consent: Participants were provided with detailed information about the study and consented before participating. Consent was obtained in accessible formats, including verbal consent where necessary.
- Confidentiality and Anonymity: The identities of all participants were kept confidential. Pseudonyms were used to report findings and any identifying information was removed from the transcripts. All data were securely stored, with access restricted to the research team.
- Ethical Approval: Ethical guidelines were adhered to throughout the study, with attention to minimising harm and ensuring participant welfare.

4. MAJOR FINDINGS AND DISCUSSION

4.1. Enhanced Social Inclusion and Awareness

Disabled People's Organizations (DPOs) have played a pivotal role in promoting social inclusion and raising awareness about the rights of Persons with Disabilities (PWDs) across the four districts studied. Through sustained

community education efforts, DPOs have significantly contributed to shifting societal attitudes toward PWDs. These interventions have fostered more inclusive environments, particularly in schools and public spaces, resulting in greater acceptance and participation of PWDs in mainstream society.

Respondents across all districts highlighted the transformative impact of DPO-led awareness programs. A participant from Thiruvananthapuram remarked: "Earlier, people in our village did not know much about disabilities and we faced a lot of discrimination. However, after the DPO organised awareness sessions, people started to understand our situation better. Now, my son can attend school and the teachers are more supportive than before." Similarly, a female respondent from Kozhikode noted: "Before these awareness campaigns, my child was often teased in school. But now, the teachers and students are more understanding. The school even made some changes to make it easier for my daughter to move around."

In Wayanad, a respondent shared the positive impact of cultural programs and street plays organised by DPOs in raising awareness: "The cultural programs and street plays conducted by the DPO helped everyone in the community understand that PWDs have equal rights. The change in attitude is visible. We are no longer looked down upon." These narratives reflect the success of DPOs in creating inclusive environments, particularly in schools. Their sustained advocacy has led to an increase in the enrolment of children with disabilities in mainstream education. In Idukki, one parent stated: "The DPO motivated us to send our children to school. Now, my son is not only attending school but is also participating in extracurricular activities, something I never thought possible before."

The findings underscore the critical role DPOs play in promoting social inclusion and raising awareness about disability rights. Grassroots interventions by DPOs have been effective in challenging societal barriers and shifting public perceptions, particularly in educational settings. These results align with the work of Ghosh (2021), who documented the success of community-based initiatives in fostering social inclusion for PWDs. By targeting schools and public spaces, DPOs have succeeded in creating environments where PWDs are no longer marginalised but actively included in daily activities.

Despite improvements in social inclusion and awareness, participants in the study still face lingering discrimination and a lack of infrastructure to fully support PWDs. While DPOs have made significant strides, continued efforts are needed to ensure these gains are sustained and expanded. Advocacy must move beyond awareness campaigns to address structural issues, such as inadequate public transportation and accessibility in rural areas. A respondent from Idukki expressed this concern: "The schools have become more supportive, but getting to the school is still a challenge due to poor transportation. We need more changes to help us participate fully." This highlights the need for comprehensive policies that address not only social attitudes but also the infrastructural barriers limiting the mobility and participation of PWDs.

4.2. Economic Empowerment and Vocational Training

Across the four districts, DPOs have played a crucial role in facilitating economic empowerment through skill development programs, self-employment initiatives and access to micro-credit schemes. In districts like Wayanad, where agriculture is the primary source of livelihood, DPOs have promoted vocational training in agro-based activities, food processing, tailoring and other trades, enabling PWDs to integrate into the local economy.

A recurring theme in the FGDs was the bureaucratic challenges that PWDs face in accessing government assistance. DPOs were seen as vital in bridging the gap between government programs and the actual needs of PWDs. A respondent from Wayanad remarked: "The government schemes are there, but they are hard to access. Without the help of the DPO, I wouldn't have been able to apply for any financial assistance. They helped me fill out the paperwork and get the necessary documents." In Kozhikode, a participant who benefited from a DPO-led vocational training program shared their experience: "I learned tailoring through the DPO's training program and now I am earning a steady income. Before this, I had to depend entirely on my family, but now I contribute to household expenses." In Idukki, another respondent discussed the importance of micro-credit schemes facilitated by DPOs: "We were trained in food processing and received a small loan through the DPO. With that, I was able to start a small business and now have a regular income."

These findings emphasise the importance of vocational training and financial support in empowering PWDs economically, particularly in rural settings where employment opportunities are limited. The outcomes align with the work of Mitra et al. (2019), who emphasised that skill development is critical to the economic empowerment of PWDs. The vocational training and resources provided by DPOs have not only equipped PWDs with the necessary skills but have also instilled a sense of independence and self-worth.

However, despite these positive developments, ongoing challenges remain. Bureaucratic hurdles, such as complex application processes for government assistance, continue to impede access to financial support, as echoed in the findings of Mohapatra and Narayan (2021). Strengthening the linkages between DPOs, financial institutions and government bodies is essential to ensure that PWDs have consistent access to the capital needed to sustain their enterprises.

4.3. Strengthening of Self-Help Groups (SHGs)

DPOs have been instrumental in forming and strengthening SHGs, which serve as vital platforms for collective advocacy and economic activities. SHGs have promoted savings and credit schemes, leadership development and group entrepreneurship, fostering solidarity among PWDs in all four districts.

A respondent from Thiruvananthapuram highlighted how SHGs promoted savings and credit initiatives: "Before joining the SHG, I did not have any regular savings. Now, with the help of the group, we can pool our resources together, which helps in times of need. It is also easier to get small loans to start a business or deal with emergencies." Similarly, in Kozhikode, another participant discussed how SHGs fostered leadership and decision-making skills: "I was

hesitant at first, but being part of the SHG has helped me learn how to lead discussions and make decisions. Now, I can represent our group and speak to the local authorities about our needs." Participants from Wayanad emphasised how SHGs empowered them to advocate for their rights: "Through the SHG, we have been able to come together and approach the local government to demand better services for people with disabilities. Together, our voices are stronger."

The findings reinforce the crucial role that SHGs play in fostering financial inclusion and collective advocacy among PWDs. SHGs not only provide economic benefits through savings and credit schemes but also empower PWDs by fostering solidarity and leadership skills. This is consistent with the findings of Gupta and Kumar (2019), who demonstrated that SHGs significantly improve the financial security and social cohesion of marginalised groups. However, the study also highlighted challenges related to the sustainability of SHGs and access to larger markets for group-based enterprises.

4.4. Rehabilitation and Healthcare Access

In remote districts like Idukki and Wayanad, access to rehabilitation services and healthcare remains a significant challenge for PWDs. DPOs have initiated home-based rehabilitation programs and organised medical camps, providing essential services and access to aids and appliances. However, the lack of government-supported rehabilitation services was a recurring concern, particularly for those requiring long-term medical care and assistive devices.

A respondent from Idukki highlighted the importance of home-based rehabilitation programs: "I could not travel to the city regularly for therapy, and my condition was getting worse. Thanks to the DPO, they arranged for a therapist to come to my home, and now I can do the exercises regularly." In Wayanad, another participant emphasised the value of medical camps: "The medical camps are a lifeline for us. They not only provide us with check-ups but also give us access to devices like crutches and hearing aids. Without these camps, many of us would have no way of getting these services."

The findings highlight a critical gap in long-term, government-supported rehabilitation services for PWDs in remote areas. Access to healthcare, especially rehabilitation, is fundamental to disability rights, as recognised by the United Nations Convention on the Rights of Persons with Disabilities (CRPD) (UN, 2006). While DPOs have initiated vital home-based rehabilitation programs and medical camps, the study indicates that these efforts alone cannot substitute for formal healthcare systems.

The findings underscore the need for greater government investment in long-term rehabilitation services and the provision of high-quality assistive devices. To ensure that PWDs in remote areas have access to sustainable healthcare services, policymakers must address the unique challenges faced by these communities.

4.5. Leadership Development and Advocacy

DPOs have significantly contributed to leadership development among PWDs across the four districts. Through structured training programs and the creation of federations at the Panchayat (local governance) level, PWDs have been empowered to engage in advocacy and participate actively in community development efforts. This capacity-building has enabled PWDs to raise their voices on issues such as discrimination, access to public services and property rights. These efforts have led to successful advocacy for policy changes within their local communities.

The formation of Panchayat-level federations has been particularly impactful in districts like Kozhikode and Wayanad, where PWDs have organised collectively to address systemic challenges. During FGDs, participants expressed a sense of empowerment, attributing their confidence in leadership roles to the support provided by DPOs. One respondent from Kozhikode shared, "Before the DPO training, we did not know how to advocate for our rights. Now, we participate in Panchayat meetings and can speak on issues that affect us directly. We even managed to get ramps built in government buildings something that seemed impossible before." Similarly, in Wayanad, another participant highlighted how leadership development had contributed to advocacy for land rights: "Through the Panchayat-level federation, we fought for our right to land, which is often denied to people with disabilities. After a long struggle, we succeeded in getting local authorities to include us in the property distribution program."

Leadership development has had a ripple effect beyond individual empowerment, influencing societal perceptions of disability. Participants noted that being seen as leaders within their communities helped dismantle stereotypes and shift societal attitudes. A participant from Thiruvananthapuram observed, "People used to pity us, thinking we could not contribute to society. But now, they see us leading meetings and advocating for our rights, which has changed their perception. We are seen as equal members of the community." However, participants also noted challenges, particularly in sustaining advocacy efforts without consistent governmental support. A respondent from Idukki shared, "We have successfully raised awareness about disability rights, but without regular support from local government officials, it is hard to maintain momentum. We need more backing from policymakers to make lasting changes."

These findings underscore the pivotal role that DPOs have played in empowering PWDs to become advocates for their rights. Leadership development is crucial for empowerment, enabling marginalised groups to challenge systemic barriers and demand greater inclusion. Research supports the notion that leadership training for PWDs is essential for fostering self-advocacy and community engagement (Shakespeare et al., 2019). The formation of federations at the local governance level has provided PWDs with a platform to voice their concerns and advocate for policy changes. This aligns with studies suggesting that the decentralisation of governance structures can be an effective means of empowering marginalised groups (Kothari, 2017).

The shift in societal attitudes resulting from the visibility of PWDs in leadership roles is particularly significant. Leadership not only empowers individuals but also challenges prevailing stereotypes about disability. As noted by Grills et al. (2020), the visibility of PWDs in leadership positions can help combat stigma and promote a more inclusive society. However, the findings also highlight the challenges of

sustaining advocacy initiatives without consistent governmental support. While DPOs have been successful in raising awareness and advocating for policy changes, stronger partnerships with local governments are needed to achieve long-term systemic change (Mitra, 2021).

4.6. Challenges in Sustainability

Despite the notable progress made by DPOs, challenges related to the sustainability of their initiatives emerged as a significant concern. Participants across all four districts emphasised the heavy reliance on external funding and the lack of consistent government support as major barriers to sustaining their work in the long term.

In Kozhikode, a respondent highlighted the financial instability faced by many DPOs: "We have done a lot of work with external funding, but when that funding stops, it becomes very difficult to continue the programs. We need more sustainable solutions, but becoming financially independent is not easy." In Idukki, another participant remarked, "We cannot always rely on foreign or NGO funding. What happens if that support dries up? We need the government to step in more regularly."

Many participants noted that while short-term government initiatives exist, long-term support from government programs is lacking. In Wayanad, a respondent expressed the need for more robust collaboration with local authorities: "We have achieved a lot, but without regular support from the government, how can we keep going? We cannot just depend on donations and grants forever." In response to these challenges, some DPOs have begun strengthening their internal capacities. For example, several organisations have initiated savings and thrift management programs to promote financial independence among their members. A participant from Thiruvananthapuram explained, "We have started thrift and savings programs to create our funds, helping us depend less on external funding and manage small-scale initiatives on our own."

These findings highlight a common issue for grassroots organisations: while DPOs are crucial in empowering PWDs and fostering social inclusion, their long-term viability often depends on external factors, such as funding and government support. The reliance on short-term, project-based funding makes DPOs vulnerable to fluctuations, as participants expressed concern about the potential cessation of donor support. This challenge is compounded by inconsistent government investment in DPO programs, particularly in rural areas where geographical isolation further limits access to resources and services.

Sustaining these initiatives will require stronger government partnerships to ensure that DPOs are not solely dependent on external, temporary funding. This aligns with broader global research, which highlights the need for long-term governmental investment in grassroots disability organisations to ensure the continuity of essential services such as advocacy, vocational training and rehabilitation (Banks & Hulme, 2012).

4.7. Impact on Women with Disabilities

Women with Disabilities (WWDs) face unique challenges compounded by both gender and disability-related discrimination. Although WWDs were a minority in the FGDs across the four districts, their participation in DPO activities has been growing steadily. However, participants reported that WWDs continue to experience greater social isolation and fewer economic opportunities compared to their male counterparts, indicating the need for more targeted, gender-sensitive initiatives within DPOs.

A respondent from Kozhikode described the double burden of exclusion: "As a woman, it is much harder to find opportunities, even harder than it is for men with disabilities. I do not feel safe going out alone, and finding work is almost impossible." Another participant from Wayanad highlighted the lack of vocational training programs specifically tailored to women: "Most of the training programs are focused on men, like carpentry or mechanics. But for women like me, there are fewer opportunities. We need more training in areas like tailoring or small-scale businesses."

Social norms also play a role in limiting the participation of WWDs in community activities. A woman from Thiruvananthapuram noted, "Even within our families, women with disabilities are often overprotected. People do not allow us to participate in community activities as much as they would allow men, thinking it is not safe for us." Despite these challenges, there is optimism that DPOs are beginning to address gender-specific barriers. A participant from Idukki observed a gradual shift: "Things are changing slowly. We now have more women's groups within our DPO, and they are starting to address issues like sexual harassment and domestic violence."

These findings highlight the critical gaps in gender equity within disability advocacy. While WWDs have historically been underrepresented in grassroots disability movements, their participation is increasing, albeit with significant barriers still in place. Global research has shown that WWDs are often "doubly disadvantaged" due to their intersecting identities (Mitra et al., 2019). Gender-based discrimination and societal expectations around femininity and disability exacerbate the social isolation and economic exclusion of WWDs (Groce & Kett, 2013).

The findings suggest that social isolation is a significant issue for WWDs, driven by deep-rooted patriarchal norms. Studies on gender and disability in South Asia have consistently highlighted how cultural norms reinforce the perception of WWDs as more vulnerable or in need of protection, further marginalising them from community life (Chaudhry, 2018). However, the FGDs indicate that DPOs are beginning to address these challenges by creating women's groups and integrating more gender-sensitive programming, as seen in Idukki's efforts to tackle issues such as sexual harassment and domestic violence. More comprehensive gender-sensitive policies and partnerships with local women's organisations are needed to ensure that WWDs are not only included in DPO activities but also empowered to challenge both gender and disability-based discrimination.

5. CONCLUSION

This study highlights the critical role that Disabled People's Organizations (DPOs) play in empowering Persons with

Disabilities PWDs) across four districts. DPOs have significantly contributed to the social, economic and political inclusion of PWDs through a wide range of initiatives, including vocational training, advocacy and leadership development. These efforts have led to tangible improvements in the quality of life for PWDs, enabling them to challenge systemic discrimination and access opportunities previously out of reach.

The formation of Panchayat-level federations has been particularly impactful in fostering leadership and advocacy skills among PWDs. These federations have provided PWDs with platforms to engage in local governance, advocate for their rights and push for policy changes, particularly in areas such as accessibility and property rights. The findings indicate that the increased visibility of PWDs in leadership roles has contributed to a shift in societal attitudes, reducing stigma and promoting greater inclusion. However, these achievements are often tempered by the challenges of sustaining advocacy efforts without consistent governmental support.

Sustainability remains a significant concern for DPOs, as they rely heavily on external funding sources, often short-term and project-based. While some organisations have initiated efforts to become financially independent, the lack of long-term government investment limits their ability to maintain and expand their programs. The inconsistent implementation of disability policies, particularly at the local level, exacerbates this issue, highlighting the need for stronger partnerships between DPOs and government institutions.

The study also underscores the unique challenges faced by women with disabilities (WWDs), who continue to experience social isolation, limited economic opportunities and gender-based discrimination. Although DPOs have made progress in addressing these issues by creating women's groups and integrating gender-sensitive programming, much work remains to be done. There is a pressing need for more targeted interventions that address the intersection of gender and disability, particularly in rural areas where patriarchal norms and overprotection further marginalise WWDs.

Overall, while DPOs have made significant strides in empowering PWDs and fostering greater social inclusion, their sustainability remains precarious. Strengthening government support, securing more stable funding mechanisms and addressing the unique challenges WWDs face will ensure the long-term success of DPOs and their ability to continue driving positive change for PWDs.

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Assessing the Impact of eLearning and Learning Management Systems on Undergraduate Education: Insights from the Appalachian Region

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Abstract:
The COVID-19 pandemic necessitated a shift in educational approaches, compelling institutions to adopt e-learning systems for remote teaching. This study evaluates the effectiveness of these systems in undergraduate courses, focusing on factors such as student preferences, experiences, and the role of prior exposure to e-learning. The theoretical framework highlights the evolution of e-learning and its increased importance during the pandemic. Efficiency was analyzed based on variables like prior experience and convenience, with hypotheses formulated to assess their impact on improving efficiency. The research was conducted as a cross-sectional study involving students from the Appalachian region (Eastern Kentucky, USA) and utilized an online survey. Regression analysis was employed to examine the relationship between the independent variables (prior experience and convenience) and the dependent variable (efficiency improvement). The results revealed a statistically significant model, with "convenience" emerging as a strong predictor of efficiency enhancement. "Prior experience with e-learning systems" also showed significance, though to a lesser extent. The study recommends prioritizing user convenience and encouraging early exposure to e-learning systems to optimize efficiency. It suggests implementing continuous improvement initiatives, training programs, and further research into additional influencing factors. These strategies aim to create a more effective e-learning environment, ensuring a seamless and efficient educational experience for students as the landscape of education continues to evolve.

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1. INTRODUCTION

The COVID-19 pandemic caused alterations in educational practices, particularly during lockdowns aimed at containing the global virus epidemic. This led many educational institutions to adopt learning management systems such as Moodle, Blackboard, and others to support e-Learning and remote learning for the benefit of the educational process, students, and teachers, to stay up to date with technological advancements, and to take advantage of them in the classroom (Al-Shboul et al., 2023). This in turn reflected the effectiveness, usefulness, and convenience of e-learning systems for some of the courses by each student group.

Furthermore, the concept of distance learning and e-learning enriches the fundamentals and ideas of educational technology by combining individual education and offering learning chances to every student based on their aptitudes and competencies. Also, a lot of students in the 21st century believe that online learning is better over traditional learning**1.** because it is more flexible, accessible, has a wider variety of**2.** learning resources, is personalized, self-paced, allows for global interaction, is more affordable, and provides immediate feedback - all of which help students succeed academically and professionally (Saxena K., 2020).

1.1 Background Problem

With advancements in technology, accessibility, and the recent impact of the COVID-19 pandemic, students' choices in their primary mode of instruction have evolved. This shift in preferences has raised questions about the implications for educational institutions, teaching and learning strategies, equity, access, and the long-term trends in education. Understanding the historical context and student preferences has been vital for institutions to adapt to changing educational landscapes and ensure quality learning experiences. In sum, the evolution of students' preferences regarding eLearning systems and traditional classroom methodologies has been a multifaceted phenomenon.

1.2 Objective

Assessing Student Preferences: The objective of this research study is to understand the student's perspective of how efficient eLearning systems are and if they prefer

eLearning systems over traditional textbooks and classroom learning methodologies.

Analyzing variation of efficiency among students within different fields of study: This objective explores any differences in efficiency perceptions and preferences among students within different fields of study.

1.3 Research Question

The potential research question addressed with the given research is "What has been the prevailing preference among students for either eLearning systems or traditional classroom methodologies as the primary mode of completing their course of study?"

1.4 Potential Contributions

E-learning offers students greater access to educational resources and courses, regardless of location. It facilitates better comprehension by customizing learning experiences to fit each learner's preferences and pace. In today's tech-driven society, the digital skills obtained through e-learning are becoming more and more valuable. Flexibility in scheduling makes education more accessible, especially for those with other commitments. Also, it cultivates a mindset of perpetual learning, advancing ongoing personal and professional development. Simultaneously, for a more effective enhancement of e-learning contributions, attention should be directed towards improving content quality, interactivity, and personalization.

This study evaluates the effectiveness of implementing e-Learning and distance learning within educational institutions during the COVID-19 pandemic, focusing on students' viewpoints. It considers the impact of utilizing these resources in public universities and their continued role in the1. distance education system under varying circumstances. 2.

1.5 Theoretical Background

While assessing eLearning in today's education system specifically for undergraduate students, a brief analysis of the distance education system is conducted. Distance education is the utilization of communication media to expand learning beyond traditional classroom settings, disseminate expert3. instruction on a broader scale than individual teachers or4. schools could achieve (Schramm, 1982, as cited in Philson, R. M., 1983). Most such courses seem to depend largely on radio and/or television as the chief medium of instruction. To understand why, it might be worthwhile to look at some of the reasons these media are chosen for language teaching.

With the growth in information technology there is a drastic change in the eLearning system. The e-learning systems' theoretical framework contains the three main components of information systems. These components are people, technologies, and services (Aparicio et al., 2016). These new technologies help in interacting with different users.

In the early 2000s, eLearning was not widely adopted, but there was a notable surge in its popularity among students. However, the landscape dramatically changed in early 2020 when the global outbreak of COVID-19 led to the suspension of various activities, including academic pursuits. As a result, eLearning became the sole viable option for university undergraduates during this period. The COVID-19 pandemic has produced an unprecedented change in the educational system worldwide. Besides the economic and social impacts, there is a dilemma of accepting the new educational system "e-learning" by students within educational institutions. University students have to handle several kinds of environmental, electronic and mental struggles due to COVID-19 (Al-Okaily et al., 2020).

The analysis takes into consideration the efficiency of undergraduate students who have used eLearning systems during COVID-19 and if they have prior experience with eLearning systems before COVID-19. The efficiency results collected during the COVID-19 period will be compared between two groups: students who were using eLearning system services before and those who recently started using them.

1.6 Project Implementation

1.6.1 Dependent Variable

Enhances Efficiency
This is the variable that is being measured or observed in the study. It represents the level or degree of efficiency improvement. In this case, it's the outcome or result that might be influenced by changes in the independent variables.
Scale Interpretation
1: Strongly Disagree
2: Disagree
3: Neutral
4: Agree
5: Strongly Agree

1.6.2 Independent Variables

Prior experience with E-Learning system:
This variable considers individuals familiarity with e-learning systems. It might be hypothesized that those with more experience in e-learning systems could potentially exhibit higher efficiency due to their familiarity with such tools.
Prior experience with E-Learning system codes
0: No
1: Yes

Convenient:
This variable assesses the convenience factor in the context of e-learning. The hypothesis posits that individuals who find e-learning convenient may demonstrate increased efficiency. This convenience could stem from user-friendly interfaces, accessibility, or other factors that make the e-learning experience more convenient for the participants.
Convenient variable codes
1: Strongly Disagree
2: Disagree
3: Neutral
4: Agree
5: Strongly Agree

1.7 Hypothesis Development

The following assumptions will be tested for the research:

1. Prior – Experience:

- Null Hypothesis (H0): Prior experience with e-learning systems has no significant impact on enhancing efficiency in students.
- Alternative Hypothesis (H1): Prior Experience with e-learning systems significantly influences the enhancement of efficiency in students.

This hypothesis assumes that prior exposure to e-learning might or might not play a role in how efficiently students engage with the system. Testing this will clarify the significance of prior experience.

2. Convenience:

- Null Hypothesis (H0): There is no significant relationship between the convenience of the e-learning system and its ability to enhance efficiency.
- Alternative Hypothesis (H1): There is a significant positive relationship between the convenience of the e-learning system and its ability to enhance efficiency.

The alternative hypothesis suggests that an easier-to-use e-learning system (more convenient) will likely lead to increased user engagement and, consequently, improved efficiency in learning tasks. Conversely, the null hypothesis assumes that the convenience level has no significant effect on the system's efficiency, implying that convenience doesn't play a substantial role in influencing learning efficiency. Different fields might demand varying levels or types of engagement with e-learning systems. This hypothesis whether the area of study affects how effectively students utilize these systems.

2. METHODOLOGY

2.1 Research Design

The study utilized a cross-sectional design to gather data from University and college students from the Eastern Kentucky Appalachian Area. The data was collected through an online survey distributed via universities' and college portal. The survey comprises questions related to prior experience with e-learning, gender, field of study, Convenience, and the level of agreement on statements reflecting efficiency enhancement in e-learning systems.

2.2 Data Collection

The dataset contains individuals' responses to the survey. It includes variables such as Student ID, Gender, Field of Study, Prior Experience with e-learning system, Convenient and the dependent variable - enhancement of efficiency. The respondents used a five-point range scale to indicate their level of agreement, with 1 denoting "Strongly Disagree" and 5 indicating "Strongly Agree". Demographic information was also gathered, revealing the distribution of students across genders and various fields of study.

2.3 Data Analysis

A regression model is employed to analyze the data. The regression analysis aimed to assess the relationship between the independent variable (Prior Experience and Convenient) and the dependent variable (Enhancement of Efficiency). Specifically, this approach allows understanding the extent to which these variables predict efficiency enhancement in e-learning systems among University and college students in the Eastern Kentucky Appalachian area.

2.4 Rationale Behind Employing Regression Model

The statistical method known as regression analysis is used based on the dataset and hypotheses developed. Regression analysis accommodates multiple predictors, offering insights into how these variables predict efficiency enhancement simultaneously. Its ability to handle interactions between predictors makes it the optimal choice for this multi-variable scenario, unlike other models that might focus on single relationships or struggle with multiple predictors.

In our instance, we tested the overall significance of the regression model using ANOVA while accounting for the predictor variables "Convenient" and "Prior experience with e-learning systems." The findings of the regression indicate that at least one of these predictor variables has a substantial impact on improving the effectiveness of the University's e-learning systems.
The whole hypothesis is statistically significant if the p-value for the ANOVA test is less than 0.05 (Significance F < 0.05). This indicates that the null hypothesis—which states that none of the predictor variables significantly affects efficiency enhancement—is rejected by the evidence.

In summary, the use of regression analysis to handle interactions between predictors makes it the optimal choice for this multi-variable scenario, unlike other models that might focus on single relationships or struggle with multiple predictors.

Table 1. ANOVA results

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.746562095							
R Square	**0.557354962**							
Adjusted R Square	0.555799092							
Standard Error	0.93153382							
Observations	572							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	2	621.7070487	310.8535	358.2271864	2.0083E-101			
Residual	569	493.7527415	0.867755					
Total	571	1115.45979						
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***	***Lower 95.0%***	***Upper 95.0%***
Intercept	0.386299338	0.083633728	4.618942	4.77361E-06	0.222030828	0.550567849	0.222030828	0.550567849
Convenient	0.718072766	0.027065678	26.53075	1.4776E-101	0.664911933	0.771233599	0.664911933	0.771233599
Prior Experience with E-Learning System	0.205922946	0.077943826	2.64194	0.008470017	0.052830211	0.359015681	0.052830211	0.359015681

3. RESULTS

The overall model, as indicated by the ANOVA, demonstrates significance (Significance F < 0.05), implying that at least one predictor significantly influences efficiency enhancement. Notably, "Convenient" exhibits statistically significant impacts on efficiency enhancement, supported by its p-value being below 0.05. Additionally, "Prior experience with e-learning systems" has a relatively low p-value, indicating statistical significance, though not as pronounced as "Convenient." This suggests a positive association, indicating that students with both prior experience and convenience tend to display improved efficiency through e-learning systems.

The regression model's R-square is 55%, signifying that 55% of the variability in the dependent variable can be explained by the combination of all independent variables.

4. CONCLUSION

The study utilized a cross-sectional research design involving university students and an online survey to explore factors influencing the efficiency of e-learning systems. Regression analysis, supported by ANOVA, proved effective in examining the relationship between predictor variables and the dependent variable. The analysis highlighted the significance of "Convenience" and "Prior experience with e-learning systems" in enhancing efficiency.

The findings reveal that the overall model is statistically significant, as indicated by the ANOVA test (Significance F < 0.05), confirming that at least one predictor has a meaningful impact on efficiency enhancement. Specifically, "Convenience" emerged as a strong predictor with a significant positive influence on efficiency. Additionally, "Prior experience with e-learning systems" demonstrated statistical significance, although its impact was comparatively less pronounced. These results suggest that students who find e-learning systems convenient and have prior exposure to such systems tend to experience greater efficiency in their learning.

The regression model's R-squared value of 55% indicates that 55% of the variability in efficiency enhancement is explained by the independent variables combined. While this represents a moderate level of explanatory power, it underscores the critical role of "Convenience" and "Prior experience with e-learning systems" in influencing e-learning outcomes.

To improve the effectiveness of e-learning, the study recommends enhancing the convenience of e-learning systems and encouraging early adoption among students. These measures could significantly contribute to fostering a more efficient and impactful e-learning environment.

Optimal Suggestions:

Enhance Convenience: Educational institutions and e-learning platforms should prioritize user-friendly interfaces, accessibility, and overall convenience in their e-learning systems. This may involve regular assessments and updates to ensure a seamless and efficient user experience.

Training and Familiarity Programs: Initiatives to provide training and familiarize students with e-learning systems should be implemented. This can contribute to increased prior experience, potentially improving overall efficiency.

Continuous Improvement: Institutions should engage in continuous improvement efforts, addressing feedback from students regarding the convenience and effectiveness of e-learning systems. Regular evaluations and adjustments can contribute to a more efficient e-learning experience.

Research on Other Influencing Factors: While the study has focused on "Convenient" and "Prior experience with e-learning systems," further research could explore additional factors influencing efficiency enhancement in e-learning. This may include aspects such as content quality, interactivity, and personalization, as mentioned in the theoretical background.

By implementing these suggestions, educational institutions can work towards maximizing the explained variability in efficiency enhancement, ultimately fostering a more effective e-learning environment for students.

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Appendix A

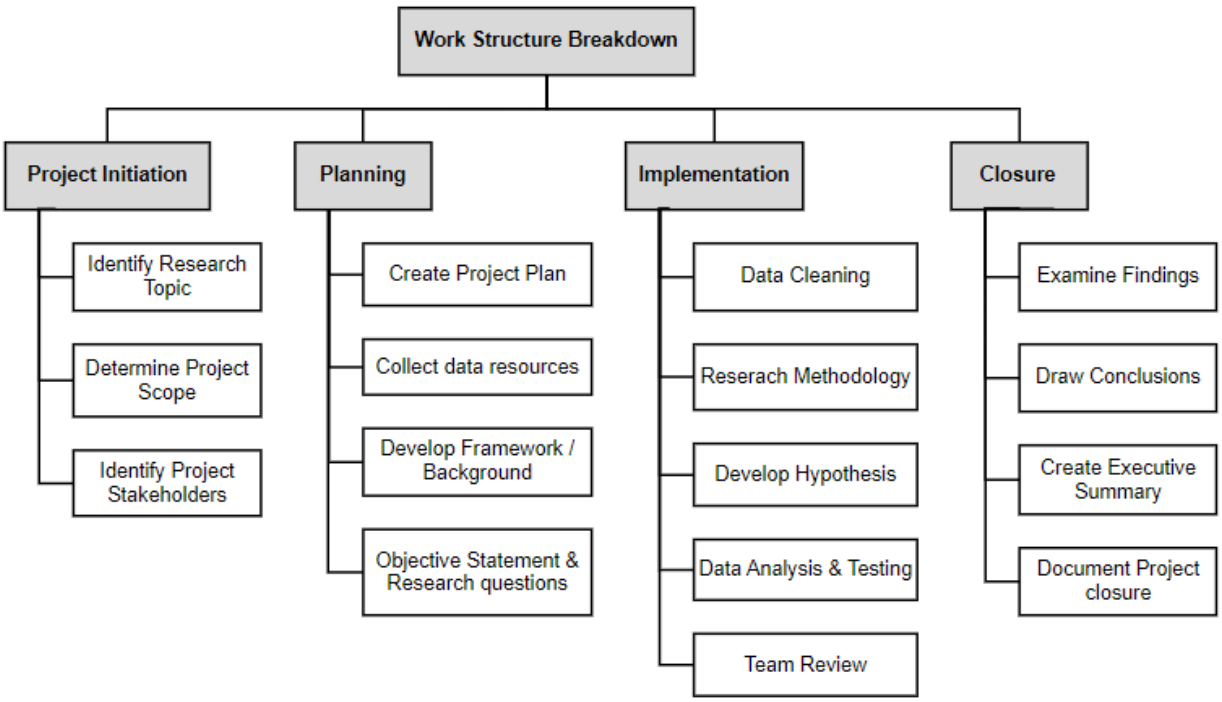
A1. Project Scope Statement

The scope of this research study has encompassed an investigation into students' perspectives on the efficiency of eLearning systems in relation to traditional textbooks and classroom-based learning approaches. It has extended to understanding their preferences regarding these modes of instruction. The scope has also included an analysis of potential variations in efficiency perceptions and preferences across students from different fields of study.

Stakeholder Register

Stakeholder	Main Interests	Category	Power and Influence	Classification
Students	Key participant in research	Internal	High	Leading
Educators/ Instructors/ Faculty	Efficiency of system and ease of use	Internal	High	Supportive
Educational Institutions and Management	Budget and efficiency	Internal	High	Leading
Educational Regulatory Boards	Ensure compliance with other institutes	External	High	Supportive
Learning Management System Providers	Technical system and support	External	Medium	Supportive

A2. Work Structure Breakdown (WSB)

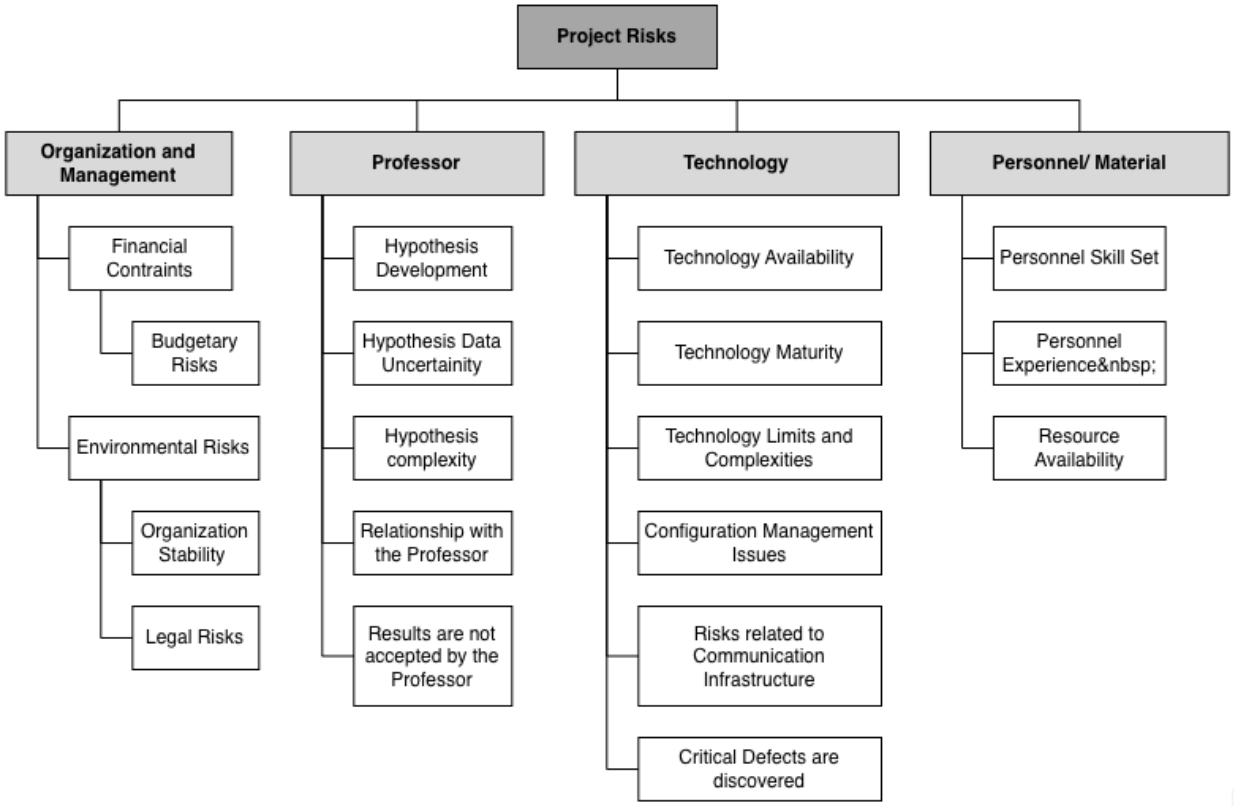


A3. Risk Breakdown Structure and Risk Register

The risk breakdown structure for the project is shown below, along with a list of the phases' categories and subcategories where risks could occur.

Risk Breakdown Structure

The project categories and subcategories that could present risk are shown below. The Risk breakdown structure is shown below.



A4. Risk Register

The project's potential risks are tracked in the risk register, which makes it easier to assess their impact and identify risk-resolution strategies.

Legends for understanding the Risk register

Response

Accept: The best course of action is to recognize the danger and its potential effects.

Mitigate: To reduce the risk, plan alternatives and workarounds in advance.

Control: Since these risks have serious repercussions, their impact needs to be under control. Effectively assess and monitor these risks on a frequent basis.

Transfer: Place the risk with another department or with a different person.

Cost

1. Low
2. Medium
3. High

Scope

1. Increase
2. Decrease
3. No impact

Quality

1. Positive
2. Negative
3. No Impact

Schedule

1. Delay
2. No impact
3. Early

Risk ID	Risk Statement	Probability	Impact				Score	Response
			Scope	Quality	Schedule	Cost		
R001	Project is over budgeted	0.9	1	3	1	3	0.9*0.05 = 0.045	Accept
R002	Legal Risks	0.1	3	3	1	3	0.1*0.8 = 0.72	Control
R003	Project is delayed	0.3	3	3	1	3	0.3*0.4 = 0.12	Control
R004	Risks related to interpretation of requirements	0.8	1	2	1	3	0.8*0.05 = 0.045	Mitigate
R005	New or updated requirement	0.1	1	1	1	2	0.1*0.1 = 0.1	Accept
R006	Risks related to communication with Professor	0.3	3	3	2	2	0.3*0.23 = 0.69	Control
R007	Results are not accepted by the professor.	0.9	1	2	1	3	0.9*0.1 = 0.90	Control
R008	Analysis Results incomplete	0.9	1	2	1	2	0.9*0.8 = 0.72	Control
R009	Not enough data	0.7	1	2	1	2	0.7*0.11 = 0.77	Control
R010	Configuration management issues	0.6	3	3	2	1	0.6*0.05 = 0.030	Accept
R011	Selected software tools are not suitable for task	0.4	1	3	1	3	0.4*0.1 = 0.40	Mitigate
R012	Risks related to communication infrastructure	0.5	3	1	1	2	0.9*0.5 = 0.35	Mitigate
R013	Risks related to hardware or infrastructure	0.3	3	1	2	2	0.3*0.05 = 0.015	Mitigate
R014	Risks related to the competence of management	0.2	3	3	2	1	0.2*0.06 = 0.012	Accept