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# SCIENCE AND TECHNOLOGY

# Utilization of ammonia in fuel cells-A Review

***Sandeep Arya* and Sonali Verma*****

## ABSTRACT

*In recent years, ammonia has gained great attention due to its outstanding properties like high energy density (when liquefied) and carbon free nature. Further, we have gone into an era where hydrogen plays an imperative role as a fuel and as an energy carrier. Hydrogen is a good energy vector due to the reason that the only product is water from either combustion or fuel cells. However there are various problems associated with direct utilization of hydrogen in fuel cells such as hydrogen does not exist naturally as well as its storage and transportation is not easy due to its low volumetric energy density and small molecular size. Therefore, on-board storage of hydrogen remains a big challenge that restricts the application of hydrogen fuel cells. Considering the need to modify the hydrogen energy systems, ammonia appears to entail a major role in the growth of hydrogen economy. The storage of hydrogen is possible in some light chemicals such as ammonia, ethanol, methanol, etc but in terms of carbon dioxide emission, ammonia is a good indirect hydrogen storage material as it will not release carbon dioxide when used as fuel. Taking in view all the advantages of ammonia this review deals with the synthesis of ammonia, hydrogen generation from ammonia, utilization of ammonia as fuel for fuel cells, future prospect as well as challenges in developing direct ammonia fuel cell.*

**Key Words:** Fuel Cells, Energy storage.

### Introduction

Different parts of the world follow different living standards. Infrastructures are under development with the intention to facilitate the living of humans. Moreover, energy plays an imperative role as it is the most basic resource for human activity. Increase in population followed by rapid industrialization and urbanization results in the great global challenge in terms of development and management of the energy resource. The present technologies cannot accomplish the escalating demand for energy. Various alternative energy sources have been suggested including wind and solar energies that exhibits the potential to replace conventional method for the generation of energy. In fact, studies on the development of alternative resource for energy generation, technology with high efficiency, eco-friendly conversion of energy and storage concern have increased globally, especially after the Fukushima nuclear disaster in 2011 [1]. Moreover, in order to reduce the emission of greenhouse gases that arise from the utilization of non-renewable fossil fuels and to expand the use of renewable sources, fuel cells exhibits all features of a promising tool for competent and harmless power generation both for stationary as well as mobile applications due to their environment friendliness and high efficiency. One of the reasons for the expansion of thermodynamic systems to generate electricity electrochemically by consuming the reactants from external sources is fuel cell

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[2]. A fuel cell generates electricity and produces water and heat by combines together both the oxygen and hydrogen. However, most of the times fuel cells and batteries come in comparison as the basic purposes of both are same. Fuel cells posses several benefits such as eco friendly, highly efficient and a technology capable of converting fuel directly into electricity. On the basis of competence, temperature at which the fuel cells are operated, overall cost and electrolyte materials used, grouping of fuel cell was done. On the basis of electrolyte material, fuel cells are classified into following six major systems [3]:

- Alkaline fuel cells.
- Solid oxide fuel cells (SOFCs).
- Phosphoric acid fuel cells.
- Proton exchange membrane (PEM) fuel cells.
- Molten carbonate fuel cells.
- Direct methanol fuel cells.

The solid oxide fuel cell (SOFC) has flexibility of fuel with non toxic electric power generation [4]. Moreover, various fuels such as biogas, hydrogen, bio-methanol and bio-ethanol can be used directly in an SOFC that functions at high temperature ranging i.e. from 1073 K to 1273 K [5]. Although hydrogen exhibits all the characteristics of an ideal fuel, there exist some serious problems related with its production, transportation and storage [6].

In 1990, the concept of hydrogen economy was renewed with the surge in fuel cell technology. One of the proficient and harmless sources of energy is hydrogen because its final product is only water from either fuel cells or combustion. So, hydrogen as fuel has some demerits; firstly no natural existence and secondly it is very difficult to transport or store hydrogen because of the small molecular size and low volumetric energy density. Alternatively, some light chemicals such as ethanol, ammonia, methanol, etc. can be used as fuel. In recent years, ammonia ($NH_3$) gain attention as a promising fuel in solid oxide fuel cells for electricity generation due to the reason that it is easy to store, carbon-free, relatively less flammable, economical and safer than other fuels because leakage of ammonia is easily detected from its odour. In addition, ammonia has the highest density of hydrogen among various fuels. Also due to the well modified infrastructure of $NH_3$ technology, the curiosity of using ammonia in solid oxide fuel cells have been increased [6, 7-13]. In terms of the emission of carbon dioxide ($CO_2$), ammonia is supposed to be a better indirect hydrogen storage material or fuel as it is carbon free, therefore, will not emit $CO_2$ when used in a gas turbine or fuel cell as a fuel. The energy density of ammonia is less than that of a typical hydrocarbon fuel but more when compared with metal halides and it is about 22.5MJ/kg at HHV (higher heating value). The liquid ammonia has raw energy density of 11.5MJ/L, which is higher than the 8.491MJ/L and 4.5MJ/L for liquid hydrogen and compressed hydrogen respectively at a pressure of 690 bar and a temperature of 15°C [14]. However, in using ammonia as the fuel, safety is considered as the major drawback. Although ammonia is poisonous, it is easily detected by humans from its pungent odour in a very little concentration of just 1ppm. Ammonia that is anhydrous in nature being lighter than air tends to diffuse in the atmosphere. Ammonia in its liquid state is a good source of hydrogen and its safety is comparable to that of gasoline. Every year more than 200 million tons of ammonia are produced and distributed worldwide through tankers, trucks and pipelines, making ammonia readily cheap and easily available.

## 1. Why Ammonia for fuel cells?

Here a comparison of ammonia as a safe, economical and sustainable fuel with other fuels is

made. Fig. 1 shows the comparison regarding energy density in terms of volume and gravity stored on-board on various fuels while Table 1 shows some traits of various important fuels together with characteristics of ammonia [15]. It consist the lists of various fuels and the type of storage with the fuel pressure and density (excluding methanol and gasoline where the density refers to the liquid itself). Other mentioned characteristics are the energy and energy densities, the higher heating value, the specific energetic cost (cost per unit of energy) and the specific volumetric cost (related to the tank internal volume). In accordance to the data illustrated in Table 1, we briefly portrayed about various resources as fuels and compare them in terms of performance, energy, thermodynamic parameters, etc.

**Gasoline**

In our comparison, Gasoline is assumed as a reference fuel. Its production via crude oil distillation is relatively expensive and intended at eliminating different toxic components such as sulphur, lead, etc. Moreover, the specific energetic cost of the fuel is also high (Table 1). Further its energy storage per unit volume is more when weigh against some other fuels. Apart from its high specific cost, gasoline emits $NO_x$, $SO_x$, large amounts of carbon dioxide and various other pollutants.

**Compressed natural gas**

Due to less emission of carbon dioxide, CNG has an advantage over gasoline. CNG consists mainly in methane. Typically, a pressure of 250 bars is required to store CNG in cars on special “integrated storage systems”; this system comprises of a number of interconnected tubular tanks and fixed firmly in safety foam to evade fracture danger during an accident. Due to its gaseous state, the storage of energy density in the CNG tank is less when compared with the gasoline. It is approximately more than three times lesser. This fact leads to high specific energetic cost however the cost of a full CNG tank is about 23 times cheaper than the gasoline of same volume. Moreover, the CNG engine runs more systematically and therefore the cost per 100 km drive of a CNG car is slightly more than that of a gasoline car.

**Methanol**

For fuel cell cars, methanol exhibits all the attributes of a potential option. As illustrated in Table 1, its higher heating value (HHV) trim downs with the energy required for reforming. The fuel cost per unit volume of tank is twice but its energy density is not higher but than gasoline.

**Liquid petroleum gas**

Pressurized vessels are used to store LPG at a pressure of about 14 bars in thermodynamic equilibrium with its vapours. Both the LPG and gasoline have the same energetic value, but the LPG tank stores energy three times less than gasoline but high engine efficiency. Thus, these fuels (LPG and CNG) being pure chemical substances in contrast to gasoline which is a complex blend containing toxic components, can be consumed in a clean way.

**Hydrogen**

Hydrogen gain attention due to its HHV and its clean combustion in which only water is produced. Hydrogen is stored in hydrides of metal in the modern systems under 14 bar pressure and densities up to 25 $kgm^{-3}$. Moreover, the cost does not depend on the choice of the hydrogen production method (gasification, electrolysis, etc.) as this fuel is relatively expensive. It also suffers storage problem.

**Ammonia**

Ammonia can be simply and inexpensively produced from synthesis gas through the well known HaberBosh process. Ammonia is formed over catalysts by simply the addition of nitrogen to synthesis gas and then separated via condensation with no energy penalty. In general, methane is the primary material to produce ammonia, but instead of using methane any other fossil fuels or biomass can also be used for the production of ammonia. Moreover, ammonia can also be produced biologically from manure and waste by some special micro-organisms. There is an interesting fact that the cost of energy in form of $NH_3$ is only 13.3 \$ $GJ^{-1}$ when compared to 38.3 \$ $GJ^{-1}$ in case of CNG which consist mostly methane.

**Ammonia resources and synthesis**

Ammonia ($NH_3$) is an inorganic chemical. Nitrogen and hydrogen combine together to give ammonia. It is a gas with a distinct odor, having no color and occurs naturally throughout the environment in the air, water, soil and in plants and animals, including humans. The human body produces $NH_3$ by converting or breaking down protein foods into amino acids and ammonia and then converts the ammonia into urea. Its natural sources include decaying of organic material, waste of animals and humans etc. Ammonium hydroxide (household ammonia) has applications in various household cleaning products that we use every day. For ammonium nitrate fertilizer, ammonia acts as a basic building block which releases nitrogen, which helps in proper plant growth. The viability of ammonia fuel is influenced by two factors mentioned below:

1) Development of efficient and green methods of synthesizing ammonia.

2) Development of various technologies to burn ammonia in power generation plants.

With the machinery that can burn NH3 in the systems of gas turbine, it is assumed that the ammonia will become a feasible green and efficient alternative fuel. In 2010, the several large-scale production plants of ammonia all over the world produce total of 131 million tonnes of nitrogen which corresponds to 159 million tonnes of ammonia. Table 2 shows that China produced approximately 32.1% of ammonia worldwide, followed by India which produced approximately 8.9% then Russia and the United States with approximately 7.9% and 6.3% production respectively. Ammonia is also used for producing explosives, fibres, nitric acid (via the Ostwald process), plastics, intermediates for dyes and pharmaceuticals and also for fertilizing agricultural crops [2].

Different methods and techniques are opted for ammonia synthesis. Haber-Bosch process which was the first chemical process used in industries, also known as synthetic ammonia process, developed by the physical chemist named Fritz Haber, is a process in which ammonia is synthesized directly from hydrogen and nitrogen. In Haber-Bosch method, chemical reaction takes place under the condition of high pressure and moderately high temperature at which nitrogen from the air combines directly with hydrogen. Usually an iron catalyst enables the reaction to take place at a lower temperature than would otherwise be practicable, while the deduction of ammonia from the batch as soon as it is formed guarantees that equilibrium is maintained so the desirable result is achieved. High pressure is the conditions for high $NH_3$ yield in the mixture at low temperature. Commercially, nitrogen and hydrogen react together at temperatures and pressure ranging from 400°-650° C and 200-400 atmospheres respectively for $NH_3$ production. Green Jr. proposed that the heat evolved from the nuclear reactors is utilized for the formation of hydrogen before the synthesis of ammonia through the Haber-Bosch process [16]. The synthesized $NH_3$, for a low- carbon term is an ideal and potential energy vector. The $NH_3$ synthesis by means of Haber-Bosch process has been greatly developed. The incessant investigation for catalysts exhibiting greater activity has permitted operation at lower

temperatures followed by lower pressures. In addition to catalyst optimization, efforts are given more in investigating new methods for the synthesis of ammonia such as synthesis of $NH_3$ electrochemically by the utilization of solid electrolyte cells [17]. The initial report was on solid state ammonia synthesis (SSAS) and over 30 different solid state electrolytes have been scrutinized and atleast 15 different catalysts have been tested as working electrodes [18].

Moreover, by using a Nafion solid electrolyte and a $SmFe_{0.7}Cu_{0.1}Ni_{0.2}O_3$ mixed-oxide electrode as cathode at 80°C temperature, the peak rate for the production of $NH_3$ is attained that is 1.13 x 10-8 mol $s^{-1}$ $cm^{-2}$. The peak rate at high temperatures (>500 °C) for the $NH_3$ formation is 9.5 x $10^{-9}$ $mols^{-1}cm^{-2}$ using $Ce_{0.8}Y_{0.2}O2_{-\delta}$-($Ca_3(PO_4)_2$-$K_3PO_4$) as electrolyte and Ag-Pd electrode as cathode [18]. The growth of an industrial process for production of ammonia is considered as the heterogeneous catalysis bellwether reaction and has played an essential role in the expansion of the chemical industry during the 20th century [19]. Molecular $N_2$ can be converted naturally into ammonia ($NH_3$) without maintaining high temperatures and pressures conditions [20,21]. This process of $NH_3$ synthesis naturally is based on the deployment of metalloenzymes that has been significantly developed and used for a long period. Another enzyme which is known as nitrogenize, contain molybdenum and iron catalyse the reaction for the synthesis of ammonia from atmospheric nitrogen, electrons and protons [21]. The high efficiency of this enzyme-catalysed synthesis has attracted the researchers in terms of nature simulation. Since for last two decades, considerable improvement has been realized in knowing the biological process method as well as developing a biological process artificially with the use of transition metal complexes [21-23]. Various researchers used the aqueous medium for the electrochemical production of ammonia [24]. Then the discovery of solid-state proton (Hþ) conductors [25] gives the opportunity of synthesizing $NH_3$ under the high temperatures and the first work on SSAS was showed by Marnellos and Stoukides [26,27].

A full review of the SSAS reported till the end of 2010 by Amar et al. [28], discuss the requirements of component of cell with main emphasis on the solid state electrolyte materials. Panagos et al. [29] developed a model which shows that by using a solid-state proton (Hþ) conductor cell, the amount of yield of the product of a hydrogenation reaction can increased by several orders of magnitude than that of the corresponding catalytic reactor and $H_2$/Pd/SCY/Pd/$N_2$ form of solid electrolyte cell is used. The Hþ conductor, strontiaceriaytterbia (SCY) perovskite, having $SrCe_{0.95}Yb_{0.05}O_3$ form was studied which consist of two porous polycrystalline Palladium films that act as electrodes. At a temperature of 570°C and atmospheric pressure, approximately 78% of the protons supplied were converted into $NH_3$. Then the use of $N_2O$, instead of $N_2$, encouraged an alternative approach for the synthesis of ammonia that uses oxygen ion conductors ($O^{2-}$). The formation rate was not high at 500°C temperature. The reaction rates observed in this process were lower than those in Hþ cells, still the use of $O^{2-}$ conductor offers additional advantages: pure $O_2$, separation from the reacting mixture, being as by-product.

Serizawa et al. [30] studied synthesis of $NH_3$ via a molten LiClKClCsCl system at 360-390 °C temperature and studied that some portion of $NH_3$ was chemically dissolved in the form of amide and imide anions in the melt, causing a drop in the yield of $NH_3$. Kordali et al. [24] produced $NH_3$ from $N_2$ and $H_2O$ at 90 °C using Nafion as proton conductor and Ru/C electrode as cathode. An analogous approach was effectively tested at high temperatures by means of a proton conductor of perovskite type and the reactants were gaseous nitrogen and steam. Wang et al. [31] make use of natural gases such as $CH_4$ and $C_2H_6$ rather than $H_2$ as a source of hydrogen for the synthesis of ammonia. Recently,

Lan et al. [32] reported $NH_3$ synthesis at room temperature from $H_2O$ and air.

### 3.1 Electrochemical Ammonia Synthesis

In the year of 1985, Pickett and Tlarmin showed an electrochemical synthesis of ammonia at room temperature via a proteolysis of cis-$(W(N_2)_2(PMe_2Ph)_4)$ [33]. Recently, electrochemical synthesis has been developed for the replacement of the Haber-Bosch process. Plasma-enabled synthesis of $NH_3$, electrolysis of $N_2$ and electro-thermochemical looping approach, etc. are the three electrochemical methods that are developed recently for the synthesis of $NH_3$.

#### 3.1.1 $N_2$ Electrolysis for Ammonia Synthesis

The electrolysis of $N_2$ is an attractive and effectual method for the production of $NH_3$ electrochemically, as it is usually carried out under ambient environment using feed stocks as water and nitrogen [34, 35]. In a typical electrolyzer of $N_2$, $N_2$ gas is fed to the cathode chamber which drops down to $NH_3$, whereas $H_2O$ is oxidized to $O_2$ gas at the anode chamber. At both the anode and the cathode, an $O_2$ evolution and a $N_2$ reduction catalyst are supplied respectively to reduce the overpotentials at the two electrodes. Metal, metal organic framework-derived C [36] and nitrides of transition metal [37] show good selectivity for $NH_3$. Recently, nanoparticles of vanadium nitride were investigated as an active catalyst for electrolysis of $N_2$ with faradaic efficiency and overpotential of approximately 6% and 200mV respectively and an initial $NH_3$ production rate of $3.3 \times 10^{-10}$ mole $s^{-1}$ $cm^{-2}$. In the electrolysis of $N_2$ while using nitrogen-containing catalysts, it is important to establish a balanced quantitative nitrogen-mass in order to calculate the $NH_3$ production rate and to confirm the nitrogen source and as feed $15N_2$ should be used. Moreover, the configuration of electrode membrane assembly is more suitable against the conventional configuration of three-electrode system as it gives large $NH_3$ to offer representative of catalyst performance of device operation level. At the overpotential of 200 mV and Faradaic efficiency of 6%, the energy cost of electrolysis of $N_2$ for the ammonia synthesis was about 5.3 MJ $mole^{-1}$ of $NH_3$ that is higher than the expenditure in case of SOA Haber-Bosch process. The deprived efficiency of reduction catalyst of $N_2$ contributes to the poor energy efficiency. Also the linear scaling relationships of activation barrier for the cleavage of N-N bond and atomic nitrogen B.E made it more difficult to design an active and selective catalyst that can cleavage the N-N bond for the formation of the $N_2H$ intermediate [38]. So, new strategies and techniques have been developed for designing an active catalyst.

#### 3.1.2 Plasma-Enabled Ammonia Synthesis

Plasma-enabled synthesis is a successful method for activating the stable molecules like $N_2$, followed by their conversion into more reactive molecules for further reactions. Plasmas can be categorized as thermal and non-thermal concerning the particles and electrons temperature. In comparison to thermal plasma, the non-thermal plasma is more efficient in terms of energy for ammonia synthesis as the former utilizes energy for heating both particles and electrons to a very high temperature. Mehta et al. [39] studied a non-thermal plasma system for $NH_3$ synthesis. The plasma reactor depends on the two electrodes system with one source of high voltage power to produce barrier-discharge plasma that is dielectric for the dissociation of nitrogen and hydrogen gas molecules into reactive species like H', N', NH', and $NH_2$' where the symbol ' represents the adsorbed intermediate. At a reactor temperature and a plasma power of 438 K and 10 W respectively, a yield of about $0.01^{-0.06}$ $s^{-1}$ i.e. a site-time yield was attained with catalyst that is metallic in nature. Also the

plasma enabled process for $NH_3$ synthesis gets enhanced by using active catalyst material. The energy cost for non-thermal plasma-enabled process was approximately 1.1 MJ $mole^{-1}$ of $NH_3$ that is based on the performance of the catalyst. Although, the non-thermal plasma process is much expensive as compared to Haber-Bosch process but still with some significant developments this process will become even better than the Haber-Bosch process [40].

### 3.1.3 Electro-Thermochemical Looping Approach

It is a technique in which both the electrochemical and thermochemical steps are merged to overcome the problems encounter in pure electrochemical processes [41, 42]. Among various metals, lithium promises the activation of $N_2$ as it will react with nitrogen under ambient conditions of temperature and pressure. McEnaney et al. [41] studied recently a Li-mediated approach for $NH_3$. Initially lithium hydroxide is used for the electrochemical production of metallic Li at 600700 K reaction temperature in a molten salt electrochemical cell followed by the formation of lithium nitride by reacting metallic Li with $N_2$, and then with the exposure to $H_2O$, $NH_3$ is produced whereas to close the loop, lithium hydroxide was formed. This procedure offers the Faradaic efficiency of ≈88.5% which is higher than the SOA electrolysis of $N_2$ by 10%. Moreover, current density achieved for the process of LiOH electrolysis (500mA $cm^{-2}$) shows improvement over the SOA electrolysis of $N_2$ process. As the electrochemical reduction of $Li^+$ ion to metallic Li is obtained at a cell potential of >3.1 V, the overall energy cost is ≈1.08 MJ mole-1 of $NH_3$ by using this method. Moreover, under ideal situations, this process costs 0.93 MJ mole-1 of $NH_3$, indicating a space for more advancement.

## 4. Hydrogen generation from ammonia

Different procedures are used to derive hydrogen from ammonia. Most of the work in literature is dedicated to catalytic cracking or ammonia thermal into $N_2$ and $H_2$, and only fewer work related to the electro-oxidation or electrolysis methods. Some work based on the hydrolysis of ammonia products (ammonia borane) was also reported.

### 4.1 Catalytic decomposition of ammonia

At a temperature of 200°C, ammonia being unstable at such high temperature begins to decompose [43]. Equation (1) illustrates the reaction mechanism of $NH_3$ decomposition.

$$2NH_3 + 92.4KJ \rightarrow N_2 + 3H_2 \quad (1)$$

This above mentioned reaction is endothermic reaction in nature. Thermodynamically, at temperatures less than 425 °C, hydrogen is produced by about 98-99% conversion of $NH_3$. However, practically the conversion rate of $NH_3$ to $H_2$ depends on both the temperature as well as the catalysts. The thermal decomposition of $NH_3$ is the extensively used mode of $H_2$ generation. Lipman and Shah [44] scrutinized that for large generation (> 1000 $m^3$/hour) of hydrogen, the reformation of natural gas is most efficient and economical, however for generation at small scale (<10 $m^3$/hour), ammonia cracking becomes slightly more economical as shown in Table $_3$.

For $NH_3$ decomposition, large number of metals, alloys, and compounds of noble metal have been scrutinized. These incorporate Fe, Pt, Ru, Pd, Ni, Ir, Rh, alloys of Fe with some oxides of metal including Ce, Si, Al, Sr and Zr, alloys such as Ni/Ru, Ni/Pt, Pd/Pt/Ru/La [45]. Different catalysts including WC, $NiCeO_2/Al_2O_3$, $Ni/Al_2O_3$, $Ru/ZrO_2$, $Cr_2O_3$ and Ru on carbon nano-fibres have also been checked for alkaline fuel cells. A high potential candidate Cs-promoted Ru supported on graphite was also investigated [43]. For proficient release of $NH_3$ to produce $H_2$ by utilizing these catalysts, there is a requirement of minimum temperature that is 300 °C. The efficiency of the catalysts depends on the

aspects like the $NH_3$ conversion fraction, the hydrogen formation rate and also the activation energy. The rate of $H_2$ production has been measured experimentally from the decomposition of $NH_3$ and can be expressed in the units of mmol/min/g (millimoles of $H_2$ produced per minute per gram of loaded catalyst). The performance of assorted catalysts (based on an $NH_3$ gas hourly space velocity (GHSV) of 30,000 mL/h/g of catalyst excluding GHSV = 60,000 mL/h/g and 150,000 mL/h/g) for $NH_3$ decomposition is summarized in Table 4.

At a temperature range of 225-925°C and $NH_3$ partial pressure of about 133 kPa, Papapolymerou and Bontozoglou [55] scrutinized the rate of decomposition of $NH_3$ by using catalyst made from polycrystalline wires of foils and categorized them according to their rate of reaction in decreasing order as: Ir > Rh > Pt > Pd. Choudhary et al. [48] at a temperature range of 400 700 °C performed analogous work through pure $NH_3$ and then arranged them as Ru > Ir > Ni and reported that Ru supported in silica based catalysts results in highest rate of decomposition with the maximum rate of conversion of $NH_3$. The influence of Ru in silica support was scrutinized by Yin et al. [45] with a conclusion that a peak value at 15% weight loading of Ru is reached by the rate of conversion of $NH_3$. Initially there was an increase 0-15% with loading of Ru, but above this, it was difficult to get the sub layers of Ru thus making them superfluous. The proposal of the silica support is to make better the dispersion and augment the effective area of the active catalyst. The support used in the experiment should stable under reaction conditions of temperature and pressure and must have a high specific surface area. Large number of supports with different characteristics has also been premeditated. An assortment of supports including silica, carbon nanotube and carbon nanotube doped with nitrogen for Ru catalyst has been investigated [48, 56-62]. Yin et al. [52] arranged the supports for Ru catalyst accordiong to their activity analyzed by rate of conversion of $NH_3$ in the decreasing order as CNT > MgO > $TiO_2$ > $Al_2O_3$ > $ZrO_2$ > AC > $ZrO_2$/BD. Among these supports, CNT proves to be the best support as it allowed the superior dispersion of Ru catalyst and also reveals no impurity with peak conductivity which sustains the electron transfer and thus encourage the step of recombinative nitrogen desorption. They further revealed that the Ru catalyst in MgO-CNT support shows better performance than in MgO or CNT base alone [53]. Literature also shows that the acidic conditions are not apt for $NH_3$ decomposition. Yin et al. [52] synthesize carbon nanotubes using potassium hydroxide and investigated that it shows good catalytic performance according to the conversion efficiency and reaction rate factors. Moreover, the results of $N_2$-temperature programmed desorption (TPD) shows that higher the basicity, the better the catalyst performance i.e. direct association [52]. They further examined the effects of the potassium concentration and promoter cation on the characteristics of the catalytic, structure and morphology of Ru/CNT [54] and monitor an increase in the $NH_3$conversion with the drop in the electronegativity values associated with the promoter cations i.e. inversely relationship. On treating Ru/CNT with potassium nitrate, potassium hydroxide, etc the rate of conversion of $NH_3$ and the rate of $H_2$ evolution are enhanced considerably (see Table 4). Yin et al. [45] concluded that the best catalyst is Ru supported on alkaline promoted carbon nanotubes for the decomposition of $NH_3$. But there is one demerit associated with the use of Ru in fuel cell that it will affect the system on economical grounds and lift up overall expenses of the system as it is a highly expensive metal for mass production. However, this limitation can be overcome via some more economically active catalyst like Nickel as at high temperatures (500- 600 °C), the performance of Ni is approachable to that of Ru operating at 400°C and has the merit of loading high concentrations to attain the aspired results.

*4.2 Reaction mechanism of ammonia decomposition*

According to various works in literature, the reaction mechanism of $NH_3$ decomposition incorporates the following reaction steps:

1) Ammonia adsorption onto catalyst sites

2) N-H bond cleavage on adsorbed ammonia

3) Recombinative desorption of $N_2$ atoms [63].

These three steps are respectively shown in equations given below as

$$NH_3 + ' \rightarrow NH_3$$

$$NH_3' + ' \rightarrow NH_2' + H'$$

$$2N' \rightarrow N_2 + 2'$$

(where the symbol ' refers to an active site and X' refers to X species get adsorbed onto an active site)

It was also studied that with respect to $NH_3$ partial pressure, the $NH_3$ rate of decomposition over catalyst like Fe and Pt, migrates from zero to first order with increase in temperature [64]. Tsai and Weinberg [65] found that the breakdown of the nitrogen-hydrogen bond of adsorbed $NH_3$ as in step 2 on Ru catalysts, above 400 °C temperature is rate limiting step, whereas the recombinative desorption of N-atoms as in step 3 below 400 °C temperature is rate limiting step as the apparent energy of activation shifts from 180kJ/mol to 21kJ/mol at low to high temperatures without accounting the influence of inhibition of hydrogen. Later studies revealed that the hydrogen is released at low $NH_3$ partial pressures and low temperatures that will act as hindrance in the decomposition mechanism of NH3. Bradford et al. [56] aspire to gain more knowledge on inhibition of $H_2$ on $NH_3$ decomposition over Ru/C catalyst and for this the partial pressure of $NH_3$ was shifted from $1.3^{-12.0}$ kPa with 370-390°C temperature range, and noticed the first order reaction rate dependence. They proposed the following equation having α and β parameters and the activation energy was 96.6 kJ/mol. Here, the α and β shifts from 0.69 to 0.75 and $^{-1.5}$ to $^{-2}$ respectively.

$$r_{H_2} = kP^{\alpha}_{NH_3} P^{\beta}_{H_2} \qquad (2)$$

Egawa et al. [66] disclosed that the inhibition by $H_2$ was connected with the set up equilibrium among adsorbed $N_2$ atoms, gas-phase $NH_3$ and gas-phase $H_2$; and that recombinative desorption of adsorbed $N_2$ atoms was regarded as the step for determining the rate by using deuterated $NH_3$ on Ru catalyst surfaces. Vitvitskii et al. [67] gave an analogous conclusion on the basis of the results obtained from the experimental using diluted $NH_3$. Boudart et al. [63] observed that over tungsten and Molybdenum catalysts, the breakage of the bond between nitrogen and hydrogen (step 2) and the surface recombinative desorption of $N_2$ atoms (step 3) are slow steps and even irreversible in the decomposition of $NH_3$. Skodra et al. [68] found that at low $NH_3$ partial pressures (0.5 2.0 kPa) and high temperatures (350-650 °C) over a Ru catalyst support, there is no importance of inhibition of $H_2$. They also scrutinized 2$^{nd}$ order reaction rate dependence by supposing that the step for determining the reaction rate is the surface recombinative desorption of $N_2$ atoms (step 3). Shustorovich and Bell [69], on the basis of BOC Morse potential method suggested that step 3. Chellappa et al. [70] studied $NH_3$ in its pure form over Ni-Pt/$Al_2O_3$ catalyst support at a temperature range of 520 690 °C, and do not detect

the inhibition of $H_2$. The activation energy was calculated to be 196.2kJ/mol and the reaction was observed to be of first order. Thus it gives an idea that low temperatures and low $NH_3$ concentrations conditions are favorable for the $H_2$ inhibition. More recent research work demonstrates a shift in the order of reaction from one to two in accordance to the temperature with respect to $NH_3$ partial pressure unlike earlier work which shows a shift from zero to one. The parameter β varies between -1.5 and -2 at low $NH_3$ concentrations and temperatures, but with increase in the $NH_3$ concentration and temperature it shifts to zero. There seems to be an agreement in the statements of various researchers that the step for determining the rate of reaction is step 3.

*4.3 Electrolysis of Ammonia*

Extraction of hydrogen from $NH_3$ is done via electrolysis. The production of Hydrogen was first discussed by Vitse et al. [71] in an alkaline medium, who scrutinized the coupling of $NH_3$ oxidation and reduction of $H_2O$ at the anode and cathode respectively.

$$2NH_3 + 6OH^- \rightarrow N_2 + 6H_2O + 6e^-,\ E^0 = -0.77V / SHE \qquad (3)$$
$$6H_2O + 6e^- \rightarrow 3H_2 + 6OH^-,\ E^0 = -0.82V / SHE$$

The thermodynamic potential for $NH_3$ is -0.77 V as compared to -1.223 V for the $H_2O$ in alkaline medium [72]. Theoretically this means that $NH_3$ electrolysis consumes 95% less energy to give out a certain amount of hydrogen than $H_2O$ electrolysis. Although, the kinetics is slow but the $NH_3$ electrolysis is thermodynamically effective. The most widely accepted mechanism for the oxidation of ammonia is:

1) Ammonia adsorption on to Pt surfaces
2) Ammonia dehydrogenation into various adsorbed intermediates such as N, NH, $NH_2$ etc.
3) The intermediates reacts to form $N_2H_4$,ad, $N_2H_2$,ad, and $N_2H_3$,ad which then produce nitrogen after the reaction with $OH^-$ [73].

Here the rate determining step is the reaction of $N_2H_{2,ad}$. Vidal-Iglesias et al. [74,75] did the differential electrochemical mass spectrometry (DEMS) analysis and suggested the presence of some azide intermediate ($N_3$-) species. Among the various adsorbed intermediates, N acts as a poison. Usually, high overpotentials are entailed for the $NH_3$ oxidation and at peak current densities the deactivation of the Pt catalyst is observed [76,77]. With Pt, at very high potentials only $N_{ad}$ is formed, thus making Pt the best catalyst for ammonia electro-oxidation. Also the alloys of Pt employed as catalysts are very effectual for $NH_3$ oxidation. Endo et al. [78] scrutinized the combined catalysts of Pt with some other metals including Ir, Ni, Cu and Ru and wind up that only the catalyst Ir and Ru can boost the catalytic properties of Pt. An alloy of bulk Pt was also tested by using bulk Ir which shows superior performance than Pt alone but still low values of oxidation current densities i.e. less than 1 mA/cm² [79]. De Vooys et al. [76] studied oxidation of $NH_3$ and intermediates on different catalyst surfaces like Pt, Rh, Ir, Pd, Ru, Cu, Au and Ag. They concluded that only Ir and Pt have a good capability of $NH_3$ dehydrogenation with a little affinity of $N_{ad}$ production. In another work, a powder of Pt-Ir mixture (50 wt.%) saturated in Teflon and painted on a platinum screen was recommended to provide much lower value of overpotentials for $NH_3$ oxidation than platinum black [80] by using a very high loading of costly metal catalysts (up to 51 mg/cm²) making them uneconomical for use in fuel cell. Botte et al. [71] studied Pt-Ru alloys as catalysts for oxidation of ammonia. Individually both Pt and Ru

resulted in fast ammonia dehydrogenation at low potentials and as a result there is fast deactivation of the catalyst. However, when Pt and Ru get combined, the Pt permitted a significant recombination rate of adsorbed $N_2$ and a low Ru catalyst loading avoid the fast dehydrogenation of $NH_3$ from dominating step of nitrogen recombination. They also proposed the method of co-electrodeposition for a low loading of noble metals (~2.5 mg/cm²). In another work, the $NH_3$ electrolysis was examined on the substrate of Raney Ni with high surface area covered with Pt and Rh [81]. The electrodes were characterized and all the characterizations demonstrated that Rh produced a synergistic effect when combined with Pt as a catalyst for electro-oxidation of ammonia. Hydrogen was produced successfully from a solution of 1M $NH_3$/5M KOH at energy consumption of 14.54 Wh/g $H_2$ and current density of 2.5mA/cm² by an anode having 1 mg/cm² and 10 mg/cm² loading values of Rh and Pt respectively at ambient conditions of pressure and temperature values. By reducing the Pt loading to about 5mg/cm², then 16.83 Wh/g of $H_2$ becomes the required energy for electrolysis. They did not mention the results of using Pt alone as catalyst. According to their XPS results 1 mg/cm² is the most favorable loading of Rh, since at this loading, the proportion of the noble metal coverage get maximized to exposed substrate metal. Conversely, the energy necessity is nearly 10 times higher when compared with the theoretical thermodynamic value for the production of hydrogen. A decrease in current density at polarization potentials with Raney Nickel substrate indicates that OH blocks the active sites due to non-uniform coverage of the substrate that results in reduction of the surface area of the catalyst. OH and $NH_3$ compete for the adsorption on to Pt, thus lessen the sites available for the electrolysis. However, Rh added to Pt solves this. Also the reactivity of the catalyst drops down over a period of time, indicating the unsuitability of Nickel substrate. In a follow up study, carbon fiber substrate electrodes are used instead of Raney Nickel which shows superior results [82,83] by allowing uniform coverage of surface of the noble metal, preventing blockage of active sites and light weight when compared with Ni. They also use the catalyst based on Pt-Ir and Pt-Ir-Rh on the substrate made of carbon fiber and observed that approximately 91-92% of $NH_3$ is converted to $H_2$ at normal temperature i.e. at room temperature by using small concentrations of $NH_3$ and in this system the electrolysis is observed to occur at current densities of up to 25mA/cm² and a loading of precious metal of about 5.5 mg/cm². Recent work scrutinizes the influence of nano-sized Pt particles unlike the previous work on bulk, but they notice that the structure of Pt particles effect the oxidation of ammonia more than their size. Vidal-Iglesias et al. [84-86] studied oxidation of $NH_3$ on stepped electrodes that comprises of terraces of Pt (1 0 0) and steps of Pt (1 1 1). They adopted chronoamperometry, voltammetry and in situ infrared spectrometry to characterize the electrodes and found that there is an increase in the electrocatalytic activity by a factor of up to 7 for Pt with orientation (1 0 0) when evaluated against Pt with orientation (1 1 0) or (1 1 1). Vidal-Iglesias et al. [87] further investigated the effect of adding nano-sized alloys to Pt. Pd, Ir, Ru and Rh were tested. It was observed that the catalyst such as Ru and Pd trim down the oxidation current. In fact, the oxidation current decreased with increase in Ru content. They give the explanation for this result by suggesting that Ru and Pd decreased both the Pt (1 0 0) site dimensions as well as density. However, at low range of potentials, the oxidation current gets boosted with Rh and Ir. They also scrutinized the influence of particle size and noticed that 9 nm Pt particles shows better oxidation results in comparison to 4nm particles due to more Pt (1 0 0). They concluded that the ammonia oxidation on nano-particles is highly sensitive to structure. To electrolyze ammonia, much research has been done for developing catalysts. Calculations revealed that the hydrogen generation rate through electrolysis of ammonia is about 0.1 to 1 mmol/min/g of catalyst, which is less than decomposition of ammonia. Also for the production of hydrogen requires energy consumption ranges from 1418 Wh/g. For having $H_2$ at US $2/kg, the

energy consumption is obliged to be trim down to 5.4 Wh/g [81]. This signifies a drop in the value of oxidation overpotentials below 200 mV at peak current densities.

*4.4 Hydrogen production from ammonia borane ($NH_3BH_3$)*

Being a source of hydrogen, products of ammonia have also gain attention with most of the literature focusing on ammonia borane. The complex of ammonia-borane ($NH_3BH_3$) has about 19.6 wt% hydrogen content with system-level H2 energy storage density of about 2.74kWh/L.

$$NH_3BH_3 + 2H_2O \rightarrow NH_4^+ + BO_2^- + 3H_2 \quad (4)$$

Ther is a needed of a suitable catalyst in case of direct $H_2$ fuel supply to enhance the hydrolysis of $NH_3BH_3$.A range of catalysts with good catalytic performance have been premeditated [88-99]. These incorporate catalysts based on Pt, Rh, Pd, Ru and Au supported on alumina; groupings of Pt with Co, Ir, Sn, Ru, Ni and Au on carbon support, nano-clusters of Rh [88-93]; and also the catalysts based on Co and Ni (non-noble metal) on alumina, and Co and Ni nano-particles, Poly(N-vinyl-2-pyrrolidone) stabilized Ni, $Cu/Cu_2O$, $NiSiO_2$ and FeNi alloys [94-99]. But except for FeNi alloy catalyst, most of the above mentioned catalysts are difficult to use repeatedly in solution because they are in a powder form. Thus, robust catalysts have to be developed with high durability for practical and commercial use.

Mohajeri et al. [100] examined the process of hydrolysis of $NH_3BH_3$ using $K_2PtCl_6$ at room temperature and observed that the rate of reaction is third order with activation energy of 86.6kJ/mol (first order with $NH_3BH_3$ concentration and second order with catalyst concentration). Their average rate of hydrogen generation was 590.3 mmol/min/g of catalyst, although this rate varies throughout the experiment. Catalysts made of non-precious metal also demonstrate good and desirable results. Eom et al. [101] studied the effect of an electroless-deposited Co-P/Ni foam catalyst in ammonia borane solution on $H_2$ generation kinetics and investigated the cyclic behavior and durability of the catalyst. The energy of activation was estimated to be 48kJ/mol using the CoP/Ni foam catalyst for the hydrolysis of $NH_3BH_3$. At temperature equal to the room temperature their rates of $H_2$ generation were lesser than as shown in ref [100], but increases with increasing the temperature of the $NH_3BH_3$ solution. The rate of $H_2$ generation, after 6 cycles diminished to about 70% of the initial values. Xu et al. [98, 99, 102, 103] obtained good results for hydrolysis of an $NH_3BH_3$ / $NaBH_4$ mixture in a mass ratio of 5:1.They use different non-precious nanocatalysts including Co/silica nanospheres, Ni/silica, unsupported Fe-Ni nanoparticles and Co nanoparticles etc for their work. For Fe-Ni and Co (unsupported), exceptionally high rates of $H_2$ generation at room temperature were accomplished. At room temperature, unsupported Co nanoparticles of about 10 nm evolved hydrogen at the rate of 775 mmol/min/g, while $Fe_{0.5}Ni_{0.5}$ evolved 178 mmol/min/g. Although $NH_3BH_3$ has 19.1wt% hydrogen content, the gravimetric hydrogen storage capacity (GHSC) of $NH_3BH_3$ is relatively low and for $NH_3BH_3$-$H_2O$ system it is only 9% when hydrolysis is proposed in stoichiometric conditions and with excess $H_2O$ it get further decreased. Practical verification revealed that the effective GHSC is usually 1% [94]. Demirci and Miele [104] store $NH_3BH_3$ in a solid form and regulate the supply of $H_2O$ and studied their effect on the effective GHSC. $CoCl_2$ was used by them as catalyst, and they observed that when $H_2O$ was supplied in stoichiometric quantities at 25 °C, an effective GHSC of 7.8% was attained. Under these conditions, they reported the rate of hydrogen generation to be 85.9 mmol/min/g of catalyst. Results show that $NH_3BH_3$ is extremely promising and potential hydrogen source. Hydrolysis

of $NH_3BH_3$ has yielded high rates of hydrogen generation when compared with ammonia decomposition, and it can be done using non-precious metal catalysts at room temperatures. Table 5 give an evidence of substantial variations at different temperature conditions in the performance of the catalysts. For example the rate of hydrogen generation using unsupported Co nanoparticles is higher than for Co nanoparticles supported on silica by 3 orders of magnitude. It should also be pointed out that in Ref [98], as the Ni loading increased, the hydrogen generation rate per gram of catalyst decreased. Thus there are still copious numbers of hidden concepts interrelated to this process. The effects of factors like loading, particle size, support etc are required to be investigated in greater detail to understand this process completely.

*4.5 Other means of hydrogen generation from ammonia and ammonia products*

Urea ($CH_4N_2O$) is one of the ammonia products that can be used for hydrogen generation. Usually, when an anode catalyst based on Ni is used, the best suited electrolyte is KOH electrolyte. But the literature encounters a problem of instability and deactivation of NiO sites during the oxidation of organic compounds [105, 106]. Ni stability gets enhanced with the doping of Rh. This modification with Rh will intensify the current densities values by a factor of about 200 and lessen the overpotentials [107]. King and Botte instead of using KOH as electrolyte used a polymer gel electrolyte, polyacrylic acid cross-linked polymer and have achieved good results [108]. They also observed that an electrolyte containing 15% PAA and 8M KOH by weight showed better mechanical strength, good conductivity and ease of preparation.

$$\begin{aligned} &CO\left(NH_2\right)_2 + 6OH^- \rightarrow N_2 + 5H_2O + CO_2 + 6e^- \\ &6H_2O + 6e^- \rightarrow 3H_2 + 6OH^- \end{aligned} \qquad (5)$$

Sifer and Gardner studied ammonia hydride which is also one of the ammonia products [109]. Their study revealed that a system of ammonia hydride could provide energy density of 483 Wh/kg and can be operated for over 50 hours and was proposed for use in various military applications that requires low power for long durations. Generation of hydrogen can also be done via the reaction between $NH_3$ and different hydrides of metal such as $LiAlH_4$ [110], $MgH_2$ [111] or $NaAlH_4$ [112] at moderate temperatures (75-150°C). Such category of systems exhibits 2-3 times higher energy density along with specific energy than ammonia cracking at 650°C. However, for enhancing the rate of Hydrogen production, some dopants such as $PtCl_4$ and $PdCl_2$ are required [111]. Paik et al. [113] showed the mechanochemical production of hydrogen from ammonia through milling on $SrTiO_3$ and $BaTiO_3$ catalysts at room temperature.

**Use of ammonia in fuel cells**

**5.1 Direct ammonia fuel cells**

Usually, there are some traces of ammonia and oxides of nitrogen in the hydrogen feed that are unconverted when $NH_3$ is used for the production of hydrogen. The $NH_3$ used in PEM type fuel cells is not opt for the Nafion membrane as it acts as a poison to it. For fuel cells operated at higher temperature, direct decomposition of $NH_3$ take place thus minimizing the requirement for an external reactor. Some work carried out on the direct use of $NH_3$ in fuel cells is discussed below.

**5.2 Polymer Electrolyte Membrane (PEM) Fuel Cells Using Ammonia**

Ammonia has been proposed for use in this type of fuel cells; however, due to low operation temperature of this fuel cell, internal decomposition of ammonia is not thermodynamically favorable.

The decomposition of $NH_3$ externally must be carried out at higher temperatures and then the hydrogen thus produced is supplied to the fuel cell. If ammonia is not 100% converted to hydrogen, some traces of ammonia remain present in the hydrogen feed and this is not apposite for the Nafion membrane used in polymer electrolyte membrane fuel cells typically. Uribe et al. [114] investigated the effect of ammonia on polymer electrolyte membrane fuel cells with 0.15-0.2 mg/cm² Platinum loading using high frequency resistance (HFR). They exposed the fuel cell periodically to hydrogen and ammonia at the anode and observed that the performance of the fuel cell degraded when exposed to 30 ppm ammonia for 1 hour. It was observed that when the cell was exposed to ammonia for a time period of about 17 hours, full performance recovery was not achieved within 4 days after switching back to hydrogen but observed full recovery after an exposure to neat hydrogen for 18 hours. The presence of any adsorbed species at the cathode or the anode is not indicated by cyclic voltammetry technique (CV), thus confirming no poisoning or toxicity in polymer electrolyte membrane fuel cells. HFR indicates that the resistance of the cell doubled in 15 hours of exposure of ammonia. Soto et al. [115] uses higher catalyst loading; 0.6 mg/cm² Pt at the cathode and 0.45 mg/cm² Pt/Ru at the anode and performed similar studies. By using the current interrupt technique, they found that the cell resistance gets enhanced by 35% with 200 ppm $NH_3$ exposure for a time period of 10 hours. As in Ref [114] no evidence of any adsorbed species at the cathode or anode was shown by CV. They suggested that exposure to ammonia affects the anode catalyst layer instead of the cathode catalyst layer primarily because ammonia supplied at the anode. In these studies, calculations suggested that the loss in fuel cell performance observed was not fully explained by ohmic losses.

In another experiment using 0.4 mg/cm² Pt at the cathode and 0.45 mg/cm² Pt/Ru at the anode with a Nafion membrane, the cell was given exposure to 10 ppm ammonia [116]. After an exposure of 24 hours, the cell resistance steadily increases and reached a steady state value which was twice the original value. During this time, there was a voltage dropped by 160 mV out of which only 8mV accounts for ohmic losses. The cell undergoes full performance recovery after an exposure of 2-4 hours to neat hydrogen. The degradation produced by exposure to 1 ppm of ammonia in operation was slower than the degradation produced by 30 ppm, but the resistance of the cell has the same steady state value that is double the original resistance after an exposure of more than one week. Szymanski et al. [117] investigated the ammonia effect on phosphoric acid fuel cells. They found that for a phosphoric acid fuel cell operating at 191°C temperature, at the cathode electrode, the mechanism for oxidation-reduction reaction depends mostly on $NH_3$. The cathode activity decreased by 84% when 1% of phosphoric acid ($H_3PO_4$) was converted to ammonium dihydrogen phosphate ($(NH_4)H_2PO_4$).

Halseid et al. [116] performed a unique experiment using a symmetric $H_2/H^2$ polymer electrolyte membrane fuel cell in which hydrogen was supplied at both cathode and anode. Then one of the electrodes was exposed to 10 ppm ammonia. They observed that the resistance of the cell did not decrease when the supply of ammonia was stopped and also a limiting current exist because of a reaction limiting current in the Tafel-Volmer hydrogen oxidation reaction mechanism possibly attributed to Tafel step. They suggested that $NH_3$ continues to be in the membrane phase which proves the low volatility of $NH_4$ in Perfluorosulfonic acid (PFSA) ionomers. In acidic solutions, the oxidation of ammonia on Pt to form $NO_x$ or $N_2$ was not significant at the anode. They suggested that at high cell potentials, the effectiveness of the catalyst get reduced due to the formation of platinum oxide at the catalyst sites. They suggested that the transfer of ammonia took place across the polymer electrolyte membrane within minutes, affecting both anode and cathode. They also postulated that in Pt

solutions, ammonium shifts the potential of the $H_2$ adsorption process, but $H_2$ desorption remains same and not get absorbed on the catalyst of anode [118]. Ammonium in sulfuric acid ($H_2SO_4$) with very low concentrations of about 10% $NH_4$ has been scrutinized and demonstrates an increase of up to 100 mV at any given value of current density in the overpotential of cathode electrode.

Hongsirikarn et al. [119,120] further studies the effects of ammonia on Nafion, measuring the conductivity of membrane in the gas and liquid phases by two probe method. To simulate desired concentrations of $NH_4^+$ and $H^+$ in the membrane, they prepared their membranes by using $NH_4Cl$ and HCl. With the increase in the content of $NH_3$ from 0 to 100%, the conductivity of Nafion 117 decreased almost linearly from 115 mS/cm to 24 mS/cm in distilled water at room temperature. $NH_3$ Tolerance also gets modified with temperature. It was also detected that the $NH_3$ influenced the conductivity more significantly in the gas phase than the aqueous phase. This is due to the reason that in the gas phase, very few water vapor were present, and the ammonium ion get stabilized by the strong anion sulfonic sites in the structure [116]. They also performed experiments in which Nafion membranes were exposed to 5-30 ppm $NH_3$ gas. Conductivity gets decreased from 30 mS/cm to a steady state value of 2.5 mS/cm over a period of time, with degradation rate increasing with the concentration of ammonia. Exposure to 30 ppm required approximately 6 hours to attain a steady state poisoning whereas 5 ppm took 36 hours. Unlike CO poisoning, $NH_3$ poisoning of polymer electrolyte membrane fuel cells is a slow process with slow recovery. The slow process of ammonium oxidation results in ammonium sinks. For use in polymer electrolyte membrane, the fuel stream must not contain ammonia i.e. $NH_3$ should be utterly eradicated from it. Saika et al. [121] proposed a recirculation system for ammonia that can reduce the content of ammonia from 300 ppm to 0 ppm in the fuel stream. This system involves recirculation of ammonia after dissolving ammonia in water ($H_2$ and $N_2$ do not dissolve). The alternative is modifying the catalysts (cathode instead of anode) with other noble metals (perhaps Ir) to enhance the oxidation of ammonium [116].

Polybenzimidazole which are an alternative intermediate temperature PEM to Nafion, is usually doped in phosphoric acid at temperature up to 200 °C. However, for decomposition of $NH_3$ internally, these conditions are not appropriate. In literature, the affect of $NH_3$ in the hydrogen feed on the PBI membranes performance is still not reported.

### 5.3 Direct ammonia solid oxide fuel cell

Since the traces of ammonia in the hydrogen feed adversely affect both activity of the catalysts used and the membrane conductivity, creating trouble for the polymer electrolyte membrane (PEM) fuel cells involving Nafion. This requires either total clean up of ammonia which is not always practical or 100% ammonia conversion to produce hydrogen which is not always guaranteed. The SOFCs have been scrutinized for direct oxidation by various researchers. In fact for smaller scale operation of SOFCs ammonia can be allowed [122]. Farhad and Hamdullahpur reported a 100W solid oxide fuel cell system where nearly 10 hours of sustained power is provided by only 1 liter of ammonia [123]. The decomposition of $NH_3$ was even not reported to act as a poison to the ceramic electrolytes used in SOFCs. There are two categories of research into ammonia SOFCs SOFC-O and SOFC-H. SOFC-O involves an oxygen ion conducting electrolyte, such as samarium doped ceria (SDC) or yittria stabilized zirconia (YSZ), and formation of water at the anode. SOFC-H produces water at the cathode and incorporates proton conducting ceramic electrolyte e.g. barium cerate.

#### 5.3.1 Ammonia Fed SOFC-O

$$H_2 + O^{2-} \rightarrow H_2O + 2e^- \quad (6)$$

$$0.5O_2 + 2e^- \rightarrow O^{2-} \quad (7)$$

The half cell equations of anode and cathode for the SOFC-O fuel cell are shown in equations (6) and (7) respectively. Wojcik et al. [124] executed the primary investigation in this area of solid oxide fuel cells. They used YSZ at 800 °C with different catalysts such as Ag, Fe and Pt as electrolyte. Their main idea was to scrutinize various electrodes exhibiting different properties as well as various catalysts. Their experiment proposes the NO formation at the anode as shown by equation 8.

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O \quad (8)$$

On the basis of their research, they ranked the catalysts in decreasing order of their performance as Pt > Fe > Ag. They observed that with Pt catalyst, the performance of the fuel cells operating with $NH_3$ is very close to those operating with $H_2$ which indicates that $NH_3$ decomposes completely over Pt.

Sammes and Boersma [122] shows that Ni perform better than Pt and Ag at 500-800 °C, with 90% ammonia conversion occurring at a temperature of 800 °C. Choudhary and Goodman [125] suggested that the power densities shown by Ni electrodes are 5-10 times higher than that of Pt or Ag. With increase in temperature, the performance of the $NH_3$ fed cell approaches that of the $H_2$ fed cell. With the Ni-YSZ/YSZ/Ag (where Ni-YSZ, YSZ and Ag act as anode, electrolyte and cathode respectively) system at a temperature of 700°C, the performance of $NH_3$ cell is actually better that the $H_2$ cell. At 800°C, a tubular SOFC, using 1 mm thick electrolytes, showed a peak power density of 10mW/cm² while a planar SOFC using a 0.4 mm thick electrolyte showed a peak power density of 75mW/cm². Fournier et al. observed that a peak power density of 60mW/cm² was obtained at 800 °C [126]. Dekker and Rietveld [127] obtained a peak power density of 55mW/cm² at 700°C by using an anode supported system NiO-YSZ/YSZ/LSM. They proposed that atleast 700°C temperature is required for sufficient conversion of ammonia. The SOFC-O study results are illustrated in Table 6.

### 5.3.2 Ammonia Fed SOFC-H

For the operation of SOFC-O relatively high temperatures (800-1000°C) is necessitated to have good conductivity of YSZ electrolyte, or else the conductivity suffers, although SDC electrolytes shows better peak power densities than YSZ electrolyte. The conductivity of SOFC-O electrolytes diminished significantly at intermediate temperatures range (400-600°C). This problem is surmounting by use of either thinner electrolytes or proton conducting electrolytes. SOFC-H type fuel cell system is an attractive substitute at intermediate temperatures (400-600°C) as at this range of temperatures, the proton conducting electrolytes such as $SrCeO_3$ and $BaCeO_3$ shows superior ionic conductivity than for the case of YSZ. Moreover in SOFC-H the probability of producing $NO_x$ are significantly reduced as no oxygen ion conducts through the electrolyte. Some of the common electrolytes are $BaZrO_3$ and $BaCeO_3$, with the latter barium cerate ($BaCeO_3$) getting a lot of attention. According to literature, gadolinium, praseodymium, and europium are the commonly reported doping materials for $BaCeO_3$. Equations 9 and 10 illustrate the half cell reactions of SOFCs.

$$H_2 \rightarrow 2H^+ + 2e^- \quad (9)$$

$$0.5O_2 + 2H^+ + 2e^- \rightarrow H_2O \quad (10)$$

Some early work on ammonia fed SOFC-H systems was reported by Maffei et al. [130-133]. They obtained a peak power density of 35mW/cm² at a temperature of 700 °C by using $BaCeO_3$ doped with praseodymium and gadolinium as the electrolyte which was 1.3 mm thick and obtain stability of up to 100 h. This obtained peak power density was similar as that when $H_2$ was utilized as the fuel. Gas chromatography analysis verified that no $NO_x$ discharge took place. Moreover the peak power density of 25mW/cm² was scrutinized by using $BaCeO_3$ doped with gadolinium electrolyte (BCG). In another publication [134], they reported $BaCeO_3$ doped with europium (BCE). Conventional solid state synthesis was used for the preparation of BCE powder using pt electrode and the final electrolyte was 1 mm thick. Very little polarization of electrode was shown by the IV curves suggesting that most of the voltage drops were caused by ohmic losses in the electrolyte. Due to significant electronic conduction in the electrolyte, the Open-circuit voltage calculated was less than 0.7 V. At 700 °C, the peak power densities observed were 38mW/cm² for the $H_2$ cell and 32mW/cm² for the $NH_3$ cell. They suggested that this difference attributed to the reduced partial pressure of hydrogen due to the formation of nitrogen in the $NH_3$ fed cell which provide stability for over 200 h. In yet another report [135], they exploited a cermet anode consisting of Ni, Eu doped $BaCeO_3$, a mixed ionic and electronic solid anode (BCE-Ni), and a $BaCeO_3$ doped with gadolinium and praseodymium (BCGP) electrolyte of 1 mm thickness. The solid state synthesis technique was employed for the production of BCE and BCGP components. They observed that merely 1% wt composition of Nickel completely decomposes ammonia at a temperature of 650 °C and concluded that the BCE-Ni anode is superior to that of the Pt anode. The Peak power densities for the NH3 fed system using the NiO as anode were 28mW/cm² compared to 23mW/cm² using Pt as anode at 600 °C. Also at 450°C, 500 h stability was attained. Thus they obtained stabilized performance, but low power densities that are primarily due to the use of extremely thick electrolytes in their experiments.

Much superior current densities were attained via proton conducting electrolytes that are very thin. Ma et al. [136] obtained a peak power density of 355mW/cm² at 700 °C by using BCG electrolytes. They observed Open-circuit voltage values of 1.102 V and 0.985 V at 600 °C and 700 °C respectively. These obtained data were in agreement with theoretical calculations suggesting that $NH_3$ decomposes completely. Zhang et al. [137] achieved peak power densities of 147mW/cm² by using $BaCeO_3$ doped with gadolinium (BCG) electrolytes dry pressed over a $Ce_{0.8}Gd_{0.2}O_{1.9}$ (CGO)-Ni anode substrate at 600 °C. Their Open-circuit voltage achieved at 600°C and 650°C temperature was 1.12 V and 1.10 V respectively. These values are slightly lower in comparison to that obtained for $H_2$ fed cell because of the reason that the partial pressure of the hydrogen get reduced by nitrogen.

Ma et al. [128,138] used 50 μm thin film BCG electrolytes with LSC-BCG cathode and Ni-BCG anode and achieved an OCV of 0.975 V at 700 °C temperature with peak power density of 355mW/cm². Gas chromatography demonstrated about 10-12 atm partial pressure of NO. Lin et al. [139] using a 35 μm $BaZr_{0.1}Ce_{0.7}Y_{0.2}O_{3-\delta}$ (BZCY) electrolyte with $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (BSCF) as cathode and BZCY/Ni as anode had similar observations. A combined EDTA citrate complexing sol-gel technique was employed for the formation of both BSCF and BZCY oxides. Their peak power densities were 135 mW/cm² and 420 mW/cm² at 450°C and 700°C respectively. The open circuit voltage (OCV) at 450°C temperature was about 0.98 V with $NH_3$ in contrast to 1.1 V with $H_2$. On account of the impedance tests, they put forward that owing to the endothermic nature of the reaction, the actual operating temperature may be lower (by about 35-60 °C). Table 7 shows the reported results of SOFC-H systems.

Zhang and Yang [137] studied CGO-Ni/BCG/BSCF system and were able to reduce further the

thickness of the electrolyte to 30 μm. At 600 °C, they obtained a peak power density of 147mW/cm². A 20 μm $BaCe_{0.9}Nd_{0.1}O_{3-\delta}$ (BCNO) electrolyte was reported as the thinnest proton conducting electrolyte that was synthesized by using a suspension spray method with a $La_{0.5}Sr_{0.5}CoO_{3-\delta}$ (LSCO)-BCNO cathode and a NiO-BCNO anode [140]. However they obtained a peak power density of 315mW/cm². They wind up with the statement that this reduction of the peak power density is caused by the dense anode layer which completely reduced NiO into Ni, thereby dropping the activity of anode catalyst.

The usage of non-precious metal as catalyst is a major advantage of direct $NH_3$ SOFCs. For both SOFC-O and SOFC-H, nickel proves to be the most effective anode catalyst for both the decomposition of ammonia and oxidation of hydrogen and it is also economical. For direct ammonia use in fuel cells, SOFCs hold the best prospects. High power densities exhibiting thin electrolytes have been acquired with both SOFC-O and SOFC-H type fuel cells. The efficiency of the SOFC gets reduced by using ammonia rather than hydrogen as the fuel cell has not been reported yet. There is no clear consent on which of the two SOFC types (SOFC-O and SOFC-H) is better. Although, the concern related to the $NO_x$ formation at the anode electrode of SOFC-O have been reported in some studies but it has not been observed in reality. In SOFC-O, when both the decomposition rate of ammonia and flow rate of ion of oxygen are higher, NO is probably formed. However, no NO detection even at 800 °C was also reported [138]. With anode supported SOFC-O systems (thin electrolytes and thick anodes), gas chromatography studies have suggest the complete decomposition of NH3 by the Ni catalyst long before the triple phase boundary (TPB) is reached [129].

**a) Temperature effects**

Ammonia has been used all over the world with different electrolytes including hydrogen-ion conducting and oxygen ion-conducting electrolytes under a wide range of operating temperatures (6731273 K) in various laboratories. Many researchers believe that there is an increase in the temperature if ammonia decomposes quickly into nitrogen and hydrogen and the performance of $NH_3$-fed SOFCs become very close to that of $H_2$-fed SOFCs. In view of the fact that temperature influences the $NH_3$ decomposition rate; thus, at high temperature ammonia decomposes completely and hence high fuel usage. The reaction rate raises notably from about 1.0 $molm^{-3}s^{-1}$ to 3.6x107 $molm^{-3}s^{-1}$ at a temperature 673 K and 1273 K respectively. This is reliable with experimental observations [141,142].

At a high range of temperature, the thermal $NH_3$ decomposition catalytic rate is also high and the ammonia fuel will decompose completely before reaching the interface of anode and electrolyte. Since the kinetics of $NH_3$ decomposition is not fast at 673 K, not more than 10% of $NH_3$ fuel decomposes throughout the anode of the SOFC-H. It is also known that in the SOFC-H, the performance of the $NH_3$-fed SOFC-H depends highly on the extent of decomposition of ammonia [6, 7, 8]. The present study indicates that for the $NH_3$-fed SOFC-H, a temperature of 673 K is pretty low, unless a very active and selective catalyst for the NH3 decomposition can be developed. However, at 773K temperature, a substantial amount of NH3 decomposes to give nitrogen and hydrogen in the SOFC-H, although the conversion of ammonia is not 100%. Therefore, it is possible to operate the $NH_3$-fed SOFC-H with acceptable cell performance at a temperature of 773 K. Ma reported that at a temperature of 873 K, 100% decomposition of ammonia is obtained for an SOFC-H, while the decomposition of ammonia is incomplete when the temperature dwindles to 773 K [8].

The equilibrium potential as well as the efficiency of SOFC-H and SOFC-O diminish with an elevation in temperature. Besides, the potential under the standard condition also varies remarkably with temperature in an inverse association. Thus, the decreased equilibrium potential causes inferior

theoretical efficiency of SOFCs. Moreover, when the temperature of an SOFC system increases, the over-potentials get decreased. Thus, the most apt temperature for the operation of SOFCs depends on the over-potentials as well as the reversible potential.

**b) Equilibrium potential of the ammonia-fed SOFC**

It is a well known fact that the partial pressure of the absorbed species affects the equilibrium potential of any fuel cell. The potential under the open-circuit conditions can be written as

$$E = E^0 + \frac{RT}{2F}\ln\left[\frac{P_{H_2}\left(P_{O_2}\right)^3}{P_{H_2O}}\right] \tag{11}$$

$$\text{where, } E^0 = -\frac{\Delta G}{nF} \tag{12}$$

In equations (11) and (12), F is the Faraday constant, G is the change in Gibbs free energy, n is the number of electrons involved per electrochemical reaction, $E^0$ is the voltage at standard pressures, and $PH_2$ , $PO_2$ and $PH_2O$ are the partial pressures of hydrogen, oxygen and steam respectively. Also, the characterization of the over-potentials affecting the cell operation is required for the investigation of the potential of SOFCs under closed-circuit conditions. The equation (11) and (12) are for SOFC-H as well as for SOFC-O. However, it should be mentioned that $PH_2O$ refers to the partial pressure of $H_2O$ at the cathode side of an SOFC-H while it refers to the partial pressure of $H_2O$ at the anode side of an SOFC-O

**a) Determination of the gas composition in the SOFC**

The partial pressure of each gaseous component can be determined by using the calculation procedure developed by Assabumrungrat et al. [143]. It is also supposed that at the inlet of SOFC, the species that are gaseous in nature are under equilibrium. At the SOFC outlet, the number of moles (n) of each component for both the SOFC-O and SOFC-H can be estimated as

$$\begin{aligned}
\eta_{NH_3} &= a - 2x \\
\eta_{N_3} &= x \\
\eta_{H_2} &= 3x - 2b \\
\eta_{H_2O} &= b \\
\eta_{O_2} &= 0.21c - 0.5b
\end{aligned} \tag{13}$$

Where a and c represents the number of moles of inlet ammonia and air respectively; b is the degree of the hydrogen electrochemical reaction; and $2x$ represents the $NH_3$ mole number.. Detailed procedure for the calculations of equation (13) be found somewhere else [144]. After calculating the partial pressure of the gas, the theoretical potential of the SOFC fed with ammonia can be attained with the average partial pressures of $O_2$, $H_2$ and $H_2O$ via the Nernst equation.

**a) Efficiency of the ammonia-fed SOFC**

When a current is drawn by the SOFC, the maximum electrical work (W) generated can be calculated as

$$W = qE \tag{14}$$

where q signify the electrical charge through the fuel cell. The efficiency of the $NH_3$-fed SOFC

can be defined as the ratio of the maximum electrical work (W) extracted from the SOFC to the maximum conversion of the chemical energy of the fuel fed to the SOFC [144,145]:

$$\eta(\%) = \frac{W}{-\Delta H^0} \times 100 \quad (15)$$

where H° indicates the lower heating value of the fed $NH_3$ under the standard condition (320.1 $kJmol^{-1}$). The theoretical efficiency has no absolute importance and is accredited to the working temperature and given fuel usage [145]. The fuel and the oxygen consumption are described as the ratio of fuel ($NH_3$) and oxidant ($O_2$) consumed to the feeding fuel and oxidant, respectively.

## 5. Comparison between the SOFC-O and SOFC-H

When different electrolytes with different fuel utilization are used in $NH_3$-fed SOFCs at 1073 K, the SOFC-H shows much higher equilibrium potential than that of the SOFC-O and hence the former shows greater efficiency than the latter. Moreover, with enhancement in the fuel usage, the efficiencies difference between the two SOFCs (SOFC-H and SOFC-O) also increases. The efficiency of the SOFC-H fed with $NH_3$ type fuel cell system is about 10% greater than that of the SOFC-O at a typical utilization of fuel (80-90%) [146]. Fig. 1(a) shows the mechanism of SOFC-O that ammonia undergoes decomposition over a Ni catalyst in the anode chamber while Fig. 1(b) shows the configuration of the direct ammonia-fed SOFC-H with proton-conducting electrolyte.

It has been seen that for the direct $NH_3$-fed SOFC operating at a temperature of 1073 K, peak current density at atmospheric pressure can be attained by employing anode-supported arrangement of the fuel cell. This explains the drop in the value of ohmic over-potential that is due to the diminution in the thickness of electrolyte. According to the thermodynamic analysis, the peak power density of $NH_3$-fed SOFC-H (based on proton conducting electrolytes) is 20-30% higher than that of SOFC-O (based on $O^{2-}$conducting electrolytes), which is commonly due to the higher hydrogen concentration at the anode in all cases [147]. Moreover, the challenges faced by high temperature $NH_3$-fed SOFCs are the cost of cell fabrication and performance durability. But if an anode electrode that is oxidation-reduction stable i.e. redox stable used in the SOFC stack, the durability of the $NH_3$-fed SOFC can be improved.

For both types of fuel cells, the voltage trims down in consequence of low concentrations of reactants at the TPB and high current densities. In addition, temperature influences the fuel cell performance. The peak power density of the SOFC-H is 50% less than SOFC-O. Therefore, the operation of SOFC-H cells at temperatures beyond 1073 K is highly discouraged.

## 6. Cost estimation and future prospect

An economical comparison among fuel cells of various categories is very convoluted since the fuel, system and applications are very different. So, rather than comparing the fuel cells, the comparison between fuel costs and future trend of lessening the SOFC price (Table 8) is presented.

For fuel selection, there are various factors need to be taken care such as safety, production, transport, storage, cost etc. Table 9 compares hydrogen and ammonia on the basis of different factors like production, transportation cost and storage.

However, ammonia still has advantages on storage cost and pipeline transport than that of hydrogen that makes ammonia more attracted. In April 2010, based on U.S. prices, coal and natural gas were less expensive than gasoline and this fact promotes the utilization of $NH_3$. Moreover, for the $NH_3$ production, one of the major ingredients is the natural gas which accounts over 80% of the total $NH_3$ production cost. As shown in Fig. 2, both the prices of ammonia and natural gas are very closely

correlated, especially since 2000.

Also in case of the generator sets, it costs approximately in the range $300$-600/kW, but the cost guesstimated for the installation will not reduce significantly faster than that of the fuel cells. So, unlike the generator set system, the cost per kilowatt of installed capacity of fuel cell is more, but the prices of fuel cells are rapidly reducing. Considering all the characteristics, the fully loaded expenditure of fuel cell system is approximately $700/kW. Moreover, fuel cell has low maintenance cost than a typical generator set. Also for the generator sets, the Bloom Energy's Levelized Cost is expected to be $0.09-$0.11/kW h after motivation for its fuel cell systems powered by natural gas as it is not easy to estimate its Levelized Cost of Energy. Consider that for a natural gas generator set, the cost of the fuel alone is approximately $0.11/kWh, the Levelized Cost of Energy of fuel cell systems is certainly less than that of generator sets. Further if commercialization efforts continue to bring down the cost of fuel cell systems in the upcoming years, fuel cell systems could possibly replace the generator sets completely in locations with consistent access to natural gas.

## 7. Other Types of Ammonia Fuel Cells (AFC)

For the alkaline fuel cells, the use of anhydrous ammonia has been suggested [178]. Unlike Nafion used in PEM fuel cells, aqueous alkaline electrolytes are liberal to ammonia [48,57, 70,179]. In a test cell, an AFC, without showing any signs of poisoning, runs on ammonia for over 100 hours [180]. As the temperature in which AFCs operate is low and ammonia will not release hydrogen atoms at that temperature, therefore there is a requirement of a separate external reformer [178]. Ganely [181] by using a eutectic mix of KOH and NaOH fueled with pure $NH_3$ and compressed air give rise to the development of a test cell. They observed a peak power density of only 40mW/cm² at a temperature of 450°C. Ni tubes dipped into the molten electrolyte were used as electrodes. During the working of the cell, the intricacy that encounters at the cathode electrode is Ni oxidation to NiO that reduces the conductivity of the cell. To overcome this problem they pretreat Ni with 3M LiOH solution for 24 h at 100 °C with a constant anodic current of 1 mA/cm². In this process, Ni was thermally and electrochemically converted into hydrated NiO and then this hydrated NiO was electrochemically oxidized by cationic exchange to form $LiNiO_2$. This stable Ni did not get polarized throughout a test of 2-4 h. However, the liquid electrolyte system exhibits large electrode separation due to which they suffers high ohmic losses when compared with solid state technology. Also the bulk nature of the electrodes reduced the active catalyst sites and this issue is inherent to alkaline fuel cells. One more potential problem with these fuel cells is that they require $CO_2$ free air because of an unfavorable reaction takes place between $CO_2$ and KOH [182]. We have already discussed about Ammonia borane ($NH_3BH_3$) as a hydrogen source. However, there are some preliminary works that suggest its use directly in fuel cells to achieve greater reversible potential of 1.616 V at a temperature of 25 °C and thus greater power [183]. The half cell reactions are illustrated in equations 16 and 17.

$$NH_3BH_3 + 6OH^- \rightarrow NH_4^+ + BO_2^- + 4H_2O + 6e^- \quad (16)$$

$$1.5O_2 + 3H_2O + 6e^- \rightarrow 6OH^- \quad (17)$$

In a test cell, a peak power density of 14mW/cm² was achieved by using a membrane of Nafion 117 having 30% Pt catalyst on Vulcan XC-72 and electrodes of carbon cloth at room temperature [183]. However at the anode, the liberation of $H_2$ gas point out that the $NH_3BH_3$ hydrolysis took place. The authors suggested that the use of thorium as an additive could hinder this hydrolysis. Moreover,

increasing the pH could avoid this hydrolysis. In another work, a 28 μm thick anion exchange membrane is used as substitute of the Nafion membrane. This time, peak power densities of 40 mW/cm² and 110mW/cm² were achieved at 25 °C and 45 °C respectively. They run the fuel cell without any evidence of performance degradation for over 20 hours at power densities of 50mA/cm² and 120 mA/cm². However, the results of energy dispersive X-ray spectroscopy (EDX) showed that ammonia borane travelled across the anion exchange membrane and at the cathode, it was directly oxidized that results in the reduction of cell performance at higher current densities [184]. Kiran et al. [185] examined an ammonia borane fuel cell and obtained a peak power density of 45mW/cm², 85mW/cm² and 110mW/cm² by using a TiC anode, Pt/C cathode with a Nafion 117 membrane at 25°C, 60°C and 80°C respectively. This work also recommends the utilization of a non precious catalyst. Zhang et al. [184] proposed that $BO_2^-$ can convert back to $BH_4^-$ via a reaction with a saline hydride (MgH). Then by using a diethyl ether, it can be reverted to $NH_3BH_3$ at room temperature and recycled. Moreover in fuel cell system based on ammonia borane, $NH_4^+$ is produced in the anode reaction that is not suitable for Nafion membranes. Based on the present studies, ammonia borane with some more modification proves to be more efficient source of producing hydrogen through hydrolysis than a direct fuel in fuel cells.

**Challenges in developing direct ammonia fuel cell**

Storage is the major drawbacks of ammonia in the transportation due to the problem of toxicity. The leakage of ammonia liquid during a car crash is unsafe for the living species. One possibility of eliminating the danger of toxicity completely is to embed $NH_3$ in metal amines because ammonia can be liberated only when the porous media is heated at a temperature of 350◦C or more. The system has an energetic drawback that comes from the energy required for the release of ammonia that adds to the cost of the system. Moreover, different challenges encounter in developing ammonia fuel cells depending on the type of the fuel cells. The real challenge in case of low temperature ammonia fuel cells based on PEM is to recognize appropriate electrocatalysts used specifically as the anode electrode and to minimize the cross-over of ammonia. Further, it is not easy to produce hydrogen from ammonia catalytically at low temperature as the cleavage of NH bonds in ammonia is very hard at low temperature. This cleavage of bonds between nitrogen and hydrogen in $NH_3$ to undergo reaction with OH− ions is extremely essential for the anode reaction to be happened at the ammonia alkaline membrane fuel cells. It is very intricate to develop a high-quality direct $NH_3$-fuel cell system that works at low temperature and results in high power density by employing present techniques. However, if the temperature is raised to 200°C or above, a good direct ammonia fuel cell with better performance would be achievable. For $NH_3$ alkaline fuel cells system, the stability based on electrolytes of molten hydroxide or hydroxide solution will be a challenge unless $O_2$ or $CO_2$-free air is used. However, the operation of the present alkaline polymeric membrane electrolyte is unstable above 200°C. Moreover, a good inorganic OH− ion conductor that acts an ideal electrolyte for $NH_3$ fuel cells and even stable at high temperature is thought to be developed. Also around 200°C temperature, $SnP_2O_7$ doped with Sb and Mo shows hydroxide conduction. Also due to the reaction between acids and ammonia, the conductivity of protons gets reduced and hence the acidic property based proton-conducting materials cannot be used as electrolyte for ammonia fuel cells. However, a solid proton conductor (like doped $BaCeO_3$/$BaZrO_3$) that operates at low temperature and is chemically compatible with ammonia will be a potential electrolyte for ammonia fuel cells at intermediate temperature. Minimization of the $NH_3$ cross-over is one of the biggest benefits of using $NH_3$ fuel cell systems based on inorganic $OH^-$ or $H^+$ ion conducting electrolytes. The key challenge for direct ammonia solid oxide fuel cells is the

integration of redox stable anode to the fuel cell in order to enhance the anode-electrolyte interface durability, which can resist the shift in local temperature and avoid the production of nitrides during the fuel cell operation. Moreover, the use of ammonia SOFC-H (based on proton-conducting electrolytes) is suggested to completely avoid the formation of $NO_x$.

## 5. Future for ammonia-fuel cells

### 10.1 Alkaline membrane fuel cells

The possibility of employing ammonia and hydrogen mixture as combined fuel in the fuel cell system demands more research. Study should be carried out to find the suitable ratio of these two fuels which could result in superior performance as well as preserve the anode activity for long time. Here control could come in calculating the anode performance and varying the composition of the fuel to enhance the performance of the cell. There is a potential for coupling with incomplete ammonia cracking or partial electrolysis of ammonia which require less intensive conditions than the cracking required in solid oxide fuel cells. The experiments performed at room temperature results in relatively stumpy power output. So the fuel cells must be operated at slightly higher temperatures than the room temperature. An operation above 100˚C could curtail the effect of water flooding in the fuel cell system. Membranes that limit the penetration of $NH_3$ between the cathode and the anode must be developed for these fuel cells.

### 10.2 Solid oxide fuel cells

In these fuel cells, ammonia is used directly as fuel and due to its high operation temperature, the complete conversion of ammonia into nitrogen and hydrogen is possible before it reaches the anode, indicating that it combines cracking of ammonia with a hydrogen fuel cell. The limitation of these SOFCs is that these fuel cells are not currently stable enough for commercial use. So modifications are necessary and the cost would also need to be reduced. Out of the two fuel cells, the SOFC-H fuel cell seems to be the more promising due to the lack of fuel dilution by water at the cathode. These fuel cells are used commercially only after the development of an anode that is redox stable in nature with some improvements for the ceramic components inside this solid oxide fuel cell.

### 10.3 Proton exchange membrane fuel cells

The fuel cells suffer due to the water flooding issue. Therefore, it is very important to find ideal water content in order to keep the ionic conduction of the membrane high without resulting in the deposition of water onto the anodes and hence the electrochemical reaction rate remain constant due to the accumulation of water in the cell. However, the estimation of specific quantity of water suitable for the cell demands more research. Research must be done to have better cathode/anode materials that are more hydrophobic and ensuring that their wettability towards water would not change with time. The Current set ups of polymer electrolyte membrane fuel cells connected to an $NH_3$ electrolytic cell demands about 60% of the fuel cell output for transmission to the alkaline electrolyte cell. As research is being carried out in both the areas, development in this technology can be supposed to take place faster than usual as any enhancement in either area results into more efficient combined set-up.

### 10.4 Alkaline fuel cells

Issues related to their inability to work with carbon dioxide ($CO_2$) usually encounters. On the basis of research into $NH_3$ fuel cells, it appears that these fuel cells are the natural evolution of this technology.

Both polymer electrolyte membrane fuel cells (PEMFCs) and alkaline membrane fuel cells

(AMFCs) require more development before their practical use in fuel cell vehicles, however if the problems faced by these fuel cells could be solved or overcome, they both will be able to replace traditional hydrocarbon vehicle. Further, for the practical use of SOFCs in the home/car, there is a constraint that a very high temperature is needed. They usually found their applications in industries, where they could prove a feasible alternative for traditional generators.

## 6. Conclusions

Ammonia is a top ranking chemical due to its volume and primary use in the fertilizer industry. It is considered as an ideal energy vector for being inexpensive and carbon-free chemical. Researchers have worked on different kinds of fuel cells that employ ammonia as a fuel by investigating different electrodes at different range of temperatures in various electrolytes in order to determine their performance and applications. By comparing economically with traditional hydrogen, $NH_3$ presents a clean, safe and reliable source of energy. The ammonia production from renewable resources together with the ammonia energy recovery technologies forms an essential part of ammonia economy. For the next-generation fuel-cell technology, the direct ammonia-fed SOFC-H is the most promising energy source but its development has however not reached the commercialization stage and more investigation is therefore necessary to solve several problems and the practical applications are yet to be discovered. Ammonia has been exposed as an economical way for storing hydrogen for its utilization in fuel cells. The expenses of energy for ammonia are less than hydrogen, methanol, natural gas and propane because of HHV and also exhibits economical power life cycle. An important advantage over hydrogen is that ammonia is being extensively produced worldwide and possesses a transport and storage infrastructure that has already existed. As a result, Ammonia has proven to be a cost effective substitute to hydrogen for fuel cells.

A number of articles have been devoted for developing appropriate catalysts for the decomposition of ammonia and its products to produce hydrogen. Studies have given the idea that Ni based catalysts works at 600 °C; but for decomposition at 400 °C temperature, Ru proves to be the best catalyst. It has been shown that carbon nanotubes perform extremely efficiently as a support for Ru. However, potassium based alkalis leaded to an increase in the catalyst activity by 5-fold while treating as a support. For being inexpensive, higher loading is permissible for Ni irrespective of the fact that at a given temperature, Ni has a lower decomposition rate than Ru. The decomposition rates are analogous to Ru as they permit the use of nano-sized particles. Thus, by using the technology termed as nanotechnology, the temperature performance of Ni catalyst can be boosted. There is a requirement to put more efforts in research regarding Ni based catalysts as compared to Ru based catalysts for the mechanism for ammonia decomposition. Thus, the working efficiency of Ru and Ni as catalysts for decomposition can be optimized by investigating the consequence of various promoters and by studying the reaction mechanism.

Another important and efficient way of generating hydrogen is by the hydrolysis of ammonia borane where the generation rates are high. A supplementary benefit in the process of ammonia borane hydrolysis is that it can take place at room temperature. Moreover, catalysts like Ni, Pt, Co and Fe have also been reported to bestow outstanding results but the reports published in literature vary in results. It was scrutinized that in the ammonia borane hydrolysis at room temperature using Co based nano-catalysts; the hydrogen generation rates in two different experiments by the similar research group disagree by three orders of magnitude. Further, the optimal particle size, loading and support that is crucial for a proficient hydrolysis catalyst has not been completely understood up till now. Hence, inspite of the incredible potential of this technology for low temperature fuel cells, a lot work is

still required for improvement.

Also due to the activity reduction of the catalyst layers and the conductivity of membrane based on Nafion, ammonia unfavorably affects PEM fuel cells. On the other hand, as a result of intrinsically poor performance related to non-solid state technology, ammonia doesn't affect alkaline fuel cells. However, these alkaline fuel cells are improbable to be pursued commercially. In SOFCs type fuel cells, ammonia decomposes at very high operating range of temperatures. It has been commonly approved by the researchers that the performance of ammonia fed SOFCs is comparable to that of hydrogen fed SOFCs at higher temperatures; the only discrepancy being the dilution of nitrogen at the anode electrode. The previously published reports show that high power densities in the range 100-1000 mW/cm² for both oxygen ion and proton conducting electrolytes; have been acquired for SOFCs and are efficiently produced at over 700 °C temperature. In the early stages, more efforts have been devoted to the research based on Pt catalysts but later on, comparable results have been achieved by the use of Ni based catalysts. However, the efficiency of producing hydrogen by converting ammonia drops down at lower temperatures with Ni based catalysts. High-quality performance efficiency is desirable for SOFC-H operation at temperatures as low as 400 °C, but no report is available at such low temperatures. In order to enhance the low temperature performance of SOFC-H, Ni based catalysts can hold remarkable potential but such work regarding the use of nano-sized Ni particles in the SOFC anode has not been reported so far.

Ammonia is certainly the wonderful fuel that makes the commercialization of fuel cell technology feasible. It permits the smaller scale operation of SOFCs even at low temperatures (~ 400 °C) due to the development of Ni based nano-catalyst and proton conducting SOFC electrolyte technology. This makes ammonia an excellent power source for stationary as well as portable small scale applications. Consequently with the existing infrastructure, ammonia can very well attain all the benefits of hydrogen economy.

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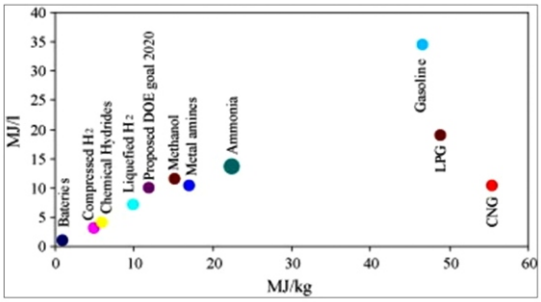
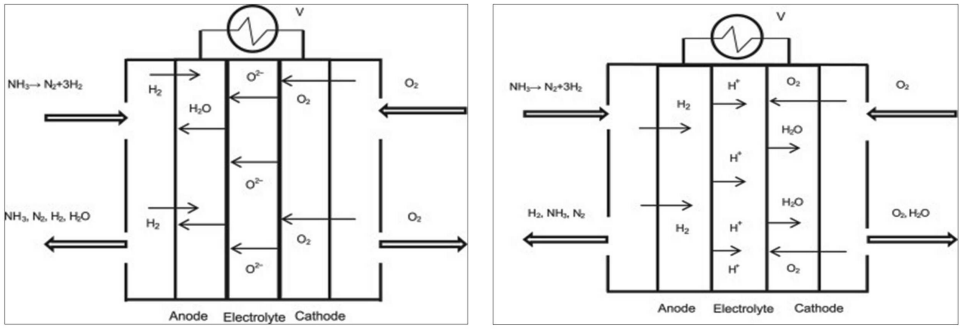



Fig. 1. Comparison of volumetric and gravimetric energy densities of various fuels. *Reprinted with permission* from ref. 15 (Copyright (2008) Elsevier).




**(a)** **(b)**

Fig. 2: (a) Schematic representation of the direct ammonia-fed SOFC-O, (b) Schematic representation of the direct ammonia-fed SOFC-H. *Reprinted with permission* from ref. 147 (Copyright (2016) Elsevier).

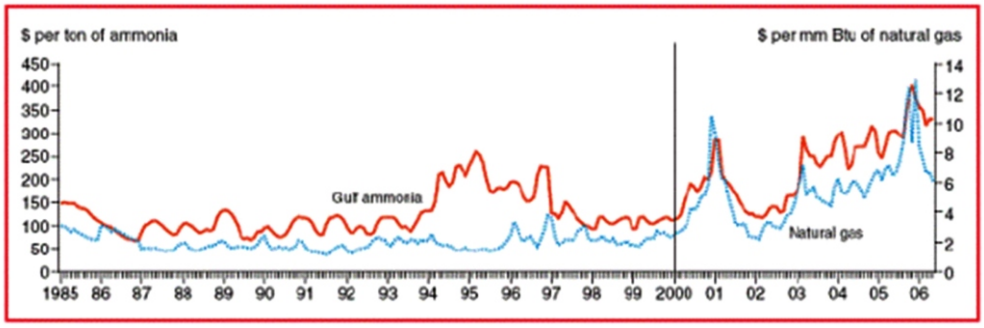



Fig. 3: Monthly U.S. price of natural gas and ammonia [177].

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Table 1: comparison of ammonia with other fuels and hydrogen [15]

| Fuel/storage | P (bar) | Density (Kg $m^{-3}$) | HHV (MJ $Kg^{-1}$) | Energy density (GJ $m^{-3}$) | Specific volumetric Cost ($ $m^{-3}$) | Specific energetic Cost ($ $GJ^{-1}$) |
|---|---|---|---|---|---|---|
| Gasoline, $C_8H_{18}$ /liquid tank | 1 | 736 | 46.7 | 34.4 | 1000 | 29.1 |
| CNG, $CH_4$/integrated storage system | 250 | 188 | 55.5 | 10.4 | 400 | 38.3 |
| LPG, $C_3H_8$/presurized tank | 14 | 388 | 48.9 | 19.0 | 542 | 28.5 |
| Methanol, $CH_3OH$/liquid tank | 1 | 749 | 15.2 | 11.4 | 693 | 60.9 |
| Hydrogen, $H_2$/metal hydrides | 14 | 25 | 142 | 3.6 | 125 | 35.2 |
| Ammonia/pressurized tank | 10 | 603 | 22.5 | 13.6 | 181 | 13.3 |
| Ammonia, $NH_3$/metal amines | 1 | 610 | 17.1 | 10.4 | 183 | 17.5 |

Table 2: Ammonia production by different countries

| Rank | Country | Production |
|---|---|---|
| **1** | China | 45,520 |
| **2** | India | 12,000 |
| **3** | Russian Federation | 10,300 |
| **4** | United States | 8730 |
| **5** | Indonesia | 5100 |
| **6** | Trinidad and Tobago | 4466 |
| **7** | Ukraine | 4160 |
| **8** | Canada | 3942 |
| **9** | Saudi Arabia | 3700 |
| **10** | Egypt | 2950 |
| **11** | Germany | 2823.41 |
| **12** | Qatar | 2665 |
| **13** | France | 2644 |
| **14** | Iran | 2500 |
| **15** | Pakistan | 2500 |
| **16** | Italy | 2365 |
| **17** | Poland | 2100 |
| **18** | Oman | 1700 |
| **19** | Uzbekistan | 1300 |
| **20** | Bangladesh | 1300 |
| **21** | Venezuela | 1200 |
| **22** | United Kingdom | 1100 |
| **23** | Japan | 1035 |

Table 3: life cycle of hydrogen production via various processes [44]

| **Scale of $H_2$ Production ($m^3$/hour)** | Cost of $H_2$ production, US$/($m^3$/hour) | | | |
|---|---|---|---|---|
| | Water Electrolysis | Natural Gas Reformation | Methanol Reformation | Ammonia Cracking |
| **10** | 0.943 | 0.390 | 0.380 | 0.343 |
| **100** | 0.814 | 0.261 | 0.285 | 0.279 |
| **1000** | 0.739 | 0.186 | 0.226 | 0.241 |

Table 4: summary of ammonia decomposition catalysts performance reported

| Catalyst / Support | Temp. (°C) | Rate of $H_2$ Gen. (mmol/min/g) | Conv. Eff. (%) | Ref. |
|---|---|---|---|---|
| **Nano-sized Ni/Santa Barbara Amorphous (SBA)-15 support** | 450 | 8.4 | 25.0 | [46] |
| | 500 | 17.4 | 52.1 | |
| | 550 | 26.8 | 80.1 | |
| | 600 | 31.9 | 95.2 | |
| | 650 | 33.2 | 99.2 | |
| **Ni/SBA-15** | 550 | 12.7 | 37.8 | [47] |
| **Ni/$SiO_2$** | 400 | 0.4 | 1.4 | [48] |
| | 500 | 3.3 | 10.5 | |
| | 550 | 6.8 | 21.6 | |
| | 600 | 11.4 | 36.4 | |
| | 650 | 21.1 | 70.0 | |
| **Ni/$SiO_2$** | 550 | 11.6 | 34.6 | [47] |
| **Ni/$Al_2O_3$** | 550 | 12.7 | 37.8 | [49] |
| **Ni/$Al_2O_3$** | 500 | 24.1 | 71.9 | [50] |
| **Ni/$Al_2O_3$ coated cordierite monolith** | 550 | 16.5 | 50.0 | [51] |
| **Ni/$Al_2O_3$ (unsupported particles < 200 µm** | 550 | 13.2 | 40.0 | |
| **Ir/$SiO_2$** | 400 | 1.2 | 3.9 | [48] |
| | 500 | 5.7 | 18.2 | |
| | 600 | 17.6 | 56.0 | |
| | 700 | 30.6 | 98.0 | |
| **Ru/$SiO_2$** | 400 | 4.5 | 14.3 | [48] |
| | 500 | 20.0 | 64 | |
| | 600 | 30.3 | 97 | |
| | 650 | 30.9 | 99 | |
| **Ru/$ZrO_2$** | 550 | 25.8 | 77.0 | [52] |
| **Ru/$Al_2O_3$** | 550 | 23.5 | 73.7 | |
| **Ru/CNT** | 400 | 6.2 | 3.7 | [52] |
| **Ru/K-CNT** | 400 | 12.2 | 7.3 | |
| **Ru/K-$ZrO_2$-BD** | 400 | 8.5 | 5.3 | |
| **Ru/$ZrO_2$** | 400 | 3.7 | 2.2 | |
| **Ru/$Al_2O_3$** | 400 | 3.8 | 2.3 | |
| **Ru/MgO** | 400 | 5.4 | 3.2 | |
| **Ru/$TiO_2$** | 400 | 4.3 | 2.6 | |
| **Ru/CNT** | 400 | 6.0 | 9.0 | [53] |
| **Ru/MgO–CNT** | 400 | 8.7 | 13.0 | |
| **Ru/CNT treated with $KNO_3$** | 400 | 33.3 | 49.7 | [54] |
| **Ru/CNT treated with KOH** | 400 | 31.6 | 47.2 | |
| **Ru/CNT treated with $K_2CO_3$** | 400 | 31.3 | 46.7 | |

Table 5: performance of various catalysts for Ammonia Borane Hydrolysis

| Catalysts | Conditions | Hydrogen Generation Rate (mmol/min/g) | Ref. |
|---|---|---|---|
| **Co-P/Cu sheet** | 30 °C | 38.7 | [101] |
| | 30 °C | 35.8 | |
| | 40 °C | 69.3 | [101] |
| **Co-P/Ni foam** | 50 °C | 130.0 | |
| | 60 °C | 220.1 | |
| **$K_2PtCl_4$ salt** | 25 °C | 590.3 | [100] |
| **20-30nm Ni/$Si_2O_3$** | 25 °C | 7.0 | [98] |
| **15-30nm Co/$Si_2O_3$nanospheres** | 25 °C, $NH_3BH_3$ / $NaBH_4$ mixture | 0.7 | [102] |
| **10nm unsupported Co particles** | 25 °C, $NH_3BH_3$ / $NaBH_4$ mixture | 775.0 | [103] |
| **$Fe_{0.5}Ni_{0.5}$ nanoparticles** | 25 °C, $NH_3BH_3$ / $NaBH_4$ mixture | 178.1 | [99] |
| **$CoCl_2$** | 25 °C, $NH_3BH_3$ / $NaBH_4$ mixture | 85.9 | [104] |

Table 6: Summary of SOFC-O peak power densities

| SOFC-O System (anode/electrolyte/cathode) | Electrolyte Thickness (µm) | Temperature | Power Density ($mW/cm^2$) | Ref |
|---|---|---|---|---|
| **Pt-YSZ/YSZ/Ag** | 200 | 1000 | 125 | [124] |
| | | 900 | 90 | |
| | | 800 | 50 | |
| **Ni-YSZ/YSZ/Ag planar** | 400 | 800 | 75 | [125] |
| **Ni-YSZ/YSZ/Ag tubular** | 1000 | | 10 | |
| **NiO-YSZ/YSZ/Ag** | 400 | 800 | 60 | [126] |
| **NiO-YSZ/YSZ/LSM** | 150 | 700 | 55 | [127] |
| **Ni-YSZ/YSZ/YSZ-LSM** | 30 | 750 | 299 | [128] |
| | | 850 | 526 | |
| **Ni-YSZ/YSZ/YSZ-LSM** | 15 | 800 | 200 | [129] |
| **Ni-SDC/SDC/SSC-SDC** | 50 | 500 | 65 | [130] |
| | | 600 | 168 | |
| | | 700 | 253 | |
| **NiO-SDC/SDC/SSC-SDC** | 24 | 650 | 467 | [131] |
| **Ni-SDC/SDC/BSCF** | 10 | 700 | 1190 | [132] |

Table 7: Summary of SOFC-H peak power densities

| SOFC-H System (anode/electrolyte/cathode) | Electrolyte Thickness (µm) | Temperature | Power Density ($mw/cm^{-2}$) | REF |
|---|---|---|---|---|
| **Pt/BCGP/Pt** | 1300 | 700 | 35 | [130] |
| **Pt/BCG/Pt** | | | 25 | [133] |
| **Pt/BCE/Pt** | 1000 | 700 | 32 | [134] |
| **Ni-BCE/BCGP/Pt** | 1000 | 600 | 23 | [135] |
| **Ni-BCG/BCG/LSCO** | 50 | 700 | 355 | [136] |
| **Ni-BZCY/BZCY/BSCF** | 35 | 450 | 135 | [139] |
| | | 700 | 420 | |
| **Ni-CGO/BCG/BSCF** | 30 | 600 | 147 | [137] |
| **NiO-BCNO/BCNO/LSCO** | 20 | 700 | 315 | [140] |

Table 8: Electrolytes and electrodes used in ammonia-fed SOFCs.

| Solid electrolyte | Working electrode | Operating temperature (°C) | Power density (mW/cm²) | Ref. |
|---|---|---|---|---|
| $BaZr_{0.1}Ce_{0.7}Y_{0.2}O_{3-\delta}$ (BZCY) | NiO–$Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (BSCF) | 450 | 135 | [148] |
| $BaCe_{0.8}Gd_{0.2}O_{3-\delta}$ (BCGO) | Ni–$Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (BSCFO) | 600 | 147 | [149] |
| $Ce_{0.8}Sm_{0.2}O_{1.9}$ (SDC) | Ni–$Sm_{0.5}Sr_{0.5}CoO_{3-\delta}$ (SSC) | 600 | 168 | [8] |
| $BaCe_{0.8}Gd_{0.2}O_{2.9}$ (BCGO) | Ni–$La_{0.5}Sr_{0.5}CoO_{3-\delta}$ (LSCO) | 700 | 355 | [7] |
| $BaCe_{0.8}Gd_{0.2}O_{3-\delta}$ (BCG) | Pt | 700 | 25 | [12] |
| $BaCe_{0.8}Gd_{0.19}Pr_{0.01}O_{3-\delta}$ (BCGP) | Pt | 700 | 35 | [12] |
| $SrCe_{0.95}Yb_{0.05}O_{3-\delta}$ (SCY) | Pd | 570 | | [150] |
| $BaCa_{0.9}Nd_{0.1}O_{3-\delta}$ (BCNO) | NiO–$La_{0.5}Sr_{0.5}CoO_{3-\delta}$ | 700 | 315 | [6] |
| $Ba_3CaZr_{0.5}Nd_{1.5}O_{9-\delta}$ (BCZN) | Ag–Pd | 620 | | [151] |
| $Ba_3Ca_{0.9}Nd_{0.28}Nb_{1.82}O_{9-\delta}$ (BCNN) | Ag–Pd | 620 | | [151] |
| $BaCe_{0.9}Sm_{0.1}O_{3-\delta}$ (BCS) | Ag–Pd | 620 | | [6] |
| $La_{0.9}Sr_{0.1}Ga_{0.8}Mg_{0.2}O_{3-\delta}$ (LSGM) | Ag–Pd | 550 | | [152] |
| $La_{0.9}Ca_{0.1}Ga_{0.8}Mg_{0.2}O_{3-\delta}$ (LCGM) | Ag–Pd | 520 | | [153] |
| $La_{0.9}Ba_{0.1}Ga_{0.8}Mg_{0.2}O_{3-\delta}$ (LBGM) | Ag–Pd | 520 | | [154] |
| $BaCe_{0.85}Gd_{0.15}O_{3-\delta}$ (BCGO) | Ag–Pd | 480 | | [153] |
| $BaCe_{1-x}Y_xO_{3-\delta}$ (BCYO) | Ag–Pd | 500 | | [155] |
| $BaCe_{0.85}Y_{0.15}O_{3-\delta}$ (BCY) | Ag–Pd | 500 | | [156] |
| $BaCe_{0.85}Dy_{0.15}O_{3-\delta}$ (BCD) | Ag–Pd | 530 | | [157] |
| $BaCe_{0.9}Ca_{0.1}O_{3-\delta}$ (BCC) | Ag–Pd | 480 | | [158] |
| $La_{1.9}Ca_{0.1}Zr_2O_{6.95}$ (LCZ) | Ag–Pd | 520 | | [159] |
| $La_{1.95}Ca_{0.05}Ce_2O_{7-\delta}$ (LCC) | Ag–Pd | 520 | | [151] |
| $La_{1.95}Ca_{0.05}Zr_2O_{7-\delta}$ (LCZO) | Ag–Pd | 520 | | [151] |
| $Ce_{0.8}La_{0.2}O_{2-\delta}$ (LDC) | Ag–Pd | 650 | | [160] |
| $Ce_{0.8}Gd_{0.2}O_{2-\delta}$ (GDC) | Ag–Pd | 650 | | [160] |
| $Ce_{0.8}Sm_{0.2}O_{2-\delta}$ (SDC) | Ag–Pd | 650 | | [160] |
| $Ce_{0.8}Sm_{0.2}O_{1.9}$ (SDC) | NiO–$Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ | 650 | 1190 | [161] |
| $Ce_{0.8}Y_{0.2}O_{2-\delta}$ (YDC) | Ag–Pd | 650 | | [162] |
| $(Ce_{0.8}La_{0.2})_{0.975}Ca_{0.025}O_{3-\delta}$ (CLC) | Ag–Pd | 650 | | [163] |
| YDC–$(Ca_3(PO4)_2$–$K_3PO4)$ (YDCPK) | Ag–Pd | 650 | | [162] |
| $Ba_xCe_{0.8}Y_{0.2}O_{3-\delta}$ þ0.04ZnO (BCYZ) | Ag–Pd | 500 | | [164] |
| $BaCe_{0.9-x}Zr_xSm_{0.1}O_{3-\delta}$ (BCZS) | Ag–Pd | 500 | | [165] |
| $BaCe_{0.8}Gd_{0.1}Sm_{0.1}O_{3-\delta}$ (BCGS) | Ag–Pd | 620 | | [6] |
| (Li–Na–K) Carbonate–$LiAlO_2$ | $CoFe_2O4$ (CFO)–Ag | 400 | | [166] |
| $BaCe_{0.85}Y_{0.15}O_{3-\delta}$ (BCY) | $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (BSCF) | 530 | | [167] |
| SDC–$(Li/Na/K)_2CO_3$ | $La_{0.6}Sr_{0.4}Fe_{0.8}Cu_{0.2}O_{3-\delta}$–SDC (LSFCO–SDC) | 450 | | [168] |
| Na?on | $SmFe_{0.7}Cu_{0.1}Ni_{0.2}O_3$ (SFCN) | 80 | | [169] |

Table 9: cost comparison of production, transportation and storage for hydrogen and ammonia

| | Hydrogen (S/Kg $H_2$) | Ammonia (S/Kg $H_2$)* |
|---|---|---|
| **Production** | 3.00 | 3.80 |
| **Pipeline transport** | 1.87 | 0.19 |
| **Storage** | | |
| **182 days** | 14.95 | 0.54 |
| **15 days** | 1.97 | 0.06 |

* Values of ammonia normalized to hydrogen

# SOCIAL SCIENCES

# Perceptions of post graduate students towards massive open online courses (MOOCS)

***S.K. Panda* and Anu Chirotra*****

## ABSTRACT

*It is an admitted fact that Information and Communication Technology (ICT) has gradually become a standard teaching technology in schools and colleges in many countries of the world. Certainly India cannot be an exception to this practice, but it is unfortunate that in India the implementation of ICT in general and Massive Open Online Courses (MOOCs) under SWAYAM in particular, in teaching and learning in schools and colleges, still fails to meet high government and public expectations. In the present study, objectives were i) To study the Perceptions of Post Graduate students towards MOOC, ii) To find out the difficulties faced by the Post Graduate students regarding MOOC and iii) To obtain suggestions from the post graduate students for effective implementation of MOOC courses. In the present study, out of 35 post graduate departments, 10 post graduate departments where students having more awareness regarding MOOC courses were selected on purposive basis. Finally, 200(10x20= 200) post graduate students were included in the sample. For collection of required data, an opinionnaire was used. Findings of study have multiple responses in related to perception and various challenges etc. with regard to MOOC.*

**Key Words:** ICT, MOOC, SWAYAM

### Introduction

The nineteenth century was marked by the transportation revolution and the twentieth century was marked by the communication revolution. The world began to be increasingly dominated by science and technology and an amazing range of Media-Audio, graphic, radio, T.V. video conferencing, computer conferencing, and Tools Computers, CD-ROM, Telephone, DVDs, Satellite and Technologies internet based, World Wide Web, e-repertories, portal, digital libraries became available for quick and reliable data. These technologies could also be used to communicate, create and manage information promoting the emergence of internationalization of education. As we advanced into the twenty first century ICT has been penetrated into all sector: education, research and development, business industry, entertainment and services sector, etc. And, it became possible to integrate visual and communication technology associated with text, sound, audio, pictures and internet and collapse all into a single device. This congruence and other incredibly fast changes in ICT ushered in knowledge revolution. New access to knowledge has increased dissemination of knowledge. Knowledge is facilitated and creation of new knowledge has accelerated. The flexibility offered by newer technological tools as made learning possible at any age in A-3 paradigm that is, anytime, anywhere, anyone (Ahmed and Garg, 2015 p-211).

The advances in ICT have brought about a major shift in higher education imparted both on

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and off campus. The teaching and learning has now moved from age old instructional paradigm where teacher was saga on stage and monolith repository of knowledge to 'learning' paradigm where teacher is guide on the side and facilitates a learner to navigate, discover and construct knowledge. Universities are now expected to produce versatile graduates equipped with multiple skills in technology communication, computation, critical thinking and problem solving, information management, interpersonal, personal as well as societal, suited to the digital. It is universally accepted that with the help of internet technologies, curricular transaction has now moved from F2F (face to face) to distance, to flexible, to blended and distributed classrooms. It incorporates the features of tutor medicated as well as self-directed learning. Even in campus teaching learning, leading conventional universities/institutions blend F2F instruction with technology to a great effect; the blackboards and chalk and talk based heavy duty lectures are being supplemented with laptops, CDs, emails, radio and sensory perspective to learners (ibid, p-212).

In India the push for the use of digital technology in higher education sector is growing. Through digital technologies, it is expected that education would be accessible to all, become affordable, increase the enrolment rate at higher education and overcome the shortage of quality faculty. Moreover, it also provides opportunities for lifelong learning.

At the national level a number of centrally sponsored schemes have been started under the National Mission on Education through Information and Communication Technology (NMEICT), the National Programme on Technology Enhanced Learning (NPTEL) and the National Knowledge Network (NKW). A large number of projects were also sanctioned under these schemes for innovative use to technology in teaching and learning for the benefits of all learners in higher education (ibid, p-248). Some of the major developments under these initiatives are:

- In 2004, EKLAVYA was developed by IIT Bombay. The ekalavya portal aims at a free exchange of knowledge and ideas, by placing all the relevant academic material in the open source (Gosh, 2018).
- The launch of EDUSAT in 2005 brought satellite connectivity to large parts of Rural India and Indira Gandhi National Open University leveraged satellite, television and internet technologies to offer online support in India and abroad.
- In 2007, the Distance Education council (DEC) took a bold decision that premier institutions like IITs and IIMs could offer online courses.
- Creation of e-content by IIT Madras for 996 courses in engineering, sciences, technology humanities and management.
- UGC initiative to create e-content for 71 Post Graduate Courses under the NMEICT.
- Sharing e-books and high quality e-journals with colleges and Universities under INFLIBNET, being run under the NMEICT, with a view to promote research in the country.
- Development of open source e-learning courseware and platforms like Sakshat by MHRD, e-gyankosh by IGNOU, Brihaspati by IIT-Kanpur (Ahmed and Garg,2015,p 250).

A step further, University Grants Commission(UGC) along with Ministry of Human Resource and Development (MHRD) has launched the MOOC(Massive Open Online Course) program and recently UGC has brought MOOCs Regulations under this and the four programmes started are namely.

- SWAYAM: The indigenous MOOCs portal
- SWAYAM-Prabha: The (32) Direct to Home Channels for transmitting high quality

educational content for transmitting high quality educational content 24x7 direct to every home, without any charge.

- The National Digital library-with more than 72 lakh digital books and,
- The National Academic Depository for authenticating them as per the need of the users (Snehi,2018).

**MOOCs**

MOOCs stands for Massive open online courses. It provides online courses to anyone, anytime, anywhere. It provides opportunity to unlimited number or participants to get enrolled in different courses. Courses on MOOC are free or at small cost and open to all. Anyone can join courses without any formal qualification restriction. MOOC is a platform of learning in which the learning materials are delivered online to anyone. These courses are specially meant for the aspiring learners according to their knowledge, need, personal academic growth and skill to enhance the professional growth. Most commonly MOOC will last to 5-8 weeks which require 2-6 hours study per week. But there are many well structured and planned regular courses with a duration ranging from one year to two years having few semesters also available. Though online course materials are provided, course transactions and evaluations are made to get enrolled in MOOC; the participant has to register his/her name at the institutions hosting the MOOC courses through online. The learning content of MOOC includes video and audio content in an organized form prepared and presented by experts in their field of study. The course activities include assignments discussions, video presentations, quiz, immediate feedbacks, per reviews, clarifications on general misconceptions, summarizing the learning contents, etc. The learners are free to download PDF, e-Books, watch and re-watch the learning content, lectures and videos. One of the most import features of MOOC is that it allows the learners to learn at one's own pace and also has the freedom to choose any course and the study material. The course interaction takes place on tweets, blogs, and other social networking and online venues. So MOOC disseminate equal education opportunities for all individuals regarding race, creed, class, income, location (Varghese and Singh, 2017)

**Justification of the Study**

Online education has potential to transform the higher education. Being flexible in nature a large number of students shows their interest towards online courses and get enrolled in these courses not only in the country but all over the world. India is second to U.S in the number of learners enrolled in online courses with increase number of enrollment and demand of online courses. India has started with Study Webs of Active learning for Young Aspiring Minds (SWAYAM) an indigenous MOOC platform launched by the MHRD, Government of India. MOOC provide opportunities to the students who cannot get enrolled in desirous courses due to the limited number of seats in the courses at the university level and concerns of raising the enrollment ratio, enhancing access and the quality education in the higher education can be addressed by massive open online courses because MOOCs integrate social networking, accessible online resources and students are facilitated by eminent professors from various universities. So, MOOCs have the possibility to revolutionize higher education scenario in the near future due to its openness, scalability and flexibility. Many universities in India have started massive online courses.

In Jammu and Kashmir, University of Jammu also took the initiative of providing MOOC through SWAYAM platform but it is at an initial stage and many students are not aware of this new initiative taken by the university. Therefore, the investigators had undertaken the present study

'Perceptions of post graduate students towards Massive Open Online Courses (MOOCs)'.

**Objectives of the Study**

- To study the perceptions of the post graduate students towards Massive Open Online Courses (MOOCs)
- To find out the difficulties faced by the post graduate students regarding Massive Open Online Courses (MOOCs)
- To obtain suggestions from the post graduate students for effective implementation of Massive Open Online Courses (MOOCs).

**Research Questions**

- What are the common perceptions among the post graduate students about the nature of Massive open online courses (MOOCs)?
- What are the challenges the post graduate students confronted regarding Massive Open Online Courses (MOOCs)?

**Methodology**

For the present study descriptive method was followed and for selection of sample, the investigators collected the views from experts and course coordinator of SWAYAM from different post graduate departments regarding the awareness level and functioning of SWAYAM in the departments. It helps a lot in selecting the sample size for the study. In the present study, out of 35 post graduate departments, 10 post graduate departments where students having more awareness regarding massive open online courses (MOOCs) programme were selected on purposive basis. Thereafter, 20 students were selected from each department randomly. Thus, 200(10x20= 200) post graduate students were included in the sample.

**Distribution of Sample**

| S. No. | DEPARTMENTS | STUDENTS |
|---|---|---|
| 1 | Electronics | 20 |
| 2 | Library and information Sciences | 20 |
| 3 | Biotechnology | 20 |
| 4 | Home Science | 20 |
| 5 | ICccR & HRM | 20 |
| 6 | The Business School | 20 |
| 7 | Economics | 20 |
| 8 | Computer Sciences & IT | 20 |
| 9 | Zoology | 20 |
| 10 | English | 20 |
| | **Total** | **200** |

In the present study, a self-prepared questionnaire was used by the investigators for collection of required data. For knowing the Perceptions of post graduate students towards Massive Open Online Courses (MOOCs), a pilot survey was conducted and information in this regard was obtained from post graduate students of the University of Jammu. The pilot survey thus enables the investigator

in getting information from the actual field setting and was helpful in exploring the diverse issues or aspects for preparing the tool for the study. On the basis of study of literature, information collected during pilot survey, a list of items pertaining to research problem in hand was prepared. A drafted questionnaire was constructed and given to the language expert for scrutinizing. Thereafter, the questionnaire was given to faculty members, University of Jammu for their comment and as per their suggestions the questionnaire was modified. The final draft, thus, ready was again given to the language expert for scrutinizing. This led to its being ready for a try out.

The questionnaire prepared for the collection of data was given to small group of subjects (post graduate students) concerned with the study for the purpose of removing some of the ambiguities and to see if the items properly communicated what they intended. This initial try out led to the further refinement of the tool for its effectiveness in attaining the intended purpose. After initial try out and revision and in the light of final try out responses, the final draft of the questionnaire was prepared for the purpose of data collection.

**Analysis and Interpretation of Data**

Analysis and interpretation of data has been presented in three sections i.e. I) Perceptions of the PG Students towards MOOCs, II) Difficulties faced by the post graduate students in related to MOOCs and III) obtain suggestions from post graduate students for effective implementation of MOOC.

**Section I: Findings related to perceptions of post graduate students towards MOOCs**

TABLE NO 1: Awareness about MOOCs

| Responses | Number | Percentage |
|---|---|---|
| Yes | 105 | 52.5% |
| No | 95 | 47.5% |
| Total | 200 | 100% |

Table No-1 shows that 105 (52.21%) respondents responded that they are aware about Massive Open Online Courses (MOOCs) whereas 95 (47.5%) respondents responded that they are not aware about Massive Open Online Courses (MOOCs). This shows that majority (52.21%) of the post graduate students are aware about MOOCs.

**TABLE NO 2 Do you know about the different online courses provided through SWAYAM platform?**

| Responses | Number | Percentage |
|---|---|---|
| Yes | 93 | 46.5% |
| No | 107 | 53.5% |
| Total | 200 | 100% |

Table No 2 shows that 93 (46.3%) respondents responded that they do not know about the different online courses provided through SWAYAM platform whereas 102 (51%) respondents responded they know about the different online courses provided through SWAYAM platform. This shows that majority (53.5%) of the post graduate students do not know about the different online courses provided through SWAYAM platform.

**TABLE NO 3 Do you want to get enrolled in courses provided through SWAYAM platform?**

| Responses | Number | Percentage |
|---|---|---|
| Yes | 127 | 63.5% |
| No | 73 | 36.5% |
| Total | 200 | 100% |

Table No 3 shows that 127 (63.5%) respondents responded that they want to get enrolled in any course provided through SWAYAM platform whereas 73 (36.5%) respondents responded that they did not want to get enrolled in any course. This shows that majority (63.5%) of the post graduate students want to get enrolled in MOOC courses under SWAYAM platform.

**TABLE NO 4 Do you think that MOOCs are beneficial to students?**

| Responses | Number | Percentage |
|---|---|---|
| Yes | 163 | 81.5% |
| No | 37 | 18.5% |
| Total | 200 | 100% |

Table No 4 shows that 163 (81.5%) respondents that MOOCs are beneficial to students whereas 37 (18.5%) respondents responded that MOOCs are not beneficial to students. This shows that majority (81.5%) of the post graduate students view that MOOCs are beneficial to students.

TABLE NO. 5 Do you think that MOOCs provide opportunity to the students to develop their academic skills and give the opportunity to those students who are not academically bright?

| Responses | Number | Percentage |
|---|---|---|
| Yes | 160 | 80% |
| No | 40 | 20% |
| Total | 200 | 100% |

Table No 5 shows that 160 (80%) respondents responded that MOOCs provided opportunity to the students to develop their academic skills whereas 40(20%) respondents responded that MOOCs did not provide opportunity to the students to develop their academic skills and give the opportunity to those students who are not academically bright. This shows that majority (80%) of the post graduate students view that MOOCs provided opportunity to the students to develop their academic skills and give the opportunity to those students who are not academically bright.

TABLE NO 6 MOOCs are better than traditional courses and MOOCs contribute to improve the quality of education

| Responses | Number | Percentage |
|---|---|---|
| Yes | 115 | 57.5% |
| No | 85 | 42.5% |
| Total | 200 | 100% |

Table No 6 shows that 115 (57.5%) respondents responded MOOCs are better than traditional courses and MOOCs contribute to improve the quality of education whereas 85 (42.5%) respondents

responded MOOCs are not better than traditional courses. This shows that majority (57%) of the post graduate students view that MOOCs are better than traditional courses and MOOCs contribute to improve the quality of education.

**Section II: Difficulties faced by the post graduate students regarding MOOCs**

TABLE NO 7 Do you give equal importance to MOOCs at par with other courses offered by the university.

| Responses | Number | Percentage |
|---|---|---|
| Yes | 98 | 49% |
| No | 102 | 51% |
| Total | 200 | 100% |

Table No 7 shows that 98 (49%) respondents responded that they will give equal importance to MOOCs at par with other courses offered by the university whereas 102 (51%) respondents responded that they will not give equal importance to MOOCs at par with other courses offered by the university. This shows that majority (51%) of the post graduate students view that they will not give equal importance to MOOC at par with other courses offered by the university.

TABLE NO 8 whether inadequate power supply, infrastructure and technological mishaps are challenges to take up MOOCs.

| Responses | Number | Percentage |
|---|---|---|
| Yes | 129 | 64.5% |
| No | 71 | 35.5% |
| Total | 200 | 100% |

Table No 8 shows that 129 (64.5%) respondents responded that inadequate power supply, infrastructure and technological mishaps are challenges to take up MOOCs online programme whereas 71 (35.5%) respondents responded that inadequate power supply, infrastructure and technological mishaps are not challenges to take up MOOCs online programme. This shows majority (64.5%) of the post graduate students view that inadequate power supply, infrastructure and technological mishaps are challenges to take up MOOCs online programme.

TABLE NO 9 whether they make commitment of hours to watch and participate in online discussions, quizzes and assignment work in MOOCs.

| Responses | Number | Percentage |
|---|---|---|
| Yes | 121 | 60.5% |
| No | 79 | 39.5% |
| Total | 200 | 100% |

Table No 9 shows that 121 (60.5%) respondents responded they make commitment of hours to watch and participate in online discussion, quiz and assignment work in MOOCs whereas 79

(39.5%) respondents responded that they do not make commitment of hours to watch and participating in online discussion, quiz and assignment work in MOOCs. This shows that majority (60.5%) of the post graduate students make commitment of hours to watch and participate in online discussion, quiz and assignment work in MOOCs.

TABLE NO 10 whether there is a need of an expert to give guidance to the students related to MOOCs provided through SWAYAM platform.

| Responses | Number | Percentage |
|---|---|---|
| Yes | 135 | 67.5% |
| No | 65 | 32.5% |
| Total | 200 | 100% |

Table No 10 shows that 135 (67.5%) respondents responded that there is a need of an expert to give guidance to the students related to MOOCs provided through SWAYAM platform whereas 65 (32%) respondents responded that there is no need of an expert to give guidance to the students related to MOOCs provided through SWAYAM platform. This shows that majority (69.5%) of the PG students view that there is a need of an expert to give guidance to the students related to MOOCs under SWAYAM platform.

TABLE NO 11 whether information regarding MOOCs provided through SWAYAM platform are available to the students.

| Responses | Number | Percentage |
|---|---|---|
| Yes | 133 | 66.5% |
| No | 67 | 33.5% |
| Total | 200 | 100% |

Table No 11 shows that 133 (66.5%) respondents responded that information regarding MOOCs provided through SWAYAM platform is available to the students whereas 67 (33.5%) respondents responded that information regarding MOOCs provided through SWAYAM platform is rarely available to the students. This shows that majority (66%) of the post graduate students view that information regarding MOOCs provided through SWAYAM platform is available to the students.

**Section III: Following are the suggestions given by the post graduate students for effective implementation of MOOCs**

- Guidance is required by the students regarding different MOOCs related to their subjects provided through SWAYAM.
- Proper information related to MOOCs should be provided through SWAYAM and its benefits to the students.
- Availability of adequate infrastructure, power supply, and internet facility should be provided to the students.
- Adequate knowledge is required by the students to operate e-learning tools.
- MOOCs should be according to the needs and interests of the students.
- Integrate the MOOC schedule into existing course in such a way that it is easy for students.
- Workshops should be organized to train teachers regarding different courses available

under SWAYAM.

**Conclusion**

- Majority (52.21%) of the post graduate students are aware about MOOCs.
- Majority (53.5%) of the post graduate students do not know about the different online courses provided through SWAYAM platform.
- Majority (63.5%) of the post graduate students want to get enrolled in MOOC under SWAYAM platform.
- Majority (81.5%) of the post graduate students view that MOOCs are beneficial to students.
- Majority (80%) of the post graduate students view that MOOCs provided opportunity to the students to develop their academic skills and give the opportunity to those students who are not academically bright.
- Majority (57%) of the post graduate students view that MOOCs are better than traditional courses and MOOCs contribute to improve the quality of education.
- Majority (51%) of the post graduate students view that they will not give equal importance to MOOC at par with other courses offered by the university.
- Majority (64.5%) of the post graduate students view that inadequate power supply, infrastructure and technological mishaps are challenges to take up MOOCs online programme.
- Majority (60.5%) of the post graduate students make commitment of hours to watch and participate in online discussion, quizzes and assignment work in MOOCs.
- Majority (69.5%) of the post graduate students view that there is a need of an expert to give guidance to the students related to MOOCs under SWAYAM platform.
- Majority (66%) of the post graduate students view that information regarding MOOCs provided through SWAYAM platform is available to the students.

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# Analysis of Educational Expenditure in Kathua District of Jammu and Kashmir

*Jasbir Singh* and Rahul Kundal***

## ABSTRACT

*Education has been a principle factor leading to development. It has the ability to enrich people's overall capacity to understand. It assists in securing socio-economic progress and an even distribution of income. A country may never develop sustainably in the absence of significant investment in human capital (Ozturk, 2001). Educational expenditure (presumed as investment in human capital) assists in development of skills in individuals. It helps in enhancing work abilities and, ultimately, production. It transforms the acquired capabilities into more developed (and efficient) ones and provides a set of freedoms to attain higher potentials among individuals. This research paper is an attempt to analyse educational expenditure of the sampled households in Kathua district of Jammu and Kashmir. Three hundred households were randomly selected and were surveyed by making use of an interview schedule. It was found that a large number of the sampled households were incurring, relatively, low educational expenditures. Pearson's (1900) chi-squared* $(x^2=\sum_{i=1}^{k}\frac{(xi-mi)^2}{mi})$ *test was run, and it was found that educational expenditure incurred by the sampled households formed a large proportion of the total household expenditure.*

**Key Words:** human capital, educational expenditure, capabilities, set of freedoms, chi-squared test.

### Introduction

#### Human Development is not about Economic Growth only

The first Human Development Report (HDR) (1990) of the United Nations Development Programme (UNDP) defines human development "as a process of enlarging people's choices". It includes important choices, such as "to lead a long and healthy life, to be educated, and to enjoy a decent standard of living" and some other choices such as "political freedom, guaranteed human rights, and self-respect". Previously, income had been considered a sufficient condition in exercising different human choices, but it proved to be partially correct for many reasons. For instance, income is only a means, but not an end. Well-being of people depends upon the income-use and not on the amount of income generated and accumulated. Evidences intend to explain that in certain cases, high level of human development is registered at normal income level, and vice-versa. There is no automatic link between human development and economic growth. The original definition of human development helps in distinguishing two aspects of human development: human capabilities' development and utilization of acquired human capabilities. As per the report, "people are the real wealth of a nation" and the objective of development is to yield a constructive environment for people in order to help them attain good health, longevity, and prosperity. However, repeatedly, well-being of people has been overlooked and focus turns towards wealth creation (and its accumulation).

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Measures to achieve human development have shown that the main objective of development is human well-being. Handsome standard of living, rise in education and health, productive work environment, cultural and socio-economic participation in community life, and provisions of security against crime enhance the quality of life. People may wish for higher incomes, but it is one choice that does not reflect the whole spectrum of human choices.

To understand insurance of people's well-being, one must understand the vitality of pillars of human development:

i. Equity: It reflects the idea of fairness for each individual with respect to right to education and health care.

ii. Sustainability: It explains that each individual is entitled with right to earn a living, and it embarks an even distribution of goods and services.

iii. Productivity: It makes provisions for overall participation of each individual in production process and income generation. It implies that authority must run effective social programs for people.

iv. Empowerment: It is about freedom that people possess in order to make an impact over developmental processes and decision-making, which leaves a mark over their lives.

v. Cooperation: It talks about participation and feeling of belongingness to society as a proponent of social meaning and collective enrichment.

vi. Security: It includes free, fair, and safe developmental opportunities to people so that they can feel confident and secure about not being disappeared in future.

If any of these pillars is/are missing, the true capabilities of a person may not be realized.

**Education and Human Development**

Education contributes vitally in development. It is seen that educational investment helps in raising level of human development, more importantly when these investments are made in primary education sector. This takes us to next level of imparting quality education. Ozturk (2001) has observed that education is amongst the primary determinants of development. No country can achieve higher levels of economic and human development without substantial investment in human capital. Education helps people to develop reasoning and understanding. It raises quality of life and results in numerous social benefits. It uplifts level of entrepreneurship and opens gates for technological advancement. It proves to be important in protecting socio-economic progress and enhancing income distribution. McGrath (2010) defines the role which education plays in development. He advocates that relationship between development and education has been considered important because education has always been a valued provider of development. This relationship is represented due to existence of some Millennium Development Goals (MDGs) on education. Education is important in planning and policy across the globe and it has promoted international competitiveness (and social inclusion). However, education is not a leading factor in enhancing developmental standards, though there are evidences of relationship between education and development. Tracking the role of education in human development, Türkkahraman (2012) has claimed that education improves the socio-economic lives of people, which may enhance well-being. It leaves a substantial impact on economic and social objectives and delivers high level of human progress.

Registering achievements in education and the role it performs in Indian human development process, Narayana (2006) enquires measurement of educational achievement and integrating

educational objectives, and set marks concerning human development. This enquiry creates incomparable measurement in educational achievement and indicators have reflected amalgamation of educational objectives at global, national, and sub-national levels. Policy implications formed out of such experiences have allowed other developing economies to look for directions in measuring educational achievement. Talking about relationship between education and development, Chatterji (2008) studies returns to education in India and has examined the role that education has performed on growth and development. He attempts to draw implications of outcomes of an empirical examination to develop sound educational policy. He concludes that female education is important. Due to emergence of externalities, primary education is quite important even when it has lower private rate of return. Savitha and David (2016) elate the fact that education is amongst the major determinants of Indian economic and human development, and it has driven growth, which is the primary focus of many developing economies. They illustrate relationship between development and education. They have tracked down importance of investment in education and human capital to achieve sustainable development. Developing economies have sought to focus completely on basic education while higher education has been neglected. Education systems that focus on human capital achieve higher level of economic growth and have been successful in eradicating poverty. They have suggested that policymakers should instrument policies for both basic education and higher education. This may yield benefits to the society and will positively influence development and growth.

**Review of Literature**

Arguing upon the impact of government's educational expenditure, Fan, Hazell, and Thorat (2000) discovered that it had a strong influence on poverty in rural India. Expenditure incurred by the government had huge potential in eradicating poverty, and it had also helped in observing rise in productivity. Public spending had led to decline in poverty. Similarly, Parida, Mohanty, and Raman (2015) found that huge marginal rise in government's educational expenditure had greater impact on human capital in rural India. With a rise in public expenditure, factors leading to accelerated economic growth were observed.

An inquiry carried out by Tilak (2002) claimed that there were important determinants deciding household educational expenditure in rural India. He said that there was nothing as such 'free' education in India. Households had to make significant amounts of educational expenditure. Despite differences in incomes of households, all incurred sizeable chunks of money on attaining education. Households made huge expenditure on school fees, uniforms, and books and stationeries. No discrimination, based on gender, was observed in context with educational expenditure. Lower-income earning groups incurred larger parts of their incomes on educational attainment than upper-income groups. Household and public expenditure did not substitute, but complemented each another. If household finances were to mobilize, government was to, significantly, raise spendings on education. Chandrasekhar and Mukhopadhyay (2006) assessed factors responsible for schooling decisions in rural India. They investigated impact of direct spendings, such as fees, and books and stationeries, etc., on primary schooling. It was clear that apart from tuition fee, there were other expenses, like expenses on uniforms, books, and transportation, which had to be incurred on children's schooling. They recognized the fact that there was an opportunity cost of educational attainment, which could have left negative impact on likelihood to attend schools. They advised that even if primary education were completely free in India, it would not have resulted in 100.0 per cent primary school attendance because many other factors, such as educational opportunity cost, gender, etc., were in play.

Dongre, Kapur, and Tewary (2014) found that, from 2007 to 2013, percentage of children in

private schools in rural India rose from 20.0 per cent to 29.0 per cent. In some states of India, around 70.0 per cent of the children in rural areas were in private schools. Households were not only making expenses on school fees, but also on coaching classes. 24.0 per cent of the children in these areas were undergoing private coaching classes. In Odisha, Bihar, and West Bengal, about 50.0 per cent of the rural children were attending private coaching classes.

Enquiring about rural household's educational expenditure and its impact on returns to education, Kambhampati (2008) talked about different types of households' educational expenditure for around ninety-nine thousand children (aged 5-14 years). It was found that some types of educational expenditure for around fifty-two thousand children was there while there was no educational expenditure for about forty-seven thousand children. While studying educational returns, he elaborated that scholarships were given to 9.0 per cent of the children while Mid-Day Meals (MDMs) were available to 19.0 per cent of the children. Free education was available to 79.0 per cent of the children. Therefore, educational returns proved to create a strong relationship with household's educational expenditure. He made concluding remarks by stating that that number of girls was higher than number of boys in the case of children who were not attending school.

Making use of household survey data of rural India, Tilak (2002) calculated elasticity coefficients and investigated about nature of household educational expenditure. There was a relation between public and household educational expenditure. Household expenditure blended favourably, but alteration in household income was larger than alteration in household expenditure. Rao (2014) interpreted household educational expenditure and discovered that rural households' reach to primary education was a costlier matter as it was for urban households. It was found that these households spent a lot at primary level. Rural poor were equally incurring expenses on education as rural rich. Bhattacharya (2009) explained that in 2004-05, there existed intra-state disparities concerning educational expenditure in UP, Bihar, MP, Chhattisgarh, Jharkhand, and West Bengal. There existed high potential of disparity with respect to monthly per capita household educational expenditure in these states. In rural areas, monthly per capita household's educational expenditure was much lower than urban areas. Proportion of educational expenditure in total household expenditure was nearly negligible in these areas, whereas it was significant in urban areas.

Kingdon (2005) investigated that gender bias with respect to allocation of educational resources, which took place in rural India, had compelled non-enrolment of female children at educational institutions. It led to zero educational expenditure by households. When educational expenditure was considered, there was insignificant level of gender bias amongst enrolled children. Preference for male child and investment motives were produced as factors responsible for significantly lower levels of educational resource allocation for female children than for male children. Chaudhuri and Roy (2006) explored areas of gender concerning educational expenditure on male and female children in rural India. They looked through intra-household allocation of educational expenditure and discovered that parents discriminated amongst their children on gender basis. Public safety-net programmes, such as MDMs, Integrated Child Development Scheme (ICDS), etc., were important in lowering gender bias. Females' high school and secondary school scholarships were of much importance in convincing households to get their female children enrolled in schools.

**Objective**

To analyse educational expenditure incurred by the sampled households in the study area.

**Hypothesis**

Educational expenditure forms a large proportion of the total household expenditure in the

study area.

**Research Methodology**

This research paper is based on primary data. However, research papers, government reports, internet sources, etc.,with respect to literature on human development and educational expenditure were also accessed in order to shape research design. For realizing the interrogative nature of this research paper, primary data were collected (method of primary data collection is explained later in this research paper).

**Sampling Frame for carrying out Field Survey**

Two blocks were selected purposively to form a sampling frame to carry out field survey. Twelve sampled villages from these blocks were also selected purposively. Twenty-five households were selected randomly from each village. Three hundred households from these villages were randomly selected and surveyed.

**Sampling Technique**

The following sampling technique was employed for this research paper:

**Selection of Study Area**

Two blocks, Kathua block and Barnoti block, were selected purposively. Among all the blocks of Kathua district, Kathua block and Barnoti block had the third highest and the first highest number of inhabited villages respectively. Twelve villages (six villages from each block) namely Patyari, Janglote, Sherpur, Changran, Basantpur, and Mehtabpur (Kathua block), and Palli, Nihalpur, Barwal, Jandore, Sumwan, and Nangal (Barnoti block) were also selected purposively. In each block, purposively selected villages were categorised into the following categories (of relative levels of development):

1. Villages with relatively high levels of development: Patyari and Janglote (Kathua block), and Barwal and Jandore (Barnoti block).
2. Villages with relatively medium levels of development: Changran and Sherpur (Kathua block), and Nihalpur and Palli (Barnoti block).
3. Villages with relatively low levels of development: Mehtabpur and Basantpur (Kathua block), and Sumwan and Nangal (Barnoti block).

It is worth mentioning that the relative levels of development of these villages were measured by making use of the data in Census of India (COI)-2011.

**Selection of Households in Study Area**

Three hundred households (one hundred and fifty households from each block and twenty-five sampled households from each village) were selected randomly through simple random sampling technique (lottery method) and surveyed.

**Primary Data Handling**

After the collection of primary data, these were analyzed through tabulation and simple percentage method. Pearson's chi-squared ($\chi^2$) test was run for hypothesis testing.

**Pearson's Chi-Squared ($\chi^2$) Test**

Pearson (1990), in a study on $\chi^2$ test, enquired about of goodness of fita test. Assume 'n' number of observations are drawn by random sampling method out of a population are termed into 'k' mutually exclusive classes concerning observed numbers xi (i = 1,2,3,4,…,k) and null hypothesis (H0) yields probability 'pi' that an observation rests inside the ith class. Thus, there lies the expected

numbers 'mi' = 'npi' for every 'I', where in:

$$\sum_{i=1}^{k} pi = 1$$

$$\sum_{i=1}^{k} mi = n \sum_{i=1}^{k} pi = \sum_{i=1}^{k} xi$$

It was presumed that, under the conditions of H0 as correct, when n → ∞, the limitation of distribution of quantity given below is $\chi^2$ distribution.

$$X^2 = \sum_{i=1}^{k} \frac{(xi - mi)^2}{mi} = \sum_{i=1}^{k} \frac{x^2 i}{mi} - n$$

Firstly, Karl attempted the case wherein expected numbers 'mi' were large known numbers in each cell supposing every 'xi' might be considered like distributed normally, and concluded that in limit 'n' became large, $X^2$ pursued $\chi^2$ distribution with 'k 1' degrees of freedom (d.f.).

After that, Karl attempted the case in which values being expected relied upon measuring which was to be appraised out of the sample, and advised that, with 'mi' as correct expected values and 'm'I' as estimated expected values, subtraction followed

$$X^2 - X'^2 = \sum_{i=1}^{k} \frac{x^2_i}{mi} - \sum_{i=1}^{k} \frac{x^2_i}{m'_i}$$

would be normally direct, positive, and small enough to be excluded. In his concluding remarks, Karl argued that if X'2 was also being distributed as $\chi^2$ distribution along with 'k 1' d.f., approximated error would not impact decisions on practical concerns.

**An Overview of Educational Status of Members of the Sampled Households in the Study Area**

Table 1 depicts data related to type of educational institution attended by members of the sampled households in the study area. Data reflect that a very large proportion (n=691, 56.6%) of members of the sampled households were attending or had attended educational institutions that funded by the government, and relatively a small proportion (n=225, 18.4%) of members of the sampled households were attending or had attended private educational institutions. 24.9 per cent (n=304) of members of the sampled households were not attending or had not attended any educational institutions.

**Table 1**

**Type of Educational Institution attended by Members of the Sampled Households in the Study Area**

| Blocks | Public | Private | NA* | Total Members |
|---|---|---|---|---|
| Kathua | 340 (57.4) | 100 (16.8) | 152 (25.6) | 592 |
| Barnoti | 351 (55.8) | 125 (19.9) | 152 (24.2) | 628 |
| Total | 691 (56.6) | 225 (18.4) | 304 (24.9) | 1220 |

**Notes:** (i) *Includes illiterate members as well as children who were not yet admitted in schools.

(ii) Figures in parentheses are percentages, and these may not add up to 100 because of rounding off.

**Source:** Field survey.

Table 2 depicts data related to level of educational attainment of members of the sampled households in the study area. Data reflect that a considerable proportion (n=263, 21.5%) of members of the sampled households were educated up to upper primary level. A large proportion (n=525, 43.0%) of members of the sampled households were educated up to senior secondary level, and a small proportion (n=125, 10.2%) of members of the sampled households were educated up to tertiary level. 21.5 per cent (n=263) of members of the sampled households were non-literate.

**Table 2**

**Level of Educational Attainment of Members of the Sampled Households in the Study Area**

| Blocks | Non-Literate | Up to Upper Primary Level (up to 7th Standard) | Up to Senior Secondary Level (up to 12th Standard) | Tertiary Level (Higher Education) | NA* | Total Members |
|---|---|---|---|---|---|---|
| Kathua | 128 (21.6) | 116 (19.5) | 261 (44.0) | 57 (9.6) | 30 (5.0) | 592 |
| Barnoti | 147 (23.4) | 147 (23.4) | 264 (42.0) | 68 (10.8) | 34 (5.4) | 628 |
| Total | 263 (21.5) | 263 (21.5) | 525 (43.0) | 125 (10.2) | 64 (5.2) | 1220 |

**Notes:** (i) *Children who were in school but had not attained any level of education as well as children who were not yet admitted in schools.

(ii) Figures in parentheses are percentages and these may not add up to 100 because of rounding off.

**Source:** Field survey.

**Analysis of Educational Expenditure of the Sampled Households in the Study Area**

Table 3 depicts data related to annual expenditure incurred on educational institution's tuition

fees by the sampled households in the study area (in ₹). It was found that a large proportion (n=140, 46.6%) of the sampled households were incurring relatively low annual expenditure on educational institution's tuition fees. Relative to these figures, a small proportion of the sampled households were incurring relatively medium and high annual expenditure on educational institution's tuition fees. A substantial proportion (n=77, 25.6%) of the sampled households were not incurring any annual expenditure on educational institution's tuition fees.

**Table 3**

**Annual Expenditure incurredon Educational Institution's Tuition Fees by the Sampled Households in the Area Study (in ₹)**

| Blocks | ₹ 0* | ₹ 1 to ₹ 6000 (Relatively Low) | ₹ 60001 to ₹ 12000 (Relatively Medium) | ₹ 12001 and Above (Relatively High) | Total Sampled Households |
|---|---|---|---|---|---|
| Kathua | 35 (23.3) | 75 (50.0) | 32 (21.3) | 8 (5.3) | 150 |
| Barnoti | 42 (28.0) | 65 (43.3) | 30 (20.0) | 13 (8.6) | 150 |
| Total | 77 (25.6) | 140 (46.6) | 62 (20.6) | 21 (7.0) | 300 |

**Notes:** (i) *Includes illiterate members as well as children who were not yet admitted in schools.

(ii) **Children who were in school but had not attained any level of education as well as children who were not yet admitted in schools.

(iii) Figures in parentheses are percentages, and these may not add up to 100 because of rounding off.

**Source:** Field survey.

Table 4 depicts data related to annual expenditure incurred on books by the sampled households in the study area (in ₹). It was found that a large proportion (n=138, 46.0%) of the sampled households were incurring relatively low annual expenditure on books. Relative to these figures, a small proportion of the sampled households were incurring relatively medium and high annual expenditure on books. A large proportion (n=122, 40.6%) of the sampled households were not incurring any annual expenditure on books.

**Table 4**

**Annual Expenditure incurred on Books by the Sampled Households in the Study Area (in ₹)**

| Blocks | ₹ 0* | ₹ 1 to ₹ 4000 (Relatively Low) | ₹ 4001 to ₹ 8000 (Relatively Medium) | ₹ 8001 to ₹ 12000 (Relatively High) | Total Sampled Households |
|---|---|---|---|---|---|
| Kathua | 65 (43.3) | 67 (59.3) | 16 (10.6) | 2 (1.3) | 150 |
| Barnoti | 57 (38.0) | 71 (47.3) | 16 (10.6) | 2 (1.3) | 150 |
| Total | 122 (40.6) | 138 (46.0) | 32 (10.6) | 4 (1.3) | 300 |

**Notes:** (i) *Sampled households, not even one of whose members was attending educational institutions as well as sampled households whose members received books either from schools or from other people free of cost.

(ii) Figures in parentheses are percentages, and these may not add up to 100 because of rounding off.

**Source:** Field survey.

Table 5 depicts data related to annual expenditure incurred on coaching classes by the sampled households in the study area (in ₹). It was found that a relatively small proportion (n=110, 36.6%) of the sampled households were incurring annual expenditure on coaching classes. 22.3 per cent (n=67) and 14.3 per cent (n=43) of the sampled households were incurring relatively low and high annual expenditure on coaching classes, respectively. A very large proportion (n=190, 63.3%) of the sampled households were not incurring any annual expenditure on coaching classes.

**Table 5**

**Annual Expenditure incurred on Coaching Classes by the Sampled Households in the Study Area (in ₹)**

| Blocks | ₹ 0* | ₹ 1 to ₹ 4000 (Relatively Low) | ₹ 4001 to ₹ 8000 (Relatively High) | Total Sampled Households |
|---|---|---|---|---|
| Kathua | 97 (64.6) | 27 (18.0) | 26 (17.3) | 150 |
| Barnoti | 93 (62.0) | 40 (26.6) | 17 (11.3) | 150 |
| Total | 190 (63.3) | 67 (22.3) | 43 (14.3) | 300 |

**Notes:** (i) *Sampled households, not even one of whose members was attending educational institutions as well as sampled households whose members did not attend coaching classes.

(ii) Figures in parentheses are percentages, and these may not add up to 100 because of rounding off.

**Source:** Field survey.

Table 6 depicts data related to annual expenditure incurred on transportation to reach educational institution by the sampled households in the study area (in ₹). It was found that a large proportion (n=118, 39.3%) of the sampled households were incurring relatively low annual expenditure on transportation to reach educational institution. Relative to these figures, an extremely small proportion of the sampled households were incurring relatively medium and high annual expenditure on transportation to reach educational institution. Almost half (n=149, 49.6%) of the sampled households were not incurring any annual expenditure on transportation to reach educational institution.

**Table 6**

**Annual Expenditure incurred on Transportation to reach Educational Institution by the Sampled Households in the Study Area (in ₹)**

| Blocks | ₹ 0* | ₹ 1 to ₹ 4000 (Relatively Low) | ₹ 4001 to ₹ 8000 (Relatively Medium) | ₹ 8001 and Above (Relatively High) | Total Sampled Households |
|---|---|---|---|---|---|
| Kathua | 59 (39.3) | 75 (50.0) | 16 (10.6) | -- | 150 |
| Barnoti | 90 (60.0) | 43 (28.6) | 16 (10.6) | 1 (0.6) | 150 |
| Total | 149 (49.6) | 118 (39.3) | 32 (10.6) | 1 (0.3) | 300 |

**Notes:** (i) *Sampled households, not even one of whose members was attending educational institutions as well as sampled households whose members walked to their respective educational institutions.

(ii) Figures in parentheses are percentages, and these may not add up to 100 because of rounding off.

**Source:** Field survey.

Table 7 depicts data related to annual expenditure incurred on miscellaneous educational expensesc by the sampled households in the study area (in ₹). It was found that an extremely large proportion (n=203, 67.7%) of the sampled households were incurring relatively low annual expenditure on miscellaneous educational expenses. Relative to these figures, an extremely small proportion of the sampled households were incurring relatively medium and high annual expenditure on miscellaneous educational expenses. A substantial proportion (n=77, 25.6%) of the sampled households were not incurring any annual expenditure on miscellaneous educational expenses.

**Table 7**

**Annual Expenditure incurred on Miscellaneous Educational Expenses by the Sampled Households in the Study Area (in ₹)**

| Blocks | ₹ 0* | ₹ 1 to ₹ 2000 (Relatively Low) | ₹ 2001 to ₹ 4000 (Relatively Medium) | ₹ 4001 and Above (Relatively High) | Total Sampled Households |
|---|---|---|---|---|---|
| Kathua | 35 (23.3) | 104 (69.3) | 9 (6.0) | 2 (1.3) | 150 |
| Barnoti | 42 (28.0) | 99 (66.0) | 9 (6.0) | -- | 150 |
| Total | 77 (25.6) | 203 (67.7) | 18 (6.0) | 2 (0.6) | 300 |

**Notes:** (i) *Sampled households, not even one of whose members was attending educational institutions.

(ii) Figures in parentheses are percentages, and these may not add up to 100 because of rounding off.

**Source:** Field survey.

Table 8 depicts data related to total annual expenditure incurred on education by the sampled households in the study area (in ₹). It was found that a considerable proportion (n=104, 34.6%) of the sampled households were incurring relatively low total annual expenditure on education. Relative to these figures, equally considerable proportion of the sampled households were incurring relatively medium and high total annual expenditure on education. A substantial proportion (n=78, 26.0%) of the sampled households were not incurring any total annual expenditure on education.

**Table 8**

**Total Annual Expenditure incurred on Education by the Sampled Households in the Study Area (in ₹)**

| Blocks | ₹ 0* | ₹ 1 to ₹ 10000 (Relatively Low) | ₹ 10001 to ₹ 20000 (Relatively Medium) | ₹ 20001 and Above (Relatively High) | Total Sampled Households |
|---|---|---|---|---|---|
| Kathua | 35 (23.3) | 64 (42.6) | 23 (15.3) | 28 (18.6) | 150 |
| Barnoti | 43 (28.6) | 40 (26.6) | 42 (28.0) | 25 (16.6) | 150 |
| Total | 78 (26.0) | 104 (34.6) | 65 (21.6) | 53 (17.6) | 300 |

**Notes:** (i) *Sampled households, not even one of whose members was attending educational institutions.

(ii) Figures in parentheses are percentages, and these may not add up to 100 because of rounding off.

**Source:** Field survey.

**Testing of Hypothesis**

In order to test the following null hypothesis against the alternate hypothesis, Pearson's $\chi 2$ test was run.

H0: Educational expenditure forms a large proportion of the total household expenditure in the study area.

HA: Educational expenditure does not form a large proportion of the total household expenditure in the study area.

**Table 9**

**Observed values on Relative Scale on which Educational Expenditure formed the Proportion of Total Household Expenditure in the Study Area**

| Relative Scale | Observed Values | | |
|---|---|---|---|
| | Kathua | Barnoti | Total Sampled Households |
| Small | 43 | 46 | 89 |
| Large | 73 | 61 | 134 |
| Total | 116 | 107 | 223* |

**Note:** *Total number of the sampled households in the study area that were incurring expenditure on education.

**Source:** Field survey.

Based on observed values, expected values were calculated (see table 10).

**Table 10**

**Expected values on Relative Scale on which Educational Expenditure formed the Proportion of Total Household Expenditure in the Study Area**

| Relative Scale | Expected Values | |
|---|---|---|
| | Kathua | Barnoti |
| Small | 46.29596 | 42.70404 |
| Large | 69.70404 | 64.29596 |

**Source:** Authors' calculation from observed values (see table 9).

With given critical value (c.v.) of 3.84 and degree of freedom (d.f.) 1, and calculated $\chi 2$ test statistics of 3.66, at 5 per cent (or 0.05) level of significance ($\alpha$), it can be concluded that the null hypothesis is accepted while the alternate hypothesis is rejected because the test statistics calculated was smaller than c.v. It should, here, be noted that c.v. is obtained by making use of the d.f. and $\alpha$. Moreover, it is c.v. that determines area of acceptance and rejection. In addition, when the test statistics calculated is less than the obtained c.v., the null hypothesis is accepted and when the test statistics calculated is more than the obtained c.v., the null hypothesis is rejected.

**Conclusion**

There are certain variables that determine household educational expenditure in rural India. There is no 'free' education. Rural households make considerable educational expenses. All households spend sizeable amounts of money on education. Low-income households spend larger parts of their incomes on educational attainment than high-income groups as public expenditure only complements and does not substitute household educational spendings (Tilak, 2002). Similar is the case of the sampled households in the study area. Most of these were low-income households, but a large proportion of their earnings had to be spent on education. Acceptance of the null hypothesis directs that educational expenditure formed a large proportion of the sampled household expenditure. Certain factors play an important role in decision-making regarding schooling in rural India. Moreover, there are a number of educational expenses, other than educational institution's tuition fees, such as expenses on books, stationery, transportation cost, uniforms, etc. There is an impact of direct spendings on primary schooling. There exists an opportunity cost of educational attainment, which may leave negative impact on likelihood to attend educational institutions (Chandrasekhar and Mukhopadhyay, 2006). In the study area, apart from educational institution's tuition fees, the sampled households incurred expenditure on books, coaching classes, transportation to reach educational institutions, miscellaneous goods and services (such as stationary items, hostel accommodation, educational tours and picnics, uniforms, etc.,). It was found that most of the sampled households were incurring relatively low educational expenditure because most of these households were low-income households. Prevalence of substantial rate of illiteracy and opportunity cost of attaining education in the study area also led to relatively low level of educational expenditure. However, it might be followed

that even the relative high level of educational expenditure in rural areas has been far low than the existing level of educational expenditure in semi-urban and urban areas.

**Notes**

a. It is the extent to which observed data match values that are expected by theory.

b. Expenditure incurred annually by the sampled households on coaching classes was calculated by multiplying number of months coaching classes attended over a year and monthly coaching fee.

c. Miscellaneous educational expenses included expenses on stationary items, hostel accommodation, educational tours and picnics, uniforms, etc.,

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# Construction Workers with Special Reference to their Social Security: a perspective

***Satinder Kumar* and Meenakshi Gandhi*****

## ABSTRACT

*The common risks faced by the members of the society like natural disasters, climatic changes, health hazards etc,. are beyond human control. These risks have massive impact on the sustainability of those who are affected by it. The present era of modern industrialized world has opened new vistas of risks including economic risks that originate from globalization, environmental changes and demographic risks from demographic structure. The economic security of the wage earners, casuals workers, self-employed workers mostly depend upon their ability and opportunity to find and hold the job and the way in which the insecurities like sickness, disability and death due to accidents and other like misfortunes can be minimized. Actually the quest for social security and freedom from deprivation has been the consistent urge of man through the ages. As such social security manifests the natural desire of workers to seek protection from uncertain problems, diseases and deprivation that are caused when there is stoppage or substantial reduction of earnings due to the factors such as sickness, maternity, employment injury, invalidity, old age, death etc. Moreover the 'cradle to grave' philosophy envisages that the social security protection must be provided to the needy people from pre-natal to posthumous care. Accordingly in a developing country like India the social security measures are of dual significance. They constitute an important step towards the goal of a welfare state that envisaged in the constitution of India by improving their standard of living including working conditions and protecting the workers against the uncertainties of the future. These measures are also important as they act as a catalyst to improve production and formation of a stable and efficient labour force.*

**Key Words:** construction industry, construction workers, social security, unorganized sector, unorganised worker.

### Introduction

The social security system in India is of dual nature. As it has been observed that the system of administration provides adequate security only to small proportion of workforce that is particularly working in the organised sector. The organized sector is in a privileged position and enjoys an access to the available protective social security benefits. On the other side the majority of the workforce that is working in the unorganised sector particularly in the construction sector remains unprotected due to various reasons.

Basically the life of a worker has two components. One consists of his social life and other his work life and both have reciprocal influence on each other. The social life of a worker enriches his work

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life whereas good work life enhances the productive capacity of workforce and social security can be considered as a means to achieve human development which in turn contributes to the economic growth. Further the social security measures have introduced an element of stability and protection in the midst of stresses and strains of modern life. The concept of social security is based on the ideals of human dignity and social justice. The underlying idea behind social security measures is, that a citizen who has contributed or is likely to contribute to his country's welfare should be given protection against certain hazards. It is an incentive for development whereas its cost is offset by gains in productive efficiency on the one hand and increased saving on the other. It is essential for the well-being of people and society. It is a basic human right though not constitutional fundamental right as its fulfillment will contribute to achieve the various developmental goals of the nations. These measures have far-reaching benefits in the form of reducing infancy and maternity mortality rates, improving productivity and promoting the sense of pride and self-respect amongst the citizens. As such from the minimal level of providing protection against health and life hazards in working situations, it can be extended to social security welfare measures involving provision of better health care, maternity care, old age provisions, etc.

Besides the social security problems of the workers who are working in the unorganised sector may be classified into two categories. In the first category the problem occurs due to deficiency or capability deprivation. It may be due to unemployment or inadequate employment, poor health, meager earnings, illiteracy etc., that leads to generalize destitution of the poorer section of the population. In the second category problem arises out of misfortune that may be due to accident, maternity, old age and death of bread earner and absence of requisite full backup mechanisms (safety nets) to meet these uncertain disruptions such as ill-health, accidents, deaths and old age and so it is high time to understand need for provision of social security for workers working in the unorganised sector specifically in construction industry.

The unorganised sector is crucial and has played a decisive role in Indian economy. It is found that more than 90 percent of workforce is working in the unorganized sector and about 50 percent of the national product is scored by this economy. Ironically, although unorganised workers make a significant contribution to the national wealth but unfortunately they do not have sufficient access to social security benefits. Also the buildings and other construction workers constitutes one of the largest categories of workers in the unorganized sector. According to Sample Survey conducted by NSSO in 2011-2012, about 5.02 crore workers are employed in the construction activities. The construction workers still lack social security measures. The concept of social security is comprehensive, wide and presently acquires a global character but it is unfortunate that it has not yet acquired any uniform standard. The most well-known constituents of social security are social assistance and social insurance. The social assistance schemes are available to groups facing contingencies or risks such as the people with disabilities and illness, the unemployed, etc. The level or amount of payment may vary and generally it is observed that it targets the specific groups. Further the social assistance schemes grant benefits to the people who are in need and these schemes are financed by means of central, regional and local government funds. The means tests are applied in providing a social benefit to the potential beneficiary.The special features of the social assistance schemes is that they are rendered by the Government or other organization to poor persons through either statutory provisions or through voluntary agencies. The social insurance provides benefits for persons of small earnings as a matter of right which combines the contributive effort of insured with subsides from the employer and the state. Social insurance is compulsory in nature based on contributory principle to provide protection in contingencies on fulfilling specified qualifying conditions

laid down under the provision of social welfare legislations. The workers in unorganized sector particularly in construction industry have limited means, can hardly provide effective security against these contingencies and basic fact is that they do not have the capacity or foresight to carry out the plan of saving or insurance. Further these contingencies impair the ability of workers to support themselves and their families.

In this endeavour the second national commission on labour, experienced the difficulty in defining the unorganised worker and commission itself admits the problem of identification and definition of unorganised sector. The commission defines the unorganised workers as who have not acquired sufficient education, they are not getting the benefits that are associated from being a member of an organization and they lack their collective bargaining power. The workers of this are engaged in various occupations or employments from traditional workers to software workers. But unfortunately they have suffered invisibility. The commission does not define the unorganised sector but emphasised that unorganized sector as that area that comes out of the range of organized sector. It is observed that there is no single characteristic that can be used for defining this sector. It is not even possible to define or describe the sector on the basis of the nature of work as various occupations are included in the sector. It cannot be defined or described on the number of employees working in undertakings as home-based workers and self-employed workers are also included in the sector. It cannot be defined on the level of organisation as workers may be working in a dispersed manner without link with an organisation. Thus under unorganized sector the vocations, employments and conditions of work in the sector are so diversified that it is not possible to provide them protection and welfare with one uniform comprehensive law for their welfare and social security.

Thus unorganized sector is very diverse as a term it eludes definition and it is not possible to confine within a conceptual definition.

Therefore it is observed that the unorganized sector is very wide and it is an interdependent sector, not exclusive. It is dependent on the organized sector for raw material, financial investment, employment generation, providing facilities for marketing etc. The organized sector also provides employment to the workers of unorganized sector through subcontracting model..As a result many efforts have been made to identify the characteristics of employments or undertakings in the sector. But none of the characteristics can be termed as crucial in defining the sector.

The general features of the unorganized sector like the wages of the workers working in the sector are very low. Even women and children are forced by their economic necessities to work for their own survival or for the survival of their family members and sometimes the whole of the family labour is employed. The workers including migrant workers are working as contractual labourers and sometimes piece-rate payments are made to them. The scattered nature of their employment further hinders them to form an organization into trade union. They cannot collectively bargain for their rights. Further the existence of health hazards in occupations concerning the construction justifies the need to study the social security as one of the measure to improve their vulnerability. The construction industry is a vital part of unorganized sector and all these inherent characteristics of this unorganized sector are visible in construction sector.

Resultantly to understand the social security needs of unorganized sector workers, especially construction worker, it is important to understand their position in the labour market in India. The workers in India can be classified into organized and unorganized workers and the dichotomy between these two classes is apparent in terms of jobs and social security as former grabs and latter struggles for throughout life.

**Objectives**

The construction workers are most vulnerable segments of the unorganized labour, the inherent risk to their life and limb are much more than that of their counterparts engaged in other organized / unorganized sector. The requirement of social security in times of contingencies to them must be viewed from human perspective rather than on charity basis. In a civilized society it is recognized as their right and India being welfare state, all its instrumentalities and intellectuals are duty bound to provide and campaign for their rights and achieve the objective laid in the Constitution of India. Throughout the country more than eight million workers are engaged in the building and construction work. The inherent characteristics of unorganized sector are also applicable to these workers as their work is of temporary nature, working hours are uncertain and there is total lack of employer and employee relationship. Due to scattered nature of work, it becomes difficult for them to organize and raise their voice collectively. These workers are migrant, illiterate, unorganized, lacking skill and experience. They build houses and other construction work such as to prepare construction sites by removing debris and possible hazards, loading and unloading building materials to be used in construction, dig trenches, backfills holes, or compacts earth to prepare for construction. The construction workers are seen arduously and meticulously laying bricks on cement-sand, mortar up to several floors in height stepping on dangerously, built make-shift ladders. The entry in the construction industry is very easy as unskilled workers starting work as assistants to the masons, plumber, electricians, carpenter etc., during working process acquire skill and upgrade to the category of skilled workers. Unfortunately this kind of upgradation is found only of male workers whereas female workers working in this sector one deprived of this type of upgradation as they only work as helpers and remain unskilled as they are engaged in work that can be performed without acquiring any skill. Due to these factors they suffer from various socio-economic problems and become the worse victims of exploitation and inhuman treatment. These compelling conditions force them to work under hazardous conditions where safety measures are hardly met. The physical nature of work and unsafe and unhealthy working environment makes construction industry unfavourable to workers. The construction workers are also exposed to various occupational and health hazards as the hazardous substances used in this industry have the tendency to cause serious occupational diseases like silicosis, asthma, asbestosis, back pain. The basic amenities like drinking water, toilets, canteens, recreational facilities are not available at their working places. For female workers the problems are much more serious as they are the most exploited and frequent changes in their work place deprive them and their families from their social environment. Moreover absence of sanitary facilities, inequality in wages, lack of opportunity for skill development, long working hours along with lack of freedom in their work place, frequent relocation, and social responsibilities coping with multiple roles often result in stress among them. The construction worker still lacks the social security benefits. In the construction industry the workers are employed informally without written contract and no benefit is provided to them other than wages. The minimum wages are not paid to construction workers in spite of the laws already made in this context.

The Construction Sector is considered as the largest industry. Regarding the generation of employment it occupies second place after agriculture. The construction workers are exposed to various kinds of serious health hazards. The accidents in the construction industry are mainly due to various factors: there are large number of small firms and self-employed workers, the duration of the construction activities is sometimes very short but the turnover of the workers is very high, the migrant and seasonal workers working in this sector are not familiar with the construction work, various types of occupation and trades are also involved in construction work.

The system of sub-contracting is also found in the construction industry. The skilled workers get their employment directly from the employer whereas the unskilled workers are employed through intermediaries who take them to contractors to employ them on daily basis or on commission basis. These intermediaries or contractors pay the wages to these unskilled workers and exploit them by giving fewer wages than due. The system of sub-contracting creates an obstacle in the establishment of employer-employee relations. In the absence of such relationship the employer cannot be made liable to provide social security or other welfare measures to construction workers. The lack of social security measures lead to high level of stress and frustration which further adversely affects their social and working life that often leads to accidents in the course of employment but unfortunately the workers are not able to get any compensation due to lack of proof of employment. The employment of child labour is prohibited by the laws made in that behalf but in construction industry children are found engaged in doing unskilled work.

The living and working conditions of construction workers are also pitiable. They are compelled to work in morning, evening, weekend, and holidays to finish the assigned work and in actual practice the working hours are not regulated and there is gross violation of laws. They have to work even in odd temperature that affects their health. The nature of construction work further adversely affects their health as it requires prolonged standing, bending, stooping, lifting and carrying heavy objects, working with dangerous tools and equipments along with the cluster of building materials, work on temporary scaffolding or at heights and in bad weather.

Moreover to provide them adequate legal protection the following legislations and welfare funds are formulated for the workers employed in the sector.

i. The Building and other Construction Worker (Regulation of Employment and Conditions of Service) Act, 1996.

ii. The Building and other Construction Workers Welfare Cess Act, 1996.

**Legal Framework**

**A. Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996**

It is a piece of social legislation. It is enacted with the object to regulate the employment and conditions concerning service of building and other construction workers. Further it also provides for their safety, health and welfare measures. It is extended to the whole of India and is applicable to every building and other construction work establishments that employed ten or more workers. The building worker is employed to do any skilled, semi-skilled or unskilled, manual, supervisory, technical or clerical work for hire or reward in connection with any building or other construction work but it does not include any person

a. Employed mainly in a managerial or administrative capacity; or

b. Employed in a supervisory capacity, either by nature of the duties attached to the office or by reason of the powers vested in him, functions mainly of a managerial nature.

The appropriate government is empowered to constitute tripartite Advisory Committee to advise on matters regarding the administration of the Act and an expert committee for advising in making rules. Further Act makes the registration of an establishment mandatory and also lays the provision relating to revocation of registration, appeal and effect of non-registration. Also act lays down the provisions for registration of building worker as a beneficiary who must be in the age of eighteen years to sixty years and engaged in any building or other construction work for at least 90

days, regulating welfare measures, normal working hours, wages for overtime work, maintenance of registers including records and to ensure facilities for drinking water, latrines and urinals separately for male and female worker, first-aid, accommodation, creches for children of workers on sites where number of woman workers are more than fifty and provisions for canteens etc.

Further the Act empowers the State Governments to constitute the Board to exercise the conferred powers and to perform assigned function. The Board constitutes a fund called the Building and Other Construction Workers' Welfare Fund and the grants / loans provided by Central Government, beneficiaries' contributions and sum received from other sources is credited to the Fund. The Board utilized fund for the welfare measures of the beneficiary like immediate assistance in case of accidents, pension after completing sixty years of age, loans / advances in connection with construction of house, premium for Group Insurance Scheme, financial assistance for the education of their children, medical expenses for the treatment of major ailments, maternity benefit and to make provision for other welfare measures and facilities etc. The current schemes of Jammu and Kashmir building and other construction workers welfare Board are maternity benefit for female workers ( up to two Children): Rs. 5,000/-; financial assistance for funeral expenses: Rs.5000/-; financial assistance to dependents in case of the death of registered worker: Rs.2,00,000/-; for school education of children of construction workers: for nursery/1st to 5th Rs.2500; for 6th to 8th Rs.3500/-; for 9th to 10th Rs.4500/-; for 11th to 12th Rs.6000/-; for under graduates Rs10,000/-; for post-graduate Rs.15,000/- and for professional courses different amount of scholarships are provided. The financial assistance provided for medical in case of injury Rs.5000/-; for permanent disability Rs. 75,000/-; for temporary disability Rs. 10,000/- and for treatment of chronic diseases Rs.1, 00,000/-. In case of natural death to the nominee/dependant of registered construction worker an amount of Rs.2,00,000/- is provided and in case of accidental death an amount of Rs.4,00,000/- is provided. Further in case of partial permanent disablement Rs.1, 00,000/- and permanent disablement an amount of Rs.2, 00,000/- is provided to registered building and construction workers. The micro-credit facility of Rs.10, 000/- and ATM cum smart Identity cards are also provided to registered construction workers. In order to ensure the effective implementation of the provisions of the Act the inspecting staff and penalty provisions are mentioned in the Act itself. Ironically the Act is applicable to building and other construction work where ten or more construction workers are employed.

**B. The Building and Other Construction Workers' Welfare Cess Act, 1996**

The object of the Act is to provide for the levy and collection of a cess on the cost of construction incurred by employers to augment the resources of the Building and other Construction Workers Welfare Boards constituted under Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996. The main source of funds for the Board is the collection of cess at a rate not less than one percent of the cost of construction incurred by an employer which shall be collected from every employer including work of the government or public sector undertaking. The proceeds of the cess collected are required to be paid to the Board after making requisite deductions. Also it empowers the State Government to authorize authorities or any officer to exercise the power to ensure the implementation of the provisions of the Act and obligates the employer to pay interest in case of delay in the payment of cess and also prescribes penalty for the non-payment of cess within specified time. The amount due is to be recovered as arrears of land revenue. The act also makes the companies liable for contravening the provisions of the Act.

**Judicial Approach**

The enactment of legislations regarding the welfare of workers gained momentum after

independence in conformity with the provisions of constitution and international labour standards and judiciary also has made a distinct contribution to the law by introducing innovative methods and devising new strategies to provide social justice to the workers working particularly in the construction sector and extending them the coverage of social security legislations. The court considered the social security legislation as a piece of beneficial legislation enacted for the welfare of the working class and while interpreting them the courts adopted a flexible and pragmatic approach and kept in mind the objectives behind the enactment of that social security legislation and ideal and principles enshrined in the Constitution of India.

The Constitution of India has endeavored upon the judiciary the task to harmonies the conflict between the rights of individual and the interests of the community.

In Diwan Chand Builders and Contractors v. Union of India, the question for consideration before the Supreme Court was whether the cess levied under the scheme of impugned Cess Act is a fee or a tax. At this the court held that the levy of cess on the cost of construction incurred by the employers on the building and other construction works is for ensuring sufficient funds for the welfare Boards to undertake social security schemes and welfare measures for building and other construction workers. The fund, so collected, is directed to specific ends spelt out in the BOCW Act. Therefore, applying the principle laid down in its earlier decisions of this court, it is clear that the said levy is a fee and not tax. The said fund is set apart and appropriate specifically for the performance of specified purpose; it is not merged in the public revenues for the benefit of the general public and as such the nexus between the cess and purpose for which it is levied get established, satisfying the element of guid pro quo in the scheme. As such Cess Act has to construe as 'fee' and not 'tax'.

In Adani Agri Logistics v. State of Haryana, the question was whether the building and construction workers Act applied to the owner of the establishment on the ground that it had outsourced their construction activity to the contractor. At this the court examined the definition of employer showing that the owner of an establishment employing building workers is covered by the said definition. The definition also includes the contractor who may be employed in relation to building and other construction work. Even when there is no privity of contract with the workers of the contractor, it is the owner for whose benefit the work is carried on. The court added that the mere fact that the liability was undertaken by the contractor did not exclude the liability of the employer. The role of owner was akin to the role of principal employer under the scheme of the Contract Labour (Regulation and Abolition) Act, 1970, and with regard to the issue whether the Building and Construction Act would apply to construction activity covered under the Factories Act, 1948, the court held that merely because the provision of the Factories Act, 1948 have been made applicable besides other labour laws to the contractors, it would not exclude the applicability of Building and other Construction Act and Cess Act to the petitioner-contractors and whether the owner of the establishment required to comply with the provisions of the Building and other Construction Act and the Building and other Construction Workers' Welfare Cess Act, 1966, the court held that the owner of the establishment for whom or for whose benefit the construction activity is carried on and who employs building workers is included and is required to comply with the provisions of the Building and other Construction Workers Act and the Cess Act. The court accordingly held that the petitioners cannot be excluded from the coverage of Building and other Construction Workers Act and Cess Act. Further in Builders Association of India v. Union of India,the court upheld the validity of Building and other Construction Workers Act, Cess Act and concerning rules and levy of cess on contractors as legal.

However in National Campaign Committee v. Union of India , The Supreme Court of India

expressed its concern to protect the interest of unorganized workers working in building and other construction workers. Moreover court observed that the overall implementation of the provisions of the Building and other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1995 as well as the Building and other Construction Workers Welfare Cess Act, 1996 is far from satisfaction and there is an urgent need to extend the benefits of the Act to unorganized section of building workers in a meaningful manner. Further the court issued following directions to the states to take measures for their welfare:

i. Welfare Boards have to be constituted by each State with adequate full time staff within three months.

Ii. Welfare Boards will have to meet at least once in two months or as specified in the rules to discharge their statutory functions.

Iii. Awareness should be built up, about the registration of building workers and about the benefits available under the Act. There should be effective use of media, All India Radio and Doordarshan, for awareness programmes regarding the Act, the benefits available there under and procedures for availing the benefits.

iv. Each State government shall appoint Registering Officers and set up centres in each district to receive and register the applications and issue receipts for the applications.

v. Registered trade unions, Legal Service Authorities and NGOs are to be encouraged to assist the workers to submit applications for registration and for seeking benefits.

vi. All contracts with Governments shall require registration of workers under the Act and extension of benefits to such workers under the Act.

vii. Steps should be taken to collect the cess under the Cess Act continuously.

viii. The benefits under the Act have to be extended to the registered workers within a stipulated time frame, preferably within six months.

ix. The Member Secretary of the Welfare Boards and the Labour Secretary shall be responsible for due implementation of the provisions of the Act. The Labour Ministry of each State shall carry out special drives to implement the provisions of the Act.

x. The CAG should audit the entire implementation of the Act and use of the funds.

xi. All Boards shall submit comprehensive reports as required under the Act and Rules to the respective Government.

**Conclusion and Suggestions**

Thus it is concluded that construction industry has become highly fragmented with fewer larger enterprises and many more small ones as contractors have outsourced their workers. The image of industry is lowered to such a level that it becomes difficult to attract new workers. The lack of skills poses a threat to the quality of products and in the long term in the quality of employment. There is a need to think on the issues of security, health, safety and skill formation of workers. Moreover the basic rights of workers are widely flouted in construction industry. The construction workers are excluded by law due to lack of employer-employee relations, as usually the workers are casual, self-employed and migrant. The discrimination between male and female workers, temporary and permanent workers in the terms and conditions of employment and in their wages are widespread. The workers working in the construction industries may sometimes look healthy but their nutritional status and immune defense mechanisms of the body may not be adequate enough to protect them from infections from

their co-workers and the toxic effects of pollutants present in the work environment. Moreover due to their socio-economic reasons these workers are compelled to work without protective devices and are often exposed to occupational hazards. The quality of work is not good and lack of skill could pose a threat to employment in the future. These workers are illiterate and have an inadequate knowledge of hygiene and basic dietary requirements. Moreover, malnutrition and lack of immunity makes them vulnerable to communicable diseases and in addition to it they develop psychological disorders due to lack of social security, work security and occupational health services. The social dialogue is hampered by fragmentation of the industry and weak workers and employers organization. The lack of social security is one of the serious concerns of construction workers as their temporary status employment causes insecurity of income. To provide them adequate insurance against periods of sickness or unemployment as well as medical and retirement benefits is of crucial importance if in future we want to retain construction workers and to attract new employment in this sector. The social assistance and social insurance schemes must be extended to all the construction workers irrespective of their employment status. The new schemes must be evolved keeping in mind the needs of construction workers. The laws are required to be updated and there is a need to promote occupational health and safety and improve wages and other terms and conditions on which construction workers are engaged. The training must be provided to acquire skill requirement of the construction industry. The illiterate and unskilled worker can be exploited but educated and skilled workers are capable to dictate their rates and terms of employment. Thus, the problem specific to the construction sector along with poor work environment, unhealthy life style, work related exposures and demographic factor have adverse effect on the health of the workers working in this sector and adds further to their vulnerability which is a matter of concern and needs to be addressed.

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# Bangladesh Foreign Policy: Evaluation of Different Political Regimes

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## ABSTRACT

*Foreign policy is the set of principles that direct a state's foreign relations with other state and non-state actors in the international system. The purpose of foreign policy is to ensure national interest of a country outside its own territory in carrying out negotiations, signing treaties, joining forums and in other issues regarding the country's economic, geopolitical and strategic interests. This paper focuses on how regime change can influence or change the foreign policy of the country like Bangladesh. The foreign policy or the foreign relations decides the reflection of an independent and sovereign nation. The foreign relations which are deemed as vital to a nation have to modify from time to time according to the need and the interest of the nation. From the time, when East Pakistan got independence from West Pakistan and Bangladesh emerged as an independent nation on world map in 1971, it started following its foreign policy, while its foreign policy has underwent considerable changes throughout these years. As per the outline, the principle of non-alignment, the principle of peaceful co-existence and resistance to racialism, colonialism and imperialism were confirmed as the major characteristics of the foreign policy of Bangladesh. The diverse regime and its foreign policy has changed due to different formula and ideology of political parties of Bangladesh in power from time to time. Since the birth of Bangladesh, it depends on different roles of people in power, who are altering the aphorism of foreign policy of Bangladesh in diverse moment according to their own wishes.*

**Key Words:** India, Bangladesh, foreign policy, USA, USSR.

### Introduction

The economic situation of Bangladesh is strongly correlated to the foreign policy of Bangladesh. From the time when Bangladesh got independence, it desired to get financial assistance from foreign countries to build its infrastructure and to nourish its countrymen. In these state of affairs, it was very necessary for Bangladesh government or successive regimes of different times to maintain healthy relations with other countries and try to get financial help from all the probable fronts. Because of this, Bangladesh has developed and encourages healthy relations with United States and Soviet Union respectively and also with their respective allies. However, Bangladesh has not joined any of the superpower. To promote and persuade the regional and economic development plans, Bangladesh takes much interest and is very active in organizing regional economic cooperation in South Asia. In International organizations, particularly those dedicated to solving the economic problems of the poorest countries in the world, Bangladesh vigorously takes part in them. To put into consideration the national security and development, Bangladesh in a planned way put the aspiration for peace in its foreign policy. However, occasionally it is not correct in implementation, because in

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'Bangladesh the different political regimes have played a different role.

Bangladesh comes out as an autonomous, sovereign and independent country in 1971 through a long-running effort. After independence in 1971, India's relations with Bangladesh, to all intents and purposes, seemed like a roller coaster ride, but with more downs than ups. This may seem inexplicable given the role played by India in the liberation of Bangladesh. But foreign policy has changed since 1971 to current time due to a change in the political regimes. The PM in diverse political regimes visited different countries to make agreements, treaties, protocols, trade agreements to preserve national interest of Bangladesh. When Sheikh Mujib took over the presidency in 1971, he stressed on nationalism, socialism, secularism, democracy, in which Bangladesh had a good relationship, especially with the Soviet Union because of its fascination with socialism and also had a good relationship with India for resorting to secularism in the Constitution. In 1978, Ziaur Rahman came to power and converted secularism into "the principle of absolute trust and faith in the Almighty Allha" and he also justified socialism in new terms as social and economic justice (Article 8, Constitution of Bangladesh) and 'Bismillahhir Rahmanir Rahim' was added in the very start of the Constitution.

The outcome of which was that Bangladesh relations become good with the Muslims countries, Pakistan and China, whereas Russia and India uttered their displeasure with Bangladesh for the subsequent change of socialism and secularism in the constitution of Bangladesh during Zia regime. After the assassination of Zia-ur-Rahman in 1981, the second military regime headed by President H.M Ershad also adopted the similar foreign policies as adopted by the Zia during his Era, but Islam was incorporated as the religion of state in the Article 2A of the constitution of Bangladesh by Ershad. Now, the situation is like that whenever Awami League (AL) forms the government and holds the authority, they follow foreign policy of Mujib as adopted by him during his era and Bangladesh Nationalist Party follows Zia's foreign policy when Bangladesh Nationallist Party (BNP) make government consecutively highlighting that Bangladesh's foreign policy is based on the two regimes basically and these two regimes will be followed by the Awami league and Bangladesh Nationalist Party.

**Bangladesh Foreign Relation during the Liberation War:**

At the time of Liberation war, the interim government of Bangladesh had made the sketch of its foreign policy and confirmed that its foreign policy stands on the principles of non-alignment, peaceful co-existence with its neighbours and foreign countries, and oppose colonialism, racialism and imperialism. After getting independence, Bangladesh restated these principles in its foreign policy which were again repeated by the foreign minister of Bangladesh when he visited India in 1972. Bangladesh after getting independence now had a different posture in following these principles of colonialism, racialism, imperialism and no-alignment as compared with foreign policy adopted when it was the part of Pakistan. From the very existence of Pakistan, Pakistan has always tried to maintain good relations with United States of America and for keeping it up, it had also joined SEATO and CENTO , a military alliance formed with plan and proposal of USA.

The consequence of this was that the foreign policy of Bangladesh after independence was regarded as pro-Western and tarnished by India's cold war attitude. Pakistan was of the belief that it was reasonable that Pakistan was alliance with the powerful United States in its foreign policy. But later, the main political party of Bangladesh ,that is, Awami League amended its political proposal which was made public in 1969, in which Hussen Shaheed Suhrawardy stated that Bangladesh in the coming time would adopt an independent, non-aligned foreign policy .It also adopted the policy of

peaceful co-existence and always stood against imperialism, colonialism, and dictatorial government.

The Basic constitutional steps of foreign relations of Bangladesh were mentioned in the constitution of Bangladesh which was formed in 1971 and determines that foreign policy of Bangladesh was directed by numeral fundamental principles. It is well mentioned in Bangladesh constitution that Bangladesh put foundation of its global relations on the principles of respect for national sovereignty and equality. Bangladesh also gives importance that no country should interfere in the internal problems of other countries till the time the respective country asks for any interference or help. Bangladesh always wants peaceful resolution of global issues and international or intercontinental issues and value international law and all the principles mentioned in the charter of the United Nations such as complete disarmament in the country, to protect the rights of the citizens of every country in the world and help the subjugated and exploited class all through the world and fight against colonialism or racism mentioned in Article 25 of Bangladesh Constitution .

**Bangladesh Foreign Relation during Mujib(1971-1975) Regime:**

Sheikh Mujibur Rahman became the president of Bangladesh when Bangladesh got independence in 1971. With the establishment of Bangladesh, he guided the foreign policy of Bangladesh which mentioned principle of the liberation war as:

- ✓ Nationalism.
- ✓ Socialism.
- ✓ Secularism.
- ✓ Democracy, these were main state policies.

At that time, Bangladesh was pursuing both India and the Soviet Union to maintain its foreign relations to preserve national interest because India recognized Bangladesh as an independent state and looked for the assistance of the Soviet Union. Basically, Sheikh Mujibur Rahman stated that the country's foreign policy is based on the principles of foreign policy of Bangladesh at the time of the liberation war. At that time, the relationship between Bangladesh and India based on the recognition of Bangladesh, signed a 25 years long treaty of peace, friendship, cooperation, etc., but at that time Bangladesh had no diplomatic relations with Pakistan and Pakistan cut its relations with Commonwealth due to the admission of Bangladesh as a member of the Commonwealth.

On the other hand, USA did not support the Bangladesh liberation war in 1971 due to the nationalist politics and international alignment of Mujib with the Soviet Union and this gravely upset the US policy makers and also Mujib's anti-American policy and support towards Vietnam war and trade with Cuba intruded Bangladesh and United State of America relations. At that time, the relationship between Bangladesh and the Soviet Union was good because the Soviet Union recognized Bangladesh as an independent state in which Mujib's socialist policy was similar to the USSR. But at that time, China did not recognize Bangladesh, where there were no diplomatic relations with China and China vetoed the admission of Bangladesh to the UN in 1974. The Muslim world did not recognize Bangladesh as a state because of the secularism and socialism of Mujib in state constitution as a fundamental principle of the state, but afterwards recognized Bangladesh considering the Muslim majority in the world.

While following the non-alignment policy and maintaining excellent bonding with the Muslim nations, Bangladesh intended to transpire its ideological principles in its foreign policy. After gaining independence, a declaration encouraging the eradication of the principle of imperialism and colonialism was made without delay. At the time of visit of Sheikh Mujibur Rahman to the Soviet Union

in 1972, he conveyed his support to the citizens of Laos and Cambodia as they were struggling for gaining their right so they can decide their future without any external interference. In 1973, Mujib insisted for appropriate enforcement of the Paris Peace Treaty on Vietnam while delivering his speech at Commonwealth Conference organized in Canada.

Pakistan considered itself in danger of extinction by the first atomic explosion in India in the middle of 1970's, but Bangladesh constantly supporting India's elucidation and justification for the peaceful use of atomic energy in the region of South Asian. However, in the era after August 1975, the notion of disarmament was received by Bangladesh completely. Bangladesh was of the view that allowing for the arms race (nuclear and conventional weapons) as the most deadly threat to world peace must be carried out.

**Bangladesh Foreign Relation or Policy during Zia regime(1976-1981):**

In November 1976, Zia took a step forward when the leader assumed the position of chief administrator of martial law. Zia became the president of Bangladesh in April, 1977 and after coming to power immediately took a major step of amending the constitution of Bangladesh by using martial law ordinance. This obvious gesture of Zia indicates his political ideology and philosophy and it also highlights that principles on which Zia governed the country during his regime. The amendments and modifications in the constitution by Zia during his regime show that Zia would follow a capitalist path and it became when Zia redefined socialism guided by the elimination of the requirement for the purchase of property without any reimbursement. Zia to put stress on Muslim identity of the nation and to maintain closer relations of Bangladesh with Islamic states of the world amended the constitution of Bangladesh, revoked and abolished Article 12 of the constitution of Bangladesh which approved secularism as the country's main principle and altered it into the “principle of absolute trust and faith in the almighty Allaha”(Article 8 of Bangladesh constitution). At that time, Zia also added 'Bismillahir Rahmanir Rahim' to the preamble of the constitution.

Both Zia and Mujib had their own priorities and preference. The government of Zia had never discarded the strategy of "opposition to imperialism, colonialism and racism" that the government of Mujib had included in the constitution as component of the foreign policy of nation. During that phase, the foreign policy of Bangladesh tilted the relations of the world triangle among the United States, China and Muslims. The relations of Bangladesh with India were cautiously observed by the new regime in which India withdrew water and dispute over the Farakka barrier. Zia-ur-Rahman internationalized the Farakka agreement with the government of Prime Minister Desai in India and the peace treaty has been severely criticized for sacrificing the national interest of Bangladesh and the government of Morarji Desai in India. It was surprising that Pakistan recognized Zia's regime and gave economic aid to Bangladesh and the establishment of diplomatic relations with Bangladesh. Bangladesh supported Pakistan's admission into the Commonwealth and Pakistan's support to Bangladesh for appointment to UN, NAM and OIC.

Zia's regime in Bangladesh was recognized by USA in which Zia changed the state socialism to take up the path of development, impressed the administration of USA and Zia's multi party democracy highly praised by the US administration and it strengthened the bilateral relations. The economic policy of the free market of Zia impressed the policy markets of the United States, where USA appeared as the largest donor and partner in aid management and provided adequate treatment to Bangladesh and, apart from mutual help and aid, many multilateral and international organizations for instance IMF, IBRD, IDA, etc,declared to help Bangladesh economically. These organizations were sponsored by United States of America.

The role of Bangladesh against the invasion of the Soviet Union in Afghanistan and the aggression of Vietnam in Kampuchea have also overshadowed the Bangladesh-Soviet Union relationship in which Zia's multiparty democracy with a presidential system opposed the socialist system and reduced the Soviet influence on Bangladesh. The free market economic policy of Zia regime was against socialist politics. The Maoists applauded that the Zia regime is considered by China to be an independent and sovereign state, and China also supported the Farakka issue between India and Bangladesh. Two more agreements were signed in Beijing in 1977 related to economic and technical cooperation and a trade and payment agreement (TAP).Zia's relationship with the Muslim world, including Saudi Arabia, recognized Zia's regime and immediately Zia's change from the Indo-Soviet orbit which means from socialism, and alignment of Bangladesh with Muslims and West world impressed the Muslim world where Bangladesh became a member of the OIC and with help from the Middle East, the OIC, OPEC and IDE to regulate the economic development of Bangladesh to a large extent.

In 1980, a regional cooperation concept in South Asia was presented to six more nations of this region on the part of Bangladesh, and at last in 1985, the South Asian Association for Regional Cooperation (SAARC) was established. Since Bangladesh regarded that cooperation on cultural level between the nations of this region could dissipate their doubt and mistrust which they have on each other. Bangladesh introduced this concept of cooperation during that period but to generate a favourable atmosphere between these South Asian nations, some conditions were there to be met. Bangladesh intended to direct this framework of cooperation in the direction of certain well-defined objectives through the production of financial benefits. These objectives incorporated the possibility of winning joint negotiations for the South Asia nations and, secondly, the creation of a favourable spot for the small nations of this region compared to India. However, these objectives have not yet become visible; the establishment of SAARC can be considered one of the main political objectives of foreign policy of Bangladesh.

**Bangladesh Foreign Policy during The Ershad Regime (1982-1990):**

After the assassination of Zia on March 24, 1982, the government was not taken over by the armed forces immediately. He took over the government and by coming to power first of all affirmed martial law as supreme, suspended the constitution of Bangladesh and the parliament of Bangladesh. Zia by introducing the Martial Law turned out to be the head administrator of Martial Law and chiefs of Navy and Air force as its deputy heads. The government of Hussian Mohammad Ershad followed the same path and policies of the Zia regime. Similar to Zia, Ershad approved all the constitutional amendments done by Zia-ur-Rahman which declared Islam as the state religion and followed the capitalist path (Jahan, 2000). At the time of Ershad, Bangladesh economy was liberalized and Bangladesh was looking out for and also getting packages and aid from foreign countries. Ershad opened up many sectors in Bangladesh for private assets and also executed donor approved policies such as structural adjustment programme. Ershad during his regime tried to cultivate good relations with the west and Islamic countries and whatever disputes Bangladesh had with India remained unsettled during his period.

The Jatiya party of Hussian Muhammad Ershad remained in power during 1982-1990 period and Ershad pursued the same foreign policy as pursued by the Bangladesh nationalist party of Zia-ur-Rahman. But regarding the relations of Bangladesh with India, the relations were improved between them at the ending period of BNP regime because of the adoption of regional cooperation plan pursued by the South Asian Countries. Thus idea of regional cooperation among South-Asian

countries was given first by Zia-ur-Rahman of Bangladesh. But during Ershad regime, the relations among India and Bangladesh remained worse and none of the issue was resolved during his regime.

At that time, General Ershad did not change the foreign policy of Zia's government. General Ershad had closed a soviet cultural centre which is located in Bangladesh in 1983 which led to dreadful situation between Bangladesh and Soviet Union. There were various direct and indirect reasons of deteriorating and worsening relation of Bangladesh to Soviet Union. Whenever there is disputes between Bangladesh and India, Soviet Union support India as it has alternate of remaining neutral in the matter. China was looking for an opportunity to come closer to Bangladesh. Bangladesh relations with Soviet Union became worse and at that time relations of China with Soviet Union were also antagonistic and unfriendly, China emerged as an alternative and optional friend to Bangladesh and Bangladesh also accepted China as its new friend. The economic condition of Bangladesh at that time was not good and it was totally reliant on support and aid that it gets from western countries.When it comes to relation of Bangladesh with USA, the relations of both the countries were good and friendly. As General Ershad followed the same path and policies followed by President Zia during his regime. The foreign policy followed by General Ershad during his regime was similar to one followed by General Zia-ur-Rahman where he had bigotry to USA in several areas and also supported them in those areas. In the Disarmament conference held in 1982, General Ershad, the president of Bangladesh met Ronald Rigan, the President of USA in UN Assembly. As a result, President Ershad visited USA in 1983. USA also admired Bangladesh's role in Afghanistan and Kampuchea. USA conferred Ershad as a man of Private Enterprise. USA also helped Bangladesh during pervasive flood in 1988. When Iraq invaded Kuwait where USA supported Kuwait and also Bangladesh supported Kuwait and voted on USA proposal for Kuwait in UN General Assembly.

During the period of Ershad government, Bangladesh had a reliable relationship with China because Ershad had not changed foreign policy promulgated by the Zia government and had also declared the diplomats of Soviet Union as Persona non granta . As a result of this action taken by the government of Bangladesh headed by General Ershad, China came closer to Bangladesh and expressed great gratification and satisfaction to Bangladesh. China and Bangladesh become good friends and this friendship was approved and accepted by both the countries. The outcome of this friendship was that President Ershad in 1982 had visited China and he was warmly received in China. The flood that came in 1988 in Bangladesh, devastated many things and hit the economy of Bangladesh, China at that time, gave financial support to Bangladesh. Islam was declared as the state religion during Ershad regime which was admired by the Muslim countries.

**Bangladesh Foreign Relation or Policy during the Khaleda Zia's government (1991-1996):**

The Khalida Zia government came into power in 1991 by overthrowing government of President Ershad and again came to power after the elections held in 2001 at national level in Bangladesh. Khaleda Zia, during her regime, pursued her husband's foreign policy. When Khalida Zia came to power, the new regime kept on pursuing a careful and central path on all social, economic and external fronts, carried on and followed the previous policies adopted by the military rule under Zia regime and Ershad regime.

Khalida Zia didn't have that much good relation with India during her governance. Khalida Zia was the first women Prime Minister of Bangladesh. Khalida Zia wanted to solve the Tin Bigha corridor dispute with India. This piece of land was in India's control from the time of independence. Both the countries arrived at an agreement related to Tin Bigha Corridor during Khalida Zia visit to India in March, 1992. It was expected that according to this agreement, the corridor should be transferred to

Bangladesh on perpetual lease by June, 1992. In the financial year of 1995-96, Bangladesh had imported goods worth 4492.60 crore and exported goods for 296 million rupees and 42 lakhs taka. There were also many other issues between India and Bangladesh and one of them being illegal immigration issue which was raised in 1992 during Khalida Zia government. There were many Bangladeshi people who were residing in India illegally. India claimed that nearby 11 million people of Bangladesh were residing in India illegally and they were taken as the major threat to national security of India. Khalida Zia during her regime did not take any initiative in improving the relationship with the Soviet Union. The relation between Soviet Union and Bangladesh remained poor at the time of Zia government and also during the Ershad government.

Khaleda Zia visited USA because at that time the relations of Bangladesh were good with USA and also there was the government of President Bill Clinton. The government of Bangladesh did commendable job as its government at that time send its troop to UN Peace Keeping Mission which was well-liked by USA. A treaty was signed by Bangladesh on the subject of UNHCR and a welcome message was send to Khalida Zia by President Bill Clinton. Bangladesh needed help economically for the rehabilitation of Rohinga refugees. An aid of 4.75 million dollars was given to Bangladesh by UNHCR and World Bank. A lot of foreign currency was given to Bangladesh. To improve and maintain the relationship with China, Khalida Zia visited China in 1991 and negotiated with the Chinese Communist Party general secretary, and also a Chinese representative visited Bangladesh to negotiate on diverse areas. However, Khalida Zia didn't take much interest in improving relations with India.

**Bangladesh Foreign Relation or Policy during Sheikh Hasina (1996-2001):**

The Awami League won the national election of 1996 and formed the government after the Khalida Zia regime. The Prime Minister Sheikh Hasina walked on the path set by her father Sheikh Mujibur Rahman. She followed the same foreign policy as taken up by her father in 1971 where Sheikh Hasina emphasized on the two main factors. The two main factors were the Awami League government drop the socialist attitude and adopt free Market economy. At the time of Awami League government in Bangladesh led by Sheikh Hasina, the relations with neighbouring country India got revived and improved a lot with India. The major accomplishment of the Hasina government was the successful negotiated solution of two long-standing disputes. In 1996, a Ganga water exchange treaty was signed for 30 years with India, and in 1997 a peace accord was signed with the rebels in the Chittagong Hill Tracts.

After the collapse of Soviet Union, the relations of Bangladesh with Russia changed. The government of Bangladesh had an option to socialist approach in the foreign policy of Bangladesh and Bangladeshi Prime Minister Sheikh Hasina had signed a few accords with Russia. As a result, Bangladesh bought a special aircraft from Russia, that is, MIG -29 fighter airplane that indicated successful international relations among Bangladesh and Russia. During the regime of Sheikh Hasina government, Bangladesh was blessed at that time with Natural resources, as a number of mines of natural resources were found in Bangladesh. It attracted many foreign countries towards Bangladesh and United State of America was one among them. As a result, President of America Bill Clinton visited Bangladesh in March, 2000. U.S.A discussed with Bangladesh the matter on the use of Chittagong port for import and export and bargained on the purchase of natural resources found in Bangladesh such as oil, gas etc. Bangladesh wished to have the opportunity to put its products in the US market. Bangladesh did not take into consideration the disappointment expressed by United States for buying a Russian MIG-29 fighter from Russia. Sheikh Hasina also maintained her

relationship with China similar to the foreign policy of her father Sheikh Mujibur Rahman.

**Bangladesh Foreign Relation during Khaleda Zia(2001-2006):**

Whenever Khaleda Zia came to power she followed the foreign policy of President Zia. The pro- Prime Minister L.K. Advani of India at that time, at a conference in Agartala, which was held on November 7, 2001, gave the statement that Al-Qaida and ISI were present in Bangladesh and operating from there against India. The pro-prime minister L.K. Advani on January 7, 2003 again gave statement that near about 11 million and 1 lakh people of Bangladesh were living in India which may be a big threat to India's national security, but it turned out to be false in report given by CIA Agency of United State of America in the year 2005. During Khalida Zia regime, Bangladesh government gave the list of terrorists and wanted that India should return these terrorists to Bangladesh, but India didn't give importance to the matter. As India didn't take concern to this request of Bangladesh and didn't return terrorists to Bangladesh, the relations between Bangladesh and India became worse and Bangladesh came closer to Pakistan. Pakistan wanted to get back its membership in the commonwealth, Bangladesh supported and helped Pakistan in this matter. The Foreign Minister of Bangladesh, Morshed Khan, fought for the membership of Pakistan in Commonwealth and the Indian Foreign Minister, Yashwant Sinha, expressed his resentment for returning membership of Commonwealth to Pakistan in Commonwealth ministerial action group conference held in London on 2 November, 2002.

The Foreign Minister of USA Kollin Powell came to Bangladesh to give positive reaction. The Foreign Minister of USA well-liked the establishment of a moderate democracy and suggested that all political parties should reach a consensus on national interest, in which each political party could have a disagreement on national affairs on June 19, 2003. He also claimed that USA had to maintain a good relationship with Bangladesh as Bangladesh exported one third percent in the US market. During the Awami League government in Bangladesh (1996-2001), Prime Minister Sheikh Hasina had purchased eight MIG-29 aircrafts. The government of Bangladesh Nationalist Party led by Khalida Zia (2001-2006) had maintained good relations with USA and China during her governance. Her government wanted to sell all the aircrafts which Bangladesh bought during Sheikh Hasina government, as she said that Bangladesh was not able to pay the cost of these eight MIG-20 aircrafts. The relations between Bangladesh and Russia became worse.

**Bangladesh Foreign Relation or Policy during Sheikh Hasina (2009-2013):**

The government of Sheikh Hasina believed in democracy and always tried to maintain good relations with countries like India, USA, and Russia and occasionally with country like China. Sheikh Hasina also tried to keep good relations with Islamic countries but Islamic countries never liked the governance of Sheikh Hasina as she stick to socialism and secularism during her governance. Sheikh Hasina, at all times, during her government in Bangladesh pursued the foreign policy adopted by her father during his regime.

Several governments after Bangladesh's independence desired to set up a nuclear power plant but were unsuccessful. During the general elections which were held in Bangladesh in 2009, the Awami League party won the election and made government in Bangladesh. The Prime minister Sheikh Hasina again came back to power in 2009 and immediately took a major step. She visited Russia on 21 May, 2010, as Sheikh Hasina wanted to sign a treaty with Russia to set up a Nuclear power plant in Bangladesh. The agreement was signed between Bangladesh and Russia successfully on the cooperation for the use of nuclear technology for peace purpose. The agreement was signed between both the countries and was renewed subsequently after every five years. Looking at the

intensity of strategic and foreign policy implications attached with nuclear deals, this agreement brought to mind an assumption that it can have implications on the foreign policy of Bangladesh. It can also have some serious implications on South Asian region.

Russia and Bangladesh became close friends and bilateral relations among them became friendly and pleasant soon after the independence of Bangladesh because Russia supported Bangladesh during liberation war in 1971. But the total graph of relations among these countries got changed after the vicious assassination of Sheikh Mujibur Rahman, military coup took over and during this time period, Zia-ur-Rahman became the president of Bangladesh. Bangladesh tried to maintain good relations with United States of America, China and the Islamic world. The foreign policy of Bangladesh, in the post Mujib era was also associated with these countries. Russia afterwards slipped out from foreign policy priorities of Bangladesh. During the first government of Sheikh Hasina (1996-2001) the relations were improved. Prime Minister Sheikh Hasina, during this time, cracked a deal with Russia, and bought eight MIG-29 aircrafts worth $124 million. As from India's strategic point of view, the agreement with Russia was a positive development. The cooperation between Russia and Bangladesh is considered as an immense support and relief for India as India had fear that China could use Bangladesh against India. China always tried to maintain good relations with Bangladesh. Sheikh Hasina wanted to setup nuclear power plant in Bangladesh and tried to do every possible thing to set up Nuclear power plant. Sheikh Hasina visited China in 2010. She was welcomed there and Beijing restated its commitment to set up nuclear power plant in Bangladesh. In light of these developments and given the intensity of bilateral relations, at one point. Sino-Bangladesh partnership in nuclear energy seemed evident at some point of time as many developments took place between both the countries which could be seen as implication for India.

The Prime Minister of India visited Bangladesh on 6-7 September 2011, to negotiate the Transit treaty and Teesta Treaty, which was useless because the Chief Minister of West-Bengal Mamta Banerjee has opposed that Bangladesh could not share more than 25% of the water where as Bangladesh expected 48% water supply before the arrival of Manmohan Singh in Dhaka. Bangladesh did not allow transit facility to India as India was not able to solve water dispute on Teesta River. An agreement was signed on the Framework agreement on development cooperation and two protocols in which access of 24 hours a day to Dahgram-Angorpota enclaves through Tin Bigha Corridor and the conservation of the Bengal tiger of Sundarbans was also signed in the Memorandum of Understanding between Bangladesh and India. Both India and China wanted to use Chittagong port of Bangladesh. There are two pillars on which foreign policy of Bangladesh stands and these two major pillars are security and development. The question is not only of the territorial security, it is also the question about securing water, food, energy, and shelter as well as environment security. Steps can only be taken by Bangladesh government for socio-economic development if the initiatives are taken to address all remaining problems done first (Star, Daily, 25 March, 2010). The power sector cooperation between Bangladesh and India is witnessing steady progress. Bangladesh and India are in negotiation to link a Power Purchase Agreement for the purchase of 250MW electricity from India to Bangladesh. A Joint Venture Agreement (JVA) setting up a 1,320MW coal power plant in Bangladesh was also signed. On January 2012 India welcomed Bangladesh's participation in power projects in India particularly in the north-eastern Indian states.

In 2012, Bangladesh allowed India's Oil and Natural Gas Corporation to ferry heavy machinery, turbines and cargo through Ashuganj for Palatana Power project in southern Tripura. From October 2013, India started exporting 500 megawatts of electricity a day to Bangladesh over a period of 35 years. A 125-kilometre Baharampur-Bheramara transmission line, 40 km of it is in Bangladesh to

connect the two substations. Bangladesh officials believe the export would greatly ease the national shortage once 500 MW flows into the national grid. The two country's Prime Ministers also unveiled the plaque of the 1,320-MW coal-fired Rampal power plant, a joint venture between the two countries. The link is being seen as a major milestone in strengthening the bilateral relationship and comes at a time when India is desperate to make up for its inability to deliver on two key pacts with Bangladesh: one on Teesta waters and the other on land boundary pact. From November 2013, a Wagah Border-like ceremony is being organised at Petrapole (in West Bengal, India) - Benapole (Bangladesh) border checkpoint. The relations between the countries are definitely moving in positive direction. South Asia is India centric region. The rising assertion of Bangladeshi identity, dynamics of party politics, that is, legitimacy crises, has hindered the amicable India-Bangladesh relations. The spread of democracy, liberalization of economy, trade, confidence building measures have brightened the prospects Bangladesh foreign policy.

**Return of Sheikh Hasina and Foreign Policy of Bangladesh (2014-2018):**

The Prime Minister of Bangladesh Sheikh Hasina of Awami League got triumph in parliamentary elections in 2014, blemished by less participation of people and bloodshed and the largest opposition group of Bangladesh's Nationalist Party whose leader is Khaleda Zia and its allies stayed away not to participate in this election on 5 January 2014. They announced that they would try to stop general strikes and voting by blockades on the highway. There have also been widespread arrests of leaders of the opposition, unrest and protests, attacks on religious minorities and extra judicial killings. The results were condemned by the United States of America, the United Kingdom, the European Union and the United Nations.

Both India and Bangladesh try to maintain good relations with Bangladesh. Bangladesh has a significant place in the foreign policy of India and China and Bangladesh also tried to resolve issues with both the countries to improve relations with both these countries. Chinese President Xi Jinping's visit to Bangladesh on 14-15 October 2016 was dubbed a 'historical state visit' poised to be a strategic changer in South Asia and the Indian Ocean region. On the sidelines of Xi Jinping visit, Bangladeshi and Chinese companies signed trade and investment deals worth USD 13.6 billion, in addition to the USD 20 billion in loan agreements signed by both governments. Strategically important geographical location in Bangladesh, physical and political proximity to India, availability of cheap labour and proximity to the Bay of Bengal have significant implications for Chinese regional geopolitics and geo-economics.

India's government has done much to make relations better with Bangladesh in its foreign policy, and give importance to its immediate neighbour. In May 2014, one of the invitees to oath ceremony of the current Prime Minister of India Narendra Modi was Bangladesh Premier Sheikh Hasina. Smt. Sushma Swaraj's first "stand-alone" visit to Bangladesh as the Minister of External Affairs in June 2014 gave further impetus to India-Bangladesh 's close and friendly relations. Modi's foreign policy is presently concentrated on enhancing ties with South Asia's neighbouring nations, involving Southeast Asia's expanded neighbourhood and significant worldwide powers. Both the governments Sheikh Hasina's Awami league in Bangladesh and government of Modi in India try to revitalize relationship between India and Bangladesh.

The agreement is also in line with India's fresh vision of foreign policy, based on increased financial involvement with its neighbours. Sushma Sawraj concluded multiple contracts to increase connections during her first official visit to India in June 2014(Bhattachary Joyeeta, 2014). These include Visa facilitation to grant numerous entry visas to minors less than thirteen years of age and

older people more than sixty five years of age, Bangladesh Special Economic Zone Proposal, Agreement to return India's accused fugitive assassination, Increase Maitri Express frequency and begin bus service between Dhaka and Guwahati and Shillong and many more. The fruitful two-day visit to Dhaka by Indian Prime Minister Narendra Modi on 6-7 June 2015 saw the signing of 22 contracts covering the full spectrum of political , economic and cultural relations with the signing of Land Boundary Agreements. Modi, for his part, gave certainty that conversations are ongoing among the appropriate stakeholders and that the two nations would quickly reach an agreement on the rivers Teesta and Feni.

Overall, the visit to Modi symbolized the bipartisan consensus among India's main political parties on improving Bangladesh relations. The Motor Vehicle Agreement (BBINMVA) among Bangladesh, Bhutan, India and Nepal is expected to substantially improve road connectivity. In August 2016, Cargo Movement's trial run on trucks from Kolkata to Agartala via Dhaka and Dhaka to New Delhi via Kolkata and Lucknow was held. There are currently around 100 flights operating weekly between India and Bangladesh connecting Dhaka and Chittagong to various Indian cities such as New Delhi, Kolkata, Mumbai and Chennai. Flights between India and Bangladesh fly, from Bangladesh, US-Bangla Airlines, NOVOAIR, Regent Airways, and Biman Bangladesh; and from India, Jet Airways, Spice Jet, and Air India. Prime Minister Sheikh Hasina had visited India before this visit for the BRICS-BIMSTEC Outreach Summit on 16-17 October 2016.

The two nations are now set to open a fresh chapter- Notun Projonmo- Nayi Disha- in their bilateral relations with established and demarcated land and maritime borders. Out of the 6 rail links that existed in the past, there were only four operational links that are broad gauge inter-country rail links between India and Bangladesh. The Radhikapur-Birol rail link was the latest to be introduced during the April 2017 visit of PM Sheikh Hasina. Also construction of two additional new rail connections is in progress. The new rail link between Agartala and Akhaura is being funded via grant provided by India, which is seventh in number. The 'Maitri Express' now operates 4 days a week between Kolkata and Dhaka and has been upgraded into a fully AC train service. The 2nd Maitri Express trial run was conducted in April, 2017 during the visit of Prime Minister Sheikh Hasina to India, which will run between Khulna and Kolkata and will soon be operational. There are frequent bus services that run via Dhaka between Kolkata-Dhaka, Shillong-Dhaka and Agartala-Kolkata. A new bus service (Dhaka-Khulna-Kolkata) was launched during Prime Minister Sheikh Hasina's visit in April 2017. During Sheikh Hasina's four-day trip to New Delhi in April 2017, Bangladesh and India signed two defence contracts. Under the contracts the two countries military will carry joint training and drills of the two nations. Throughout the visit, 36 bilateral agreements were concluded in different fields including Civil Nuclear Power, Space, Information Technology, defence, Security, capacity Building etc. The two Premieres attended the memorial ceremony in order to pay tribute to Indian soldiers martyred in Bangladesh's Liberation War.

India also expanded its first defence credit line to a neighbouring nation by offering $500 million to Bangladesh for the acquisition of defence machinery. This is the third line of credit to Bangladesh from Indian side. Prime Minister Narendra Modi provided Sheikh Hasina $5 billion in two distinct loan lines in April 2017, including $500 million for defence procurement intended to wean Bangladesh off Chinese military buying during her visit to India. Modi announced that both nations will jointly create a biopic on Sheikh Mujib-ur-Rahman, published on his 100th birthday in 2020. Chief Minister of West Bengal then joined the two prime ministers to launch three fresh transport connections between West Bengal and Bangladesh.

India has also provided meritorious Bangladeshi scholarships for undergraduate and

postgraduate learners and doctoral scientists to study traditional medicine systems like Ayurveda, Unani and Homeopath. In 2017, Prime Minister Modi offered that India would rebuild Rohingya homes in Rakhine during his visit to Myanmar if they were allowed to return, and Ms. Swaraj enquired about progress on the repatriation of the refugees during her visit. Bangladesh has given refuge from Myanmar to almost 11 million Rohingya since 2017, and is building homes for them in Bangladesh's Cox Bazar. Bangladesh's boundaries with India and Myanmar have not been well defined. Prime Minister Sheikh Hasina adhered to Maritime Boundary Ruling Arbitrations and constructive measures were taken with the then Prime Minister Manmohan Singh and present Prime Minister Modi to resolve the border dispute. On April, 2018, Prime Minister Narendra Modi met Prime Minister Sheikh Hasina in London on the sideline of the Commonwealth summit to tackle climate Change, protectionism and cyber attack and the two leaders also attended the convocation of the Vishwa Bharati University in Shantiniketan. On the Rohingya issue, PM Sheikh Hasina in 2018 called on India and other countries to intervene in the crisis on an urgent basis, warning that heavy rains of that season may wash away some of the camps, and heighten the chances of casualties and disease.

On 30 December 2018, general elections were held in Bangladesh to elect members of the Jatiya Sangshad. The result was a thumping triumph for the Awami League by Sheikh Hasina but the elections were again marred by allegations of violence and ballot-making. India's Prime Minister Narendra Modi Congratulated Bangladesh Prime Minister Sheik Hasina on the phone during her re-election as Bangladesh's PM in the 11th Parliamentary elections held on December 30 , 2018. Both the governments in Bangladesh and India have taken new measures to strengthen ties and foreign policy in the years ahead. The dubious electoral win of the Awami League is bad news for Bangladesh, where it will further cement an oppressive political order with a mask of democracy. It is doubtful that China and India will help restore democratic norms. So long as Beijing can continue to extend its diplomatic and economic footprint within the country, it will not raise awkward questions about the internal political arrangements in Bangladesh. After all, it has absolutely little interest in promoting democratic progress. Eventually, there will be a bit opposition from Prime Minister Narendra Modi's government in India to a move toward authoritarianism. Modi, a reticent democrat at best, has studiously avoided any criticism of the democratic process. Instead of criticism, he was among the first foreign leaders to congratulate Hasina on her victory. His key interests in Bangladesh are to contain the expansion of Chinese power and to obtain some limited cooperation in curbing Islamic radicalism's rise.

Finally, the Trump administration, to the extent it has paid any interest to South Asia has mainly been thoughtful with the future of the United States of America involvement in Afghanistan. It has paid little attention to political developments and changes that takes place in Bangladesh or elsewhere in the region. Subsequently, it seems highly unlikely that Washington will expend much energy, let alone political capital, to address the shortfalls of this election. Despite fairly widespread reports of unfair practices that marked recent polls, the Trump administration, the Washington, has readily accepted the outcome of the 2018 election At a time when democracy across much of the world is under cordon or in hysteria, the Bangladeshi government's ability to get away with a profoundly compromised election has disturbing consequences for the region. It adds to the growing roster of states in South

Asia, including Pakistan, Sri Lanka, and even India, where democracy isto varying degreesunder duress. Worse still, the drift toward authoritarianism may actually lead to greater political instability within Bangladesh as legitimate channels of dissent will become increasingly blocked.

**Conclusion**

In the end, it can be seen that foreign policy of Bangladesh was based on two regimes in the past: the regime of Sheikh Mujibur Rahman (1971-1975) and the regime of President Zia-ur-Rahman (1978-1982). The Awami League of Prime Minister Sheikh Hasina follows her father's foreign policy and Nationalist party of Khalida Zia follows foreign policy of her Husband Zia-ur-Rahman. The small countries have their foreign policy and its very significant for small countries to execute its foreign policy in relation to the superpower that diplomatic excellence, especially in developing countries, and must also remember that, the countries will not commit themselves to the goal of losing national interest when Bangladesh goes to conclude a treaty with the neighbouring country and other countries. As in past few decades, India's relations with Bangladesh have certainly witnessed a significant upswing despite some persistent challenges. During NDA government, the Indian Parliament unanimously passed the Land Boundary agreement as its 100th constitutional amendment, thereby resolving all 70-years old border dispute since the end of British Raj and Bangladesh also allowed India to ferry food and grains to the landlocked Northeast using its territory and infrastructure. There can be no overnight successes but sustained efforts are essential. Both the countries and their governments need to strengthen their relations as well as military ties. Both the countries must peruse positive foreign policy towards each other. These recent developments which are going on between the two countries strengthen foreign relations and move them towards positive direction.

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# BUSINESS STUDIES

# Antecedents and Consequences of Social Media Multitasking among University Students

***Komal Nagar*, Suvidha Khanna** and Tejeshwar Singh******

## ABSTRACT

*The present study proposes and tests an integrative conceptual model which incorporates boredom proneness and social media self-efficacy as antecedents while social media fatigue is modeled as an outcome of social media multitasking. A convenience sample of 318 respondents was used to test the model. Structural equation modelling was used to test the hypothesized linkages among the constructs. Findings of the study demonstrates strong associations between boredom proneness and social media self-efficacy with social media multitasking. This study also corroborates the negative effect of social media multitasking on social media fatigue among students. Findings of the study are expected to contribute to the field of social media by unraveling the antecedents and consequences of social media multitasking, which has not been addressed in the previous literature.*

**Key Words:** boredom proneness, social media self-efficacy, social media multitasking, social media fatigue, structural equation modeling

### Introduction

In today's society, social media has become an indispensable part of our everyday life, particularly among university students, who consume multiple media streams simultaneously. This phenomenon has recently motivated scholars to explore the antecedents and consequences of a phenomenon associated with social media, namely, social media multitasking. Particularly scholars argue that social media multitasking among students has several detrimental outcomes such as reduced cognitive abilities (Uncapher et al., 2017), mental health and learning performance (Bowman et al., 2010). Despite the deleterious effects of social media multitasking, research examining factors leading to an increase in social media multitasking is still in its early stage where majority of the studies have focused exclusively on the academic performance of the students as an outcome of social media multitasking (Junco et al., 2011). In comparison to this body of literature, the relationship between the causes and psychological outcomes of social media multitasking has not yet been fully studied. This gap has been addressed in the present study that examines variables influencing the multitasking behavior of university students in India. Particularly, the present study explores the relationship between boredom proneness, social media self-efficacy and social media fatigue in the context of social media multitasking.

### Literature Review

*Boredom Proneness and Social Media Multitasking*

A systematic review of prior social media multitasking literature suggests that social media may take on several forms such as social networking sites, blogs, chat platforms, photo and video

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sharing (Gastelum and Whattam, 2013). Specifically, multitasking is the engagement in more than one activity at the same time and can take one of three forms: dual tasking, rapid attention switching and continuous partial attention (Wood and Zivcakova, 2015). The concept of dual tasking, as the name suggests, involves individuals completing more than one task simultaneously. Rapid attention switching requires the individual to rapidly change focus from one activity to the other, while continuous partial attention deals with only partial attention being paid by the individual to more than one task continuously. Furthermore, media multitasking can occur between multiple devices (e.g. using the computer while watching television) and can also happen within the same device (e.g. viewing multiple windows on the computer screen). Irrespective of the form or medium of multitasking, studies suggest that social media multitasking (SMM) exists, particularly among the youth who are exposed to a large number of devices such as computers, smartphones and tablets which support the viewing of social media anytime and anywhere.

Evidence suggests that engaging in social media multitasking can be motivated by several factors. A study by Wang and Tchernev (2012) showed that a person's previous multitasking behaviour determined his/her multitasking behaviour. Studies suggest that users of mass media, including social media, seek gratification from its use (Dunne et al., 2010). The motivation behind using different forms of media is grounded in Uses and Gratification (U&G) approach, which emphasizes that consumers indulge in the use of media to seek gratification. Furthermore, research also suggests that there are a number of stressors in our environment that put strain on the consumer resulting in deleterious outcomes. One such stressor is the boredom proneness, which has resulted in more individuals engaging in the use of social media to “kill time”.

Boredom proneness is the lack of external stimulus that is exciting and challenging (Derringer et al., 2010). Social media provides an endless stream of entertaining content. Different forms of social media provide different challenges and experiences resulting in individuals shifting from one type of social media to the other in search of something interesting for emotional stimulation required to keep them entertained and thus alleviate their boredom. Therefore, based on the above discussion, we hypothesize that;

**H01: Boredom proneness is positively related to social media multitasking.**

*Social Media Self-Efficacy and Social Media Multitasking*

While self-efficacy is defined as a person's judgment of his/her ability to organize and execute a behavior successfully (Bandura, 1977), social media self-efficacy is judgment of one's ability to be able to engage in multiple social media platforms effectively. According to Bunz (2004), social media self-efficacy depends on a person's level of social media content production and consumption, perceived social media skill, and confidence in his/her ability to successfully find information online. Furthermore, self-efficacy beliefs are considered to be specific to a particular task, such that a person with higher self-efficacy will tend to exhibit certain positive personal qualities such as persistence, strategic planning and high achievement (Bandura, 1977). Tower, Latimer and Hewitt (2014) showed that social media platforms have the potential to increase the self-efficacy of students. Given that students consider themselves as having the skills to exercise control over challenging demands posed by the social media, they are also likely to engage more in social media activities, often shifting attention from one social media platform to another, resulting in social media multitasking. In light of the above discussion it is hypothesized that;

**H02: Social media self-efficacy has a positive relation with social media multitasking.**

*Social Media Multitasking and Social Media Fatigue*

Studies in the field of medicine suggest that fatigue is a multi-dimensional phenomenon representing a subjective and unpleasant feeling (Piper, Lindsey, and Dodd, 1987, p. 19) and may be caused by several factors. In the domain of social media, fatigue has been widely studied as an outcome of stress caused by excessive media use (Dhir, Kaur, Chen and Pallesen, 2019). More recently, researchers have found fatigue among social media users (Ravindran, Kuan and Lian, 2014) and have defined it as "a subjective, multidimensional user experience comprising feelings such as tiredness, annoyance, anger, disappointment, guardedness, loss of interest, or reduced need/motivation associated with various aspects of social media use and interactions" (Ravindran et al. (2014, p.2317) and is widely accepted by studies examining social media fatigue. As the levels of social media usage increase, researchers reveal the existence of fatigue among the users, which is the tendency of participants to back away from social media as it becomes too overwhelming for them.

According to the Limited Capacity Model (LCM), people have a limited amount of mental resources to process information (Lang, 2000). In the context of social media which has a spreading landscape, participants are likely to be overwhelmed with too many platforms, too much content too many friends and too much information to process and therefore do not allocate enough cognitive resources to process the message resulting in fatigue. This means that individuals who are exposed to social media more are also more likely to experience a surge of information overload. In other words, individuals who multitask on social media are likely to feel fatigue. Therefore, we hypothesize that;

**H03: Social media multitasking has a positive relation with social media fatigue.**

Figure 1 represents the proposed research model along with the hypothesized relationships between the four constructs boredom proneness, social media self-efficacy, social media multitasking and social media fatigue.

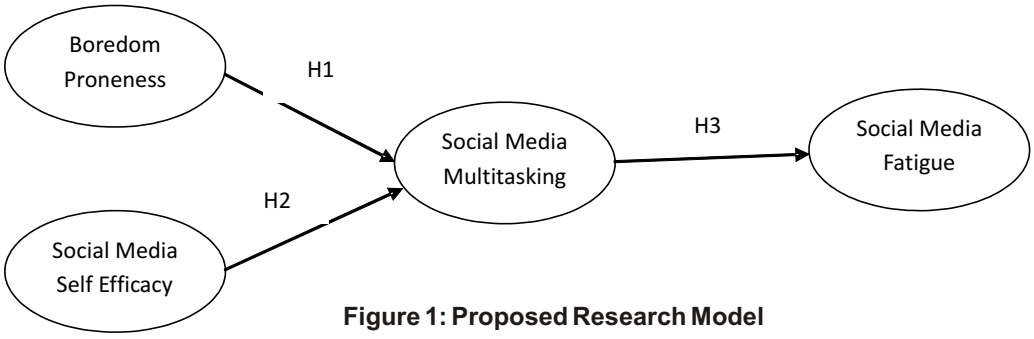


**Figure 1: Proposed Research Model**

## Research Methodology

### *Data Collection*

A sample of 320 respondents based on convenience was surveyed. Out of 320 questionnaires, 318 questionnaires which were complete in all respects were selected. The questionnaire had a total of 23 statements based on boredom proneness, social media multitasking self-efficacy, social media multitasking and social media fatigue. Each variable was measured using a previously developed scale. A short version of boredom proneness scale developed by Struk et al. (2017) consisted of 8 items (e.g. Many things I have to do are repetitive and monotonous) on a 5 point likert scale. The social media multitasking self-efficacy scale developed by Wu (2017) consisted of 6

statements (e.g. I typically connect on social media while studying and still study sufficiently). Three statements for social media multitasking were adapted from Ozer, (2014) and Lau (2017) (e.g. I engage in social media multitasking while studying). Finally, 6 items measuring social media fatigue were adapted from Zhang et al. (2016). All the items were rated on a 5-point Likert-type scale from 1 (strongly disagree) to 5 (strongly agree).

**Data Analysis**

A total of 318 valid responses were analyzed to study the relationship between the variables.

Results of the Measurement Model

SEM of this study examined the two levels of analysis, the measurement model and the structure model. The means, standard deviations, and correlation matrix among boredom proneness, social media multitasking self efficacy, social media multitasking and social media fatigue are shown in Table 1.

**Exhibit 1**

**Means, Standard Deviation and Correlations of the Constructs**

| Constructs | Mean | Standard Deviation | A | B | C | D |
|---|---|---|---|---|---|---|
| **A. Boredom Proneness** | 4.23 | 1.24 | 1 | | | |
| **B. Social Media Self Efficacy** | 4.67 | 1.17 | 0.57** | 1 | | |
| **C. Social Media Multitasking** | 4.21 | 1.59 | 0.44** | 0.62** | 1 | |
| **D. Social Media Fatigue** | 4.34 | 1.25 | 0.53** | -0.34** | -0.37** | 1 |

***Correlation significant at p<0.01*

The factor analysis of the four constructs is shown in Exhibit 2. Each construct in the study can be classified into only one factor. The study referred to the previous studies to design questionnaire items.

**Exhibit 2**

**Factor Analysis**

| Constructs | Number of items | Number of factors |
|---|---|---|
| **A. Boredom Proneness** | 8 | 1 |
| **B. Social Media Self-Efficacy** | 6 | 1 |
| **C. Social Media Multitasking** | 3 | 1 |
| **D. Social Media Fatigue** | 6 | 1 |

Exhibit 3 lists Cronbach's alpha for the constructs. In general, the minimum requirement of Cronbach's alpha coefficient is 0.7 (Hair et al., 1998). It can be observed that the Cronbach's alpha coefficient of “boredom proneness” is 0.824; that of “social media self efficacy” is 0.891; that of “social

media multitasking" is 0.768; and that of "social media fatigue" is 0.851. Because the Cronbach's a coefficients of all four constructs are more than 0.7, the measurement of this study is acceptable in reliability.

**Exhibit 3**

**Item loadings and the construct's Cronbach's alpha and AVEs**

| Constructs | Items | Item Loadings | Cronbach's Aplha | AVE | Square root of AVE |
|---|---|---|---|---|---|
| **A. Boredom Proneness** | BP1 | 0.773 | 0.824 | 0.871 | 0.933 |
| | BP2 | 0.701 | | | |
| | BP3 | 0.649 | | | |
| | BP4 | 0.614 | | | |
| | BP5 | 0.608 | | | |
| | BP6 | 0.516 | | | |
| | BP7 | 0.511 | | | |
| | BP8 | | | | |
| **B. Social Media Self Efficacy** | SE1 | 0.691 | 0.891 | 0.736 | 0.856 |
| | SE2 | 0.680 | | | |
| | SE3 | 0.591 | | | |
| | SE4 | 0.589 | | | |
| | SE5 | 0.548 | | | |
| | SE6 | | | | |
| **C. Social Media Multitasking** | MM1 | 0.686 | 0.768 | 0. 758 | 0.870 |
| | MM2 | 0.647 | | | |
| | MM3 | 0.566 | | | |
| **D. Social Media Fatigue** | SMF1 | 0.694 | 0.851 | 0. 714 | 0.845 |
| | SMF 2 | 0.656 | | | |
| | SMF 3 | 0.542 | | | |
| | SMF 4 | 0.531 | | | |
| | SMF 5 | 0.517 | | | |
| | SMF 6 | 0.512 | | | |

Furthermore the study applied Fornell and Larcker's measure of average variance extracted (AVE) to access the discriminative validity of the measurement (Fornell and Larcker, 1981). The AVE measures the amount of variance captured by the construct through its items relative to the amount of variance due to the measurement error.

In order to satisfy the requirement of the discriminative validity, the square root of a construct's AVE must be greater than the correlations between the construct and other constructs in the model. For example, the square roots of the AVEs for the two constructs, boredom proneness and social media self-efficacy, are 0.933and 0.856 in Exhibit 3 which are more than the correlation between them, 0.57, in Exhibit 1. This demonstrates that there was adequate discriminative validity between the two constructs. The square roots of all constructs' AVEs in Exhibit 3 of this study are all greater than the correlations among all constructs in Exhibit 1. Therefore, the discriminative validity of the measurement in this study is acceptable. Also, if the AVE of a construct is greater than 0.5, convergent validity for the construct is established. As shown in Exhibit 3, the AVEs of the four constructs are

greater than 0.5 indicating that there is convergent validity in this study. Thus, the measurement of this study is acceptable in discriminative validity and convergent validity.

**Test of the Proposed Model**

A Structural Equation Modeling (SEM) technique was used to test the model. AMOS Ver. 21 was used. The observed variables used to predict the latent variables in SEM were obtained by processing the data in the instrument. Results of SEM analysis indicate that the model offers a good fit to the data (see Exhibit 4).

**Exhibit 4**
**Summary statistics of model fit**

| Fit index | Recommended values* | Observed values |
|---|---|---|
| Chi-square/degrees of freedom | <=3.00 | 2.41 |
| GFI | >=0.90 | 0.93 |
| AGFI | >=0.80 | 0.89 |
| NNFI | >=0.90 | 0.90 |
| CFI | >=0.90 | 0.91 |
| RMSR | <=0.10 | 0.07 |
| RMSEA | <=0.08 | 0.06 |

GFI=goodness-of-fit index; AGFI=adjusted goodness-of-fit;
NNFI= non-normed fit index; CFI = comparative fit index;
RMSR= root mean square residual;
RMSEA= root mean square error of approximation.

* Source: *Schumacker and Lomax (2004)*

The graphical presentation of results is shown in Figure 2 along with the standardized path coefficients. All three paths estimated are significant. Hypotheses one postulates that boredom proneness is positively associated with social media multitasking. The direct path from boredom proneness to social media multitasking is significant since the regression coefficient is 0.35 with a significant t value. Therefore the hypothesis that increased boredom proneness is positively associated with social media multitasking is supported. Also the direct path from social media self-efficacy to social media multitasking is significant since the regression coefficient is 0.29 with t value of t= 4.61 and p<0.05. The second hypothesis, social media multitasking has a significant relationship with social media multitasking is accepted. The third hypothesis is also accepted because the direct path from social media multitasking to social media fatigue is significant at 0.18 with t value of t= 2.18 and p< 0.05. Therefore, the hypothesis that social media multitasking has a significant positive relationship with social media fatigue is accepted.

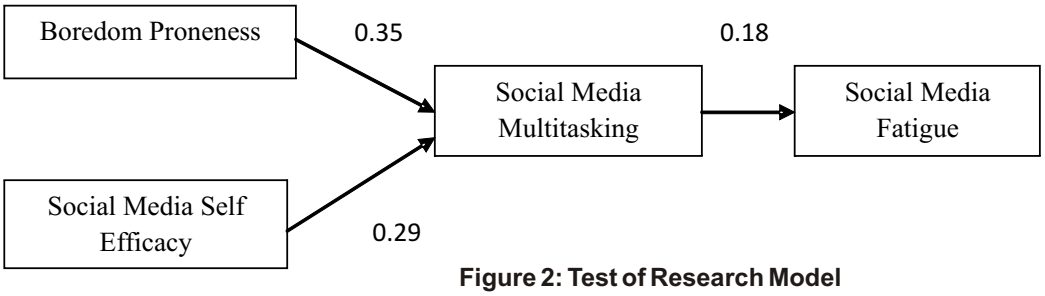


**Figure 2: Test of Research Model**

**Discussion and Implications**

There is much talk of a change in modern youth with respect to their ability to simultaneously process multiple channels of information. Owing to the social media revolution, individuals have become more knowledgeable, which is beneficial for students. Changes in the media landscape have important implications for communication researchers and advertising professionals who seek to understand this behavior in order to effectively communicate with audiences. As one of the first attempts to investigate the effects of social media multitasking, a model is developed to show that boredom proneness and social media self-efficacy can be used to predict social media multitasking among students. Further, findings of the study suggest that social media multitasking negatively affects social media fatigue.

**Theoretical and Practical Implications**

The present study findings have several theoretical and practical implications. This paper highlights the basic reasons for students' social media multitasking behavior and the subsequent outcome of this behavior. This study extends the literature on the relationship between social media multitasking and students' psychological wellbeing. Prior literature in the field of social media has not yet examined the psychological well being related aspects of social media multitasking. The present study is, therefore, one of the first empirical study that examined this relationship, thereby significantly contributing to theory development as well as making significant additions to the existing literature. The present study also fills the gap in the understanding of the antecedents and consequences of excessive social media use.

With respect to practical implications, the results of the present and previous studies urge educators and students to be aware of what constitutes social media multitasking and understand its potential negative effects on wellbeing. Social media users should understand that excessive social media use results in social media fatigue. Consequently, it becomes important for service providers as well as social media companies to specifically devise and develop features and interfaces which would likely result in minimum fatigue to users.

**Study Limitations and Future Research**

The findings of the present study must be looked at in light of certain limitations. First, the study was conducted in only one country with only a certain age group (namely, students). To overcome this limitation, other researchers are encouraged to conduct similar studies in different cultural contexts and among different age groups. Second, this research considered social media as a general platform. However, social media may be used for both academic as well as non-academic purposes. Consequently, there is need to validate the findings of the present study by considering different social media platforms depending on the purpose for which that social media is used (e.g. hedonic or utilitarian). Finally, although the present study considered important variables in the model to understand social media multitasking and social media fatigue, further investigation should extend the study by exploring other variables, such as fear of missing out, compulsive smartphone use and life satisfaction.

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# ARTS AND HUMANITIES

# Assessment of Digital Literacy Skills among the PG Students of the Department of Dogri and the Department of Punjabi in the University of Jammu: A Case Study

***Harjinder Singh****

## ABSTRACT

*The main purpose of the study is to know about the use of computer and digital literacy skills among the PG Students of the Department of Dogri and the Department of Punjabi in theUniversity of Jammu, Jammu. The primary data was collected by the survey method and a structured questionnaire was prepared. After the data collection and analysis of the questionnaire it has been found that out of the total 57respondents, the maximum number of students from the department of Dogri were male while in the department of Punjabi, a large number of students were female. Both the departments' students were between 21 to 25 age group and they were using computer occasionally. Both the departments' students were well aware of MS Word application software. However, both the departments' students were using mobile data for connecting the internet.*

**Key Words:** Digital Literacy, Department of Dogri, Department of Punjabi, University of Jammu

### Introduction

The digital literacy skills play an most important role in the present era, without digital literacy skills we cannot search or retrieve authentic information from the web. Digital literacy is very much related to information literacy. According to Naik &Padmini, "In recent century information is growing at surprisingly fast speed in the society every person whether men or women, rich or poor, adult or child needs information for their work. If you have information at every step then only you can proceed in your life. In today's scenario information is compulsory. Information Literacy is the process of knowing when and why information is required, where to find it and how to evaluate, use and communicate it in an ethical way."(2014)

### University of Jammu

University of Jammu 'A+' grade university accredited by NAAC in 2016 was established in the year 1969 vide Kashmir and Jammu Universities Act 1969 following bifurcation of the erstwhile University of Jammu and Kashmir: "The University provides instructions in such branches of learning as it deems fit and makes provision for research and the advancement and dissemination of knowledge. The University stands for spiritual and material elements in life, thirst for knowledge and virtue under the backdrop of holy peaks of Trikuta Hills. The University of Jammu holds examinations, grants degrees, generates knowledge and confers diverse academic distinctions on persons who pursue approved courses of study in the University or in constituent colleges/institutions approved for the purpose also for those who appear as external/private candidates.It also confers honorary degrees or other distinctions on the persons of exceptional calibre. The University also admits, maintains, recognizes, affiliates colleges and other institutions. It is primarily a research, teaching, affiliating, examining body involved in the promotion of arts, science and other branches of learning.

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The University is open to all classes and creeds with the sole objective to carry people from darkness to light." (http://jammuuniversity.in/uni_profile.asp)

**Department of Dogri**

Dogri is the primary language of the people of Jammu region. Department of Dogriis one of the most famous departments in the University of Jammu and has a historical progression from a Cell to a full fledged department offering PG in Dogri besides research and other language promotion activities: "The Post-Graduate Department of Dogri started its functioning in the University of Jammu in the form of Dogri Research Cell in the year 1971 with one post of Senior Fellow in Dogri. During this period Prof. Ram Nath Shastri, who was the Senior Fellow in Dogri made some important contributions in the form of Dogri renderings of some valuable Sanskrit works. In 1975 this Research Cell was upgraded as Dogri Research Centre & then Dr. Bal Krishan Shastri joined as Director-cum-Senior Fellow in Dogri. Dr. Veena Gupta joined the Research Centre as Fellow in Dogri in 1976. After the retirement of Dr. Bal Krishan Shastri, Dr. Champa Sharma joined the Centre in December, 1980 as Director cum Senior Fellow in Dogri. The Centre produced quality research work in the field of Linguistics, Grammar, Literary Criticism, Poetics, etc. One major research work entitled *Dogri Nikas te Vikas* (Origin and Development of Dogri language) was completed by the then Director-cum-Senior Fellow Dr. Bal Krishan Shastri and a book entitled *Hindi-Dogri Conversational Guide* written by Dr. Veena Gupta, Fellow-in-Dogri was also published. The Centre also produced two Ph.D.s in Dogri and got published 7 books including two volumes of its research journal namely *Dogri Shodh.* The Centre also used to give coaching to the students of Shiromani that is, Honours in Dogri. It also organized a three-week national workshop on Phonetics and Dogri Phonology in December, 1982-January, 1983. Later in August 1983, the Dogri Research Centre was upgraded as Post-Graduate Department of Dogri. Since then, the department has been producing quality research work in the field of linguistics, grammar, literary criticism, poetics etc.

The department takes the responsibility of providing research material to its students and scholars engaged in their research activities. In this connection, the department has been publishing its Annual Research Journal, entitled *Dogri Shodh* since 1981. To date, it has published 20volumes."(http://jammuuniversity.in/departments/dogri/intro.asp)

**Department of Punjabi**

University of Jammu is one of the few universities outside Punjab which has a Post-Graduate Department of Punjabi. The Department of Punjabi, established in 1972, has been offering Post-Graduate, Masters of Philosophy and Doctorate of Philosophy degrees in Punjabi course since its inception. The curriculum has been formed in such a manner that a student pursuing the course not only learns about Punjabi language, literature and culture but also understands the concept of Indian Literature and world classics. Thus the knowledge acquired by a student/scholar acquaints him/her with global perspective of literary and cultural traditions. The main objective of the Department has been quality education and acquaints the students/scholars with the latest techniques of teaching and research with professional competency. (http://jammuuniversity.in/departments/punjabi/intro.asp)

**Scope of the Study**

The scope of the present study is limited to two departments in the University of Jammu that is, the Department of Dogri and the Department of Punjabi. And it is also limited to PG students of both the departments.

**Objectives of the Study**

The objectives of the present study are:

1. To analyse how frequently computer is used by the respondents
2. To identify the respondents familiarity with the MS Office application software
3. To examine how the respondents rate his/her computer literacy skills
4. To analyse the respondents use of connectivity for an Internet connection
5. To examine the purpose of access to the Internet by the respondents

**Methodology**

For the collection of primary data for the study the survey method has been found suitable and a structured 60 questionnaire format was prepared and distributed among the students of both the departments (department of Dogri and department of Punjabi),and 57 filled questionnaires were received from the students of both the departments. The collected data was organised, tabulated and has been shown by the using of simple arithmetic methods.

**Data Analysis**

***Gender wise classification of respondents***

**Figure 1** shows the gender-wise classification of respondents. Maximum 18 respondents were male while the rest respondents were female that is, 10 from the department of Dogri. However, in the department of Punjabi, the maximum 28 respondents were female, and only 1 male respondent.

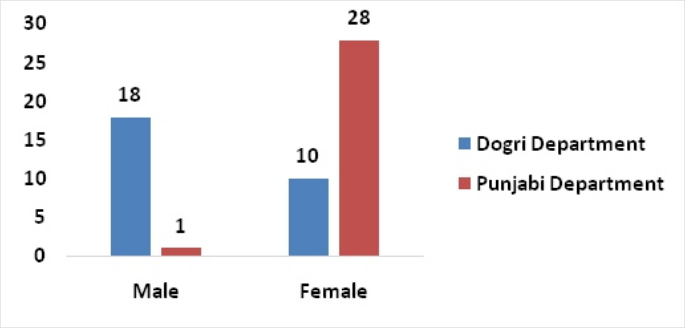


**Figure 1: Gender wise classification of respondents**

***Age-wise distribution of respondents***

**Figure 2** illustrates the age-wise distribution of respondents from both the departments. 22 students from the department of Dogri were between 21 to 25 years group while the remaining 6 respondents were between26 to30 years age group. However, in the department of Punjabi, 28 students were between 21 to 25 years age group and only 1 student was between 26 to 30 years age group.

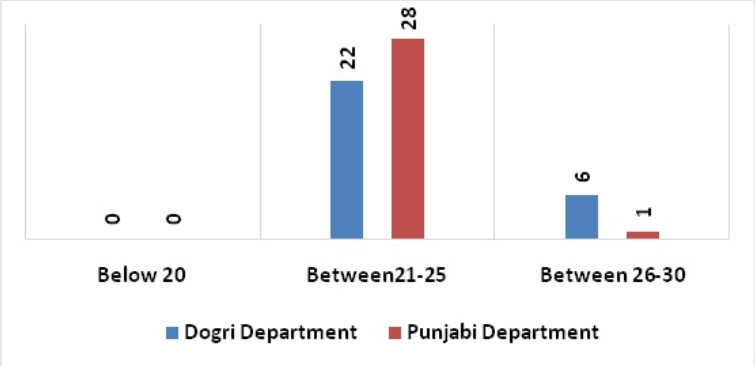


**Figure 2: Age-wise distribution of respondents**

***Frequent use of a computer by the respondents***

**Figure 3** reveals the frequency of computer use by the respondents in both the departments. The maximum of 18 students from the department of Dogri occasionally used computer while the rest 11 respondents used computer regularly. However, from the department of Punjabi, 25 students used computer occasionally and only 4 students used computer on regular basis.

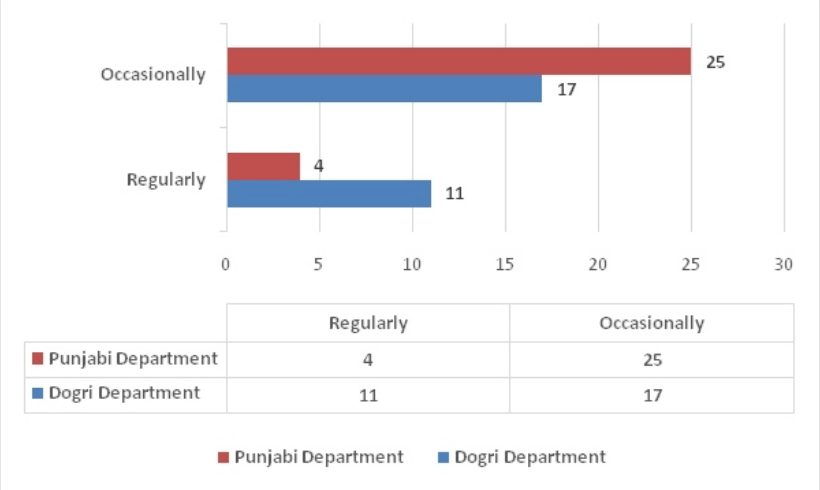


**Figure 3: Frequent use of a computer by the respondents**

***Year-wise use of computer by the respondents***

Table 1 shows the year-wise use of computer by the respondents in both the departments. After the analysis, it has been found that 12 respondents from the department of Dogri have been using computer for the last 4 years ; 11 students have used computer for the last 8 years; 3 students have been using computer for12 years and only 2 students have been using computer since 16 years. However, the maximum 21 respondents from Punjabi department have been using computer for the last 4 years, followed by 4 students using it for the last 8 years, and 4 respondents using, i.e. 4 students each.

| Table 1: Computer use by the respondents | | | |
|---|---|---|---|
| **Years** | **Dogri Department** | **Punjabi Department** | **Total** |
| 1 to 4 | 12 | 21 | 33 |
| 5 to 8 | 11 | 4 | 15 |
| 9 to 12 | 3 | 4 | 7 |
| 13 to 16 | 2 | 0 | 2 |
| **Total** | **28** | **29** | **57** |

***Respondents familiar with MS Office application software***

Table 2 reveals the respondents familiarity with the MS office application software in both the departments. The department of Dogri students were familiar with word application software, followed by PowerPoint software and the same response came for their familiarity to excel and access applications software. However, in comparison to Dogri respondents the department of Punjabi students were less aware with word software, followed by excel and PowerPoint and with access application software.

| Table 2: Respondents familiar with the MS Office application S/W (Chose more than one option) | | | |
|---|---|---|---|
| **Application S/W** | **Dogri Department** | **Punjabi Department** | **Total** |
| Word | 20 | 17 | 37 |
| Excel | 10 | 10 | 20 |
| PowerPoint | 13 | 7 | 20 |
| Access | 10 | 0 | 10 |
| **Total** | **53** | **34** | **87** |

***Respondents preferred computer for Learning***

Table 3 illustrates that the respondents from both the departments preferred computer for learning. The maximum 20 students from the department of Dogri preferred it as very useful for learning while the rest 8 students found it useful. However, from the department of Punjabi, maximum 18 students found computer very useful for learning followed by 10 respondents who found it useful and only 1 student did not find it useful for learning.

| Table 3: Respondents preferred computer for Learning | | | |
|---|---|---|---|
| | **Dogri Department** | **Punjabi Department** | **Total** |
| Useful | 8 | 10 | 18 |
| Very Useful | 20 | 18 | 38 |
| Not Useful | | 1 | 1 |
| **Total** | **28** | **29** | **57** |

***Respondents rate his/her computer literacy skills***

Table 4 shows the respondents in both the departments rate his/her computer literacy skills. The maximum number of respondents from the department of Dogri highly rated his/her computer literacy skills, followed by average rating while the maximum number of the respondents from the department of Punjabi highly rated his/her computer literacy skills followed by minimum average rating. The overall data of the respondent rate of his/her computer literacy skills has been shown in Table 4.

| Table 4: Respondents rate his/her computer literacy skills | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Computer Literacy Skills** | **Dogri Department** | | | | **Punjabi Department** | | | |
| | **High** | **Average** | **Low** | **Total** | **High** | **Average** | **Low** | **Total** |
| Open & Save file | 20 | 5 | 3 | 28 | 12 | 11 | 5 | 28 |
| Draw pictures | 17 | 5 | 2 | 24 | 13 | 11 | 4 | 28 |
| Print document/file | 17 | 6 | 1 | 24 | 11 | 12 | 5 | 28 |
| Copy/transfer files | 21 | 4 | 1 | 26 | 9 | 14 | 6 | 29 |
| Search in OPAC | 6 | 10 | 7 | 23 | 1 | 10 | 12 | 23 |
| Write a research paper using the word | 5 | 16 | 6 | 27 | 6 | 15 | 5 | 26 |
| Make a Power Point Presentation | 7 | 10 | 6 | 23 | 11 | 9 | 7 | 27 |
| **Total** | **93** | **56** | **26** | **175** | **63** | **82** | **44** | **189** |

***Frequency of the use of the Internet by respondents***

Table 5 shows the respondents in both the departments frequent use of the internet. 20 students confirmed everyday use of the Internet, followed by 4 respondents who used internet a few times in a week and another 2 respondents who accessed internet once a month. However, from the department of Punjabi, a large number of respondents (14) used internet daily followed by another 14 respondents who used it a few times in a week and only 1 respondent confirmed being always online.

**Table 5: Respondents frequently use the Internet**

| Frequency | Dogri Department | Punjabi Department | Total |
|---|---|---|---|
| Everyday | 20 | 14 | 34 |
| Always online | 2 | 1 | 3 |
| Once a Month | 2 | 0 | 2 |
| Few times a week | 4 | 14 | 18 |
| **Total** | **28** | **29** | **57** |

***Tools used for accessing the Internet by the respondents***

Table 6 illustrates the tools used by the respondents in both the departments for accessing the Internet. 22 students used a smart phone, followed by 9 students using laptop and 3 students using desktop computer and only 1 student used tablet. However, maximum of 24 students from the department of Punjabi used a smart phone, followed by 6 students using laptop and 1 respondent each used desktop computer and tablet.

**Table 6: Tools used for accessing the Internet by the respondents. (Chose more than one option)**

| Tools | Dogri Department | Punjabi Department | Total |
|---|---|---|---|
| Laptop | 9 | 6 | 15 |
| Desktop Computer | 3 | 1 | 4 |
| Tablet | 1 | 1 | 2 |
| Smart phone | 22 | 24 | 46 |
| **Total** | **35** | **32** | **67** |

***Respondents use of connectivity for an Internet connection***

Table 7 shows the respondents of both the departments use of connectivity for an internet connection. 21 students from the department of Dogri used mobile data, followed by 9 students who used university wi-fi connectivity; 4 students used data card and only 2 respondents used university LAN connection. However, 25 respondents from the department of Punjabi used mobile data whereas 9 respondents used data card and only 4 students used university wi-fi connectivity for the internet.

**Table 7: Respondents use of connectivity for an Internet connection**

| Type of Connectivity | Dogri Department | Punjabi Department | Total |
|---|---|---|---|
| Data Card | 4 | 9 | 13 |
| Mobile Data | 21 | 25 | 46 |
| University LAN connection | 2 | 0 | 2 |
| University Wi- Fi connectivity | 9 | 4 | 13 |
| **Total** | **36** | **38** | **74** |

**Respondents search the information from the Internet by using various databases**

Table 8 reveals that the respondents search the information from the internet by using various databases. The maximum numbers of students from the department of Dogri have used websites, followed by a search engine while a large number of students from the department of Punjabi also used websites, followed by the search engine. The overall data of the respondents' search the information from the Internet by which source has been shown in below Table 8.

**Table 8: Respondents search the information from the Internet by using various databases**

| | Dogri Department | Punjabi Department | Total |
|---|---|---|---|
| Databases (e-Shodhsindhu) | 2 | 0 | 2 |
| Website | 22 | 27 | 49 |
| Search engine | 9 | 2 | 11 |
| Open access journal Directories | 0 | 1 | 1 |
| **Total** | **33** | **30** | **63** |

**Respondents search the information on the Web**

Figure 4 illustrates the respondents in both the departments search the information on the web. The maximum numbers of 22 respondents from the department of Dogri preferred simple search, followed by 4 respondents who accessed the Boolean search while in the department of Punjabi, 18 respondents preferred simple search, followed by 10 students with the guided search. The overall data of the respondents' search of the information on the web is shown below in figure 4.

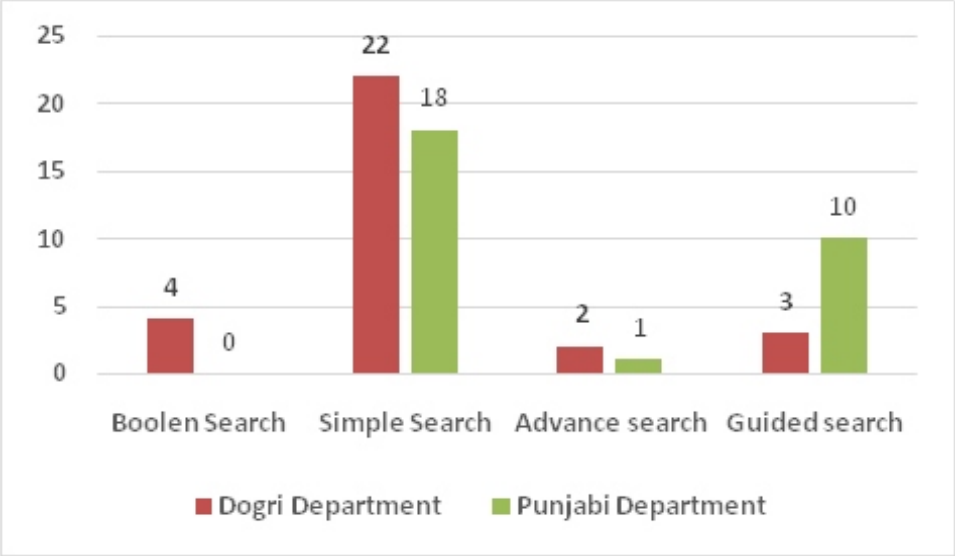


**Figure 4: Respondents search the information on the Web**

***Purpose of access the Internet by the respondents***

Table 9 shows the purpose of access the Internet by the respondent in both the departments. The maximum numbers of respondents from the department of Dogri preferred email, followed by information search while a large number of students from the department of Punjabi preferred information search purpose, followed by searching subject databases. The whole data regarding the purpose of access the Internet by the respondents is shown below in Table 9.

**Table 9: Purpose of access the Internet by the respondents (Chose more than one option)**

| Purpose | Dogri Department | Punjabi Department | Total |
|---|---|---|---|
| Academic Communication | 14 | 6 | 20 |
| E-mail | 18 | 8 | 26 |
| Teaching/Research | 9 | 3 | 12 |
| Information search | 17 | 17 | 34 |
| Games and Entertainments | 12 | 3 | 15 |
| Use of Social networking sites | 11 | 8 | 19 |
| Searching subject databases | 14 | 10 | 24 |
| **Total** | **95** | **55** | **150** |

**Conclusion**

This paper analysed the digital literacy skills among the PG students of the department of Dogri and the department of Punjabi. "The information literacy has been used as a collective term covering all or several of literacies viz. Computer literacy, digital literacy, hyper literacy, information technology literacy, interactive literacy, multiple literacy, network literacy, oral literacy, internet literacy, reading literacy, water literacy and visual literacy etc. Here each of these literacies is necessary to understand the specific process has special importance. The users who inculcate in themselves with new and updated methods obtain the quality of creating meaningful work." (Naik & Padmini, 2014). It has been observed that students are often inexperienced in learning new skills related to computer and technology as classroom teaching still takes place in the traditional mode, with no exposure to information technology to turn their knowledge into application As students of Dogri and Punjabi are usually trained with analytic skills for literary and linguistic analyses blending digital literacy is desirable or even necessary for them though there are challenges which need to be overcome by the students with active encouragement from the teachers and inclusion of digital literacies in curricula focused on languages.

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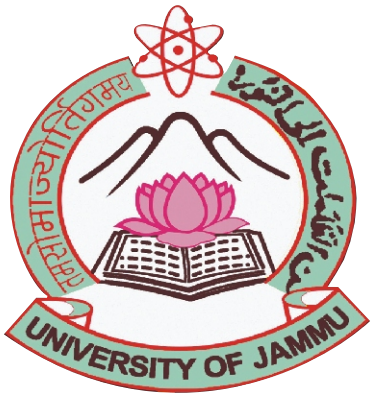
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