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DOSIMETRIC COMPARISON STUDY OF THREE DIMENSIONAL CONFORMAL RADIOTHERAPY (3DCRT) VERSUS DIFFERENT INTENSITY MODULATED RADIOTHERAPY (IMRT) TECHNIQUES IN PROSTATE CANCER TREATMENT

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ABSTRACT

IMRT is a well-known and widely used treatment technique for carcinoma of the prostate (PCa) because it permits dose escalation to the tumour while sparing normal tissues. In Sri Lanka, along with IMRT, the 3DCRT technique is also used in the treatment of PCa. This study was carried out to compare 3DCRT treatment against Simultaneous-Integrated Boost Intensity Modulated Radiation Therapy (SIB-IMRT), Sequential IMRT, and Standard IMRT using dosimetric parameters such as Planning Target Volume (PTV) coverage by prescribed dose, Conformity Index (CI), Homogeneity Index (HI), percentage of maximum, minimum and mean dose to PTV and dose to 50% volume (D50) of the rectum, bladder, and femoral heads. Thirty-one PCa patients' treatment plans were included in the study. For evaluation purposes, the Dose-volume Histograms (DVHs) were compared in all techniques. The D50 to femoral heads showed a significant difference ($p < 0.05$) in the 3DCRT technique against all IMRT techniques as the dose to femoral heads was significantly greater in 3DCRT therapy in many patients. SIB-IMRT showed a significantly higher PTV coverage and dose conformity in PTV than 3DCRT while the Sequential IMRT technique showed a greater homogeneity in PTV and critical organ sparing to 3DCRT technique. However, when considering other dosimetric parameters, there was no significant difference between 3DCRT and IMRT.

KEYWORDS: *Dosimetric, 3DCRT, IMRT, SIB-IMRT, Sequential IMRT, Prostate Cancer*

1. INTRODUCTION

According to the national cancer registry data, the incidence of prostate cancer reported in Sri Lanka is rising and majority of cases have metastatic spread at the time of diagnosis (Abeygunasekera *et.al.*, 2015). 3D conformal radiation therapy (3DCRT) and Intensity Modulated Radiotherapy (IMRT) is the main radiotherapy techniques used to treat PCa. The use of these advanced techniques allows better sparing of more normal tissue high doses than with the conventional two dimensional (2D) radiotherapy. During 2D radiotherapy, a large volume is treated to high doses to ensure proper coverage of the PTV due to difficulties in localization of the tumour (Spiess, 2011). Therefore, surrounding normal tissues were incorporated in the treated volume. As a result, the prescribed dose was limited by the tolerance of organs at risk such as rectum and bladder, to a dose of 60-65Gy (Choe & Liauw, 2010). With 3DCRT, it has been possible to deliver a higher dose with more conformity using standard dose fractions (2 Gy per fraction). Previous studies have shown improved prostate-specific antigen (PSA) control with dose escalation, at the cost of increasing probability surrounding tissue toxicity (Zelevsky *et. al.*, 2008). There is a study confirming the significant increase in late rectal complications in the delivery of 70 Gy or more on 25% of the rectum volume (Webb & Naham, 1993). A study by Zelevsky *et.al.*, (2008) has reported that the dose levels beyond 75.6 Gy with 3DCRT increased risks of Grade 2 rectal and bladder-related late toxicities.

At present, IMRT is a commonly used treatment technique in developing countries like Sri Lanka as it helps to reduce the volume of the rectum and bladder being exposed to higher doses in clinically localized PCa. The volume of the rectum and bladder receiving more than 40 Gy is reduced by 20% in conformal 3DCRT radiotherapy and it is further reduced by 45% in IMRT (Taylor & Powell, 2004). In contrast to 3DCRT, IMRT can deliver a dose up to 81 Gy with 99% conformity to the clinical target volume (CTV) and limiting the doses carried to the rectal wall in between 50 and 77 Gy and the bladder wall between

55 and 85 Gy, and the femoral heads between 25 and 60 Gy (Zelevsky *et. al.*, 2000).

With the increasing use of the simultaneous integrated boost intensity-modulated radiotherapy (SIB-IMRT), it has been possible to deliver a simultaneously escalated per fraction dose to different tissues (PTVs) in a single treatment session resulting in an increased therapeutic ratio and shortening of overall treatment time (Mohan *et. al.*, 2000 and Orlandi *et. al.*, 2010). The previous treatments used dose escalation with daily doses of about 2 Gy per fraction up to a total dose higher than 80 Gy for treatment where the treatment times were prolonged for more than eight weeks.

In Sri Lanka, 3DCRT is commonly used in most cancer treatment centres due to the lack of advanced treatment facilities such as IMRT. Moreover, the cancer treatment centres equipped with IMRT treatment facility is continuously using 3DCRT technique to manage the workload and patients' waiting list. The main purpose of this study is to evaluate 3DCRT against IMRT based on the dosimetric parameters such as PTV coverage by prescribed dose, dose conformity in the target volume (CI), dose homogeneity in the target volume (HI), percentage of maximum, minimum and mean dose to PTV and D50 of organs at risk (OAR) (such as bladder, rectum and femoral heads).

2. METHODOLOGY

2.1. Patient Selection

This study was a retrospective cohort study conducted at National Cancer Institute Maharagama, Sri Lanka between the years 2016-2018. Treatment plans for patients with localized prostate cancer and with or without lymph nodes (LN) metastasis treated with standard IMRT, SIB-IMRT and Sequential IMRT were included in the study. Eleven patients have had prostate cancer confined to the prostate gland and had been treated using standard IMRT and twenty patients' prostate cancer had spread beyond the prostate gland and had been treated using

sequential IMRT and SIB-IMRT techniques. 3DCRT plans were generated for each IMRT plan of patients. The ethical clearance for the study was obtained from the Institution of Biology Sri Lanka.

2.2. Target volume delineation

In a low risk patient, the gross tumor volume (GTV) was equal to CTV1, which in turn was equal to the total prostate gland. In Intermediate risk patients, CTV1 included prostate gland and seminal vesicles, and CTV2 included prostate gland only. In high-risk patients CTV1 included regional pelvic lymph nodes, seminal vesicles and prostate, and CTV2 included prostate gland and seminal vesicles, whereas CTV3 included prostate only.

2.3. Treatment planning

A 6 MV clinical linear accelerator with 80 pairs of the dynamic multi-leaf collimator (MLC) has been used in the generation of IMRT treatment plans, and static MLC has been used in 3DCRT treatment plans. The prescribed dose used in both IMRT and 3DCRT treatment plans was 56-76 Gy to the PTV. The treatments have been planned to deliver 95% -107% of the prescribed dose to the isocenter. All plans have been generated using the Eclipse (version 8.6) treatment planning software, and plans have been optimized using direct parameter machine optimization. The parameters for optimization used are the specified dose to the PTV, the dose limits for each of the critical structures, and the respective penalties for deviation from these criteria. According to the Radiation Therapy Oncology Group (RTOG) protocol, dose-volume constraints for 3%, 15%, 30%, 50% and 60% of rectum volume were 74Gy, 70Gy, 65Gy, 60Gy, and 50Gy respectively. Dose-volume constraints for 5%, 25%, and 50% volume of the bladder were 74Gy, 60Gy, and 50Gy respectively. The dose-volume constraint for 50% volume of the femoral head was 50Gy.

2.4 Dose prescriptions

The low-risk group (T1-T2a and Gleason Score (GS) ≤ 6 and PSA ≤ 10 ng/ml) or the intermediate-risk group

(T2b and/or GS = 7 and/or PSA > 10-20 ng/ml) has been treated with a standard dose of 66 Gy -76 Gy over 33 to 38 fractions (2Gy/F). The two techniques, i.e. Sequential IMRT technique and SIB-IMRT were used to treat high-risk patients (T2c or PSA > 20 ng/ml or GS > 8-10). In Sequential IMRT, treatment radiation has been delivered in two to three phases within 6 to 7 weeks. In each phase, the same dose of 2 Gy/fraction has been delivered to pelvic nodes, seminal vesicles and the prostate using a dynamic multi-leaf collimator. In the first-phase, for all the cases equally spaced, non-opposed 8-coplanar beams have been used and for the boost phases, different IMRT beam arrangements have been used in the plans. In the first-phase, the dose for the CTV1 (pelvic lymph nodes, seminal vesicles and prostate) has been 54 Gy (27 fractions, 2 Gy/fraction), in the second phase, the dose to the CTV2 (prostate and seminal vesicles) has been 12 Gy (6 fractions, 2 Gy/fraction) and in the third phase, the dose to the CTV3 (prostate) has been 8 Gy (4 fractions, 2 Gy/fraction). The total physical dose for pelvic nodes was 54 Gy, for seminal vesicles it was 66 Gy and for prostate it was 74 Gy.

In SIB-IMRT treatment, the radiotherapy has been given as a single phase, using a dynamic multi-leaf collimator. In all SIB-IMRT plans equally spaced, non-opposed 8- coplanar beams have been used. Respectively 54 Gy, 66 Gy and 74 Gy doses have been delivered to pelvic lymph nodes, seminal vesicles and prostate in 30 fractions at a 1.8 Gy/fraction, 2.2 Gy/fraction and 2.5 Gy/fraction within 6 weeks.

In the 3D-CRT method, 4 beams; anterior posterior (AP) and posterior anterior (PA) and 2 lateral beams were used in treatment plans. The Low-risk or intermediate-risk group's patients were treated with a standard dose (66 Gy -76 Gy over 33 to 38 fractions (2Gy/Fraction)). For the high-risk group, radiation was delivered in three phases using a static multi-leaf collimator, reducing the field size of the target volume. In the first phase, the dose for CTV1 (pelvic lymph nodes, seminal vesicles and prostate) was 54 Gy (27 fractions, 2 Gy/fraction), in the second phase, the dose to the CTV2 (prostate and seminal vesicles)

was 12 Gy (6 fractions, 2 Gy/fraction) and in the third phase, the dose to the CTV3 (prostate) was 8 Gy (4 fraction, 2 Gy/fraction). The total physical doses were 54 Gy for pelvic nodes, 66 Gy for seminal vesicles and 74 Gy for prostate.

2.5. Method of assessment and comparison of 3DCRT and IMRT plans

To compare the 3DCRT and IMRT techniques dose volume histograms (DVHs) of the PTV and the OAR (rectum, bladder and femoral heads) were used. The dose to every delineated structure in the PTV was obtained using these DVHs. To compare treatment modalities, the dosimetric parameters analyzed were the percentage of prescribed dose to 100% PTV, percentage of maximum, minimum and mean dose to PTV, Homogeneity Index (HI), Conformal Index (CI) and D_{50} of rectum, bladder and femoral heads. D_{50} of rectum, bladder and femoral heads were assessed to see whether doses are at or above dose constraint values of RTOG protocol. The Dose volume constraints as per RTOG protocols for D_{50} of Rectum, Bladder and Femoral heads are 60Gy, 50Gy and 50Gy respectively. HI index and CI index were calculated using equations 1 and 2.

$$HI = \frac{D_5}{D_{95}} \quad (1)$$

$$CI = \frac{PTV_{95\%PD}}{V_{PTV}} \quad (2)$$

Where, D_5 and D_{95} are the doses delivered to 5% and 95% of the PTV respectively. HI value approximate to 1 indicates the homogenous dose distribution in the PTV. CI value approaching 1 indicates a higher degree of conformity. The results obtained under each group were presented as mean with standard deviation. The Wilcoxon signed rank test is used to compare the dosimetric parameters of the treatment strategies. The probability value (p value) < 0.05 was considered as statistically significant.

3. RESULTS

3.1. Comparison and assessment of 3DCRT against standard IMRT

The results obtained for the comparison of 3DCRT against standard IMRT treatment are discussed in this section.

Table 1: The percentage of maximum, minimum and mean dose to PTV and percentage of prescribed dose to PTV in the standard IMRT against 3DCRT.

Patients no	Maximum dose (%)		Minimum dose (%)		Mean Dose (%)		%Prescribed dose to 100% PTV volume	
	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT
1	105.4	104.0	75.3	85.6	96.2	99.1	88.0	83.0
2	104.9	103.7	79.0	88.9	100.6	98.9	92.0	92.0
3	105.2	102.1	83.0	76.1	100.1	98.3	87.6	86.5
4	107.5*	104.1	80.6	85.2	102.0	100.0	91.3	86.5
5	106.2	102.6	82.7	87.2	100.0	97.3	87.9	90.0
6	108.0*	102.5	89.0	78.6	104.4	99.2	94.0	93.0
7	107.3*	104.3	79.6	92.1	97.3	99.8	86.0	94.0
8	107.4*	106.9	79.5	79.8	102.8	99.5	88.0	86.0
9	103.0	103.1	79.1	80.7	97.3	73.4	96.0	90.0
10	100.4	104.3	84.2	90.1	97.2	100.1	90.0	93.0
11	105.6	105.3	71.5	87.9	100.0	99.0	86.0	92.0
Mean (SD)	105.5 (2.2)	103.9 (1.4)	80.3 (4.6)	84.7 (5.2)	99.8 (2.6)	96.8 (7.8)	89.7 (3.3)	89.6 (3.6)
Z value	-1.956 0.050		-1.600 0.110		-1.156 0.246		0.000 1.000	

Table 1 summarizes the percentage of maximum, minimum and mean dose to PTV and percentage of prescribed dose to 100% PTV. The maximum doses (D_{max}) to PTV in standard IMRT is significantly higher than the 3DCRT except the patient number 10 (see figure 1(a)). However, there was no statistically

significant difference in D_{max} values between two treatment methods ($p=0.050$). The minimum doses (D_{min}) in standard IMRT method are inferior to the 3DCRT method except the patient number 3 and 6 (see figure 1(b)). There is no statistical significance between D_{min} values in the two treatment methods ($P=0.110$).

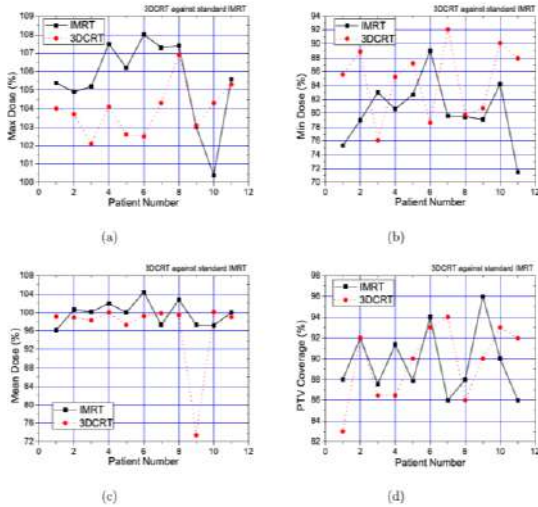


Figure 1: Comparison of 3DCRT against standard IMRT (a) maximum dose (b) minimum dose (c) mean dose and (d) PTV coverage

The mean doses (D_{mean}) are comparable and within the acceptable limit except the patient number 9 where the mean dose is very low (73.4%) in 3DCRT plan (see figure 1(c)). Further, there is no statistical significance between mean dose (D_{mean}) values in two treatment methods ($P=0.246$). The PTV coverage is also comparable in the two methods (see figure 1(d)). Some 3DCRT plans (patient no. 5,7,10 and 11) show better tumour coverage than IMRT techniques. However, there is no statistical significance between mean PTV coverage in the two techniques ($P = 1.000$).

Table 2 and figure 2(a) reveal that both Standard IMRT and 3DCRT have a uniform distribution of dose in the PTV as mean HI values calculated for both methods are comparable and approximating to 1. Therefore, there is no statistical significance in the homogeneity of dose in the two methods ($p=0.610$). CI values show a variation between the two methods. For instance, plans of 1, 6 and 10 provide high

conformity in IMRT than that in 3DCRT. In contrast, 3DCRT plans of patients 5, 7 and 11 shows high conformity to the target volume compared to IMRT. The rest of the CI values are comparable in one method against the other. Overall, CI values showed no statistical significance between the two methods ($p=0.285$).

Table 2: Comparison of HI values and CI values in the standard IMRT against 3DCRT

Patient no.	HI value		CI value	
	IMRT	3DCRT	IMRT	3DCRT
1	1.13	1.05	0.95	0.70
2	1.07	1.07	1.00	0.95
3	1.08	1.08	0.97	0.95
4	1.10	1.08	0.99	0.95
5	1.03	1.01	0.89	0.92
6	1.02	1.09	1.00	0.85
7	1.13	1.07	0.80	1.00
8	1.10	1.11	0.96	0.92
9	1.04	1.07	0.98	1.00
10	1.06	1.06	0.98	0.85
11	1.09	1.08	0.90	0.95
Mean (SD)	1.08(0.04)	1.07(0.03)	0.95(0.06)	0.91(0.09)
Z value	-0.5096		-1.0669	
P value	0.610		0.285	

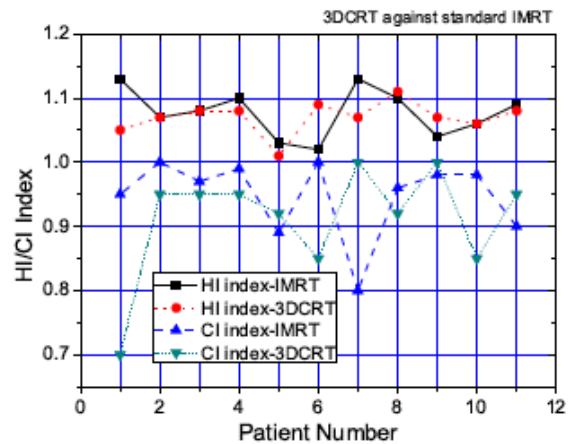


Figure 2a: HI and CI Index

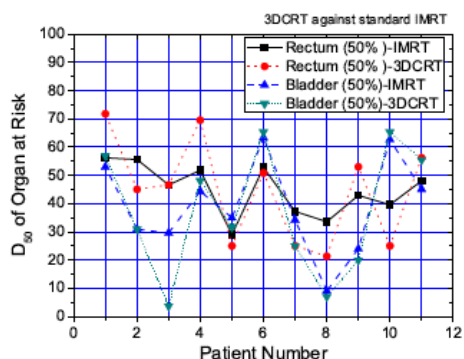


Figure 2 b: D₅₀ Rectum and Bladder

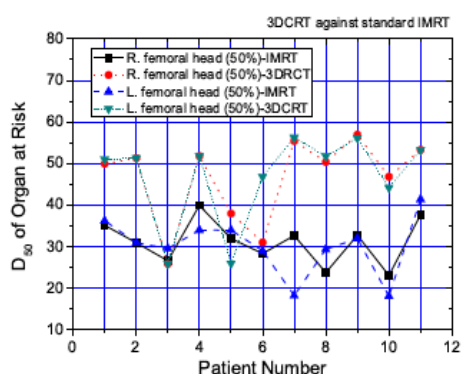


Figure 2 C: D₅₀ Femoral heads

Table 3 summarizes dose to 50% volumes (D₅₀) of organs at risk. In the comparison of D₅₀ of the rectal wall there is no statistical significance found between the two methods (p=0.881). Further evaluation revealed that in 3DCRT method, the patient numbers 1 and 4 have received an obvious higher D₅₀ rectal dose, which exceeds the dose constraint. While in IMRT method, all eleven patients have received a dose under the dose constraint (see figure 2(b)).

In the comparison of D₅₀ of bladder, D₅₀ of bladder of patient plans 1, 6 and 10 exceeded the dose constraint in both methods and overdoses are greater in 3DCRT method than in IMRT. In the patient 8 plan, it is noted that bladder gets under dose in both methods. Additionally, in the patient plan 3, bladder gets a very lower dose in both

methods. In the patient plan 11, bladder gets a greater dose in 3DCRT plan than in IMRT. However, there is no significant difference between the two methods (p=0.803).

In the comparison of D₅₀ to right and left femoral heads the two methods are statistically significant (p=0.0044, p = 0.007). It is clearly observed that overdose to femoral heads are seen in 3DCRT method in many patients' plans while all IMRT plans have delivered a dose below the doses constrain (see table 3). Overdose in 3DCRT was particularly seen in plans where dose is at or above the 74Gy.

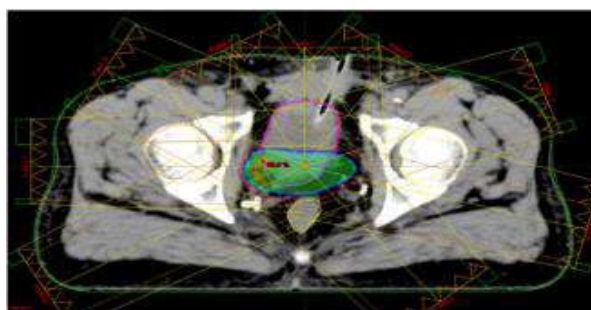


Figure 3: IMRT plan of the patient 10 shows a part of the bladder volume ink out line structure) is included within the PTV (Red out lined)

Table 3: The Comparison of the D50 Rectum, D 50 Bladder and D50 Femoral heads in the Standard IMRT against 3DCRT

Patient no	Rectum D ₅₀ (Gy)		Bladder D ₅₀ (Gy)		D ₅₀ Right femoral head (Gy)		D ₅₀ Left femoral head (Gy)	
	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT
1	56.2	71.8*	53.0*	57.0*	35.2	50.0	36.3	51.1*
2	55.6	45.1	31.0	31.0	31.0	51.3*	31.0	51.3*
3	46.6	46.6	29.6	3.7*	26.6	25.9	29.6	25.9
4	51.8	69.6*	44.4	48.1	40.0	51.8	34.0	51.8*
5	29.0	25.1	35.0	31.7	32.0	38.0	34.0	26
6	52.8	50.8	63.4*	65.3*	28.4	31.0	29.0	46.9
7	37.2	25.1	34.2	25.1	32.7	55.5*	18.2	56.2*
8	33.6	21.4	9.1*	7.0*	23.8	50.4	29.4	51.8*
9	42.9	53.0	24.0	20.0	32.8	56.9*	32.0	56.2*
10	39.6	25.1	62.7*	65.3*	23.1	46.9	18.2	44.2
11	48.1	56.2	45.1	55.5	37.7	53.3	41.4	53.3*
Mean (SD)	44.9 (9.2)	44.5 (18.2)	39.2 (16.5)	37.2 (22.3)	31.2 (5.4)	46.4 (10.2)	30.3 (7.0)	46.8 (10.9)
Z value	-0.1529		-0.255		-2.845		-2.667	
P value	0.88076		0.803		0.0044		0.00758	

Table 4: The percentage of Maximum, Minimum and Mean dose to PTV and percentage of prescribed dose to PTV in the SIB-IMRT against 3DCRT.

Patient No	Max Dose (%)		Min Dose (%)		Mean Dose (%)		PTV Coverage (%)	
	SIB-IMRT	3DCRT	SIB-IMRT	3DCRT	SIB-IMRT	3DCRT	SIB-IMRT	3DCRT
12	105.5	105.3	89.3	76.7	102.5	98.6	94.0	84.0
13	98.9	105.7	85.3	82.2	96.3	98.2	90.5	85.0
14	109.0*	102.7	92.6	58.4	105.3	77.7	97.0	88.5
15	105.8	103.5	78.7	77.1	96.8	98.9	94.4	90.9
16	104.4	105.0	71.5	64.5	95.2	97.4	90.2	96.5
17	107.8*	106.0	85.4	76.5	102.5	99.9	92.5	85.7
18	104.0	102.0	62.4	65.0	85.7	82.2	94.0	86.0
19	104.2	107.4*	82.0	89.0	97.0	102.0	86.0	92.0
20	104.0	99.4	79.2	92.5	100.0	101.3	88.0	76.6
21	106.0	104.0	90.5	72.6	102.0	98.7	94.0	85.0
Mean SD	105.0 (2.7)	104.1 (2.3)	81.7 (9.3)	75.5 (10.8)	98.3 (5.6)	95.5 (8.4)	92.1 (3.3)	87.0 (5.4)
P value	0.3843		0.1676		0.384		0.037	

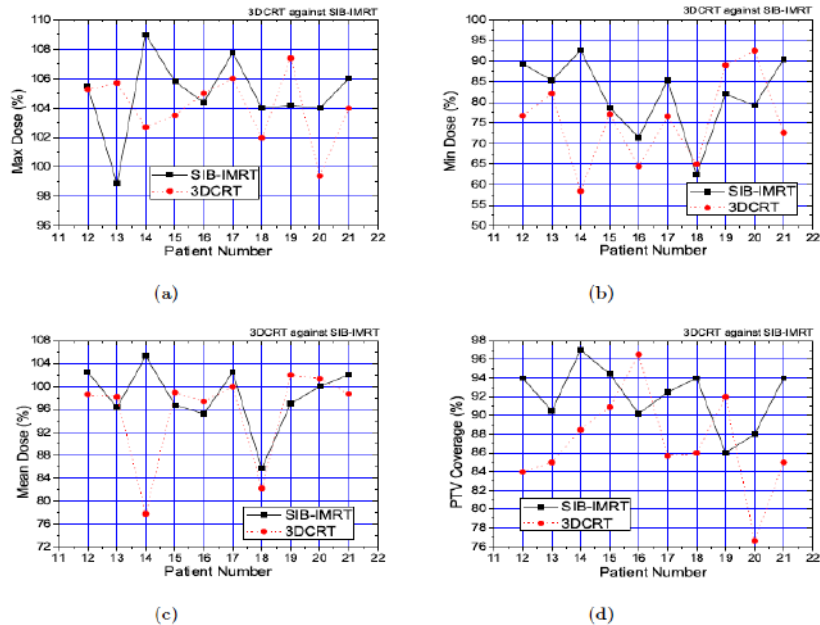


Figure 4: Comparison of 3DCRT against SIB-IMRT (a) maximum dose (b) minimum dose (c) mean dose and (d) PTV coverage

3.2 Comparison and assessment of 3DCRT against SIB-IMRT

Results of maximum PTV dose (D_{max}), minimum PTV dose (D_{min}), mean PTV dose (D_{mean}) and percentage of prescribed dose to 100% PTV volume (DV 100%) obtained for the comparisons of 3DCRT against SIB-IMRT treatment are summarized in tables 4 and analyzed graphically in figure 4. Except for the PTV coverage ($p= 0.037$), other parameters showed no statistical significance between the two methods. SIB-IMRT plans show a better PTV coverage than the 3DCRT plans (see table 4).

Figure 5(a) and table 5 disclose that SIB-IMRT and 3DCRT have achieved the uniform homogeneity in the PTV. But mean HI value in SIB-IMRT is more approximate to 1, which indicates that the dose distribution is more uniform with SIB-IMRT. Conversely there is no statistical significance ($p=0.152$) in homogeneity in 3DCRT against SIB-IMRT. The conformity index (CI) is statistically superior in SIB-IMRT plans ($p=0.037$). However, both HI and CI values are comparable between the methods in the patient plans 16, 17, 18 and 19 (See table 5).

In the comparison of D_{50} of the rectum in 3DCRT against SIB-IMRT, all the patients have received a dose less than the dose constraint (60Gy) to 50% of the rectum wall in both methods. So both methods have been successful in Preventing rectum being overdosed (see Table 6 and figure 5(b)). There is no statistical significance in D_{50} rectum in SIB-IMRT against 3D-CRT ($p=0.168$). In the comparison of D_{50} the bladder walls are under the dose constraint in both methods except in the patients 14, 16 and 18 where the dose has exceeded by 8 Gy, 10 Gy and 4 Gy respectively in 3DCRT plans. In patients 15 and 21, both techniques have overdosed bladder by 2.5 Gy to 8 Gy respectively (See table 6). However, there is no statistical significance between the D_{50} of bladder in two methods ($p=0.263$).

Table 5: Comparison of HI values and CI values in the SIB-IMRT against 3DCRT

Patient no	HI value		CI value	
	SIB-IMRT	3DCRT	SIB-IMRT	3DCRT
12	1.06	1.12	0.99	0.9
13	1.04	1.1	0.92	0.9
14	1.07	1.2	1.0	0.97
15	1.02	1.13	1.0	0.97
16	1.08	1.05	0.95	1.0
17	1.08	1.08	0.99	0.95
18	1.04	1.06	1.0	0.95
19	1.09	0.96	0.95	0.95
20	1.09	1.18	0.95	0.84
Mean	1.06	1.10	0.97	0.94
SD	0.02	0.07	0.03	0.05
P value	0.152		0.037	

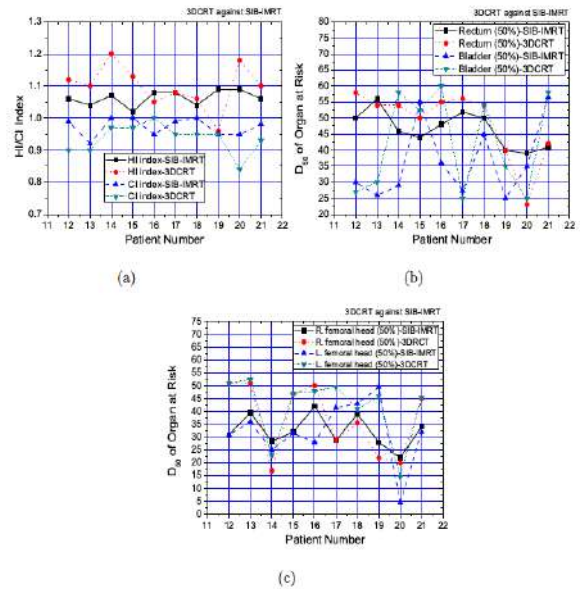


Figure 5: Comparison of 3DCRT against SIB-IMRT (a) HI and CI Index (b) D_{50} Rectum and Bladder (c) D_{50} Femoral heads.

In the study, D₅₀ dose to femoral heads in all patients in both methods were below dose constraint (see figure 5(c)). But D₅₀ to left femoral heads were noticeably greater in 3DCRT plans (See table 6) than in SIB-IMRT plans and this difference was statistically significant (p=0.0285). Even though D₅₀ to right femoral heads were also higher in 3DCRT plans over SIB-IMRT plans, this difference was not statistically significant (p=0.308).

Table 6: The Comparison of the D₅₀ Rectum, D₅₀ Bladder and D₅₀ Femoral heads in the SIB- IMRT against 3DCRT

Patient No	D50 Rectum		D 50 Bladder		D 50 Right Femoral head		D50 Left. Femoral head	
	SIBIMRT	3DCRT	SIB-IMRT	3DCRT	SIB-IMRT	3DCRT	SIB-IMRT	3DCRT
	12	50	58	30	27	31	51	31
13	56	54	26	30	39.5	51	36	52.5
14	46	54	29	58*	28.5	17	25	23
15	44	50	55*	52.5	32	47	31.5	47
16	48	55	36	60	42	50	28	48
17	51.9	56	27.4	25	28.8	28.8	41.5	49.5
18	50	54	45	54*	39	35.5	43	41
19	40	40	25	35	28	22	49.5	46
20	39	23	35	25	22	20	4.5	14.5
21	41	42	56.5*	58*	34	45	32	45.5
Mean	46.59	48.6	36.49	42.45	32.48	36.73	32.2	41.8
SD	5.6	10.8	11.7	15.2	6.2	13.8	12.3	12.7
P value	0.168		0.263		0.308		0.0285	

3.3. Comparison and assessment of 3DCRT against sequential IMRT

The results obtained for the comparison of 3DCRT against Sequential (phase) IMRT treatment plans are summarized in table 7. The D_{max} values in PTV in the sequential IMRT is slightly greater than that in 3DCRT except in the case of patient numbers 28, 30 and 31 (see figure 6(a)). However there is no significant difference in the D_{max} values in the two

methods (p=0.093). D_{min} is almost comparable in the two methods and there is no significant difference in the D_{min} in the two methods (p=0.447). Conversely, there is a significant difference in D_{mean} (p=0.037) between two methods.

Table 7: The percentage of Maximum, Minimum and Mean dose to PTV and percentage of prescribed dose to PTV in the standard Sequential IMRT against 3DCRT

Patient no	Max Dose (%)		Min Dose (%)		Mean Dose (%)		PTV Coverage (%)	
	Sequential IMRT	3DCRT	Sequential IMRT	3DCRT	Sequential IMRT	3DCRT	Sequential IMRT	3DCRT
22	106.4	101.26	67	29.12	95.5	90.4	70.8	85
23	100.2	97.77	87.46	72.05	96.56	85.2	89.2	74.32
24	103.19	101.63	60.3	69.99	82.9	80.01	91.6	66.6
25	107.13	101.2	81.1	66.58	100.15	81.8	92.3	106.1
26	107.5	103.3	78.94	60.38	99.33	84.12	90.27	93
27	105.1	103.3	84.9	91.26	100.35	99.38	89.7	95
28	102.5	105.3	75.7	82.22	94.9	100.1	85.1	91.2
29	106.6	103.94	75.2	87.3	100.12	98.9	87.8	91.2
30	104.6	105.28	83.93	87.03	100.28	99.44	92.3	92.94
31	103.8	105.38	86.6	86.58	100.24	98.96	98.21	89.28
Mean	104.7	102.8	78.1	73.3	97.0	91.8	88.7	88.5
SD	2.2	2.3	8.4	17.7	5.1	7.9	6.8	10.5
P value	0.093		0.447		0.037		0.803	

The mean PTV coverage with prescribed dose is more or less similar in both sequential IMRT and 3DCRT. Except in the patient 23 and 24, the sequential IMRT shows a better PTV coverage than that in the 3DCRT (see figure 6(d)). However, there is no significant difference in the PTV coverage in the two methods (p>0.803).

Table 8 reveals that sequential IMRT and 3DCRT homogeneity in the PTV is statistically significant (p=0.0226). But CI values in the two methods are comparable and there is no statistical significance between the two methods (p =0.638).

Table 9 compares Dose to 50% volume of rectum, bladder and femoral heads in 3DCRT and sequential IMRT. In the comparison of D₅₀ to rectum all the patients have received a dose less than dose constraint (60Gy) in both sequential IMRT and 3DCRT methods (see figure 7(a)). Therefore, there was no statistical significance in the D₅₀ to rectum in the two methods (p=0.13)

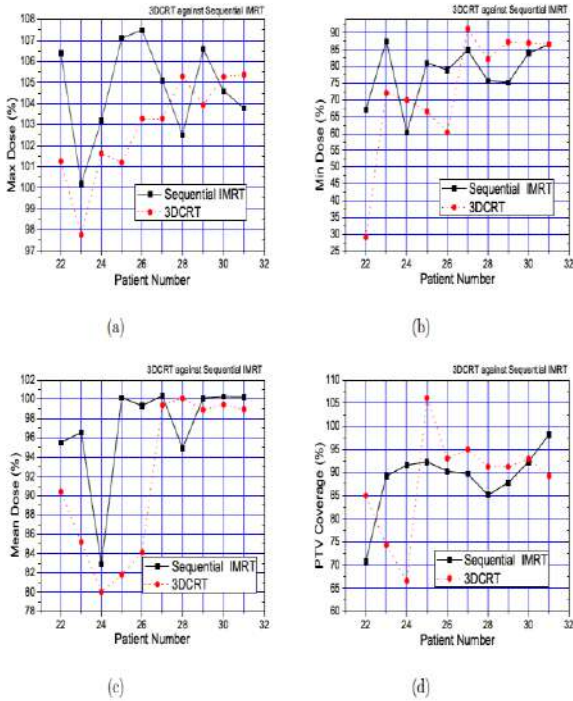


Figure 6: Comparison of 3DCRT against Sequential IMRT (a) maximum dose (b) minimum dose (c) mean dose and (d) PTV Coverage

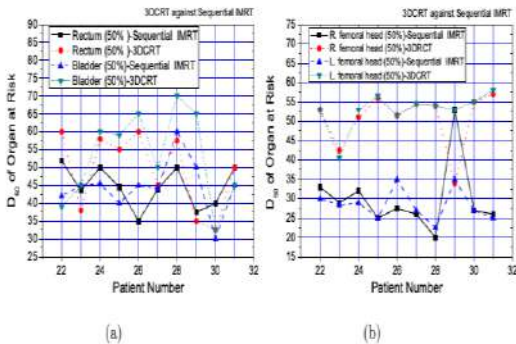


Figure 7: Comparison of 3DCRT against Sequential IMRT (a) D₅₀ Rectum and Bladder (b) D₅₀ Femoral heads

Table 8: Comparison of HI values and CI values in the Sequential IMRT against 3DCRT

Patient no		HI value		CI value	
		Sequential IMRT	3DCRT	Sequential IMRT	3DCRT
22	PTV1	1.11	1.15	0.92	0.92
	PTV2	1.4	1.15	0.86	0.95
	PTV3	1.24	1.06	0.73	0.73
23	PTV1	1.06	1.2	1	0.95
	PTV2	1.11	1.2	1	1
	PTV3	1.12	1.04	0.85	0.1
24	PTV1	1.08	1.18	0.97	0.97
	PTV2	1.1	1.21	1	1
	PTV3	1.08	1.2	1	1
25	PTV1	1.12	1.14	0.95	1
	PTV2	1.17	1.7	1	1
26	PTV1	1.09	1.4	1	1
	PTV2	1.13	1.19	1	1.0
27	PTV1	1.41	1.43	0.99	0.98
	PTV2	1.07	1.05	0.95	1
28	PTV1	1.15	1.15	1	1
	PTV2	1.09	1.09	0.7	0.98
29	PTV1	1.3	1.4	1	0.97
	PTV2	1.1	1.14	0.95	0.93
30	PTV1	1.4	1.57	0.98	0.98
	PTV2	1.07	1.1	0.98	0.95
31	PTV1	1.2	1.35	1	0.98
	PTV2	1.1	1.09	0.95	0.95
Mean		1.16	1.23	0.95	0.92
SD		0.11	0.17	0.08	0.19
P value		.0226		0.638	

In the patients 24,25,26 and 29 of 3DCRT plans, D₅₀ dose to bladder were above the dose constraint (see table 8 and figure 7(a)), and there is statistical significance between the D₅₀ of bladder in the two methods (p=0.03).

The comparison of sequential IMRT with D₅₀ of femoral heads (left and right) showed statistical significance as the mean dose to D₅₀ femoral heads are 20 Gy higher in 3DCRT. However, the doses to femoral heads in both methods were below the dose constraint value (see figure 7(b)).

Table 9: The Comparison of the D₅₀ Rectum, D₅₀ Bladder and D₅₀ Femoral heads in the Sequential IMRT against 3DCRT

	D ₅₀ Rectum		D ₅₀ Bladder		D ₅₀ Right femoral head		D ₅₀ Left femoral head	
	Sequential IMRT	3DCRT	Sequential IMRT	3DCRT	Sequential IMRT	3DCRT	Sequential IMRT	3DCRT
22	52	60	42	39	33	53	30	53
23	43.5	38	45	45	29	42.5	28.5	40.5
24	50	58	45.5	60*	32	51	29	53
25	44.5	55	40	59*	25	56	25	56.5
26	35	60	45	65*	27.5	51.5	35	51.5
27	44	45	44	50	26	54.5	27	54.5
28	50	57.5	60*	70*	20	54	22.5	54
29	37.5	35	50	65*	53	34	35	53
30	40	32.5	30	32.5	27	55	27	55
31	50	50	45	45	26	57	25	58
Mean	44.65	49.1	44.65	53.05	29.85	50.85	28.4	52.9
SD	5.85	10.74	7.52	12.54	8.91	7.18	4.11	4.75
P value	0.13		0.03		0.005		0.005	

4. DISCUSSION

In the Standard IMRT plan (Figure 1) and SIB-IMRT plan (Table 4) there were regions where the maximum dose is greater than 107% of the prescribed dose which were to be assumed as hot spots. These hot spots should be taken into account as they can affect toxicity and tumor control probability (Arno *et. al.*, 2005). According to the International Commission on Radiation Units and measurements, a “Hot spot” is an area outside PTV but within the GTV, which receives a higher dose than the prescribed dose (> 100 % of the prescribed dose). Hot spots are considered significant if the minimum diameter exceeds 15 mm. It is noted that areas in the standard and SIB-IMRT plans with the maximum dose which is greater than 105% of the prescribed dose but as the area of such overdose was significantly negligible (minimum diameter of area < 1 mm) they were not considered as a hot spot and identified as pin point.

The minimum doses in most patients in Standard IMRT, Sequential IMRT, SIB –IMRT and corresponding 3DCRT were less than 93% of the

prescribed dose (Table 1,4 and 8). A cold spot is an area which receives a lower dose than the prescribed dose (< 93 % of prescribed dose). The total volume of any cold spot should be <1 % of the PTV (Arno *et. al.*, 2005). It is noted that this was, as doses were not normalized to 107% but to 100%. Anyhow this had no effect on the patient’s treatment. There were no significant differences between the minimum doses to PTV in any IMRT and corresponding 3DCRT treatment plans.

Comparison of 3DCRT against standard IMRT; the over dose to the rectum in patient 1 and 4 in 3DCRT plan (see table 3) is due to the large PTV margin including part of the rectal wall in the prostate PTV. But in IMRT, due to the ability to modulate beam intensity and curve iso-dose lines to the shape of the tumour volume spared the rectal wall being overdosed. Overdose to bladder in patient plans 1,6 and 10 in both techniques (see table 3) is due to the portion of bladder volume being included within the PTV (see figure 3). Though patients were advised to follow bladder protocol before radiotherapy scanning, bladder may not have been fully filled or the size of the prostate may have been large. It was also found that the bladder volume of patient 6 was anatomically smaller in size (39 cm²) and 66% of bladder volume was overdosed. In the patient 10, the bladder was overdosed by both methods as about 48% bladder volume was included within the PTV and 52% of total bladder volume was overdosed. However, in both treatments plans, D₅₀ bladder outside PTV and volume of bladder outside PTV were in acceptable range. (D₅₀ bladder dose outside PTV was 43 Gy and 35Gy respectively in IMRT and 3DCRT plans). In the patient plan 3, the bladder gets very lower dose in both methods as PTV enclosed only prostate, and the rectum, bladder and femoral heads are lined outside the PTV. In the patient plan 11, the bladder gets a greater dose in 3DCRT plan due to optimization limitations in 3DCRT technique, and thus the plan cannot be improved further, as resultant would under dose PTV. Overdose to femoral heads in 3DCRT plans above 74 Gy is mainly due to use of opposed beams (AP/PA and Lateral beams) and inability to shape the beam according to the geometry of the tumor. It has been

confirmed in previous studies that four-field technique is suitable for prescribed dose of up to 74 Gy and further dose escalation delivers a dose above 50Gy to femoral necks, which is above RTOG dose constraint protocols (Hardcastle *et. al.*, 2010). In the use of 4 fields opposed beams technique, the two lateral incidence beams and transmitting beams of opposite lateral fields pass through the femoral heads. The 3DCRT techniques is safe to use in patient treatments when the prescribed dose to PTV is below 74Gy. However, if 3DCRT is used for the treatment with a dose above 74Gy, overdosing of femoral heads can be reduced with less weight to lateral fields or with more beams incorporated into the treatment plan.

The PTV coverage was found to be statistically high in SIB-IMRT plans compared to corresponding 3DCRT plans (Table 4, Figure 4). This may be due to the ability of the SIB-IMRT technique to deliver an escalated hypo-fractionated dose to planning target volume (i.e. 1.8 Gy, 2.2Gy and 2.5 Gy) in a single phase yielding a high conformity and a better PTV coverage. The previous studies also have confirmed that the SIB-IMRT technique is more conformal to the target and revenues a better coverage (Orlandi *et. al.*, 2010, Bansal *et. al.*, 2012 and Hernandez *et. al.*, 2013). 3DCRT delivers the same per fraction dose in 2-3 phases to planning target volume which requires optimization of several plans and therefore the dose is less conformal to the target.

The conformity index (CI) too is statistically superior in SIB-IMRT plans (Table 4). This may be due to capability of SIB-IMRT in delivering a conformal dose to target through escalated hypo-fractionated dose. It is confirmed in past studies, that SIB-IMRT has a higher dose conformity and homogeneity in the target volume (Khayaiwong, 2012). Mohan *et. al.*, (2000) has stated in his studies that when the majority of dose has already been delivered, it is difficult to achieve a high level of dose conformation with remaining fractions in the boost plans due to non-homogenous dose distribution. This can be the reason for 3DCRT technique showing a less dose conformity.

In the patient plans 14 and 18, there were overdoses to bladder in 3DCRT plans due to the pelvic lymph nodes been included in the treatment PTV (see figure 6). As the 3DCRT has its limitation in beam shaping, the bladder has received an overdose. It was also noted that in-patient 16 the bladder is overdosed in 3DCRT plan due to an anterior field being passed through the bladder. In the patient 15 and 21 the bladder is overdosed in both plans due to PTV including part of the bladder. D_{50} of the bladder outside PTV volume is 31 Gy and the volume of bladder overdose is about 2% of the total bladder volume, and as the dose and the volume (dose < 50 Gy and volume < 50 cm³) were in the acceptance limit both treatment plans were approved for treatment. In the patient plan 21 about 22.2% of the total bladder volume was included as a part of PTV.

In the comparison of sequential IMRT and 3DCRT, the patient number 22 (see table 7) shows a very lower value for the D_{min} in 3DCRT plan. This is not considered as a cold spot as the volume is less than 1 mm. D_{mean} is statistically significant ($p=0.037$) in the two methods. This may be because many patient plans of the sequential-IMRT show better D_{mean} values compared to 3DCRT plans (see figure 6(c)).

The Homogeneity Index (HI) was statistically improved in sequential IMRT because optimization of several plans in sequential IMRT is more feasible than optimization of several plans in 3DCRT. 3DCRT has its limitations in controlling beam intensity modulation and shaping, whereas in IMRT, beam intensity can be modulated and diverse intensity doses can be delivered to the complex target volume to gain a uniform dose distribution (Shimizuguchi *et al* (2017)). However, HI values are comparable in the patient plan 27-31(see table 8).

In the patients 24,25,26 and 29 of 3DCRT plans, D_{50} doses to bladder was above the dose constraint (see table 8 and figure 7(a)). This is because the pelvic lymph nodes of the patient were involved in the PTV. In the patient 28, both methods have overdosed the bladder, as the bladder was included in the PTV due to Bladder metastasis.

As in 3DCRT method, the mean D₅₀ to right and left femoral heads are approximately 20Gy higher than sequential IMRT and there is a statistically significant (p=0.005) in the D₅₀ to femoral heads (see table 8) in the two methods. Higher dose in 3DCRT is due to lateral incidence beams and opposing lateral transmitting beams are passing through the femoral heads in 3DCRT plans.

5. CONCLUSIONS

Results of the study demonstrated that SIB- IMRT showed foremost PTV coverage by prescribed dose, dose conformity and dose homogeneity compared to 3DCRT, and it may be due to the ability to deliver increasing per fraction doses to booster volumes in a single treatment session. With the Sequential IMRT, better critical organ sparing was noted compared to 3DCRT. This may be due to a low dose per fraction to critical organs along with low per fraction (<2Gy) dose to target volume. Furthermore, the study also provides a proof-of-principle that 3DCRT is also reasonably good enough to use in treatment for low and intermediate risk groups of prostate cancer as PTV coverage is above 85% of prescribed dose and also as critical organ sparing was not inferior to standard IMRT at prescribed dose below 74Gy.

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ASSERTIVENESS AND ITS ASSOCIATIONS AMONG NURSING UNDERGRADUATES IN GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY, SRI LANKA

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ABSTRACT

Assertiveness is considered as a valuable skill in the nursing profession as it contributes to strengthening inter-professional relationships, preventing workplace violence, reducing occupational stresses, minimizing negligence, and improving nurses' leadership ability, job satisfaction, professional autonomy, and professional efficacy. Therefore, assertiveness is an important skill that should be developed from the beginning of nursing studentship. However, there is a dearth of studies published on assertiveness among nursing students in Sri Lanka. The aim of this study was to assess the assertiveness and its association with the socio-demographic variables among the BSc. Nursing undergraduates at the General Sir John Kotelawala Defence University (KDU), Sri Lanka. The study was conducted as a descriptive cross-sectional study among all (n=147) nursing undergraduates of KDU during the period January to June 2021. A pretested self-administered questionnaire was used to assess socio-demographic data and a validated Sinhala version of the assertiveness scale developed by Begley and Glacken, 2004 to measure the level of assertiveness. The study instruments were shared online once informed consent was obtained. The data were analysed using SPSS 23.0, and descriptive statistics followed by the independent sample t-test and the one-way ANOVA test were used to estimate population parameters. The mean assertiveness of the study population was 81.35 ± 6.51 . The majority (74.8%) of the study population was females. Many participants had attended leadership programmes (85.7%) and assertiveness training programmes (19.7%) conducted by the University and other institutes. The assertiveness is not significantly different within the associated factors such as gender, marital status, nationality, parents' assertiveness, age group, number in the family, academic year, English proficiency, childhood trauma, the assertiveness of close peers, interest in the nursing profession and other course work ($P > 0.05$). A greater assertiveness was found among the nursing undergraduates enrolled to KDU. However, there were no statistically significant mean differences found on assertiveness among socio-demographic variables. Frequent assessments are recommended to identify the nursing students who need special attention to enhance their assertiveness skills.

KEYWORDS: Assertiveness, nursing undergraduates, Sri Lanka

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1. INTRODUCTION

Assertiveness means speaking up for one's interpersonal freedoms or as required by one's role responsibilities to engage others in finding viable, stable solutions. It is a learnable skill rather than a personality characteristic (Chambers, 2009). Further, it is considered as a valuable nursing skill since it brings numerous benefits (Roya et al., 2014). It has been noted that in the healthcare settings, assertiveness strengthens interprofessional relationships prevents workplace violence (Karakaş & Okanlı, 2015), reduce occupational stresses, minimizes negligence, and improves nurses' leadership skills, job satisfaction, professional autonomy, and professional efficacy.

It is very important to possess a boarder and a comprehensive understanding about the needs pertaining to health in both local and global communities. This becomes very influential when educating nurses compatible with the 21st century. Moreover, nursing education has the potential in creating opportunities to get nursing students engage in the global village. This is achieved by facilitating educational opportunities via clinical and theory-based exposure for undergraduate and graduate nursing students (Nicholas et al., 2012). In addition, enhancing self-confidence among nursing students is a core objective of a quality nursing education. This will then promote the ability of nursing students to improve their creative, analytical and critical thinking skills along with management and communication skills (İlhan et al., 2016). It is evident that assertiveness plays a vital role in interpersonal communication that enables nurses in making independent decisions regarding every aspect of their nursing practice (İlhan et al., 2016).

Assertiveness is also directly correlated with nurses' caring skills (Montini et al., 2008), and it enhances nurses' professional dignity, enabling them to solve their professional problems and prevent them from making inaccurate judgments (Yin, 2011). Young adulthood is considered as one of the most vulnerable categories, where young people encounter many problems related to mental health (Jurewicz, 2015).

The mental health issues faced by young adults by the time they enter their university life may have potential threats to the success of their academic life (McLafferty et al., 2017). Hence, university undergraduates are classified as one of the particular risk groups as they tend to volatile lifestyle deviations connected with new friendships and social norms (Sravani et al., 2018). Moreover, their perception and coping strategies are affected during the transition from secondary education to university education, and they should be expedient the needs of new routines, independence and increased academic demands due to active learning methods (Orgilés et al., 2021).

Assertive students are considered to have fewer issues with adaptation and they continue to be achievers throughout their education (Rezayat & Dehghan Nayeri, 2014). However, it has been noted that the nursing students had lack of moral courage to challenge poor practice, despite acknowledging their professional and moral duty to do so (Fagan et al., 2016). Working in a defensive culture, the pressure to fit into the team and conforming to prevailing practice (Bickhoff et al., 2017), theory-practice gap (O'Mara et al., 2014) and a fear of consequences (Levett-Jones & Lathlean, 2009) have all been suggested as reasons which preclude exhibiting assertive behaviours among nursing students. In addition, difficulties that student nurses may face in the clinical setting after commencing their theoretical and clinical education may negatively affect their assertiveness (İlhan et al., 2016). If students maintain good communication skills and use their professional knowledge and skills more effectively, they must be individuals with high self-esteem who can exhibit attitudes of assertiveness (Ünal, 2012).

The simultaneous presence of low assertiveness in the students results in interrupted educational performance, low learning process, weakened ability, and undeveloped talents (Rezayat & Dehghan Nayeri, 2014). Further, nursing students are expected to develop strategies to establish and maintain a better relationship with all the teachers, the health care team, and the patients during the undergraduate period. Therefore, good communication is crucial to nursing students' well-being and that facilitates them

to cooperate with the various specialists and patients they interact with (Nishina & Tanigaki, 2013). Hence, assertiveness is considered as an essential requirement for effective nurse/patient communication, and it is suggested that having assertive skills improves the confidence of the nursing professional (Yurtsal, 2015).

As a personal skill, assertiveness mitigates personal powerlessness and results in personal empowerment (Binuja & Nagarajaiah, 2020). In addition, it enhances nurses' effective communication to build effective team relationships (Boone et al., 2008) and patient care/safety (Nakamura et al., 2017). Therefore, educational methods should encourage assertive behaviour, and nurses should receive this educational preparation during undergraduate programmes (Mc Cabe & Timmins, 2003). In order to develop assertive graduates, nurse educators have a pivotal role in facilitating development of assertiveness skills and assess students' assertiveness levels within the degree programmes (Mc Cabe & Timmins, 2003).

Currently, the whole healthcare system in Sri Lanka is overburdened with patients, and a lack of resources and most Sri Lankan nurses have a passive way of reacting to the day-to-day activities happening in the work setting and the nurses' voice is not heard in the operational management of the hospital (De Silva, 2010). Therefore, a change in nursing education is required and university must prepare nurses with Assertiveness and technical competence to work in the rapidly changing healthcare environment (Jayasekara & McCutcheon, 2006). Moreover, it is essential to assess the Assertiveness among nursing students before making necessary changes in nursing education in Sri Lanka.

Though there are studies that have been conducted on assertiveness among nursing students worldwide, evidence on this topic is not reported in Sri Lanka. Moreover, assertiveness is an area that is still not significantly focused in nursing education in Sri Lanka. Therefore, this study was conducted to assess assertiveness and to compare the assertiveness among the personal characteristics of nursing

undergraduates at General Sir John Kotelawala Defence University (KDU), Sri Lanka. Further, the study findings may contain important information that will be very useful in upgrading the existing nursing education system in Sri Lanka, that would contribute to improve the assertiveness skills among future nurses.

2. METHODOLOGY

Study Design

The current study was conducted as a descriptive cross-sectional study to assess the Assertiveness among all the nursing undergraduates (n= 173) who are registered in the BSc. Nursing degree programme of Faculty of Allied Health Sciences, KDU, Sri Lanka. Participants who have not consented for the study were excluded.

Data Collection

The data collection was conducted completely online once the ethical approval and the institutional permission was obtained. The contact details of the students were obtained from the Department of Nursing & Midwifery and the google forms contain questionnaires were forwarded to the students via online.

Study instruments

The questionnaire which was shared online had two sections. The first section was to assess participants' characteristics and the second section consisted of the validated Sinhala version of the Begley and Glacken's Assertiveness Scale (Kumara & Warnakulasuriya, 2021). The Begley and Glacken's assertiveness scale (Begley & Glacken, 2004) that has been designed to measure assertiveness among nursing students, and it has been developed adopting the scale "Assertive behaviour in nurses" (Gerry, 1989). It consisted of 28-items with a four-point "forced choice" format with the options 'Always', 'Often', 'Rarely' and 'Never' which was also deemed to be preferable to the five-point scale that allows the respondent to avoid making a clear choice (Gray &

Grove, 2020). The test for internal consistency (Cronbach's Alpha) rendered a score of 0.653 in a previous study, demonstrating an acceptable reliability coefficient (Delsidou, 2009) and the instrument was thus considered appropriate for its use. Further, the Sinhala validation of the Begley and Glacken's assertiveness scale has shown a good content and consensual validity and an acceptable internal consistency ($\alpha = 0.753$) to use in this study (Kumara & Warnakulasuriya, 2021).

Data analysis

The data analysis was conducted using the Statistical Package for the Social Sciences version 23.0. The normality of the assertiveness distribution was assessed by the Shapiro Wilk test performed in SPSS version 23.0, and it was a normal distribution. Descriptive statistics were used to describe the characteristics of the study population and to summarize the data. Independent t-test and one-way ANOVA were used to compare the mean differences among various participant characteristics in the study population.

Ethical aspects

Ethical approval was received from the Ethics Review Committee, KAATSU International University, Sri Lanka and, institutional approval was received from the Dean, Faculty of Allied Health Sciences KDU for the study. All procedures were performed in compliance with relevant laws and institutional guidelines. Further, the study objectives were discussed with the participants before the data collection. Moreover, informed consent was obtained online from the study participants before administering the study instrument.

Privacy and confidentiality were ensured at all stages of the research. The names of participants were not recorded on the questionnaires. Instead, a serial number was provided to each participant to maintain privacy and confidentiality. Participants were allowed to ask questions and register any complaints via contacting the investigators by providing contact details. There were no physical or psychological risks

for the participants. However, the participants were informed that the participation is voluntary and they could withdraw from the study at any stage without giving the reasons for the withdrawal. Further, they were explained that withdrawing from the study does not affect their academic activities.

Confidentiality of the database was maintained in a completely secured way, and all the data were handled only by the principal investigator of the study. Data and other information were not given to any third parties. All collected data were stored in an electronic device under password-protection, and they will be permanently deleted after five years. All the participants were informed that their participation would be voluntary and that there would be no incentives or rewards for their contribution to the study.

3. RESULTS

Participant Characteristics

The response rate of the target population was 88.02% (n= 147). The mean age of the study group was 24.26 ± 4.10 . The participants' personal and predictive factors related to assertiveness are shown in the table 1.1 and 1.2.

Table 1.1 Personal characteristics

Characteristic		Number	Percent -age
Gender	Male	37	25.2
	Female	110	74.8
Marital Status	Unmarried	133	90.5
	Married	14	9.5
Birth order in the family	First	82	55.8
	Second	47	32.0
	Third	10	6.8
	Fourth	6	4.1
	Fifth	2	1.4
Nationality	Sinhala	145	98.6
	Muslim	2	1.4
Academic Year	First	29	19.7
	Second	44	29.9
	Third	35	23.8
	Fourth	39	26.5

Table 1.2 Predictive factors related to assertiveness

Characteristic		Number	%
Was father assertive?	Yes	138	93.9
	No	9	6.1
Was mother assertive?	Yes	136	92.5
	No	11	7.5
Have you been a victim of bullying in childhood?	Yes	8	5.4
	No	139	94.6
Had assertive close friends in childhood?	Yes	126	85.7
	No	21	14.3
Having assertive close friends at present?	Yes	129	87.8
	No	18	12.2
Extracurricular activities (School/ University):	Leaderships	126	85.7
	Oratory (Debating, announcing)	5	3.4
	Sports	68	46.3
	Media	29	19.7
	Adventurous activities (Scouting/Cadet)	14	9.5
	Music	16	10.9
	Social activities (Leo club, Rotaract)	4	2.7
The highest grade obtained for English in GCE Advanced Level	A pass	17	11.6
	B Pass	29	19.7
	C Pass	65	44.2
	S Pass	34	23.1
Do you like to get involved in the nursing profession	Yes	121	82.3
	No	26	17.7
Additional courses	English Diploma	51	34.7
	Computer Diploma	43	29.3
	Nursing Diploma	9	6.1
	First aid	1	0.7
	Counselling & Psychology	12	8.2
	Music	2	1.4
	Human Resource	1	0.7

Characteristic	Number	%	
	Management		
Have you ever attended leadership programmes?	Yes	126	85.7
	No	21	14.3
Ever attended assertiveness training programmes?	Yes	29	19.7
	No	118	80.3

Assertiveness among the nursing undergraduates of KDU

The mean assertiveness score of the study population was 81.35± 6.51. The mean assertiveness scores of the first, second, third and fourth academic years were identified as 81.34 ± 0.99, 81.66 ± 1.00, 81.43 ± 1.13, 80.95 ± 1.15 respectively. When considering the descriptive statistics of the items in the assertiveness scale, it was noted that the items "I find it difficult to compliment and praise friends and acquaintances" scored the highest assertiveness total mean score from all the items. Further, the item "I try to avoid conflict at work" was the lowest assertiveness total mean score from all the items (Table 2).

Table 2 Item wise distribution of assertiveness score among the study participants

Item	%	Mean	SD
At work I tend to keep my feelings to myself	37.0	1.85	0.541
I feel uncomfortable asking a colleague to do a favour for me	62.0	3.10	0.659
I find it difficult to compliment and praise friends and acquaintances	75.8	3.79	0.486
If a senior colleague made an unreasonable request, I would refuse	68.2	3.41	0.774
I enjoy starting conversations with acquaintances and strangers	59.6	2.98	0.667
I find criticism from friends and acquaintances hard to take	61.0	3.05	0.649
I want to know what my rights are	69.2	3.46	0.685

Item	%	Mean	SD
in the work situation			
If a friend makes an unreasonable request, I would find it difficult to refuse	66.8	3.34	0.745
I would feel uncomfortable paying a compliment to a junior colleague	74.6	3.73	0.553
If I was busy, I would ignore the demands of a senior colleague	38.0	1.90	0.676
When I know a friend's opinion is wrong, I would disagree with him/her	67.2	3.36	0.682
At work I feel unsure what to say when I am praised	63.0	3.15	0.779
I tend to be over-apologetic to friends and acquaintances	65.0	3.25	0.739
I try to avoid conflict at work	24.2	1.21	0.426
I am very careful to avoid hurting other people's feelings	26.2	1.31	0.491
In a group I make the decisions	50.4	2.52	0.666
I would ask for constructive criticism about my work	58.0	2.90	0.627
When I am with friends, I am frank and honest about my feelings	65.4	3.27	0.580
If a colleague upsets a patient, I would challenge him/her about it	59.8	2.99	0.781
If I disagreed with a decision made by a senior colleague, I would tell him/her	56.8	2.84	0.759
At work I avoid asking questions for fear of sounding stupid	62.0	3.10	0.666
I feel uncomfortable asking friends to do favours for me	60.4	3.02	0.815
When someone pays me a compliment, I feel unsure of what to say	64.4	3.22	0.660
If I was impressed by the actions of a senior colleague, I would tell	73.0	3.65	0.583

Item	%	Mean	SD
him/her			
I tend to be over-apologetic to colleagues	66.0	3.30	0.771
I tend to be over-concerned about patients' welfare	38.8	1.94	0.654
I would feel uncomfortable expressing annoyance at a senior colleague	63.4	3.17	0.788
I am a follower, rather than a leader	50.8	2.54	0.796

Comparison of Assertiveness scores among various participant characteristics of the nursing undergraduates of KDU

The independent-sample t-test and one-way ANOVA were used to compare the means of the assertiveness scores with the participant characteristics like gender, marital status, nationality, parents' assertiveness, age group, number in the family, academic year, English proficiency, childhood trauma, assertiveness of closed peers, interest on the nursing profession and other course work. However, it was observed that there was no statistically significant mean difference in assertiveness between these participant characteristics and assertiveness ($P > 0.05$) (Table 3).

Table 3 Comparison of assertiveness among various participant characteristics

<i>Independent sample t test analysis</i>					
Characteristic	Component	Mean	SD	t	P value
Gender	Male	82.30	5.99	1.019	0.310
	Female	81.04	6.67		
Marital status	Married	83.57	8.112	1.343	0.181
	Unmarried	81.12	6.311		
Nationality	Sinhala	81.36	6.555	0.077	0.939
	Muslim	81.00	1.414		
Do you think your father could speak up for himself honestly and respectfully?	Yes	81.58	6.558	1.657	0.100
	No	77.89	4.781		
Do you think your mother	Yes	81.26	6.546	-	0.530
	No	82.55	6.186		

<i>Independent sample t test analysis</i>					
Characteristic	Component	Mean	SD	t	P value
could speak up for herself honestly and respectfully?					
Have you been a victim of bullying from family members or outsiders for a long time as a child?	Yes	81.25	8.730	-0.046	0.963
	No	81.36	6.402		
Did you have close friends in childhood who could talk directly / who had the ability to speak up for themselves honestly and respectfully?	Yes	81.73	6.388	1.729	0.086
	No	79.10	6.942		
Do your current close friends who could speak up for themselves honestly and respectfully?	Yes	81.61	6.541	1.292	0.198
	No	79.50	6.148		
Do you like to get involved in the nursing profession	Yes	81.83	6.349	1.916	0.057
	No	79.15	6.926		
Have you ever	Yes	81.57	6.277	0.993	0.322
	No	80.05	7.820		

<i>Independent sample t test analysis</i>					
Characteristic	Component	Mean	SD	t	P value
attended leadership programmes?	Yes	82.07	6.059	0.659	0.511
	No	81.18	6.630		
Ever attended assertiveness training programmes?	Yes	79.92	5.885	-1.963	0.052
	No	82.11	6.726		
Followed an English course	Yes	81.89	6.827	0.254	0.800
	No	81.32	6.514		
Followed a Nursing Diploma	Yes	83.50	7.428	1.193	0.235
	No	81.16	6.420		
Followed a Counselling & Psychology coursework	Yes	79.50	6.364	-0.404	0.687
	No	81.38	6.531		
<i>One way ANOVA analysis</i>					
Characteristic	Component	Mean	SD	F	P value
Age Group	18-20	80.67	2.082	1.216	0.307
	21-25	81.32	6.390		
	26-30	75.50	4.203		
	31-35	84.00	7.368		
	36-40	82.57	8.942		
Number in the family	First	81.95	6.246	1.148	0.337
	Second	81.34	7.023		
	Third	79.10	7.187		
	Fourth	77.00	3.521		
	Fifth	81.50	6.364		
Academic Year	First	81.34	5.354	0.083	0.969
	Second	81.66	6.637		
	Third	81.43	6.683		
	Fourth	80.95	7.189		
The highest grade obtained for English in GCE Advanced Level	A	82.29	6.162	1.121	0.343
	B	81.03	5.003		
	C	80.37	7.277		
	S	82.71	6.196		

4. DISCUSSION

Globally, it is recognized that assertiveness skills are essential, at all levels of health care delivery, and in all health care roles, from student nurse to qualified

practitioner, from the field of direct patient care to that of health strategy development (Benton, 1999). As nurses and midwives move away from traditional roles, an increasing need to behave assertively has been recognized. Plenty of studies support the use of assertiveness skills in clinical settings (Burnard, 1991; Poroeh & McIntosh, 1995; Rayo et al., 2014; Timmins & McCabe, 2005).

The assertiveness among the nursing undergraduates of the KDU was measured using the Sinhala version of the Begley and Glacken's scale (Kumara & Warnakulasuriya, 2021). The mean score of the assertiveness scale was 81.35 ± 6.51 among the nursing undergraduates of KDU. A study conducted among the Irish nursing students by Begley and Glacken, the total "level of assertiveness" score was 69.87 ± 6.83 in the first administration and was 73.73 ± 7.21 in the second administration after the assertiveness course (Begley & Glacken, 2004). A similar study conducted among the nursing undergraduates in Greece, the Assertiveness mean scores were assessed in the first semester with the advanced semester using this Begley and Glacken assertiveness scale. It was found that the mean "level of assertiveness" score achieved by first semester participants was 72.36 ± 6.671 , whereas, 74.71 ± 6.850 among advanced semesters participants, (Deltsidou, 2009). Thus, it shows that the nursing undergraduates who participated in the current study have a comparatively higher assertiveness mean score than the nursing students in those studies conducted in other countries. Therefore, we can assume that the nursing degree programme of KDU plays an essential role in enhancing the Assertiveness of the students. Further, the leadership programmes inculcated in the system and the military environment in KDU might have influenced positively for this incensement.

When considering the descriptive statistics of the items in the assertiveness scale among the undergraduates of the KDU, it was noted that the items "I find it difficult to compliment and praise friends and acquaintances" scored the highest assertiveness total mean score from all the items. Further, the item "I try to avoid conflict at work"

scored the lowest assertiveness total mean score from all the items. A similar study conducted among nursing students in the first semester in a nursing education institute in Greece found that the item "I try to avoid conflict at work" scored the lowest assertiveness total mean score from all the items (Deltsidou, 2009). Further, the item "I would feel uncomfortable paying a compliment to a junior colleague" gained the highest Assertiveness mean score. The item "I am very careful to avoid hurting other people's feelings" gained the lowest Assertiveness mean score among the nursing undergraduates of the University of Colombo. It was noted that the item "I would feel uncomfortable paying a compliment to a junior colleague" also gained the highest mean score in the study conducted by Begley and Glacken among Irish nursing students (Begley & Glacken, 2004). Moreover, the item "I am cautious to avoid hurting other people's feelings" has also gained the lowest mean score in a study conducted among nursing students in Greece (Deltsidou, 2009).

In the current study, there was no significant difference between the two genders with the Assertiveness score of the undergraduates of KDU. Some of the previous studies conducted on Assertiveness have also pointed out that there was no statistically significant difference in assertiveness between two genders (Larijani et al., 2017; Seyedfatemi et al., 2013; Taghavi Larijani et al., 2009). However, some studies have revealed that men have a higher degree of Assertiveness than women (Adejumo, 1981; Eskin, 2003; Hersen et al., 1974), and on the contrary, some studies have revealed that women have higher levels of Assertiveness than men depending on various contexts and situations (Chandler et al., 1978).

The nationality of the study group has some degree of influence on the assertive behaviour of the individuals. However, the majority of the current study group consisted of Sinhalese students and statistically significant difference in Assertiveness among the nationality groups were not observed. A significantly vital area to be explored is the influence of the Sri-Lankan culture and religion upon the level

of Assertiveness among the nurses.

There were some evidences that an individual's order of birth within the family had influenced characteristic style of interacting with others (Murawski et al., 1995). Moreover, previous research has repeatedly supported the belief that oldest children should rate higher in leadership than later born children (Schultz, 1993). Therefore, the characteristic birth order was questioned from the study population, and in the current study the majority of the participants were firstborn of the family. Similarly, Cobb and French (1966) found that firstborns were overly represented among a sample of American medical students (Cobb & French Jr., 1966), and Shaver, French, and Cobb (1970) indicated that the same was true for Swedish medical students (Shaver et al., 1970). However, there was no statistically significant difference found in assertiveness among the participants as per their birth order.

The influence received from the family has a more significant impact on Assertiveness. Therefore, the undergraduates were questioned on their perception on the parents' Assertiveness with the question "Do you think your father/ mother could speak up for himself/ herself honestly and respectfully?" Majority of the participants believed that both parents had the ability to speak up for themselves honestly and respectfully. Further, the results revealed that there was no statically significant difference in assertiveness between their views on parents' Assertiveness and the assertiveness of the participants in the current study. Moreover, undergraduates were assessed on whether family members or outsiders have bullied them during their childhood and its relationship towards Assertiveness. However, no statistically significant difference in Assertiveness was noted among the participants who had atraumatic childhood and who did not have such childhood.

Undergraduates of the KDU were further assessed on the closed peers' Assertiveness and its relationship towards Assertiveness. This was assessed by asking the close-ended questions "Did you have close

friends in childhood who could talk directly / who could speak up for themselves honestly and respectfully?" and "Do your current close friends speak up for themselves honestly and respectfully?" However, there was no statistically significant difference between these variables with the Assertiveness. Further, a similar study conducted in Turkey on the relationship between peer pressure and Assertiveness found that there was no significant correlation between mean assertiveness scores and mean peer pressure scores of the students (Arslan et al., 2013).

The nursing undergraduates of KDU consist of a group of students who had joined as lateral entrants to follow the degree programme after attending the three-year nursing diploma course from the government, and most of them are matured and married. Therefore, the relationship between marital status and Assertiveness was assessed, but there is no statistically significant difference in the assertiveness between the married and unmarried participants. Further, there was no statistically significant difference in the assertiveness between the nursing undergraduates who had already completed the government nursing diploma (lateral students) and those who have not. However, a previous study has proven that the nurses who possessed a nursing diploma as their highest level of academic qualification had lower levels of Assertiveness than the nurses who have completed their Bachelor's degrees and above (Kilkus, 1993).

In the current study there was no statistically significant differences in the assertiveness score among the undergraduates at different study levels in four academic years. However, the study conducted by Begley and Glacken revealed that the Irish nursing students who participated in the study reported an increase in levels of Assertiveness as nursing students approached completion of their three-year education programme (Begley & Glacken, 2004). Furthermore, another four-year longitudinal study conducted among nursing students to determine the effect of nurse education assertiveness of nursing students revealed that there was a significant difference in the Assertiveness in all academic years (İlhan et al.,

2016). Moreover, the current study, there was no statistically significant difference in the assertiveness score between the participants who have attended leadership or assertiveness training and those who did not participate in such trainings. However, several studies have proved the positive impact of assertiveness training programmes to improve Assertiveness among nursing students (Kilkus, 1993; Omura et al., 2018; Yoshinaga et al., 2018).

Conclusion and Recommendation

The results showed considerably high assertiveness score among the nursing undergraduates of KDU. However, it was observed that there was no statistically significant mean difference in assertiveness between these participants' characteristics and assertiveness. Therefore, we can assume that the current nursing programme of KDU plays an essential role in enhancing the Assertiveness of the students. Further, it is recommended to study the different nursing curriculums in different universities in Sri Lanka on the assertiveness teaching and its effectiveness. With that, an updated well designed assertiveness teaching protocol can be developed parallel to the nursing education programmes in Sri Lanka.

Furthermore, frequent assessments can be conducted to identify the nursing students who need special attention to enhance their assertiveness skills. Moreover, the nursing students can be motivated to do extracurricular activities, which enhance their assertiveness skills. And also, further research is needed to investigate other interrelated factors like communication patterns and paternal dominance that might have impact on Assertiveness.

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FACTORS IMPACTING ON CUSTOMER PROMOTION ACCEPTANCE IN THE FAST FOOD INDUSTRY IN SRI LANKA

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ABSTRACT

Fast food chains in Sri Lanka are a recently emerging industry which makes revolutionary transmutations within the frequent consumer patterns. The purpose of this research is to point out the factors which influence the consumers' acceptance of promotions made by fast food restaurants. A total of 384 questionnaires were conveniently distributed among teenagers, youngsters, professionals and middle-aged consumers in the Colombo suburb via online platforms and physical modes. Data analysis was done using SPSS Version 26. The relationship between variables and their impact were identified by correlation and regression respectively. According to frequency distribution analysis the consumers in the age group of 25 to 35 are mostly interested in accepting promotion messages through SMS and Facebook. Further, out of respective promotion categories buy one get one free is the most outstanding promotion type among consumers. The study observed price, income, attitude and promotional deals as the significant factors for the acceptance of promotion. Also results revealed that price, attitude and promotional deals had a highly positive correlation with promotion acceptance rather than income. Due to the time constraint and Covid-19 pandemic, respective respondents were selected only from the Colombo region. The paper provides useful information and new insights for potential marketers and academicians about the factors to be considered in customer promotion message acceptance in the fast food industry.

KEYWORDS: *Fast Food Industry, Promotion Acceptance, Income, Attitude, Price, Promotional Deals*

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1. INTRODUCTION

Fast food chains have become an incredible and revolutionary trend within the busy lifestyle of human beings and where fast food items are hassle free to prepare and consume. In addition, we can determine that fast food has taken a major space in the respective industry. However, the conception of the fast food industry has widely influenced to make changes in habits and culinary preferences of dual income earning families as they can pay more attention to their priorities. Further, the women workforce and the young generation are rapidly exposed to a variety of fast foods in fulfilling their basic and fundamental food needs.

In accordance with the 2019 Fast Food & Quick Service Restaurant Trends analysis report, the global size of the market for the fast food industry emerged by USD 257.19 billion. Over the years, it has kept growing with an annual growth rate of 5.1% from 2020 onwards, and in 2019, the size of the fast food industry was valued at over USD 500 billion. Fast food entities and quick service restaurants have emerged as a main provider of this mass production of food. Better taste, ease of purchasing and being economical in terms of both prices and time are some of the essential attributes for the boon of the marketplace for fast food and quick service restaurants.

In 2019 America, China and Italy have mainly grabbed a wide portion of shares in fast food and quick service restaurants all over the globe respectively. When it comes to the American cuisines the market is direct, and it accounted for more than 25% of shares of the world revenue in 2019. The context's category includes restaurants with a huge variety of food items. The scope of the American cuisine is enriched with major factors such as the process of the industry, hustling lifestyle, upcoming franchises and the production efficiency (Fig.1).

During the past colonial era, Sri Lanka had an influence of the fast food industry where the name

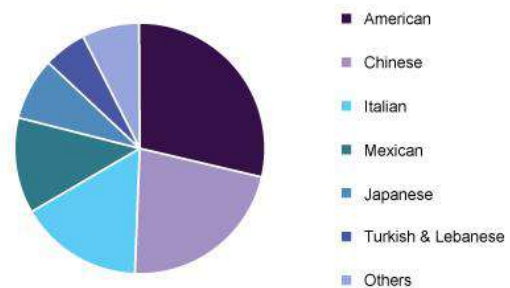


Figure 1: Global fast food & quick service restaurant market share by cuisine, (2019).

Perera and Sons got established in 1902 with the commencement of their business life cycle as a fast food provider to Sri Lankans (Gunasekara, 2001).

With the elapsed time, the industry kept growing by gathering newcomers such as Royal Bakers and many others. Apart from that, as a result of globalization and proliferation of multinationals companies, fast food service sources, i.e. top rated companies such as McDonalds, Pizza Hut and KFC started fulfilling the needs for appeasement of hunger in an innovative way. When it comes to Sri Lankan culture, food and food preparation have played a vital role from earliest times as the country carries multicultural and multi religious people. As a result of that it drives the country to have such a diverse food variety in their diverse habits (Rasanthika & Gunawardana, 2013).

Promotion can be known as a general strategy used by the fast food service industry in order to enhance the sales and attract customers towards the organization. According to (Raed Momani & Sima Magatef, 2016) one of the crucial elements of promotional mix, sales promotions can be used to encourage competitive advantages. By stimulating the customer purchase decision, it increases the sales for marketers and this is a precious tool when it comes to marketing.

The industry usually obtains customer promotions to capture brand switchers, motivate price-sensitive customers, and encourage daily usage. Sometimes it is all about providing a value-added service for the customer. As stated by R. Sritharan, et al., 2015, sales promotion affects customers' purchasing decisions with exceptional preference to particular

products. Furthermore, various studies have mentioned different arguments pinpointing the relationship between promotional activities and brand loyalty. These sales promotions are used by restaurants in the fast food industry in a substantial manner with the intention of building a loyal customer population. Along with these past literature reviews we researchers can conclude that there is a remarkable relationship between promotional deals and customers in the fast food industry in the Sri Lankan context.

This research explores factors that influence customer promotion acceptance in the fast food industry within the Sri Lankan context. However, this study considers the four factors, i.e. price, income, attitude and types of the promotion. Along that the study merges the variable factors with the promotion acceptance in order to extract a relationship between these two aspects. Basically, there are both local and international fast food outlets currently performing within the country, adding value to the competitive advantage (Hirunika Nirmani, et al., 2017). In such a circumstance, fast food marketers are encountered with the challenge of identifying whether their customers respond to the promotions sent via different advertising platforms.

Prior to coming up with a new comprehension, we researchers directed a pilot survey separately for companies and the customers in order to make sure there was a mismatch between companies' perception towards the promotion acceptance by the customers and the customers' point of view towards the promotion sent from the companies. So, the endeavor of this research was to recognize the factors which drive the customer into the promotion acceptance once the promotion offer is received by their mobile devices. And by such an approach it is easy to figure out the effectiveness of a company's promotion on its sales as long as they send the promotion messages to the customer. That motivates the customers to taste the food based on the promotion offer.

2. METHODOLOGY

The quantitative approach was used to gather needful data in order to achieve the objectives of the study. To support the achievement of the objectives with the gathered data, three questionnaires were developed for the study, including a pilot survey to make sure that there was an unfilled gap to answer.

Research approach

The study stands on a deductive approach and it is developed on the theory-based hypothesis based on the data collection and analysis. Further a quantitative research approach was used in the study since the collected data fall under a numeric form in order to identify both independent and dependent variables. The illustrated map (Fig. 2) of the conceptualization framework narrates the path of the research and how it is based constantly on theoretical pillars by showing the relationship between independent and the dependent variable.

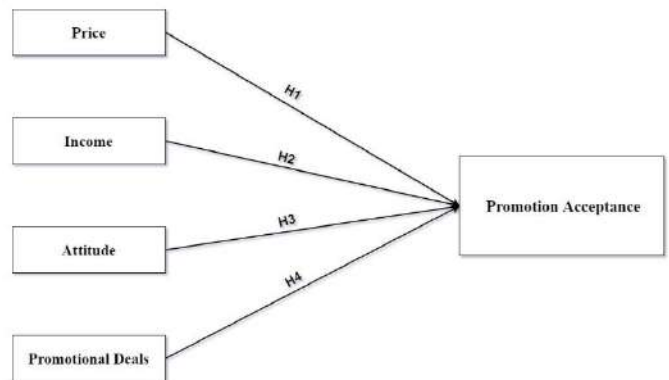


Figure 2: Conceptualization Framework

Research design

The way of answering the research questions and the overall plan of the research is well described under the research design. Based on the objectives of the study following has to be focused, namely; the sources of data collection, the data collection procedure, the way it is researched and addressing the ethical issues. The research design brings the view of

how the study was planned and scheduled and how it has to be carried out. Understanding of this research design is crucial when it comes to identify various tools and techniques which are to be used in the methodology.

Population and Sampling design

The population of the study consists of the people in the age group of 15 to 55 living around Colombo. Theoretically, according to Krejcie & Morgan, 1970, the sample size we chose which is 384 was the entire population for the particular study.

Method of data collection

Before implementing the main survey, a pilot study was conducted to identify the research problem of the study. Mainly the pilot survey was conducted in two ways where one targeted the general population and the other targeted restaurants in the industry. The main survey consisted of 32 questions including Likert scale and close ended questions. With the Covid-19 pandemic outbreak, collecting data physically through the main questionnaire was limited. But the researchers were competent to collect a considerable amount of data physically with a pre-approval from a reputed government institution which convinced the researchers to approach the fast food consumers in order to enhance the category of employed population. The rest of the needful data was collected by sending the main questionnaire in a digital mode. In total, more than 200 questionnaire responses were collected though online google forms.

Data Analysis

Correlation coefficient

Table 1: Pearson Correlation Rank.

Value of r	Relationship
$r = +1$	Perfect positive correlation
$+0.5 \leq r < +1$	High positive correlation
$r = +0.5$	Moderate positive correlation
$0 \leq r < +0.5$	Weak positive correlation
$0 = r$	No correlation
$0 < r \leq -0.5$	Weak negative correlation
$r = -0.5$	Moderate negative correlation

Table 1: Pearson Correlation Rank.

Value of r	Relationship
$-0.5 < r \leq -1$	High negative correlation
$r = -1$	Perfect negative correlation

As Schober, et al., (2018) stated, the correlation can be defined as a test measure which has been done to measure the strength of the association among two or more variables. This study was conducted through Pearson’s correlation analysis which was used to measure the significance and the trend of the relationship between variables. Basically, the correlation coefficient value is denoted by “r” and it can be different in between the +1 to -1 in which it takes within both independent and dependent variables. The clear explanation of correlation used is emphasized in Table 01. Source - (Hauke & Kossowski, 2011)

Regression (multiple regression)

R square value is named as coefficient of determination and it illustrates the portion of the difference in the dependent variable which is described by the independent variable. The high rate of R square indicates how long the model fits suitably ($R^2 > 50\%$) and it can be changed from 0 to 1. However, it cannot predict that a good regression model has the highest r square value where it depends on the variable used, the units of the measurements, processing of the survey question and the existence. Consequently, a higher R square value always comes up with an issue with the regression model.

3. RESULTS

Reliability and the Validity

Reliability

Reliability refers to a proportion where the obtained scales are capable of reproducing the same results if it was applied into different sample groups at a various time. (Hair, et al., 2003) According to the research, on analyzing the factors which impact upon the promotion acceptance by the customer, a questionnaire was built and each factor consisted of a number of questions on it so as to make sure that the

developed questions are reliable enough to continue with the study to achieve the goals. Sekaran & Bougie (2006) stated that the alpha value which is above 0.8 is a good level of reliability.

Table 2: Reliability Statistics

Cronbach's Alpha	N of Items
0.943	24

Based on Cronbach's alpha, Table 02 shows the value of our study is 0.943 where the reliability can be taken as acceptable to carry on the study further.

Table 3: Reliability Statistics for individual variable

	Corrected Item-Total Correlation
Income	0.748
Attitude	0.835
Promotional Deals	0.867
Price	0.82
Promotion Acceptance	0.823

According to the SPSS results (Table 03) the alpha values are separately taken to the variables as 0.748 for income, 0.835 for attitude, 0.867 for promotional deals, 0.820 for price and 0.823 for promotion acceptance as the dependent variable. Eventually in this research a minimum 0.7 value of alpha is required and more than 0.7 is acceptable for the study.

Validity

Table 4: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.805
Bartlett's Test of Sphericity	Approx. Chi-Square	987.677
	df	276
	Sig.	0

Validity is measured based on KMO and Bartlett's test, and it is the adequacy of a sample in which if it is higher than 0.5, it tends that the sample is in a satisfactory level to conduct the analysis process (Quang Nguyen, et al., 2018). The Table 04 shows

the Kaiser-Meyer-Olkin (KMO) of the current research and the result of the test is 0.805 where it can be considered acceptable KMO and the sample taken is adequate to go with further studies.

Frequency distribution analysis of background data

Table 5: Frequency distribution analysis of background data

	Frequency	Percentage (%)
Gender		
Male	210	54.7
Female	174	45.3
Age		
15 – 24	152	39.5
25 – 34	183	47.7
35 – 44	37	9.7
45 – 54	7	1.8
55 – 64	5	1.3
Status		
Employed	262	68.2
Unemployed	21	5.5
Studying (university or school)	101	26.3
Income Level		
Less than Rs.15000	6	1.6
Rs.15000 – Rs.30000	38	9.9
Rs. 30000 - Rs. 50000	104	27.1
Rs.50000 - Rs.100000	85	22.1
More than Rs.100000	31	8.1
Dependence	120	31.3
Amount allocation		
Less than Rs.1000	197	51.3
Rs.1000 to Rs. 2500	123	32
Rs. 2500 to Rs.5000	39	10.2
More than Rs.5000	25	6.5

	Frequency	Percentage (%)
Frequency of buying fast food		
At least once a week	123	32
1–3 times per month	105	27.3
Once in every 2 months	94	24.5
Few times a year	62	16.1
Promotion message view platform		
SMS	202	52.6
Facebook	103	26.8
Instagram	51	13.3
Mobile apps	17	4.4
Websites	11	2.9
Promotion type		
Buy one get one free	176	45.8
Special day promotions	83	21.6
Family combo pack promotions	58	15.1
Credit card promotions	45	11.7
Dine in and take away promotions	22	5.7

According to Table 5, out of 384 respondents 210 were male and 174 were female, which is 54.7% and 45.3% of the total outcome respectively. It shows that the majority of the fast food consumers are male respondents and females too have the nearby taste according to the male. And the respective age respondents are categorized under 5 sectors between 15 to 64 in the survey. According to the distribution of age categories the highest percentage was carried by the age group 25 to 34, and the lowest percentage value was represented by 55 to 64 elders. There it shows a drastic value drop down in percentages from 35 years onwards. Among these respondents there are employees, unemployed and university and school students. the majority of respondents are employees and students, which is 262 and 101 respectively. The

rest of the results belong to the unemployed population which indicated a frequency value as 21 respondents. The researchers have classified the income into 6 areas including the option as dependence, by taking note of the unemployed and the studying population. The most contributed income range for the survey is from Rs. 30,000 to Rs. 50,000 and Rs. 50,000 to Rs. 100,000. On the other hand, the very lowest frequency with 6 respondents belongs to the lower income range where they earn less than Rs. 15,000 per month. According to the results, 197 respondents were highly passionate to allocate less than Rs.1000 on fast food. As the opposite result 6.5% which represented the lowest percentage value given for the amount allocation range of more than Rs.5000 from 25 respondents. When it comes to the frequency of buying fast food, it can be varied under 4 different frequencies, i.e. at least once a week, 1–3 times per month, once in every 2 months and a few times a year. The highest frequency of purchasing fast food was at least once a week. The least frequency of buying fast food is recorded as a few times a year where it was recorded only as 62 respondents. In addition to that SMS, Facebook, Instagram, mobile apps and websites are taken down as most viewed promotion offers in platforms. Short Message Service (SMS) and Facebook have the most frequent value with users 202 and 103 respectively. Furthermore, mobile apps and websites have gained the lowest rate of responses in the survey. Eventually, the most embraced types of promotion are buy one get one free, special day promotions, family combo pack promotions, credit card promotions and dine in and take away promotions. The fast food consumers pay more attention to buy one get one offer rather than other offerings. The least level of preference is towards the dine in and take away promotions among the society

Objective 1 - Pearson Correlation Coefficients between price and promotion acceptance

In general, positive correlation can be identified as a positive r value that increases the value of one variable influence to increase in the second variable value. In the *table 17* below, Pearson correlation of price and promotion acceptance is depicted as 0.650 (r= 0.650), and it can be apprehended that when the

price increases, it tends to increase promotion acceptance by 65%. Besides the results interpret that there is a highly positive correlation (correlation coefficient is 0.650 which is in $+0.5 \leq r < +1$) between the two variables, which provides the values of $r = 0.650$, $N = 384$, which depicts the mean of price and promotion acceptance from a total count of respondent with price and promotion, $p = 0.000$.

Objective 2 - Pearson Correlation Coefficients between Income and Promotion Acceptance

As per the Pearson’s correlation result below, it represents that the Pearson value as 0.566 ($r=0.566$) between income and the promotion acceptance. The researchers observe that when the income rises up, the promotion acceptance tends to increase by 0.566. Therefore, the outcomes reveal a positive value, but it is a moderate positive correlation (correlation coefficient is 0.566 which is in $r = + 0.5$ according to the Pearson Correlation Rank table) between the two variables.

Objective 3 - Pearson Correlation Coefficients between Attitude and Promotion Acceptance

The following *table 19* displays the correlation coefficient value between attitude and promotion acceptance as 0.607. Along with that, it can be defined as a high positive correlation where the attitude variable increases, parallely the acceptance of promotion tends to increase by 0.607. However, it is accepted as a high positive correlation due to the correlation coefficient or r value is in $+0.5 \leq r < +1$ according to the Pearson correlation rank table above.

Objective 4 - Pearson Correlation Coefficients between Promotional deals and Promotion acceptance

As depicted in *table 20*, a correlation coefficient of 0.669 ($r=0.669$) was evident between the two variables, namely promotional deals and acceptance of promotion. Therefore, the study recognized that increment of promotional deals by one unit would influence an increment in promotion acceptance by 0.669. The outcome results emphasize a high positive

correlation whose r value is between $+0.5 \leq r < +1$ rank according to the Pearson correlation rank Table 06.

Table 6: Pearson Correlation Coefficients between variables

	IN	AT	PD	PR	PA
Income	1	.557**	.505**	.516**	.566**
Attitude	.557**	1	.677**	.700**	.607**
Promotional Deal	.505**	.677**	1	.712**	.669**
Price	.516**	.700**	.712**	1	.650**
Promotion Acceptance	.566**	.607**	.669**	.650**	1

Regression Equation

$$PA = 0.719 + 0.207 [Price] + 0.224 [Income] + 0.090 [Attitude] + 0.307 [Promotional Deal] + \epsilon$$

As per the above regression equation, the interpretations for regression model coefficients could be as given below. The Beta value of the price is 0.207 where it represents a positive relationship with the promotion acceptance by consumers. The significant level of price is 0.000 under the acceptable level of 0.5 speaks that and an increment of the price by 1 unit will result in 0.207 by increasing the promotion acceptance. When it comes to the attitude factor, the Beta value shows 0.090 where the significant value is greater than 0.5 significant level. So, the attitude can be taken as an insignificant factor which makes an impact on the promotion acceptance (Table 7).

Table 7: Coefficients value for regression model

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
Constant	0.719	0.167		4.314	0
IN	0.224	0.042	0.229	5.384	0
AT	0.09	0.049	0.098	1.851	.065
PD	0.307	0.05	0.32	6.087	0
PR	0.207	0.048	0.234	4.319	0

Objective 5 - Regression between price, income, attitude, promotional deal and promotion acceptance

So, the identification of the relationship between the factors (price, attitudes, income level and the promotion type) and promotion acceptance by the customer as our final objective of the research was successfully accomplished. With the above generated results the independent variables, namely the factors income, promotional deals, price make an impact on the customer when he/she is on a purchasing decision. But, the individuals do not pay much attention on their attitudes while they are making purchasing decisions.

Hypothesis testing

This study consisted of 4 hypotheses for each independent variable. Below explain the results of hypothesis testing which support to evaluate the acceptance and rejection of hypotheses.

H1 – There is a significant relationship between Price and Promotional Acceptance

As the analysis conveys that there is a statistically significant relationship between price of the promotion and the customer promotion acceptance where the independent variables P value ($P=0.000$) is less than 0.05. Therefore, the researcher would be able to accept the hypothesis.

H2 – There is a significant relationship between Income and Promotional Acceptance

According to SPSS result, it conveys a significant value as ($P=0.000$) which is less than 0.05. Therefore, it is concluded that there is a statistically significant bond between customer's income and the consumer promotion acceptance, and the hypothesis can be accepted.

H3 – There is a significant relationship between Attitude and Promotional Acceptance

Since the study shows that there is a statistically significant relationship between customers' attitude

towards the promotion and the consumer promotion acceptance where the independent variables P value is not more than 0.05, which supports the acceptance of the hypothesis

H4 – There is a significant relationship between Promotional Deals and Promotional Acceptance.

Based on the result there is a statistically proved relationship between promotional deals and the consumer promotion acceptance where the P value is 0.000, and the value comes below 0.05, which means the hypothesis can be accepted.

4. DISCUSSION

According to the generated result from the analysis, the regression coefficient of price is shown as 0.573 with a 0.000 significant value. It means there is a significantly positive impact on price and the intention of promotional acceptance of customers in the Colombo suburb. Furthermore, the research accepts the hypothesis 01 (H1) “there is a significant relationship between price and promotional acceptance”. Also, it results when changing the price from 1 unit the promotion acceptance change is 0.573 units. A research done by (Huang, et al., 2014), according to their result analysis they found that price promotion has a significant positive influence on the quality of the food and beverage. Also, the price promotion has shown a direct impact on the satisfaction of the customer, and at the same time this satisfaction showed a significant influence on purchase intentions. The price promotion too has shown a direct impact on repeat purchasing intentions. Moreover, their results confirm that price promotion motivates non-frequent customers to come again and frequent customers are more likely to keep purchasing regardless of this price promotion.

As per the generated results, the regression coefficient of consumers' income is valued as 0.554 with a 0.000 significant value, where it says that a significantly positive relationship can be seen in customers' income and their promotion acceptance decisions. Also, the study accepts the hypothesis 02 (H2) “there is a significant relationship between income and promotional acceptance”, where it results

when the customer's income fluctuates from 1 unit, the promotion acceptance impacts from 0.554 units. According to Ifeanyichukwu & Nwaizugbo (2019), they have noted over two billion human beings in developing countries spend up to 70% of their income on food. A study done by Ozdemir & Ergin (2017) stated that there is a significantly highly positive relationship between income and the frequency of fast food consumption, where it concludes that the higher income earners visit fast food restaurants often and the income level of the fast food consumer is significantly correlated with frequent food consumption.

The study's regression coefficient of consumer attitude is 0.554, shown with a 0.000 significant value, where it can be concluded that a significantly positive relationship can be seen between the customer's attitude and his promotion acceptance intention.

Also, the thesis accepts the hypothesis 03 (H3) "there is a significant relationship between attitude and promotional acceptance", where it impacts when the customer's attitude differs from 1 unit the promotion acceptance differs with 0.554 units. Xue, et al. (2021) generated their research result and they observed a positive relationship between attitude and fast food purchase, where it significantly increased by household structures. Also Devendra & Kennedy (n.d.) has stated that according to their research attitudes of the consumers are making a significant impact on fast food consumption. Also, many other studies predict the theory that there is a positive effect on attitudes and fast food consumers' intentions (Ajzen, 2015)

The results of the study interpret the regression coefficient of promotional deals as 0.624 projected with a value of 0.000 significant, where it can be said that a significantly positive relationship can be observed in promotional deals and promotion acceptance decisions by the fast food consumer. Also, the study accepts the hypothesis 04 (H4) "there is a significant relationship between promotional deals and promotional acceptance", where it influences when the promotional deal changes by 1 unit, the promotion acceptance changes by 0.554

units. A research done by Ehsan (2012) considering 3 cities in Pakistan and considering the factors which are more influential in selecting fast food restaurants among Pakistanis. As per the result generated by the authors to measure the significance of these factors considered in 3 cities, people are always aware and interested about promotional deals. According to that opinion, it is important that the price, timely service and promotional deals are the main factors to be considered when it comes to selecting a restaurant in Pakistan.

5. CONCLUSION

As discussed in the section above, it can clearly be stated that the factors income, price, attitudes and promotional deals are positively related with promotion acceptance. The results generated in the previous sections show that there is a significant relationship among these factors, and moreover the created hypotheses are all accepted by proving more about the relationship of these factors with the dependent variable, which is promotion acceptance. All the objectives constructed by the researcher for the accomplishment at the end of this research were successfully achieved and the results generated are clearly defined as well. So, the current paper expands the empirical findings of the gathered data.

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CYBER BULLYING AMONG UNDERGRADUATES IN A NIGERIAN UNIVERSITY: OCCURRENCE AND IMPACT ON THEIR SELF-IMAGE

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ABSTRACT

Purpose: This study explored the impact of cyber bullying on undergraduates' self-image. The study also investigated whether respondents' views will vary based on their age, gender, purpose of using the internet, duration of internet usage and average time spent online. **Design/Methodology:** The study adopted descriptive research design of correlational type using simple random sampling procedure to select a sample of 419 respondents. A self-developed three sectioned questionnaire entitled "Cyber bullying and Self-image Questionnaire (CBSIQ)" was employed to gather data. Data collected were analysed using percentages, Pearson's Product Moment Correlation and Univariate Analysis of Variance. **Findings:** The findings showed that majority of the undergraduates (82.1%) experienced low level of cyber bullying and 66.8% of the respondents reported negative self-image. The findings also showed significant positive relationship between the experience of cyber bullying and negative self-image of respondents ($r=.161, p < 0.01$). Respondents' views regarding the influence of cyber bullying on self-image did not differ on the basis of their age, gender, purpose of using the internet, length of years in using the internet, and the amount of time spent online. **Implication:** Based on the findings of this study, there is a need for school counsellors to introduce self-image development skills training in the orientation programme organised for the undergraduates regardless of their age, gender, purpose of internet use and length of years in using the internet

KEYWORDS: Cyber Bullying, Self-Image, Undergraduates

1. INTRODUCTION

The ease of access to modern information and communication technologies such as mobile phones and computers has re-oriented human social relationships in a variety of ways, particularly among enlightened adolescents who are currently turning the technology into essential means of communication. Nigeria is one of the developing countries that is integrating the use of cutting-edge mobile devices as it thrives globally. More than 101.7 million Nigerians are anticipated to use mobile internet by 2021 (Ceci, 2021). During the corona pandemic, several enterprises and agencies, including higher and lower education institutions, have boosted their use of mobile internet. Despite the fact that it has several benefits for human interactions, education, healthcare, and commerce, it has also been accomplished by its negative characteristics. With the increase in online teaching and learning in Nigerian universities, the number of hours spent on the internet by undergraduates has increased as a matter of necessity. Studies (Olumide et al., 2015, Englander, 2018) have found that teenagers who are 'heavy cell phone users' are more likely to engage in bullying, as well as to be bullied online. Meyer (2019) emphasised that cyber bullying is a unique feature that might be especially harmful to victimised youth. Individuals who are subjected to cyber bullying can get an unrestricted number of vexing messages over a variety of networks (chat rooms, social networking sites, emails, etc.) and channels.

Cyber bullying is defined as a form of aggression including the use of information and communication technologies such as mobile phones, video cameras, email, and web pages to harass or disgrace another person. It is the systematic and voluntary exploitation of others, with terrible consequences for victims. According to researchers (George & Odgers, 2015), cyber bullies frequently employ swear words (showing wrath), insults, jokes, mobility, and phoney names.

Researchers (Popovac & Leoschut, 2012) have also observed that cyber bullying is an extension of traditional bullying in schools, although it varies in

some significant and concerning aspects. Cyber bullying, for example, is largely anonymous (Belsey, 2007; Slonge & Smith, 2008; Meter & Bauman, 2018). The anonymity of this phenomenon (cyber bullying) is the most dangerous component of it since the bully lacks the fear of being discovered, which aids in controlling behaviour; and when this is the case, the cyber bully may behave in ways that they would not in a face-to-face meeting. Unlike traditional bullying, the aggressor knows who the victim is, but the victim often has no idea who is bullying him or her.

Bullying behaviour in Nigeria has also evolved from a physical face-to-face encounter in the school yard to a more psychologically devastating experience. According to Ada et al. (2016), this type of bullying is a huge problem in Nigerian higher educational institutions because it occurs indirectly through electronic media (Smith, 2014). Cyber bullying can also take many forms, such as sending hurtful or threatening messages to a person's email account or cell phone, spreading rumours online through texts, posting hurtful or threatening messages on social networking sites or web pages, stealing a person's account information to break into their account and send damaging messages, pretending to be someone else online to hurt another person, and taking unflattering pictures of a person and spreading them online (Meter & Bauman, 2018; Smith, 2014).

Several factors have been suggested to motivate individuals' cyber bullying behaviours, including retribution, detestation, and the desire to deflate the victim's knowledge. That is owing to envy (Hoff & Mitchell, 2009) the nature of cyber bullying (anonymity) to feel or demonstrate power, for ego enhancement, having already suffered bullying, and for fun. Attention seeking, peer influence, alcohol/drug abuse, believing it is normal to indulge in it, a lack of skills to settle problems and cover up one's flaws, and prejudice against the victim's race, religion, or sexual orientation are all motivating factors (Topçu, 2014).

The findings of studies on gender disparities in cyber bullying perpetration have not been consistent.

According to Barlett et al. (2014), female students engage in cyber bullying mostly through sharing secrets they have been told, gossiping about persons in the virtual world, assaulting the individual's personality or sexual identity, or labelling people as untrustworthy. According to Keith and Martins (2005), females engage in a more relational sort of cyber bullying than males. This could be due to cultural norms and gender role expectations. Calvate et al., (2010), on the other hand, had previously discovered that more guys, 48 percent, had participated in at least one act of cyber bullying compared to 40 percent of the girls. The researchers also discovered differences in bullying behaviours; boys were more likely to film and distribute images of physical aggression and also images of embarrassing and sexual nature. One possible explanation for a heightened inclination in boys is a difference in gender role socialisation, specifically a potential difference in amount of empathy (Topcu & Erdur-Baker, 2012). Barlett and Coyne (2014) discovered that age mediates gender differences, with females reporting more cyber bullying during early adolescence and boys reporting more in late adolescence.

Researchers have revealed a curvilinear link among kids, with the maximum engagement rates happening between 12-15 years of age (Kowalski, Giumetti, Schroeder & Lattanner, 2014; Tokunaga, 2010). (Kowalski, Giumetti, Schroeder & Lattanner, 2014; Tokunaga, 2010). Despite the fact that certain researchers, including Pichel, Foody, O'Higgins, Feijóo, Varela, and Rial (2021), have discovered that cyber bullying victimisation can continue to rise in late adolescence.

According to Pichel et al., (2021), cyber bullying tends to peak between the ages of 14 and 15 before declining during adolescence. Although social networking and gaming sites technically require users to be at least 13 years old, it is worth noting that one in every four (25.1 percent) of those extremely young kids has lately been cyber bullied (i.e., in the last 30 days).

Based on the intensive use of the internet, Yang and

Tung (2007) reported that students are connected to internet for 12.1 to 21.2 hours a week. According to Rice, Petering, and Rhoades (2015), at least three hours of Internet use per day was connected with both cyber bully perpetration and victimisation. Also, studies (Lei & Wu, 2007; Subrahmanyam & Lin, 2007) found that adolescents use the Internet primarily for amusement and communication rather than academic goals. Adolescents commonly communicate through the internet and frequently identify themselves differently while talking, which may expose them to victimisation or perpetration.

Cyber bullying is a common phenomenon in Nigeria (Akor, 2012; Oyewusi & Orolade, 2014; Okoie, Anayochi & Onah, 2015; Olumide, Adams & Amodu, 2015; Ada, Okoli, Obeten & Akeke, 2016). According to Olumide, Adams, and Amodu (2015), 39.8 percent of respondents have been bullied online, and 21.0 percent have been both victims and perpetrators. Phone calls (63.5 percent), chat rooms (44.9 percent), (38.5 percent) to follow SMS. The majority of the kids were cyber bullying perpetrators, and the correlates of perpetration were history of cyber victimisation and everyday internet use. Ada, Okoli, Obeten, and Akeke (2016) found a significant frequency of cyber bullying at Nigerian higher educational institutions in a similar study.

Researchers (Notar & Padget, 2013; Hertz & Wright, 2013) discovered that cyber bullying has a negative impact on the psychological well-being of young people. Cyber bullying victims report more social and emotional problems, such as isolation and emotion management issues compared to traditional bullying victims (Ak, Zdemir & Kuzucu, 2015; Elipe, Mora-Merchán, Ortega-Ruiz, & Casas, 2015). Students who are victims of cyber bullying are more likely to suffer from sadness, anxiety, and substance addiction (Palermi, Servidio, Bartolo & Costabile, 2017). According to Deschamps and McNutt (2016) and Nixon (2014), victims of cyber bullying had increased suicide ideation/behavior, social isolation, mental illness, physical symptoms, and school anxiety.

School-age cyber victims were found to be at a higher

risk of depression (Perren et al., 2010; Gradinger et al., 2009; Juvonen & Gross, 2008), psychosomatic symptoms such as headaches, abdominal pain, and sleeplessness (Sourander et al., 2010), and behavioural issues such as alcohol usage (Mitchell et al., 2007). Cyber bullying victims report feeling uncomfortable and alienated at school and at home, as has been documented in studies of face-to-face bullying. Cyber bullying can cause considerable emotional and psychological harm, leading to students acquiring low self-esteem, a negative self-concept, and being less effective in their engagement with the environment (Sourander et al., 2010). According to O'Brien and Moules (2013), cyber bullying can have an impact on victims' self-image.

The personal vision or mental picture that an individual has of himself or herself is referred to as self-image (Nair, 2016). Self-image can also be defined as the cognitive realm of an individual's self-evaluation (Wosik-Kawala, 2007). Self-image is a "internal dictionary" that describes the self's traits, such as intelligence, beauty, and ugliness, as well as talent, selfishness, and kindness. These traits form a collective depiction of individual assets (strengths) and liabilities (weaknesses) as they are seen (Nair, 2016). According to Bailey (2003), there are four types of self-images: self-image resulting from how an individual sees himself/herself; self-image resulting from how others see the individual; self-image resulting from how the individual perceives others see them; and self-image resulting from how the individual perceives the individual sees oneself.

Self-image is not the same as self-concept or self-esteem. The entirety of an individual's ideas and feelings with reference to himself as an object is referred to as self-concept. It is a person's overall perception of who he or she believes he or she is. Self-esteem, on the other hand, relates to a person's emotions of self-worth or the value they place on themselves, whereas self-image refers to how an individual sees themselves, both physically and intellectually, but it does not have to be accurate (Rosenberg, 2015). Self-image is similar to self-concept but is less comprehensive. A person's self-image is based on how they see themselves, but self-

concept is a more thorough evaluation of the self, based mostly on how a person sees, values, thinks about, and feels about oneself (Ackerman, 2021; McLeod, 2008).

A person's self-image develops over time and is shaped by the experiences they have had. A positive and negative self-image possesses a number of qualities. Feeling confident; comparing themselves positively with peers; being contented with how they look and believing in their own ability; and receiving positive feedback from friends and family on looks and abilities are some of the characteristics of a positive self-image, whereas negative self-image characteristics include doubting one's own ability; comparing themselves negatively with peers and images on social media/TV/magazines; and receiving negative comments from friends and family on looks and abilities (Singh & Dhillon, 2020; Frisen, Berne & Lunde, 2014).

In the past, age and gender disparities in self-esteem were more common than differences in self-image, but only a few researchers looked at age differences in self-image. Webster and Tiggemann (2003) discovered, for example, that the link between self-esteem and negative self-image or body dissatisfaction was larger in women aged 35 to 49 ('middle age' group) than in women aged 20 to 34 ('young adulthood') or 50 to 65 ('older adults'). Although age disparities in self-esteem patterns are stable across genders, several research have found that girls exhibit slightly higher age differences than males (Orth, Trzesniewski & Robins, 2010; Robins, Trzesniewski, Tracy, Gosling & Potter, 2002).

An individual's attitude toward himself/herself, particularly his/her appearance, is a crucial component of one's total image of self and is significantly related to psychological and physical well-being (Vilhelmsson, Kristjansdottir & Ward, 2012). Negative self-image is a serious issue that jeopardises the psychological health of both young men and women (Ackard, Fulkerson & Neumark-Sztainer, 2007). People who have been insulted or taunted about their appearance are more likely to exhibit body dissatisfaction (Ackard et al., 2007).

Victims of cyber bullying reported being mocked about their physical appearance by their peers via social media and electronic messages, and as a result reported having low body esteem or being unhappy (Frisen et al., 2014). Unfortunately, being unhappy with one's own self-image had detrimental consequences such as depression symptoms (Rawana, Morgan, Nguyen & Craig, 2010).

In today's image-dominated world, one of the most important factors of social standing is physical attractiveness; hence, positive self-presentation in social media is primarily directed toward visual components of self-image. Photographs in the social media sphere have evolved into images designed to elicit acclaim from an often-invisible audience. The goal of both the content and the method of presentation of images is to project the development of an ideal self and to gain social acceptability. In a circumstance when people receive contradicting feedback, this may have a negative impact on their self-image (Frisen et al., 2014).

Cyber bullying is one of the problems that undergraduate students in Nigeria face, (Olumide et al., 2015, Ada et al., 2016), and it has created health concerns (Okoiye, Anayochi & Onah, 2015). As a result, studies such as Plichta, Pyalski, and Barliska (2018) concentrated on how teenagers self-image impairments predisposed them to cyber bullying. Similarly, Martinez-Monteaudo, Delgado, Garcia-Fernández, and Ruz-Esteban (2020) discovered that a high degree of sadness and stress increases the likelihood of becoming a victim of cyber bullying. They also discovered that undergraduates' psychological, emotional, and social adaption predisposes them to cyber bullying experiences. However, little or no attention was paid to the impact of cyber bullying on undergraduates' self-image, particularly in Nigerian universities, and this is the vacuum that this study filled. Filling this gap identified in the literature would assist in expanding knowledge of the impact of cyberbullying on self-image thereby, intimating counsellors and other stakeholders on the need to address the self-image of undergraduates who are victims of cyberbullying. The objective of this study is to analyse the

relationship between cyberbullying and self-image of undergraduates in Nigeria and the power of cyberbullying on the positive and negative self-image of undergraduates for being a victim of cyberbullying in Nigerian universities. Considering the limited number of prior studies in this area, this study seeks to find out:

- i. undergraduates' perception of their self-image
- ii. undergraduates' experience of cyberbullying
- iii. how cyberbullying experience impacts undergraduates' self-image
- iv. if the variables of age, gender, what they use internet for, and the length of time spent online moderate the impact of cyberbullying experience on respondents' self-image

Research Questions

The study answered two research questions stated thus:

1. What is self-image of undergraduates in the Nigerian university?
2. What is the level of cyber bullying experienced by undergraduates in the Nigerian university?

Research Hypotheses

The following hypotheses were formulated and tested in the study:

1. There is no significant relationship between the self-image and cyber bullying experience of undergraduates in the Nigerian university.
2. Gender, age, length of years in using the internet, amount of time spent on line, and what internet is use for will not significantly affect the influence of cyber bullying on self-image of undergraduates in the Nigerian university.

2. METHODOLOGY

This is a descriptive survey of the correlational variety. The survey approach is best suited for gathering information from a representative sample

of the target population as well as establishing relationships between or among several sorts. In this study, the population consisted of all undergraduate students in the study area, which was estimated to be fifty thousand (50,000) students, and a sample of 420 respondents was chosen. Required sample size of 357 is suggested by Research Advisor (2006) for population of this magnitude, however, a total of 420 undergraduates was selected to cater for attrition. A random sample technique was used to choose five out of the fifteen (15) faculties in the area of study, which included Agriculture, Arts, Education, Life Sciences, and Social Sciences faculties. Similarly, 84 respondents were chosen at random from each of the faculties. The respondents were stratified based on gender, age, length of years in using the internet, amount of time they spent on line and what they use the internet for.

A researchers designed questionnaire entitled: “Influence of Cyber Bullying on Self-Image Questionnaire (ICBSQ), which was validated by five experts in the Department of Counsellor Education, University of Ilorin. A test re-test reliability was carried out on the instrument and reliability coefficient of 0.75 and 0.72 were obtained for sections (B & C) on experience of cyberbullying and cyberbullying impacts on self-image respectively, which made the instrument suitable for the study.

The questionnaire was based on a four-point Likert Type scale of Strongly Agree (SA), Agree (A), Disagree(D), Strongly Disagree (SD), and it was used for scoring with the highest score for each item being four (4) and the lowest being one (1). Sections A, B and C of the instrument were analysed using percentage, and Pearson’s Product Moment Correlation and Univariate Analysis of Variance were used to test the formulated hypotheses at 0.05 significance level.

3. RESULTS

Table 1 shows that females make up the bulk of participants in this study, with 240 (57.3 percent) of the population sample, while males make up just 179 (42.7 percent). Students aged 21–25 years had the highest participation rate (274, 65.4 percent),

followed by participants aged 16–20 years (110 (26.3 percent), while participants aged 26 years and above have the lowest participation rate, accounting for just 35(8.4 percent) of the total sampled population.

Table 1: Demographic Distribution of Respondents

Variables	Frequency	Percent
Gender		
Male	179	42.7
Female	240	57.3
Total	419	100.0
Age		
16-20yrs	110	26.3
21-25yrs	274	65.4
26yrs and above	35	8.4
Total	419	100.0
Internet Usage		
News	54	12.9
Learning	176	42.0
Social Interaction	111	26.5
Communication	44	10.5
Entertainment	34	8.1
Total	419	100.0
Time spent on Internet		
Less than an hour	69	16.5
1 - 5 hours	153	36.5
6 hours and above	197	47.0
Total	419	100.0
Years of Internet Usage		
Less than a year	34	8.1
1 - 5 yrs	154	36.8
6 - 10 yrs	173	41.3
Over 10 yrs	58	13.8
Total	419	100.0

Table 1 also shows that individuals are divided into five groups based on their internet usage. Participants who use the internet for Learning account for 176 (42.0 percent) of the total respondents, followed by those who use it for Social Interaction, who account for 111 (26.5 percent), 54 (12.9 percent) of the total sample, 44 (10.5 percent) of the total, and 34 (8.1 percent) of the total respondents. Participants who use the internet for Entertainment account for 34 (8.1 percent). According to Table 1, participants who

spent 6 hours or more make up the majority of the sample, accounting for 197 (or 47.0 percent) of the total sampled population. Despite the fact that 153 (36.5 percent) of the participants spend 1 – 5 hours on the internet, 69 (16.5 percent) of them spend less than an hour. The table finally divided the participants into four groups based on the amount of years they had been using the internet. On this basis, the greatest number of participants, 173 (41.3 percent) have spent 6 – 10 years using the internet, followed by those who have spent 1 – 5 years, 154 (36.8 percent), while 58 (13.8 percent) of the participants have spent more than 10 years using the internet, with the smallest number being those who have spent less than a year, 34 (8.1 percent) of total participants.

Research Question 1: What is self-image of undergraduates in Nigerian university?

Table 2: Undergraduates’ Self-Image

Level	Frequency	Percentage
Negative	280	66.8
Positive	139	33.2
Total	419	100

Table 2 revealed that majority of the undergraduates (66.8%) had negative self-image while 33.2% of the undergraduates had positive self-image.

Research Question 2: What is the level of cyber bullying experienced by undergraduates in Nigerian university?

Table 3: Undergraduates’ Level of Cyber bullying Experienced

Level	Frequency	Percentage
Low	344	82.1
Moderate	70	16.7
High	5	1.2
Total	419	100

Table 3 showed that majority of the respondents (82.1%) reported low cyber bullying experience, 16.7% of the respondents reported moderate level of cyber bullying experience while 1.2% of the respondents reported high level of cyber bullying experience.

Hypotheses Testing

Hypothesis 1: *There is no significant relationship between the self-image and cyber bullying experience of undergraduates in Nigerian university.*

Table 4: Pearson’s Correlation Results showing the relationship between cyber bullying and self-image of University of Ilorin undergraduates

Variables		Cyber bullying	Self-Image
Cyber bullying	Pearson Correlation	1	.161**
	Sig. (2-tailed)		.001
	N	419	419
Self-Image	Pearson Correlation	.161**	1
	Sig. (2-tailed)	.001	
	N	419	419

** . Correlation is significant at the 0.01 level (2-tailed).

Table 4 showed that the correlation between cyber bullying and self-image is 0.161, which is significant as $p < 0.01$ level for 2-tailed test based on 419 complete observations. It is therefore observed and concluded that: cyber bullying and its influence on self-image have a statistically significant linear relationship ($r = .161, p < 0.01$). Also, the direction of the relationship is positive (i.e., cyber bullying experience and self-image of participants are positively correlated), meaning that these variables tend to increase together (i.e., the greater the cyber-bullying experience, the greater the influence on self-image). Hence, there is a significant relationship between the self-image and cyber bullying experience of undergraduates in Nigerian university.

Hypothesis 2: *Gender, age, length of years in using the internet, amount of time they spent on line, and what they use the internet for will not significantly affect cyber bullying influence on self-image of undergraduates in Nigerian university.*

Table 5 showed the results of the Univariate Analysis of Variance of the respondents’ demographic data on influence of cyber bullying on self-image. The table

revealed that gender (df = 1, F-value =0.02, p= .865), age (df = 2, F-value =0.33, p= .719), what they use the internet for (df = 4, F-value =2.04, p= .089), amount of time they spent on line (df = 2, F-value = 0.12, p = .882), length of years in using the internet (df = 3, F-value =2.61, p=.052) did not significantly affect respondents' views on cyber bullying influence on self-image of undergraduates in Nigerian university.

Table 5: Univariate Analysis of Variance showing differences in the Respondents' Demographic Data on Influence of Cyber bullying on Self-Image

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	23065.34 ^a	164	140.64	1.53	.001
Intercept	248891.19	1	248891.19	2717.91	.000
Gender	2.64	1	2.64	.02	.865
Age	60.62	2	30.31	.33	.719
Internet Use	747.30	4	186.82	2.04	.089
Duration of Usage	22.91	2	11.45	.12	.882
Yrs. of Int. Use	717.70	3	239.23	2.61	.052
Error	23259.89	254	91.57		
Total	966546.00	419			
Corrected Total	46325.24	418			

4. DISCUSSION

The study revealed that majority of the undergraduates (66.8%) had negative self-image. The finding of the study is related to the study of Kearney, Cooke and Tieger (2015) who reported that 68% of teenagers studied felt upset and ashamed in relation to their self-image which could probably be due to undergraduates' interactions or experiences with teachers, friends or family. In this study however, respondents reported negative self-image due to experience of cyber bullying.

The finding of the study also showed that 16.7% of the respondents experienced moderate level of cyber bullying while 1.2% of the respondents experienced high level of cyber bullying. This study is similar to studies of Akor (2012), Oyewusi and Orolade (2014), Okoiye, Anayochi and Onah (2015), Olumide, Adams and Amodu (2015), Ada, Okoli, Obeten and Akeke (2016) who reported occurrence of cyber

bullying in Nigeria. This could be as a result of undergraduates' accessibility to various social media platforms while many of them hide their identity to perpetrate cyber bullying.

The study revealed that there was a significant relationship between self-image and cyber bullying experiences of undergraduates in Nigerian university. The finding is related to the assertion of O'Brien and Moules (2013) who stated that cyber bullying may have effect on victims' self-image. Ghinea and Vladislav (2020), Estevez et al., (2019), Smith (2011) Patchin and Hinduja (2010) found significant relationships between cyber bullying and self-image. Smith (2011) reported that persons with disabilities and persons whose appearance was altered by disability experience were subjected to cyber bullying significantly more often. Also, Sourander et al. (2010) asserted that cyber bullying can cause significant emotional and psychological harm that can result in affected students developing low self-esteem and poor self-concept and becoming less efficacious in their relationship with their environment. Estevez et al. (2019) established that the self-image of a cyber-bully victim is negative compared to that of the perpetrator.

It was found that gender, age, what they use the internet for, amount of time they spent on line, length of years in using the internet did not significantly affect respondents' views on cyber bullying influence on self-image of undergraduates in Nigerian university. This implies that the impact of cyber bullying on undergraduates' self-image is not affected by gender, age, what they use the internet for, amount of time spent online and length of years in using internet. The outcome of the enquiry is in tandem with that of de Vries, Peter, de Graaf and Nikken (2016), who discovered that gender did not moderate the impact of social media usage on self-image of teenage boys and girls. However, the outcome negates the findings of McLean et al., (2019); Mills, Musto, Williams and Tiggemann (2018) who found female self-image to be more negatively impacted when they experience cyber bullying than that of males.

Different researchers (Schneider et al., 2012; Schenk & Fremouw, 2012; Bonanno & Hymel, 2013) who worked across students of varying school levels (middle, high and college) that cut across age range found that cyber bullying significantly relate to lower self-image in their respondents regardless of their age. The results of the inquiry regarding what they use the internet for is in line with that of Steinsbekk, Wichstrom, Stenseng, Nesi, Hygenand Skalicka (2021) who discovered that it is not what adolescents use the internet for that impact on their self-image, rather the kinds of social media usage determine the negative impacts it has on their self-image. This outcome also relates to the study of Niemz, Griffiths and Banyard (2005) who stated that usage of internet for any means sometimes lead to loneliness and may have opposite effect on self-worth or self-esteem. The finding supports the study of Rohall, Cotton and Morgan (2002) who found that hours spent using the internet for e-mail or other forms of online communication is not associated with self-esteem. The reason for the findings may be that the intensity of cyber bullying experience may not necessarily relate with the amount of time spent online since Paiban et al., (2021) found the intensity of cyber bullying victimization relate to the level of negative self-image.

5. CONCLUSIONS

In this study, it is established that cyber bullying impacts negatively on the self-image of Nigerian undergraduates regardless of their age, gender, time spent online, duration of using the internet and what they use the internet for. The outcomes emphasize the need for future study to inquire how different kinds of cyber bullying impact undergraduates' self-image. Undergraduates, academic staff of universities in Nigeria, counsellors and other professionals, parents, university administrators should take note of the negative impacts of cyber bullying on self-image and subsequent effects.

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PERCEPTION OF CAREGIVERS ON THE ATTITUDE OF PARENTS TOWARDS THE EDUCATION OF PERSONS WITH DISABILITY IN KWARA STATE, NIGERIA

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ABSTRACT

This study investigated the perception of caregivers on the attitude of parents towards the education of persons with disability in Kwara State, Nigeria. The population comprised all caregivers of persons with disability in Ilorin Metropolis. A two-stage sampling method was also used in this study. Data were collected using a researcher-designed instrument tagged “Attitude Towards Education of Persons with Disability Questionnaire (ATEPDQ)”. The tool has sections A and B. Section A of the instrument elicited information on the respondents’ demographic data while section B contained items on parents’ attitudes towards the education of persons with disability. A reliability coefficient of 0.72 was obtained, which shows that the instrument was reliable for the study. Most respondents perceived that “educating persons with disability is a waste of time” (with a mean score of 3.06). Also, the findings of the study revealed that gender, school type, religion, and years of working experience did not significantly influence parents’ attitudes towards the education of persons with disability as perceived by caregivers in Ilorin metropolis. Based on the findings of the study, it was therefore recommended that the government should provide access to free education for persons with disability. This is expected to encourage parents to send their wards with disabilities to school. This, in turn, will enhance their skills and talents for employability.

KEYWORDS: *Parents Attitude, Care Givers, Persons with Disability*

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1. INTRODUCTION

Disability is a measurable functional loss that hampers an individual's performance, and it can also be referred to as a medically diagnosable impairment problem. Ajobiewe (2000) defined disability as any restriction resulting from an impairment that prevents an individual from performing an activity in a manner that is required. Neinstein (2008) revealed that there are different types of disability, and this includes people with visual impairment, speech impairment, learning disabilities, multiple disabilities, mental retardation and hearing impairment, etc. Education is the primary tool for rehabilitating children with disability and this process is majorly used in imparting skills that are needed to live a meaningful life (Artale, 2003 & Uzoma, 2013).

Ajobiewe (2000) noted that historically, many believe that people with disability cannot be educated or trained, but through the assistance of caregivers, schooling is made easy. Obani (2003) noted that a negative attitude towards the education of persons with disability can be more disabling than the disability itself. Providing education and psychological support makes life more meaningful to this group of students. A caregiver is an individual who offers primary care for persons with disability. The primary caregivers may be trained professionals and personnel within the school system or other individuals who relate and assist these students directly (Barbara, Ann & Janny, 2010). Olalekan (2016) observed that parents of people with disability also experience burnout in the course of carrying out their duties. These challenges make the task of a caregiver extremely difficult. Akinpelu (2016) and Ozoji (2005) explained that students with disability need to be assisted because of their disabling condition. The government, in a bid to provide adequate support for persons with disability, introduced special education (Duruh, 2013 & Aldawid, 2010).

Irrespective of one's disability, the National Policy on Education clearly stated the need for equal educational opportunities for every member of the society (Federal Republic of Nigeria, 2004). For this purpose to be achieved, the Federal Government of Nigeria approved

the disability act. This act provided legal protection for Nigerians with disability. The bill ensures that people with disability are taken care of regardless of their level of disability. With this bill, persons with disability are entitled to opportunities, equal privileges, and rights. Also, the government is mandated to provide a free and appropriate education for these categories of people (Ewang 2019). The enforcement of this bill has encouraged integration and removal of stigmatization and physical barriers existing in different spheres of society, which is likely to result in negative attitudes (Onaolapo, 2007).

The perceptions of parents about their children with disability are essential because this influences the acceptance and integration of their ward into the family (Olalekan, 2016). The misconception of parents about children with disability is a barrier for opportunities of assisting these groups of children. This is because most of these children cannot take some major decisions without the consent of their parents (Abang, 2005). Parents play a significant role in providing opportunities for their wards with disability. Most parents of children with disabilities are plagued with constant recurrence of guilt, sadness, shock, shame and pain and most often deny their ward access to education (Chandramuki, Shastry, Vranda 2012). According to Peck, Staub, Gallucci & Schwartz (2004), the attitude of students with disability towards life can be influenced by the perception of their parents. The attitude of parents plays a significant role in the education of persons with disability.

Oladipo (2006) revealed that in Nigeria, most parents believe that sending persons with disability to school is a waste of time and resources. The number of people with disabilities has continued to increase daily (Kolo, 2001). Ozoji (2005) noted that despite the establishment of special needs schools, many parents prefer to keep their wards at home rather than enroll them in school. Abdulganiyu (2017) also reported that majority of parents are not interested in the academic performance of their wards with disability. According to Chandramuki, Shastry, & Vranda (2012), such negative attitudes often affect the physical and psychological well-being of children with disability.

In Nigeria, societal attitude towards people with disability is negative; this can be linked to different cultural and religious belief systems. In Nigeria, most parents do not want to identify with challenged children, and these children are taken to caregivers for daily upkeep. Seeking their opinions is paramount in this study. From the religious point of view, Omotosho (2010) explained that in some Nigerian cultures, people with disability are considered close to God, while some have a contrary opinion that they are demonic agents that must be destroyed. Society believes persons with disability cannot make a meaningful contribution to their respective communities, and they are seen as a curse and as signs of bad luck. As such, people often avoid associating with them (Onaolapo, 2007). Olawale (2000) observed that the attitude of parents towards the education of these categories of people is not encouraging, while some of them have developed a nonchalant attitude towards their ward as a result of cultural beliefs. This has led to gender inequality in Nigeria and Africa at large (Obadiya, 2011). Psacharopoulos and Patrinos (2002) explained that religious and socio-cultural factors have contributed to the low participation of women in education. This tradition affects even female students with disability.

Through integration, parents have gladly embraced a positive attitude towards the education of their wards with disability. This has helped in reducing the level of stigmatization. From the view of social psychologists, attitudes have three main components, and they include cognitive, behavioral, and affective levels. The cognitive attitude explains the belief a person has about an object, the behavioral attitude discusses about the way people react towards an object while the affective attitude includes feelings about an object, (Salta & Tzougraki, 2004). Attitude can be conveyed towards any object where a comparison with another is involved. As such, attitude is a psychological tendency expressed in one's belief system. (Eagly & Chaiken, 2008).

Parents' attitude towards the education of their ward with disability is often determined by the school type (mainstream, inclusive, or special Needs schools).

Bennett and Gallagher's study (2013) revealed that most parents' attitude towards the inclusion system is positive; however, some do not see the need for such an arrangement because they are concerned about the quality of instruction their ward with disability receives. In the same vein, Okunyibo, Oyewumi, and Adedidran (2009) observed that the type of school a child with disability attends is determined by variables such as the nature of the disability and the parent's educational level. The result of Leyser and Kirk's (2004) study confirmed that while some parents encouraged inclusion and mainstreaming, others feared possible isolation and stigmatization of their ward with disability.

It is assumed that most attitudes spring from one's belief system. Albert Ellis propounded a theory called Rational Emotive Behaviour Therapy (REBT) in the year 1950. This theory is based on certain assumptions that a person's belief system influences his or her attitude. As such, man can act either rationally or irrationally. According to David and Avellino (2002), REBT believes that it is not events that directly influence the attitudinal behaviour of a person but one's beliefs about such an event. According to REBT theory,

A - The activating event which is the disability,

B - Belief of A,

C - The emotional consequences or how a person reacts about A,

D - Counsellors disputing the client's irrational thoughts,

E - Presumed consequences of the therapist intervention,

F - The new feelings the client has regarding the situation

REBT explains that it is not the A (Activating event which is the disability) that causes the negative attitudes of parents but their B (belief about disability). This often leads to C (emotional consequences). If parents of children with disability have a negative belief system towards their wards with disability, this

will naturally result in negative emotional consequences. That is why most people feel that educating their ward with disability is a waste of time and resources (Table 5). These are illogical sentences that parents of a person with disability repeat to themselves, which can negatively influence their attitudes. The primary aim of REBT is to reduce irrational thoughts in favour of rational beliefs. At the D, the counsellor or caregiver disputes or invalidates the irrational beliefs which the parents have about their children with disability. If the caregivers successfully dispute the irrational belief, the parents will develop new feelings and attitudes towards their children with disability.

2. PROBLEM STATEMENT

According to Olalekan (2016) there are over 3 million people with disability in Nigeria, and many of them are out of school. As a result of superstitious beliefs associated with this category of children, parents often discourage them from attending school to prevent discrimination. As a result of lack of cooperation from parents, caregivers face extremely challenging tasks in dealing with these students. Sandra (2018) worked on challenges of teaching pupil's visual impairment in inclusive classroom, Akinade (2019) carried out a study on problems of managing adolescents with special needs as expressed by teachers in Oyo State while Tatjana and Karmen (2016) looked at views of Geography teachers on working with students with special educational needs. To the best knowledge of the researchers', none has worked on parents' attitudes towards the education of persons with disability as perceived by caregivers in Ilorin Kwara State, Nigeria, hence the need for this study. The research question aimed at looking at the perception of caregivers on the attitudes of parents towards the education of persons with disabilities. The hypotheses checked if there is no significant difference in the perception of caregivers on the attitude of parents towards the education of person with disability based on gender, school type religion, and working experience.

3. METHODOLOGY

The descriptive casual comparative design was used in

this research, and the study involved all caregivers of persons with disability in Ilorin Metropolis. According to Research Advisor (2013) for a population of 400, the table suggested 196 respondents at 95% confidence level and a margin error of 5.0%. Thus, to cater for the attrition rate, the sample size was increased to 210. After the administration, the researchers were able to retrieve 200 questionnaires. The sampling method used was a two-stage procedure. At the first stage, all the schools that had students with disability were purposively sampled for this study. A proportionate sampling technique was used in selecting two hundred respondents across board. This gives an equal opportunity to the respondents of being selected according to the number of caregivers in each school. For example, fifty percent of the staff population in each of the schools were chosen, (Integrated schools - 15 respondents, Mainstream School - 22 caregivers, and Special School - 163 respondents).

Data were collected using a researcher-designed instrument tagged Attitude Towards Education of Persons with Disability Questionnaire (ATEPDQ). The instrument has two sections. Section A of the instrument elicited information on the respondent's demographic data while section B contained 15 items on parents' attitude towards the education of persons with disability. This was scored on four-point Likert scale of Strongly Agree - 4 points, Agree -3 points, Disagree- 2 points and Strongly Disagree-1 point. The validity of the instrument was ascertained by giving copies of the questionnaires to experts for face and content vetting. Their suggestions were considered in the final draft. Reliability is the ability of a test to consistently measure what it was supposed to measure (Sanni, 2002). For the reliability of the instrument, the same test was administered and re-administered to 20 teachers in a secondary school setting who were not part of the respondents within an interval of four weeks. The two scores obtained were correlated using Pearson Product Moment Correlation Formula (PPMC) and a reliability index of 0.72 was obtained. This method is appropriate because it ensures that the information obtained in the two sittings are both representative and stable over time.

4. RESULTS

The demographic data of the respondents entail the distribution of respondents by the moderating variables of gender, school type, religion, and years of working experience.

Table 1: Distribution of Respondents by Gender, Religion and Years of Working Experience

Variable	Frequency	Percentage
Gender		
Male	87	43.5
Female	113	56.5
Total	200	100
Religion		
African Traditional Religion	7	3.5
Christianity	85	42.5
Islam	108	54.0
Total	200	100.0
Years of Working Experience		
Below 5 years	23	11.5
6 – 10 years	64	32.0
11 years and above	113	56.5
Total	200	100.0

The above table indicates the distribution of respondents by gender, school type, religion, and years of working experience. It is observed that out of 200 respondents, 87(43.5%) are male while 113(56.5%) are female. This implies that female respondents participated more in the study. Also, 15(7.5%) were from integrated schools, 22(11.5%) were from mainstreamed schools while 163(61.5%) were from schools for special needs students. The result additional explains that 7(3.5%) are into African Traditional Religion, 85(42.5%) are of Christian religion while 108(54.0%) are practicing Islamic religion. 23(11.5%) had below 5 years of working experience, 64(32.0%) had 6-10 years of working experience while 113 (56.5%) had 11 and above years of working experience.

Research Question 1: What are the perceptions of caregivers on the attitudes of parents towards the education of persons with disabilities in Ilorin Kwara State?

Table 2: Percentages and Mean on the Perception of CareGivers on the Attitudes of Parents Towards the Education of Persons with Disabilities

Item No	As far as I am concerned many parents:	Mean	Rank
5	feel that educating persons with disability is a waste of resources	3.06	1 st
4	believe that their children with disability cannot display maturity which require skills needed for education	3.05	2 nd
9	believe that most of the things that are learnt in school are not relevant to persons with disability	2.83	3 rd
8	believe that their children with disability cannot comprehend academic activities	2.82	4 th
6	believe that persons with disability cannot perform well academically	2.79	5 th
13	Prefer to abandon their children with disability with the school caregivers	2.76	6 th
11	do not identify with their children with disability	2.62	7 th
12	are not interested in the academic performance of their children with disability	2.50	8 th
14	Feel that sending children with disability to school is a waste of time	2.46	9 th
3	are ashamed of bringing their wards with disability to school	2.44	10 th
7	believe that persons with disability can never be useful in life so they should not be in school	2.38	11 th
15	do not assist these students with school assignments	2.37	12 th
10	believe that persons with disability should learn a trade rather than going to school	2.36	13 th
1	feel that identifying with persons with disability is a disgrace	2.18	14 th
2	are not positive about the future career of their ward with disability so they prefer them to stay at home	2.15	15 th
<ul style="list-style-type: none"> Standard Reference Mean = 2.50; 			

Table 2 shows that “as far as I am concerned parents feel that educating persons with disability is a waste of resources” has the highest mean of 3.06 and is ranked first while item 2 with the mean of 2.15 ranked the last. However, with a benchmark mean of 2.50, all items above the benchmark mean are considered as the major factor in the perception of care givers on the attitudes of parents towards the education of persons with disabilities in Ilorin Kwara State.

Hypotheses Testing

Four null hypotheses were generated and as well tested for this study. The hypotheses were tested using chi-square statistical method at 0.05 level of significance.

Hypothesis One: *There is no significant difference in the perception of care givers on the attitudes of parents towards the education of persons with disabilities in Ilorin metropolis based on gender*

Table 3: Chi-square showing the perception of care givers on the attitudes of parents towards the education of persons with disabilities in Ilorin metropolis based on gender

Gender	Frequency			df	Cal. X^2	p-value	Decision
	Disagree	Agree					
Male				1	0.002	0.96	Accepted
Observed	28	59	87				
Expected	27.8	59.2					
Female							
Observed	36	77	113				
Expected	36.2	76.8					
Total			200				

Table 3 shows that the calculated X^2 value is 0.002 and p-value is 0.96. Since the calculated p-value is greater than the alpha level of 0.05, the hypothesis is accepted. This implies that there is no significant difference in the perception of care givers on the attitudes of parents towards the education of persons with disabilities in Ilorin metropolis based on gender.

Hypothesis Two:

There is no significant difference in the perception of care givers on the attitudes of parents towards the education of persons with disabilities in Ilorin metropolis based on school type.

Table 4 shows that the calculated X^2 value is 0.67 and p-value is 0.71. Since the calculated p-value is greater than the alpha level of 0.05, the hypothesis is accepted. This implies that there is no significant difference in the perception of care givers on the attitudes of parents towards the education of persons with disabilities in

Ilorin metropolis based on school type.

Table 4: Chi-square showing the perception of care givers on the attitudes of parents towards the education of persons with disabilities in Ilorin metropolis based on school type

School Type	Frequency			df	Cal. X^2	p-value	Decision
	Disagree	Agree					
Integrated							
Observed	6	9	15	2	0.67	0.71	Accepted
Expected	4.8	10.2					
Mainstream							
Observed	6	16	22				
Expected	7.0	15.0					
Special							
Observed	52	111	163				
Expected	52.2	110.8					
Total			200				

Hypothesis Three:

There is no significant difference in the perception of care givers on the attitudes of parents towards the education of persons with disabilities in Ilorin metropolis based on religion

Table 5: Chi-square showing the perception of care givers on the attitudes of parents towards the education of persons with disabilities in Ilorin metropolis based on religion

Religion	Frequency			df	Cal. X^2	p-value	Decision
	Disagree	Agree					
ATR							
Observed	4	3	7	2	2.30	0.32	Accepted
Expected	2.2	4.8					
Christianity							
Observed	25	60	85				
Expected	27.2	57.8					
Islam							
Observed	35	73	108				
Expected	34.6	73.4					
Total			200				

Table 5 shows that the calculated X^2 value is 2.30 and p-value is 0.32. Since the calculated p-value is greater than the alpha level of 0.05, the hypothesis is accepted. This implies that there is no significant difference in the

perception of care givers on the attitudes of parents towards the education of persons with disabilities in Ilorin metropolis based on religion.

Hypothesis Four: *There is no significant difference in the perception of care givers on the attitudes of parents towards the education of persons with disabilities in Ilorin metropolis based on years of working experience.*

Table 6: Chi-square showing the perception of caregivers on the attitudes of parents towards the education of persons with disabilities in Ilorin metropolis based on years of working experience

YOWE	Frequency			df	Cal. X^2	p-value	Decision
	Disagree	Agree					
Below 5 years							
Observed	7	16	23	2	0.04	0.97	Accepted
Expected	7.4	15.6					
6 – 10 years							
Observed	21	43	64				
Expected	20.5	43.5					
11 years and above							
Observed	36	77	113				
Expected	36.2	76.8					
Total			200				

Table 6 shows that the calculated X^2 value is 0.04 and p-value is 0.97. Since the calculated p-value is greater than the alpha level of 0.05, the hypothesis is accepted. This implies that there is no significant difference in the perception of care givers on the attitudes of parents towards the education of persons with disabilities in Ilorin metropolis based on years of working experience.

5. DISCUSSION

From the findings of this study care givers revealed that parents acknowledged that educating persons with disability is a waste of resources, which shows that their attitude towards the education of persons with disability is negative. This impression comes from what caregivers perceived from the response of parents concerning their wards. Adogo (2006) revealed that the attitude of parents towards the education of learners with disability is negative. According to Akinade

(2019), majority of parents of persons with disability are overwhelmed with mixed feelings of self-blame and helplessness, this often leads to the establishment of adverse attitudes towards their wards with disabilities. Society also believes that educating children with special needs might be a waste of time. With the passage of disability bill into law in Nigeria in 2019, there is the likelihood that the public take the education of persons with disability seriously.

Gender, religion and type of school of the respondents did not significantly influence the perceptions of the caregivers in Ilorin metropolis. All caregivers irrespective of gender are likely to experience the same attitude from parents of persons with disability. Caregivers believe that the misconception of parents about disability are barriers for opportunities of rendering assistance to these groups of children (Tajana & Krmen, 2016).

Most Nigerians are tied to different belief systems. Adewara (2012) noted that since the tenets in the three major religions in Nigeria are different, parents of persons with disability and their care givers are likely to hold different views about children with special needs. Despite the fact that respondents are of different religious settings, their perceptions were not different on parents' attitude towards the education of persons with disability. Kolo (2001) noted that educating children with disability is still a major challenge in Nigeria. In the same vein, Obani (2003) reported that negative attitudes and stereotypical behaviours of society towards people with disability is a major challenge.

Irrespective of school type, respondents have similar opinions concerning parents' attitude towards the education of children with special needs. The plausible reason might be due to the fact that care givers have similar experience and they are committed to giving care, as such they serve as a link between the parents and children with disability (Kindersley, 2013).

However, the perception of the respondents was significantly different based on their years of experience. Experiences are gained in a task through constant practice, and it is therefore implied that years

of experience are expected to influence the perception of the care givers. Lisa Pau Le Low, Wai Tong Chien, Lai Wah Lam, and Kayla Ka Yin Wong (2017) noted that caregiving is a great task that is challenging and extremely sensitive. This process requires enduring commitment which can be obtained through various years of experience.

6. CONCLUSION AND RECOMMENDATIONS

The findings of the study revealed that all the hypotheses on the perception of the caregivers on attitude of parents towards the education of persons with disability were accepted. It was therefore recommended that

1. The school caregiver should constantly enlighten the public and parents of persons with disability on the need to invest on the education of these children.
2. Care givers should encourage parents with challenged children to bring their wards to school irrespective of gender.
3. Despite the care givers' years of experience, parents should constantly give required support to them. This will help in enhancing the education of persons with disability.
4. Parents of the physically challenged students should give their children required attention by assisting them in their school assignments and participating in the school activities.

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A RECHARGEABLE PULSE OXIMETER FOR REMOTE MONITORING OF MULTIPLE PATIENTS

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ABSTRACT

Pulse oximetry is a widely used medical respiratory method that is used to measure arterial blood oxygen saturation and pulse rate. Pulse oximeters enable measurements of the oxygen saturation in blood, which is an essential parameter in most clinical applications including diagnosis and rehabilitation. The demand for pulse oximeters is rapidly rising with the increasing occurrence of respiratory diseases and cardiovascular diseases. However, the existing pulse oximeters can only be used for a single patient, and multiple patient monitoring systems for patients in hospitals and home-based patients are not yet available in the current market. The existing devices also require manual patient data recording and frequent examinations of oxygen saturation levels. Also, most of the existing pulse oximeters are powered by batteries which will have to be periodically replaced. Hence, the main aim of this research is to develop a wireless wearable pulse oximeter for continuous patient monitoring by incorporating communication technologies such as the IoT technology- the Internet of Things. The proposed pulse oximeter will be a rechargeable one that allows Wi-Fi data transmission for temporary data storage. This is used for remote monitoring of multiple patients over a vast geographical area and it supports contact minimization to reduce transmissible diseases. An integrated alarming system is used to warn the doctor if the oxygen levels deplete abnormally, through a mobile application. The developed pulse oximeter has the ability to monitor 62 patients successfully, for a period of 2 days without charging. This non-invasive device will be developed in the future to support more patients, to increase the accuracy and the stability of the data displayed, and to minimize the time delay experienced during the transmission of data.

KEYWORDS: *Pulse Oximeter, Remote Monitoring, IOT- Internet of Things*

1. INTRODUCTION

The oxygen saturation of the blood is required for different healthcare applications including diagnosis procedures and treatment processes. Hence, a special procedure known as Pulse Oximetry is used to measure the level of oxygen that is dissolved in the blood. It is an indirect, safe, cost-effective, and quick procedure that measures the arterial oxygen saturation of the blood as a percentage. The normal blood oxygen percentage value for a healthy individual lies between 95%-100%. But the SpO₂ value can drop below normal due to different health conditions including lung cancer, chronic obstructive pulmonary disease (COPD), heart failure, anaemia, asthma, pneumonia, etc., and when undergoing sedation during different surgical procedures as well. It is essential to monitor the blood oxygen levels and take necessary measures such as supplying artificial ventilation to supply the required levels of oxygen to the body. Hence, most clinical scenarios require data about the amount of oxygen carried by the blood for the diagnosis of diseases and to prescribe further medications. Pulse oximetry is widely used in healthcare applications by clinicians to ensure that a sufficient amount of oxygen is delivered into the bloodstream and to check the health condition of patients suffering from different diseases that affect the oxygen saturation in the blood. Moreover, pulse oximetry is a vital tool in measuring the oxygen saturation of blood during different clinical applications including examination of the effectiveness of certain drugs and medical procedures.

Pulse oximeters are major diagnostic tools employed for the process of pulse oximetry and most pulse oximeters provide measurements for multiple physiological parameters. A pulse oximeter is a non-invasive medical tool that gives results within a few seconds without drawing any blood samples and is tested in medical laboratories using different complex equipment. A conventional pulse oximeter gives two readings including blood oxygen saturation as a percentage and pulse rate in Beats Per Minute (BPM). Thus, depending on the application and the requirement, a pulse oximeter can be placed on the

finger, earlobe, or around the leg of an infant, and accurate results can be obtained.

The pulse oximeter reading, which gives the arterial blood oxygen saturation, is determined using the principles of light absorption characteristics in blood. Pulse oximeters contain a sensor that includes two light sources that are two light-emitting diodes and a photodetector to measure the absorption. The two light-emitting diodes consist of two separate wavelengths. The two LEDs emit the light of wavelength 660nm for the red light and infrared light of 940nm wavelength. Thus, when the light passes through the blood in the finger, the absorption of the emitted light will be different for oxygenated blood and deoxygenated blood. Pulse oximeters calculate the light absorption difference between haemoglobin (Hb) and oxyhemoglobin (HbO₂), where oxyhemoglobin absorbs more infrared light of 660 nm wavelength and lesser red light of 940 nm wavelength than Hb. Thus, Deoxyhemoglobin absorbs more red light, and infrared is absorbed highly by oxygenated hemoglobin. The ratio of absorption is measured between two points and is compared with reference values. (John Hopkins Medicine, 2019) Hence the amount of oxygen saturation in the blood can be determined (Nitzan, Romem and Koppel, 2014).

There are two main methods of pulse oximetry. (Figure 1)

1. Reflective mode
2. Transmissive mode

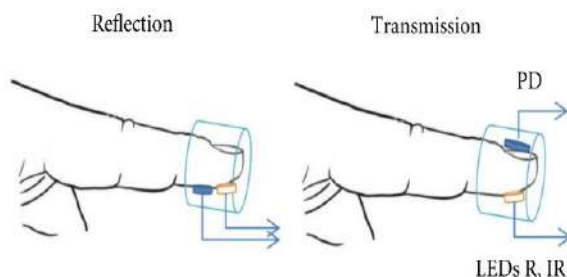


Figure 1. Reflective mode and transmissive mode of pulse oximetry. Source: (Fine and Kaminsky, 2019)

Depending on the measurement site and the application, either the transmissive or the reflective mode can be used (Lee, Ko and Lee, 2016). In the Reflective method, the light sources and the photodetector is placed on the same side. In contrast, in the transmissive mode, the sensor containing two light sources is situated on a side, and in a separate site opposite that, the photodetector is placed. The light emitted from the red and infrared LEDs passes through the fingertip and by using the photodetector on the opposite side, the transmitted light is captured for measurement. The transmissive mode is the most widely used method in pulse oximeters due to its higher accuracy and high stability (Lee, Ko and Lee, 2016). But, since the measurement is placed between the light source sensor and the photodetector, only thin measurement sites can be measured effectively. But in the reflective mode, since the light sources and the detector are on the same side, a thin site is not compulsory for accurate results as the thickness and the size will not be limiting factors for the measurement.

2. LITERATURE REVIEW

Pulse oximeters are non-invasive detectors that are used to assess the oxygen saturation levels of an individual's blood peripherally. The accuracy of a conventional pulse oximeter is 2-4% (Webster, 1997). Usually, the blood oxygen level lies between 95%-100% for a healthy individual (McCallum, 2020) This can be lowered due to different abnormalities in the body. Especially the uprising Covid-19 pandemic has led to an increase in the demand for pulse oximeters and thereby for the supply of pulse oximeters since this respiratory disease leads to the deterioration of the lungs and causes a decrease in the blood oxygen levels. Therefore, detection of the oxygen levels can indicate the severity of the disease. (Gotter, 2017)

The most widely used pulse oximeter is the finger-tip oximeter which is lightweight and compact. Pulse oximeters are predominantly used in hospitals, with a 36.5% market share. However, pulse oximeters used for homecare settings, have risen in number and they had the fastest-growing market in 2021 especially

due to the prevailing pandemic. (Health, C. for D. and R., 2021). The accuracy of the pulse oximetry readings is a highly important parameter when using the device. The accuracy of the readings obtained by the pulse oximeters can be reduced due to different reasons. Some of them include anemia, hyperpigmentation, low perfusion, electromagnetic interference, reduced body temperature, low blood pressure, and the presence of nail polish on fingernails. (Feiner, Severinghaus and Bickler, 2007)

With the advent of oxygen saturation detectors in the 1980s, bedside pulse oximeters that converted the pulse patterns and the infrared light and red-light absorption values into SpO₂ values were developed. These devices had great inaccuracies unless the sensors were perfectly calibrated. These limitations were overcome with the advancements of modern technology. However, exclusion of motion artifacts is still not successfully achieved (Welch, 2005). With advancements in innovative technology, the sensitivity of the device was increased, and wearable sensors were developed so that these machines became portable. The power consumption was lowered, and the range of applications was expanded. Latest pulse oximeters are able to monitor sportsmen, and sleep apnea and even aid the rehabilitation of patients. (Milner and Mathews, 2012) Different improvements have been made to the existing pulse oximeters to enhance accuracy, reduce motion artifacts, pair them with mobile phones, and aid sports and sleep monitoring. Moreover, wireless data transmission technologies are incorporated into the new and emerging pulse oximeters, which enable the transmission of obtained data remotely in real-time. (Hornberger et al., 2000)

The existing pulse oximeters can accurately measure the SPO₂ levels and the heart rate. However, most oximeters operate with two 1.5V AAA batteries which have to be periodically replaced. This is an added cost to the user and it is inconvenient too. Apart from this, the existing pulse oximeters obtain readings from a single patient. Multiple patient monitoring would not be possible using the existing pulse oximeters. In a hospital setting, where data from numerous patients would have to be constantly

monitored, it is inconvenient to check the oxygen saturation levels and blood pressure values of all patients frequently. If these variables are not frequently observed, it would be difficult to detect the abnormalities using the existing pulse oximeters. Also, manual recording of vital patient parameters increases the contact with a patient. This can increase the spread of infections in a hospital setting, from the patient to the health workers including nurses and doctors. (Welch, 2005)

It is also a commonly known fact that these pulse oximeters are slow in measuring and displaying their readings. Most common pulse oximeters take around 15 seconds to provide reliable SpO2 and Heart rate readings. This time delay is large enough to be noticeable and will be unsuitable when continuous monitoring of vital parameters is performed (FierceHealthcare, n.d.), (Greenhalgh et al., 2021).

The prevailing pandemic has brought about social distancing practices and quarantine measures. In Sri Lanka, around 10 Covid patients are assigned to one doctor to be monitored. However, it will be a strenuous task to observe multiple patients from different locations around the country throughout the day. The blood oxygen levels of Covid patients are subjected to constant fluctuations and if it drops to dangerously low levels, the life of the patient will be at stake. Thus, it is important to detect low blood oxygen levels in quarantined patients with a minimal time delay. (Watson, 2019) For patients who are crippled and are unable to move and especially for old patients, leaving their residence for regular hospital checkups would be inconvenient. The oxygen levels of old and diseased patients are also subjected to constant variations. Thus, it is vital that the oxygen levels and heart rates of these groups be monitored, and abnormalities should be detected immediately for further medications. However, existing telemetry systems fail to achieve this. (Hannhart et al., 1991).

3. METHODOLOGY

This project aimed to develop a wireless and rechargeable pulse oximeter that can be used for

remote monitoring of multiple patients simultaneously in real-time. This system was designed to measure the blood oxygen levels of all individuals. This would be highly useful for monitoring multiple patients in hospital wards and Intensive Care Units (ICU), patients who are quarantined at home, elderly patients, and individuals who are crippled, or bedridden. This system is comprised of 3 main parts: (Figure 2)

1) *The patients' end:* The wearable pulse oximeter is clipped to the patients' fingertips for the patients to view their oxygen saturation levels and to collect data from patients. A wireless data transmission unit is incorporated into the patients' end to send data.

2) *The database:* It enables temporarily storing and comparing the obtained data with the threshold SpO2 and heart rate values. Patients' SpO2 values and their heart rate readings will be uploaded to the database remotely in real-time. This was built using Firebase.

3) *The doctor's end:* A mobile application to view the readings of the patients simultaneously. This was designed using Android Studio.

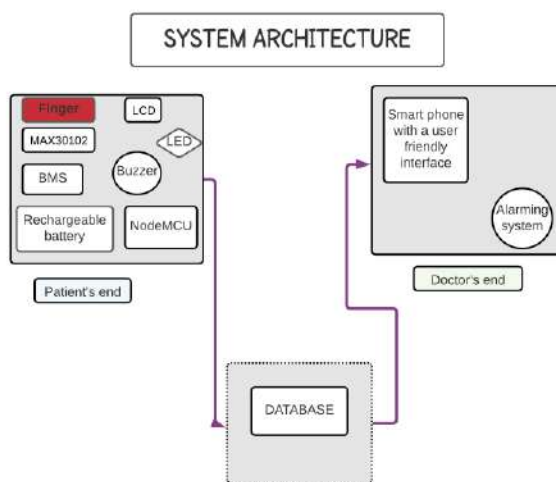


Figure 2. System Architecture Source: Author

This wearable IoT device is integrated with a Node MCU for data transmission through Wi-Fi. This allows data transmission over a large distance, irrespective of the geographical location. Data from multiple patients (in a hospital ward or home-based

patients) can be collected and transmitted through a Node MCU to the central database. A Mosquito MQTT was used for high-speed data collection to minimize time delay. The data is transmitted to the central database that collects data at a slower speed. The use of MQTT is to prevent the loss of patient data (Eclipse Mosquitto, 2018).

This will temporarily store the real-time data. A threshold is set so that if the SpO₂ value falls below 95%, a notification will be sent through the mobile application at the doctor's end. This mobile application can be used by doctors or the clinical staff to monitor patients. If the SpO₂ level drops below 95%, an alarm will notify the doctor along with the patient's details. This will eliminate the need for continuous monitoring and periodic check-ups of the patients since the patient will only have to be observed when the alarm indicates abnormal oxygen levels. This will allow the doctor to take corrective measures at the right time. Thus, this will be an efficient system and will minimize time delay.

This pulse oximeter has a competitive advantage over those that currently exist in the market since most are not rechargeable. They will require the replacement of batteries after some time. Replacing the conventional batteries with rechargeable batteries will be a cost-effective solution since new batteries do not need to be frequently purchased. By including a Battery Management System (BMS), rechargeable batteries, and a charging port, the system can be integrated with a recharging mechanism.

This will be integrated with an LCD to display the real-time SpO₂ and pulse rate readings to the patient. The proposed pulse oximeter will be provided as a kit with a central monitoring system, and the number of pulse oximeters per kit can be adjusted.

A. Components

The hardware components used for the pulse oximeter are:

1) *Data acquisition module*: MAX30102 pulse oximetry sensor- the biosensor that measures heart

rate and the SpO₂ levels simultaneously. This contains a red light and an IR module, photodetectors, optical components, and a noise-cancelling electronic circuit. This also represses ambient light to increase the accuracy of the reading.

2) *NodeMCU*: An open-source firmware for ESP8266 Wi-Fi module. This is the IoT platform that enables the pulse oximeter to be connected to Wi-Fi for wireless data transmission for remote patient monitoring.

3) *BMS Board along with the Tp4056 charging module*: This allows the rechargeable battery to be safely connected to the circuit by controlling the operating voltage so that it will only operate within safe limits.

4) *OLED 0.91" 128X32 12C Display*: This will provide real-time readings of SpO₂ and heart rate (in BPM) to the patient. This enables the pulse oximeter to be used as a standalone device for home users.

5) *Rechargeable battery*: A 18650 Lithium-ion rechargeable battery is used. This will allow the pulse oximeter to be recharged and reused, without replacing the battery.

6) *Charging cable*: To recharge the pulse oximeter by connecting it to a power supply.

7) *Buzzer*: Makes a beeping noise when the oxygen saturation falls below the threshold. This can be used as an alarm for the patient.

8) *Light Emitting Diode*: Used to notify the patient of low oxygen levels.

The developed system was initially simulated in a virtual environment, using the proteus software. Replacements were used for the libraries of the sensor and the NodeMCU since they were not available in the platform used. (Figure 3)

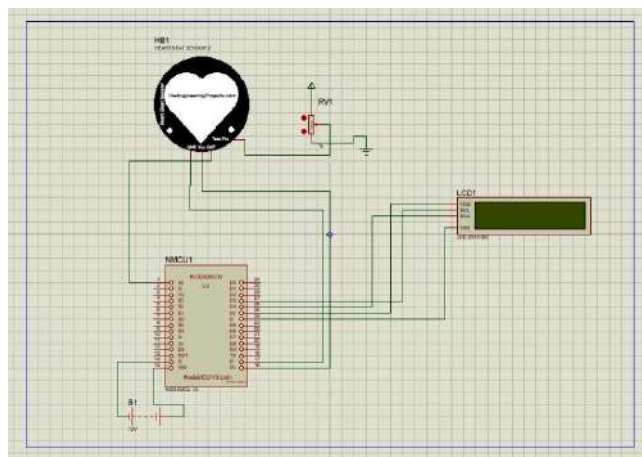


Figure 3. Schematic Diagram Source: Author

The circuit was successfully implemented on a breadboard where the connections were established. (Figure 4).

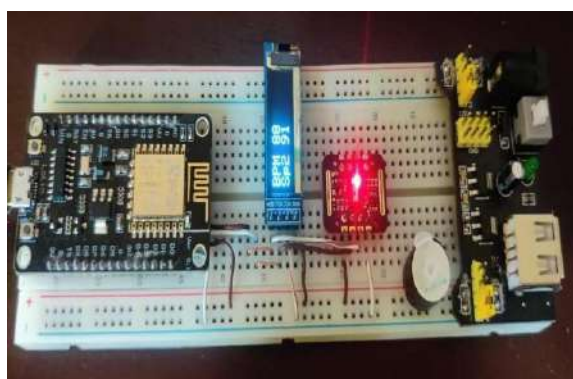


Figure 4. Connections of the pulse oximeter on breadboard Source: Author

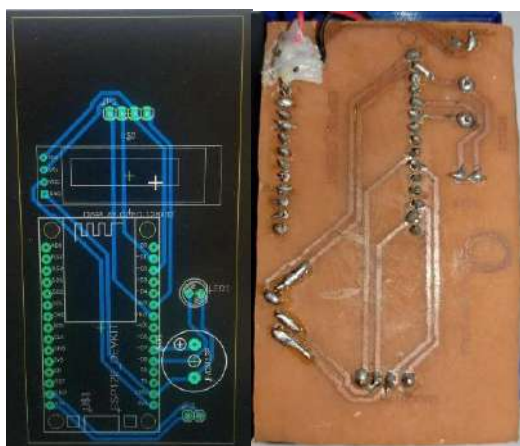


Figure 5. PCB design and development Source: Author

A PCB was developed for the wireless pulse oximeter. This was designed using the Autodesk EAGLE software. The PCB was manually printed on a copper board as shown in Figure 5. Following the PCB design, the final connections were established. (Figure 5)

The components of the charging circuit were the Battery Management system, a Tp4056 charging module, a rechargeable battery, and a charging cable. The charging module contains a micro USB interface, for the charging cable to be connected when needed. This also acts as a safe charging interface. The BMS board was included to make sure the rechargeable battery ran within the designated safe operated voltage. The red light on the charging module serves as an indicator of the battery level. The device can be used for roughly 2 days after fully charging it.

The code for displaying the heart rate and SpO2 values were implemented using Arduino IDE. This is an open-source platform that is based on C++. Libraries such as SpO2, Heart rate sensors, LCD, and Node MCU were used. Using a loop, stored data values will be removed from the system. To detect if the finger has been positioned accurately on the sensor, an intensity threshold is set up. The intensity increases as the finger approaches the sensor. If this value is less than 7000, this indicates that the finger is distal so the outputs will be displayed as zero. Once the finger is detected, the algorithm will calculate the heart rate and display it. When the device is switched on, the display will be initialized and the connections with the database will be established.

The mobile application was designed and developed using Android Studio. The front-end and the backend of the application were implemented using the programming language Java. A system-generated ID will be used to identify the heart rate and oxygen saturation readings from each patient. This will allow the backend to identify the value and update itself.

The database of the system was developed using Firebase. The reference ID represents the unique patient code that is used for the identification of the patient. This is generated by the system. The heart rate and SpO2 values that are displayed will be

changed when the database is updated. The values that are updated in the database will be derived by the listener function and will be stored in the heart rate and SpO2 variables. This will be fed into the UI of the mobile application.

The housing of the system was designed using the SolidWorks software. This was manufactured by 3D printing using plastic as the raw material for the final product. (Figure 6).

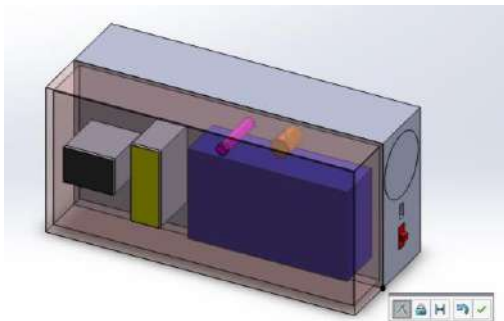


Figure 6. System Design in 3 Dimensions using SOLIDWORKS. Source: Author

4. RESULTS

The device captures data from the sensor and allows the user to view it. This will be simultaneously uploaded to the cloud. The cloud will send the data to the database using the NodeMCU module. This will require the WIFI username and password through which the NodeMCU connects to the internet. Using the host and the authentication key of the firebase, the device will identify the database. The database of the system was designed using Firebase to temporarily store data from multiple patients. (Figure 7). This was linked to the mobile application to display the readings.



Figure 7. The database that was developed using Firebase Source: Author

The mobile application was designed in a simple, yet user-friendly manner. The initial interface displayed data for multiple patients. (Figure 8) The system allows new patients to be added via the application, where a unique patient ID, Patient Name, Age, Gender, and Device number can be defined.

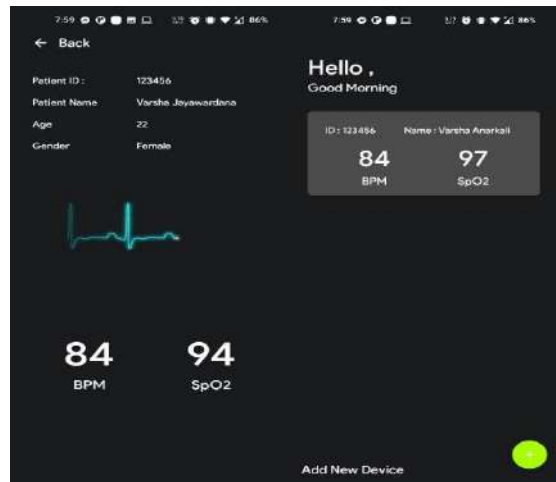


Figure 8. UI of the mobile application Source: Author

The doctor can view the heart rate as a BPM value and oxygen saturation (SpO₂) as a percentage for a single patient by selecting the desired patient. The alarming system was implanted by setting a threshold. If the SpO2 value drops below 90%, the mobile application notifies the doctor through a sound. The product was given the name 'Oxycare' for commercial purposes. (Figure 9)



Figure 9. Final product with the complete housing Source: Author

5. DISCUSSION

The main aim of this research was to develop a wearable, WI-FI-enabled pulse oximeter that could be used for remote patient monitoring. Long-distance data transmission is a major advantage of the designed device. This was done by integrating a NodeMCU, which was able to transmit the heart rate and oxygen saturation data to a database and then to a mobile application on the doctor's end. Previous research articles discussed pulse oximeters which had the ability to transmit data over a long distance. All these devices had the ability to transmit data within a range of 50 ± 5 m. The device designed through this study will allow transmission of data across 350 ± 10 m distance when using a PCB antenna (Benchoff, 2014). The database of the novel pulse oximeter was developed on an online platform called Firebase. While the existing oximeters are able to transmit data within a household, "Oxycare" has the ability to transmit data across cities. This allows patients from remote locations to be monitored by doctors from cities, despite the geographical barriers. Optimizing the network settings would allow data transmission across countries, which would be implemented in the future.

The second aim of this research was to develop a multiple-patient monitoring system. Referring to the existing literature, all of the devices focused on monitoring a single patient at one time. However, "Oxycare" allows multiple patient monitoring, and up to 60 patients could be added to the database as the mobile application was developed to enroll a maximum number of 60 patients. This would mean that multiple patients from different locations could be monitored at one central clinical point, and the doctor can observe the patient data from different locations at any time of the day. This system did not allow the 63rd patient to be added, due to the limitations in data processing capacities of the software used. Further optimization of this software would allow more patients to be monitored simultaneously, which would be a part of the future works of this research. The time delay of this system was only 0.2 ± 0.1 s, and this may be due to the network lag. Another possible reason for this could be the slow uptake of data by the database; the

Firestore cannot store data at the speed that data is transmitted from the system. This could lead to minor losses in data. However, by incorporating a Mosquitto MQTT, it would collect and store data before it reaches the Firestore, so data can be transmitted at a slower pace to it. This would avoid the potential loss of data.

The final goal of this research was to develop a rechargeable pulse oximeter. The rechargeable battery had a battery life of 2 hours as the battery that was used for the pulse oximeter was low in capacity. This would mean that the cost of battery replacement would be cut down. If a battery with a battery life of 3 to 5 days was included, the device would be bulky and uncomfortable for the patients. Thus, the battery that is currently being used is the one that can provide the maximum battery life with minimum inconvenience. To make the device more compact and lighter-weighted and to include a battery percentage indicator will be advancements in the "Oxycare" pulse oximeter in the future.

While factors like remote and continuous monitoring, long-distance data transmission, and rechargeability were given prominence, the accuracy of the data collected appeared to be compromised. By comparing the developed device with a device in the current market, the accuracy was validated. The readings obtained using the two devices appeared to be similar for most of the instances. However, fluctuations in the data values were observed, which gave unstable readings on rare occasions. This was due to the ambient light interfering with the Red light/IR sensor. In the future, the algorithm will be developed to cut down the effect of ambient light and the device will be optimized by placing the sensor internally.

6. CONCLUSION

Health care sectors had to take a huge blow due to the Covid-19 pandemic, which led to a demand for new technological medical devices. The development of a wireless pulse oximeter for remote patient monitoring can facilitate monitoring of blood oxygen saturation (SpO_2) and heart rate in Covid patients from a safe distance in this time of health disaster.

Not only Covid patients but bed-ridden and crippled patients at homes and healthcare facilities can also be easily monitored through the newly developed Oxycare pulse oximeter. The advancement which can monitor the SpO₂ and heart rate values of several patients simultaneously over a wireless mobile platform proved to be highly useful and convenient. The use of Wi-Fi technology for long-range data transmission has opened a new door in telemedicine for pulse oximetry, enabling the safest and most efficient non-invasive monitoring of SpO₂ and heart rate. The rechargeable battery of the novel pulse oximeter added a competitive advantage over existing pulse oximeters which will be convenient for long-term use. In the future, this device will be developed to enhance the number of patients that can be added to the system. Furthermore, this system would be optimized to minimize the time delay in data transmission. The development of the mobile application to access the real-time data values and the warning notifications, and the compact and portable nature of the device have made the “Oxycare” pulse oximeter a better alternative to the conventional pulse oximeters.

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USE OF RUBBERIZED CONCRETE TO REDUCE HIGH VELOCITY IMPACT ON WALLS IN TRAINING BASES

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ABSTRACT

Discarded waste rubber has become a major problem to the environment due to the increase of rubber usage in the modern world. As a solution, waste rubber can be embedded in rubberized concrete by partially replacing the fine and coarse aggregates. Due to the nature of rubber, there is a high potential for the rubberized concrete to have high impact absorbent properties. Most of the firing range walls are made with normal concrete and bricks in Sri Lanka. Therefore, this study focuses on investigating the use of rubberized concrete for firing range walls. The study consists of an experimental analysis of live fire tests and a numerical analysis of the high velocity impacts. Penetration depth and crater diameter were taken as the scales of measuring the level of damage to the walls. Numerical analysis results show lower penetration depth in rubberized concrete than in normal concrete. However, experimental analysis shows higher penetration depth in rubberized concrete compared to normal concrete. However, it is worth noticing that the crater diameter and cracks around the penetration are comparatively improved in the case of rubberized concrete. Therefore, rubberized concrete appeared to be a better alternative for firing range walls.

KEYWORDS: *Rubberized Concrete, High Velocity Impacts, Bullet Penetration, Live Fire Test, Experimental Analysis, Numerical Analysis*

1. INTRODUCTION

Disposal of waste rubber causes severe environmental threats specially in developing countries due to the non-biodegradable nature of rubber materials (Edirisinghe, 2013). As a solution for this matter, several tests and studies have been done on rubber granules and crumb rubber to see the possibility of embedding rubber crumbs in concrete as a replacement to aggregates. It was observed through these studies that the rubber crumbs in concrete leads to a considerable drop in the compressive strength. As a result, rubberized concrete was limited only to applications where low level of strength is required. However, it was worth noting that rubber as a material has a high shock absorbent property. Therefore, there is a research interest that arose in analyzing the shock absorbent properties of rubberized concrete.

Military firing ranges are the places where soldiers/military officers conduct live firing exercises. Current practice is to make firing ranges using brick and concrete walls. However, during the training these walls get damaged and with time the damages become severe. Due to the high shock absorbent properties of rubberized concrete, there is a high potential for rubberized concrete to be a better alternative for the walls in firing ranges. Therefore, this research focuses on studying the feasibility of using rubberized concrete for the walls in firing ranges.

2. LITERATURE REVIEW

Mixing of rubber crumbs to concrete has been found beneficial in different usages such as for lightweight concrete, as a lightweight filler, as a modifier in asphalt paving mixtures and to build crash barriers and bumpers. Most of these applications are owing to the lower density of rubber compared to the conventional aggregates used in concrete. Crumb rubber and chipped rubber are two main forms of rubber waste that can be used as an additive in rubberized concrete. These two forms of rubber are used as an alternative substitute for fine and coarse aggregates, respectively. Previous studies have proven that the fine crumb

rubber in concrete gives a better performance than chipped rubber (Gerges, Issa and Fawaz, 2018).

However, many studies have concluded that the rubber aggregates in concrete reduces the compressive strength of concrete drastically with the increase of percentage of rubber in concrete (Gerges, Issa and Fawaz, 2018). This finding demotivated the use of rubberized concrete to a great extent.

However, J. Xue and M. Shinozuka (2013) have shown that the increment in the percentage of crumb rubber additives into the concrete can cause a nonlinear behaviour between stress and strain as shown in Figure 2.1.

According to the previous studies (Senin *et al.*, 2017), the ordinary cement concrete is generally brittle while the addition of crumb rubber in the concrete can increase the impact resistance and ductility.

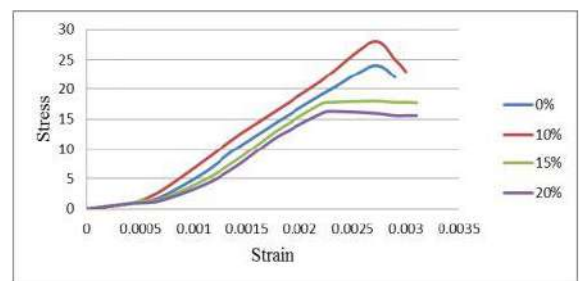


Figure 2.1: Relationship between stress and strain for different crumb rubber percentages in concrete (Dass and Sharma, 2013)

Najim & Hall (2012) has concluded that the bonding between rubber particles and cement paste is weaker compared to the bonding between coarse aggregate and cement paste, which causes a reduction of compressive strength of rubberized concrete (Najim and Hall, 2012). A study done by Xue and Shonozuka (2013) has also discovered that the compressive strength of rubberized concrete drops due to lack of bonding between rubber and cement particles and they have further discovered that this bond can be improved by adding Silica Fume.

Xue & Shinozuka (2013) have identified that the damping coefficient of rubberized concrete has been amplified compared to normal concrete while a reduction is seen in the seismic response acceleration of the structure. Due to the decrement of the seismic response acceleration of the structure, rubberized concrete is capable of being used as an energy absorption material in order for the reduction in high velocity impacts.

Another study done by Senevirathne et al (2020) has discovered that the impact energy of rubberized concrete increases as the rubber percentage increases (Figure 2.2). They have observed the maximum impact energy when the rubber replacement is 10% of the fine aggregate. (Senevirathne, Kulathunga and Kuruwitaarachchi, 2020)

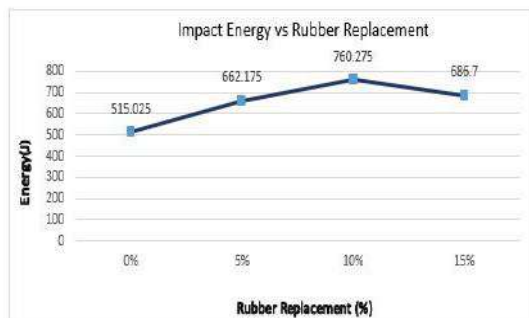


Figure 2.2: Change of Impact Energy (Senevirathne, Kulathunga and Kuruwitaarachchi, 2020)

Concrete can be used as a widely utilized construction material in civil engineering aspects and its impact properties such as crack propagation, penetration depth and perforation are important concerns. The depth of penetration due to high velocity impact has an inverse correlation with the compressive strength (Li, Brouwers and Yu, 2020). The penetration depth of a bullet can be depended on the shape, density, cross-section, pattern of deformation and the kinetic energy of the bullet. A closed cellular structure is developed by the additives in concrete when a bullet impacts on the lightweight concrete (Fabian *et al.*, 1996).

3. METHODOLOGY

This study uses two approaches to reach the conclusions, namely numerical approach and experimental approach.

3.1 Numerical Analysis

For the numerical analysis, LS Dyna software was used. To analyze concrete structures subjected to impacts, the Karagozian & Case Concrete (KCC) model is available in LS-Dyna, and it allows automatic generation of all parameters by importing only the unconfined compressive strength and density of the concrete. Material card (MAT72REL3) which is used for KCC models requires a few parameters to define the material properties of concrete. It includes failure criteria, triaxial strength surface, and strain rate effect. Some parameters such as unconfined compressive strength are automatically generated from the model. Rubberized Concrete material properties are rarely studied by numerical simulations. The material properties for the KCC model should be modified to model the Rubberized Concrete (RubC) accurately differentiating it from Normal Concrete (NC). In this study, the damage to the normal concrete and rubberized concrete caused by a high velocity impact is simulated using the KCC model, and rubberized concrete and normal concrete with compressive strength of 35 MPa were focused in this study

3.1.1 Material Properties

Seconds (s), meters (m), kilograms (kg), and pascals (Pa) are applied as the units for time, mass, length, and stress in the simulation. Parameters needed for the KCC model were extracted from the literature (Gholampour, Ozbakkaloglu and Hassanli, 2017) (Malvar *et al.*, 1997) (Yang *et al.*, 2019)

The values of parameters used for KCC model in this study are listed in Table 3.1 and Table 3.2. In table 3.1 and 3.2, Compression Strength, Tensile Strength, Young's Modulus and Poisson's Ratio are

denoted by f_{co} , f_t , E and v while a_{0m} and a_{0y} represent the maximum and yield cohesion, respectively, and a_{1m} , a_{1y} and a_{if} ($i = 1, 2$) are the hardening parameters performed on the maximum, yield limit and failure, respectively.

Table 3.1: Fitting Results of Normal Concrete (NC) and Rubberized Concrete (RubC) (Gholampour, Ozbakkaloglu and Hassanli, 2017)

Material type	f_{co} (Pa)	a_{0m} (pa)	a_{1m}	a_{2m} (Pa ⁻¹)	a_{0y} (Pa)
NC	34.9e6	1.30e7	0.495	2.4e-9	5.08e6
RubC	32.6e6	1.19e7	0.495	2.63e-9	4.65e6
Material type	a_{1y}	a_{2y} (Pa ⁻¹)	a_{if}	a_{2f} (Pa ⁻¹)	
NC	0.492	1.93e-8	0.754	1.16e-9	
RubC	0.492	2.12e-8	0.754	1.27e-9	

Table 3.2: Static Test Results of Normal Concrete and Rubberized Concrete (NC & RubC) (Yang *et al.*, 2019)

	f_{co} (Pa)	f_t (Pa)	E (Pa)	N
NC	34.9e6	3.06e6	25.85e9	0.21
RubC	32.6e6	3.04e6	24.28e9	0.19

Modified damage parameters of normal and rubberized concrete were also identified from the literature and are listed in the Table 3.3 (Feng *et al.*, 2021)

Table 3.3: Fitted Results of α , α_c , α_d , and λ_m (Yang *et al.*, 2019)

Material type	A	α_c	α_d	λ_m
NC	3	0.17	1.92	3.5e-4
RubC	3	0.25	1.55	4.1e-4

According to the test results of Grinys *et al.* (2013), the fracture energy of the Normal Concrete and Rubberized Concrete were estimated as shown in the Table 3.4.

Table 3.4: Fracture Energy of Normal Concrete and Rubberized Concrete (NC & RubC) (Grinys *et al.*, 2013)

Material Type	Fracture energy Gf (J/m ²)
NC	84.84
RubC	451.57

3.1.2. Equation of State

For the complete characteristics of behaviour of concrete, KCC model required the Equation of State (EOS) which is required to compute the relationship between current pressure and volumetric strain. In the KCC model, EOS#8 (Equation of State, type 8) in LS-DYNA has described the relationship between current pressure (p) and volumetric strain (μ) as the Equation 1 (Livermore Software Technology Corporation (LSTC), 2014)

$$P = C(\mu) + \gamma_0 \theta(\mu) E_0 \quad \text{Equation 1: Relationship Between Pressure and Volumetric Strain}$$

Where, E_0 - the internal energy per initial volume
 γ_0 - the ratio of specific heat. $C(\mu)$ and $\theta(\mu)$ - the tabulated pressure valuated along a 0K isotherm and tabulated temperature-related parameter as functions of the volumetric strain.

Since the high velocity impact causes damages although it does not have an adequate period for thermal transmission, the temperature-related parameter ($\theta(\mu)$) will be neglected in EOS#8.

Table 3.5: EOS parameters of Normal Concrete and Rubberized Concrete (NC & RubC)

Point no.	Volumetric strain	NC		RubC	
		P (C(μ)) (Pa)	K (Pa)	P (C(μ)) (Pa)	K (Pa)
1	0	0	7.44 x 10 ⁹	0	7.44 x 10 ⁹
2	-1.5 x 10 ⁻³	1.12 x 10 ⁷	7.44 x 10 ⁹	1.12 x 10 ⁷	7.44 x 10 ⁹
3	-4.3 x 10 ⁻³	4.92 x 10 ⁷	1.52 x 10 ¹⁰	4.75 x 10 ⁷	1.47 x 10 ¹⁰
4	-1.01 x 10 ⁻²	7.89 x 10 ⁷	1.6 x 10 ¹⁰	7.63 x 10 ⁷	1.55 x 10 ¹⁰
5	-3.05 x 10 ⁻²	1.5 x 10 ⁸	1.9 x 10 ¹⁰	1.45 x 10 ⁸	1.84 x 10 ¹⁰
6	-5.13 x 10 ⁻²	2.26 x 10 ⁸	2.21 x 10 ¹⁰	2.19 x 10 ⁸	2.14 x 10 ¹⁰
7	-7.26 x 10 ⁻²	3.21 x 10 ⁸	2.51 x 10 ¹⁰	3.1 x 10 ⁸	2.43 x 10 ¹⁰
8	-9.43 x 10 ⁻²	4.91 x 10 ⁸	2.74 x 10 ¹⁰	4.75 x 10 ⁸	2.65 x 10 ¹⁰
9	-1.74 x 10 ⁻¹	2.87 x 10 ⁹	6.17 x 10 ¹⁰	2.77 x 10 ⁹	5.97 x 10 ¹⁰
10	-2.08 x 10 ⁻¹	4.38 x 10 ⁹	7.52 x 10 ¹⁰	4.24 x 10 ⁹	7.27 x 10 ¹⁰

The EOS parameters were obtained from previous studies (Feng *et al.*, 2021) and the values are listed in the Table 3.5.

3.1.3 Validation of the KCC model

Single element test was conducted by Yang *et al.*(2019) to validate all the parameters which are required for the KCC model, and it was done by the uniaxial unconfined compression and tension single element test (SET). The tests were conducted to the 1x1x1 cm³ single element model as shown in the Figure 3.1.

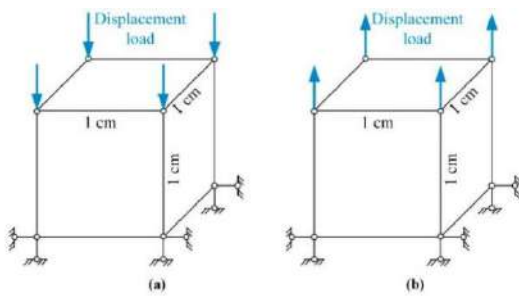


Figure 3.1: Single-element Model for (a) Compression and (b) Tension (Yang *et al.*, 2019)

The results of uniaxial unconfined compression test are shown in the Figures 3.2 and 3.3. It can be seen that the modified KCC model agrees well with the experimental data for rubberized concrete as well as for normal concrete.

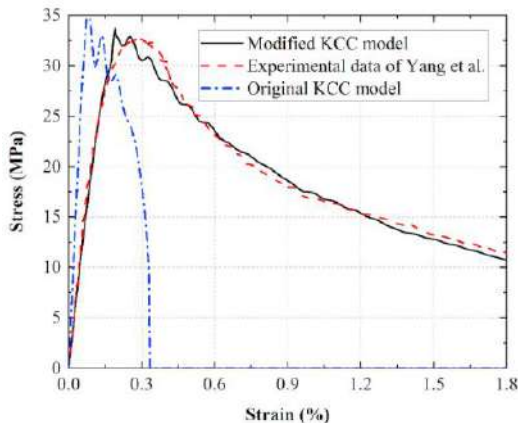


Figure 3.2: Compressive Stress-strain Curve of Rubberized Concrete (Yang *et al.*, 2019)

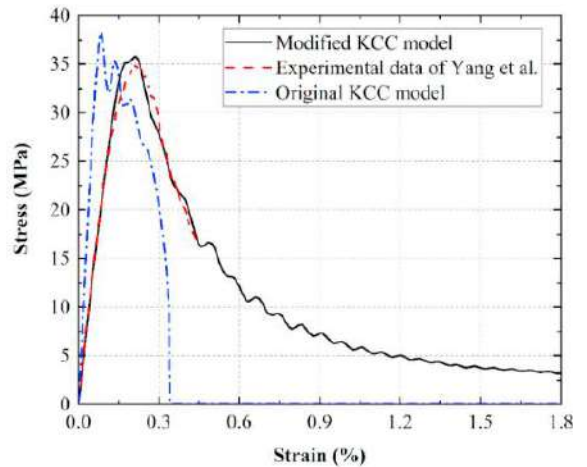


Figure 3.3: Compressive Stress-strain Curve of Normal Concrete (Yang *et al.*, 2019)

The modified KCC model tensile stress strain curve overlaps with the empirical formula in Figure 3.4, indicating that it is more reliable than the original KCC model tensile stress strain curve.

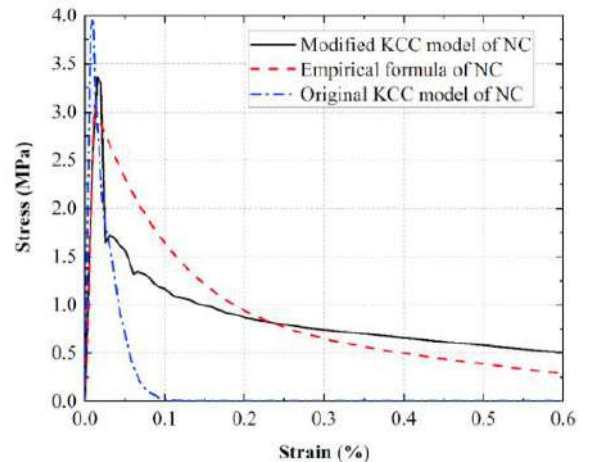


Figure 3.4: Comparison Between Modified KCC Model, Original KCC Model, and Empirical Formula of Normal Concrete (Yang *et al.*, 2019)

3.1.4 Projectile Material Properties

Since the steel core of a projectile (bullet) has the maximum mass and volume compared to other components, namely copper-plated steel jacket and lead filler, steel was considered as the material of the projectile. In the LS-Dyna simulation, the

*MAT_JOHNSON_COOK material was used to simulate the projectile. The material properties which were used for the projectile are listed in Table 3.6 (Carbajal, Jovicic and Kuhlmann, 2011).

Table 3.6: Johnson - Cook Material Model Properties (Carbajal, Jovicic and Kuhlmann, 2011)

Bullet Component	7.62x39mm mild steel core
Density (ρ) (kg/m ³)	9765.4
Shear modulus (G) (Pa)	1.22 x 10 ¹⁰
Young's Modulus (E) (Pa)	3.172 x 10 ¹⁰
Poisson's Ratio	0.3
A (Pa)	2.344 x 10 ⁸
B (Pa)	413.8 x 10 ⁸
N	0.25
C	0.00333
M	1.03
D ₁	5.625
D ₂	0.3
D ₃	-7.2
D ₄	-0.0123
D ₅	0

3.1.5 Numerical Simulation

In the numerical simulation, the projectile was shot into normal concrete which has the strength of 35MPa and rubberized concrete which has the strength of 32.6MPa concrete targets.

To reduce the run time, only a quarter of the concrete block and projectile was modelled as shown in the Figures 3.5 and 3.6, and the projectile was initiated near the concrete target. The concrete block was fixed in three directions and throughout the simulation, the concrete block and the projectile were fixed on symmetric planes.

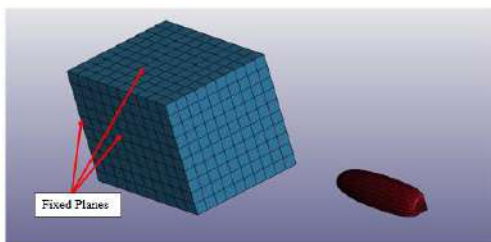


Figure 3.5: Numerical Simulation; Fixed Planes

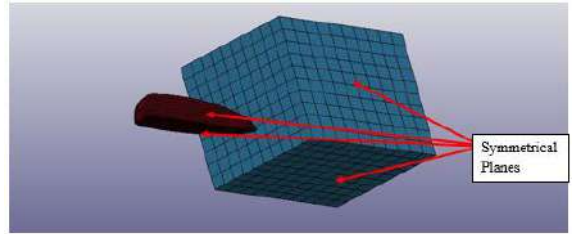


Figure 3.6: Numerical Simulation; Symmetrical Planes

Elements in the fixed planes are restricted in 3 directions while the elements in the symmetrical plane are allowed to move along the plane. Both the concrete block and projectile are made with solid elements. Therefore, the contact between projectile and concrete surface had to be defined through erosion criteria. *MAT_ADD_EROSION in LS-Dyna is used to define the maximum principal strain since KCC model has no obtainable element erosion criteria. Since the projectile has a high velocity, the termination of the simulation was done with seconds (s).

3.2 Experimental Analysis

3.2.1 Preparation of Samples

Firstly, the sieve analysis was done to compare the particle size distribution of varying fine aggregate types (river sand and crumb rubber) with the lower and upper bounds of BS882 – specification for aggregates from natural sources for concrete.

To increase the bond between crumb rubber and concrete components, crumb rubber needs surface modification which helps to improve the crumb rubber to absorb some amount of water. Before using the crumb rubber in concrete, the surface modification was done by soaking rubber particles in 1N solution of NaOH (Sodium Hydroxide) for about 1 and ½ hours. The crumb rubber particles were settled after 1 and ½ hours. After it soaked well, the rubber particles were washed with clean water to reduce the basicity.

3.2.2 Concrete Mix Design

The mixed design was done according to the British Standards (BS). The grade of Normal Concrete was taken as M25 (25 N/mm²). The fine aggregate for the Rubberized Concrete was replaced by 10% of sand with crumb rubber.

Table 3.7: Mix Proportions of Normal Concrete and Rubberized Concrete (NC & RubC)

Quantities	Crumb Rubber (kg)	Cement (kg)	Water (kg)	Fine aggregate (kg)	Coarse aggregate (kg) / 10mm
Per m ³ (to nearest 5kg) for NC	-	375	205	805	985
Per m ³ (to nearest 5kg) for RubC	80	375	205	725	985

According to the range design criteria ('RANGE DESIGN CRITERIA Office of Health, Safety and Security', 2012), the thickness of material to stop the penetration of 7.62mm caliber, 7in (=177.8mm) minimum thickness is required for the concrete material. Therefore, the thickness for the samples of concrete blocks is selected as 200mm. The dimension of each sample concrete block is 250x250x200mm.

3.2.3 Live Fire Test

Live fire test was carried out by using 4 samples of Normal Concrete Blocks (NC1, NC2, NC3 & NC4), 4 samples of Rubberized Concrete (RC1, RC2, RC3 & RC4) and 2 samples of Masonry Blocks (MB1 & MB2).

Attention was paid to the following points while conducting the Live-fire tests:

- It is necessary to determine the depth of penetration for single strikes at a single spot on the bullet trapping block.

- Target should be maintained in such a way that the spalling of concrete is avoided

Live-fire testing was done at an outdoor range. The shooter to target distance was maintained at 13m. The test blocks were placed in a steel frame which can handle the sudden impacts and the steel frame was levelled from the split-level and grounded as shown in the Figure 3.7.



Figure 3.7: Steel Frame

The rifle was mounted and maintained the level on a steel frame. The experimental setup is shown in the Figure 3.8.



Figure 3.8: Experimental Setup

Damages on the concrete due to a bullet can occur in 4 methods. They are Ricochet, Perforate, Penetration and Fragmentation. In this experiment, the bullets were trapped inside the blocks due to Penetration. After each concrete block was shot, the bullets were safely removed with a tweezer. Before extracting the bullet, the penetration path was drilled and expanded to remove the bullet. There are 3 types of bullet deformations. They are Deform, Full Fragment and Partial Fragment. After all the bullets were removed, it was seen that the bullets were deformed by Partial Fragments.

The apparent depth of penetration and the crater of the bullet hole were measured using a vernier caliper. The craters of the bullet holes were measured by taking the average diameter of the crater.

4. RESULTS

4.1 Numerical Analysis

The penetration depth of the concrete was measured under four different projectile velocities: 200ms^{-1} , 300ms^{-1} , 400ms^{-1} and 500ms^{-1} . Figure 4.1 and 4.2 show the deformed shapes of the normal concrete and rubberized concrete models after the impact of 300ms^{-1} projectile velocity.

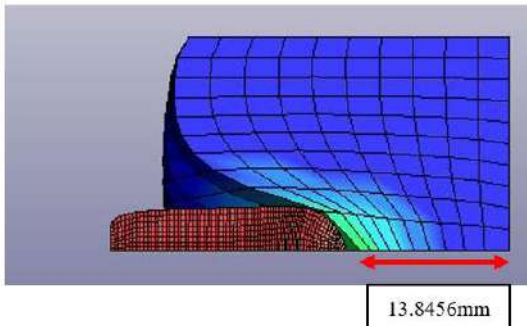


Figure 4.1: Normal Concrete Deformed Shape of the Model after the Impact under 300ms^{-1} Projectile Velocity

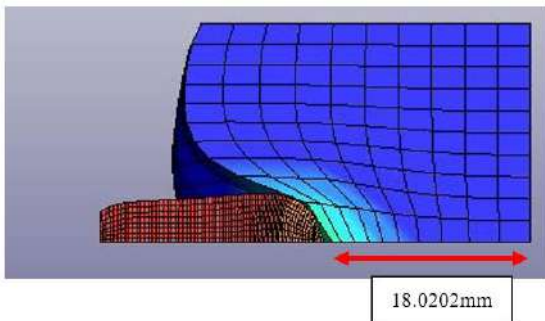


Figure 4.2: Rubberized Concrete Deformed Shape of the Model after the Impact under 300ms^{-1} Projectile Velocity

Velocity of the projectile versus penetration depth is shown in Figure 4.3 for normal concrete and rubberized concrete.

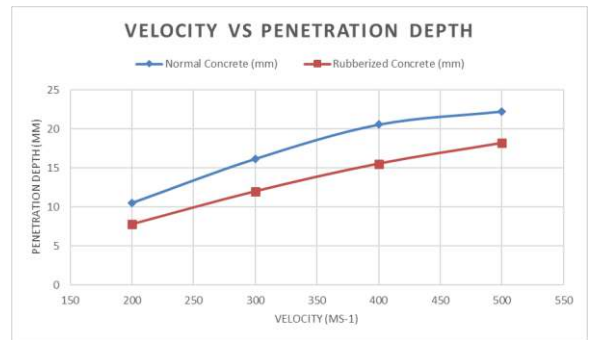


Figure 4.3: Velocity vs Penetration Depth

4.2 Experimental Analysis

4.2.1 Preparation of Samples

Figure 4.4 shows that the river sand and the mix of river sand and crumb rubber, which are used to make normal concrete and rubberized concrete respectively were within the upper and lower bounds of the BS882 requirement of concrete.

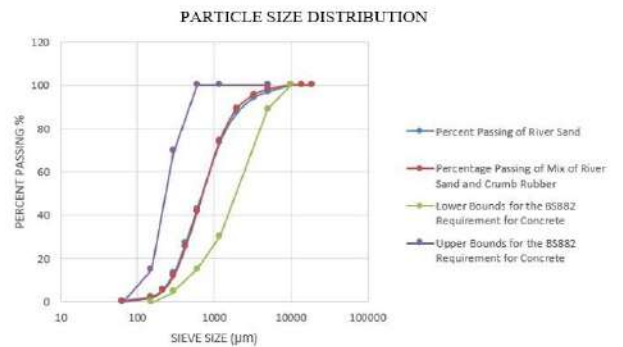


Figure 4.4: Particle Size Distribution

The specific gravity of the sand sample is 1.56Mg/m^3 while the specific gravity of the crumb rubber sample is 0.97Mg/m^3 , which makes the specific gravity of the mixed (G_{mixed}) sample (the sand mixed with 10% of crumb rubber) to be 1.47Mg/m^3 . The mix of sand and crumb rubber has a lower specific gravity compared to the specific gravity of the sand. Therefore, the crumb rubber reduces the specific gravity of the sand. The partial replacement of fine aggregate by 10% from crumb rubber results in the slump value getting decreased. Slump values are shown in Table 4.1.

Table 4.1: Slump Values of Normal Concrete and Rubberized Concrete (NC & RubC)

Sample	Slump Values (mm)
NC	100
RubC	90

4.2.2 Compressive Strength Test Results

The compressive strength of concrete was measured after 56 days of curing. Table 4.2 shows the compressive strength values of each test samples.

Table 4.2: Compressive Strength Test Results

Mixture	Weight (kg)	Density (kg/m ³)	Compressive strength (N/mm ²)	Compressive strength decrease (%)
Control mix				
1) Sample 1	7.846	2324.74	34.290	
2) Sample 2	7.871	2332.15	36.025	
Average				
10% Rubber Replacement				
1) Sample 1	7.8585	2328.445	35.1575	
2) Sample 2	6.336	1877.33	7.084	
Average	6.088	1803.85	6.627	
1) Sample 1	6.212	1840.59	6.8555	80.5%
2) Sample 2				
Average				

4.2.3 Live Fire Test Results

Figure 4.5, Figure 4.6 and Figure 4.7 show the damages occurred in 3 samples of Normal Concrete (NC1), Rubberized Concrete (RC1), and Masonry Blocks (MB2) respectively.



Figure 4.5: Damage Pattern on the NC1 Block



Figure 4.6: Damage Pattern on the RC1 Block



Figure 4.7: Damage Pattern on the MB2 Block

Penetration depths obtained for each sample are shown in Figure 4.8.

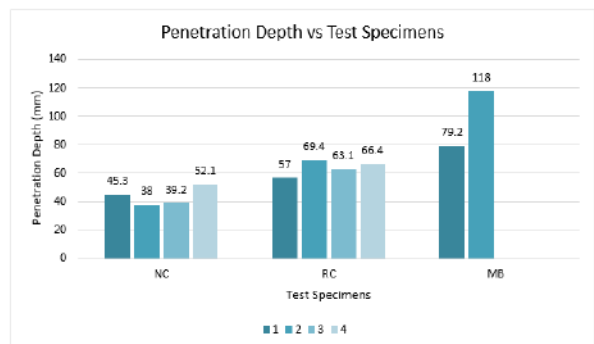


Figure 4.8: Penetration Depth vs Test Specimens

Crater diameter values obtained for each test specimens are shown in the Figure 4.9.

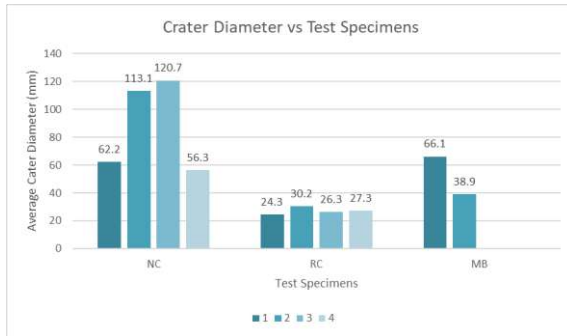


Figure 4.9: Crater Diameter vs Test Specimens

5. DISCUSSION

5.1 Numerical Analysis

According to the results obtained for the numerical analysis, it was seen that the penetration depth of rubberized concrete is lesser than the penetration depth of normal concrete for all the projectile velocities (200ms^{-1} , 300ms^{-1} , 400ms^{-1} and 500ms^{-1}) considered in the analysis (Figure 4.3). Also, it was noticed that the penetration depth increases as the velocity of the projectile increases.

5.2 Experimental Analysis

It was clear from the results shown in Figure 4.4 that the sieve analysis results of the mix of river sand and crumb rubber are acceptable as per the requirements specified in BS882.

As per the compressive strength results obtained for the rubberized concrete (Table 4.2), it can be seen that there is a significant drop in compressive strength of rubberized concrete. Although, it was evident from the literature also that the compressive strength significantly drops with the addition of rubber, the drop obtained in this study is comparably higher.

Figure 4.5, Figure 4.6 and Figure 4.7 show the damage patterns for each type of test specimens and

Figure 4.8 shows the penetration depths. The average penetration depth of the bullet into the normal concrete Block is 43.65mm (penetration as a percentage is 21.83%).

The average penetration depth of the bullet into the Rubberized Concrete Block is 63.9mm (penetration as a percentage is 31.95 %). In the case of masonry walls, only one sample could be used to measure the penetration depth and crater diameter as the other samples were damaged severely due to the impact. The penetration depth of the bullet into the masonry block is 118mm (penetration as a percentage is 59%). Therefore, in the experimental analysis, penetration depths of the Rubberized Concrete blocks were observed to be higher than that of the normal concrete blocks but less than that of masonry blocks. This contradicts the results observed in the numerical analysis. However, it should be noted that in the case of the numerical analysis, the strengths used for normal and rubberized concrete were approximately the same. In the case of experimental analysis, the strength of rubberized concrete drastically reduced due to the addition of rubber. Therefore, in the experimental analysis, the rubberized concrete samples are significantly lower in strength than the normal concrete sample. This reduction in strength caused rubberized concrete to show a higher penetration depth during the experimental analysis. If the numerical analysis was conducted as per the strengths achieved in the experimental analysis, the results could have been compared effectively and stronger conclusions could have been drawn. However, due to the unavailability of material properties to fit the KCC model, it was not possible to conduct the numerical analysis for the strengths achieved in the experimental analysis.

Figure 4.9 shows the crater diameter for each specimen. The average crater diameter of normal concrete, rubberized concrete and masonry blocks were 88.1 mm, 27 mm and 38.9 mm, respectively. It was clear from the results that the crater diameter and the visible cracks of the Rubberized Concrete blocks were less than those of the normal concrete blocks and the masonry blocks. The failure pattern observed in the samples shows that rubberized

concrete targets are less damaged compared to the normal concrete and masonry samples despite the lower strength of the rubberized concrete. Therefore, it is evident from the results that rubberized concrete has a potential as a better alternative to firing range walls.

6. CONCLUSIONS

This study uses both the numerical and experimental approaches to investigate the potential of Rubberized Concrete to be used in firing range walls. Live firing test was done in the experimental analysis. The damage was identified by the penetration depth of the projectile. The numerical analysis was carried out using LS-DYNA software.

For the numerical analysis, the strength of the normal and rubberized concrete samples was considered as 35 MPa. This strength was selected due to the availability of material properties for the KCC model in the literature. Results of numerical analysis show that rubberized concrete has a lower penetration depth compared to normal concrete, which implied that rubberized concrete has a higher shock absorbing property.

The experimental analysis was done for normal concrete samples of 25 MPa. The strength of the rubberized concrete samples used in the experiment is found to be considerably lower than the strength of normal concrete. Therefore, in the experiment results, the rubberized concrete samples showed a higher penetration depth than the normal concrete. However, the damage occurred is considerably lower in rubberized concrete samples despite the lower strength. Therefore, rubberized concrete seems to be a better solution in the case of resisting the impact, and hence it appeared to be a better alternative for the walls in firing ranges. Therefore, it is worth investing further effort in a detailed analysis to identify the feasibility of rubberized concrete in applications such as walls in firing ranges.

7. REFERENCES

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MOTIVATIONS TO CHOOSE ENGINEERING; PERSPECTIVES OF YOUNG WOMEN ENGINEERS IN SRI LANKA

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ABSTRACT

From its inception to today, engineering has been a profession in which male engineers dominate. Although technology and education have developed to a higher level, there can still be seen a hesitation among young female students to choose engineering as their future career. The masculine nature of the engineering profession is further reinforced with the belief that engineering is not meant for women but men. Numerous factors like balancing work-life conflicts, existing discriminatory practices on women engineers, lack of role models, and the demanding nature of the engineering profession have demotivated young female students to choose engineering and young female engineers to sustain in the engineering profession. Still, the literature is not saturated with studies on women engineers who could sustain in the gendered industries in various contexts. Hence, this study aims to investigate the perception of the self-confidence of young women engineers in the Sri Lankan context and to recommend staying strategies for future women engineers based on their industrial experience, which will motivate young female students to choose engineering. A self-administered questionnaire comprised of several close-ended questions with five-point Likert-type responses and an open-ended question was designed to achieve this study's objectives. It was circulated among a conveniently selected sample of 250 young women engineers in Sri Lanka via email & Facebook. 82 responses were received. Responses for Likert-type questionnaires were analyzed using a simple graphical method, while open-ended responses were analyzed using the thematic analysis technique. Analysis revealed that most respondents were confident in discharging their duties as women engineers. Further, they recommended that future women who wish to become engineers should choose the engineering discipline wisely, be passionate, and be dedicated to the engineering profession if they want to sustain themselves in it. The findings of this study will motivate and guide future young women engineers to succeed in the profession.

KEYWORDS: *Motivation, Profession, Sri Lanka, Women Engineers*

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1. INTRODUCTION

Engineering is a unique profession in today's world that uplifts the general public's lives. People heavily rely on engineering products and processes developed, run, and maintained by engineers. However, since its inception, engineering has been a profession dominated by men (Ramachandran, Ramanathan and Khabou, 2020). Considerably fewer female enrolments can be observed in engineering degree programmes worldwide (Rincon, Korn and Williams, 2019). Furthermore, sustaining percentage of women engineers in various engineering disciplines is also considerably less due to numerous socio-cultural and professional issues in engineering workplaces (Ayre, Mills and Gill, 2013). Although different precautionary measures have been taken to increase the number of women engineers worldwide, they still count for the minority gender-wise. This observation is valid for the Sri Lankan context (Menezes, 2018). Various societal misconceptions demotivate young female students from choosing engineering as their future career (Meiksins *et al.*, 2019). Such misconceptions should be disproven with the support of the experiences of women engineers who are working successfully in the industry to encourage the young female generation to take up the challenge in engineering. This study aims to investigate the self-confidence of young women engineers in the Sri Lankan context and recommend staying strategies for future women engineers. This study's findings can be considered catalysts to encourage young female students to choose engineering as their future career and to remain in the engineering field confidently and competently with men.

2. LITERATURE REVIEW

Women are underrepresented in Science, Technology, Engineering & Mathematics (STEM) fields worldwide, creating a gender disparity (Nimmesgern, 2016; Meiksins *et al.*, 2019). Still, women could not occupy a considerable percentage in the engineering profession worldwide, as well as in Sri Lanka. According to the statistics of the Institution of Engineers Sri Lanka (IESL), which is the apex body for professional engineers in Sri Lanka, women engineers count for 17.6% out of the

total membership, which is still a considerably lower value. In other countries also, the situation is like that. A developed country like the United Kingdom also had only 14.5% women engineers in 2021 (*Gender disparity in engineering - EngineeringUK | Inspiring tomorrow's engineers.*, 2021). Furthermore, a severe gender imbalance exists in several engineering disciplines like construction, heavy industries, and the worldwide power sector (Watts, 2009; *Pathways to Power; South Asia Region Baseline Assessment for Women Engineers in the Power Sector*, 2018). In the Sri Lankan construction industry, women engineers' representation is less than 10% (Menezes, 2018).

Engineering is a challenging and demanding profession where a higher mathematics and scientific knowledge is required with better cognitive skills to solve complex problems (Chan and Fishbein, 2009). Hence, some adults in society motivate young female students not to choose engineering as their future career due to the complex nature of the profession, emphasizing that only men can do it (Wahid, 2020). Moreover, lack of understanding and less interest in the engineering profession among young female students has also reduced their enrollment for engineering degree programmes (*Gender disparity in engineering - EngineeringUK | Inspiring tomorrow's engineers.*, 2021).

After finishing the university education, women engineers confront difficulties in finding suitable engineering job opportunities since some employers hesitate to recruit women engineers to challenging and demanding positions in their companies (Subri, 2018). Some employers have concerns about women's commitment towards their families as a mother and as a caregiver will affect the duties of the engineering job role if they are recruited for such positions. Compared to men, women require maternity leave and additional leave for babysitting and other family commitments (Maji, 2019). Hence, women engineers find it challenging to fulfil their professional responsibilities over the family commitments creating issues in work-life balance.

Most engineering job roles carry a huge workload that requires additional working time to complete

over the traditional work hours. In such situations, women engineers also confront work-life balancing issues (Maji, 2019). Generally, why women engineers leave engineering is a widely discussed topic in the research arena (Fouad *et al.*, 2017; Singh *et al.*, 2018). A study conducted to identify the reasons behind women engineers' decisions to leave the engineering profession in the United States of America (USA) based on a sample of 1461 women engineers who have left the profession has identified three primary reasons (Fouad *et al.*, 2017). The first reason is the poor and/or inequitable compensation, poor working conditions, an inflexible and demanding work environment that made work-family balance difficult for women engineers. The second reason is the unmet achievement needs that reflected unhappiness with the effective application of their engineering knowledge gained from the universities. The third reason is the unmet needs concerning lack of recognition at work and inadequate opportunities for career advancement in the engineering profession. Furthermore, Subri (2018) has identified 14 factors that challenge women engineers' staying in the engineering profession after marriage from a comparative study conducted on previous studies of women engineers worldwide. Those 14 factors were leadership, gender discrimination, sexual harassment, work-life balance conflict (working-family), child care, safety, support, health, work environment, communication, salary, transportation, leave, and women mentors. Of them, gender discrimination, work-life balance conflicts, and child care were the key factors that strongly influenced married women engineers to leave engineering jobs. Faulkner (2009) has highlighted that the engineering workplace culture is still not friendly for women engineers to remain and progress in the profession. Engineering workplace culture should be modified to be a welcoming, comfortable, and supportive place for women engineers. According to Devi, Golden and Regi (2020), women engineers in the Indian construction industries face harassment, discrimination, limited networking opportunities, and long & inflexible working hours. All these factors cause tremendous mental stress for women engineers while catalyzing the decision of leaving the

engineering profession early. Similarly, a qualitative study conducted on a sample of women engineers working in the infrastructure development sector in Sri Lanka about their everyday experiences has identified three major groups of categories as "Everyday life as a struggle, Everyday life as a truce, and Everyday life as persistence" since women engineers' working day comprises with various challenges (Menezes, 2018).

Although numerous studies have identified that women engineers have to face more issues and challenges in the engineering workplace than male engineers do, it does not mean that engineering is not for women (Smith and Dengiz, 2010). According to Devi, Golden and Regi (2020), women are more multi-tasked than men, are professionally ethical, committed to their work, less corrupt, with better listening and soft skills. Furthermore, women are loyal, practical, innovative, and patient and know how to improve the company's reputation. If women engineers are experts in technical matters, with the above qualities they can perform better in the engineering profession than men.

According to the literature, the studies conducted on various aspects of women engineers who stay and sustain themselves in the engineering profession are in the infant stage (Ayre, Mills and Gill, 2013; Buse, Bilimoria and Perelli, 2013). Today, successful and world-famous women engineers have won the world with their passion-driven commitment and persistence while shattering the glass ceiling. The American Society of Mechanical Engineers (ASME) web page displays an article about 10 influential women in engineering who serve in the top management positions in world-leading tech organizations, becoming role models of women engineers. According to the website, their passion for engineering has been the primary reason behind their success (Sethi, 2020). Buse, Bilimoria and Perelli (2013) have identified that women engineers who retained themselves in the engineering profession are persistent. They can overcome countless difficulties in male-dominated industries, enabling them to find fulfilling and rewarding experiences in the engineering profession. Such women engineers

demonstrate high levels of self-efficacy and are motivated by the profession's challenges and novelty. According to Ayre, Mills and Gill (2013), women who stay in the engineering profession firmly believe in themselves as engineers and are self-confident. However, they too had to experience being isolated, overlooked and marginalized in the prevailing masculine culture of engineering workplaces. Thanks to their persistence, such women engineers could successfully retain themselves in the industry for a long time.

Many pieces of evidence can be found in both local and international research literature regarding the challenges and issues faced by women engineers in their job role while focusing on reasons to leave the profession (Watts, 2009; Fouad *et al.*, 2017; Menezes, 2018; Devi, Golden and Regi, 2020). However, studies conducted to identify the reasons and motivations behind women engineers staying in the engineering profession are limited, creating a grey area in the literature (Ayre, Mills and Gill, 2013; Buse, Bilimoria and Perelli, 2013). Such studies are rare in the Sri Lankan engineering sector. Hence, this study aims to fill the existing gap to some extent by investigating the self-confidence of young women engineers in the Sri Lankan industrial sector, which causes their retention in the profession.

3. METHODOLOGY

This study used both quantitative and qualitative approaches to achieve the objectives by sharing a self-administered online questionnaire among the target participants. The questionnaire consisted of three sections. The first section consisted of questions to capture the participants' demographic information. The second section consisted of several statements with five-point Likert-type responses to capture participants' perceptions of their self-confidence. The third section consisted of an open-ended question, for which the participants could express their advice and recommendations for future women engineers freely as a qualitative survey. Google form was created, including the questionnaire and a brief description of the research study to share with the participants. It

was shared among a conveniently selected sample of 250 young women engineers in Sri Lanka via email and Facebook within 2021. Nowadays, various scholars widely use convenient sampling because it is convenient in reaching the research participants for data collection (Jager, Putnick and Bornstein, 2017).

Simple data analysis strategies were followed to analyze the responses since authors wish to disseminate the findings, especially among women engineering undergraduates and young school girls, to popularize engineering as a career choice for them. Responses received for Likert-type statements were analyzed using simple bar charts for the convenience of understanding (Robbins and Heiberger, 2011). Responses to the open-ended question were analyzed following the thematic analysis approach to identify the emerging patterns and themes relevant to the positive workplace experiences of young women engineers in Sri Lanka (Braun and Clarke, 2006).

4. RESULTS & DISCUSSION

For the questionnaire, eighty-two responses could be collected from young women engineers in Sri Lanka. Hence, the response rate is 32.8%. Young women engineers who responded to this questionnaire will be known as 'respondents' hereafter in this paper.

Demographic information of respondents

In this section, the demographic information of the respondents is demonstrated.

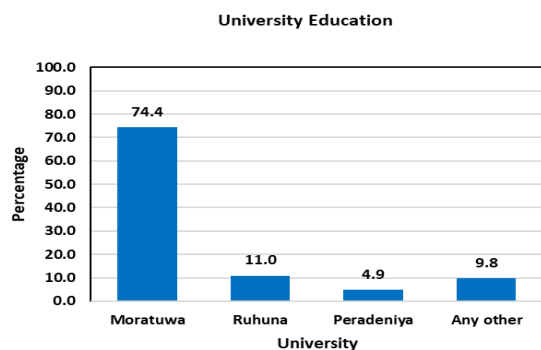


Figure 1: University wise education of respondents

Most respondents have studied at the University of Moratuwa (74.4%). All respondents were below the age of 35 years at the time of this study.

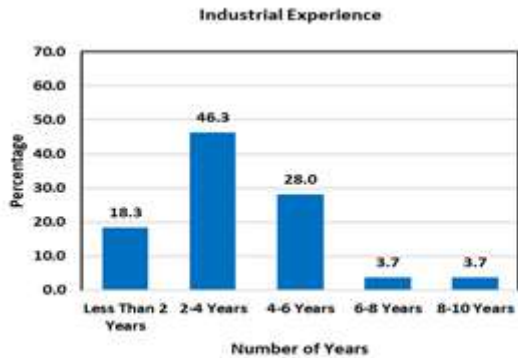


Figure 2: Industrial experience of respondents

According to figure 2, the industrial experience of respondents was below 10 years. The majority of the respondents have the industrial experiences for 2 – 4 years (46.3%).

Young women engineers from various engineering disciplines have responded to the questionnaire. Table 1 shows the percentage of respondents who answered from each engineering discipline.

Table 1: Engineering discipline wise distribution of respondents

Engineering Discipline	Percentage
Chemical & Materials Engineering	28.0
Civil Engineering	24.4
Electrical & Electronics Engineering	24.4
Mechanical & Production Engineering	6.1
Computer Engineering	2.4
Any Other	14.6
Total	100.0

Furthermore, 63.4% of respondents work in the private sector organizations as engineers, while 36.6% of respondents work in the state sector organizations as engineers. 12.2% of respondents are the only female engineers who work in their workplaces, while 87.8% have other female engineers in the workplace.

The self-confidence of young women engineers

Several statements were given to respondents to

investigate their perception on self-confidence as young women engineers in Sri Lankan industrial sector. Their responses on a five-point Likert scale were illustrated as bar charts for easy readers' understanding.

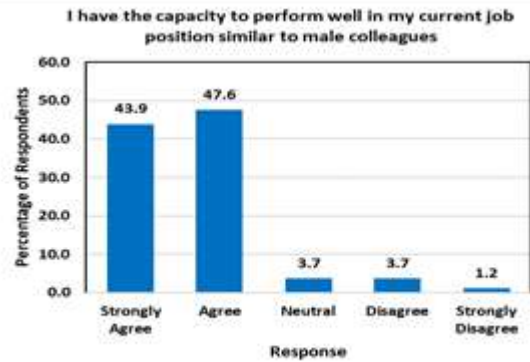


Figure 3: Perception on capacity to work in current job position

Figure 3 illustrates respondents' perception on their capacity to perform well in the current job position in comparison with the male colleagues. Majority of them (91.5%) have the confidence to perform competently in their current engineering job positions. Society has a belief that women engineers do not have the required capacity to fulfill engineering job related responsibilities (Ramachandran, Ramanathan and Khabou, 2020). The above finding disproves the misconception prevailing in the Sri Lankan society to some extent.

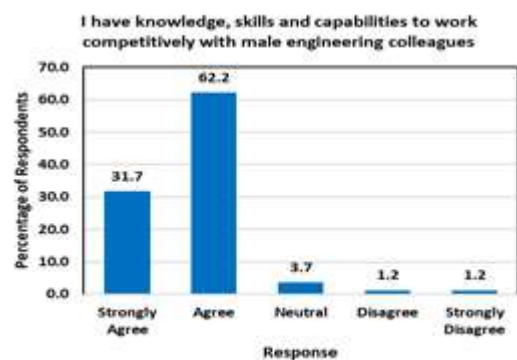


Figure 4: Perception on ability to work competitively with male engineering colleagues

Since male engineering colleagues represent the majority of the engineering profession, the minority

of women engineers have to work competitively with them if they expect to sustain themselves in the profession. If women engineers do not have the required persistence, they will automatically opt-out of the profession without competition (Buse, Bilimoria and Perelli, 2013). According to figure 4, most respondents (93.9%) have verified that, as per their experience, they have knowledge, skills, and capabilities to work competitively with male engineering colleagues. Only a few respondents were not confident of performing competitively with male engineering colleagues.

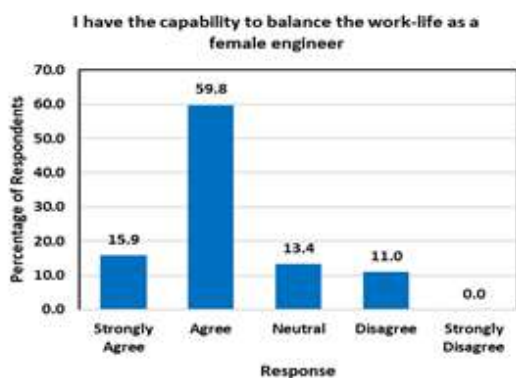


Figure 5: Perception on ability to balance the work-life

Most of the available literature highlights that women engineers confront issues in balancing the work-life with their job-related responsibilities (Watts, 2009; Menezes, 2018). However, 75.7% of respondents believe that they can balance their work-life as female engineers. Only 11.0% of respondents have disagreed with it, while 13.4% of respondents have stayed in a neutral attitude. This observation can be considered a positive trend happening among the young female engineers' community to balance their work-life. As Sethi (2020) emphasized, if they have the passion and commitment for the engineering profession, work-life balancing is not a very difficult or complex thing to achieve.

According to figure 6, 63.3% of respondents are happy about their achievements as female engineers, while 21.9% of respondents are unhappy about their accomplishments. However, more than half of the respondents have emphasized that they are satisfied with their current achievements demonstrating that

Sri Lankan industrial sector is not an unsuitable place for women engineers.

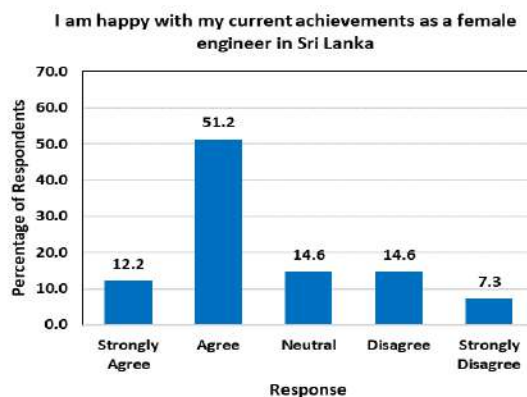


Figure 6: Perception on current achievements as a female engineer

As Menezes (2018) highlighted, most Sri Lankan women engineers have the required dedication and courage to achieve what they need in their professional life while overcoming day-to-day struggles and barriers.

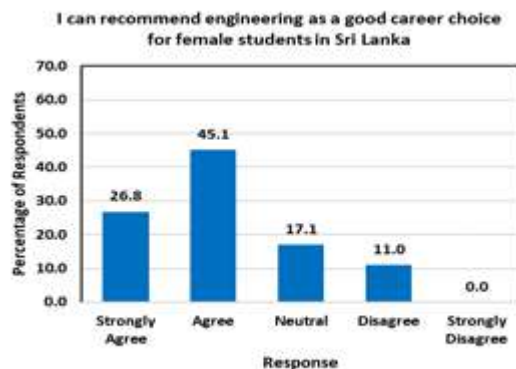


Figure 7: Perception on recommending engineering

Based on the industrial experience and current achievements, 71.9% of respondents have verified that they can recommend engineering as a good career choice for female students in Sri Lanka. 11.0% of respondents have disagreed with it while 17.1% have stayed neutral. However, the majority is recommending young female students to choose engineering as their future career since engineering is a promising profession not only for men, but also for women in Sri Lanka.

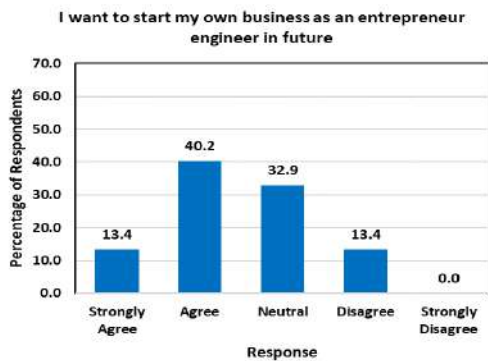


Figure 8: Perception to be a women entrepreneurial engineer

Nowadays, entrepreneurship has become a promising wealth creation by establishing innovative firms. Figure 8 demonstrates the perception of respondents on establishing their own business ventures as women entrepreneurial engineers in Sri Lanka. It was observed that women entrepreneurial engineers are scarce in the Sri Lankan context (Wijesinghe, Jayawardane and Dasanayake, 2021). According to figure 8, a considerable number of respondents are willing to start up their own firms as entrepreneurs in Sri Lanka (53.6%), while 32.9% of respondents have stayed neutral on this statement. All engineers cannot become entrepreneurial engineers due to various reasons. However, this is an excellent evidence to show the entrepreneurial intention of young women engineers in Sri Lanka. Women entrepreneurial engineers need the support of the government and international organizations to empower them as successful female entrepreneurs in engineering disciplines (Mehrzhad *et al.*, 2021).

These findings show that most respondents are self-confident to compete with male engineering colleagues while fulfilling the engineering-related job responsibilities competently in the Sri Lankan industrial sector. The majority of them are satisfied with their current achievements as female engineers, while they also recommend the engineering profession for young females.

Recommendations for future women engineers

Thematic analysis of the responses received for the open-ended question in the questionnaire as advice & recommendations for future women engineers reveals three themes of advice. They are ‘choose the field wisely, be passionate, and be dedicated to the profession.’

- **Choose the field (engineering discipline) wisely**

Since there are several engineering disciplines nowadays for any engineering undergraduate to be specialized, selection should be made wisely as it affects the entire professional life of the engineer irrespective of gender. Several respondents have mentioned that young female engineering undergraduates should be extra careful in selecting their engineering disciplines. A respondent has mentioned her advice as “*Get a thorough awareness about all the engineering disciplines before choosing your field.*” According to her, selecting the discipline without a background check will be disastrous for any female engineer as such selections will not suit their professional expectations. “*Better to study in a field you are interested in; if not, work-life will be stressful.*” Another response is as above. Studying in an uninterested field is stressful during undergraduate education for any student. Similarly, performing job-related responsibilities in an uninterested engineering discipline will give women engineers the same stressful experience, causing them to leave the engineering profession in a shorter time. Two other respondents also emphasize “*Select your favourite field*” and “*Choose what you prefer.*” Choosing the preferred field is sometimes difficult in engineering degree programmes offered by state-sector universities in Sri Lanka. It is based on the merit list prepared based on the marks for semester-end examinations of the first year of the degree programs. If anybody wants to choose the preferred engineering discipline, they should work hard and score higher marks in the examinations above.

- **Be passionate about engineering**

Choosing engineering just because you are an expert

in Mathematics is not a reason to become a successful engineer irrespective of gender (Fouad *et al.*, 2017). As Devi, Golden and Regi (2020) highlighted, men typically have engineering-related hobbies like assembling and disassembling complex toys during their childhood. However, young girls have soft hobbies like playing with dolls that do not have any association with engineering. Hence, females are less passionate about engineering subjects from childhood. Several respondents have emphasized that young women engineers should be passionate about engineering. *“Do not select engineering if you are not truly passionate about the field and new technologies.”* As the above advice highlights, women engineers should also have a keen eye for new technologies. They should get updated with the latest technologies relevant to their practice area.

“Being a girl is not an obstacle to being an engineer. If you are interested and have good analytical skills, you can perform well in an engineering profession.” According to Ramachandran, Ramanathan and Khabou (2020), women engineers coming out from Indian Universities are confident to work competitively with male engineers in rapidly growing industrial sectors in India since such women are interested in engineering like males. Sri Lankan young women engineers have identified the same from their experience in the industry.

Another respondent has verbalized her advice as *“Do not consider the gender as a disadvantage. It's not the gender that matters, it is the knowledge, and the passion always matters.”* This, too, highlights the significance of self-induced passion for engineering for the success of women engineers in Sri Lanka. As per her experience, gender disparity is nullified if the female engineer has sufficient knowledge and passion for the engineering profession. According to Hersh (2000), there is a higher tendency for women engineering graduates who do not have the passion for engineering to leave the engineering profession within a short period of employment to non-engineering positions in various other organizations. Hence, women engineers, especially the young generation, should have the passion and interest in

engineering to sustain the industry successfully.

- **Be dedicated to the profession**

The majority of the respondents have mentioned that young women engineers should be more dedicated to the profession in various ways if they want to sustain themselves in the engineering profession. As Ayre, Mills and Gill (2013) highlighted, persistence is required for women engineers to be in the profession amidst various conflicts. If dedication is not there, they cannot be persistent. To work competently in the engineering profession, women engineers should dedicate themselves to their job, although it is not easy. A respondent has verbalized her concern as *“Work hard until you reach your destination and of course, at the starting stage of the engineering profession, as a fresh graduate or without field experience may lead to some stress full career in your life. But after two or three years, it will change. If you work hard in your career, definitely you will become a successful engineer in society. So don't give up.”* According to her, becoming a successful women engineer is not that easy. There may be a lot of ups and downs due to various reasons like lack of industrial experience and knowledge. If the female engineers have the endurance to face the challenges while working hard, two-three years are enough to grab the essence to sustain in the industry. As Chan and Fishbein (2009) highlighted, gaining industrial experience is very important for any young engineer to sustain in the industry. *“Need to be thorough on basic engineering principles and important to have hands-on experience on the field you are in.”* The above excerpt also proves that women engineers should be thorough in engineering knowledge and have hands-on experiences in engineering activities relevant to the field of practice. Hence, it is not required to be afraid of making firm decisions in a professional capacity if she is confident about her knowledge and experience. *“Due to lack of knowledge and experience, many young women engineers cannot make firm decisions in their jobs. Because of that, they have to seek the support of male engineering colleagues, which in turn support the claim that female engineers are incompetent (Subri, 2018)”*

A respondent has expressed her advice as, “*I am telling you this advice from my personal experience. If you are interested in the engineering profession, ignore all negative thoughts and comments from others.*” Still, society is full of negative thoughts and instructions which could demotivate any young female student from choosing engineering as her future career choice (Ramachandran, Ramanathan, and Khabou, 2020). According to the above excerpt, if any young female student is interested in engineering, she may not consider the negative thoughts and comments of others, which discourage them since engineering is a promising profession for women worldwide (Sethi, 2020). Another respondent has articulated her advice to the young generation as “*Choose engineering as the profession if you are really ready to accept challenges as a female engineer.*” Female engineers indeed have to face more challenges than male engineering colleagues in any society (Watts, 2009). However, sustaining them in the engineering profession is not difficult if they are dedicated to meeting those challenges.

“*Must develop their communication skills, personality, & leadership skills, etc.*” Engineers should have a balanced set of technical and soft skills for better performance (Chan and Fishbein, 2009). Hence, irrespective of gender, engineers should develop soft skills like communication, personality, and leadership skills. Since women engineers have to undergo various difficulties in the field, they should have the above skills to face the challenges successfully. Furthermore, another respondent has stated that they should “*respect to all workers and technicians.*” Women engineers should also focus on this matter since they have to maintain a healthy relationship with subordinate employees where the majority are males. It is essential for long-term existence in the profession.

Work-life balancing is another issue confronted by a majority of women engineers in the world (Watts, 2009; Singh *et al.*, 2018). Hence, another respondent has mentioned it in her advice: “*Personal & professional life balance is the main challenge faced by lady engineers. All must be more concerned about it.*” To tackle this problem, the support of senior women engineers is essential for young women

engineers as mentors. They can guide the young generation on balancing personal and professional life. However, the lack of female role models in the engineering field is widespread in most countries globally (Devi, Golden, and Regi, 2020). In such situations, professional engineering associations should take the lead to share the experiences of successful senior women engineers with young women engineers to fill this gap.

From the above findings, it is clear that young women engineers should focus on selecting the preferred or interested engineering discipline to perform successfully in that discipline. Furthermore, they should be passionate and dedicated to the engineering profession if they really need to sustain themselves as women engineers in Sri Lanka.

5. CONCLUSIONS

Based on this study, it can be concluded that the majority of the young women engineers who participated in this study are confident about themselves as women engineers. As per their responses, they have the capacity, knowledge, skills, and capabilities to work competently in the industry with men. The majority of them are satisfied with their current achievements and have recommended engineering as a promising career choice for young female students in Sri Lanka. As advice, they instruct future young women engineers in Sri Lanka to choose the field wisely, be passionate, and be dedicated to the engineering profession if they want to retain themselves in it. The findings of this study can be considered as recommendations for future women engineers to consider as stay strategies in the engineering profession.

This research, too, has several limitations. Choosing the convenient sampling strategy limits the generalizability of this study's findings to the entire young women engineer population. Depending only on the data collected from young women engineers can be identified as another significant limitation of this study. Hence, further studies should be conducted with senior women engineers, engineering employers and male engineering colleagues in Sri

Lanka to expand the research literature associated with the minority group of women engineers in Sri Lanka.

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ASSESSMENT OF GROUNDWATER QUALITY USING MULTIVARIATE STATISTICAL METHODS AT NAGADEEPA AREA IN BADULLA DISTRICT, SRI LANKA

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ABSTRACT

The study area, Nagadeepa is situated in Badulla District within the dryer parts of the country. Groundwater is the main drinking water source in the area. The study was carried out from 2013 to 2016 and the main objective of the study was to examine the chemical status and pollution levels by examining of 25 water quality parameters namely Na⁺, K⁺, Mg²⁺, Ca²⁺, Pb, Mo, Cr, Cd, Mg, Hg, As, Al, Zn, Se, Cl⁻, F⁻, NO₃⁻, HCO₃⁻, SO₄²⁻, PO₄³⁻, DO, pH, temperature, electrical conductivity and water hardness in 28 wells. The results of the factor analysis indicated that conductivity, alkalinity, hardness, Calcium, Fluoride, Mo, Cr and Cd have a strong impact on the water quality compared to the categories of moderate and weak loadings. The parameters namely; Mg, Na, As and Al, Zn, Se and Water Level, Se, Cl, pH and DO, Pb have a moderate impact on water quality based on the moderate loadings indicated by the PC analysis. The weak impact on water quality is indicated by Cl⁻, SO₄²⁻ and K, PO₄, Hg, Se and Hg, Se, Al and Temperature, Cl⁻, pH and PO₄³⁻. Analysis indicated that; (i) significant and positive correlation with alkalinity, hardness, Ca²⁺ and Mg²⁺, (ii) positive and significant correlation only with hardness and Ca²⁺, (iii) Hardness shows positive and significant correlation only with Ca²⁺, (iv) Fluoride has a positive and significant correlation with Mo²⁺ and (v) Na⁺ has a positive and significant correlation only with Mg²⁺. Cluster analysis indicated, cluster 1 with less polluted water in 9 wells, cluster 2 with moderately polluted water in 11 wells, cluster 3 with highly polluted water in 7 wells, and cluster 4 with very highly polluted water in one well. Factor analysis indicated that pH, conductivity, alkalinity, hardness, dissolved oxygen, chloride, and sulfate are the major factors that affect the quality of the water. In the majority of the sampling wells, the correlation coefficient revealed a geogenic nature. Cluster analysis revealed that 29% of wells are unsuitable for drinking purposes.

KEYWORDS: Groundwater quality, Multivariate Statistical Methods

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1. INTRODUCTION

Water and land are the vital resources of life that are progressively being polluted due to poor land-use management, population growth, industrialization, agricultural activities and anthropogenic impacts on the area (Olajire and Imeokparia, 2001). Groundwater is the main water source for human consumption, specifically in the dry areas where the surface water sources are unavailable. Analysis of water pollutants of groundwater is a very useful tool which provides important information for water quality management (Pazand et al., 2011). 80% of diseases in developing countries are directly related to poor drinking water (Olajire and Imeokparia, 2001).

Major chemical factors such as Na^+ , K^+ , Mg^{2+} , Ca^{2+} , Cl^- , F^- , NO_3^- , HCO_3^- , SO_4^{2-} , PO_4^{3-} pH values, temperature, electrical conductivity and hardness play an important role in the groundwater quality. Several parameters and their correlation are necessary to determine the water quality characteristics in the study area.

The multivariate statistical method of factor analysis is one of the tools used to identify the major factors responsible for groundwater contamination as discussed in Balasuriya et al (2021), Senanayake, Indunil et al. (2021) and Olajire and Imeokparia, 2001). In addition to that Cluster Analysis (CA), Descriptive Analysis (DA), and Principal Component Analysis (PCA) were used in this research work. These techniques can be used to obtain relationships and interactions between parameters and sampling locations, to identify the factors and sources influencing groundwater quality and to suggest useful tools for both management of water resources and monitoring of groundwater quality (Nosrati and Eekhault, 2012). CA was used to examine the spatial groupings of the sampling wells. It is a common method to classify variables into clusters (Massart and Kaufmann, 1983). CA and PCA are commonly supported by DA as a confirmation for CA and PCA, and they are usually referred to as pattern recognition techniques (Adams, 1998). The application of different pattern recognition techniques to reduce the complexity of a large data set has proven to give a

better interpretation and understanding of water quality data (Brown et al., 1980). This method is widely applied to study the interrelation and correlation of variables in hydrology, geology, environmental science, etc. (Liu et al., 2003; Singh et al., 2004). Factor analysis acts as a tool that could measure and observe the variables and can reduce large data sets to fewer latent variables and share a common variance and are unobservable (Bartholomew, Knott and Moustaki, 2011). The unobservable factors are not directly measured, but it is essential to construct hypothetically to represent the variables (Cattell, 1973 cited in Yong and Pearce, 2013). Further, factor analysis is useful for easy interpretation of a large data set reducing to a smaller set by considering common key factors placing variables into meaningful categories (Rummel, 1970, cited in Yong and Pearce, 2013).

The eigenvalues and scree test (i.e., scree plot) are used to determine how many factors to retain. One criterion that can be used to determine the number of factors to retain is Kaiser's criterion, which is a rule of thumb. Therefore, it is suggested to use the scree test in conjunction with the eigenvalues to determine the number of factors to retain. The scree test consists of eigenvalues and factors (Cattell, 1978). The number of factors to be retained is the data points that are above the break (i.e., point of inflexion).

1.1 The objectives

The main objective of the present study is to examine the chemical status and pollution levels of the groundwater of Nagadeepa study area with respect to Na^+ , K^+ , Mg^{2+} , Ca^{2+} , Cl^- , F^- , NO_3^- , HCO_3^- , SO_4^{2-} , PO_4^{3-} , hardness and pH values, temperature, electrical conductivity and hence to ascertain the status of these elements in the water.

Many studies already carried out in the past exists (Chandrajith et al., 2011a; Jayasekara et al., 2013; Wanigasuriya et al., 2011; Bandara et al., 2010; Illeperuma et al., 2009; Wanigasuriya, 2007; Hittarage, 2004) on ground water quality in the study

area. However, based on the multivariate statistical methods such as Factor Analysis, Cluster Analysis (CA), Descriptive Analysis (DA), and Principal Component Analysis (PCA) of such water quality parameters used in clustering the ground water sources which could be used for consumption is not available. The present study is to fill that research gap and to help people to use groundwater from clustered areas which are safer to use for consumptive purposes. The findings of this study will be significant for detecting such water sources for the people in the area to use for consumption. Particularly due to the Chronic Kidney disease with uncertain etiology (CKDu) reported in the area, this research will provide valuable information to use safer drinking water sources for consumptive purposes.

The problem statement of this research was to find out whether there are interconnected activities among the water quality parameters. The research question is to find out the suitability of the groundwater for drinking purposes. The significance of the research is important to find out the effect of such parameters and their composite effects on groundwater quality and to fill the information gap on water quality in the study area.

1.2 Study Area

The study area of Nagadeepa is situated in Badulla District, which falls within the dryer parts of the country. A small part of the Nagadeepa study area is irrigated by the Nagadeepa tank and the majority survives by receiving water from the monsoons. Groundwater is the main drinking water source for the people in that area. The Nagadeepa study area falls within 16 GN divisions in the Rideemaliyadda DS division of the Badulla district with the geographical positions of 81.072° longitude, 7.355° latitude and 81.145° longitude, 7.228° latitude and the total population is 19103 (Census, 2012), the study area receives rainfall mainly from the northeast monsoon.

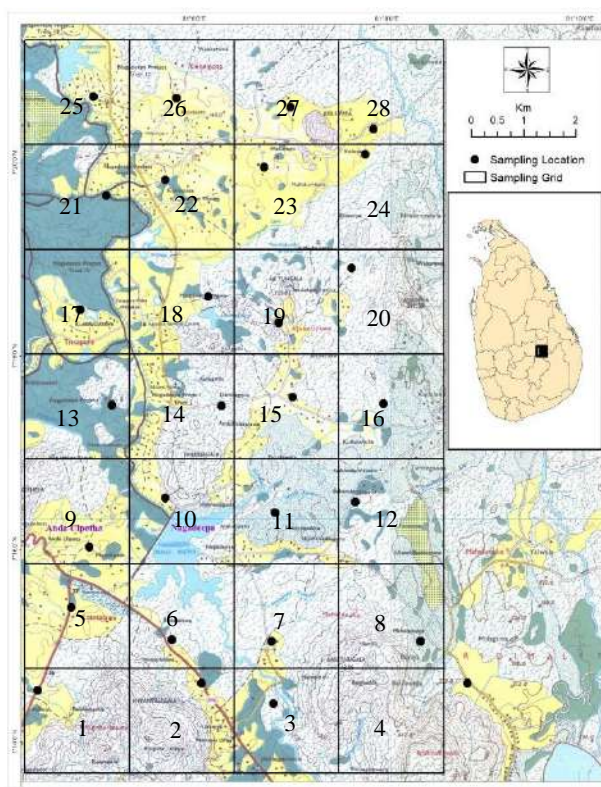


Figure. 1. Sampling locations

2. METHODOLOGY

Nagadeepa study area map (1:50,000) was divided into 28 squares to mark the approximate sampling points in each area (Fig. 1). The approximate middle point of each square was selected as the groundwater sampling location and GPS points were taken to locate the sampling points from which samples were collected.

Sample collection and storage:

The samples from dug wells were collected in two different sampling bottles. (i) 500 ml HDPE bottles to collect samples to analyze chloride, sulfate, fluoride, nitrate and phosphate. (ii) Samples were collected in 100 ml sample bottles and 2 ml trace metal nitric acid was added to each sample to analyze trace metals.

Water quality analysis:

pH, DO, Electrical Conductivity (EC), Temperature, Alkalinity and Hardness were analyzed in the field, using HACH sensION portable kits. In addition, the water levels of all the wells were noted. Hardness, chloride and alkalinity were determined using HACH digital titrator. Analyses of fluoride, nitrate, phosphate, sulfate, and iron were carried out using HACH DR 2700 Spectrophotometer.

Determination of the trace elements:

Atomic Absorption Spectrophotometer (AAS Thermo Scientific, iCE 3000 series) was used for the analysis of Ca⁺² while Inductively Coupled Plasma Mass Spectrophotometer (ICP-MS; Thermo Fisher iCAP Q) was used for the analysis of Na⁺, K⁺, Mg⁺², Zn⁺², Pb⁺², Cd⁺², As, Cr, Al⁺³ Hg, Mo.

Data Analysis and Interpretation of the results:

In this study, SPSS Version 16 and Minitab Version 16 software packages were used to analyze the water quality data.

Multivariate Statistical Analysis:

Correlation Coefficient and Multivariate data analytical methods of Factor analysis and Cluster analysis were used to interpret the underlying pattern of the data sets. These techniques were used to identify different groups of variables and their relationships.

4. RESULTS & DISCUSSION

Multivariate Statistical Analysis on water quality parameters of the study area

Multivariate analysis of the statistical methods such as Factor Analysis, Cluster Analysis and Correlation Coefficient is widely used, and it is capable of analyzing a data set to get an insight into the underlying pattern of such data set.

These techniques are useful to identify different groups of variables and their relationships.

In the present study, initial factor loadings were calculated by 1st step of the Factor Analysis based on the extraction method of Principal Component Analysis (PCA). The 2nd step of the analysis was the Factor rotation performed by the most common orthogonal method called varimax rotation to explain the number of characteristics of factors.

Table 1. Total Variance Explained by Principal Component Analysis Extraction Method in Nagadeepa

Component No.	Initial Eigenvalues		
	Eigenvalues	% of Variance	Cumulative %
1	4.122	15.852	15.852
2	3.383	13.013	28.865
3	2.855	10.982	39.847
4	2.156	8.292	48.139
5	1.634	6.286	54.426
6	1.243	4.782	59.208
7	1.151	4.427	63.635
8	.996	3.831	67.466
9	.936	3.600	71.066
10	.895	3.440	74.507
11	.820	3.155	77.661
12	.684	2.630	80.291
13	.640	2.461	82.752
14	.570	2.192	84.944
15	.553	2.126	87.070
16	.530	2.039	89.109
17	.470	1.809	90.918
18	.434	1.669	92.587
19	.389	1.497	94.084
20	.336	1.293	95.377
21	.313	1.204	96.582
22	.264	1.015	97.597
23	.198	.763	98.360
24	.173	.666	99.027
25	.131	.504	99.531
26	.122	.469	100.000

Extraction Method: Principal Component Analysis.

Table 1 illustrates the initial factor loadings which exhibit the eigenvalues, percentage of variance and cumulative percentage of variance associated in Nagadeepa study area. Twenty-six parameters in sampling locations have been considered for this analysis. The analysis generated 7 factors for the total variance. Eigenvalues greater than 1 were considered as a criterion for the extraction method of principal parameter components vital for explaining the sources of variance in the data.

As illustrated in Table 1, the results revealed that 7 factors have eigenvalue greater than 1 and these factors explain more than 63% of the total variance. Therefore, 7 factors namely; pH, conductivity, alkalinity, hardness, dissolved oxygen, chloride and sulfate are considered for explaining the major factors that affect the water quality in Nagadeepa study area. The seven factors account for 15.9, 13.0, 10.9, 8.3, 6.3, 4.8 and 4.4 of the percentage of total variance respectively. Fig. 2 illustrates the Eigenvalues vs Parameter components.

Table 2 illustrates the results of the verimax rotation. The significance of the factors classified according to Liu et al. (2003) are summarized in Table 3.

Table 3 illustrates Rotated Component Matrix in the Nagadeepa study area, in factor 1 that accounts for 15.85% of the total variance. Strong positive loading was observed in conductivity, alkalinity, hardness and calcium while it shows that the moderate loading of Mg^{2+} and weak loading of Cl , SO_4^{2-} and K^+ . In factor 2, there were strong loadings in F and Mo while Na, As and Al were moderately loaded and PO_4^{3-} was weakly loaded. In the 3rd factor, there was strong loading only on Cr, moderate loading in Zn, Se and water level, and Hg was weakly loaded. Four parameters were observed in factor 4 where SO_4^{2-} and NO_3^- were with moderate loading and Se and Hg with weak loading.

Cd indicated a strong loading in factor 5 and Cl^- was moderate and Se, Al and Temperature were observed as weakly loaded.

Table 2. Variables and factor loadings after varimax rotation for the study period in Nagadeepa

Rotated Component Matrix ^a							
Parameter	1	2	3	4	5	6	7
pH	.028	-.006	-.264	-.071	.041	.690	.396
Conduc.	.911	.159	-.008	.082	-.024	.018	.088
Alkalinity	.888	.055	-.139	.047	.078	-.014	.055
Hardness	.855	-.157	-.198	.131	.234	-.079	.025
DO	-.270	.082	.205	-.128	-.078	.699	-.030
Cl	.341	-.150	-.185	.133	.521	.346	-.323
SO4	.352	.269	-.077	.674	-.071	.003	.177
F	.233	.778	-.206	-.097	.185	.085	.136
NO3	.080	-.045	.125	.671	-.087	.058	-.070
PO4	-.141	.400	-.338	.212	.100	-.021	.315
Na	.048	.686	.030	.114	-.479	.070	.093
K	.476	.019	.100	-.604	-.222	.004	.285
Ca	.753	-.283	.144	.073	-.074	-.013	-.112
Mg	.621	.209	.230	-.347	-.235	-.014	.127
Fe	-.120	-.067	-.103	-.265	-.088	-.617	.221
Zn	-.027	-.056	.637	.073	-.198	.217	.161
Pb	.129	.055	.153	-.030	.045	-.011	.715
Cd	-.016	.173	-.155	-.055	.755	-.033	.160
As	-.138	.704	.061	.030	.018	.015	.027
Cr	-.007	.119	.750	-.160	-.118	-.057	.022
Se	.008	-.088	.565	.454	.329	-.059	.069
Al	-.157	.647	.171	-.184	.316	.002	-.188
Hg	-.075	-.085	.412	.311	-.028	-.265	.140
Mo	.076	.829	.030	.035	-.030	.000	.024
Tem.	-.030	.296	-.155	.116	.327	.168	-.098
WLevel	-.059	.045	.576	.153	-.451	.158	-.296

Extraction Method: Principal Component Analysis
 Rotation Method: Varimax with Kaiser Normalization

a. Rotation converged in 9 iterations

Table 3: Summary of classified factor loadings as strong, moderate and weak in Ngadeepa as indicated in Liu et al. (2003) derived from Table 2

Factor Loadings				
Factor	Strong loading- >0.75	Moderate loading- 0.75 – 0.5	Weak loading- 0.5 – 0.3	% of Variance
1	conductivity, alkalinity, hardness, calcium	Mg	Cl, SO ₂ and K	15.852
2	Fluoride, Mo	Na, As and Al	PO ₄	13.013
3	Cr	Zn, Se and Water Level	Hg	10.982
4	None	Se	Se and Hg	8.292
5	Cd	Cl	Se, Al and Temperature	6.286
6	None	pH and Do	Cl	4.782
7	None	Pb	pH and PO ₄	4.427

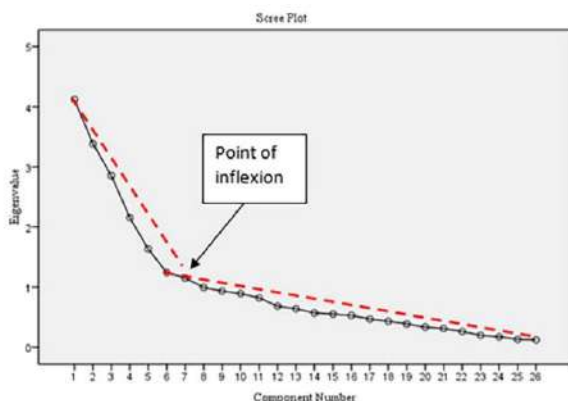


Figure: 2 Scree plot showing Eigenvalues vs. component number (parameters) in Nagadeepa study area

In factor 6, pH and DO were with moderate loading and Cl⁻ was observed a weakly loading effect. Pb indicated a moderate loading in factor 7 while pH and PO₄³⁻ were weakly loading.

These results indicated that conductivity, alkalinity, hardness, calcium, Fluoride, Mo, Cr and Cd have a strong impact on the water quality of Nagadeepa study area compared to the categories of moderate and weak loadings. The parameters namely; Mg, Na, As and Al, Zn, Se and Water Level, Se, Cl, pH and DO, Pb have a moderate impact on water quality based on the moderate loadings indicated by the PC analysis. The weak impact on water quality is indicated by Cl⁻, SO₂²⁻ and K, PO₄, Hg, Se and Hg, Se, Al and Temperature, Cl⁻, pH and PO₄.

Correlation coefficient

The results of the correlation analysis are considered in the subsequent interpretation.

High correlation coefficient of nearly 1 or -1 expresses a good relationship between two variables, and a correlation coefficient around zero means no relationship.

The variables having a coefficient value (r) > 0.5 or < -0.5 are considered significant. Positive values indicate a positive relationship while negative values of r indicate an inverse relationship. The correlation coefficients (r) among various water quality parameters of Nagadeepa study area were calculated and the values of correlation coefficients (r) are given in Table 4.

Correlation coefficients of parameters in the study area

The results are illustrated in Table 4 that pH has no significant correlation with other parameters, but it shows a weak positive and negative association with all. Negative correlations were observed in F⁻, Na⁺, Mg²⁺, Fe²⁺, Cd, As, Cr, Se and water level. Following ions act as a negative association, NO₃⁻, Na⁺, Ca²⁺, Fe²⁺, Zn²⁺, Cd²⁺, Cr, Se²⁺, Al³⁺, Hg and water level. The results of conductivity indicated a significant and positive correlation with alkalinity, hardness, Ca²⁺ and Mg²⁺.

**Table 4 Correlation Coefficient in Nagadeepa study area –
Correlations: pH, Conduc, Alk, Hard, Do, Cl, SO4, F,**

	pH	Conduc	Alk	Hard	Do	Cl	SO4	F
Conduc	0.241							
Alk	0.141	0.823						
Hard	0.164	0.771	0.803					
Do	0.201	-0.154	-0.182	-0.216				
Cl	0.268	0.261	0.286	0.362	0.008			
SO4	0.103	0.447	0.380	0.349	-0.003	0.007		
F	0.186	0.360	0.348	0.101	0.026	0.077	0.296	
NO3	-0.105	0.070	0.028	0.070	0.022	0.071	0.250	-0.152
PO4	0.186	-0.030	-0.027	-0.102	-0.106	0.082	0.123	0.354
Na	-0.004	0.182	0.096	-0.188	0.060	-0.270	0.320	0.474
K	0.156	0.410	0.341	0.260	-0.029	-0.074	-0.148	0.154
Ca	-0.007	0.605	0.535	0.627	-0.116	0.227	0.208	-0.215
Mg	0.055	0.537	0.499	0.390	-0.087	-0.067	0.046	0.326
Fe	-0.104	-0.152	-0.148	-0.148	-0.025	-0.136	-0.061	-0.103
Zn	-0.000	-0.050	-0.149	-0.216	0.108	-0.172	-0.015	-0.073
Pb	0.109	0.129	0.107	0.072	-0.037	-0.106	0.099	0.102
Cd	-0.285	-0.072	0.115	0.086	0.050	-0.065	0.051	0.092
As	0.047	0.011	-0.095	-0.150	0.104	-0.165	0.089	0.341
Cr	-0.085	0.032	-0.080	-0.126	0.122	-0.207	-0.006	-0.104
Se	-0.082	0.030	-0.031	0.012	0.001	0.144	0.208	-0.141
Al	-0.026	-0.072	-0.094	-0.194	0.147	0.006	0.019	0.415
Hg	-0.163	-0.036	-0.069	-0.076	-0.066	-0.121	0.107	-0.141
Mo	0.011	0.165	0.080	-0.086	0.045	-0.153	0.239	0.587
Tem	0.159	0.063	0.078	0.002	-0.049	0.227	0.022	0.234
Water L	-0.153	-0.044	-0.048	-0.097	0.225	-0.117	0.081	-0.162
	NO3	PO4	Na	K	Ca	Mg	Fe	Zn
PO4	0.021							
Na	0.018	0.190						
K	-0.258	-0.060	0.111					
Ca	0.081	-0.288	-0.188	0.258				
Mg	-0.065	-0.037	0.249	0.596	0.262			
Fe	0.042	-0.006	-0.092	0.181	-0.093	-0.046		
Zn	0.037	-0.058	0.093	0.063	-0.028	0.071	-0.027	
Pb	-0.040	0.085	0.041	0.162	0.115	0.096	-0.005	0.107
Cd	0.018	-0.072	0.061	-0.094	-0.201	-0.020	0.069	-0.035
As	0.089	0.247	0.323	-0.018	-0.244	0.055	-0.046	0.016
Cr	0.075	-0.162	0.069	0.169	0.025	0.170	0.032	0.237
Se	0.247	-0.051	-0.086	-0.191	0.108	-0.098	-0.103	0.292
Al	-0.113	0.151	0.243	-0.064	-0.226	-0.064	0.022	0.014
Hg	0.056	-0.090	0.053	-0.130	-0.014	-0.026	0.013	0.151
Mo	-0.066	0.219	0.561	0.004	-0.050	0.182	-0.111	-0.072
Tem	-0.008	0.182	0.045	-0.123	-0.169	-0.036	-0.118	-0.101
Water L	0.243	-0.169	0.206	-0.093	0.079	0.158	-0.033	0.313
	Pb	Cd	As	Cr	Se	Al	Hg	Mo
Cd	-0.001							
As	0.034	-0.042						
Cr	0.112	-0.215	0.054					
Se	0.055	0.009	-0.023	0.104				
Al	-0.024	0.225	0.449	0.165	-0.029			
Hg	0.023	-0.123	-0.037	0.207	0.297	-0.090		
Mo	0.149	0.124	0.539	0.079	-0.015	0.410	-0.055	
Tem	0.060	-0.203	0.073	-0.069	0.112	0.163	-0.101	0.233
Water L	-0.088	0.062	0.006	0.383	0.119	0.004	0.181	0.049

Tem

Water L -0.172

Cell Contents: Pearson correlation

It indicated a negative correlation with Do, phosphate, Fe^{2+} , Zn^{2+} , Cd^{2+} , Al^{3+} , Hg and water level and others were in weak positive correlation. The result of measured alkalinity in the study area shows a positive and significant correlation only with hardness and Ca^{2+} and a negative correlation with Do, phosphate, Fe^{2+} , Zn^{2+} , As, Cr^{2+} , Se^{2+} , Al^{3+} , Hg and water level, and other 12 ions indicated weak positive correlations. Total hardness has a positive and significant correlation only with Ca^{2+} but it shows a negative correlation with 11 ions of Do, phosphate, Na^+ , Fe^{2+} , Zn^{2+} , As, Cr^{2+} , Al^{3+} , Hg, Mo^{2+} and water level. The rest of the ions were in a weak positive correlation. Dissolved Oxygen (DO) has no positive and significant correlation with measured parameters. But it indicated a negative correlation with sulfate, phosphate, K^+ , Ca^{2+} , Mg^{2+} , Fe^{2+} , Pb^{2+} , Hg and temperature and others show a weak positive correlation. It was observed that chloride does not indicate with significant correlation with any parameter but indicated a negative correlation with Na^+ , K^+ , Mg^{2+} , Fe^{2+} , Zn^{2+} , Pb^{2+} , Cd^{2+} , As, Cr^{2+} , Al^{3+} , Hg and water level, and others indicated weak positive correlation. Sulfate (SO_4^{2-}) revealed that there is no significant correlation with any parameter but there is a negative indication with K^+ , Fe^{2+} , Zn^{2+} and Cr^{2+} . Others indicated a weak positive correlation. Fluoride (F^-) has a positive and significant correlation with Mo^{2+} and Na^+ and Al^{3+} indicating marginal positive and significant values of 0.474 and 0.415 respectively. That indicates a weak positive correlation with others. Nitrate (NO_3^-) has only a weak positive correlation with some parameters, and a negative correlation with K^+ , Mg^{2+} , Pb^{2+} , Al^{3+} , Mo^{2+} and temperature. Phosphate (PO_4^{3-}) has no positive and significant correlation and it has a weak correlation with some parameters. It has a negative correlation with K^+ , Ca^{2+} , Mg^{2+} , Fe^{2+} , Zn^{2+} , Cd^{2+} , Se^{2+} , Hg and water level. Sodium (Na^+) has a positive and significant correlation only with Mg^{2+} and a negative correlation with Ca^{2+} , Fe^{2+} and Se. That indicates a weak positive correlation with other parameters. Potassium (K^+) has a positive and significant correlation with Mg^{2+} ; a negative correlation with Cd^{2+} , As, Al^{3+} , Hg, temperature and water level and a weak positive correlation with other parameters in Nagadeepa. The result of Calcium

(Ca^{2+}) has a negative correlation with Fe^{2+} , Zn^{2+} , Cd^{2+} , As, Al^{3+} , Hg, Mo and temperature, and weak positive correlation with other parameters. Magnesium (Mg^{2+}) revealed a negative correlation with Fe^{2+} , Cd^{2+} , Se^{2+} , Al^{3+} , Hg and temperature; and a weak positive correlation with other parameters. Iron (Fe^{2+}) has a negative correlation with Zn^{2+} , Pb^{2+} , As, Se^{2+} , Mo, temperature and water level; and a weak positive correlation with other parameters in Nagadeepa. Zinc (Zn) in the area has a negative correlation with Cd^{2+} , Mo and temperature and a weak correlation with other parameters. Lead (Pb) indicates a negative correlation with Cd^{2+} , Al^{3+} , water level and a weak positive correlation with As, Cr^{2+} , Se^{2+} , Hg, Mo and temperature. The result of Cadmium (Cd) revealed a negative correlation with As, Cr^{2+} , Hg and temperature. Arsenic shows a negative correlation with Se^{2+} and Hg and a weak correlation with Cr^{2+} , Al^{3+} , Mo, temperature and water level. Chromium (Cr^{2+}) has a negative correlation only with temperature and a weak positive correlation with Se^{2+} , Al^{3+} , Hg, Mo and water level. Selenium (Se) has a negative correlation with Al^{3+} and Mo and a weak correlation with Hg, temperature and water level. Al^{3+} has a negative correlation with Hg and a weak positive correlation with Mo, temperature and water level in Nagadeepa. Mercury (Hg) has a negative correlation with Mo and temperature and a weak positive correlation with the water level. Molybdenum (Mo) has a weak positive correlation with temperature and water level. The temperature has a weak positive correlation with the water level in the study area.

Cluster Analysis

Q-mode Cluster Analysis was applied to the water quality data set to evaluate the spatial variability among the monitoring wells (sampling locations). This analysis resulted in the grouping of monitoring wells into four groups in the study area as shown in Fig. 3. This analysis is a useful method for grouping groundwater wells into homogenous groups according to their water quality. The wells were grouped into four cluster categories namely; less polluted, moderately polluted, highly polluted and as very highly polluted.

Hierarchical cluster analysis

Dendrogram using Ward Method

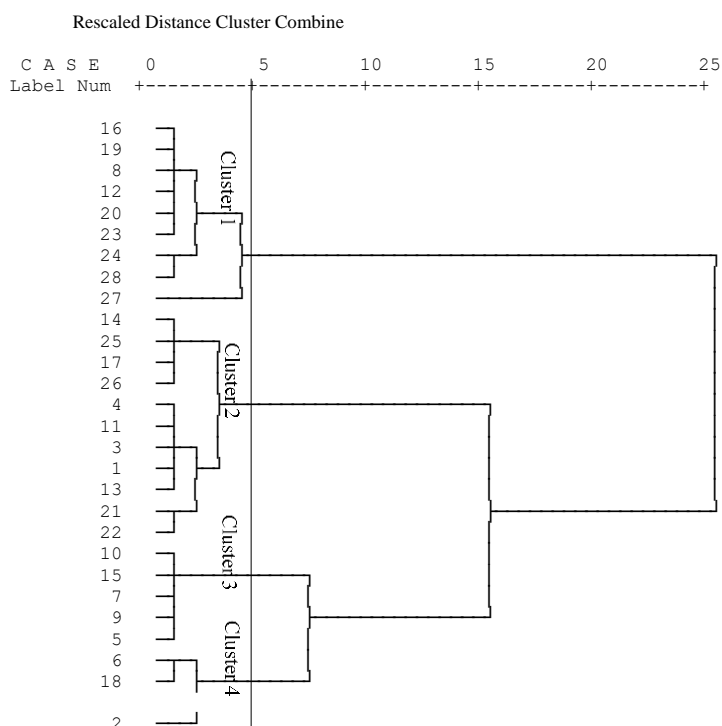


Figure. 3 Dendrogram of Cluster analysis in Nagadeepa study area

The results obtained exhibit; cluster 1 includes well location numbers; 8, 12, 16, 19, 20, 23, 24, 27 and 28 classified as less polluted. Cluster 2 includes well location Nos. of 1, 3, 4, 11, 13, 14, 17, 21, 22, 25 and 26 classified as moderately polluted, cluster 3 consists of sampling Nos. 5, 6, 7, 9, 10, 15 and 18 classified as highly polluted and cluster 4 includes only one well with location No. 2 as very highly polluted. The water quality categories based on the cluster analysis revealed that the marginal to very high are distributed in the study area. However, the good quality water category was absent.

5. CONCLUSIONS

The study exhibits the application of multivariate

statistical methods in assessing the hydro geochemical characteristics in the area. Factor analysis revealed that 7 factors of pH, Conductivity, Alkalinity, Hardness, Dissolved Oxygen, Chloride and Sulfate are the major factors that affect the water quality.

The correlation coefficient (r) among various water quality parameters of Nagadeepa study area indicated positive and significant correlation between Conductivity, Alkalinity, Hardness, Sulfate, Na^+ , K^+ and Fluoride with other parameters of Ca^{2+} , Mg^{2+} , Mo^{2+} and PO_4^{3-} in most of sampling wells indicating their geogenic nature.

According to the cluster analysis, 32% wells in the study area indicated less polluted waters. 39% represented moderate type of water quality, and the remaining 29% indicated polluted conditions water that is unsuitable for drinking purposes.

The geological and soil conditions of the area and the usage of chemical fertilizers and agrochemicals are the major deterioration factors since some wells are in paddy fields or close to paddy fields.

6. ACKNOWLEDGMENT

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APPLICATION OF ARTIFICIAL NEURAL NETWORK FOR SHORT TERM ELECTRICITY DEMAND FORECASTING

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ABSTRACT

Many researchers around the world work on short term electricity demand forecasting (STLF) in order to establish an accurate power planning and generation system in their countries. This research, with its focus on short-term load forecasting, aims to fill this gap by implementing two methodologies based on Artificial Neural Network (ANN) and Autoregressive Integrated Moving Average (ARIMA) applied on a set of half an hourly load demand data of six years, provided by Ceylon Electricity Board in Sri Lanka. The data of first five years (~70% of the dataset) were used to train the algorithms and those of the last year (~30% of the dataset) were used for testing. The effect of historical load demand patterns on making the prediction of the next 24 hours were studied. Moreover, with the historical data, unlike in most literature which forecasts only one value (either peak load demand of the day or only the load demand of the next half an hour), the demand of the entire day (48 values for each half an hour) is forecasted at once. The predictions obtained by the application of ANN were compared with those of ARIMA methodology which is a benchmark of comparing predictions in STLF. None of the applications provided deviated predictions compared to each other and ANN can be used to predict the next day half-hourly electricity demand since the application was successful in grasping the periodic patterns that exist in half hourly series.

KEYWORDS ANN, ARIMA, Half Hourly Electricity Demand, STLF

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1. INTRODUCTION

In electrical generation, short term electricity demand forecasting plays a supreme role as the main target of power generation sector of a country is to provide a continuous and uninterrupted power supply to the people. Demand forecasting has been studied since the 1960's. A demand forecasting strategy with higher accuracy is vital in order to establish an accurate power planning and generation procedure in a country. In addition to that, demand forecasting for a short time period is very essential. In order to utilize the above sources efficiently to meet the load demand, scheduling of power generation is essential as generators cannot be started up and shut down instantly and some types of plants (e.g. thermal) involve a startup and shutdown cost. Therefore, it is essential to forecast the load demand for a short period of time (e.g. 24 hours) and to prepare a power generation plan for that period.

Many researchers around the world have investigated load forecasting models based on various forecasting techniques to prepare a better generation plan. They have classified load forecasting into three or four categories according to the time span. Singh et al. (2013) have divided load forecasting into three categories, i.e. short-term forecasts which are usually from one hour to one-week, medium forecasts which are usually from a week to a year, and long-term forecasts which are longer than a year. According to Zor et al. (2017), there are four categories of electric load forecasting with respect to time span, i.e. long-term where 3-year and 50-year electric load is predicted, medium-term where the forecast ranges from 2 weeks to 3 years, and short-term electric load forecasting (or short-term load forecasting, generally abbreviated as STLF in the literature), which refers to hour, day or week ahead predictions, and very short-term electric load forecasting which includes few minutes to an hour ahead forecasting of electric loads Yang (1974), Lee et al. (1992) and Al-Hamadi and Soliman (2004).

For strategic planning of the development of the electric power systems, both long-term and medium-term forecasts have significant advantages which

include scheduling of construction of new generation and transmission capacity, maintenance scheduling, as well as long-term demand side measurement and management planning (Amjadi 2001). However, an accurate STLF technique can reduce operating costs, keep energy markets efficient, and provide a better understanding of the dynamics of the monitored system. Out of the load forecasting systems, STLF is a method where historical data are fine-tuned using more recent data. In addition to that, main requirements of the STLF process are accuracy and reliability. Further, it is preferred if the forecasting process can be automated (Yang 1974). Therefore, it is very important to maintain an error-reduced forecasting plan for the next 24 hours and to prepare a power generation plan for that period since there is not a well-planned strategy to forecast load for the next day yet.

In Sri Lanka, the electricity generation authorities forecast the next day demand based on the demand history. First, the electricity demand pattern during the 24 hours' period, prior to the required time slot, is manually matched with the load demand pattern in history. Then the best match is found and the pattern following that best match will be considered as the forecasted pattern for the next 24 hours. However, this technique leaves room for forecasting errors according to the study carried out by Somarathne et al. (2020). Accordingly, there is a necessity of more research to study the interrelationships among daily patterns in forecasting the demand for next 24 hours.

In implementations of STLF, Autoregressive Integrated Moving Average (ARIMA) modelling has been used as a sophisticated benchmark and exponential smoothing techniques including Holt Winters method have been used in many research investigations; Taylor (2003), Taylor et al. (2006) and Taylor (2010). With the use of computing technologies for load forecasting fuzzy logic systems and neural network systems are used to model the complexity and nonlinear behaviour of load data by Abraham et al. (2001) and Liu et al. (1996). Some researchers pay their attention on artificial neural networks and a great number of papers reported successful investigations with them (e.g. Hippert et al., 2001), but it is still not clear whether neural

networks and more complex non-linear models outperform simpler and more standard forecasting procedures such as ARIMA modelling and exponential smoothing techniques. When considering multivariate nonlinear techniques, artificial neural network methods have been used by using weather variables in some research papers as in Taylor et al. (2002), and Khan et al. (2004).

In this study, short term load forecasting for 24 hours ahead based on half hourly electricity demand in Sri Lanka will be investigated by using Seasonal ARIMA modelling and Artificial Neural Network modelling. Then the accuracy measures of both models were compared to each other by considering forecasts of the selected two weeks.

2. METHODOLOGY

2.1 Data collection

Half hourly electricity load demand (in MW) in Sri Lanka from 01/01/2009 to 31/12/2014 was considered for the analysis by assuming that the demand is equal to the generation.

The data of 2009-2013 (~70% of the dataset) were used to train the algorithm and data of 2014 (~30% of the dataset) were used for testing as given in Fig. 1.

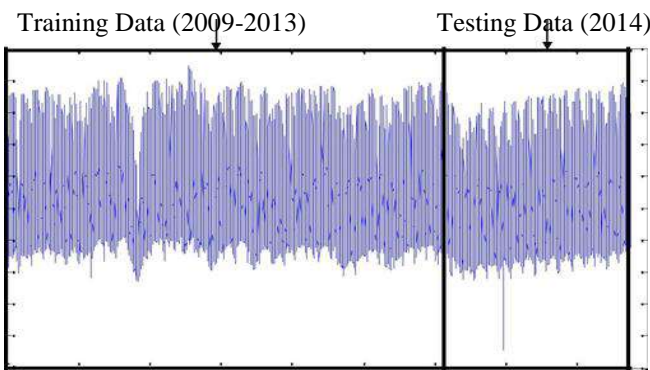


Figure 1: Data allocation for Training and Testing

The next day load will be predicted using, ARMA methodology and Artificial Neural Network. So, the load series was divided into 48 numbers of individual time series (based on half hours) and the proposed

methodologies were applied to each series.

E.g.

Let $\{L_{n,m,o}\}$ is the load of n^{th} half an hour of m^{th} day of the o^{th} year ; $n=1,2,\dots,48, m=1,2,\dots,365$ and $o=1,2,3,4,5$

Half hourly electricity demands of five years =

$$\begin{Bmatrix} L_{1,1,1} & L_{1,2,1} & L_{1,3,1} & \dots & L_{1,364,1} & L_{1,365,1} \\ L_{2,1,2} & \dots & \dots & \dots & \dots & L_{2,365,2} \\ L_{3,1,3} & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ L_{48,1,5} & L_{48,2,5} & \dots & \dots & \dots & L_{48,365,5} \end{Bmatrix} = \begin{Bmatrix} L_1 \\ L_2 \\ \dots \\ L_n \\ \dots \\ L_{48} \end{Bmatrix}$$

Proposed techniques were applied to each half hourly series

Accordingly, half hourly electricity demands were predicted for the weeks 01st–07th January 2014, 1st–7th February 2014 and 01st–07th October 2014.

2.2 Technology

Seasonal ARIMA Technology

The each half hourly series were checked for stationary and if so, the series was differenced to make it stationary before applying ARIMA.

The autocorrelation function of each series was plotted to observe non-stationary.

E.g. consider the series of electricity demand during the half an hour 7.00pm-7.30pm in Figure 2(a) and Figure 2(b).

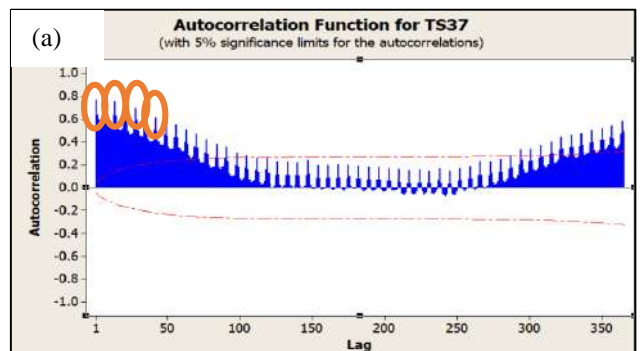


Figure 2(a)

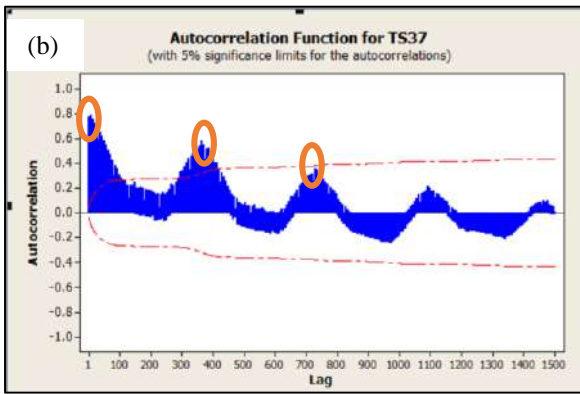


Figure 2(b)

Figure 2: Plots of Autocorrelation functions with respect to 37th half an hour (Lag in days)

Figure 2(a) and 2(b) show annual, weekly and daily periodic patterns in the series, and it is seen that the first few lags do not decay to zero immediately. This reveals that the series is stationary. Therefore, differencing of the series is needed to make the series stationary.

Based on the patterns exhibited in ACF, each of $\{L_n\}$ was differenced at lags 1, 7 and 365 according to the annual and weekly patterns that exist in load as follows. Then, 48 ARMA models were developed to forecast load of each half an hour for one week ahead. The model formats which were shown by the models were stored separately.

Considering the load demand series of each n up to 31st December 2013, the load demand of the weeks 01st - 07th January 2014, 01st - 07th February 2014 and 01st - 07th October 2014 with respect to each n were forecasted.

Identification of tentative models is the first step of ARIMA methodology. Identification consists of specifying the appropriate structure (AR, MA or ARMA) and order of model. It is sometimes done by looking at plots of the sample autocorrelation (acf) and the sample partial autocorrelation function (pacf). Tentative models under each case will be identified. Then, the accuracy measures will be compared between each tentative models under each case and two models will be finalized under each case. The coefficients which are obtained by the

models were considered, will be estimated and then diagnostic checking or verification will be performed. In this step, two important elements of checking are to test that the residuals of the model are random, and to ensure that the estimated parameters are statistically significant. Usually, the fitting process is guided by the principle of parsimony, by which the best model is the simplest possible model – the model with the fewest parameters and reduced error that adequately describes the data.

Artificial Neural Network

In this method, artificial neural networks were built with the intention to provide a better forecast of load demand of electricity for the next 24 hours. Here, the load demand of electricity of n^{th} half hour of the next day was predicted using the load demand of the same half hour of history through an artificial neural network. Thus, 48 neural networks were developed with respect to each half hourly series. This can be illustrated using the following diagramme (Figure 3).

For an artificial neural network, several parameters are to be selected appropriately to come up with the best architecture. They are the number of layers, the number of nodes in each layer and the number of arcs which interconnect with the nodes. Other network design decisions include the selection of activation functions of the hidden and output nodes, the training algorithm, data transformation or normalization methods, training and test datasets, and performance measures. Initially, the first five years of the original dataset were taken as the training dataset in creating the neural network, and it was tested for the last year (of the original dataset).

Figure 4 illustrates the neural network designed for the load demand prediction for the next 24 hours. Let d = no of historical demands and m =no of neurons in the hidden layer.

Consider the load demand series of n^{th} Half hour $\{L_n\}$ in Figure 4.

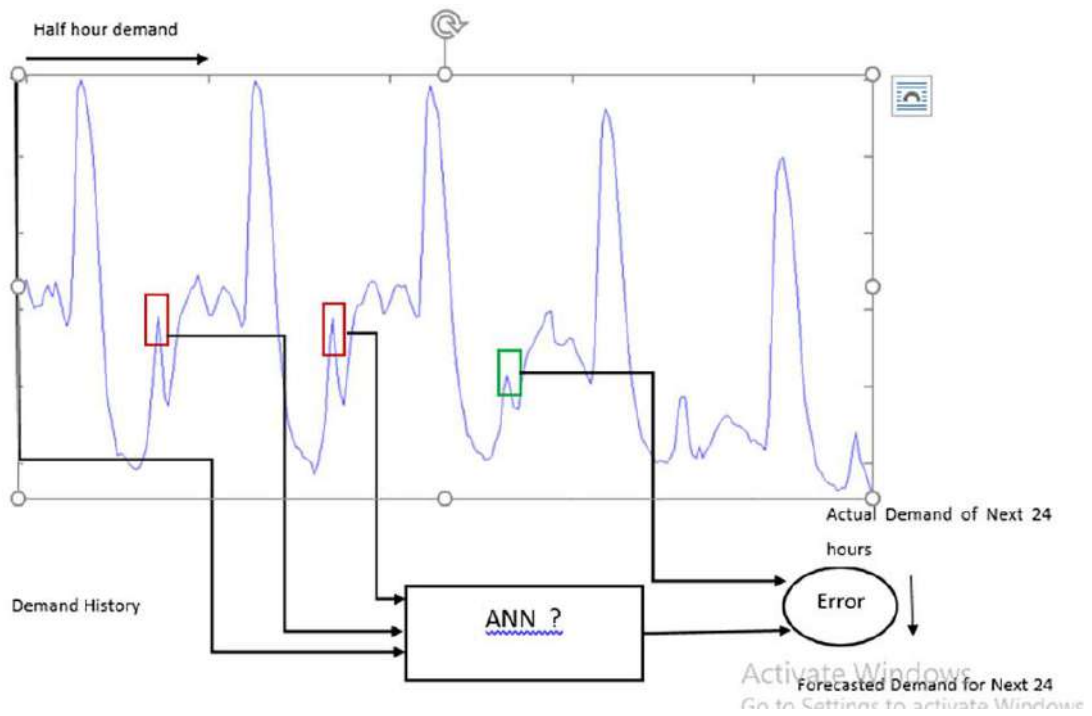


Figure 3: Illustration of Neural Network model

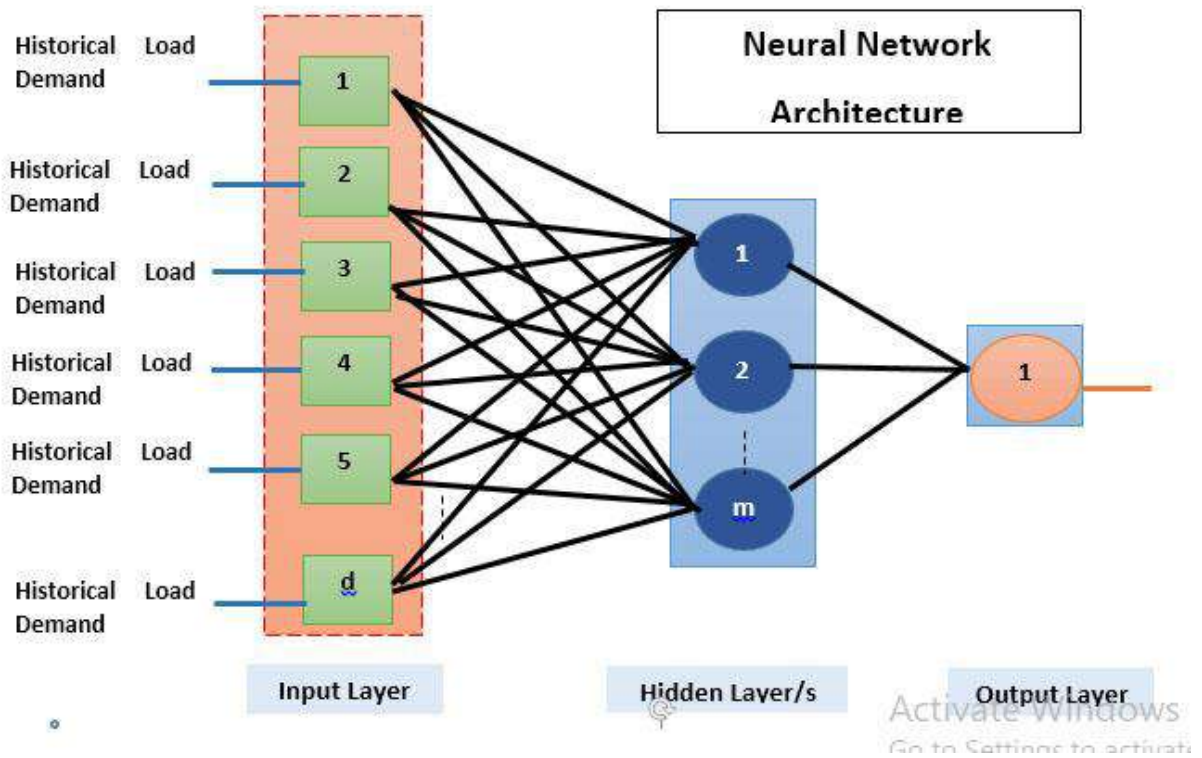


Figure 4: Architecture of Neural Network

48 numbers of neural network models were developed with the use of the following inputs. Suppose we need to forecast the demand of i^{th} half an hour of the day – D , year- Y $X_{i,D,Y}$ Following Inputs were considered.

- $X_{i,D-1,Y}$
- $X_{i,D-7,Y}$
- $X_{i-1,D-1,Y}$
- $X_{i,D,Y-1}$
- $X_{i,D-1,Y-1}$
- $X_{i,D-7,Y-1}$

After several trials with the aforesaid inputs, the following inputs have been identified as the most effective inputs in order to increase the model accuracy.

- Inputs
- $X_{i,D-1,Y}$
 - $X_{i,D-7,Y}$
 - $X_{i-1,D-1,Y}$
 - $X_{i,D,Y-1}$

After several trials, the most appropriate structures were selected. Table 1 provides a description for the created artificial neural networks for each case

Table 1: Informative Neural Network

Parameter	Value
No of hidden layers	2
Input Variables	4
No of input patterns	1826
No of outputs	1
Transfer function	Hyperbolic tangent sigmoid transfer function
training function	training function that uses Levenberg-Marquardt optimization

Then, the load demand of the weeks 01st -07th January 2014, 01st -07th February 2014 and 01st - 07th October 2014 with respect to each n were forecasted.

Checking Model Accuracy

The electricity demands of selected weeks were forecasted using ARIMA modelling technique and ANN.

Then, the below mentioned accuracy measures RMSE- Root Mean Square Error, NRMSE- Normalized Root Mean Square

Error, MAE – Mean Absolute Error, MAPE –Mean Absolute Percentage Error, Coefficient of Determination (R^2) and ME-Mean Error of the finalized ARIMA models and ANN models will be compared to find the applicability of ANN as a better technique to forecast the electricity demand one day ahead.

Let the accuracy measures,

RMSE

$$\sqrt{\frac{\sum_{i=1}^r (x_{obs,i} - x_{model,i})^2}{r}}$$

NRMSE

$$\sqrt{\frac{\sum_{i=1}^r (x_{obs,i} - x_{model,i})^2}{\sum_{i=1}^r (x_{obs,i} - \bar{x}_{obs})^2}}$$

MAE

$$\frac{1}{r} \sum_{i=1}^r |x_{obs,i} - x_{model,i}|$$

MAPE

$$\frac{1}{r} \sum_{i=1}^r \frac{|x_{obs,i} - x_{model,i}|}{x_{obs,i}} * 100$$

Coefficient of Determination (R^2) $1 - (NRMSE)^2$

where, $x_{obs,i}$ is the observed/actual demand for i^{th} half an hour, $x_{model,i}$ is the modeled/predicted value for i^{th} half an hour, \bar{x}_{obs} is the mean of observed demand, and r is the number of demand values in the series.

Table 2: Model Formats Observed for each half our demand serie

TS	MODEL
1	$(1 - \phi_1 B)(1 - \phi_2 B^2) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ A
2	
3	
4	
5	
6	
7	
8	
9	$(1 - \phi_1 B) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ B
10	
11	$(1 - \phi_1 B)(1 - \phi_2 B^2) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ C
12	
13	$(1 - \phi_1 B) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ B
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	$(1 - \phi_1 B)(1 - \phi_2 B^2) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ C
24	$(1 - \phi_1 B) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ B
25	
26	
27	
28	
29	
30	$(1 - \phi_1 B)(1 - \phi_2 B^2) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ A
31	$(1 - \phi_1 B)(1 - \phi_2 B^2)(1 - \phi_3 B^3) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ D
32	$(1 - \phi_1 B)(1 - \phi_2 B^2)(1 - \phi_3 B^3)(1 - \phi_4 B^4) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ E
33	$(1 - \phi_1 B) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ B
34	
35	$(1 - \phi_1 B)(1 - \phi_2 B^2) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ C
36	$(1 - \phi_1 B) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ B
37	
38	
39	$(1 - \phi_1 B^2)(1 - \phi_2 B^4)(1 - \phi_3 B^7)(1 - B)(1 - B^7)(1 - B^{365}) x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ F
40	$(1 - \phi_1 B) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ B
41	$(1 - \phi_1 B)(1 - \phi_2 B^2)(1 - \phi_3 B^4)(1 - \phi_4 B^7)(1 - B)(1 - B^7)(1 - B^{365}) x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ G
42	$(1 - \phi_1 B)(1 - \phi_2 B^2)(1 - B)(1 - B^7)(1 - B^{365}) x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ A
43	$(1 - \phi_1 B)(1 - \phi_2 B^2) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ C
44	
45	$(1 - B)(1 - B^7)(1 - B^{365}) x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ H
46	$(1 - \phi_1 B) \nabla_{\omega} x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ B
47	$(1 - B)(1 - B^7)(1 - B^{365}) x_t = (1 - \theta_1 B)(1 - \theta_2 B^7)(1 - \theta_3 B^{365}) e_t$ H
48	

3. RESULTS & DISCUSSION

Seasonal ARIMA

Each half-hourly series were converted into stationary by differencing in order to apply Seasonal ARIMA.

The finalized 48 numbers of seasonal ARIMA models with respect to each half an hour were stored in Table 2.

$$\text{Let } \psi_{dD} = (1 - B)(1 - B^7)(1 - B^{365}) .$$

Table 2 consists of the ARIMA models obtained for each half hourly series. According to the model formats in Table 2, model format B is the most frequently resulting model among 48 numbers of half hourly demand series. Most of the half hourly demand series recorded during the day time demonstrate the model format B. According to the obtained models, the demand of the same half an hour in the previous day is highly correlated with that of the next day. Also, the demand of the same half an hour is highly correlated with that of the day before the previous day and the same day of the last week according to the other models such as A, C and G.

Artificial neural network

The following parameters were considered as the inputs to 48 numbers of neural networks by trialing several sets of inputs.

Forecast the demand of i^{th} half an hour of the day – D, year- Y $X_{i,D,Y}$

Inputs $-X_{i,D-1,Y} , X_{i,D-7,Y} , X_{i-1,D-1,Y} , X_{i,D,Y-1}$

Table 3: Accuracy measures of all techniques for the week 1-1-2014 to 7-1-2014

Model	NRMSE	RMSE	MAPE	MAE	Coefficient of Determination
ARIMA	0.2904	87.8026	4.7280	60.0652	0.9157
ANN	0.3212	97.1261	5.8009	73.3915	0.8968

According to the accuracy measures in Table 3, ARIMA approach resulted in better forecasting during the week 1-1-2014 to 7-1-2014.

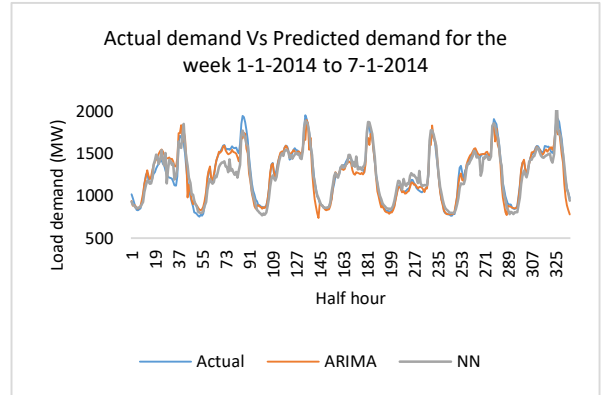


Figure 5: Actual Demand Vs Predicted Demand obtained by models during 1-1-2014 to 7-1-2014

Table 4: Accuracy measures of all techniques for the week 1-2-2014 to 7-2-2014

Model	NRMSE	RMSE	MAPE	MAE	Coefficient of Determination
ARIMA	0.3684	111.324	5.9100	72.486	0.8642
ANN	0.4332	130.919	7.3951	87.547	0.8123

Table 5: Accuracy measure of all techniques for the week 1-10-2014 to 7-10-2014

Model	NRMSE	RMSE	MAPE	MAE	Coefficient of Determination
ARIMA	0.2554	75.4554	4.6329	60.2893	0.9348
ANN	0.2220	65.7278	4.1177	51.8170	0.9507

Table 6: Accuracy Measures Day-wise during 1-1-2014 to 7-1-2014

Day	ARIMA				ANN			
	NRMSE	RMSE	MAPE	MAE	NRMSE	RMSE	MAPE	MAE
1-1-2014	0.5126	128.637	8.5420	105.5981	0.4478	112.3715	7.5387	91.1397
2-1-2014	0.2873	99.7026	6.3674	79.3276	0.4745	164.6483	9.9451	140.2511
3-1-2014	0.3042	93.0170	4.1728	54.4379	0.2214	67.6919	4.6069	55.2543
4-1-2014	0.2306	61.2703	3.4607	45.3574	0.1570	41.7246	2.5219	32.5148
5-1-2014	0.1121	34.7181	2.1199	24.7236	0.2363	73.2026	5.7980	62.1438
6-1-2014	0.2523	80.3157	4.2706	54.8496	0.2732	86.9649	4.9581	62.6595
7-1-2014	0.2745	86.1093	4.1627	56.1619	0.2677	83.9838	5.2373	69.7774

Table 7: Accuracy Measures Day-wise during 1-2-2014 to 7-2-2014

Day	ARIMA				ANN			
	NRMSE	RMSE	MAPE	MAE	NRMSE	RMSE	MAPE	MAE
1-2-2014	0.1383	35.9172	2.3072	28.2262	0.1758	45.6365	2.7554	35.2660
2-2-2014	0.0933	26.4792	1.8326	20.0127	0.2646	74.7748	5.6888	62.8215
3-2-2014	0.3967	122.0826	7.2145	103.4017	0.2238	68.8617	4.2126	55.4857
4-2-2014	0.7771	234.2617	18.6603	198.176	0.9228	278.1671	22.2259	236.835
5-2-2014	0.2773	97.0562	5.5811	78.21	0.3693	129.2624	8.3389	108.9475
6-2-2014	0.2206	66.0051	3.5164	49.8776	0.3052	91.3287	5.6196	70.4719
7-2-2014	0.1113	34.6488	2.2581	29.4977	0.2302	71.6631	2.9258	43.0051

Table 8: Accuracy Measures Day-wise during 1-10-2014 to 7-10-2014

Day	ARIMA				ANN			
	NRMSE	RMSE	MAPE	MAE	NRMSE	RMSE	MAPE	MAE
1-10-2014	0.3689	113.7863	6.8430	94.9607	0.2235	68.9450	4.7882	56.5008
2-10-2014	0.2505	78.8657	4.4911	58.9610	0.2192	69.0095	4.0802	55.3816
3-10-2014	0.2985	91.5506	4.6333	59.2600	0.1137	34.8568	2.1290	28.6940
4-10-2014	0.2506	64.4021	4.1949	54.6840	0.2561	65.7861	4.3141	55.5242
5-10-2014	0.2072	57.7893	4.4896	50.2103	0.2583	72.0291	4.6428	52.8097
6-10-2014	0.2845	91.1579	4.9718	62.8256	0.2288	73.3096	4.3952	58.7150
7-10-2014	0.2820	78.0188	5.4007	68.2925	0.2457	67.9701	4.4741	55.0932

In the predictions of 1st and 2nd January 2014, deviations from the regular daily pattern can be diagnosed in both ARIMA and ANN predictions. This is owing to the holidays of the previous week which sets within Christmas vacation because the demand of the same time slot on the previous week is one of the inputs in ANN methodology. However, the predictions have captured the daily and weekly patterns of electricity demand as shown in Figure 5

Table 4 illustrates that ARIMA modelling results a better accuracy compared to the ANN for the first

week of February 2014.

Comparison of actual demand and predicted demand for the first week of February 2014 shows that (Table 4 and Figure 6) application of ARIMA indicates a better accuracy than ANN. However, both approaches have been unsuccessful to acquire the demand of 4th February which is a public holiday. Also, the day after the Independence Day is also poorly forecasted, as the inputs to that day forecasts consist of unusual day data.

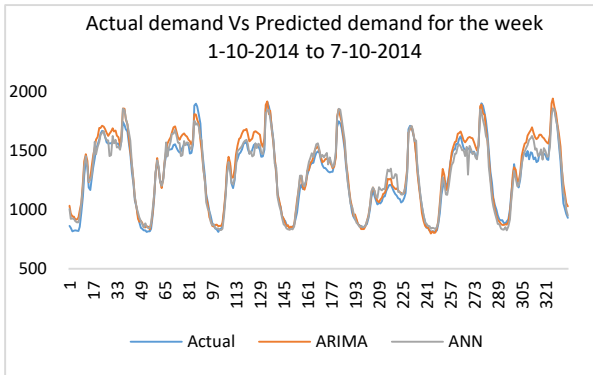


Figure 6: Actual Demand Vs Predicted Demand obtained by ANN during 1-10-2014 to 7-10-2014

For the prediction done for the first week of October, 2014 ANN methodology shows a higher accuracy than ARIMA.

According to Figure 7, some deviations can be observed in the predictions obtained by ARIMA but ANN predictions demonstrate more stability.

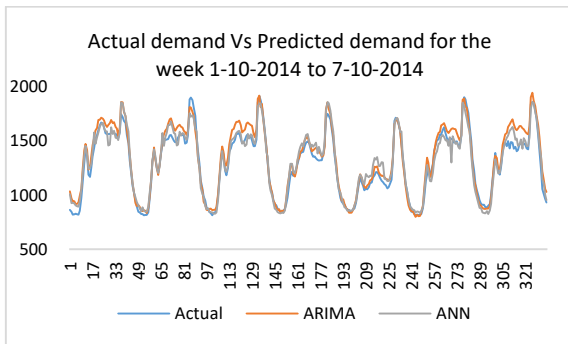


Figure 7: Actual Demand Vs Predicted Demand obtained by ANN during 1-10-2014 to 7-10-2014

4. CONCLUSIONS

Predictions with less accuracy were observed by the implementations of existing techniques for half hourly series and Seasonal ARIMA modelling provides predictions with better accuracy according to Somarathne et al. (2020). Existing techniques were unable to capture the weekday-weekend pattern as well as predictions were highly deviated according to the involvement of holidays (Somarathne et al. 2020). Accordingly, this study proposed ANN technique in addition to ARIMA in order to predict the next day

electricity load demand based on the historical data. According to the accuracy measures given in Table 3, 4 and 5, ANN methodology provides better accuracy than ARIMA for the considered week of October, 2014. For the considered weeks of January and February 2014, ARIMA methodology provided better predictions than ANN but the differences of accuracy measures were very low. Thus, it is unable to ignore either ANN or ARIMA as prediction methodologies with less accuracy.

According to the results of Table 6, 7 and 8, predictions made by using artificial neural networks consisted of better accuracy in some of the considered days. However, ARIMA predictions also consisted of better accuracy in some of the days during the considered three weeks. When the prediction time period goes to the end of the year, ANN methodology provides more accurate and stable predictions.

According to the findings of this study, ARIMA and ANN modellings need some improvements so as to reduce the error associated with their predictions to come up with better accuracy. Understanding the effect of special days (e.g. holidays, festive days, etc.,) on load demand is useful as such information may be accommodated to ARIMA, ANN models to improve their prediction accuracy.

In addition to that, weather components like rainfall can be associated with ANN model to obtain predictions with better accuracy because rainfall is highly correlated with the load demand.

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MARITIME SEARCH AND RESCUE OPERATIONS OF SRI LANKA: AIR DIPLOMACY FRAMEWORK AND WAY FORWARD

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ABSTRACT

The term air diplomacy first came into the limelight in the first half of the 20th century amidst the advent of air power. Air diplomacy is the employment of air power elements in support of the foreign policy of a country. The study explored how an air diplomacy framework could be incorporated into the air strategy to strengthen Maritime Search and Rescue (MSAR) engagements in Sri Lanka, which in turn would benefit in bolstering the tangible and non-tangible capabilities of the Sri Lanka Air Force (SLAF). The contemporary world has seen that regional/global air forces have been attempting to leverage air power in quest of protecting national interests and human capital beyond its seashores. However, it is observed that Sri Lanka has not been exploiting the air diplomacy to the fullest extent as done by other regional counterparts. The SLAF being the only air arm capable of providing aircraft assistance to air crash Search and Rescue (SAR) operations in Sri Lanka has a unique role to play whilst bearing a huge responsibility in aircraft Search and Rescue operations within the Colombo Search and Rescue Region (SRR). Thus, it is imperative to fill the critical gap between existing capabilities/capacities and structure of MSAR units within SLAF and integration with external maritime agencies locally/regionally to facilitate effective MSAR services within the SRR. Hence, the researcher has derived the conceptual framework on a par with the study objectives, which enables the finding of dependent and independent variables. This exploratory study resorts to the inductive approach and interpretivist research philosophy while conducted as a qualitative research. Eventually, the researcher developed an air diplomacy framework that could schematically be embedded into SLAF's air strategy. The study results indicated the development of a joint maritime-air architecture through an integrated system comprising all aerial and maritime stakeholders. Hence as a remedy smart, stretched re-fleeting of assets, formulation of joint/combined maritime-air command structure, multinational cooperation and conduct of joint training are recommended to address challenges pertaining to conducting effective and efficient MSAR operations in the future.

KEYWORDS: Air Diplomacy, Integration, Maritime Search and Rescue (MSAR), Search & Rescue Region (SRR)

1. INTRODUCTION

Aviation has become an integral tool of modern globalization due to its unique ability to operate swiftly in the third dimension. Therefore, the contemporary world has seen highly dense airspaces full of aircraft across the world operating for various purposes. This has led to an increase in air crashes around the world over the years, where it demands highly skilled and trained personnel to rescue aircrew and personnel in distress in quest of saving lives and properties. Sri Lanka Air Force (SLAF) being the only air arm capable of providing aircraft assistance to aircraft Search and Rescue (SAR) operations in Sri Lanka has a unique role to play whilst bearing a huge responsibility in aircraft SAR operations within the Search and Rescue Region (SRR). Lespions (2012) underpinned that air diplomacy is the employment of air power in quest of the foreign policy aspirations of the country.

Background of the Study

The International Civil Aviation Organisation (ICAO) established SAR divisions which laid the basis to launch well-coordinated and integrated Aeronautical Rescue Coordination Centres (ARCC) with the objective to swiftly react to any circumstances concerned with an aircraft accident (ICAO,1946). The SLAF forms an integral part of the ARCC which functions as a rescue unit within the Colombo Search and Rescue Region (CSRR) along with the Sri Lanka Army (SLA) and the Sri Lanka Navy (SLN). Within the SLAF, a dedicated response unit has been established with specially trained personnel and required rescue gears to provide swift rescue assistance during an air crash situation. At its inception, it was named the Jungle Rescue (JR) unit though subsequently changed to Disaster Assistance and Response Team (DART) in 2018 while giving a wider array of operations in addition to the air crash rescue operations.

The SAR units, demand a highly professional, skilful, and trained crew to attend in such circumstances without undue delay. Regional air forces do practice the same way where a dedicated

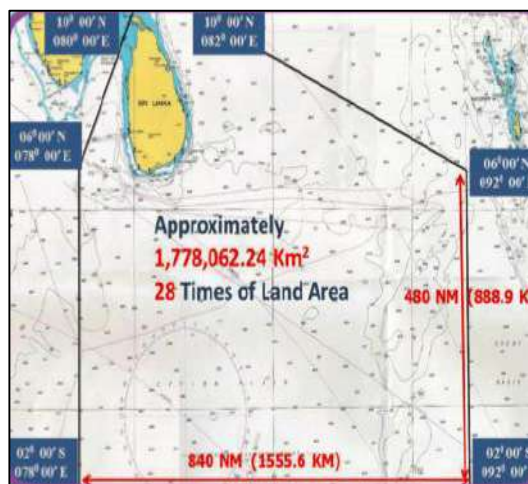


Figure 1: Extensive maritime domain of Sri Lanka Source: Sri Lanka Navy (2020)

crew has been predetermined and made readily available at respective airfields under the direct control of the Air Traffic Control (ATC) units. In the recent past, CSRR saw several fatal aircraft accidents predominantly SLAF ones and a couple of minor ones from domestic operators, even though, fortunately, no civil international passenger aircraft had been involved in any accidents. Therefore, it is deemed necessary to be given insight to augment the capabilities and capacities required for attending SAR operations within an extensive maritime domain along with a proper operational framework embedded with a joint approach by responsible stakeholders.

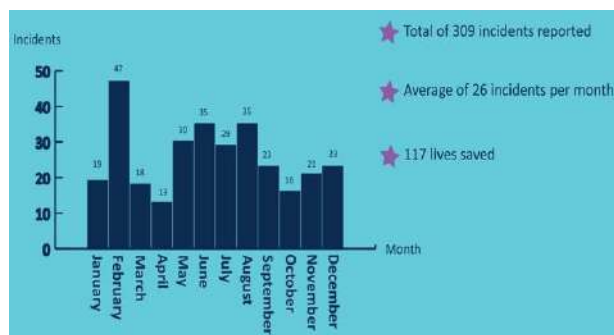


Figure 2: Reported maritime incidents that demanded MSAR services within CSRR during 2020 Source: Sri Lanka Navy (2021)

Though air diplomacy is rising in popularity among regional and global Air Forces, proper insights have

not been given in the context of SLAF. Wijetunge and Wanasinghe (2021) have summarised that air diplomacy could be extended to bolster SLAF's potential as well as the country's foreign policy.

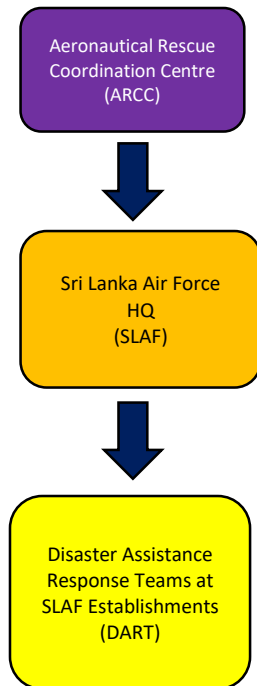


Figure 3: SLAF as a SAR unit within the ARCC
Source: Author (2022)

Statement of the Problem

The SAR services in Sri Lanka are systematized following Standard and Recommended Practices (SARPs). The overall responsibility for the administration and SAR operations within Colombo SRR lies with the Civil Aviation Authority of Sri Lanka (CAASL) (CAASL, 2020). The SAR Point of Contact (SPOC) is designated as the Colombo Aeronautical Rescue Co-ordination Centre (ARCC). SLAF being the only air arm capable of providing aircraft assistance, for aircraft SAR operations forms an integral part of the RCC as a SAR unit. Thus, SLAF requires to provide SAR assistance for civil/military aircraft within Colombo SRR and demands to be equipped with the required gears and skilled/trained personnel. Further, the SLAF is responsible for initiating and conducting SAR operations in respect of SLAF military aircraft besides being an integral part of

overall SAR operations of the country within the SRR. Thus, it is prudent to comprehend that SLAF has to be possessed with necessary rescue apparatus and a qualified workforce suited to engage in SAR within any part of the SRR.

According to the Aeronautical Information Publication (AIP, 2021), Sri Lanka's area of responsibility (AOR) extends nearly 800 nm towards the Eastern and Southeast edges of the SRR, which signified that SLAF needs to be equipped with the necessary capabilities and capacities for swift responding in such situations. With that backdrop, it was learned that operational readiness just does not suffice to cater to the necessities demanded by the ICAO to meet SAR objectives. Particularly, strategic reach is necessary for aircraft being engaged in SAR operations along with other communication and rescue gears. Thus, it is prudent to comprehend that SLAF is necessary to augment its potential because of engaging SAR operations within the SRR as the country has obliged for delivering a swift response. Hence, SLAF could be employed as an approach embedded with air diplomacy in quest of attaining the preceding objective.

Wijetunge and Wanasinghe (2021) recommended establishing a combined MSAR centre in Sri Lanka while identifying the strategic depth of the maritime domain concerned. Further, the present Commander of the Air Force, then Director Air Operations (DAO, 2018) underpinned the necessity of establishing a combined air task force hub in Mattala considering the geo-strategic location of the tiny Island. Thus, it is understood that establishing these strategic partnerships through an air diplomacy approach would certainly abet SLAF's endeavours in MSAR operations and seal the existing gaps which curtail SLAF's effective engagements in this regard.

Further, International Aeronautical and Maritime SAR (2013), underpinned that states have obliged to provide maritime SAR services on a round the clock basis within their respective AOR and the high seas. Wanasinghe and Wijetunge (2021) identified three

determinants, i.e. the location of the incident, weather, and the nature of distress that determined the engagement in maritime SAR by SLAF and SLN.

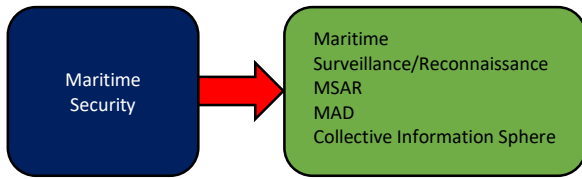


Figure 4: MSAR within the maritime security spectrum Source: Wijetunge and Wanasinghe (2021)

Besides, they have underscored that inadequate integration between air and naval elements and a dearth of air assets has largely become detrimental. Thus, SLAF’s presence in such situations is limited by these factors as well as being made ineffective owing to the absence of a well-coordinated mechanism between regional air and naval forces. Thus, air diplomacy could be outstretched to bridge these gaps effectively whilst enhancing regional stability as well.

With that backdrop, the study aimed to strengthen SLAF’s potential concerning MSAR operations through an air diplomacy framework and to explore the way forward by identifying challenges and threats.



Figure 5: CSRR and adjacent SRRs Source: Australian Maritime Safety Authority (2020)

Research Questions

What are the existing capabilities and capacities that SLAF possesses for engaging in MSAR operations?

What are the roles within the spectrum of air diplomacy which could be employed to MSAR?

What are the constraints and challenges being faced by SLAF in respect of MSAR operations?

What are the ways, means, and ends to design an air diplomacy framework in view of strengthening the SLAF’s MSAR operations?

Research Objectives

To examine the existing capabilities and capacities that SLAF possesses for engaging in MSAR operations.

To discern the roles within the spectrum of air diplomacy which could be employed in relation to MSAR.

To identify constraints and challenges being faced by SLAF in respect of MSAR operations.

To determine the ways means and ends to design an air diplomacy framework in view of strengthening the SLAF’s potential in MSAR.

Significance of the Study

The study would probably add knowledge to the prevailing literature and will help to bridge the gap between MSAR operations and employment of air diplomacy whilst being significant to developing an air diplomacy framework that could be incorporated into the SLAF’s air strategy. Thus, this would be the first kind of study in this field in Sri Lanka.

Scope of the Study

SAR operations have a wider array of roles that demand close integration of various agencies. However, the study has focussed only on MSAR

operations where a significant gap has been created regarding available capabilities as well as approaches. Besides, air diplomacy windows will be discussed which could be correlated to the MSAR context.

2. METHODOLOGY

This section discusses how the research methodology has been incorporated into the study. Further, it describes the study population, sampling technique, sample size, data collection methods, conceptual framework, and operationalisation. The qualitative study has used thematic analysis as the data analysis tool. Further, the research design of the study is as follows.

Research Approach- Inductive approach has been used to find solutions to the observed phenomenon.

Research Choice- The study resorts to a qualitative exploratory study.

Research Philosophy- The researcher has used interpretivism as the study philosophy to interpret the reasons and meanings of the observed phenomenon.

Research Strategy- The study encompassed grounded theory strategy to develop an air diplomacy framework for SLAF's air strategy.

Time Horizon- Cross-sectional time horizon employed.

Technique and Procedure- Data collection and analysis are the technique and procedure of the study.

Conceptualisation

The conceptual framework of the study has been illustrated along with identified dependent and independent variables, which the researchers expect to explore through this study. The following conceptual framework has been developed in line with the four exploratory research objectives which aim to work as the blueprint of the study.

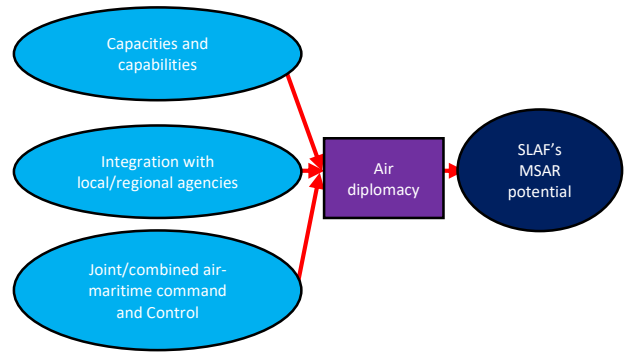


Figure 6: Conceptual framework Source: Author (2022)

3. RESULTS

The researcher derived four peculiar themes after coding interview data through the open coding technique. Besides, this section has been articulated on a par with preceding themes.

SLAF's Capabilities and Capacities for MSAR

Weerasinghe (2021) underscored that SLAF has been designated as a SAR unit within the ARCC, the country's principal agency in respect of SAR. Maligaspe (2021) stressed that SLAF should be equipped with the required capabilities/capacities as well as a well-trained workforce to afford SAR operations. However, a respondent from SLAF explained that currently SLAF's capabilities and capacities have been limited and mainly capable of performing SAR operations within mainland and littorals. Moreover, Maligaspe (2021) highlighted the necessity of having an all-inclusive package with a holistic approach to engaging in SAR operations, particularly within the maritime domain. Thus, the researcher learned that SLAF has a pivotal role to play in SAR operations within the SRR. However, it was explored that existing capabilities/capacities are not sufficient to yield broader MSAR operations owing to limitations of the air assets as well as an inadequate dedicated ground crew. Therefore, it is deemed necessary to augment SLAF's capabilities and capacities in view of MSAR engagements.

Table 1: SLAF’s helicopter capabilities and deployment for SAR operations Source: Sampath (2015)

LOCATION	HELICOPTER TYPE	PERFORMANCES			TYPE OF SAR	CAPABILITIES OF AIRCRAFT			
		RANGE	SPD*	SAR EQUIPMENT		NVG	FLIR	AFCS	FLOATS
Ratmalana	MI 171	100 NM	200km/h	WINCH	RESCUE/MEDEVAC(01)	NO	NO	3 AXIS	NO
	Bell 212	70 NM	100 knots	01 WINCH & 01 BOWMAN KIT	RESCUE/MEDEVAC(HEM S(01)	NO	NO	NO	NO
	Bell 412	80 NM	120 knots			NO	NO	3 AXIS	YES
	Bell 412 EP	90 NM	120 knots			NO	NO	3 AXIS	NO
Anuradhapura	MI 171			NIL	ROPE	NO	NO	3 AXIS	
Hingurakgoda	MI 171			NIL	RESCUE ONLY	NO	NO	3 AXIS	NO
	Bell 212					YES	NO	NO	NO
KKS	Bell 212					NO	NO	NO	NO

The above table illustrates the existing capabilities of SLAF being kept on readiness for SAR operations. As enunciated in the United Nations Convention on Law of Seas (UNCLOS) Sri Lanka possesses an exclusive economic zone (EEZ) of 200 nm from its coastal bed which nearly accounts for 27 times her landmass.

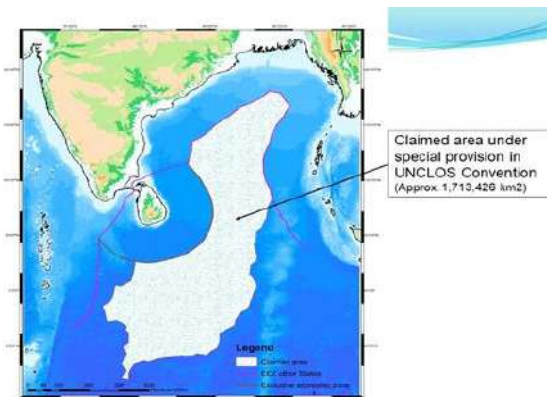


Figure 7: Existing EEZ and proposed claim Source: BCIS Signature Seminar on Blue Economy (2017)

Thus, it was visible that none of the SLAF's rotary-wing aircraft has the required reach to operate on high seas. Even operating at extreme edges of the EEZ is also marginal mainly owing to the limited range of these machines. Besides, the non-availability of dedicated SAR equipment as well as a heli-deployment in the East and South East of the Island, also constituted critical

capability gaps in swift response for MSAR engagements towards the area concerned. Therefore, these implications underpinned the necessity of extended reach and restructuring the SAR deployments.

According to respondents from Bangladesh Air Force (BAF) and Pakistan Air Force (PAF) (2021), they do have dedicated rotary-wing platforms with the necessary apparatus to facilitate SAR services within their respective SRRs. Table 2, has illustrated these platforms and they are capable of all-weather, day/night operations. Thus, it is prudent to comprehend SLAF’s obligation to facilitate SAR services within AOR as well as the requirement to be possessed with required platforms/apparatus.

Table 2: SAR platforms available in regional Air Forces Source: Author (2022)

Type of Platform (a)	BAF	PAF
	(b)	(c)
	B-212	Alvert 3
	B-206	Mi-171
	AW 119	Augusta
AW 139	Z-9 Sea King	

Air Diplomacy Framework to Bolster the MSAR Potential of the SLAF

Cooke (2021) and Wijetunge and Wanasinghe (2021a, 2021b) summarized that incorporation of air diplomacy in the air strategy of small air forces would be bolstered by their capabilities and capacities. Particularly Wijetunge and Wanasinghe (2021a) underpinned that non-kinetic engagements of air diplomacy could be used as a tool in this regard. Thus, in view of this, SLAF needs modernization of the existing platforms, new acquisitions, upgraded and enhanced workforce competency which could be underscored as salient inevitabilities. Thus, based on these findings the researcher developed an air diplomacy framework to attain preceding necessities.

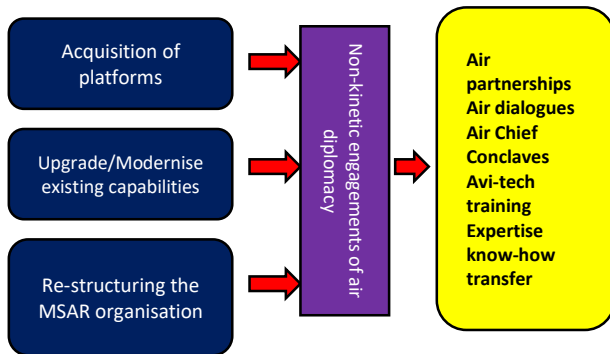


Figure 8: Air diplomacy approach to bolster SLAF MASR capabilities and capacities

Source: Author (2022)

Besides, Maligaspe (2021) recommended acquiring dedicated SAR platforms through a smart-stretched re-fleeting principally to MSAR engagements within the SRR. Hence, the researcher learned that air diplomacy could be abetted to have new acquisitions through air partnerships, air dialogues and air chief conclaves. Even despite having fiscal constraints, these endeavours would allow having a soothing backdrop to acquire new platforms. Further, developing skills and competency of the workforce engaged in SAR operations could be done through specialised training programmes obtained from friendly foreign Air Forces. Further, respondents revealed that the conduct of joint/combined SAR exercises is also vital in view of boosting pragmatic exposure of SAR personnel with a proper evaluation plan. Thus, establishing a dedicated SAR squadron with the assistance of air partnerships also could be accentuated, which could abet to boost SLAF’s potential in respect of MSAR operations. The researcher should underscore that small Air Forces necessary to enrich multinational corporation in order to prevail and to maintain the momentum in order to meet operational demands.

Integrated mechanism Between Local/Regional Naval and Air Forces for MSAR Operations

The researcher learned that promptly delivering MSAR services largely relies on effective integration. The integration must be bi-folded as joint and combined integration. Joint integration

would permit a collaborative exercise between local agencies whilst the latter would allow closely-knit regional agencies for engaging in MSAR operations. Wanasinghe and Wijetunge (2021) critically pointed out that currently aerial and naval elements are being inadequately integrated. Particularly, the post-conflict epoch saw these two elements working in isolation and facing difficulties in system/human integration. Maligaspe (2021) underscored that a very minimum number of joint maritime exercises have been conducted and recommended to study establishing a collective MSAR mechanism between SLN, Sri Lanka Coast Guard (SLCG) and CAASL. Further, the gradual shifting of operational focus and intent of the government has flagged the path to reduce the cohesion and relationship between the two entities.

Wanasinghe and Wijetunge (2021) have identified that SLAF needs effective integration with responsible maritime entities to form a maritime-air joint partnership. This partnership could act as a catalyst in the execution of MSAR. Execution of maritime air operations (MAO) such as intelligence, surveillance, reconnaissance (ISR), and SAR requires the establishment of joint maritime-air command and control (C2). Maligaspe (2021) clearly stated that SLAF has yet to induce an effective integration mechanism with external agencies within the country or outside. Owing to such, existing mechanisms tend to increase the reaction time of SLAF’s SAR elements to attend to distress location and accessibility to the crash site. According to respondents from the BAF and PAF (2021), it is underpinned that they have integrated SAR squadrons with external agencies through MOUs, particularly the Civil Aviation Authority (CAA). Thus, the researcher has explored the absence of such MOU or agreement invariably curtailing SLAF’s effectiveness in MSAR engagements. Firstly, establishing a joint maritime-air mechanism is necessary whilst secondly, a combined one with the collaboration of regional entities.

Sri Lanka’s geo-strategic location remains pivotal, as the Island is located equidistant from the African

and Australian continents. Present Commander of the Air Force then Director Air Operations Air Marshal Sudarshana Pathirana underscored Mattala airport as the ideal location to establish a ‘Combined Air Task Force Hub’ during the Colombo Air Symposium 2018. The researcher also explored that Jaffna, Trincomalee, Hambanthota and Katunayake too are equally significant since all geographic locations could act as connectivity hubs considering the air/land/sea connectivity, and strategic importance and depth. Further, Wijetunge and Wanasinghe (2021) opined to establish a regional MSAR centre in Sri Lanka considering the extensive maritime domain and congested sea and air traffic within the region. However, the researcher underscored that the domestic political consensus approach is also highly essential before establishing such military partnerships. Else wrong socio-politico manipulations could be propagated in view of attaining political compensation. Besides, the researcher explored that air diplomacy endeavours such as having a collective information sphere, regional air partnerships, and air dialogues are the salient ones that could be abetted to strengthen the combined approach.

Table 3: Present agencies involved in the coordination of SAR operations Source: Wanasinghe and Wijetunge (2021)

S/N	Organization	Assets
01	SLAF Central Air Ops Room	Maritime and SAR aircraft
02	SLN Head Quarters (HQ) Ops Room	Different types of vessels
03	SLCG Central Ops Room	Different types of vessels and equipment
04	Directorate of Military Intelligence (DMI)	Intelligence network
05	Maritime Rescue Coordinating Center (MRCC)	Link with merchant shipping and SLN
06	Director-General Merchant Shipping (DGMS)	Link with merchant shipping

Preceding table indicates the agencies that are involved in the coordination of SAR engagements in Sri Lanka. However, it was noted that these

elements have been working in isolation rather than working in a closely knitted environment which demands a SAR event. Thus, the researcher explored that these elements should be integrated and a dedicated agency shall be established with necessary communication and other interoperable elements. Further, required legislative and institutional frameworks are also to be established whilst delegating authority to discharge operations.

Command and Control for MSAR

Indian Air Force (IAF) ATC manual (2015) has indicated that centralized control of SAR operations is essential through respective Flight Information Centres (FIC)/Area Control Centres (ACC). An SLAF representative revealed in 2021 that such extent is not embedded within the SLAF or Sri Lankan context. Maligaspe (2021) illustrated the methods of air crash notification received by SLAF’s SAR units, which reflect the non-availability of centralized control. Besides, this has critically implicated on non-reception of precise instructions on SAR units or duplication of instructions which restricts the SAR unit’s effective employment in aircraft SAR operations. Thus, the researcher opined to establish unified command and control in view of alleviating/ceasing such circumstances on SLAF’s engagements related to aircraft SAR.

The maritime-air command could function through a Maritime-Air Command and Control Centre (MAC&CC), and this would further allow inducing a centralised C2 environment. Thus, MAO including MSAR can be performed under the direct command and control of this establishment which would strengthen the mechanism and circumvent duplication of events. The following entities can be linked with the MAC&CC for communication and coordination. The aerial and maritime platforms coming under these entities are indicated against them. Besides, it is prudent to comprehend that MAC&CC would be employed as the agency which would integrate with other regional SAR entities to respond swiftly in an event of maritime aircraft SAR.

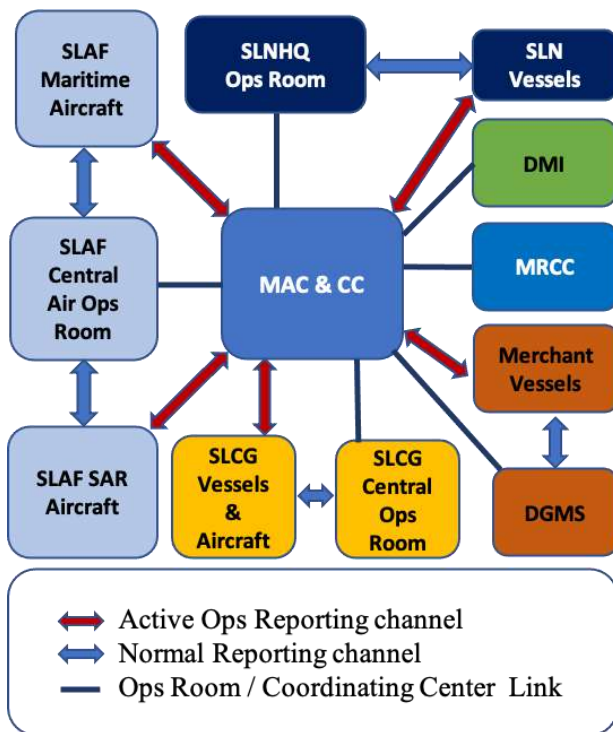


Figure 9: Conceptual structure for joint Maritime-Air command and control
Source: Wanasinghe and Wijetunge (2021)

The researcher found that air diplomacy could be acted as a catalyst for establishing either a combined maritime task force or a combined MSAR centre in Sri Lanka. Besides, this unique C2 platform must be integrated with regional ARCCs with the objective of availing a prompt information flow and dissemination of the same towards every tactical component within the organisation without undue delay.

4. DISCUSSION

The respondent from the BAF (2021) stressed that communication challenges are the most common pitfall to be encountered during SAR operations. Besides, he underpinned that terrain and weather also pose operational constraints for Bell helicopter operations. New acquisitions of AW 119, and AW139 helicopters with advanced avionics do not have significant pitfalls for attending SAR ops either in adverse weather or mountainous areas for the BAF. However, Maligaspe (2021) has indicated

that apart from weather/terrain, SLAF platforms curtailing attendance on SAR operations extensively within the Colombo SRR due to lack of reach and non-availability of required capabilities.

The absence of an integrated mechanism on SAR in Sri Lanka with the involvement of external agencies is a serious concern that needs to be addressed. Further, the lack of joint exercises at frequent intervals has been limiting SLAF's exposure to attending large-scale aviation disasters where regional Air Forces have significantly improved. Albeit, it is deemed necessary to have a system and human interoperability with other external agencies, principally CAASL, SLN, SLA and SLCG. Further, Maligaspe (2021) and Wanasinghe and Wijetunge (2021) have stressed the requirement to upgrade the existing platforms as suited to the SAR context and to establish a dedicated SAR squadron in SLAF with the integration of external agencies.

Wijetunge and Wanasinghe (2021) capabilities/capacities, and the existing fleet are necessary to be modernised in accordance with the preceding objectives. Thus, it is imperative to augment surveillance and MSAR capabilities considering the strategic depth of the maritime domain.

According to Kainikara (2019), financial constraints are the most common pitfall that small Air Forces experience in the contemporary world. The prevailing pandemic has further deepened fiscal constraints as the country's economy has been severely contracted by -3% according to President Rajapaksa (2021). Thus, the researcher explored that acquisition of new platforms at this critical juncture would implicate socio-political criticisms against the government as well as the SLAF. Thus, in turn, the government would lose popular support while creating a political gain on opponents.

The researcher has identified the IOR power rivalry as the principal challenge before Sri Lanka in forms of geopolitical aspects. Emerging power competition between the Quad (USA, Australia, Japan and Australia) and China's Belt and Road

Initiative (BRI) have constituted a significant impact on the geopolitical sphere concerning Sri Lanka, despite the country adopting a neutral foreign policy. As indicated by Kainikara (2019), geopolitical concerns have serious implications in acquisition of new platforms and technological advancements for developing economies since the aviation technology is mainly within the purview of few developed economies.

Wijetunge and Wanasinghe (2021a), underscored that the domestic political consensus approach is also highly essential prior to establishing military partnerships. Thus, researcher also explored that wrong socio-political manipulations could be propagated in view of attaining political compensation by political entities in the opposition.

5. RECOMMENDATIONS

It was identified that air power's core characteristics of speed, reach and height permit it to be employed to exert a state's soft power through air diplomacy. Consequent to the extensive study and discussion, the author makes the following recommendations in accordance with the study objectives and findings.

1. To establish air partnerships by the SLAF with regional Air Forces to facilitate an effective maritime SAR services within the Colombo SRR. The necessity of a common maritime SAR mechanism between regional air forces would be permitted to have a better mutual understanding as well as proper MOU between stakeholders within the Colombo SRR. Further, these kinds of partnerships should be encompassed collective MSAR engagements.

2. To establish a regional combined MSAR centre in Sri Lanka to facilitate MSAR services to aircraft/ships in distress conditions within the SRR/IOR.

Considering the geostrategic location of Sri Lanka and its strategic depth, the tiny Island is ideally suited to establish a regional MSAR centre through collaboration with regional Air and Naval Forces. Seeing the connectivity, the identified locations for

such a combined centre are Hambanthota, Trincomalee, Jaffna and Katunayake. Though considering the depth, reach and proximity to the extensive maritime domain, Hambanthota could be underpinned as the ideal location.

3. To establish a collective information sphere among regional Air Forces with the objective to obtain prompt information, and intelligence in relation to aircraft accidents. A common information-sharing mechanism among regional Air Forces within the IOR and adjacent seas is essential to take swift and prompt actions in order to circumvent unnecessary delays in engaging in MSAR. Absence of such a mechanism in the present context invariably curtails the swift participation of the Air Forces in the situation.

4. To induct a consensus political approach between the government and oppositions prior to establishing combined air partnerships in order to circumvent unnecessary socio-political manipulations.

A consensus approach is deemed necessary to circumvent socio-political implications against intended air diplomacy aspirations. The current socio-political environment saw numerous manipulations and adverse implications on political stability due to the absence of an agreed approach between the government and the opposition. Further, effective communication is essential between political leaders and the SLAF to convey/establish the right politico-air intents and its benefits to the public accurately while projecting the right image of the SLAF.

5. To bolster the capacities and capabilities of the SLAF concerned in MSAR operations.

The acquisition of new platforms and new technologies is a costly affair. However, attaining professional maritime-air capabilities consumes a considerably longer time even if the assets are procured. Hence, smart stretched re-fleeting and gradual acquisition of new technologies step by step would result in a better geared maritime-air force

with proper mass, mix and mobility to counter future maritime-air challenges in the long run without adding much financial pressure at once.

6. To formulate an integrated joint maritime-air command structure between responsible stakeholders in MSAR such as SLN, SLAF, CAASL, ARCC and the SLCG.

Formulation of such a structure is within the capacity of the relevant elements at present, and it would expand gradually with an air diplomacy approach. At present also certain integration is available among the maritime entities. Incorporating the aerial entity into the mix and configuring them to form up a structure as discussed above need a thorough and unpretentious discussion among these forces. The structure and the command are to be aimed to attain the maritime-air objectives effectively and efficiently in line with national objectives.

To conduct joint maritime-air exercises at frequent intervals. Carefully designed joint training can translate the theory into a reality. Across the globe, such joint training and exercises are a common practice to achieve, maintain and master the cohesion and understanding among conceptually different elements to achieve common objectives. Hence, continuous joint training and exercises involving all levels of professionals who will engage in future maritime-air operations would be an underlying component of developing the integrated maritime-air structure.

7. To obtain specialised training programmes from foreign Air Forces for SLAF personnel involved in SAR operations in view of bolstering their know-how to aircraft SAR.

These programmes would entail firefighting, sea rescue, jungle and land rescue, and participation in foreign combined SAR exercises.

8. To establish a dedicated SAR unit/squadron equipped with all necessary apparatus and qualified personnel in view of discharging effective and efficient SAR services within AOR.

9. To induct a consensus approach between external agencies within Sri Lanka and offshore in order to sign MOUs to yield quite efficient SAR services within the SRR.

6. CONCLUSION

The advent of air power created a significant impact on warfare and the aviation industry which abetted to increase connectivity between regions/continents, due to its unique ability to operate swiftly in the third dimension. This study endeavoured to conceptualise an air diplomacy framework which could be incorporated into the air strategy while bolstering the capabilities and capacities of SLAF's MSAR endeavours. The study has identified that air diplomacy could be employed in the quest of MSAR engagements within the Colombo SRR in two spheres of kinetic and non-kinetic engagements. Eventually, the researchers underpinned that an effective air diplomacy framework would be integrated into the air strategy to bolster the SLAF's capabilities/capacities in relation to MSAR.

Failure to optimise the geostrategic benefit for the furtherance of the nation by responsible authorities, the oceanic region around the Island has become a loitering ground for state counterparts and regional stakeholders. Increasing the maritime-air capacity and capability with a clear intent to exploit the vast maritime zone around us would make the region safe and secure for legitimate operations, thus limiting the opportunity for illicit activities. By the time the authorities are ready to explore the marine heirloom, it would be safe and secure to do so in future.

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