International Journal of Physical Sciences

October 2013 - Vol. 8 Num. 40

Submit manuscripts: www.ms.academicjournals.org

Editorial Office: ijps@academicjournals.org

URL: www.academicjournals.org

academicJournals

ABOUT IJPS

The **International Journal of Physical Sciences (IJPS)** is published weekly (one volume per year) by Academic Journals.

International Journal of Physical Sciences (IJPS) is an open access journal that publishes high-quality solicited and unsolicited articles, in English, in all Physics and chemistry including artificial intelligence, neural processing, nuclear and particle physics, geophysics, physics in medicine and biology, plasma physics, semiconductor science and technology, wireless and optical communications, materials science, energy and fuels, environmental science and technology, combinatorial chemistry, natural products, molecular therapeutics, geochemistry, cement and concrete research, metallurgy, crystallography and computer-aided materials design. All articles published in IJPS are peer-reviewed.

Submission of Manuscript

Submit manuscripts as e-mail attachment to the Editorial Office at: ijps@academicjournals.org. A manuscript number will be mailed to the corresponding author shortly after submission.

For all other correspondence that cannot be sent by e-mail, please contact the editorial office (at ijps@academicjournals.org).

The International Journal of Physical Sciences will only accept manuscripts submitted as e-mail attachments.

Please read the **Instructions for Authors** before submitting your manuscript. The manuscript files should be given the last name of the first author.

Editors

Editorial Board

Instructions for Author

Electronic submission of manuscripts is strongly encouraged, provided that the text, tables, and figures are included in a single Microsoft Word file (preferably in Arial font).

The **cover letter** should include the corresponding author's full address and telephone/fax numbers and should be in an e-mail message sent to the Editor, with the file, whose name should begin with the first author's surname, as an attachment.

Article Types

Three types of manuscripts may be submitted:

Regular articles: These should describe new and carefully confirmed findings, and experimental procedures should be given in sufficient detail for others to verify the work. The length of a full paper should be the minimum required to describe and interpret the work clearly.

Short Communications: A Short Communication is suitable for recording the results of complete small investigations or giving details of new models or hypotheses, innovative methods, techniques or apparatus. The style of main sections need not conform to that of full-length papers. Short communications are 2 to 4 printed pages (about 6 to 12 manuscript pages) in length.

Reviews: Submissions of reviews and perspectives covering topics of current interest are welcome and encouraged. Reviews should be concise and no longer than 4-6 printed pages (about 12 to 18 manuscript pages). Reviews are also peer-reviewed.

Review Process

All manuscripts are reviewed by an editor and members of the Editorial Board or qualified outside reviewers. Authors cannot nominate reviewers. Only reviewers randomly selected from our database with specialization in the subject area will be contacted to evaluate the manuscripts. The process will be blind review.

Decisions will be made as rapidly as possible, and the journal strives to return reviewers' comments to authors as fast as possible. The editorial board will re-review manuscripts that are accepted pending revision. It is the goal of the IJPS to publish manuscripts within weeks after submission.

Regular articles

All portions of the manuscript must be typed double-spaced and all pages numbered starting from the title page.

The Title should be a brief phrase describing the contents of the paper. The Title Page should include the authors' full names and affiliations, the name of the corresponding author along with phone, fax and E-mail information. Present addresses of authors should appear as a footnote.

The Abstract should be informative and completely self-explanatory, briefly present the topic, state the scope of the experiments, indicate significant data, and point out major findings and conclusions. The Abstract should be 100 to 200 words in length.. Complete sentences, active verbs, and the third person should be used, and the abstract should be written in the past tense. Standard nomenclature should be used and abbreviations should be avoided. No literature should be cited.

Following the abstract, about 3 to 10 key words that will provide indexing references should be listed.

A list of non-standard **Abbreviations** should be added. In general, non-standard abbreviations should be used only when the full term is very long and used often. Each abbreviation should be spelled out and introduced in parentheses the first time it is used in the text. Only recommended SI units should be used. Authors should use the solidus presentation (mg/ml). Standard abbreviations (such as ATP and DNA) need not be defined.

The Introduction should provide a clear statement of the problem, the relevant literature on the subject, and the proposed approach or solution. It should be understandable to colleagues from a broad range of scientific disciplines.

Materials and methods should be complete enough to allow experiments to be reproduced. However, only truly new procedures should be described in detail; previously published procedures should be cited, and important modifications of published procedures should be mentioned briefly. Capitalize trade names and include the manufacturer's name and address. Subheadings should be used. Methods in general use need not be described in detail.

Results should be presented with clarity and precision. The results should be written in the past tense when describing findings in the authors' experiments. Previously published findings should be written in the present tense. Results should be explained, but largely without referring to the literature. Discussion, speculation and detailed interpretation of data should not be included in the Results but should be put into the Discussion section.

The Discussion should interpret the findings in view of the results obtained in this and in past studies on this topic. State the conclusions in a few sentences at the end of the paper. The Results and Discussion sections can include subheadings, and when appropriate, both sections can be combined.

The Acknowledgments of people, grants, funds, etc should be brief.

Tables should be kept to a minimum and be designed to be as simple as possible. Tables are to be typed double-spaced throughout, including headings and footnotes. Each table should be on a separate page, numbered consecutively in Arabic numerals and supplied with a heading and a legend. Tables should be self-explanatory without reference to the text. The details of the methods used in the experiments should preferably be described in the legend instead of in the text. The same data should not be presented in both table and graph form or repeated in the text.

Figure legends should be typed in numerical order on a separate sheet. Graphics should be prepared using applications capable of generating high resolution GIF, TIFF, JPEG or Powerpoint before pasting in the Microsoft Word manuscript file. Tables should be prepared in Microsoft Word. Use Arabic numerals to designate figures and upper case letters for their parts (Figure 1). Begin each legend with a title and include sufficient description so that the figure is understandable without reading the text of the manuscript. Information given in legends should not be repeated in the text.

References: In the text, a reference identified by means of an author‘s name should be followed by the date of the reference in parentheses. When there are more than two authors, only the first author‘s name should be mentioned, followed by ’et al‘. In the event that an author cited has had two or more works published during the same year, the reference, both in the text and in the reference list, should be identified by a lower case letter like ’a‘ and ’b‘ after the date to distinguish the works.

Examples:

Abayomi (2000), Agindotan et al. (2003), (Kelebeni, 1983), (Usman and Smith, 1992), (Chege, 1998; 1987a,b; Tijani, 1993,1995), (Kumasi et al., 2001)

References should be listed at the end of the paper in alphabetical order. Articles in preparation or articles submitted for publication, unpublished observations, personal communications, etc. should not be included in the reference list but should only be mentioned in the article text (e.g., A. Kingori, University of Nairobi, Kenya, personal communication). Journal names are abbreviated according to Chemical Abstracts. Authors are fully responsible for the accuracy of the references.

Examples:

Ogunseitan OA (1998). Protein method for investigating mercuric reductase gene expression in aquatic environments. Appl. Environ. Microbiol. 64:695-702.

Gueye M, Ndoye I, Dianda M, Danso SKA, Dreyfus B (1997). Active N2 fixation in several Faidherbia albida provenances. Ar. Soil Res. Rehabil. 11:63-70.

Charnley AK (1992). Mechanisms of fungal pathogenesis in insects with particular reference to locusts. In: Lomer CJ, Prior C (eds) Biological Controls of Locusts and Grasshoppers: Proceedings of an international workshop held at Cotonou, Benin. Oxford: CAB International, pp 181-190.

Mundree SG, Farrant JM (2000). Some physiological and molecular insights into the mechanisms of desiccation tolerance in the resurrection plant Xerophyta viscasa Baker. In Cherry et al. (eds) Plant tolerance to abiotic stresses in Agriculture: Role of Genetic Engineering, Kluwer Academic Publishers, Netherlands, pp 201-222.

Short Communications

Short Communications are limited to a maximum of two figures and one table. They should present a complete study that is more limited in scope than is found in full-length papers. The items of manuscript preparation listed above apply to Short Communications with the following differences: (1) Abstracts are limited to 100 words; (2) instead of a separate Materials and Methods section, experimental procedures may be incorporated into Figure Legends and Table footnotes; (3) Results and Discussion should be combined into a single section.

Proofs and Reprints: Electronic proofs will be sent (e-mail attachment) to the corresponding author as a PDF file. Page proofs are considered to be the final version of the manuscript. With the exception of typographical or minor clerical errors, no changes will be made in the manuscript at the proof stage.

International Journal of Physical Sciences

Table of Contents: Volume 8 Number 40, 30 October, 2013

ARTICLES

academicJournals

Vol. 8(40), pp. 1923-1933, 30 October, 2013
DOI: 10.5897/IJPS2013.3978
ISSN 1992 - 1950 © 2013 Academic Journals
http://www.academicjournals.org/IJPS

International Journal of Physical Sciences

Full Length Research Paper

Empirical analysis of road traffic accidents: A case study of Kogi State, North-Central Nigeria

Agbeboh G. U. and Osabuohien-Irabor Osarumwense

Department of Mathematics, Ambrose Alli University, Ekpoma, Nigeria.

Accepted 22 August, 2013

This paper studied the trend of road accident in Kogi State from January, 1997 to December, 2010, using a univariate time series data collected from the Federal Road Safety Commission (FRSC), Lokoja, Kogi State. The model for the data was found to be Y = 22.062 + 0.252T. Test for the existence of trend and seasonal variation was conducted at 0.05 level of significance, and a four years forecast for road accident was made for the year 2012, 2013, 2014 and 2015. It was found that there is no seasonal variation but trend which shows steady increase in Kogi State accident rate. All Statistical analyses were done using a statistical package called SPSS.

Key words: Trend, variation, Kogi, SPSS, road accident, forecast, smoothing and federal road safety commission (FRSC).

INTRODUCTION

Road Traffic accident (RTA) can be said to be an unplanned occurrence of auto crash that may result in injuries, loss of lives and properties. RTA are having a worsening effect on our society and economy. RTA claim the largest toll of human life and tend to be the most serious problem all over the world (Kual et al., 2005). Worldwide, the number of people killed in RTA each year is estimated at almost 1.2 million while the number of people injured could be as high as 50 million (WHO, 2004). Currently, motor vehicle accidents rank 9th in order of disease burden and are projected to be ranked 3rd in the year 2020. Nearly three-quarters of deaths resulting from motor vehicle crashes occur in developing countries (Odero, 1998) and this problem appears to be increasing rapidly in these countries (Jacobs et al., 2000). Apart from humanitarian aspect of the problem, traffic accidents and injuries in these countries incur an annual loss of $65 billion to $100 billion annually. These costs include both loss of income and the burden placed on families to care for their injured relatives. The Americans bear 11% of the burden of road traffic injury mortality (WHO, 2002). The socio-economic costs of RTA in Nigeria are immense and the direct cost of traffic casualties can perhaps, at best be understood in terms of the labour lost to the nation's economy (Adekunle, 2010). It has been estimated that persons injured in accidents on Nigerian highways and streets no longer participate in the economic mainstream and this amounts to a loss of labour of millions of person's years to the nation (Pratte, 1998).

The causes of road traffic accidents are numerous, some are; according to Pludemmann et al. (2004), use of Alcohol contribute to traffic injuries by impairing driving capabilities and thus increasing the risk of crash involvement. Although alcohol is generally thought to be the most important risk factor among all drugs, some evidence has also linked the use of minor tranquilizers such as benzodiazepines to increase risk of crash

*Corresponding author. E-mail: ujagbegoddy@yahoo.com

involvement (Gururaj, 2004). Again, there is evidence that drivers with diabetes, epilepsy, cardiovascular disease or mental illness experience higher crash and violation rates (Mishra et al., 2010) but there is an equal number of studies indicating that neither chronic medical conditions nor disabilities among automobile drivers put them at greater risk of RTAs (Mohan, 2007). According to Cutter (1993), geographical scale is important for impacts and their reduction. Land use pattern, types of road network, local business and activity pattern will influence the system risk in an area (Komba, 2006).

The cost to society such as lost of able bodied men and women who hitherto, would have been involved in productive economic activities, lost of intellectuals in our schools, lost of resources to government and families, to insurance companies and damage to properties, etc are inestimable. Again, valuing the psychosocial impact on victims is another difficult task. Issues like suffering and loss of life injuries associated with road traffic accidents is difficult to assign monetary value. According to Onakonaiya (1992), with injuries, people often suffer physical pain and emotional anguish that is beyond any economic compensation. Permanent disability such as paraplegia, (paralysis of the lower half of the body), Quadriplegia (paralysis of all four limbs), loss of ability to achieve even minor goals and result in dependence on other people for economic support and routine physical care which may although not in all cases for the rest of the victim's life (Jacob, 1990).

According to Nnadede (1997), "Equal protection to all road users should be aimed at, since non-motor vehicle users bear the disproportionate share of road injuries and risk. The traffic system should help users to cope with increasingly demanding condition".

Around the world, road traffic injuries pose a major public health challenges that requires concerted efforts to reduce through effective and sustainable method of preventions. An estimated 1.3 million people are killed through road accident annually around the world and as many as 50 million people suffer injuries (Interstate.statejournals.com/year2011). The World Health Organization (WHO) believes that this figure will increases to 1.9 million if concrete action is not taking by the end of 2020, especially in developing country such as Nigeria (Road Safety Nigeria, June 2009 and the Nigerian Tribune march 13th, 2009).

Statistics has it that the country with the highest road accident in the world is India with 105,725, followed closely by China with 96,611 and United state of America with 62,272 cases of reported road accident as at 2009 (Inyang, 1986). In Nigeria, the Federal Road Safety Commission (FRSC) is the government agency with statutory responsibilities for road safety administration. Prior to the establishment of FRSCE in 1988 by Former Head of State, Ibrahim Babangida; there was no concrete and sustainable policy action to address the carnage on our road. Earlier attempt in this direction were limited to discrete and isolated attempt by individuals. Shell petroleum tried and they failed in 1960-1965 (www.shellpetrolleum.com). The Nigerian Army started the first training of its men on road safety campaign in 1972. It was officially created in 1994 which was then called Nigerian Road Safety Commission (NRSC) by Babangida Ibrahim. The impact of the commission was not however sustained.

With the continued dangerous trend of road traffic accidents in Nigeria then, which place it as one of most road traffic accident (RTA) pruned countries in the world after Ethiopia, the Nigerian government saw the need to establish the present Federal Road Safety Corps in 1988 to address the road safety carnage on the high way. In February 1988, the Federal Government established the (FRSC) through Decree No.45 of the 1988 as amended by Decree 35 of 1992 which is referred to in the status book as the FRSC ACT cap 141 laws of the federation of Nigeria (Nigerian Constitution 1999). The commission was privileged at inception to be under Wole Soyinka (now Professor Soyinka). At that time, the commission was incorruptible. Traffic offenders were made to pay fines in distant places which serve as deterrent against further traffic offences. Many years later, when the duo of Babangida and Soyinka left office, the commission appeared to completely lost focus, except only that it is now relevant for purpose of issuing driving license for identification or for other transactions, particularly collecting money for vehicles plate numbers.

The objectives of this study amongst others are;

(i) The trend of road traffic accident rate in Kogi state from 1997-2010.
(ii) Whether there is a significant difference in the rate of accident in Nigeria and Kogi in particular from 1997-2010 using a suitable test statistics.
(iii) To find a suitable model for the data.
(iv) Whether the measures taken in reducing road traffic accident really yielded any desired result. (v) Forecasting the future status of road traffic accident in Kogi State.

Statutory functions of FRSC

The functions of the commission include:

(i) Making the high way safer for motorist and other road users.
(ii) Recommending work and devices designed to eliminate or minimize accidents on the high way and advising the government on what to do about road problem in Nigeria.
(iii) Educating motorist and members of the public on the importance of discipline on the road.
(iv) Designing and production of drivers' license and plate numbers to be used by various road users.

(v) Giving prompt attention and care to victim of road accident, conduct researches into the causes of the accident and method of preventing them and putting into use such finding.
(vi) Determining speed limit for all road users.
(vii) Providing roadside and mobile clinics for the treatment of accident victims free of charge.

In exercising these functions, the commission shall have the power to arrest and prosecute persons reasonably suspected of having committed any traffic offences. Federal Road Safety Commission of Nigeria is a body that aims at encouraging good driving habits and help reduce and limit the impact of Road traffic accidents. This can be done by:

1. Providing information on how road safety issues can be achieved.
2. Publicizing important governmental and community initiative to help reduce traffic accident and make our roads safer.
3. Regulate and coordinate all road traffic safety management activities through robust data management.
3. Role of government in road safety.

In order to achieve the FRSC full mission, the Federal Government and all it stakeholders have the following role to play. The following are the suggested roles if played by the government; accident will be reduced to its beeriest minimum:

(i) Creating awareness about Federal Road Safety: The government will have to increase efforts to promote awareness about the road safety issues and their social economic implications. The strategy to implementing this policy is by rising existing awareness, among stakeholders for planning and promoting road safety and their roles and responsibility.
(ii) Providing enabling legal, institutional and financial environment for road safety: Many government departments as well as various public and private agencies, share the responsibility of the various stakeholders and taking appropriate measures to ensure that the required environment for road safety is in place. Strategy to implement this policy is strengthened and the institutional framework for managing road safety at different levels financing it, is established for a dedicated road safety fund, through providing budgetary support as well as earmarking a percentage of fines collected for violation of motor vehicle related offences for the FRSC.
(iii) Road safety information data base: Detailed analysis of road accidents is essential if the causes of the accident are to be fully understood. At present time, the policy prepares a report for the accident that they are aware of. Accident report requires a precise location of the accident and condition at the time of the accident. Example: weather, road surface, etc. The policy statement for this role is that the government should improve data collection details at the scene of accident, improve the storage and accessibility of all data relevant to an accident such as vehicles involved, road, environment and drivers detail, etc.
(iv) Safer road infrastructure: According to Isabel magazine (1995), who studied driver's attitudes by a group discussion method which many drivers consider that road improvement, are the main and almost the only condition for road safety. Buchannan (1995) commented on the likely increases in cars in the next 70 years. He wondered how many more roads could be provided to cope with these increase in volume of traffic and concluded that it is impossible to provide adequate roads to contain the volume of traffic. Notwithstanding, the government can undertake additional steps to encourage safety by conscious planning and designing of new road networks as well as rehabilitating road schemes. Nnadede (2005) recommended that the Federal government should increase the number of road signs on the high way as well as on the access roads. Strategies for implementing this policy include: all proposed new and rehabilitation road schemes are to be checked from safety perspective for all types of road users during the planning and designing stages through road safety adult adopt accident reduction strategies for existing roads through black spot improvement programmed, to facilitate improvement of engineers on various road safety aspects through training and dissemination of appropriate road safety knowledge.
(v) Safer vehicles and driving habit: The federal government should take steps to strengthen the system to ensure that safety aspects are built and maintenance of vehicles in line with prevailing international standards in order to minimize adverse safety and environmental effects of vehicles operating on road. Strategies to implement this policy is to encourage setting up of modern driving schools with adequate infrastructure, to set up computerize data base of drivers and vehicles, as per the standardized software developed by the Federal Government.
(vi) The Government will strengthen the system of driver licensing and training to improve the competence and capability of drivers (Strategies to implement policy of this role): To encourage setting up of modern driving schools with adequate infrastructure, to set up computerized software developed by the federal Government.
(vii) Emergency medical services for road accident victims: According to Jacobs and Bardsley (1992), study shows that about 50% of deaths from road collisions occur within a few minutes at scene of the crash or else on the way to a hospital but before arrival. Here the stress on the "Golden Hour'' that is, the first hour from road accident being critical for the survival of the victim. It is important that all persons involved in road accidents

benefit from speedy and effective trauma care and health management. The essential functions of such service would include the provision of rescue operation and administration of first aid at the site of the accident. It aims at improving communication system available with police and other emergency services as a means to reduce response time and also train police, fire and other emergency service such as ambulances and paramedics in basic first aid for road crash victims.

A road is a thoroughfare, route or way on land between two places which typically has been parked or otherwise. According to Ado (2007), Nigeria has one of the best and modern transport systems that are highly developed in Africa. rail, road, air and in-land waterways traverse the length and breadth of the country to link the individual commercial agricultural centers. Kogi State road network fall into three categories:

(i) The trunk “A” roads which is the responsibility of the Federal Government to create and maintained it at all time.
(ii) The trunk “B” roads are owed and are funded by the state and are within the State metropolis.
(iii) The trunk “C” road, which are referred to local government roads and are the responsibilities of the local government (Annual abstract of statistics 2001 Edition).

The length of the Federal Government roads in Kogi State is said to vary with time. This variation can be caused by the development or construction of new roads to link other existing one thereby increasing the total length. Rallis (1990) in his examination of safety on roads observed that the number of person killed in road accident has increased very much since the Second World War. This result he obtained by dividing the number in rural and urban accidents and further into car driver and passenger, pedestrians and two wheeled. The number of persons killed in urban transport accident per 1,000,000 passengers per hour is 0.02 for buses, 0.2 for automobiles and for pedestrians but more for cyclists and motorcyclists.

Etaghere further emphasized that our road deserve better road signs. This is as a result of the fact that there are strangers on our road who are not used to the road. Epicson (1980) asserted that the ability to make decision in traffic which is both quick and accurate is something that should be cultivated during training. A decision may be worse than useless if it is unduly delayed. Fatter or severe accidents on the road are more frequent than milder accidents. Morple (1979) declared that everybody on the road should drive as if the other chaps were a complete fool. Since there is no way of knowing who is a foolish driver, the best is to act as if tax other driver belong to the category of foolish ones. This will entail large margins of safety, clearance, wide berths and so on.

According to John Cohen in his book, causes and prevention of road accidents “says if we had the will, we should find ways, for we cannot assume to the problem of road safety are beyond the wit of man to solve once they are identified. We do not have the will because we are not sufficiently moved by disaster on the road".

From the foregoing, the meaning of road accident vary not only in the definitions, nature of the causative agent (human and nonhuman) and state or statues, but also the extent of damage and the degree of response needed input to reducing the effect. In substances they all convey that never ending process of sudden or impromptu incident of collision which calls for careful and mindful road users, dedicated law enforcement agencies, and the like as to reduce loss of live and properties. Whitelegy (1982) defined accident as the product of an unwelcome interaction between two or more moving object or fixed and a moving object. The Oxford Advance Learner’s Dictionary (1989) defined accident as event that happed unexpectedly and causes damage or injury. Onakomaiya (1992) define accident as a chance occurrence, which produce unexpected and unpleasant consequences resulting from unforeseen and often a disastrous event. Mohammed (2005) defines accident as an unexpected happening with a potential to cause injury or damage. Thus, he envisaged accident to have occurred due to simple or multiple causes. He further said that road traffic accident, as the names implies, is a sudden incident or occurrence whose end product is always on loss of lives and properties. He further explained that since road accidents are foreseen and can be avoided, then the task of preventing road traffic accident and ensuring safety on our highway and on the road is a collective responsibility for all drivers, other road users and the traffic enforcement agencies.

MATERIALS AND METHODS

The exponential smoothing is one type of weighted average that arraigns the arrangement of positive weight to past and present values only. A simple weight W called the exponential smoothening constant is selected so that W is between 0 and 1. Then the exponential smoothed series E 1 is calculated as follows:

$E_1=Y_1$.
$E_2=WY_2 + (1-W) E_1$.
$E_3=WY_3 + (1-W) E_2$.
$E_4=WY_4 + (1-W) E_3$.
$E_5=WY_5 + (1-W) E_4$.
:
:
:
$E_t = WY_t + (1-W) E_{t-1}$

These exponential smoothened values at time t assigns the weight W to the current series values Y and the weight (1-W) to the previous smoothed values. Small value W gives less weight to current values of the series and yield more variables series.

Table 1. Regression parameters.

Source	DF	SS	MS	F-Calculated	F-Tabulated
Regression	1	SSR	SSR/1	MSR/MSE	
Error	n-1	SSE	SSR/n-1		
Total	N		-		

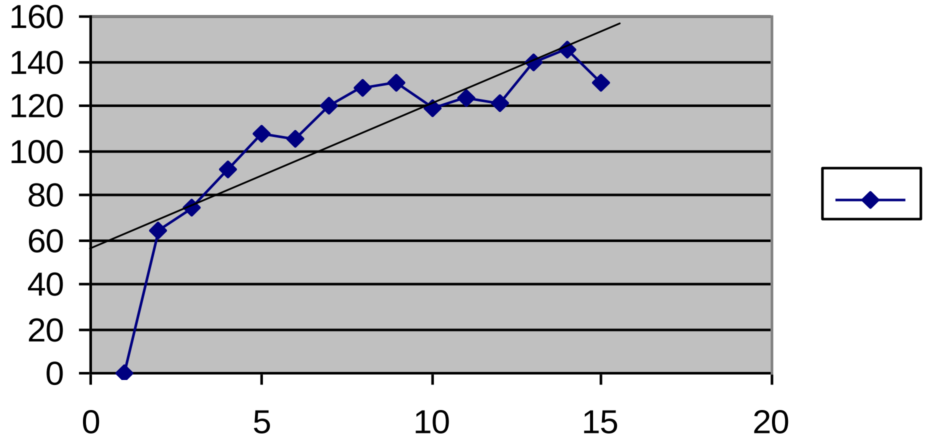


Figure 1. Time plot.

However, larger choice of W arraigns more weight to the current values of the series and yields more variables series. if W is near 0, then it places more emphasis on (Wt) on past values of the time series and yields a smoother series while a choice of W near 1 gives more weight to the current values to the series.

The least square method was used in describing the trend by means of the objectively determined mathematical equation called the equation of the straight line

$\hat{Y}_t = \acute{\alpha} + \hat{\beta}x_t$

$Y = a + bt$

$\sum y = na + b\sum t$ (1)

$\sum ty = a\sum t + b\sum t^2$ (2)

$\sum t\sum y = \sum tna + b(\sum t)^2$ (3)

$n\sum ty = na\sum t + nb\sum t^2$ (4)

$$b = \frac{n\sum ty - \sum t\sum y}{n\sum t^2 - (\sum t)^2}$$

$$a = \overline{Y} - b\,\overline{t}$$

Analysis of variance (ANOVA) regression is then carried out at $\alpha = 0.05$ level of significant to test the significant of the regression coefficient (Table 1). The hypothesis is:

$H_O : \hat{\beta} = 0$

$H_1 : \hat{\beta} \neq 0$

SSR (Sum of square of the regression) $= \hat{\beta}\, SXY$

SST (Sum of square of the total) $= SYY$

SSE (Sum of square error) $= SST - SSR$

Where s xy = standard error of the XY $= \sum XY - \sum x\sum y\ n$

S_{xx}= standard errors of X $= \sum X^2 - (\sum X)^2 / n$

S_{yy}= standard error of Y $= \sum y^2 - (\sum y)^2 / n$

The method of Moving average method was also applied in estimating the trend from the collected data and the specific seasonal index is gotten by dividing the accident cases for each inventory with the corresponding central moving average and multiplying the result by 100. Then the corrective factor was used in calculating the typical index for each quarter in order to smoothing the fluctuations that arose.

RESULTS AND DISCUSSION

The trend of road traffic accident in Kogi State was discovered to be increasing steadily with little fluctuation on the data collected (Figure 1). One particular and important use of seasonal values is to seasonally adjust the original data. The effect of seasonal adjusted is to smooth away seasonal fluctuation, leaving a clear view of what might be expected. The specific seasonal index for each quarters for Kogi state accident rate from 2007 to 2010 was calculated while the central moving average is gotten by finding the average of two moving average. That is, adding two of the averages and dividing by two as shown as follows (Table 2):

Sum of the mean

$\sum \overline{X}$ = 99. 525 + 93. 404. + 57. 479 + 149. 349

= 399.756

Table 2. Quarterly researcher's calculation.

Years	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1997	-	-	28.77	145.95
1998	165.33	52.97	50.34	129.73
1999	124.52	88.89	73.83	110.32
2000	154.17	86	38.46	170.87
2001	104.5	83.24	77.67	123.36
2002	90.48	122.8	49.18	148.12
2003	98.71	98.36	36.78	171.42
2004	99.62	88.89	59.38	150.98
2005	103.45	94.74	17.93	206.29
2006	47.24	123.08	79.67	137.03
2007	68.38	120.69	42.98	178.89
2008	61.77	84.79	110.34	131.13
2009	80	96.55	81.9	137.44
2010	95.65	91.24	-	-

Corrective factor = 400 ÷ 399.756
= 1.000610372
~ 1.00061

Since it is not up to 400, we use the corrective factor in calculating the typical index for each quarter in order to smoothing the fluctuations that arose. The corrective factor for each mean in the respective quarters calculated as:

(99.525) (1.00061) = 99.586
(93.403) (1.00061) = 93.460
(57.479) (1.00061) = 57.514
(149.349) (1.00061) = 149.440

Sum of the corrected factors which is 99.586 + 93.460 + 57.514 + 149.514 = 400
Hence the typical seasonal index for each quarter, using the minimal average in 3d.p are:

1st = 99.586
2nd = 93.460
3rd = 57.514
4th = 149.440

While the deseasonal data calculated as: (inventory ÷ seasonal index) X100 (Table 3)

The sum of the deseasonal index with respect to the period T is:

$\sum T=$	$\sum Y=$	$\sum TY=$	$\sum T^2$
1596	1637.68	50355.56	60116

Where T is the period T; Y is the deseasonal index.

Therefore, "a" and "b" in the regression equation is also calculated as: a = 22.062 and b = 0.252. Hence the least square equation:

$$Y' = 22.062 + 0.252\, t$$

Where 22.062 is our intercept and 0.252 is our slope. Hence the least square equation

$$Y = 22.062 + 0.252\, t$$

Hence, the anticipated forecast for road accident for 2012, 2013, 2014 and 2015 are shown in Table 4 and Figure 2.

The sign test was applied to the data in testing the existence of seasonal variations. The sign of the first difference is obtained by subtracting an observation from the one following it. An unbroken sequence of signs called "Runs" is observed; that is, sequence of +'s and -'s. If R is the number of runs, then R is known to be normally distributed with mean $(\bar{X}) = (2n-4) \div 3$ and variance $=\sqrt{(16n-29)/90}$, therefore, $Z=R-\{(2n-4)/3\} -0.5 \sim N(0, 1)$. The hypotheses of interest are:

H_0: There is no seasonal variation.
H_1:There is a seasonal variation.

Then the test statistic is given as:

$$Z= R-\{(2n-4)/3\}-0.5\div\sqrt{(16n-29)/90} \quad \sim N(0, 1)$$

Comparing the data to obtain Run = R
(74-64), (92-74), (108-92), (105-108), (120-105), (128-120), (130-128), (119-130), (123-119), (121-123), (140-121), (145-140), (130-145)
Run = + + + - + + + - + - + + -
R = 4, and α = 0.05

Table 3. Expanded periodic quarterly researcher's calculation.

Years	Quarter	Period (T)	Accident	Index	Index(Y)
1997	1st	1	20	99.586	20.08
	2nd	2	12	93.46	12.84
	3rd	3	5	57.515	8.69
	4th	4	27	149.44	18.07
1998	1st	5	31	99.586	31.13
	2nd	6	10	93.46	10.7
	3rd	7	9	57.514	15.65
	4th	8	24	149.44	16.06
1999	1st	9	26	99.586	26.11
	2nd	10	20	93.46	21.4
	3rd	11	18	57.515	31.3
	4th	12	28	149.44	18.74
2000	1st	13	37	99.586	37.15
	2nd	14	17	93.46	18.19
	3rd	15	10	57.514	17.39
	4th	16	44	149.44	29.44
2001	1st	17	29	99.586	29.12
	2nd	18	23	93.46	24.61
	3rd	19	20	57.515	34.77
	4th	20	33	149.44	22.08
2002	1st	21	25	99.586	25.1
	2nd	22	35	93.46	37.45
	3rd	23	15	57.514	26.08
	4th	24	45	149.44	30.11
2003	1st	25	29	99.586	29.12
	2nd	26	30	93.46	32.1
	3rd	27	12	57.515	20.86
	4th	28	57	149.44	38.14
2004	1st	29	34	99.586	34.14
	2nd	30	30	93.46	32.1
	3rd	31	19	57.514	33.02
	4th	32	47	149.44	31.45
2005	1st	33	30	99.586	30.12
	2nd	34	27	93.46	28.89
	3rd	35	5	57.515	8.7
	4th	36	57	149.44	38.14
2006	1st	37	15	99.586	15.06
	2nd	38	40	93.46	42.8
	3rd	39	25	57.514	43.47
	4th	40	43	149.44	28.77

Table 3. Contd.

2007	1st	41	20	99.586	20.08
	2nd	42	35	93.46	37.45
	3rd	43	13	57.515	22.6
	4th	44	53	149.44	35.47
2008	1st	45	20	99.586	20.08
	2nd	46	30	93.46	32.1
	3rd	47	40	57.514	69.55
	4th	48	50	149.44	33.46
2009	1st	49	30	99.586	30.12
	2nd	50	35	93.46	37.45
	3rd	51	30	57.515	52.16
	4th	52	50	149.44	33.46
2010	1st	53	33	99.586	33.14
	2nd	54	30	93.46	32.1
	3rd	55	20	57.514	34.77
	4th	56	47	149.44	31.45

Table 4. The estimated cases of road traffic accident for these 4 years.

Year	Quart	Time	Seasonal index	Deseasonal forecast	Inventory case	Estimated cases of accident
2012	1	61	61	19.586	20	30.34=30
	2	62	62	93.46	12	37.31=37
	3	63	63	57.514	5	39.63=40
	4	64	64	147.44	27	44.95=45
2013	1	65	65	19.586	31	40.28=40
	2	66	66	93.46	10	30.40=30
	3	67	67	57.514	9	37.92=38
	4	68	68	147.44	24	50.24=50
2014	1	69	69	19.586	26	45.36=45
	2	70	70	93.46	20	42.88=43
	3	71	71	57.514	18	30.20=30
	4	72	72	14744	28	45.52=51
2015	1	73	73	19.586	37	50.84=51
	2	74	74	93.46	17	40.38=40
	3	75	75	57.517	10	11.93=12
	4	76	76	147.44	44	70.18=70

$Z = 4- [28-4]/3-0.5/ \sqrt{224} – 29 \div 90$
$Z=-3.057$
Z cal=-3 057
Z tab, 0.05 = 1.96

Since Z calculated < Z tabulated we accept H_0 and concluded that there is no seasonal variation. And from the above test, it shows that the seasonal variation does not exist; this is because the seasonal fluctuations recur

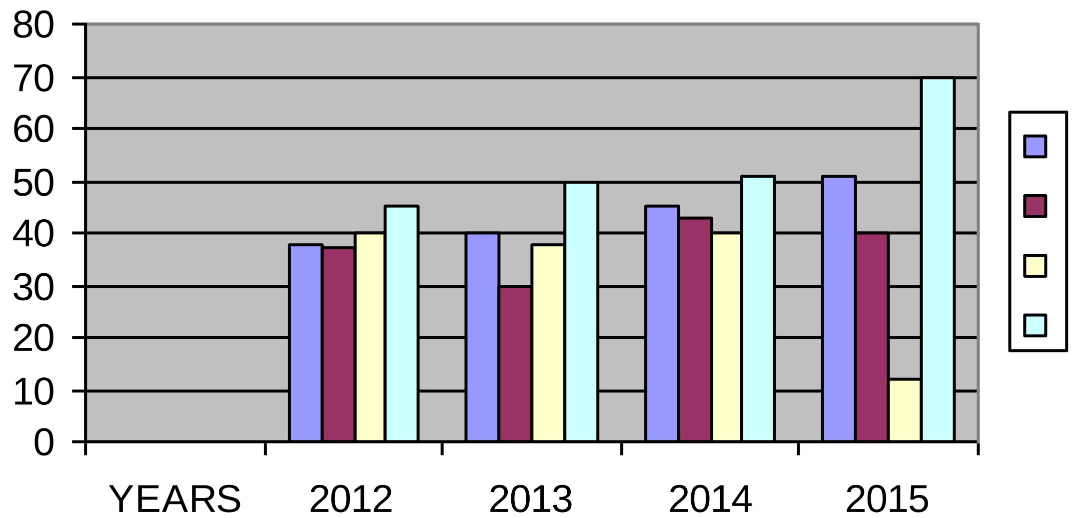


Figure 2. Component Bar-chart showing four years forecast of road traffic accident rate in Kogi State.

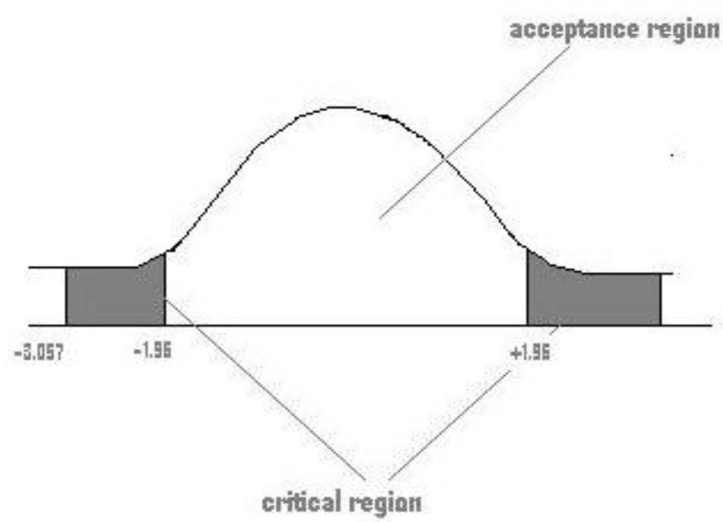


Figure 3. Normal distribution of RTA in Kogi State.

during the course of a year. It is always the case if the values of a variable for any twelve consecutive mouth, or is total, led up the effect of the seasonal automatically disappearing. From this it follows that the probability of estimating the seasonal variation arises only when the data is for "part" of years Gupta (1996). The critical region graph is shown in Figure 3.

Conclusion

From calculations carried out, it was discovered that the specific seasonal index was not up to 400. This became our corrective factor for the purpose of smoothening the fluctuations that may arise. The model for road accident in Kogi State was found to be Y=22.062 + 0.252 t . Road accident rate in Kogi State is expected to maintain a steady increase from 2012 to 2015, and the last quarters in the four (4) years forecast comprising September, October, November and December will have the highest numbers of road accident rate as usual; and November, 2015 is expected to record a minimal number of accident rate as seen in Table 4.

Using the sign test, it was discovered that there is no seasonal variation at α = 5%. Since Z cal < Z (Appendix Table 1) 1.1496< 1.96; we therefore, accept the H_1 reject H_0 and conclude that there is a trend. Of particular importance is the use of seasonal values which seasonally adjust the original data. The effect of seasonally adjusted values is to smooth away seasonal fluctuation occuring, leaving a clear view of what might be expected. We were able to show that:

(a) The trend was increasing randomly, or in an irregular marmal.
(b) There was a significant difference in the rate of occurrence of accident in Kogi State.
(c) Test for seasonal variation: when the sign test was use to test for the existence of seasonal variation and setting of hypothesis.
(d) It was discovered that there is no seasonal variation because the value of Z calculated was 3.057 and Z tabulated at 5% was found to be 1.96.
(e) The Kendall non parametric test was used to test for the existence of trend. And it was discovered that the data has a trend.
(f) The least square equation was use to derive the trend equation by finding the value of “a" and "b" which give us 22.062 and 0.252 respectively.
(g) It is observed in Appendix Graph 1 and Figure 2 that there is an increase in the cases of road accident, which is pronounced from 2001 to 2003. The rate of accident in the state has its highest value in 2009. While in 2000 to 2006, there was a depression in the accident rate and a steady increase was observed from 1997 to 1999. There is an observed fluctuation of accident rate from 2004 to 2007.
(g) From the analysis it is on the record that the last quarter of all the years has a high number of cases of road traffic accident. The forecasting analysis shows that 2014 will have the overall aggregate of road traffic accident. With a total of 173 while 1997 has the lowest case of road traffic accident among the years.

In spite of the ever increasing number of people using our road and the increasing occurrence of road accidents in Kogi State, the problem can be reduced if every citizen of the state can strictly adhere to all the preventive measures; and if the Federal Government can allocate more fund for road maintenance and construction, and the drivers strictly adhering to all the preventive measures.

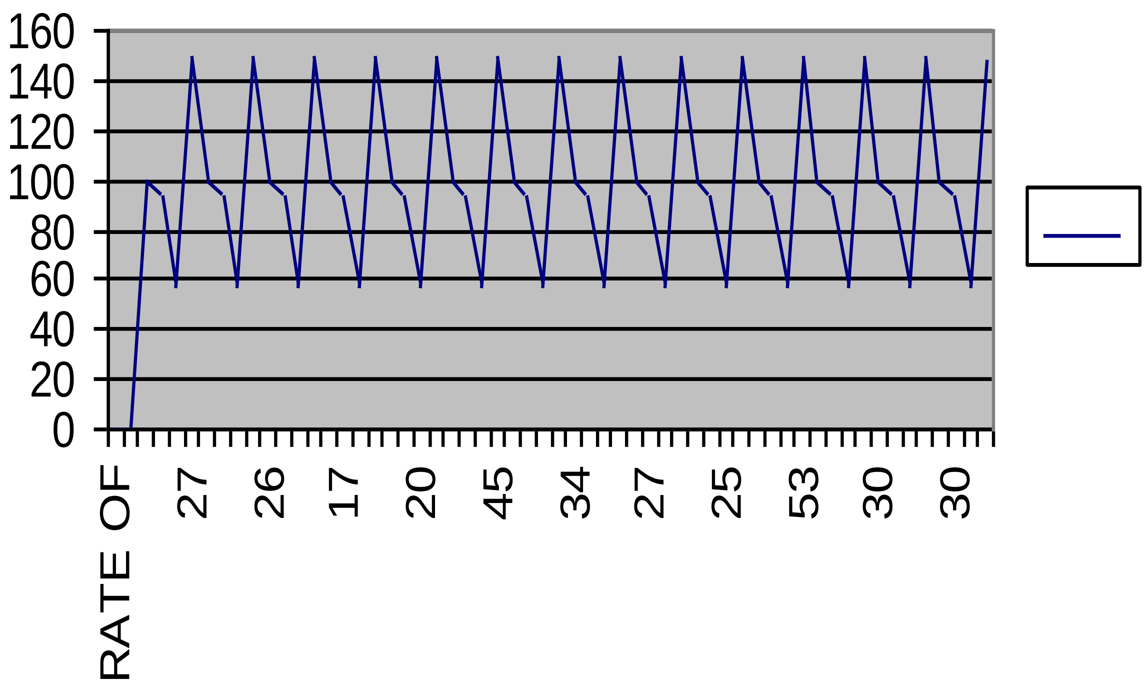
REFERENCES

Adekunle JA (2010). Road Traffic accident deaths and socio-economic development in Nigeria. Int. Rev. Bus. Soc. Sci. 1(5):47-60.
Gururaj G (2004). Alcohol and Road Traffic Injuries in South Asia: Challenges for prevention, *JCPSP.* 14(12):713-718.
Inyang O (1986). “Road Accident in developing counties” J. computational statistics Data Analysis. 5(2).
Cutter SL (1993). Living with Risks: Geography of Technological Hard.Great Britain: Edward Arnold.
Jacobs G, Aeron-Thomas A, Astrop A (2000). Estimating global road fatalities. London England: Transport Research Laboratory Report 445.
Komba E (2006).Traffic fatalities and economic growth. Accid. Anal. Prev. 37:169-178.
Kual A, Sinha VS, Pathak YK, Singh A, Kopoor AK, Sharma S, Singh S (2005). Fatal Road Traffic Accidents, Study of Distribution, Nature and Type of Injury, JIAFM. 27(2):71-78.
Mishra B, Sinha ND, Sukkla SK, Sinha AK (2010). Epidemiological Study of Road Traffic Accident Cases from Western Nepal, Indian J. Community Med. 35(1):115-121.
Mohan D (2007). Road safety in less-motorised environments: Future concerns. Int. J. Epidemiol. 31:327-532.
Odero W (1998). Alcohol-related road traffic injuries in Eldoret, Kenya, East Afr. Med. J. 75:708-711.
Pludenmann A, Parry CDH, Donson H, Sukhai A (2004). Alcohol use and trauma in Cape Town, Durban and Port Elizabeth, South Africa: 1999-2001, Injury Control and Safety Promotion, 11(4):265-267.
Pratte D (1998). Road to Ruin: Road Traffic Accidents in the Developing World. NEXUS, 13:46-62.
World Health Organisation (2002). A 5-year WHO strategy for road traffic injury prevention. Retrieved from; http://whqlibdoc.who.int/hq/2001/WHO -NMH-VIP-01.03 pdf. Accessed 07-12-2009.
World Health Organisation (2004). World Report on road traffic injury prevention: Summary, Genera.
Gupta CB (1996). “An Introduction to Statistical Method” Ninth Revised Edition, Vikas Publication house PVT LTD/.

APPENDIX

Table 1. The data here shows the reported cases of road accident in kogi state from the office of the federal Road Safety Corps FRSC Lokoja Kogi State for interval of 14 years (1997-2010).

Years	January- March	April-June	July-September	October- December	Total
1997	20	12	5	27	64
1998	31	10	9	24	74
1999	26	20	18	28	92
2000	37	17	10	44	108
2001	29	23	20	33	105
2002	25	35	15	45	120
2003	29	30	12	57	128
2004	34	30	19	47	130
2005	30	27	5	57	119
2006	15	40	25	43	123
2007	20	35	13	53	121
2008	20	30	40	50	140
2009	30	35	30	50	145
2010	33	30	20	47	130



Graph 1. Accident against typical seasonal index.

academicJournals

Vol. 8(40), pp. 1934-1943, 30 October, 2013
DOI: 10.5897/IJPS2013.4032
ISSN 1992 - 1950 © 2013 Academic Journals
http://www.academicjournals.org/IJPS

International Journal of Physical Sciences

Full Length Research Paper

Characteristics of supercritical flow in rectangular channel

Sumit Gandhi* and Vishal Yadav

Department of Civil Engineering, Jaypee University of Engineering and Technology, Guna, MP, India.

Accepted 10 October, 2013

The present study deals with the supercritical flow characteristics and the effort has been made to verify analytical and empirical relations based on extensive experimentation for different characteristics namely: sequent depth ratio (h_2/h_1), efficiency of jump (E_2/E_1), relative height of jump (h_j/E_1) and relative length of jump (L_j/h_2). Also, the existing models for different channel conditions are discussed; significance of Froude number and Reynolds number for a range of velocity mentioned in literatures are highlighted; models proposed by different authors and its validation were also explained. Undular jump formation and the role of turbulent boundary layer were also explained for Froude number varying between 1.3-2.3. All the characteristics are found suitable with existing relations and can be used as guidelines for the analysis of different channel and channel conditions.

Key words: Froude number, Reynold's number, characteristics curve, shear stress, boundary layer thickness, undular jump.

INTRODUCTION

Supercritical flow in rectangular channel can be explained with the formation of hydraulic jump when high velocity flow is subjected to sudden obstruction or undergoes sufficient bed friction. Hydraulic jump (from supercritical flow) is one of application in dissipating energy downstream of spillways, weir, etc. when the Froude number (F_{r1}) of the incoming stream is more than 1. Stilling basin on downstream of spillway (of a gravity or earthen or rock fill dam), not only dissipate additional energy but controls high velocity to deviate from the channel bottom and also dissipate the part of kinetic energy of the flowing stream to get safe flow in downstream channel which causes no erosion and scouring of bed.

Experimental studies on rectangular channel are significant as it generates the idea to understand the behavior of flow in non-prismatic channels also; like abruptly expanding channel, sloping channel, trapezoidal channel. It helps in developing models, economical stilling basin design criteria for varying natural or artificial conditions for hydraulic and structural design. Some analytical and empirical models relating h_2/h_1, E_2/E_1 and L_j/h_2 can be predicted but the analysis of other characteristics (that is, relative energy loss E_L/h_1, relative pre-jump energy E_1/h_1, relative pre-jump length L_j/h_1, relative post jump depth h_2/E_1, and relative length of roller L_r/h_1) are quite cumbersome as they depend upon geometry, dimensions, relative position of toe and inflow condition.

Hydraulic jump was first investigated experimentally by Bidone in 1818; thereafter, many studies were made and the results were quoted by many engineers. Contributions to our present knowledge about the hydraulic jump are Bakhmeteff and Matzke (1936), Forster and Skrinde (1950), Yasuda and Ohtsu (1994), Chanson and Montes (1995) and many others.

Different researchers (Ranga-Raju, 1993; Bakhmeteff and Matzke, 1936; Bremen, 1990; Khalifa and McCorquodale, 1979; Afzal and Bushra, 2002) have proposed the computed model for calculating the length

*Corresponding author. E-mail: sumit_gandhi2001@yahoo.co.in

of jump. Rajaratnam and Subramanyam (1968), Herbrand (1973) and Negm et al. (2000) have also proposed the empirical and analytical relations for sequent depth ratio. Using the experimental data of Rajaratnam and Subramanya (1968), Negm (2000) proposed the empirical relation for length of roller, valid for Froude number in the range of 2 to 8.5 and different channel width. Matin et al. (1998) has proposed an expression by introducing modified Froude number for sequent depth ratio (h_2/h_1) using the general momentum equation and assuming pressure distribution as hydrostatic, velocity distribution as uniform and the effect of turbulence, air entrainment and wall friction as negligible. Ranga-Raju (1993) and Agarwal (2001) have also proposed the analytical equation for sequent depth ratio and relative energy loss.

These results and characteristics curves facilitates hydraulic engineer to develop a correlation between the range of conditions under which the structure is to be designed and operated. These curves show clearly the formation of jump for different gate openings under given head. As such the present study is carried out to understand and validate various characteristics namely h_2/h_1, E_2/E_1, h_j/E_1 and L_j/h_2 of the hydraulic jump against F_{r1} for horizontal rectangular channel.

THEORY

Although various ways and models have been presented in terms of tables, graphs, and monographs or a set of empirical equations valid in a specified range, it is difficult to design economical energy dissipater due to unavailability of direct equations which are valid for all possible values of discharge and energy loss in the jump. Moreover, no standard equation is available to start the calculations as initial conditions are unknown. Rajaratnam (1965) made detailed measurements of the boundary friction within the jump using a Preston tube and his observations showed that the frictional force is not negligible. He used momentum equation and derived an analytical equation for computing sequent depth ratio:

$$\left(\frac{h_2}{h_1}\right)^3 - \left(\frac{h_2}{h_1}\right)\left(1 - k_f + 2F_{r1}^2\right) + 2F_{r1}^2 = 0 \qquad (1)$$

where k_f is the boundary friction coefficient which was evaluated experimentally and found to be a function of F_{r1}. Hager et al. (1990) proposed the relative length of roller model:

$$\frac{L_r}{h_1} = -12 + 160\left(\frac{e^z - e^{-z}}{e^z + e^{-z}}\right), \text{ were } Z = (F_{r1}-1)/22 \qquad (2)$$

Khalifa and McCorquodale (1979) studied radial hydraulic jumps in a gradually expanding channel of rectangular cross section and the results showed that the divergence of side walls increases the relative energy loss and decreases the length of jump for Froude number greater than three. Afzal and Bushra (2002) compared well their experimental result with the experimental data of length of roller reported by Hager and Bremen (1989) and Hager et al. (1990) for $2 < F_{r1} < 15$ in the rectangular channel. Jamil and Khan (2008) proposed models for sequent depth ratio and relative energy loss on the basis of theoretical study of hydraulic jump for different side slopes and compared well with Silvester (1964) result.

$$F_{r1}^2\left[4 + 4n\left(2 + n + n\frac{h_2}{h} + \frac{h_2}{h_1}\right)\right] - \left[2 + \frac{8h_2^3}{3h_1^3}n + \frac{2}{3}n\left(\frac{h_2^2}{h_1^2} + \frac{h_2}{h_1}\right) + \frac{h_2}{h_1}\right] = 0 \qquad (3)$$

$$\frac{E_L}{E_1} = \frac{\left(1 + 0.5F_{r1}^2\right) - \left[\frac{h_2}{h_1} + \left\{F_{r1}^2 \frac{(1+n)^2}{2\left(1 + n\frac{h_2^2}{h_1^2}\right)\frac{h_2^2}{h_1^2}}\right\}\right]}{\left(1 + 0.5F_{r1}^2\right)} \qquad (4)$$

$$\frac{E_2}{E_1} = 1 - \frac{E_L}{E_1} \qquad (5)$$

$$\frac{E_L}{h_1} = \frac{1}{4\left(\frac{h_2}{h_1}\right)}\left[\left(\frac{h_2}{h_1} - 1\right)^3\right], \quad \text{were, } n = zh_1/B \qquad (6)$$

Chaurasia (2003) suggested direct explicit empirical equations using momentum principle for prejump depth (h_1), postjump (h_2) depths and specific energies for a horizontal rectangular channel applicable for wide range of discharge and head loss without any limitations. Author compared his results with standard technique as presented in Table 1.

$$h_j = \frac{h_1\left[\sqrt{1 + \frac{8q^2}{gh_1^3}} - 3\right]^3}{16_1\left[\sqrt{1 + \frac{8q^2}{gh_1^3}} - 1\right]} \qquad (7)$$

$$h_1 = 0.19q^{0.98}h_j^{-0.47}\left[1 + 1.262qh_j^{-1.5}\right]^{-0.026} \qquad (8)$$

$$h_2 = 1.0518q^{0.518}h_j^{0.223}\left[1 + 0.0476q^{2.667}h_j^{-4}\right]^{-0.0221} \qquad (9)$$

Table 1. Comparison of result of Chaurasia (2003) with other results.

Items	Actual value	Chaurasia method	%age error	Actual value	Chaurasia method	%age error
Discharge 'q' in m^3/s/m	10.0	10	-	1.70	1.70	-
Head loss in m	1.63	1.63	-	2.50	2.50	-
Prejump depth h_1, from Equation(2) in m	1.03	0.995	3.40	0.19	0.196	-3.16
Postjump depth h_2, from Eq. (3) in m	3.96	3.747	5.38	1.68	1.698	-1.07
D/S specific energy, E_2, from Eq. (4) in m	4.30	4.303	-0.07	1.70	1.715	-0.88
U/S specific energy, E_1, from Eq. (5) in m	5.93	5.933	-0.05	4.20	4.215	0.36
h_j in m	2.93	2.752	6.08	1.49	1.508	-1.21
Length of jump, $L_j = 5(h_2 - h_1)$, in m	14.65	13.76	6.08	7.45	7.54	-1.21

Table 2. Experimental values of Wu and Rajaratnam (1996), Channel Dimensions 7.6 × 0.466 × 0.60 m.

Exp.	h_1 (m)	u_1 (m/s)	F_{r1}	h_2 (m)	L_r (m)
1	0.0165	1.56	3.87	0.083	0.30-0.35
2	0.0165	2.07	5.14	0.109	0.40-0.50
3	0.0165	2.71	6.73	0.146	0.70-0.80
4	0.0165	3.45	8.57	0.192	0.90-1.00
5	0.0165	4.22	10.48	0.233	1.20-1.30

$$E_2 = 1.029 q^{0.513} h_j^{0.223}\left[1 + 0.4329 q^{0.733} h_j^{-1.1}\right]^{-01631} \quad (10)$$

$$E_1 = E_2 + h_j \quad (11)$$

Equation of prejump (h_1) and postjump (h_2) depth involved maximum error of ±5.8 and ±5.86% respectively which is considerably less. These equations have very high accuracy when compared to other methods attempted so far, and they can be used for analytical investigations of rectangular horizontal channel without any limitation of discharge intensity and energy loss.

Khosla et al. (1993) suggested graphical relation between head loss h_j and energy after the jump E_2 for calculating downstream total energy for various values of q. From E_1, E_2 and q, the values of prejump and postjump depth can be found from specific energy curves. Chow (1995) and USBR (1973) have given various graphs and equations, but none of these gives values of prejump and postjump depths directly for given values of discharge and head to be dissipated. Wu.and Rajaratnam (1996) presented empirical study of transition flow from a hydraulic jump with wall jet structure to fully developed open channel flow with a semi-logarithm profile for Froude number 3.87 to 10.48. They suggested that during transition, bed shear stress continues to decrease rapidly to become constant at the end of the transition. Based on all these observations, the length of the transition region was found to be approximately equal to 10 h_2 and this study points out the three dimensional nature of the flow in the transition region. Table 2 gives the details of the experiment. Swamee and Rathie (2004) conducted experiment in downstream of barrage for known value of energy loss (E_L) and critical depth (h_c). Determination of sequent depths involves the solution of two implicit equations using Lagrange's theorem. Exact analytical equations for sequent depths have been obtained in terms of infinite series.

$$h_c = \left(\frac{q^2}{gb^2}\right)^{1/3} \quad (12)$$

$$E_L = \frac{(h_2 - h_1)^3}{4h_1h_2} \quad (13)$$

$$p_1 = \frac{1}{\beta} - \left(\frac{f_L\beta}{2}\right)^{1/3} \quad (14)$$

$$p_2 = \frac{1}{\beta} + \left(\frac{f_L\beta}{2}\right)^{1/3} \quad (15)$$

For $f_L < 3.3$

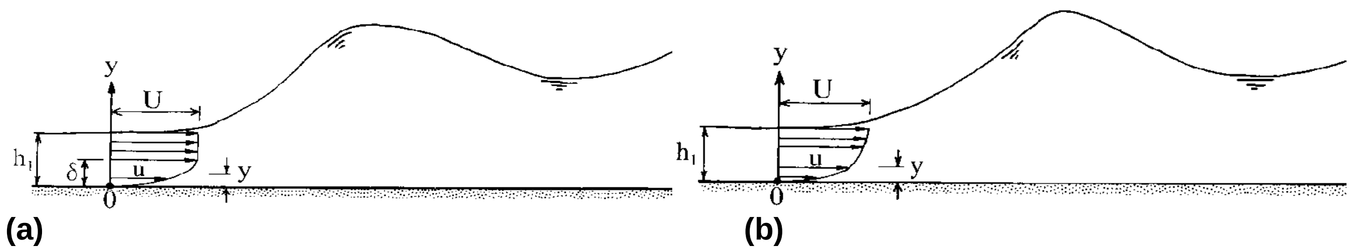


Figure 1. Undular jump with (a) developing inflow, (b) developed inflow.

$$\beta = 1 - \left(\frac{f_L}{10.39230}\right)^{2/3} + \left(\frac{f_L}{7.08476}\right)^{4/3} - \left(\frac{f_L}{6}\right)^{2} + \left(\frac{f_L}{5.49997}\right)^{8/3} - \left(\frac{f_L}{5.24108}\right)^{10/3} + \left(\frac{f_L}{5.10966}\right)^{4} - \left(\frac{f_L}{5.06012}\right)^{14/3} + \left(\frac{f_L}{5.07508}\right)^{16/3} - \left(\frac{f_L}{5.15552}\right)^{6} + \left(\frac{f_L}{5.32820}\right)^{20/3} - .... \quad (16)$$

Utility of above equations has been demonstrated by an example; the objective is to find the lengths of the jump downstream for the following conditions, high flood condition q/b = 7 m^3/s m and E_L = 0.95 m. Adopting g = 9.8 m/s^2 and using Equation 12 for high flood condition, h_c = 1.71 m. Thus f_L = 0.95/1.71 = 0.55556. As $f_L < 3.375$, using Equation 16, β = 0.88484, from Equations 14 and 15 p_1 = 0.50374, p_2 = 1.75655. Thus h_1 = 0.86 m and h_2 = 3.00 m, therefore length of jump L_j = 6(3.00 - 0.86) = 12.84 m.

The undular jump is formed for low supercritical Froude numbers and is characterized by undulations of the water surface. According to Chow (1995), the undular jump is formed for the inflow Froude number less than 1.7. Iwasa (1995) and Hager and Hutter (1984) investigated the boundary between undular jump and surface roller; and proposed the upper limit of the inflow Froude number as $F_{r1limit}$ = 1.4 - 1.7. Chanson and Montes (1995) reported that it depends upon Froude number and the aspect ratio; whereas undular jump forms if the value of the inflow Froude number F_{r1} is larger than 1.7. Based on Froude similarity law, Reinauer and Hager (1995) proposed the boundary between an undular jump and a jump with a surface roller as $F_{r1limit}$ = 1.3 - 1.6.

A systematic investigation has shown that the flow condition of the undular jumps is governed by the inflow Froude number ($F_{r1} = v_1/\sqrt{gh_1}$), aspect ratio B/h_1, and turbulent boundary layer development δ/h_1 (Figure 1) as the fundamental hydraulic quantities considering Reynolds number (Ohtsu et al., 1994, 1995, 1996, 1997). For the formation of the undular jumps, the upper limit of the Froude number shown experimentally as $F_{r1limit}$ = 1.3 - 2.3 and for the fully developed inflow, the upper limit is 1.7 (Table 3 gives the details of experiment).

For a small boundary layer thickness ($\delta/h_1 < 0.22$), a jump with surface roller is formed even if the value of the Froude number is smaller than 1.7. If the Froude number approaches the upper limit of the Froude number $F_{r1limit}$, the velocity of the first wave crest is maximum near the water surface, and the velocity becomes the critical velocity ($v_c = \sqrt{gh_c}$). Considering the flow immediately before the breaking and streamline along the water surface between the toe of jump, the first wave crest gives the upper limit of the Froude number for undular jump.

EXPERIMENTATION AND OBSERVATIONS

Experiments were carried on an experimental system involving a rectangular channel of dimension 5 × 0.2 × 0.115 m. The transparent sides of channel were made from acrylic material for observational purpose. The setup consists of a constant head tank from where the water reaches to the inlet tank through feeding pipe provided with regulating valve. Sharp edge regulating gate at the inlet was provided to prevent side wave reflection and surface undulation so that a stabilized flow is available at the inlet of main channel. Also, controlling gate at the end of channel was provided to maintain certain volume of water in the main channel. Parallel rails were mounted at the top of side walls for sliding of pointer gauge in order to measure depth at different positions along the length and across the width of the main channel. Figure 2a and b shows experimental set-up and top and sectional view of pattern of jump formation respectively.

A series of run for different values of Froude number (varying within 1 to 7) were performed. For each experiment pre jump depths, post jump depths were recorded by pointer gauge and lengths of jump were measured using scale calibrated on the sidewall of the channel. Observations obtained are presented in Table 4. Ratio of non-dimensionless functional group of jump characteristics to the Froude number is graphically presented through which their behavior at different velocity is examined.

RESULTS AND DISCUSSION

Supercritical flow responsible for all hydraulic jump characteristics considered in the present work have been computed from the measured data as discussed earlier and is plotted against the Froude number as shown in

Table 3. Experimental conditions of Ohtsu et al. (1995, 1996, 1997, 2001).

B (cm)	0.105	0.155	0.20	0.28	0.40	0.80
L (m)	5.0	5.0	17.20	17	17.20	14.5
h_j (cm)	0.026-0.033	0.039-0.051	0.022-0.011	0.080-0.107	0.022-0.117	0.036-0.106
$Q(m^3/s) \times 10^3$	2.20-3.02	6.54-9.02	4.79-31.5	30.4-38.5	9.36-65.5	38.5-100
F_{r1}	1.30-2.16	1.23-2.39	1.16-2.39	1.24-1.54	1.15-2.38	1.13-2.46
$R_e \times 10^4$	2.0-2.9	4.0-5.4	2.5-17.0	8.8-11.5	2.1-15.9	4.5-12.0
δ/h_l	1.0	1.0	0-1.0	0-1.0	0-1.0	0-1.0

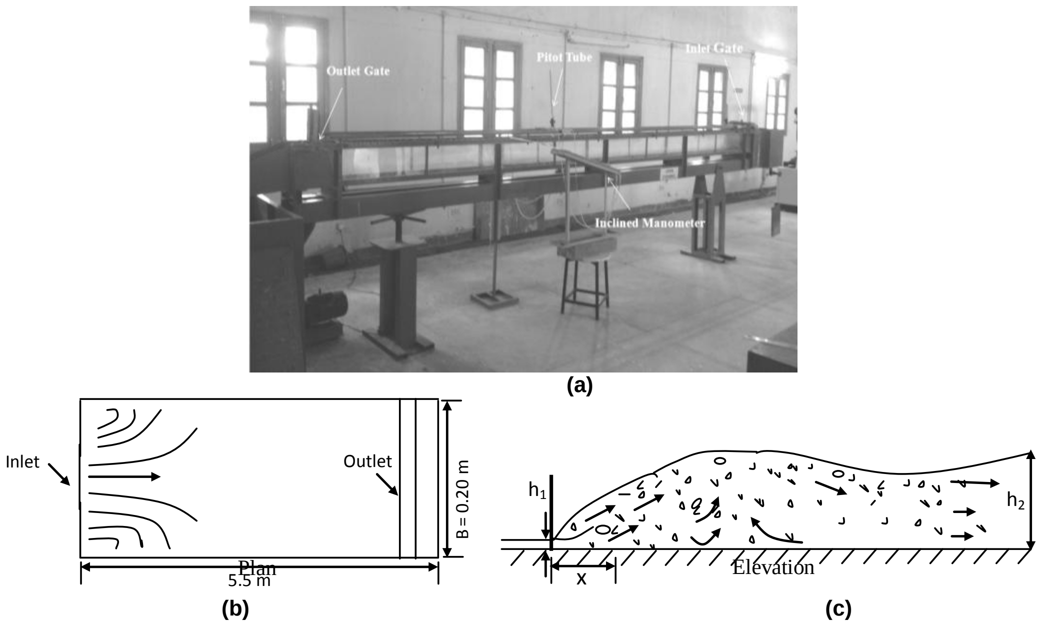


Figure 2. Showing (a) Experimental setup, (b) plan and elevation of jump formation in horizontal rectangular channel.

Figures 3 to 6. All these plots are developed using experimental results of Table 4 and following are the main inferences drawn from the present study.

Sequent depth ratio versus Froude number

Figure 3 shows a linear variation of sequent depth ratio (h_2/h_1) against the Froude number (F_{r1}) varying from 1 to 7. The R^2 value (0.93) of the linear fit shows that linear variation holds well within h_2/h_1 and F_{r1}. The analytical equation (Table 5) given by Chow (1995) is also verified in plot using author's data and it is found to be highly satisfactory. The figure shows that most of the experimental data points lie within ±15% of the best fitted line (Table 5). So, it can be concluded that the given equation of fitted line ($h_2/h_1 = 1.331F_{r1} - 0.679$) can be used to calculate sequent depth for $1 < F_{r1} < 7$ and may be for higher ranges. Results are also in agreement with Virginia Tech University's result with slight deviation. Empirical equation developed by Herbrand (1973) is satisfactory for predicting the sequent depth h_2.

Linear variation of h_2/h_1 with F_{r1} has been well reported in the literature (Chanson, 1995; Reinauer and Hager, 1995; Ranga-Raju, 1993; Ohtsu et al., 1995, 1996, 1997); a good agreement for the experimental results can be seen at higher values of Froude numbers ($4 \leq F_{r1} \leq 8$). Few data points are seen deviating from the best fitted line which may be due to inaccurate measurement of depth and discharge.

Efficiency versus Froude number

Figure 4 shows that efficiency (E_2/E_1) decreases non-linearly with Froude number from 1 to 7. The analytical equation (Table 6) given by Chow (1995) is also verified in plot using author's data and it is found to be highly

Table 4. Experimental observations and computed hydraulic jump characteristics.

Exp. No.	h_1	h_2	$F_1=u_1/(gy_1)$	h_2/h_1	E_2/E_1	h_j/E_1	L_j/h_2
1	0.048	0.074	1.589	1.538	0.788	0.238	2.691
2	0.044	0.077	1.709	1.771	0.835	0.314	3.103
3	0.039	0.085	1.898	2.207	0.903	0.431	3.867
4	0.036	0.073	2.131	2.000	0.787	0.306	3.505
5	0.027	0.068	2.482	2.494	0.802	0.366	4.158
6	0.033	0.068	2.537	2.231	0.722	0.292	3.842
7	0.028	0.081	2.606	2.916	0.826	0.436	4.711
8	0.025	0.085	2.609	3.342	0.912	0.532	5.197
9	0.029	0.095	2.970	3.227	0.698	0.412	4.965
10	0.028	0.102	3.269	3.699	0.659	0.426	5.179
11	0.029	0.106	3.336	3.602	0.605	0.397	5.110
12	0.027	0.111	3.552	4.150	0.624	0.431	5.422
13	0.023	0.102	3.866	4.500	0.599	0.413	5.392
14	0.020	0.099	4.218	5.051	0.597	0.410	5.638
15	0.023	0.098	4.496	4.609	0.449	0.325	5.492
16	0.018	0.109	4.612	6.189	0.593	0.446	6.037
17	0.019	0.111	4.638	5.707	0.534	0.401	5.801
18	0.020	0.093	4.732	4.712	0.412	0.305	5.396
19	0.015	0.104	4.798	6.761	0.628	0.461	5.981
20	0.018	0.097	4.905	5.472	0.451	0.344	6.000
21	0.013	0.085	4.972	6.350	0.528	0.401	6.024
22	0.017	0.075	5.054	4.392	0.346	0.247	5.491
23	0.016	0.099	5.394	6.340	0.436	0.344	6.141
24	0.016	0.102	5.538	6.489	0.437	0.336	5.902
25	0.014	0.104	5.790	7.279	0.447	0.354	6.038
26	0.014	0.104	6.044	7.233	0.417	0.324	6.174
27	0.012	0.079	6.246	6.611	0.366	0.274	6.176
28	0.013	0.108	6.353	8.500	0.444	0.354	6.223
29	0.012	0.103	6.640	8.800	0.428	0.339	6.331
30	0.011	0.100	6.940	9.121	0.408	0.324	6.279

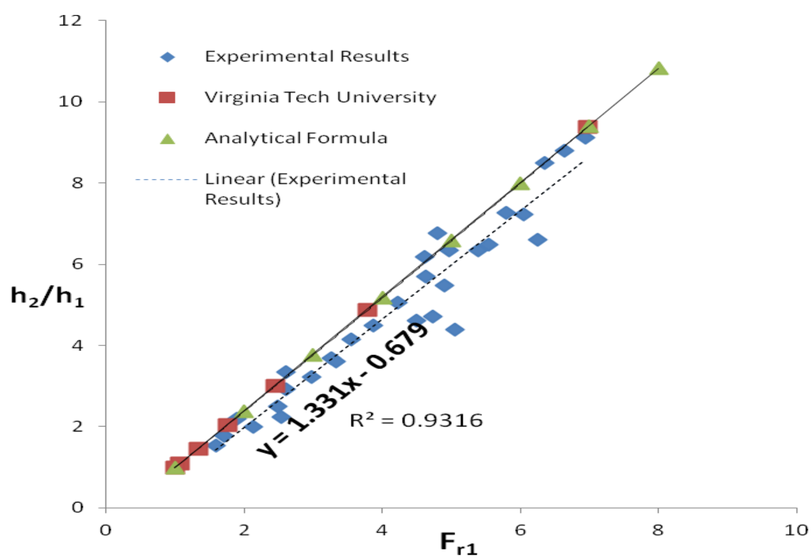


Figure 3. Variation of Sequent depth ratio with Froude number.

Table 5. Comparison of h_2/h_1 with analytical relation used by Chow (1995).

S/N	Present study		Analytical relation		%age error
	$F_{r1}=V_1/(\sqrt{gh_1})$	h_2/h_1	F_{r1}	$h_2/h_1=0.5[\sqrt{(1+8F_{r1}^2)}-1]$	
1	1.708	1.77	1.708	1.967	-11.05
2	2.606	2.92	2.605	3.218	-10.36
3	2.969	3.23	2.96	3.716	-15.14
4	3.552	4.15	3.55	4.545	-9.53
5	3.866	4.50	3.86	4.981	-10.70
6	4.218	5.05	4.21	5.475	-8.39
7	4.637	5.71	4.63	6.067	-6.31
8	5.394	6.34	5.39	7.139	-12.59
9	5.789	7.28	5.78	7.689	-5.64
10	6.640	8.80	6.64	8.904	-1.18

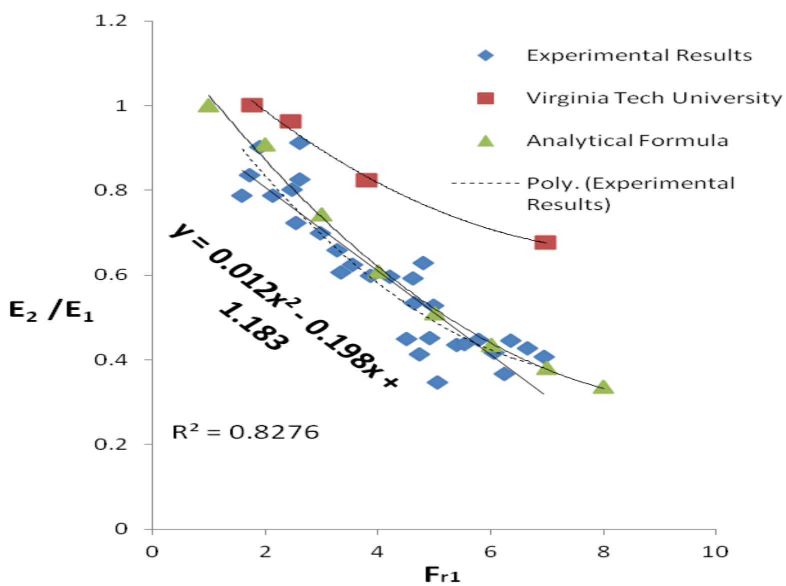


Figure 4. Variation of efficiency with Froude number.

Table 6. Comparison of E_2/E_1 with analytical relation used by Chow (1995).

S/N	Present study		Analytical relation		%age error
	$F_{r1}=V_1/(\sqrt{gh_1})$	E_2/E_1	F_{r1}	$\frac{E_2}{E_1}=\frac{(8F_{r1}^2+1)^{3/2}-4F_{r1}^2+1}{8F_{r1}^2(2+F_{r1}^2)}$	
1	1.709	0.835	1.71	0.953	-14.12
2	2.606	0.826	2.61	0.807	-2.34
3	2.969	0.698	2.96	0.749	-7.35
4	3.552	0.624	3.55	0.664	-6.46
5	3.866	0.599	3.86	0.625	-4.34
6	4.218	0.597	4.21	0.585	1.92
7	4.638	0.534	4.63	0.543	-1.69
8	5.394	0.436	5.39	0.478	-9.65
9	5.789	0.447	5.78	0.450	-0.82
10	6.640	0.428	6.64	0.398	6.83

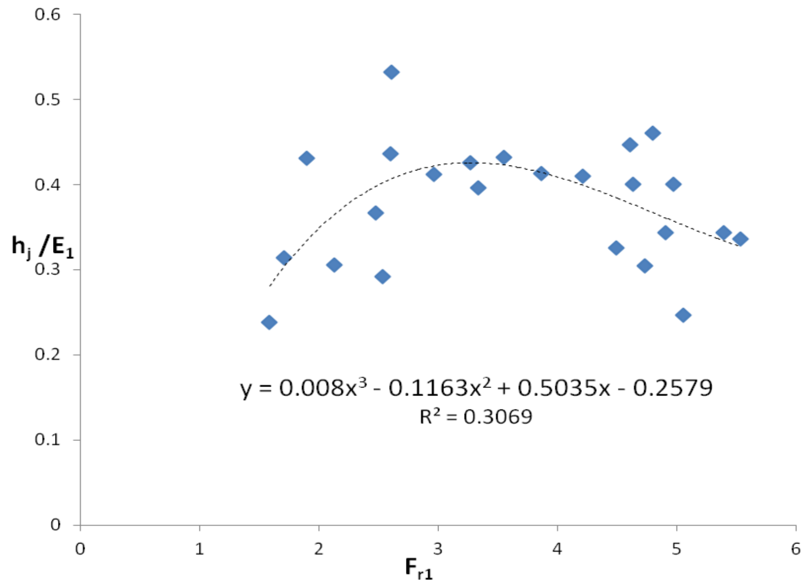


Figure 5. Variation of relative height with Froude number.

satisfactory. The figure shows that most of the experimental data points lie within ±15% of the best fitted line and about 90% data points are lying within ±10% limit of the best fitted curve (Table 6) with R^2 value = 0.83. So, it can be concluded that the given equation of fitted line ($E_2/E_1 = 0.012F_{r1}^2 - 0.198F_{r1} + 1.183$) can be used to calculate efficiency for $1 < F_{r1} < 7$ and for higher value. Similar behavior was also coated by different researchers (Chow, 1995; Ranga-Raju, 1993; Subramanya, 2008). Slight deviation of experimental results from Virginia Tech University is attributed to different experimental conditions (channel bed/side condition).

Relative height of jump versus Froude number

Figure 5 shows that relative height of jump (h_j/E_1) increases up to Froude number 3 and then decreases non-linearly as the value of Froude number increases to 7. It shows that most of the experimental data are scattered with R^2 value = 0.31. Observations taken by Chow (1995) and Bremen and Hager (1989) also give the same results. From the figure, the maximum relative height of jump occurs at F_{r1} = 3.3, which is otherwise maximum at F_{r1} = 2.77 as per USBR standard. It is clearly seen in the figure that about 80% of data points are lying within ±10% limit of the best fitted curve and about 20% of are seen deviating.

Relative length of jump versus Froude number

Figure 6 shows a typical increasing non-linear variation of relative length of jump (L_j/h_2) against Froude number (F_{r1}) with good fitting of data points (R^2 = 0.92). Relative length of jump is observed maximum at Froude number 5.5 as evident from the literature (Elevatorski, 1959; Hager, 1989; Ranga-Raju, 1993; Ohtsu et al., 1995). Maximum value can be observed at F_{r1} = 6 because of large deviation in data points and may be attributed to inaccurate judgment to locate correct position of start and end of jump. The figure also shows some deviation of experimental results from Virginia Tech University as it is conducted on natural channel which having different experimental conditions. Hager (1989) also shows that there is a relation between length of jump and length of roller and large scattering of data observed for relative length of roller L_r/h_1 against Froude number; which again is explained on the basis of inaccuracy in measurement of length of jump and roller.

Conclusions

The equation of prejump and postjump depth given by Khosla et al. (1993) involved maximum error of ±5.8 and ±5.86% respectively which is considerably less. These equations have very high accuracy when compared to other methods and they can be used for analytical investigations of stilling basins in a horizontal rectangular channel.

Except h_j/E_1 results obtained for h_2/h_1, E_2/E_1 and L_j/h_2 are in good agreement with the existing result and can be used for field analysis, these result may also be significant for calculating other characteristics like (E_L/h_1, E_1/h_1, L_j/h_1, h_2/E_1, and L_r/h_1, etc.) for horizontal rectangular channel. It can also be concluded from the present study and the existing result that it is equally

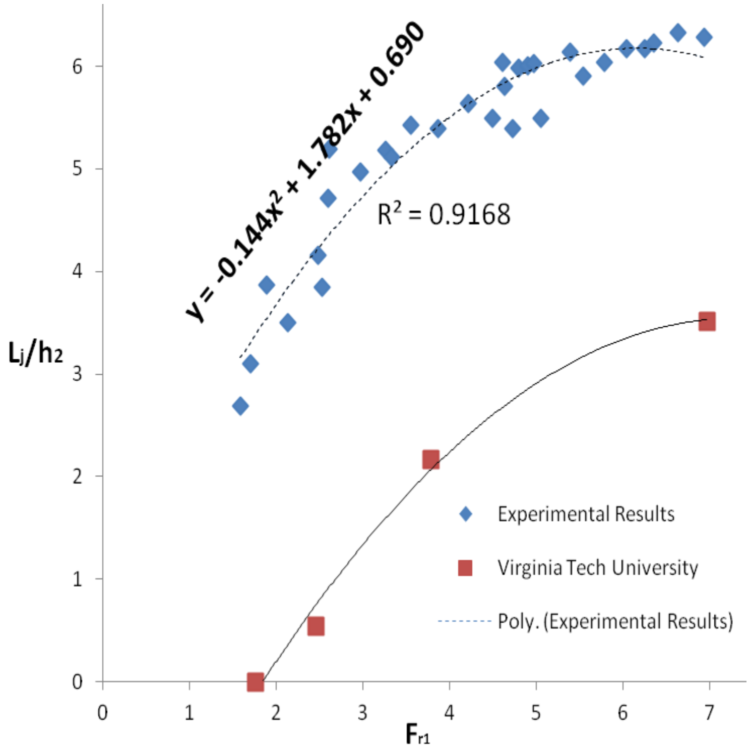


Figure 6. Variation of relative length of jump with Froude number.

applicable to non-prismatic channel (whose dimension and slope vary) as well with little modification for higher range of Froude number.

ACKNOWLEDGEMENTS

The authors would like to thank Hydraulics Laboratory, Department of Civil Engineering, Jaypee University of Engineering and Technology, Guna (M.P., India) for providing lab facility to carryout experimental work.

Notations: B, width of channel; **b,** length scale for velocity profile; $\mathbf{E_1}$**,** energy before the jump; $\mathbf{E_2}$**,** energy after the jump; $\mathbf{E_L}$**,** energy loss; $\mathbf{F_{r1}}$**,** supercritical Froude number; $\mathbf{f_L}$**,** head loss parameter (non-dimensional); **g,** acceleration due to gravity; $\mathbf{h_1}$**,** height of flow before jump; $\mathbf{h_2}$**,** height of flow after jump; $\mathbf{h_c}$**,** critical depth; $\mathbf{h_j}$**,** head loss; **U,** free stream velocity; $\mathbf{u_1}$**,** velocity at gate; **L,** length of channel; $\mathbf{L_r}$**,** length of roller of hydraulic jump; $\mathbf{L_j}$**,** length of hydraulic jump; $\mathbf{p_1}$**,** prejump parameter (non-dimensional); $\mathbf{p_2}$**,** post jump parameter (non-dimensional); **q,** discharge; $\mathbf{R_e}$**,** Reynold's number; **u,** time-averaged velocity at any point (m/sec); $\mathbf{v_1}$**,** average velocity at the toe of the jump; **x,** distance from gate (or start of jump); **y,** distance from bed; **z,** side slope of channel; **v,** kinematic viscosity of fluid; **δ,** thickness of the boundary layer at the toe of the jump.

REFERENCES

Afzal N, Bushra A (2002). Structure of Turbulent Hydraulic Jump in a Trapezoidal Channel, J. Hydraulic Res. 40(2):205–214.
Agarwal VC (2001). Graphical Solution to the Problem of Sequent Depth and Energy Loss in Spatial Hydraulic Jump, Water Maritime Eng. 14B(1.A):1-3.
Bakhmeteff BA, Matzke AE (1936). The Hydraulic jump in terms of Dynamics Similarity, Trans. ASCE 100:630-680.
Bremen R, Hager WH (1989). Classical Hydraulic Jump: Sequent Depths, J. Hydraulic Res. 27(5):565–585.
Bremen R (1990). Expanding Stilling Basin, Laboratoire De Constructions Hydrauliques, Communication 3, Lausanne.
Chanson H, Montes JS (1995). Characteristics of undular hydraulic jumps: experimental apparatus and flow patterns, J. Hydraulic Eng. ASCE, 121(2):129-144.
Chow VT (1995). Open channel hydraulics, McGraw-Hill International, New York, USA.
Chaurasia R (2003). Direct Equations for Hydraulic Jump Elements in Rectangular Horizontal Channel, J. Irrigation drainage Eng. (ASCE), July/August, 291–294.
Elevatorski EA (1959). Haydraulic Energy Dissipators, McGraw-Hill, New York.
Forster JW, Skrinde RA (1950). Control of the Hydraulic Jump by Sills, Trans. ASCE, 115:973–987.
Hager WH, Hutter K (1984). On pseudo-uniform flow in open channel hydraulics, Acta Mechanica, 53:183-200.
Hager WH (1989). Hydraulic Jump in U -Shaped Channel, J. Hydraulic Eng. 115(5):667–675.
Hager WH, Bremen R (1989). Classical Hydraulic Jump: Sequent Depths Ratio, J. Hydraulic Res. 27(5):565-585.
Herbrand K (1973). The Spatial Hydraulic Jump, J. Hydraulic Res. Delft, 11(3):205-217.
Iwasa Y (1995). Undular jump and its limiting condition for existence, Proc. of the 5th Japan National Congress for Applied Mech., 315–319.

Jamil M, Khan SA (2008). Theoretical Study of Hydraulic Jump in Trapezoidal Channel Section, J. Instit. Eng. (India), 89:28–32.

Khalifa AM, McCorquodale AM (1979). Radial Hydraulic Jump, J. Hydraulic. Division, ASCE 105(HY9):1065–1078.

Khosla AN, Bose NK, Taylor EM (1993). Design of weir on permeable foundations, Publication No. 22, Central Board of Irrigation and Power, New Delhi, India.

Matin MA, Alhamid AA, Negm AM (1998). Prediction of Sequent Depth Ratio of Hydraulic Jump in an Abruptly Expanding Channel, Proceedings of International Conference on Hydro-Science and Engineering Hydro-Science and Engineering ICHE98, Advances in Hydro-Science and Engineering, Vol.III, Cottbus/Berlin, Germany.

Negm AM, Ibrahim AA, Salem MN (2000). Modeling of Depth Ratio of Hydraulic Jumps in Abruptly Enlarged Stilling Basins, Civil Engineering Research Magzine (CERM), Faculty of Engineering, Ain Shams University, Cairo, Egypt.

Ohtsu I, Yasuda Y (1994). Characteristics of supercritical flow below sluice gate, J. Hydraullic Eng. ASCE, 120(3):332-346.

Ohtsu I, Yasuda Y, Gotoh H (1995). Characteristics of undular hydraulic jumps in rectangular channels, Proc. 26th IAHR Congress, 1C14, London, UK.

Ohtsu I, Yasuda Y, Gotoh H (1996). Discussion of nonbreaking undular hydraulic jumps, J. Hydraulic Res. IAHR, 34(2):567–572.

Ohtsu I, Yasuda Y, Gotoh H (1997). Discussion of characteristics of undular hydraulic jumps: experimental apparatus and flow patterns, J. Hydraulic Eng. ASCE, 124(2):161-162.

Ranga Raju KG (1993). Flow through Open Channels, McGraw Hill, New Delhi, 2nd Edn.

Rajaratnam N (1965). The Hydraulic Jump as a Wall Jet, J. Hydraulics Division, ASCE, 91(HY9):107.

Rajaratnam N, Subramanya K (1968). Profile of Hydraulic Jump, Proc. ASCE, J. Hydraulics Division, 94(HY3):663–673.

Reinauer R, Hager WH (1995). Non-breaking undular hydraulic jumps, J. Hydraulic Res. IAHR, 33(5):1-16.

Silvester R (1964). Hydraulic Jump in All Shape of Horizontal Channels, J. Hydraulic Division 90(1):23–55.

Subramanya K (2008). Flow in Open Channels, Tata McGraw Hill, 23rd print, 289-290.

Swamee PK, Rathie PN (2004). Exact Solutions for Sequent Depths Problem, J. Irrigation Drainage Eng. 130(6):520–522.

USBR (1973). Design of small dams, Oxford and IBH, New Delhi, India, 394–410.

Wu S, Rajaratnam N (1996). Transition from hydraulic jump to open channel, J. Hydraulic Eng. 122(9):526–528.

Yasuda Y, Ohtsu I (1994). Characteristics of Supercritical Flow below Sluice Gate, J. Hydraulic Engineering, 120(3):332–346.