International Conference On Recent Trends In Engineering Science And Management ISBN: 978-81-931039-2-0

Jawaharlal Nehru University, Convention Center, New Delhi (India), 15 March 2015 www.conferenceworld.in

HONDA MOTORS INDIA: THE FIGHT FOR MARKET SHARE

Atul Gupta[1], Rahul Jain[2], Aditi Jain[3]

[1, 2] School of Business and Economics, Lynchburg College, USA

[3]Lady Shri Ram College for Women, University of Delhi, (India)

I. INTRODUCTION

Hironori Kanayama, President and CEO of Honda Motors India, was on the flight back from the Auto Expo in India. He pondered how the event went and where Honda Motors India was headed in the future. Honda Motors was trying to gain market share in the India Auto Industry. The industry was experiencing a current slowdown. Recent events had given the Honda Motors executives reasons to think that they could be in position to take more market share. Hoping to jump start the market, Honda had a big showing at the Auto Expo that was held in India on Feb 7 2014. They also hoped that the recent legislation by the government of India, which approved an easement on the excise duty, would also help boost sales.

Hironori Kanayamaalso faced many challenges in the Indian market. The debate continued on how the middle class would affect the auto industry. Hironori Kanayamaalso noted that other forms of transportation could be preferred by many in India. Honda Motors needed a plan that would position Honda automobiles for the most market share. To accomplish this Honda needed to act fast and take advantage of the current and future market conditions.

II. AUTOMOBILE INDUSTRY IN INDIA

The automobile industry in India was currently slowing down. The growth rate for domestic sales from 2011 to 2012 was growing at 12.24%.[4] 2014was off to a slow start. The industry sales were down 7.59% in January from the previous year.[5]The automobile industry only had sales of 160,289 units from 173,449 units the year before. Regardless of this slowed growth, the India automobile industry was expected to be one of industries that would see the most growth in the years to come. In 2013 India produced 3.23 million cars and that number was expected to grow the over 10 million by the year 2020-2021. Figure 1 shows the past and predicted production of passenger vehicles in India. One of the major reasons for the increased production was because of the Chinese market. Many of the high end vehicles that were produced in India were shipped to China. While India had exports of cars from companies like Honda, BMW, GM, Chevrolet, Toyota and others, India also

---

[1]*School of Business and Economics, Lynchburg College, USA*
[2] *School of Business and Economics, Lynchburg College, USA*
[3] *Lady Shri Ram College for Women, University of Delhi, India*
[4] *http://www.siamindia.com/scripts/industrystatistics.aspx*
[5] *http://zeenews.india.com/business/automobiles/auto-news/auto-industry-slump-continues-car-sales-drop-7-59-in-january_94257.html*

exported many of the cars sold in Europe such as Audi, Hyundai, Mercedes-Benz, and Volvo. Figure 2 shows the increase in revenues of automobile manufacturers in India for the period 2007-2011.

The automobile industry also had to face the large number of two-wheeler owners. Most people in India owned two-wheelers as opposed to the passenger automobiles. This industry was also growing. The motorcycles sales grew by 8.85percent in January 2014 from January 2013. The increase in the market share of two wheelers between 2011 and 2013 can be seen in Figure 3. This was because it was cheaper to own these types of vehicles and cheaper to operate the vehicles as gas costs were very high in India. Because of the high number of two-wheeler consumers, much of the growth in the passenger vehicle market was from consumers who were trading in their two-wheelers to get a passenger automobile. The market for passenger cars only grew by 2.19 % in 2012. Consumer's driving this growth were likely looking at many of the entry level models that were popular and consumers could afford.

II. HONDA'S COMPETITION

Honda Motors was faced with many different forms of competition in India. First was the used car market. The used car market offered cheaper cars to consumers that were looking for entry level models. This market was expected to see 16% growth from 2013 to 2017. Honda Motors also had competition not only from the domestic market but also from the foreign markets. From the premium automobile end of the market, Mercedes-Bens, was the fastest growing demand worldwide. Demand for these cars and SUV's in the premium India market was also growing. Figure 4 shows the growth in the luxury car market in India between the years 2012 and 2013.

In the domestic market Honda had to compete with the market leader Maruti Suzuki India. They had sales of 94,556 units in January 2014. Although they had seen the impact of the overall market demand downturn as their sales were down from 103,026 in January of 2013. Hyundai Motors was the second market leader selling 33,405 in January 2014 which was also down from 34,302 units in January 2013.[6]

Maruti Suzuki had been in business in India for over 30 years. They started in Gurgaon, Haryana, a suburb of New Delhi. They first started making only 40,000 cars every year and in 2014 are projected to build 1.5 million cars for India. Maruti has 17 cars that have over 150 variants in the models. This has given them success to help Indians customize their cars to their lifestyle and their budget. Maruti also has over 1,436 service stations in India and 917 sales offices. This gives them a solid footprint wherever Indians go they can have their car serviced or look to purchase a Maruti close by. In 2014 they have two factories that produce their cars, one in Manesar and the other in Gurgaon. Their most popular car, the Alto 800, starts at ₹241,137 and has 10 variations in that model.[7]

Hyundai India was established in 1998. Hyundai finished building its first plant that year. Hyundai has seen a recent surge in sales in India. In 2005, the Hyundai Getz was given the India's Best car award. The Hyundai Verna won the Best Car of the Year award in 2007 from the Indian auto magazine Overdrive. They are constantly developing new cars, with their latest car, the EON, which came out in 2011. Hyundai is also committed to the service of their vehicles. They recently released the mobile care program that lets consumers

[6] *http://www.siamindia.com/scripts/industrystatistics.aspx*
[7] *http://www.marutisuzuki.com/Maruti_Car_Home.aspx*

find the Hyundai service center that is closest to them. This service allows consumers to access vehicle service history, schedule maintenance, provide service reminders, and many other features. Hyundai's most popular model, the i10 is a small compact 4 door car. There are 3 different models within the i10 line, the ERA, Magna, and Sportz.[8]

The two-wheeler industry was growing. The motorcycles sales in India increased 8.85% in January 2014 from the sale in January 2013.Figure 5 shows the sales of two wheelers in India between the years 2007 and 2013. Honda Motors was competing in this industry as well. Some of the most popular two wheelers on the market are the Hero Honda Karizma and the Honda Unicorn. Honda also competes with several other two wheeler manufacturers like Suzuki, Kawasaki, and Bajaj. Consumers are buying these two wheelers because they are economically priced, the good safety ratings, highly fuel efficient and the decent comfort level. Most consumers do not want the high end performance bikes not only because of the cost, but they prefer cheaper two wheelers that are less expensive and easier to maneuver.

III. CONSUMERS

As of 2014 India had an overall population of 1.2 billion. From the overall population there are only 21 million passenger vehicles in India. The ratio of people to passenger vehicles was only 58:1. The growth rate of India's population and motor vehicles can be seen in Figure 6. India's population historically grows 15-20 million every year. The overall population is expected to grow to 1.4 billion by the year 2025. Of these consumers in the auto industry approximately 77% of consumers using some form of transportation use two-wheelers.[9]The two-wheeler industry is very popular in India.

The focus of many companies in India was their rapidly growing middle class. It was estimated that the middle class population was 267 million people. This middle class was expected to grow to 583 million by the year 2025. India's middle class prefer to drive automobiles because of the poor public transportation. With the middle class growing the other factor that had automobile companies targeting this group was their disposable income.

Figure7 shows what number of households projected levels of income. As seen in 2005 the majority of households are in the Aspirers or Deprived category. In 2005 the middle class which was the Seekers and Strivers in the chart only make up 13.3 million households and have a very small amount of disposable income which they use and even smaller amount for actual consumption. In just 10 years, 2015, many of the Deprived have moved into a high level with the Seekers growing the most from 10.9 million to 55.1 million. This trend also continues as this class had more disposable income ₹15.2 trillion from ₹3.1 trillion. Most importantly consumption also rises from ₹2.1 trillion to ₹11.8 trillion. Projected in 2025 the middle class gets even larger; with the strivers having the biggest increase from 5.5 million in 2015 to 33.1 million in 2025. Also in this year the Deprived only represent 49.9 million households down from 2005 of 101.1 million households. By 2025 the middle class was projected to have 128 million household in India, which was up from 13.3 million in 2005.

[8] *http://www.hyundai.com/in/en/Main/index.html*

[9] *http://www.ibef.org/industry/india-automobiles.aspx*

They also have ₹51.5 trillion in disposable income, of which they are expected to use ₹30.6 trillion for consumption. [10]

India's consumers also use many different modes of transportation. Figure 8 shows different cities in India and the percentage of consumers that use different modes of transportation. The consumers are assumed to walk, use non-motorized vehicles, use private motorized vehicles, or take the public transit. The transportation preference differs widely from city to city. In the highly populated Delhi, most consumers use the public transit system or simply walk. In other cities like Pune all four methods of travel are widely used.

IV. OTHER FACTORS

Another factor for Honda Motors was the Indian government. The government was currently concerned about air pollution in many of India's cities. Delhi was the world's most polluted city and the Indian government believes that it was partly due to car emissions. Since the government wants to cut down on the emissions from the cars they have developed fuel-efficiency ratings for automobiles. The government hopes that this encourages car owners to consume less petrol or diesel. The government had also raised the basic customs duty from 75% to 100% on cars and motor vehicles with a value of $40,000 or more.

To increase domestic sales, the government had lowered the excise duty tax. This wasan indirect tax that was levied on goods which are manufactured in India and are sold within the country.[11] The government had lowered this tax as seen in Figure 9.[12]This tax was paid by the manufacturer which then passes on the cost to the consumer. Lowering this tax should reduce the overall costs to Honda Motors in India so they may be able to lower prices for their customers. This tax reduction should also help with Honda Motors inventory. The tax was payable on any excisable goods, or places that store those goods, and they have to pay the duty on these goods regardless of sale. The reduction that Honda would be interested in was the SUV reduction to 24%, the mid-sized car reduction to 20%, and the small size car reduction to 8%. While Honda gets the benefits of the cost reduction from the excise tax, this benefit should be realized throughout the industry. However, this duty reduction also means that two wheeler companies also receive a reduction in costs.

India's workforce also faced some questions. If the middle class does grow and the demand for these cars increases then the workforce needs to adapt. It was estimated that by 2022 the India could need 35 million workers to sustain growth. Figure 10 shows what the percentages of workers are in certain industries with India. This chart puts the Motor Vehicle industry in with Machinery and Equipment and transport for a total of 13.3% of the workforce in this sector in 2010. Figure 11 shows how much the average hourly compensation costs are for workers in different industries.[13] The chart shows Motor vehicles and trailers in the 4th highest paid hourly wage in Indian manufacturing. However that wage, for comparison purposes, was slightly over US $2.00 per hour. Included in that wage was the Social Insurance and directly paid benefits, meaning that the worker was only making around $1.50 per hour while the $.50 was being used for these other benefits.

---

[10] *http://india.blogs.nytimes.com/2013/05/13/indias-middle-class-growth-engine-or-loose-wheel/?_php=true&_type=blogs&_php=true&_type=blogs&_php=true&_type=blogs&_r=2&*

[11] *http://business.gov.in/taxation/excise_duty.php*

[12] *http://articles.economictimes.indiatimes.com/2014-02-17/news/47412280_1_excise-duty-central-excise-manufacturing-sector*

[13] *http://www.bls.gov/fls/india.htm*

V. HONDA MOTORS INDIA

Honda Motors India was established in 1997 in Greater Noida. Every year they have increased production to fill the demand of the growing Indian market. In 2013 Honda was the 4th largest carmaker in India. They produce 4 different models in India. The Brio was Honda's entry level car selling at ₹399,900 to ₹599,900. The Honda Brio was only offered in petrol models. The Amaze was the next level up selling from ₹499,900 to ₹755,000 for the petrol models and from ₹597,500 to ₹749,500 for the diesel models. The Honda City was the high end 4 door car starting at ₹719,000 to ₹1,080,000 for petrol and ₹837,000 to ₹1,089,000 for Diesel. Honda India also sells a sport utility vehicle (SUV) called the CR-V. The CR-V starts at ₹2,025,000 to ₹2,436,000 and only comes in petrol. In July 2014, Honda entered the Multi-Utility Vehicle (MUV) market by launching the new Mobilio. Its price was set between ₹649,000 and ₹946,000 for the petrol version, while the diesel version was priced between ₹789,000 and ₹1,155,000.[14]

Honda Motors was coming off of strong January sales. Where all of the other top market share automobile manufacturer's sales went down compared to the year before, Honda's sales went from 5,493 units in January 2013 to 15,714 units in January 2014.

Honda also struggled to find itself in the top ten passenger cars for India. As seen in Figure 12, the top 4 models came from Maruti. Three out of ten came from Hyundai and Mahindra, Tata, and Toyota rounded out the top ten cars list. Figure 13 shows the sales for the past 12 months. Honda is the 3rd largest passenger car manufacturer in India with a market share of 8.02%. They are ahead of many of the American and German made vehicles, but fail to surpass many of the Asian car manufacturers. Also shown in figure 13 is the percentage of increase or decrease in sales from month to month. Honda's sales varied in large quantities from month to month. The largest decrease in sales came in December of 2013, a drop of 41.14%. However in January, the sales were extremely high with an increase of 186.07%. While seasonal sales are expected, many of the other car manufacturers didn't have large fluctuations like Honda. Figure 14 shows the sales figures of every Honda car in India for the last one year.

While Honda had some troubles breaking into the top 10 sold passengers cars in India, Honda Motors had a worldwide presence among the top brands. In Figure 15, Honda is shown as the 7th highest selling car manufacturers in the world. Honda Motors was doing something right in the rest of the world and needed to transfer that success it had globally into the Indian Market. Honda was globally known for the high quality cars that it produced at a price that was reasonable for people to afford. Honda also had the reputation of having cars that lasted a long time and got good gas mileage compared to some of their competitors. Honda's worldwide car production can be seen in Figure 16. The Honda Civic and Accord were Honda's most popular cars around the world.

In February of 2014 Honda Motors started production in a new facility in Rajasthan. The plant was capable of producing 120,000 units per year.[15] The facility spread across 450 acres. This was the 2nd plant for Honda Moto Company in India. With this new plan in place Honda Motors hopes to take advantage of theincrease in demand that it had seen over the last year. This plant should also bring more jobs to the area. Approximately 3,200 associates could be employed at the plant full time. This plant also gave Honda the ability to produce

---

[14] *https://www.hondacarindia.com/default.aspx*
[15] *https://www.hondacarindia.com/mediaCenter/view_press_releases.aspx?pr_id=301*

more cars that were built locally to India and allow them to ship cars easily. The transportation and shipping system in India made it difficult for cars to be shipped all across the country. By Honda opening its second plant, it meant that cars could then be shipped from the closet production plant instead of the one that was very far away.

VI. LOOKING AHEAD

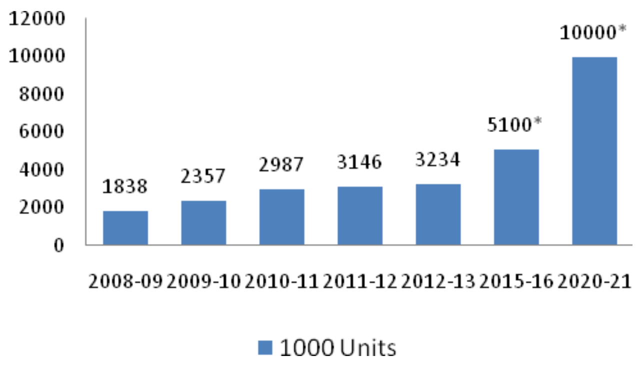
Hironori Kanayama wanted to have a short term plan to take advantage of the excise tax. He knew this would bring more consumers to the market and wanted Honda to be in a position to capture these consumers before their competition did. While Hironori Kanayama wanted this short term success, he also was focused on what Honda Motors could do to become a more consistent leader in the Indian automotive market. As he stepped off the plane he saw in the distance a group of people riding motorcycles. Hironori Kanayama knew that these were also potential customers. He thought about the changes that were coming for the Indian auto industry and recognized the opportunity that Honda had.

How should Honda handle the growth of the middle class? This class could ultimately determine who the market leader in the automobile industry was and Honda needs to make sure they capture their share of this market. How can Honda capitalize on what the government was currently doing? With the lower excise duty, should Honda Motors market share increase or decrease? With 77% of the market riding two-wheelers Honda may have to convince consumers that upgrading to Honda vehicles was the next step. What can Honda to do capture the two wheeler market before their competitors? With what seems to be a cost driven decision making by the consumers in the India Auto Industry, what supply chain methods can be used in order to drive costs down and deliver a cheaper car to the market?

VII. EXHIBITS

Figure 1

Production of Passenger Vehicles



Figures for Financial Year – April to March

(*Estimates)

- Compound Annual Growth Rate 2008-12: 14%
- Compound Annual Growth Rate 2012-21: 13%*

Figure 2

Revenues

The gross turnover of automobile manufacturers in India expanded at a compound annual growth rate (CAGR) of 17.7 per cent over FY07-11.

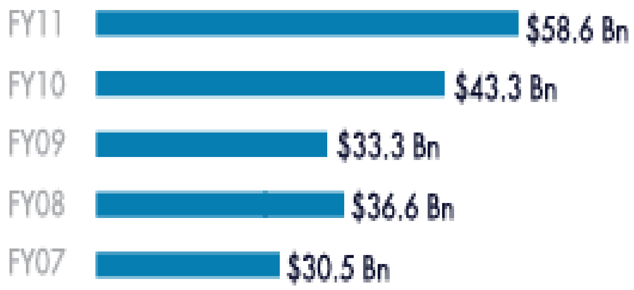


Figure 3

Market Segments

Two wheelers segment accounted for about three quarters of the total automotive production in the country during FY13.

Excluding three wheelers, trucks accounted for the largest share of revenues (47.8 per cent in 2011).

Figure 4

Luxury Car Sales in India			
	2012	**2013**	**Percentage Change**
Audi	9,003	10,002	11.1%
Mercedes-Benz	6,840	9,003	31.6%
BMW	9,375	7,327	-21.8%
Jaguar Land Rover	2,393	2,913	21.7%
Total	**29,623**	**31,258**	**5.5%**

Source: www.team-bhp.com[16]

Figure 5

Two Wheeler Sales in India						
	2007-08	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**
Sales	9,654,435	9,724,243	12,295,397	15,481,381	17,376,624	17,815,618
Percent Change		0.72%	26.44%	25.91%	12.24%	2.53%

Source: SIAM India[17]

[16] http://www.team-bhp.com/news/2013-luxury-segment-sales-audi-mercedes-bmw-jlr

Figure 6

Population and Motor Vehicle Growth

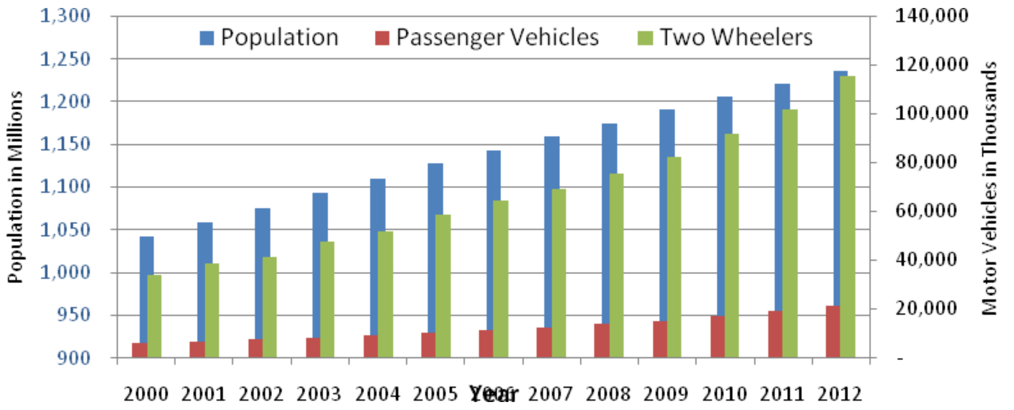


Figure 7

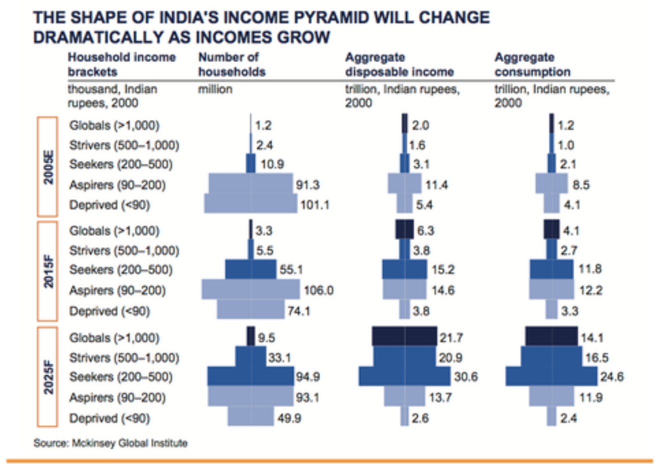
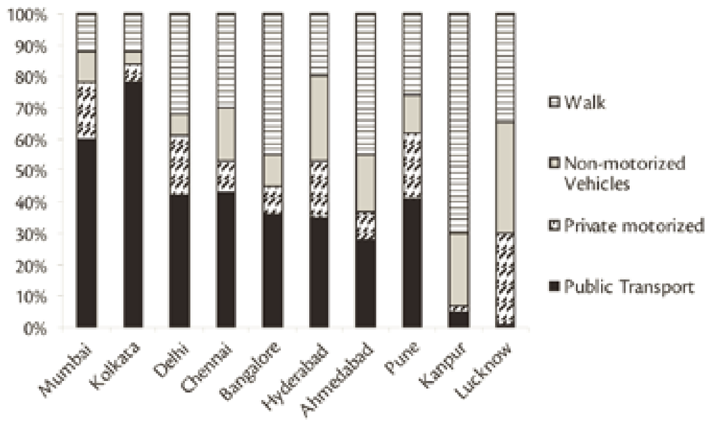


Figure 8

Percentage of consumers using different modes of transportation in major Indian cities



[17]http://www.siamindia.com/scripts/domestic-sales-trend.aspx

Figure 9

Excise Duty

Type of Automobile	Previous	After Reduction
Small Cars/Two Wheelers	12%	8%
Sport Utility Vehicles	30%	24%
Large Vehicles	27%	24%
Mid-Sized Cars	24%	20%

Figure 10

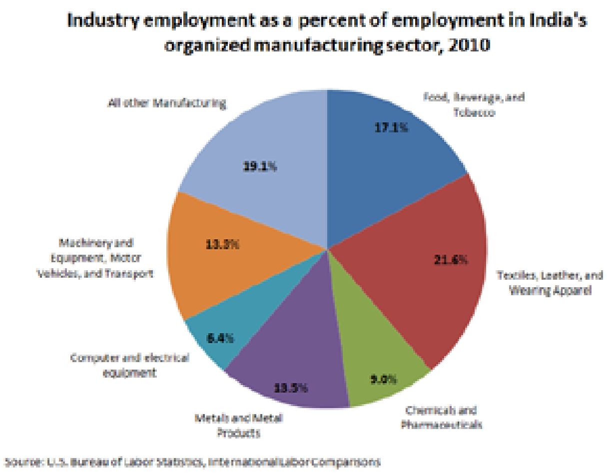


Figure 11

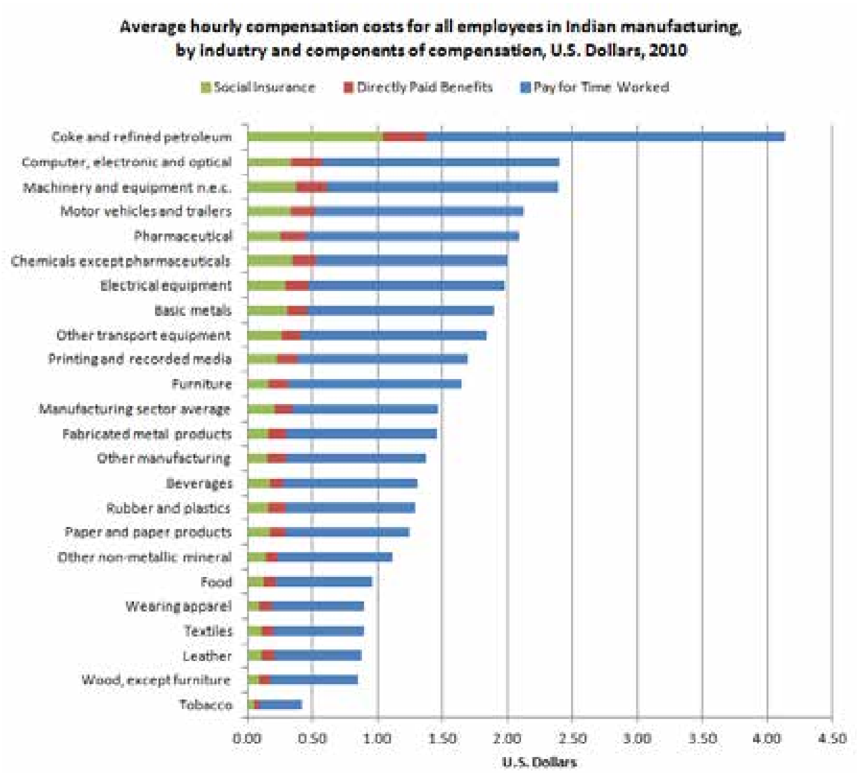


Figure 12

India's Top 10 Selling Passenger Cars in 2013				
Rank	Model	Segment	Company	Number of Units Sold
1	Alto	Small	Maruti	266,785
2	Swift	Small	Maruti	184,897
3	Dzire	Small	Maruti	169,571
4	WagonR	Small	Maruti	135,694
5	Bolero	SUV	Mahindra	117,666
6	i10	Small	Hyundai	92,897
7	i20	Small	Hyundai	91,400
8	Eon	Small	Hyundai	88,836
9	Indica	Small	Tata	77,936
10	Innova	SUV	Toyota	77,062

Source: The Economic Times[18]

Figure 13

Number of Cars Sold in India (2013-14)

Manufacturer	Aug'13	Sept'13	Oct'13	Nov'13	Dec'13	Jan'14	Feb'14	Mar'14	Apr'14	May'14	Jun'14	Jul'14	Aug'14	Total Units Sold	Market Share (%)	Y-Y Change (Aug.)
Maruti	73,147	87,223	92,985	82,608	83,399	94,556	99,713	102,269	79,119	90,560	100,964	90,093	98,304	1,174,940	47.03	34.4%
Hyundai	28,311	30,600	36,002	33,501	28,345	33,405	34,005	35,003	35,248	36,205	33,514	29,260	33,750	427,149	16.15	19.2%
Honda	**8,851**	**10,308**	**11,154**	**9,332**	**5,493**	**15,714**	**14,543**	**18,426**	**11,033**	**13,357**	**16,306**	**15,701**	**16,758**	**166,976**	**8.02**	**89.3%**
Mahindra	15,821	18,916	22,924	16,771	16,436	19,792	19,226	23,433	17,330	18,063	16,045	13,984	13,276	232,017	6.35	-16.1%
Toyota	12,007	12,015	13,162	10,208	10,648	10,910	10,100	8,206	7,562	11,806	12,010	11,921	11,215	141,770	5.37	-6.6%
Tata	11,564	12,839	14,133	10,376	9,272	10,974	11,325	12,640	7,441	9,230	7,911	9,119	10,975	137,799	5.25	-5.1%
Ford	8,008	10,486	8,753	7,698	5,870	6,706	6,799	6,356	6,651	6,055	7,259	7,592	6,801	95,034	3.25	-15.1%
Chevrolet	6,673	7,048	7,715	6,214	5,705	5,557	5,607	6,601	5,302	4,865	5,165	4,720	4,232	75,404	2.02	-36.6%
Volkswagen	4,779	4,503	4,828	4,206	3,034	4,106	3,512	3,739	3,033	2,657	3,078	3,409	4,007	48,891	1.92	-16.2%
Renault	3,733	4,822	5,403	4,044	4,113	3,304	4,101	5,464	3,333	3,650	4,277	3,015	3,235	52,494	1.55	-13.3%
Nissan	2,494	2,350	4,879	4,163	2,557	5,183	2,011	5,007	2,604	3,027	3,265	2,700	2,901	43,141	1.39	16.3%
Skoda	942	1,622	1,843	1,362	1,375	1,412	1,315	1,481	1,014	1,046	1,122	1,120	1,330	16,984	0.64	41.2%
Datsun								2,068	2,690	1,992	1,097	800	1,098	9,745	0.53	
Fiat	1,003	1,086	1,212	1,005	770	1,385	1,302	1,503	828	800	801	718	1,124	13,537	0.54	12.1%
HM-Mitshubishi	173	170	154	112	81	240	250	328	200	250	90			2,048	0.00	
	177,506	203,988	225,147	191,600	177,098	213,244	213,809	232,524	183,388	203,563	212,904	194,152	209,006	2,637,929	100	

	Aug'13	Sept'13	Oct'13	Nov'13	Dec'13	Jan'14	Feb'14	Mar'14	Apr'14	May'14	Jun'14	Jul'14	Aug'14
Honda	**8,851**	**10,308**	**11,154**	**9,332**	**5,493**	**15,714**	**14,543**	**18,426**	**11,033**	**13,357**	**16,306**	**15,701**	**16,758**
		16.46%	8.21%	-16.33%	-41.14%	186.07%	-7.45%	26.70%	-40.12%	21.06%	22.08%	-3.71%	6.73%

Source: www.team-bhp.com[19]

Figure 14

Number of Honda Cars Sold in India (Model/Segment-wise) 2013-2014															
Model	Segment	Aug'13	Sept'13	Oct'13	Nov'13	Dec'13	Jan'14	Feb'14	Mar'14	Apr'14	May'14	Jun'14	Jul'14	Aug'14	Total	Percentage Share
Amaze	Sedan	6,242	6,679	9,564	7,598	4,458	7,398	6,030	7,374	3,355	4,750	7,073	4,507	9,198	**84,226**	50%
Brio	Small/Hatch	1,508	1,452	1,472	1,712	1,026	1,015	1,235	1,456	577	1,333	1,438	74	1,211	**15,509**	9%
City	Sedan	953	2,043	31	-	-	7,184	7,213	9,518	7,038	7,216	7,715	7,697	757	**57,365**	34%
CRV	SUV	148	134	87	22	9	117	65	78	63	58	80	58	62	**981**	1%
Mobilio	MUV												3,365	5,530	**8,895**	5%
Grand Total		**8,851**	**10,308**	**11,154**	**9,332**	**5,493**	**15,714**	**14,543**	**18,426**	**11,033**	**13,357**	**16,306**	**15,701**	**16,758**	**166,976**	100%

Source: www.team-bhp.com[20]

---

[18] *http://economictimes.indiatimes.com/slideshows/auto/indias-top-10-selling-passenger-cars/slideshow/19674805.cms*

[19] *http://www.team-bhp.com/forum/indian-car-scene/157381-october-2014-indian-car-sales-figures-analysis.html*

[20] *http://www.team-bhp.com/forum/indian-car-scene/157381-october-2014-indian-car-sales-figures-analysis.html*

Figure 15

World's Top Car Manufacturers in 2012-2013				
Rank	**Group**	**Car Units Manufactured 2012**	**Car Units Manufactured 2013**	**Percentage Change**
1	Toyota	8,381,968	10,104,424	20.5%
2	G.M.	6,608,567	9,285,425	40.5%
3	Volkswagen	8,576,964	9,254,742	7.9%
4	Hyundai	6,761,074	7,126,413	5.4%
5	Ford	3,123,340	5,595,483	79.2%
6	Nissan	3,830,954	4,889,379	27.6%
7	Honda	4,078,376	4,110,857	0.8%
8	PSA	2,554,059	2,911,764	14.0%
9	Suzuki	2,483,721	2,893,602	16.5%
10	Renault	2,302,769	2,676,226	16.2%

Source: OCIA[21], www.therichest.com[22]

Figure 16

Honda Worldwide Production (2013)													
Region	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Total**
Japan*1	58,772	60,392	61,666	57,058	53,400	59,427	66,368	62,129	80,206	90,707	96,835	93,690	840,650
Outside of Japan*2	283,315	267,835	295,693	297,915	294,382	280,460	272,563	277,794	298,394	328,525	301,403	254,798	3,453,077
North America*3	150,666	154,840	150,823	160,764	155,507	141,229	127,739	161,038	147,010	173,155	145,605	112,818	1,781,194
(USA)	107,061	116,519	110,274	118,306	114,403	100,327	93,262	121,208	108,751	129,157	105,835	84,814	1,309,917
Europe	18,982	16,642	11,690	7,281	7,452	9,200	12,003	5,752	12,648	13,398	14,544	10,501	140,093
Asia	100,722	82,642	118,973	116,046	116,958	116,047	122,178	95,990	123,410	126,836	129,001	120,740	1,369,543
(China)	52,005	33,376	65,659	64,920	59,364	62,144	67,665	57,998	71,199	79,387	85,644	84,710	784,071
Others	12,945	13,711	14,207	13,824	14,465	13,984	10,643	15,014	15,326	15,136	12,253	10,739	162,247
Worldwide Total	**342,087**	**328,227**	**357,359**	**354,973**	**347,782**	**339,887**	**338,931**	**339,923**	**378,600**	**419,232**	**398,238**	**348,488**	**4,293,727**

*1 based on report to JAMA (Japan Automobile Manufacturers Association Inc.)

*2 Local line-off basis

*3 includes Mexico

REFERENCES

[1] http://www.ibef.org/industry/india-automobiles.aspx

[2] http://www.siamindia.com/scripts/industrystatistics.aspx

[3] https://www.hondacarindia.com/default.aspx

[4] https://www.hondacarindia.com/mediaCenter/view_press_releases.aspx?pr_id=301

[5] http://business.gov.in/taxation/excise_duty.php

[6] http://www.chevrolet.co.in/content_data/AP/IN/en/GBPIN/001/index.html

[7] http://articles.economictimes.indiatimes.com/2014-02-17/news/47412280_1_excise-duty-central-excise-manufacturing-sector

[21] http://www.oica.net/wp-content/uploads/2013/03/worldpro2012-modification-ranking.pdf

[22] http://www.therichest.com/business/companies-business/driven-to-succeed-the-worlds-10-largest-automotive-companies/

[8] http://zeenews.india.com/business/automobiles/auto-news/auto-industry-slump-continues-car-sales-drop-7-59-in-january_94257.html

[9] http://www.thehindu.com/business/Industry/auto-industry-grabs-the-lifeline/article5699762.ece

[10] http://edition.cnn.com/2014/02/06/business/delhi-auto-expo/

[11] http://economictimes.indiatimes.com/news/news-by-industry/auto/automobiles/honda-plans-india-rd-unit-with-initial-investment-of-rs-500-crore-to-develop-affordable-cars/articleshow/30916858.cms

[12] http://articles.economictimes.indiatimes.com/2014-02-10/news/47200694_1_national-skill-development-corporation-auto-industry-growth-indian-automotive-industry

[13] http://india.blogs.nytimes.com/2013/05/13/indias-middle-class-growth-engine-or-loose-wheel/?_php=true&_type=blogs&_r=0

[14] http://www.bls.gov/fls/india.htm

[15] http://india.angloinfo.com/transport/public-transport/

[16] http://www.delhimetrorail.com/needformetro/metro-need.aspx

[17] http://www.nctr.usf.edu/jpt/pdf/JPT%207-3%20Pucher.pdf

[18] http://www.marutisuzuki.com/Maruti_Car_Home.aspx

A LUNG CANCER AREA PREDICTION APPROACH WITH TOTAL DEATHS WORLDWIDE CAUSED BY CANCER EACH YEAR PREDICTION OF LUNG CANCER IMAGES USINGPARALLEL SALIENCY ALGORITHM

Aman Sharma[1], Swarnalatha P.[2], Jagraiti Bhardwaj[3]

[1,2] *School of Computing Science & Engineering, Vellore Institute of Technology, Vellore, Tamil Nadu, (India)*

[3]*Global Institute Technology, Jaipur, (India)*

ABSTRACT

To design prediction of the lung cancer from the body is depending on the lung cancer images and parallel saliency algorithm. Lung cancer images with parallel saliency algorithm for predict the lung cancer and produce the parallel saliency map. To solving the medical issues as well as reducing the work for doctors by using parallel saliency algorithm. Parallel Saliency algorithm able to predicts the specific part of the lung cancer by using image of lung cancer. The objective of applying parallel saliency algorithm over cancer images to predict the most affected phase of the lung cancer, second parallel saliency algorithm works in multi-core environment so compare to exiting saliency algorithm parallel saliency algorithm provides more performance to the researchers and scientist.

Keyword: Parallel Saliency, Lung Cancer Images.

I. INTRODUCTION

To design prediction of the lung cancer from the body is depending on the lung cancer images and parallel saliency algorithm. Lung cancer images with parallel saliency algorithm for predict the lung cancer and produce the parallel saliency map. Behind proposed work is combining multiple techniques and producing a new research for image processing researchers and animators. In the proposed work is combining multiple techniques and producing the new algorithm with the help of lung cancer images as well as parallel saliency algorithm. On the particular wall more objects are there so separation of the objects are major issue through the human eyes very easy to find the difference between foreground and background but using software and machine could be difficult. To solving lungcancer separation object problems from the images by using parallel saliency algorithm in the terms of efficient performance. Apart from leukemia all modules image results apply on the parallel saliency algorithm for finding the area of lungcancer and stage of the lung cancer whatever it might be.

Lung cancer is the uncontrolled growth of abnormal cells that start off in one or both lungs; usually in the cells that line the air passages. The abnormal cells do not develop into healthy lung tissue; they divide rapidly and form tumors. As tumors become larger and more numerous, they undermine the lung's ability to provide the bloodstream with oxygen. Tumors that remain in one place and do not appear to spread are known as "benign tumors".

Malignant tumors, the more dangerous ones, spread to other parts of the body either through the bloodstream or the lymphatic system. Metastasis refers to cancer spreading beyond its site of origin to other parts of the body. When cancer spreads it is much harder to treat successfully.

Primary lung cancer originates in the lungs, while secondary lung cancer starts somewhere else in the body, metastasizes, and reaches the lungs. They are considered different types of cancers and are not treated in the same way.

According to the National Cancer Institute, by the end of 2012 there will have been 226,160 new lung cancer diagnoses and 160,340 lung-cancer related deaths in the USA.

According to the World Health Organization (WHO), 7.6 million deaths globally each year are caused by cancer; cancer represents 13% of all global deaths. As seen below, lung cancer is by far the number one cancer killer.

Total deaths worldwide caused by cancer each year:

- **Lung cancer** - 1,370,000 deaths
- **Stomach cancer** - 736,000 deaths
- **Liver cancer** - 695,000 deaths
- **Colorectal cancer** - 608,000 deaths
- **Breast cancer** - 458,000 deaths
- **Cervical cancer** - 275,000 deaths

The American Cancer Society says that lung cancer makes up 14% of all newly diagnosed cancers in the USA today. It adds that annually, more patients die from lung cancer alone than prostate, breast and colon cancers combined (in the USA). An American man's lifetime risk of developing lung cancer is 1 in 13; for a woman the risk is 1 in 16. These risk figures are for all US adults, including smokers, ex-smokers and non-smokers. The risk for a regular smoker is dramatically higher.

Most lung cancer patients are over the age of 60 years when they are diagnosed. Lung cancer takes several years to reach a level where symptoms are felt and the sufferer decides to seek medical help.

Female lung cancer rates set to rise rapidly

Over the next three decades, female lung cancers will increase thirty-five times faster than male lung cancers, scientists from King's College London reported in October 2012.

In the UK, female lung cancer deaths will reach 95,000 annually in 2040, from 26,000 in 2010 – a rise of more than 350%. Male annual lung cancer deaths will increase by 8% over the same period, to 42,000 in 2040 from 39,000 in 2010.

The authors of the report say that lung cancer will continue being the largest cancer killer over the next thirty years. Twice as many people will be living with lung cancer in 2040 compared to 2010. The main reason for the increase will be longer lifespans - the older you are, the higher your risk of cancer is, including lung cancer.

1.1 How Is Lung Cancer Classified?

Lung cancer can be broadly classified into two main types based on the cancer's appearance under a microscope: non-small cell lung cancer and small cell lung cancer. Non-small cell lung cancer (NSCLC) accounts for 80% of lung cancers, while small cell lung cancer accounts for the remaining 20%.

NSCLC can be further divided into four different types, each with different treatment options:

Squamous cell carcinoma or epidermoid carcinoma. As the most common type of NSCLC and the most common type of lung cancer in men, squamous cell carcinoma forms in the lining of the bronchial tubes.

Aden carcinoma. As the most common type of lung cancer in women and in nonsmokers, adenocarcinoma forms in the mucus-producing glands of the lungs.

Bronchi alveolar carcinoma. This type of lung cancer is a rare type of adenocarcinoma that forms near the lungs' air sacs.

Large-cell undifferentiated carcinoma. A rapidly growing cancer, large-cell undifferentiated carcinomas form near the outer edges or surface of the lungs.

Small cell lung cancer (SCLC) is characterized by small cells that multiply quickly and form large tumors that travel throughout the body. Almost all cases of SCLC are due to smoking.

1.2 What Causes Cancer?

Cancer is ultimately the result of cells that uncontrollably grow and do not die. Normal cells in the body follow an orderly path of growth, division, and death. Programmed cell death is called apoptosis, and when this process breaks down, cancer begins to form. Unlike regular cells, cancer cells do not experience programmatic death and instead continue to grow and divide. This leads to a mass of abnormal cells that grows out of control.

Lung cancer occurs when a lung cell's gene mutation makes the cell unable to correct DNA damage and unable to commit suicide. Mutations can occur for a variety of reasons. Most lung cancers are the result of inhaling carcinogenic substances.

1.3 Carcinogens

Carcinogens are a class of substances that are directly responsible for damaging DNA, promoting or aiding cancer. Tobacco, asbestos, arsenic, radiation such as gamma and x-rays, the sun, and compounds in car exhaust fumes are all examples of carcinogens. When our bodies are exposed to carcinogens, free radicals are formed that try to steal electrons from other molecules in the body. These free radicals damage cells and affect their ability to function and divide normally.

About 87% of lung cancers are related to smoking and inhaling the carcinogens in tobacco smoke. Even exposure to second-hand smoke can damage cells so that cancer forms.

1.4 Genes

Cancer can be the result of a genetic predisposition that is inherited from family members. It is possible to be born with certain genetic mutations or a fault in a gene that makes one statistically more likely to develop cancer later in life. Genetic predispositions are thought to either directly cause lung cancer or greatly increase one's chances of developing lung cancer from exposure to certain environmental factors.

II. RELATED WORK

The aim this paper to solve the medial problems and produce the new research scenario for solving Lung cancer problems. Parallel saliency algorithm is the best solution for separation of lung cancer area from the main image. Parallel saliency algorithm is much better than exiting saliency algorithm in terms of performance. Parallel saliency algorithm implemented with the help of image signature as well as channel map for producing a saliency map. Image signature, within the region of signal mixing helps in approximating the foreground of an image. Then it is studied through various experiments whether this approximate foreground overlaps with locations, which are visually conspicuous. Parallel saliency algorithm playing the major role for image processing researches for developing new algorithms using saliency map, improving exiting algorithms using saliency mapping concept in parallel environment approach. In this paper lung cancer image concepts and the results are retrieved from one by one image parallel saliency algorithm, which is finally produces a saliency map.

III. METHODOLOGIES

3.1 Parallel Saliency Algorithm

The proposed research work based on parallel saliency algorithm with image transformation technique with the help of image descriptor for finding the saliency map using image transformation. As well as various experiments we are focusing on parallel saliency algorithm. The separation of the objects from whole the wall that is refers to as FGS which is stands for Figure Ground Separation. Thus the propose work is making parallel saliency algorithm applying on image transformation for finding the saliency map using different modules like input image , RGB colour , channel map and saliency map using image descriptor. According to Parallel Saliency Algorithm where splitting the colour image into constituent channels then combing the output into saliency map. All the channel maps of parallel saliency obtained by transforming the channel to the DCTD that is Discrete Cosine Transform domain and takes signs all values in this domain for reconstructing the signs in the image domain for reconstructing the signs squaring each value, image domain and smoothing by convolution with a Gaussian-kernel. It is possible to parallelize the proposed algorithm even further by parallelizing the computation of the IDCT, DCT, convolution sign and squaring functions. This can be done by distributing the computation of each matrix across different cores. K-means Cluster algorithm using image transformation results applying on parallel saliency algorithm for finding the saliency map for each modules. The memory usage is also lesser as it uses only more one of the core to execute, other cores also work.

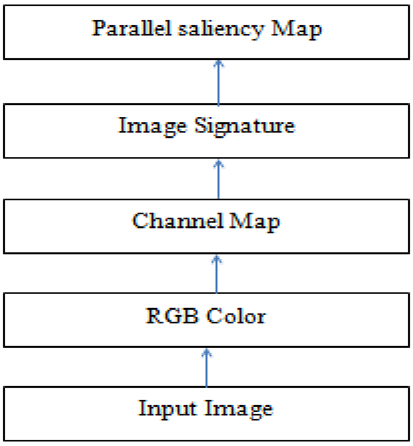


Figure 1: Architecture of Parallel Saliency Algorithm

3.2 Lung Cancer Images

Lung cancer is the uncontrolled growth of abnormal cells that start off in one or both lungs; usually in the cells that line the air passages. The abnormal cells do not develop into healthy lung tissue; they divide rapidly and form tumors. As tumors become larger and more numerous, they undermine the lung’s ability to provide the bloodstream with oxygen. Tumors that remain in one place and do not appear to spread are known as “benign tumors”.

3.3 Parallel Saliency Algorithm Using Lung Images

Parallel saliency algorithm able separate from foreground to background objects by using parallel saliency environment. The region behind that to separates lung cancer phase from the main image of the lung cancer image.

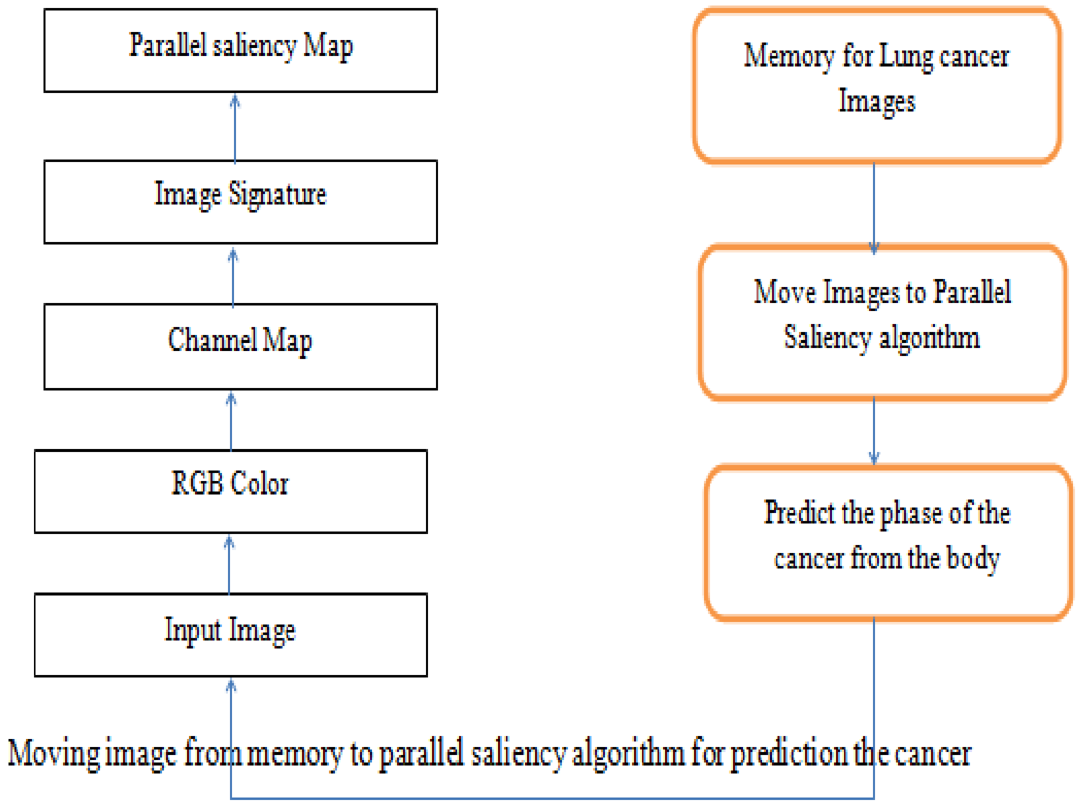


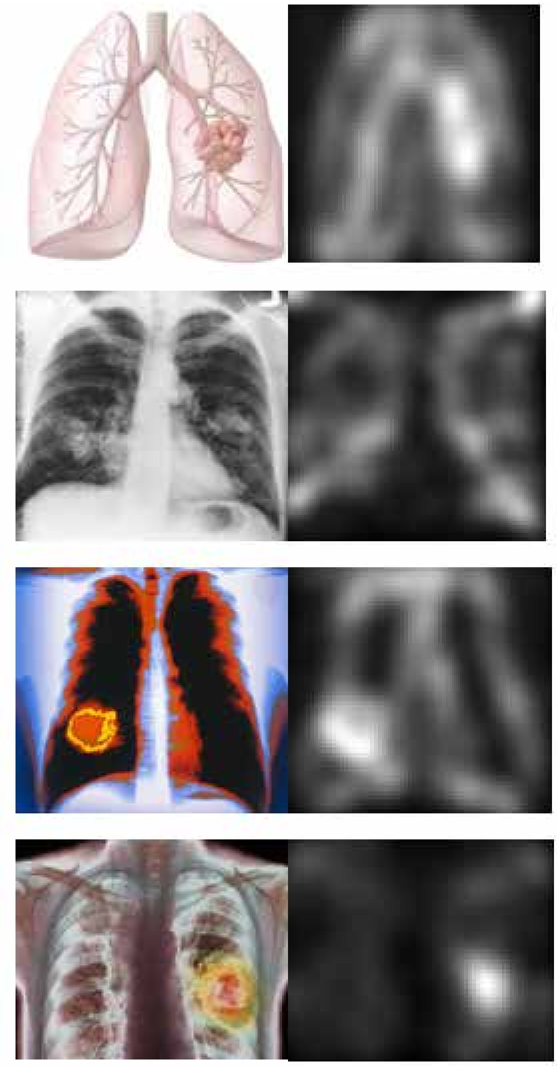
Figure2: Proposed Method for Lung Cancer Prediction Using Parallel Saliency Algorithm

IV. CONCLUSION

The parallel saliency map algorithm could be applicable for other algorithm also. For merging algorithm and producing new research using parallel saliency map which gives satisfactory performance compare to exiting saliency algorithm. The prediction the lung cancer will be helpful for researchers, students and scientist those who are involved in medical image processing and health & research and development.

V. RESULT ANALYSIS

Input Images Parallel Saliency Map



REFERENCES

[1] Aman Sharma, M Rajasekara Babu, "Saliency Algorithm using image signature in parallel environment", "Interdisciplinary engineering & suitable management sciences", February 2013 Madurai, India.

[2] Hongliang Li, King NgiNgan,"A Co-Saliency Model of Image Pairs", IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 20, NO. 12, DECEMBER 2011.

[3] Yuming Fang, Zhenzhong Chen, Weisi Lin, and Chia-Wen Lin,"Saliency Detection in the Compressed Domain for Adaptive Image Retargeting", IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 21, NO. 9, SEPTEMBER 2012.

[4] Alexander Andreopoulos and John K. Tsotsos," On Sensor Bias in Experimental Methods for Comparing Interest-Point, Saliency, and Recognition Algorithms", IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 34, NO. 1, JANUARY 2012.

[5] XiaodiHou, Jonathan Harel, and Christof Koch" Image Signature: Highlighting Sparse Salient Regions", IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 34, NO. 1, JANUARY 2012.

[6] Jingbo Zhou, Zhong Jin, Jingyu Yang," Multiscale saliency detection using principle component analysis", WCCI 2012 IEEE World Congress on Computational Intelligence June, 2012 - Brisbane, Australia.

[7] FanmanMeng, Hongliang Li, Guanghui Liu, and King NgiNgan", Object Co-Segmentation Based on Shortest Path Algorithm and Saliency Model", IEEE TRANSACTIONS ON MULTIMEDIA, VOL. 14, NO. 5, OCTOBER 2012.

[8] X. Hou and L. Zhang, "Saliency Detection: A Spectral Residual Approach," Proceeding .IEEE Conference Computer Vision and Pattern Recognition, 2007.

[9] Alexander Berengolts and Michael Lindenbaum," On the Distribution of Saliency", IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 28, NO. 12, DECEMBER 2006.

[10] J. van de Weijer, Th. Gevers," Boosting Saliency in Color Image Features", Proceedings of the 2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2005 IEEE.

[11] Suk Tomáš, Šimberová Stanislava: New YHS color coordinate system and its spplication in remote sensing, Proceedings of the 1st Pattern Recognition for Remote Sensing Workshop, p. 6-9, Eds: Petrou M., BMVA Press, (Surrey 2000), PRRS 2000 /1./, (Andorra La Vella, AD, 01.09.2000)

[12] Levkowitz, H. and G. T. Herman "GLHS: A Generalized Lightness, Hue, and Saturation Color Model." Computer Vision, Graphics, and Image Processing: Graphical Models and Image Processing, Vol. 55, 271-285, 1993

ONLINE VOTING SYSTEM USING DIFFERENT FACE DETECTION TECHNIQUES

Priya Taneja[1], Rajender Kumar Trivedi[2], Rajani Sharma[3]

[1]B.Tech Student, GEU, Dehradun, (India)

[2,3] GEU, Dehradun, (India)

ABSTRACT

Internet voting systems have gained esteem and have been used for government elections and referendums in the United Kingdom, Estonia and Switzerland as well as municipal elections in Canada and party primary elections in the United States. Voting system can engross transmission of ballots and votes via private computer networks or the Internet. Electronic voting technology can speed the counting of ballots and can provide improved accessibility for disable voters.

This paper deals with design and build a highly secure online voting system using some face based recognition techniques. There are many techniques of face detection and recognition such as Eigen face algorithm, Gabor filter and many others. This paper demonstrates a golden ratio method to recognize the different postures and faces using online voting system. For this different facial expressions and poses of individual faces are detected and stored in a database system. Then we estimate the ratios of different face parts and matches it with the ratio of the face image we have stored in the database system. If it matches the person will be allowed to cast the vote. If the image is not recognized the person is not eligible to cast its vote.

General Terms: Techniques,Demonstrates,Voting,Database.

Keywords: Eligible,Ratio,Postures,Faces,Golden Ratio.

I. INTRODUCTION

In the development of any country democracy plays a vital role. Democracy System runs by a leader of the country who is selected by citizen of a country. Citizens have right to choose leader through election. Process of election consumes lots of man-power as well as resources and preparation is started many days before commencement of the election .During thispreparation it may happen that involved people make an illegal arrangement with each other or try to replace with their henchmen in this process to win the election . Election is the system which gives people a chance to choose their leader, so it must be transparent, Meddle-Proof, Usable, Authenticated, Accurate, Verifiability and Mobility. In the existingsystem there are certain drawbacks such as damage of machines, chances of violence, dummy voting and problem of proper monitoring is also an issue. Also Manual voting system has been developed in many parts of our country. However then also people could not attend the vote as this process is place oriented and there is region wise distribution, voters need to reach the place of voting Security can be achieved using some of techniques like Gabor filter, Eigen face, golden ratio and line edge map technique for electronic voting. To solve this problem there is a need for online voting system using mobile application. In modern world mobile phones are easily available to each individual so developing a mobile application will make the system more expedient and effortless for the user to cast its vote from home or any other place oriented location.

II. PROBLEMSTATEMENT

Online voting has not been yet implemented in our country.Manual voting system has been developed in many parts of our country which is not safe and secure too.The voter which is not eligible can also cast its vote by fake means.This may lead to many problems such as an untalented,undesirable leader will get selected and it will have a direct impact on the growth of our nation.

III. EXISTING VOTING SYSTEM

In current voting system allocation of polls is done by election commission in advance. Generally polling booth is setup in school and community halls. Voter's card is distributed before one week so; the people can come to know about the location of voting. Time and place for voting is predefined. Each polling station is opened for at least 8 hours on the Election Day. Different fingerprints of a person are taken. Here there is a high security risk. A person may with fake voting card can also cast its vote. Such a method is not an effective way. It must be stopped. Also to maintain discipline and security requires a huge amount of man power therefore; it is bit difficult to accomplish election in a single day. Due to such problems of existing voting system there is a need to develop a anticipated system in which user can cast its vote without any reason or excuse of not casting the vote.

IV. DIFFERENT PROPOSEDTECHNIQUES FOR FACE RECOGNITION

4.1 Gabor Filter Technique

The voter's image which is captured using a webcam is used as the input in this face detection algorithm. Before entering image to Gabor filters, it must be normalized. Gabor filter algorithm consists of 40 filter used to detect faces from the captured image; the proposed system applied different Gabor filters on the image to generate 40 images with different angles and orientation. Next, maximum intensity points in each filtered image are calculated and marked as fiducially points. If the distance is minimum between these face points then system reduces the points. The next step is calculating the distances between the reduced points using distance formula. At last, the calculated distances are compared with Gabor database. If match occurs,it means that the image is recognized as a face.

4.2 Eigen Face Technique

In Eigen face algorithm we acquire a database of face images, calculate the eigenfaces and determine the face space with all them. It will be necessary for further recognitions. When a new image is found, calculate its set of weights. Determine if the image is a face; to do so, we have to see of it is close enough to the face space. Finally, it will be determined if the image corresponds to a known face of the database of not. Analysis and experimental results indicate that the eigenface algorithm, which is essentially a minimum distanceclassifier, works well when lighting variation is small. Its performance deteriorates significantly as lighting variation increases.

4.3 Golden Ratio Technique

The human face golden ratio means the most beautiful face ratio. It has 'Three parts' and 'Five eyes', the 'Three parts' means from hairline to eyebrow, from eyebrow to nose and from nose to chin. The 'Five eyes' means human face is five eyes width. If human face conform the two conditions, we can call human face golden ratio.

4.4 Line Edge Map (LEM) Technique

Face recognition using line edge map .This algorithm describes a new technique based on line edge maps (LEM) to accomplish face recognition. In addition, it proposes a line matching technique to make this task possible. In opposition with other algorithms, LEM uses physiologic features from human faces to solve the problem. It mainly uses mouth, nose and eyes as the most characteristic ones. These are all the above techniques we can use for face recognition. But in my opinion the best one which we can use are line edge map technique and golden ratio technique.

V. PROPOSED TECHNIQUE

In India today also ballot machines are used for voting instead of many algorithms present which can be implemented practically to form a system through which people can online conduct the voting system. To implement or form such a system different algorithms are present through which we can practically implement this system. But this research paper proposes the use of two techniques mainly line edge map technique and the golden ratio technique. As the discussion begins with voting through mobile device, first an application is required through which voters can commune. Secure data centre is required to store and fetch the data as per requirement. Still there is a question of gathering voter's information. We need to use existing database in which voters information exist. Voters/citizens information is available in "ADHAR CARD" database. Assume that almost every next person is having mobile phone on which our application program will execute. To begin with mobile based voting system throughout voting process an internet connection is essential. After connection is established voters need to download application from a specific source. After downloading and installing, start the application for face recognition to do this need to start front camera of smart device once it's started then need to examine face throughfront camera of smart device then system compares scanned image with centralized stored information this is called as sign in process. Once face is recognized successfully the complete detail of voter comes from "ADHAR CARD" database and related information exists on mobile device. Within this application list of candidates appear as per place which is fetched from "ADHAR CARD". From the list, voters can select any one candidate as per his/her choice and after selecting the candidate voting is accomplished. So, after selecting particular candidate counting is incremented by one centrally.Database is used to fetch the information of voter and only one flag attribute constructed when user performs face recognition flag default value is zero changes to one which indicates that particular voter has given the vote and another separate database is used to store count of votes. So, as per Indian constitution it also preserves secure ballot. If Voters do not have any smart device in such situation one common location is assigned for voting through mobile phones. So, on this location only few persons are involved to carry out this process. To implement such an application we chiefly using two techniques in this research work. These are Line Edge Map technique and golden ratiotechnique.

5.1 Methodlogy

Line edge map (LEM) describes a technique to accomplish face recognition. In addition, it proposes a line matching technique to make this task possible. In conflict with other algorithms,LEM uses physiologic features from human faces to resolve the problem. It mostly uses mouth, nose and eyes as the majority feature ones.

In order to determine the similarity of human faces the face images are firstly converted into gray-level pictures. The images are preset intobinary edge maps using Sobel edge detection algorithm. This system is much related to the way human beings identify other people faces as it was acknowledged in many psychological studies. The main advantage of line edge maps is the low sensitiveness to illumination changes, because it is a halfway image representation derived from low-level edge map representation. The algorithm has another important improvement; it is the low memory requirements because the kind of data used. It also keeps face features in a very simplified level.

One of the most important parts of the algorithm is the Line Segment Hausdorff Distance (LHD) described to accomplish an exact matching of face images. This method is not oriented to calculate exact lines form different images; its main characteristic is its flexibility of size, position and orientation.

Given two LEMs = {,. . .} (face from the database) and an (input image to be detected); the LHD is represented by the vector Ā(). The elements of this vector represent themselves three difference distance measurements: orientation distance, parallel distance and perpendicular distance respectively.

(,) = , (,)=min() , ()=

The function $\boldsymbol{\theta}$ (represents the smallest intersection angle between the lines The function f is a penalty nonlinear function that ignores smaller angles and penalizes greater ones. It can be used as the penalty function. Then the parallel and perpendicular distance are calculated with distance formula. Finally, the distance between the two segments is calculated.

The main strength of this distance measurement is that measuring the parallel distance, we choose the minimum distance between edges. It helps when line edge is strongly detected and the other one not. It avoids shifting feature points. However, it also has a weakness; briefly, it can confuse lines and not detect similarities that should be detected. In order to avoid errors, another measurement can be made. We can add a new parameter to the Hausdorff distance, comparing the number of lines in the images is a good method to exclude images. After measuring the parallel distance we will calculate the golden ratio with the help of parallel distance we have calculated. The golden ratio of the with the help of distance of line will give the exact ratio between the position of different face parts and we can recognize the face moraccurately and competently.

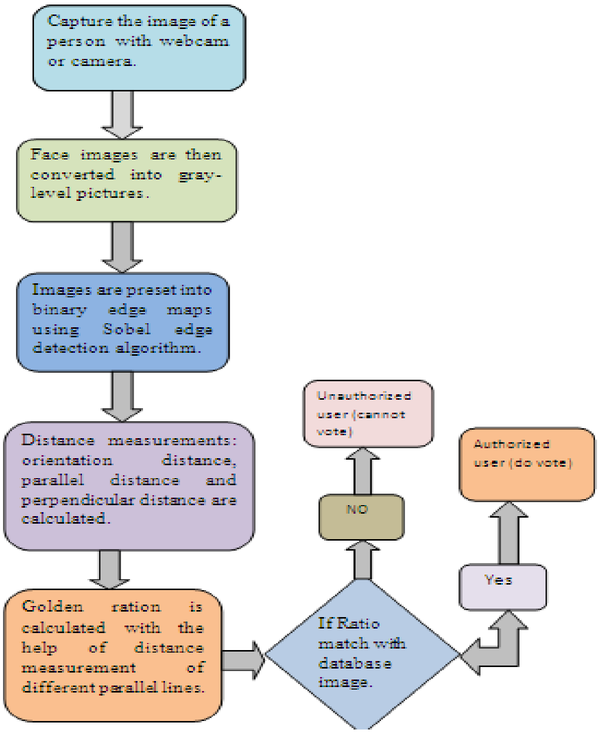


Figure1: Process Of Face Detection

VI. CONCLUSION

In this paper we have enforced a technique for improving the status of voting system to present a highly secure Online Voting System.The security level of our system is greatly improved by the new application method for each voter. The user authentication process of the system is improved by adding face recognition in an application which will identify whether the particular user is authenticate user or not.The recognition portion of the system is secured as each person will have a different golden ratio.This system will preclude the illegal practices like rigging. Thus, the citizens can be sure that they alone can choose their leaders, thus exercising their right in the democracy. The usage of online voting has the capability to reduce or remove unwanted human errors. In addition toits reliability, online voting can handle multiplemodalities, and provide better scalability for large elections. Online voting is also an excellent mechanism that does not require geographical proximity of the voters. Thus,we will be able to change the face of today's voting system by making it corruption less. It will give a fair chance to every leader to win on the basis of his/her talent, ability and not on the basis of strength of money, powerand rule. The scope of the project can be raised to the society,institutional or nation level by using a more secure and efficient database management system that could handle hundreds, thousands or billions of users.

REFERENCES

[1]. Roddick, John F., and Myra Spiliopoulou. "A bibliography of temporal, spatial and spatio-temporal data mining research." ACM SIGKDD Explorations Newsletter 1.1 (1999): 34-38.

[2]. Kosala, Raymond, and Hendrik Blockeel. "Web mining research: A survey."ACMSigkdd Explorations Newsletter 2.1 (2000): 1-15.

[3]. Pang, Bo, and Lillian Lee. "Opinion mining and sentiment analysis."Foundations and trends in information retrieval 2.1-2 (2008): 1-135.

[4]. Ding, Xiaowen, Bing Liu, and Philip S. Yu. "A holistic lexicon-based approach to opinion mining." Proceedings of the 2008 International Conference on Web Search and Data Mining. ACM, 2008.

[5]. Xia, Yun-Qing, et al. "The unified collocation framework for opinion mining."Machine Learning and Cybernetics, 2007 International Conference on. Vol. 2. IEEE, 2007.

[6]. Phillips, P. J. "Face Recognition: A Literature SurveyB W. Zhao2 Sarnoff Corporation R. Chellappa and A. Rosenfeld3 University of Maryland.".

[7]. Maciel, João, and João Costeira. "Human Face Image Synthesis by Computer." (1998).[8]. Pang, B., & Lee, L. (2008).

[8] Maruyama, Minoru, Satoru Asano, and Yasuaki Nakano. "Face recognition by bidirectional view synthesis." Pattern Recognition, 1998. Proceedings. Fourteenth International Conference on. Vol. 1. IEEE, 1998.

[9]. Shih, Frank, Camel Fu, and Kai Zhang. "Multi-view face identification and pose estimation using B-spline interpolation." *Information Sciences* 169.3 (2005): 189-204.

[10] Chai, Xiujuan, et al. "Local linear regression (LLR) for pose invariant face recognition." *Automatic Face and Gesture Recognition, 2006. FGR 2006. 7th International Conference on*. IEEE, 2006.

[11]. Chai, Xiujuan, et al. "Pose invariant face recognition under arbitrary illumination based on 3d face reconstruction." *Audio-and Video-Based Biometric Person Authentication*. Springer Berlin Heidelberg, 2005.

[12]. Turk, Matthew, and Alex Pentland. "Eigenfaces for recognition." *Journal of cognitive neuroscience* 3.1 (1991): 71-86.

[13]. Mandal, Tanaya, Angshul Majumdar, and QM Jonathan Wu. "Face recognition by curvelet based feature extraction." *Image Analysis and Recognition*. Springer Berlin Heidelberg, 2007. 806-817.

[14]. Sandeep, K., and A. N. Rajagopalan. "Human Face Detection in Cluttered Color Images Using Skin Color, Edge Information." *ICVGIP*. 2002.

[15]. Yang, Ming-Hsuan, David Kriegman,and Narendra Ahuja. "Detecting faces in images: A survey." *Pattern Analysis and Machine Intelligence, IEEE Transactions on* 24.1 (2002): 34-58.

EFFECT OF THERMOPHORESIS ON TRANSIENT FREE CONVECTION BOUNDARY LAYER FLOW OF A WALTERS-B FLUID

B. Vasu[1], Rama Subba Reddy Gorla[2], V. R. Prasad[3]

[1]*Department of Mathematics, Motilal Nehru National Institute of Technology Allahabad, (India)*

[2]*Department of Mechanical Engineering, Cleveland State University, Ohio, USA*

[3]*Department of Mathematics, Madanapalle Institute of Technology and Science, (India)*

ABSTRACT

The present paper considers the free convective, unsteady, laminar convective heat and mass transfer in a viscoelastic fluid along an impulsively started vertical plate in presence of thermophoresis. The Walters-B viscoelastic liquid model is employed to simulate medical creams and other rheological liquids encountered in biotechnology and chemical engineering. This rheological model introduces supplementary terms into the momentum conservation equation. The dimensionless unsteady, coupled, and non-linear partial differential conservation equations for the boundary layer regime are solved by an efficient, accurate and unconditionally stable finite difference scheme of the Crank-Nicolson type. The velocity, temperature, and concentration fields have been studied for the effect of thermophoresis, Prandtl number, viscoelasticity parameter, Schmidt number, and buoyancy ratio parameter. The local skin-friction, Nusselt number and Sherwood number are also presented and analyzed graphically. It is observed that, when the viscoelasticity parameter increases, the velocity increases close to the plate surface. An increase in Schmidt number is observed to significantly decrease both velocity and concentration.

Keywords: Unsteady Viscoelastic Flow, Impulsively Vertical Plate, Walters-B Short-Memory Mode, Finite Difference Method, Mass Transfer, Thermophoresis, Schmidt Number.

I. INTRODUCTION

The flow past an impulsively started plate is very important in industrial systems. Such flows are transient and therefore temporal velocity and temperature gradients have to be included in the analysis. The flow of a viscous incompressible fluid past an impulsively started infinite vertical plate, moving in its own plane was first studied by Stokes [1]. Soundalgekar [2] presented an exact solution to the flow of a viscous fluid past an impulsively started infinite isothermal vertical plate. The solution was derived by the Laplace transform technique and the effect of heating or cooling of the plate on the flow field was discussed through Grashof number. Raptis and Singh [3] studied the flow past an impulsively started infinite vertical plate in a Porous medium by a finite difference method. Muthucumaraswamy and Ganesan [4] studied the unsteady flow past an impulsively started isothermal vertical plate with mass transfer by an implicit finite difference method. Viscoelastic flows arise in numerous processes in chemical engineering systems. Such flows possess both viscous and elastic properties and can exhibit normal stresses and relaxation effects. An extensive range of mathematical models has been developed to simulate the diverse hydrodynamic behaviour of these non-Newtonian fluids. An eloquent exposition of viscoelastic fluid models has been presented by Joseph [5]. Examples of such models are the Rivlin-Ericksen second order model, the Oldrotd model, Johnson-Segalman model, the upper convected Maxwell model and the Walters-B model [6]. Both steady and unsteady flows have been investigated at length in a diverse range of geometries using a wide spectrum of analytical and computation methods. The Walters-B viscoelastic model [6] was developed to simulate viscous fluids possessing short memory elastic effects and can simulate accurately many complex polymeric, biotechnological and tri-biological fluids. The Walters-B model has therefore been studied extensively in many flow problems. Soundalegkar and Puri [7] presented one of the first mathematical investigations for such a fluid considering the oscillatory two-dimensional viscoelastic flow along an infinite porous wall, showing that an increase in the Walters elasticity parameter and the frequency parameter reduces the phase of the skin-friction. Chang et al [8] analyzed the unsteady buoyancy-driven flow and species diffusion in a Walters-B viscoelastic flow along a vertical plate with transpiration effects. Nanousis [9] used a Laplace transform method to study the transient rotating hydromagnetic Walters-B viscoelastic flow regime. Thermophoresis is a radiometric force by temperature gradient that enhances small particles moving toward a cold surface and away from a hot one. It plays a significant role on particle transport in laminar boundary layer flow. Generally, the mainly effect of thermophoresis on small particle size is especially effective in a range of *dp* = 0.01-1.0 μ*m*. Thermophoresis on particle deposition onto a surface in laminar boundary layer flow is now rather well understood theoretically. Goren [10] developed the thermophoretic deposition of particles in a laminar compressible boundary layer flow past a flat plate. There are some other proposed models for particle deposition by coupled of thermophoresis and Brownian diffusion (Batchelor and Shen [11]). Chamkha *et al*. [12] studied the effect of thermophoretic force in free convection boundary layer from a vertical flat plate embedded in a porous medium with heat generation or absorption. Partha [13] used similarity technique to obtain the solutions about effect of suction/injection on thermophoretic particle deposition in free convection onto a vertical plate embedded in a fluid saturated non-Darcy porous medium. In recent years, non-Newtonian fluids have been appearing in increasing numbers. In spite of the extensive research over the past few decades which dealt with the flow of non-Newtonian fluids, there has been little work done on the unsteady flow for non-Newtonian fluids. To our best knowledge, study on thermophoresis effects on Walters-B viscoelastic fluid flow past an impulsively started vertical plate has never been considered before. Therefore, in this paper we investigate the effects of thermophoretic parameter in the Walters-B model over the vertical plate. The transformed boundary layer equations are solved with a versatile, validated implicit finite difference procedure, benchmarked where appropriate with previous studies. The values of skin friction, wall heat transfer and wall deposition flux are also tabulated. Another motivation of the study is to further investigate the observed high heat transfer performance commonly attributed to extensional stresses in viscoelastic boundary layers.

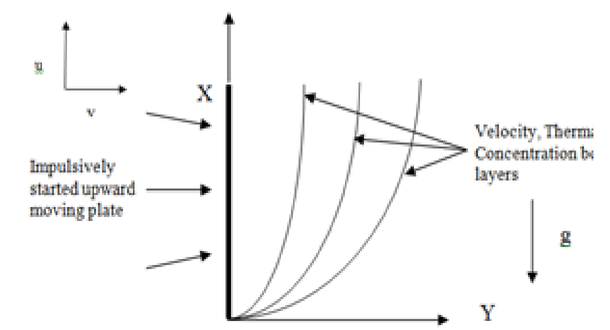


Fig 1(a) Physical model and coordinate system

II. MATHEMATICAL FORMULATION

An unsteady two-dimensional laminar free convective flow of a viscoelastic fluid past an impulsively started vertical plate is considered. The x-axis is taken along the plate in the upward direction and the y-axis is taken normal to it. The physical model is shown in Fig.1. Initially, it is assumed that the plate and the fluid are at the same temperature T'_{∞} and concentration level C'_{∞} everywhere in the fluid. At time, $t'>0$, the plate starts moving impulsively in the vertical direction with constant velocity u_0 against the gravitational field. Also, the temperature of the plate and the concentration level near the plate are raised to T'_w and C'_w respectively and are maintained constantly thereafter. It is assumed that the concentration C' of the diffusing species in the binary mixture is very less in comparison to the other chemical species, which are present, and hence the Soret and Dufour effects are negligible. It is also assumed that there is no chemical reaction between the diffusing species and the fluid. Then, under the above assumptions, the governing boundary layer equations with Boussinesq approximation are

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

$$\frac{\partial u}{\partial t'}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=g\beta\left(T'-T'_{\infty}\right)+g\beta^{*}\left(C'-C'_{\infty}\right)+\nu\frac{\partial^2 u}{\partial y^2}-k_0\frac{\partial^3 u}{\partial y^2\partial t'} \tag{2}$$

$$\frac{\partial T'}{\partial t'}+u\frac{\partial T'}{\partial x}+v\frac{\partial T'}{\partial y}=\frac{k}{\rho c_p}\frac{\partial^2 T'}{\partial y^2} \tag{3}$$

$$\frac{\partial C'}{\partial t'}+u\frac{\partial C'}{\partial x}+v\frac{\partial C'}{\partial y}=D\frac{\partial^2 C'}{\partial y^2}-\frac{\partial}{\partial y}\left(c'V_t\right) \tag{4}$$

The initial and boundary conditions are

$$\begin{aligned}
&t'\le 0: u=0, v=0, T'=T'_{\infty}, C'=C'_{\infty} && \\
&t'>0: u=u_0, v=0, T'=T'_w, C'=C'_w && at\ y=0\\
&\qquad u=0, T'=T'_{\infty}, C'=C'_{\infty} && at\ x=0\\
&\qquad u\to 0, T'\to T'_{\infty}, C'\to C'_{\infty} && as\ y\to\infty
\end{aligned} \tag{5}$$

Where *u, v* are velocity components in *x, y* directions respectively, t'- the time, *g* - the acceleration due to gravity, β - the volumetric coefficient of thermal expansion, β^* - the volumetric coefficient of expansion with concentration, T' -the temperature of the fluid in the boundary layer, C' -the species concentration in the boundary layer, T'_w - the wall temperature, T'_{∞} - the free stream temperature far away from the plate, C'_w - the concentration at the plate, C'_{∞} - the free stream concentration in fluid far away from the plate, ν - the kinematic viscosity, α - the thermal diffusivity, ρ - the density of the fluid and D - the species diffusion coefficient.

On introducing the following non-dimensional quantities

$$\begin{aligned}
&X=\frac{xu_0}{\nu}, Y=\frac{yu_0}{\nu}, U=\frac{u}{u_0}, V=\frac{v}{u_0}, t=\frac{t'u_0^{\,2}}{\nu}, Sc=\frac{\nu}{D}, T=\frac{T'-T'_{\infty}}{T'_w-T'_{\infty}}, C=\frac{C'-C'_{\infty}}{C'_w-C'_{\infty}},\\
&\Gamma=\frac{k_0u_0^{\,2}}{\nu^2}, \Pr=\frac{\nu}{\alpha}, \tau=\frac{k\nu(T'_w-T'_{\infty})}{T_wu_0}, Gr=\frac{\nu g\beta(T'_w-T'_{\infty})}{u_0^{\,3}}, Gm=\frac{\nu g\beta^{*}(C'_w-C'_{\infty})}{u_0^{\,3}}
\end{aligned} \tag{6}$$

Equations (1), (2), (3), (4) and (5) are reduced to the following non-dimensional form

$$\frac{\partial U}{\partial X}+\frac{\partial U}{\partial Y}=0 \tag{7}$$

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}=\frac{\partial^2 U}{\partial Y^2}+GrT+GmC-\Gamma\frac{\partial^3 U}{\partial Y^2\partial t} \tag{8}$$

$$\frac{\partial T}{\partial t}+U\frac{\partial T}{\partial X}+V\frac{\partial T}{\partial Y}=\frac{1}{\Pr}\frac{\partial^2 T}{\partial Y^2} \tag{9}$$

$$\frac{\partial C}{\partial t}+U\frac{\partial C}{\partial X}+V\frac{\partial C}{\partial Y}=\frac{1}{Sc}\frac{\partial^2 C}{\partial Y^2}+\frac{t}{Gr^{1/4}}\left[\frac{\partial C}{\partial Y}\frac{\partial T}{\partial Y}+C\frac{\partial^2 T}{\partial Y^2}\right] \tag{10}$$

The corresponding initial and boundary conditions are

$$\begin{aligned}
&t\le 0: U=0,\ V=0,\ T=0,\ C=0 \\
&t>0: \ U=1,\ V=0,\ T=1,\ C=1 \qquad at \qquad Y=0 \\
&\qquad\ U=0,\ T=0,\ C=0 \qquad at \qquad X=0 \\
&\qquad\ U\to 0,\ T\to 0,\ C\to 0 \qquad as \qquad Y\to\infty
\end{aligned} \tag{11}$$

where Gr is the thermal Grashof number, Pr is the fluid Prandtl number, Sc is the Schmidt number, Gm is the solutal Grashof number and Γ is the viscoelastic parameter.

To obtain an estimate of flow dynamics at the barrier boundary, we also define several important rate functions at $Y = 0$. These are the dimensionless wall shear stress function, i.e. local skin friction function, the local Nusselt number (dimensionless temperature gradient) and the local Sherwood number (dimensionless species, i.e. contaminant transfer gradient) are computed with the following mathematical expressions

$$\tau_X=-\left(\frac{\partial U}{\partial Y}\right)_{Y=0},\quad Nu_x=-X\left(\frac{\partial T}{\partial Y}\right)_{Y=0},\quad Sh_X=-X\left(\frac{\partial C}{\partial Y}\right)_{Y=0} \tag{12}$$

We note that the dimensionless model defined by Eqns. (7) to (10) under conditions (11) reduces to Newtonian flow in the case of vanishing viscoelasticity i.e. when $\Gamma \to 0$.

III. NUMERICAL SOLUTION

In order to solve these unsteady, non-linear coupled equations (7) to (10) under the conditions (11), an implicit finite difference scheme of Crank-Nicolson type has been employed. This method was originally developed for heat conduction problems [14]. Prasad et al [15] described the solution procedure in detail. The region of integration is considered as a rectangle with $X_{\max}=1$ and $Y_{\max}=14$ where $Y_{\max}$ corresponds to $Y=\infty$ which lies well outside the momentum, thermal and concentration boundary layers. After some preliminary numerical experiments the mesh sizes have been fixed as $\Delta X=0.05$, $\Delta Y=0.25$ with time step $\Delta t=0.01$. The computations are executed initially by reducing the spatial mesh sizes by 50% in one direction, and later in both directions by 50% and the results are compared. It is observed that, in all the cases, the results differ only in the fifth decimal place. Hence these mesh sizes are considered to be appropriate mesh sizes for present calculations. The local truncation error in the finite difference approximation is $O(\Delta t^2+\Delta X+\Delta Y^2)$ and it tends to zero as $\Delta t, \Delta X$ and ΔY tend to zero. Hence the scheme is compatible. The scheme is unconditionally stable and explained in detail by Prasad et al. [15] and Vasu and Manish [16]. Stability and compatibility ensures convergence.

IV. RESULTS AND DISCUSSION

A representative set of numerical results is presented graphically to illustrate the influence of viscoelastic parameter G, thermophoretic parameter t, Grashof number *Gr*, mass Grashof number *Gm*, Schmidt number *Sc* on the velocity, temperature, concentration, skin-friction, Nusselt number and Sherwood number. *Pr* defines the

Gr=Gm	τ	X = 0.1			X = 0.5			X = 1.0		
		τx	Nux	Shx	τx	Nux	Shx	τx	Nux	Shx
0.0	0.0	3.48356	0.14283	0.15065	1.00545	0.23450	0.38949	0.67170	0.32328	0.70751
	0.1	3.48356	0.14283	0.14072	1.00545	0.23450	0.36609	0.67170	0.32328	0.67117
	0.5	3.48356	0.14283	0.09884	1.00545	0.23450	0.26522	0.67170	0.32328	0.51290
	1.0	3.48356	0.14283	0.04034	1.00545	0.23450	0.11602	0.67170	0.32328	0.27231
0.2	0.0	3.34829	0.14977	0.15519	0.68704	0.27542	0.41870	0.24776	0.40430	0.77784
	0.1	3.34688	0.14988	0.14510	0.68436	0.27592	0.39375	0.24432	0.40519	0.73827
	0.5	3.34066	0.15039	0.10260	0.67222	0.27821	0.28654	0.22865	0.40937	0.56740
	1.0	3.33136	0.15119	0.04346	0.65289	0.28201	0.12997	0.20306	0.41645	0.31446
1.0	0.0	2.86312	0.16519	0.16661	-0.38096	0.33911	0.47610	-1.11375	0.52132	0.90380
	0.1	2.85724	0.16546	0.15610	-0.39091	0.34003	0.44918	-1.12577	0.52284	0.86061
	0.5	2.83186	0.16666	0.11194	-0.43499	0.34417	0.33470	-1.17938	0.52975	0.67665
	1.0	2.79503	0.16845	0.05089	-0.50223	0.35062	0.17178	-1.26238	0.54071	0.41367
5.0	0.0	0.83466	0.20210	0.19678	-4.59606	0.45555	0.59469	-6.28649	0.72420	1015131
	0.1	0.81089	0.20265	0.18516	-4.63054	0.45698	0.56440	-6.32538	0.72644	1.10277
	0.5	0.70942	0.20502	0.13637	-4.77976	0.46322	0.43756	-6.49448	0.73635	0.89961
	1.0	0.56547	0.20841	0.06906	-4.99703	0.47245	0.26328	-6.74311	0.75124	0.62047

ratio of momentum diffusivity (n) to thermal diffusivity. The values of *Sc* are chosen such that they represent water vapor (0.6), Ammonia (0.78), Carbon dioxide (0.94) and Ethyl Benzene (2.0). Selected computations are presented in Figures and tables. The default values for the control parameters are selected as: G= 0.005, t = 0.5, *Sc* = 0.6, *Pr* = 0.71 (air) and *Gr* = *Gm* = 2, 4.

In Tables 1 the variation of dimensionless local skin friction t_X Nusselt number Nu_X and the Sherwood number Sh_X, for various *Gr* or *Gm* and thermophoretic parameters (t) at different *X* = 0.1, 0.5 and 1.0 along the plate are tabulated in Table 1(a). Shear stress is clearly decreased with increasing the values of *Gr* or *Gm,* whereas Nu_X and Sh_X increases with an increase in the values of *Gr* or *Gm.* The opposite behaviour is observed for increasing thermophoretic parameter t

Gr = Gm	Γ	X = 0.1			X = 0.5			X = 1.0		
		τx	Nux	Shx	τx	Nux	Shx	τx	Nux	Shx
0.0	0.000	2.33434	0.17850	0.11768	0.70438	0.27825	0.27405	0.47338	0.37546	0.52798
	0.003	2.86552	0.16138	0.10821	0.84489	0.25660	0.26997	0.56658	0.34879	0.52201
	0.005	3.48356	0.14283	0.09884	1.00545	0.23450	0.26522	0.67170	0.32328	0.51290
0.2	0.000	2.25584	0.18089	0.11925	0.51296	0.29935	0.28840	0.21306	0.42504	0.56371
	0.003	2.75818	0.16567	0.11070	0.58956	0.28785	0.28769	0.22322	0.41618	0.56602
	0.005	3.34066	0.15039	0.10260	0.67222	0.27821	0.28654	0.22865	0.40937	0.56740
1.0	0.000	1.95737	0.18861	0.12439	-0.15840	0.34658	0.32472	-0.65434	0.51917	0.64588
	0.003	2.36179	0.17725	0.11785	-0.28198	0.34500	0.32988	-0.89291	0.52445	0.66147
	0.005	2.83186	0.16666	0.11194	-0.43499	0.34417	0.33470	-1.17938	0.52975	0.67665
5.0	0.000	0.64077	0.21334	0.14111	-2.84205	0.44634	0.40943	-3.97098	0.69877	0.82686
	0.003	0.66542	0.20885	0.13853	-3.72700	0.45518	0.42383	-5.12525	0.71868	0.86361
	0.005	0.70942	0.20502	0.13637	-4.77976	0.46322	0.43756	-6.49448	0.73635	0.89961

Table 2 show that the values of local skin friction t_X Nusselt number Nu_X and the Sherwood number Sh_X for different Gr, Gm and G at X = 0.1, 0.5 and 1.0. It is observed that an increase in the values of viscoelastic parameter G causes an increase in the shear stress rate at various X = 0.1, 0.5 and 1.0. It is also observed that the reverse behaviour for Nu_X , Sh_X .

Sc	Pr = 0.01			Pr = 0.71			Pr = 7.0		
	τx	Nux	Shx	τx	Nux	Shx	τx	Nux	Shx
0.25	-3.57960	0.09803	0.74851	-2.84827	0.63359	0.56013	-2.26594	1.93322	0.28518
0.60	-3.39355	0.09765	1.04682	-2.67080	0.60660	0.75601	-2.16310	1.91450	0.15704
0.78	-3.33503	0.09756	1.15543	-2.61676	0.59942	0.82357	-2.14869	1.91135	0.07018
0.94	-3.29292	0.09750	1.23871	-2.57835	0.59466	0.87381	-2.14593	1.91029	-0.01245
2.0	-3.12046	0.09731	1.63069	-2.42482	0.57827	1.08969	-2.24432	1.92417	-0.62059
5.0	-2.91296	0.09714	2.22222	-2.25194	0.56411	1.32786	-3.90130	2.19475	-4.50153

From **Table 3** we observed that the variation of t_X , Nu_X and Sh_X for various *Sc* and Pr at various *X* = 0.1, 0.5 and 1.0 along the plate. The local Nusselt number values decreases with increases in *Sc*, whereas t_X and Sh_X increases with an increase in the values of *Sc*. The same behaviour is observed for increasing Pr also.

In Figures 2(a) to 2(c), we have presented the variation of the velocity, temperature and concentration with collective effects of thermophoretic parameter (t) and Schmidt number (Sc) at X = 1.0. Sc defines the ratio of momentum diffusivity (n) to molecular diffusivity (*D*). For Sc<1, species will diffuse much faster than momentum so that maximum concentrations will be associated with this case (Sc = 0.6). For Sc > 1, momentum will diffuse faster than species causing progressively lower concentration values. With an increase in molecular diffusivity concentration boundary layer thickness is therefore increased. For the special case of *Sc* = 1, the species diffuses at the same rate as momentum in the viscoelastic fluid. Both concentration and boundary layer thicknesses are the same for this case. An increase in Schmidt number

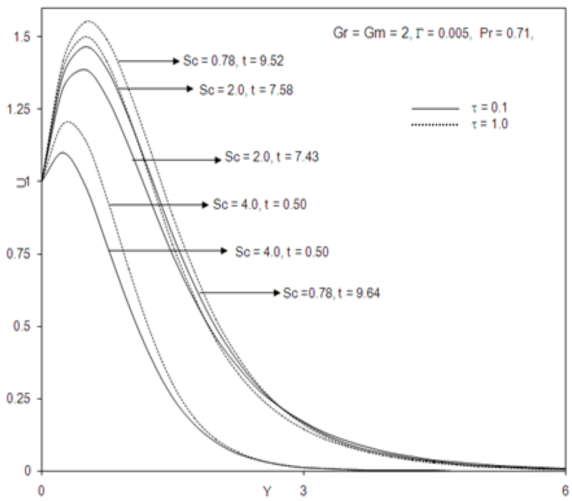


Fig.2(a). Steady state velocity profiles at X=1 for different Sc and τ

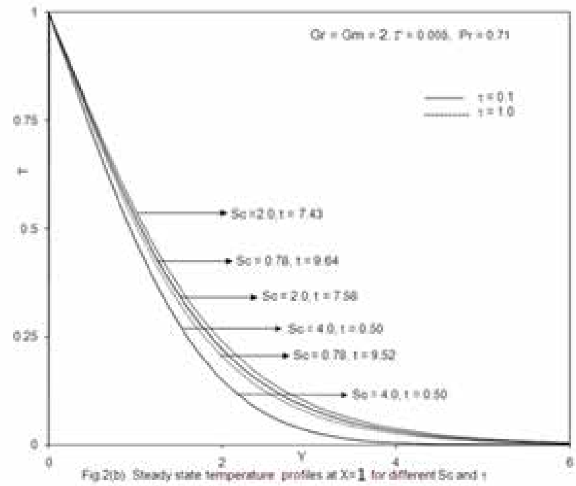


Fig.2(b) Steady state temperature profiles at X=1 for different Sc and t

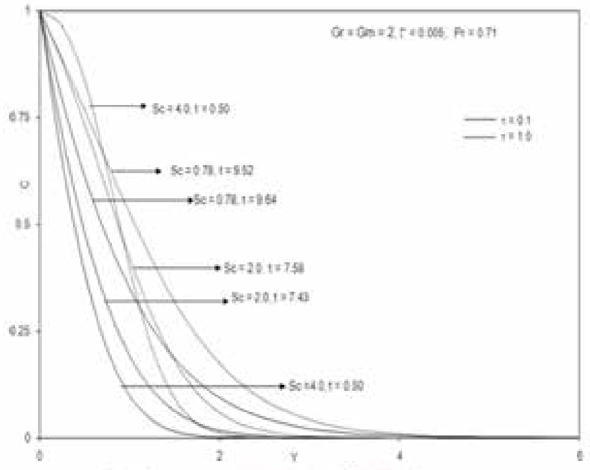


Fig.2(c) Steady state concentration profiles at X=1 for different Sc and t

effectively depresses concentration values in the boundary layer regime since higher *Sc* values will physically manifest in a decrease of molecular diffusivity (*D*) of the viscoelastic fluid i.e. a reduction in the rate of mass diffusion. Lower *Sc* values will exert the reverse influence since they correspond to higher molecular diffusivities. Concentration boundary layer thickness is therefore considerably greater for *Sc* = 0.6 than for *Sc* = 2.0. From Figure 2(a), it is seen that an increase in the values of t from 0.0 to 1.0 leads to enhance the velocity for different values of *Gr*, *Gm*, *Sc*, $G$and for fluid Prandtl number *Pr* (=0.71). It is also observed that the velocity decreases due to increase in *Sc*. Figure 2(b) shows that the temperature decreases throughout the boundary layer with the increasing values of t. all profiles decay from the maximum at the wall to zero in the free stream. The graphs show therefore that increasing thermophoretic parameter cools the flow. It is also observed that the temperature profiles decreases due to an increase in the values of Sc. From Figure 2(c), it is noticed that an increase in the values of t from 0.0 to 1.0 leads to an increase in the concentration. It is also observed that the concentration decreases due to increase in the values of Schmidt number. Concentration values are also seen to increase continuously with time t. An increase in Schmidt number effectively depresses concentration values in the boundary layer regime since higher Sc values will physically manifest in a decrease of molecular diffusivity (D) of the viscoelastic fluid i. e. a reduction in the rate of mass diffusion. Lower Sc values will exert the reverse influence since they correspond to higher molecular diffusivities.

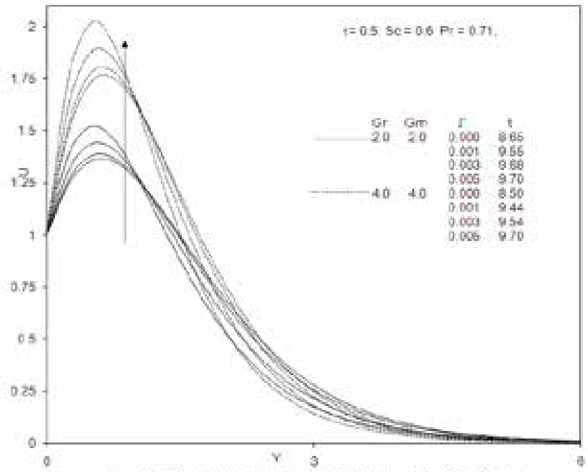


Fig.3(a) Steady state velocity profiles at X=1 for different Gr, Gm and Γ

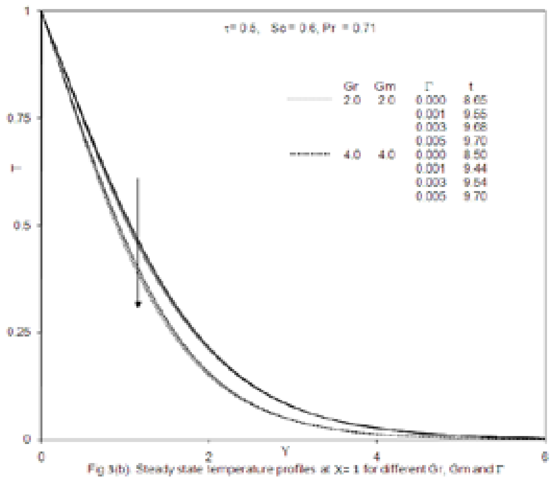


Fig.3(b) Steady state temperature profiles at X=1 for different Gr, Gm and Γ

Figures 3(a) to 3(c) illustrate the effect of viscoelastic parameter (Γ), Grashof number *Gr*, mass Grashof number *Gm* on the velocity, temperature and concentration at *X*=1.0. From Figure 3(a), it is observed that the velocity increases due to an increase in the values of *Gr* or *Gm*. With increasing the values of Γ from 0.000 through 0.001, 0.003 to the maximum value of 0.005, clearly enhances the velocity which ascends sharply and peaks in close vicinity to the plate (*Y*=0). With increasing distance from the plate however the velocity is adversely affected by increasing the values of Γ i.e. the flow is decelerated. Therefore close to the plate the flow velocity is maximized for the case of Γ= 0. But this trend is reversed as we progress further into the boundary layer regime. The switchover in behavior corresponds to approximately *Y* =1.5, with increasing velocity profiles decay smoothly to zero in the free stream at the edge of the boundary layer. The opposite effect is caused by an increase in time. A rise in t from 8.65, through 9.55, 9.68 and to the maximum value of 9.70 causes an increase in flow velocity near the wall, in this case the maximum velocity arises for the largest time progressed. Again there is a reverse in the response at *Y* =1.5, and thereafter velocity is maximized with the least value of time. From Figure 3(b), it is observed that the temperature decreases with an increase in the values of *Gr* or *Gm*. With increasing the values of Γ causes a decrease in the temperature decreases both in the near-wall regime and the far-field regime of the boundary layer. As we approach the free stream the effects of viscoelastic parameter Γ are negligible since the profiles are all merged together. From Figure 3(c), it is observed that an increase in the values of *Gr* or *Gm* causes a decrease in the concentration. It is also observed that the concentration decreases throughout the boundary layer due to an increase in Γ All profiles decay from the maximum at the wall to zero in the free stream.

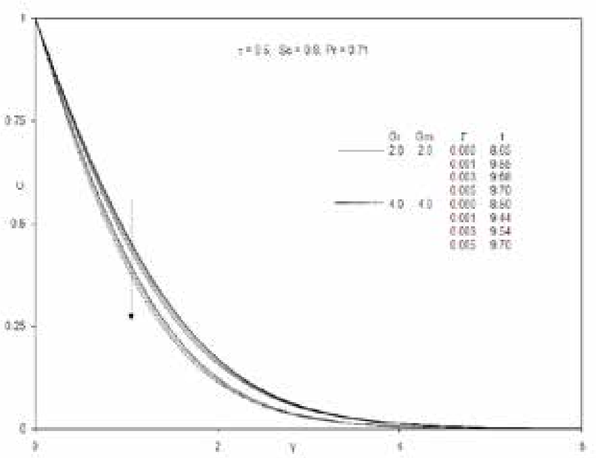


Fig 3(c) Steady state concentration profiles at X= 1 for different Gr, Gm and Γ

V. CONCLUSIONS

A two-dimensional, unsteady laminar incompressible boundary layer model has been presented for the external flow, heat and mass transfer in a viscoelastic buoyancy-driven flow past an impulsively started vertical plate under the influence of thermophoresis. The Walters-B viscoelastic model has been employed which is valid for short memory polymeric fluids. The dimensionless conservation equations have been solved with the well-tested, robust, highly efficient, implicit Crank-Nicolson finite difference numerical method.

The present computations have shown that

- Increasing thermophoretic parameter accelerates the velocity and concentration, but reduces the temperature.
- Increasing viscoelastic parameter accelerates the velocity, but reduces the temperature and concentration.
- Increasing Gr or Gm accelerates the velocity, but reduces the temperature and concentration.
- Increasing Schmidt number accelerates the temperature, but reduces the velocity and concentration.

- Increasing thermophoretic parameter decreases the dimensionless wall shear stress function, i.e. local skin friction function and mass transfer rate (local Sherwood number). At the plate with the opposite effect sustained for the local heat transfer rate (local Nusselt number)

VI. ACKNOWLEDGEMENTS

One of the authors (B Vasu) is thankful to the Motilal Nehru National Institute of Technology Allahabad, India, for the financial support under the Cumulative Professional Development Allowance [CPDA].

REFERENCES

[1] G. G. Stokes., On the effect of internal friction of fluids on the motion of pendulums, *Cambridge Phil. Trans., 9*, 1995, 8-106.

[2] V. M. Soundalgekar., Free convection and mass transfer effects on the viscoelastic flow past an impulsively-started vertical plate, *ASME J. Applied Mechanics*, 46, 1979, 757-760.

[3] A. Raptis and A. K. Singh., free convection flow past an impulsively started vertical plate in a porous medium by finite difference method. *Astro physics and Space Science. 112*, 1985, 259-265.

[4] R. Muthucumaraswamy and P. Ganesan., The first order chemical reaction on flow past an impulsively started vertical plate with uniform heat and mass flux. *Acta. Mech. 147*, 2001, 45-47.

[5] D.D. Joseph, *Fluid dynamics of viscoelastic liquids* (Springer-Verlag, New York, 1990)

[6] K. Walters., Non-Newtonian effects in some elastico-viscous liquids whose behaviour at small rates of shear is characterized by a general linear equation of state, *Quart. J. Mech. Applied. Math., 15*, 1962, 63-76.

[7] V. M. Soundalgekar and P. Puri On fluctuating flow of an elastico-viscous fluid past an infinite plate with variable suction, *J. Fluid Mechanics, 35(3),* 1969, 561-573.

[8] T.B. Chang, Bég, O. Anwar, J. Zueco and M. Narahari, Numerical study of transient free convective mass transfer in a Walters-B viscoelastic flow with wall suction, *Comm. in Nonlinear Sci and Num Sim, 16*, 2011, 216-225.

[9] N. Nanousis, Unsteady magnetohydrodynamic flows in a rotating elasto-viscous fluid, *Astrophysics and Space Science, 199(2)*, 1993, 317-321.

[10] S. L. Goren., Thermophoresis of aerosol particles in the laminar boundary layer on a flat surface, *Journal of Colloid and Interface Science, 61*, 1977, 77-85.

[11] G. K. Batchelor, and C. Shen., Thermophoretic deposition in gas flow over cold surfaces, *Journal of Colloid and Interface Science, 107*, 1985, 21-37.

[12] A. J. Chamkha, A. F. Al-Mudhaf and I. Pop., Effect of heat generation or absorption on thermophoretic free convection boundary layer from a vertical flat plate embedded in a porous medium, *International Communications in Heat and Mass Transfer, 33*, 2006, 1096-1102.

[13] M. K. Partha., Suction/injection effects on thermophoresis particle deposition in a non-Darcy porous medium under the influence of Soret, Dufour effects, *International Journal of Heat and Mass Transfer, 52*, 2009, 1971-1979.

[14] J. Crank, and P. Nicolson, A practical method for numerical evaluation of solutions of partial differential equations of the heat conduction type, *Proc. Camb. Phil. Society, 43*, 1947, 50-67.

[15] V. R. Prasad, N. Bhaskar Reddy and R. Muthucumaraswamy, Radiation and mass transfer effects on two-dimensional flow past an impulsively started infinite vertical plate, *Int. J. Thermal Sciences*, *46(12)*, 2007, 1251-1258.

[16] Vasu B and Manish K, Transient Boundary Layer Laminar Free Convective Flow of a Nanofluid over a Vertical Cone/Plate, International Journal of Applied and Computational Mathematics, January 2015, DOI: 10.1007/s40819-015-0027-9, Article in press.

THE DEVELOPMENT OF THE MALAYSIAN TECHNOLOGY CONTENT FRAMEWORK TOWARDS THE ESTABLISHMENT OF THE MALAYSIAN TECHNOLOGY INDEX IN MANUFACTURING INDUSTRY

Abdullah Ibrahim[1], Siti Aishah Md Hasan[2]

[1]*Professor, Faculty of Engineering Technology, Universiti Malaysia Pahang, Malaysia*

[2]*Faculty of Industrial Management, Universiti Malaysia Pahang, Malaysia*

ABSTRACT

Appropriate technology plays a vital role in the ability of manufacturing enterprises to be productive and competitive. Today, most companies accept the fact that they must acquire relevant technology to strengthen their technological capabilities and core competencies. The proposed study intends to investigate the content of technology in that affect the application of new technology in Malaysian manufacturing industry. Next, this study aims to develop the Malaysian Technology Content Framework, in which this framework will form the basis for the development of Malaysian Technology Index for manufacturing industry. This study is carried out through three phases which involves survey of literature and practices, interviews or participatory dialogue with industry players, and pilot testing. This study indicates that all technology contents are significantly correlated with the technology strategy implementation at p-value of 0.000 ($p<0.05$). In detail, the results show that human, technology, organization and information are significantly correlated with technology strategy with a correlation value of 0.880, 0.798, 0.857, and 0.449 respectively. It is also found a significant correlation between technology strategy and technology application at 0.839 which will lead to the application of new technology.

Keywords – Technology Content Framework, Technology Index, Technology Strategy, Manufacturing Industry, Technology Capability

I. INTRODUCTION

Continuous updating of technology is important for a modern manufacturing organisation to become a global competitor. Competitiveness in the manufacturing environment can be characterised by world class manufacturing principles. Such principles would include the manufacture of products at competitive cost, supply of products at competitive price, high quality, short lead times and variety of product features. A major role of technology is to optimise these characteristics, and the direct impact of technology in the organisation can thus be seen in the fewer, faster and more accurate processes within the product development, manufacturing and supply cycles. Although most manufacturing organisations accept the fact that they must acquire relevant technology to strengthen their technological capabilities, the task of choosing and exploiting the newly acquired technology to get optimum results, remain a difficult one.

In order to apply and manage technology effectively, Malaysian firms need to develop their technological capability that guides their utilization of technological resources. However, Malaysia's technological performance does not achieve up to the mark, showing that most of the firms in Malaysia still lack of capabilities to make available and use of latest technology. A study by UNIDO found that manufacturing industry in Malaysia was characterised by assembly and processed type production which resulted the level of skills required were relatively simple in assembly and process activity. The implication of this situation is that the industries involved require workers with a low level of technical skills. This paper, therefore, intends to investigate the content of the technology within the manufacturing industry in Malaysia and tries to establish the Technology Content Framework. This framework is hoped can be used as a basis for the development of the Malaysia Technology Index.

II. TECHNOLOGY

Technology has become one of the important elements to the society, business and industry in newly industrialized countries [1]. It always plays a major role in the creation of wealth and now technology is accepted as a key source of competitive advantage [2]. There are several technological entities besides hardware such as software and human skills. Lorentzen et al.[3] state that technology involved knowledge, equipments, and documents that help firms to upgrade their performance whereas Van Wyk [4] suggests that technology is competence, created by people, and expressed in devices, procedures and human skills, in which these constituent elements need to be combined to form as a technology entity.

A study conducted by Dolinsek and Strukelji [5] on some of the largest companies in the technologically most advanced manufacturing sectors such as ExxonMobil, iRobot, Boeing, Microsoft, and Sony shows that in these companies, technology refers to methods, techniques, procedures, processes, machine, and devices that people and organizations use in their activities. Also, their study shows that these companies do not immediately refer to technology as knowledge or skills, but they rather emphasize technological or technical expertise, technical knowledge, and technical skills.

III. TECHNOLOGY CAPABILITY

Technological capability has been explained in various ways depending on the interest of the researchers. Garcia-Muina [6] conceptualized technological capability as a tool for implementing competitive strategy and creating value in any given environment. They further defined it as the ability to jointly mobilize different scientific and technical resources which enables a firm to successfully develop its innovative products or productive processes. Technological capability is also able to make the right investment choices; increase production capacity, and engage in continuous upgrading of product quality [7]. However, Wang et al [8] argue that technological capability plays a critical role in competitive strategy for business performance but such an impact depends on the characteristics of business environment.

IV. TECHNOLOGY CONTENT

Technology contents makeup a 'TIHO Framework' where Sharif [10] proposes that any technology consists of four components; 1) Technoware (T) is the physical assets such as equipment or machinery that is used to carry out a specific activity or task, 2) Inforware (I) is the knowledge and information of how to use hardware in order to carry out the required activity or task, 3) Humanware (H) is the human skills needed for using hardware and infoware in order to carry out the required activity or task, 4) Orgaware (O) is the organizational and managerial structure to coordinate three above components in order to carry out the required activity or task.

4.1 Technology

Rush et al. [11] posited once a new technology option is decided upon, a firm needs to deploy the resources to exploit it either by creating technology via in-house R&D, or acquiring it through a joint venture or technology licensing. According to Lane et. al [12], the ability of a firm to manage the acquisition of new technology and modify such acquired technology will determine the successful of implementation of firm's technology strategy. Therefore, the following hypothesis is proposed:

H1: The acquisition of technologies significantly predicts the implementation of technology strategy.

4.2 Human

The capabilities of the companies often rely on its people since they are essentially as part of mechanism for innovation in organization [13]. Identify and recruit the right employees with the right education and skill sets will ensure the successful of firms and organizations. According to Monappa [14], employees are recognized as a finite resource and the key to implement a new strategy of the organization. A study by Ashekele and Matengu [15] on an SME manufacturing enterprise at the northern town of Rundu, Namibia found that relatively high levels of skill among employees provided impetus for a desire to be more competent.

Mohamed et al. [16] reveal that knowledge base factor, level of employee's readiness which includes technical skills, experience, and willingness to learn give affects to the technology transfer performance. Meanwhile, a research carried out by United Nations Commission [17] found that a lack of sufficiently skilled labour force unable to assimilate and adapt new knowledge to local conditions is an impediment to the implementation of new strategy for technology transfer activities. As such, the following hypothesis is proposed:

H2: Human with core competencies significantly predicts the implementation of technology strategy.

4.3 Information

Empirical research has looked at the nature of the linkages distinguishing between the role played by specific factors such as suppliers, customers, and universities [18] as source of information. The importance of some knowledge sources may also have been overestimated when they have been examined in isolation from other sources of knowledge [19].

Reichstein and Salter [20] argue that knowledge from suppliers enhances process innovations in firms with a cost-focus strategy. In addition, Bodas Freitas et al. [19] discover that firms with process innovations pursuing innovative strategies are generally tend to set up linkages with customers and governmental research institutes while firms with product innovations tend to engage in formal collaborations with competitors, suppliers, and other firms in the group. In this regard, the following hypothesis is proposed:

H3: Successful technology strategy implementation depends on information gained from external linkages.

4.4 Organization

Organization is very important as it makes management and scheduling work load easy. It brings together all the components of technology implementation. Efficient organizational design is very important as a source of competitive advantage in a world of temporary advantage [21]. According to Crossan and Berdrow [22], designing organizations in the present economy context should take into account organizational learning, as knowledge is considered to be one of the most important resources to the designation of sustainable competitive advantage. In leading firms, the learning process can become conscious and formal leads to continuous improvements in effectiveness, efficiency, and strategy formulation [11]. Therefore, the following hypothesis is proposed:

H4: Successful strategy implementation depends on good internal organization.

V. TECHNOLOGY STRATEGY

Conventionally, the broad objective of technology strategy is to guide a firm in acquiring, developing and applying technology for competitive advantage. It is one of the important factors for determining a firm's long-term competitiveness [23]. According to Beer et al.[24], strategy can be implemented by aligning an organization's goals, resources, and capabilities together with the environmental factors. More specifically, the adoption of technology strategy is considered as the most important thing especially for high-tech industries because it is directly related to the development of the technological capabilities through its interaction with the external environment [25].

A study that was carried out by Cooper and Edgett [26] in Corning Glass which manufactured fibre-optic cable, and Nortel Network which produced the boxes at each end of the cable to convert the light signal into an electronic signal shows that by developing a renewed innovation strategy resulted into better product innovation performance. Sharma [27] has shown that technology strategy is correlated with the organizational performance in firm level particularly for the firms in the growth stage and involved in the production of consumer and industrial goods.

VI. METHODS

This study was conducted in two phases: Phase 1 was a survey of literature and practices, while phase 2 was a participatory dialog and consultation with industrialists. Phase 1 aimed to search literature on the development of framework for technology contents as well as current practices both in Malaysia and abroad. Phase 2 was a survey whereby questionnaires were mailed and delivered to the targeted manufacturing firms. This study focused only on electrical and electronics manufacturing firms in Malaysia with more than 500 employees. Electrical and electronics manufacturing companies were chosen because they are the leading sector in Malaysia's manufacturing sector. Furthermore, the electrical and electronic manufacturing companies have developed significant technological capabilities and skills for the production of higher value-added products.

6.1 Data Collection

About 161 electrical and electronics manufacturing companies hiring more than 500 employees have registered with the Federation of Manufacturing Malaysia (FMM). The researcher was able to reach 131 companies for a survey but only 110 returned, making 84% response rate. Data were also collected from focused group discussion with top management of four related companies. The discussion was focused on the issues related to technology content, such as techniques applied to identify the appropriate technologies that can be exploited, the process of matching the technology used with the knowledge and skills of employees.

6.2 Questionnaire Design

The questionnaire was designed by adapting and modifying from Rush et al.[11], who assessed the technological capabilities of the firms by emphasising the development of technology policy. The questionnaire was divided into two sections which consist of 29 items. Section A comprises questions about demographic information of respondent. A total of 24 questions in Section B comprising independent and dependent variables were measured using five-point Likert scale from 1= strongly disagree to 5= strongly agree. A pilot test that was carried on 25 managers of manufacturing companies found the instrument was reliable with a score of 0.616 and above [28].

IV. RESULTS AND DISCUSSION

This study employed the Statistical Package for Social Science (SPSS) to analyse data in the first phase to compute the frequencies, means, and standard deviations. In the second phase, Structural Equation Modelling (SEM) was employed. SEM allows the simultaneous modeling of relationships among multiple independent and dependent constructs [29]. The analysis of the research model was conducted using PLS because PLS allows the analysis of both reflective and formative measures [30].

7.1 Validity of the Constructs

Validity was examined by using both convergent and discriminant validity analysis. According to Sekaran [31], convergent validity examines whether the measures of the same construct are correlated highly, whereas discriminant validity determines the measures of a construct have not been correlated too highly with other constructs. Factor loadings, composite reliability and average variance extracted were used to assess convergent validity. According to Gholami et al.[32], all factor loadings should be statistically significant and standardized loading estimate should be 0.5 or higher. Composite reliability (CR) equal to or greater than 0.7 and average variance extracted (AVE) equal to or greater than 0.5 is considered acceptable.

Table 1: Measurement Model

Contruct	Item	Loadings	Cronbach α	AVE	CR
Search	S8	0.960	0.914	0.921	0.959
	S9	0.959			
Competence	CC10	0.841	0.687	0.760	0.863
	CC11	0.901			
Awareness	AW6	0.840	0.624	0.727	0.842
	AW7	0.864			
Learning	L21	0.892	0.700	0.627	0.829
	L22	0.876			
	L23	0.564			
Assess and Select	AST15	0.811	0.642	0.733	0.846
	AST16	0.899			
Acquisition	TA17	0.950	0.890	0.901	0.948
	TA18	0.949			
Linkage_1	EL24	0.789	0.836	0.753	0.901
	EL26	0.889			
	EL27	0.920			
Linkage_2	EL25	0.660	0.767	0.695	0.870

	EL28	0.909			
	EL29	0.908			
Technology Strategy	TS12	0.857	0.892	0.823	0.933
	TS13	0.954			
	TS14	0.909			
Technology Application	IT19	0.915	0.744	0.795	0.886
	IT20	0.867			

Table 1 shows that the Crobach Alpha for all the constructs range between 0.624 and 0.914 which meet the benchmark of 0.6 as suggested by Hair et al.[32]. In addition, the loadings for all reflective items are greater than the recommended value of 0.5 indicating convergent validity at the indicator level [35]. The AVE values are range between 0.627 and 0.921, which exceed the recommended value of 0.5, indicating convergent validity at the construct level. The CR values are range between 0.829 and 0.959, which exceed the recommended value of 0.7, indicating acceptable reliability.

Next, the discriminant validity was examined by comparing the square root of the AVE for the construct with the inter-construct correlations. As shown in Table 2, the square root of each AVE (shown on the diagonal) is greater than the related inter-construct (shown off the diagonal) in the construct correlation matrix, indicating adequate discriminant validity for all of the reflective constructs. As can be seen, all model evaluation criteria have been met, providing support for the measures of reliability and validity.

Table 2: Inter-construct correlations

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
acquisition	**0.949**									
application	0.815	**0.892**								
assess	0.748	0.750	**0.856**							
awareness	0.595	0.719	0.759	**0.853**						
competence	0.539	0.539	0.535	0.559	**0.872**					
learning	0.783	0.754	0.714	0.607	0.647	**0.792**				
linkage 1	0.410	0.460	0.450	0.543	0.246	0.430	**0.868**			
linkage 2	0.127	0.215	0.320	0.483	0.288	0.115	0.639	**0.834**		
search	0.619	0.784	0.804	0.827	0.545	0.774	0.431	0.211	**0.960**	
strategy	0.708	0.830	0.790	0.771	0.665	0.766	0.488	0.309	0.849	**0.907**

Note: Values in the on diagonal represent the square root of the AVE while the off diagonal represents the correlation

7.2 Hierarchical Component Model

Hierarchical component models (HCM) or higher order models most often involve testing second-order structures that contain two layers of components [33]. In addition, higher-order modeling involves summarizing the lower-order components (LOCs) which capture the sub dimensions of the abstract entity, into a single multidimensional higher-order construct (HOCs) which captures the more abstract entity [38]. As shown in Table 3, there are four HOCs and eight LOCs applied in this study.

Table 3: Hierarchical Component of Study

Lower-Order Components	Higher-Order Constructs
Competence	Human
Search	
Awareness	Organization
Learning	
Assess and select	Technology
Acquisition	
Internal Linkage	Information
External Linkage	

An HCM is characterized by reflective-formative relationship which indicates a formative relationship between the HOCs and the LOCs, whereby each of the constructs is measured by reflective indicators. To establish the HOCs' measurement model, Hair et al.[34] indicate that all the indicators from the LOCs should be assigned to the HOCs in the form of a repeated indicators approach. Number of indicators should be similar across the LOCs otherwise the relationships between the HOCs and LOCs may be significantly biased by the inequality of the number of indicators per LOC. Figure 1 provides the graphical presentation on the Hierarchical Component Model for this study.

Then, convergent validity of each HOCs' indicators should be determined first. According to Gholami et al.[32] all factor loadings should be statistically significant and standardized loading estimate should be 0.5 or higher. Next is to validate the formative measures, multicollinearity between indicators. Multicollinearity can be assessed by looking at the value of tolerance and variance inflation factor (VIF). Tolerance is an indicator of how much of the variability of the specified independent variable is not explained by the other independent variables in the model [40]. If this value is very small, it indicates that the multiple correlation with other variables is high (above 0.9), suggesting the possibility of multicollinearity. VIF, on the other hand, is the inverse of tolerance value.

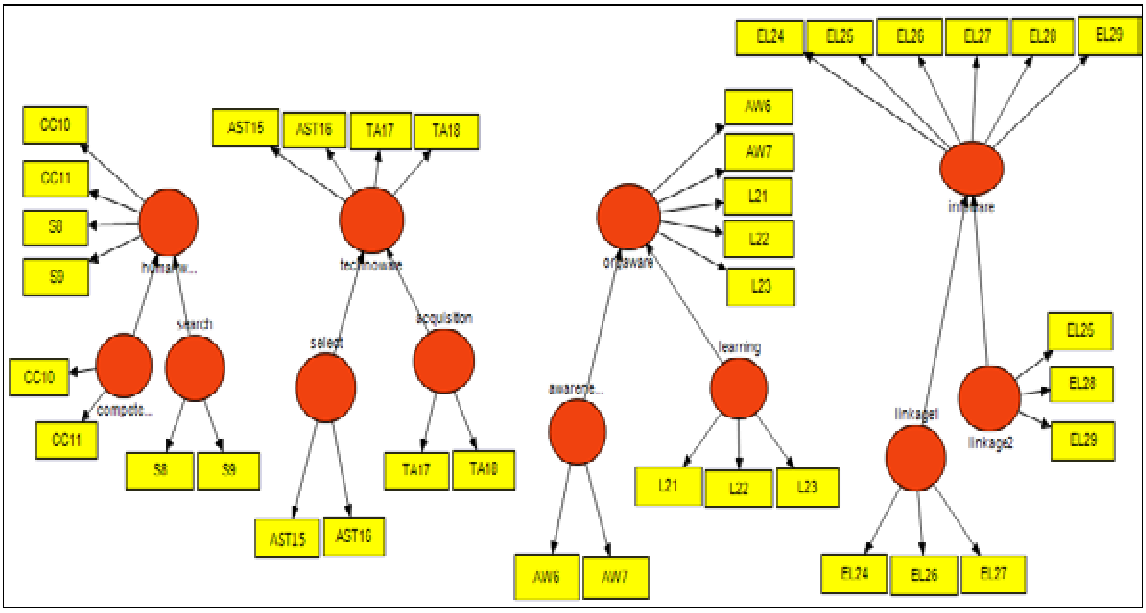


Figure 1: Hierarchical Component Model (Reflective-Formative Type)

In the context of PLS-SEM, a tolerance and VIF values of less than 0.2 and greater than 5.0 respectively indicate a potential collinearity problem [32]. These levels indicate that 80% of an indicator's variance is accounted for by the remaining formative indicators associated with the same construct.

As presented in Table 4 below, the results show that all the loadings of each HOCs' indicators are greater than recommended value of 0.5 except for indicator L23 (0.433), however, this indicator will not be deleted. In addition, the result of collinearity statistics shows that the tolerance values of all HOCs constructs are within the recommended value (greater than 0.2) indicate that the data has not violated the multicollinearity assumption. This is also supported by the VIF value which is below the cut-off of 5.0.

Table 4: Outer Loading, Tolerance and VIF for Hierarchical Component Model

Item	Construct	Weight	Tolerance	VIF
AST15	Technology	0.666	0.453	1.587
AST16		0.887		
TA17		0.903		
TA18		0.897		
CC10	Human	0.636	0.564	1.772
CC11		0.793		
S8		0.894		
S9		0.875		
EL24	Information	0.636	0.643	1.554
EL25		0.683		
EL26		0.877		
EL27		0.864		
EL28		0.756		
EL29		0.760		
AW6	Organization	0.711	0.630	2.206
AW7		0.767		
L21		0.749		
L22		0.909		
L23		0.431		

7.3 Correlation

The result of correlation matrix indicates that all the technology contents are significantly and positively correlated with technology strategy implementation at p-value of 0.000 ($p<0.05$) as presented in Table 5. In detail, the results show that human, technology, organization, and information are significantly and positively correlated with technology strategy implementation with a correlation value of 0.88, 0.798, 0.857, and 0.449 respectively. In addition, there is also a significant and positive relationship between technology strategy implementation with technology application when the analysis shows the correlation value of 0.839 at p-value of 0.000 ($p<0.05$).

Table 5: Correlation Matrix of All Variables

		H	T	O	I	TS	TA
Human (H)	Pearson	1					
	Sig. (2-tailed)						
Technology (T)	Pearson	0.781**	1				
	Sig. (2-tailed)	0.000					
Organization (O)	Pearson	0.915**	0.840**	1			
	Sig. (2-tailed)	0.000	0.000				
Information (I)	Pearson	0.372**	0.381**	0.473**	1		
	Sig. (2-tailed)	0.000	0.000	0.000			
Technology Strategy (TS)	Pearson	0.880**	0.798**	0.857**	0.449**	1	
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		
Technology Application (TA)	Pearson	0.785**	0.830**	0.883**	0.389**	0.839**	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	

*Correlation is significant at $p<0.05$ (2-tailed).

**Correlation is significant at $p<0.01$ (2-tailed).

7.4 Measuring Structural Model

After analysing the measurement model, the next step in a PLS analysis is to create a structural model by the inner model. To do this, the researcher first examined the path loadings between constructs to identify significance using computed T-statistics. To test the significance, all the data were run using 500 bootstrapped samples with 0 cases per sample. Table 6 presents the path coefficients (β), t-value, and significance for the structural model.

Table 6: Summary of the structural model

Hypothesis	Relationship	Std Beta (β)	SE	t-value	p-value	Decision
H1	Technology à Strategy	0.258	0.097	2.826**	0.002	Supported
H2	Human à Strategy	0.594	0.115	5.341**	0.000	Supported
H3	Information à Strategy	0.1	0.054	1.763*	0.039	Supported
H4	Organization à Strategy	0.051	0.199	0.277	0.391	Not Supported
H5	Strategy à Application of Tech	0.83	0.034	24.503**	0.000	Supported

**$p<0.01$, *$p<0.05$

As shown, four out of the five hypotheses were supported. Technology (β=0.258, $p < 0.01$), Human (β=0.594, $p < 0.01$), and Information (β=0.100, $p < 0.05$) were all positively predict the adoption and implementation technology strategy. Thus, H1, H2, and H3 were supported while H4 was not supported. On the other hand, the implementation of technology strategy positively related to the application of new technology (β=0.830, $p < 0.01$). This supports for H5 of this study. It also demonstrates that human has the strongest effect in predicting the implementation of technology strategy followed by technology and information.

In addition, Figure 2 provides the graphical presentation of the model with the explanatory power of the estimated model which can be assessed by observing the R^2 of the endogenous constructs. The R^2 values of 0.75, 0.50, or 0.25 for the endogenous constructs can be described as substantial, moderate, and weak [34]. Therefore, the R^2 value of technology strategy is 0.816 which indicates substantial while application of technology is 0.689 can be considered moderate. This study also revealed that approximate 82% of the variation in technology strategy adoption can be explained by all the technology content variables (Human, Organization, Information, and Technology) while approximate 69% of the variation in the new technology application can be explained by the implementation of technology strategy.

VIII. CONCLUSION

The findings obtained from this study reveal that there are strong relationships between the key technology content and technology strategy implementation as well as between technology strategy implementation and technology adoption and application. The results will guide industry players in selecting and applying new technology, hence make it competitive globally.

IX. ACKNOWLEDGEMENTS

The authors are thankful to the Ministry of Education Malaysia for financial support provided through the Fundamental Research Grant Scheme (FRGS).

REFERENCES

[1] Tai-Yue, W. and Shih-Chien, C., "The influences of technology development on economic performance - The example of ASEAN countries", Technovation. 27, 2007, 471-488.

[2] Reisman, A., Comparative technology transfer: A tale of development in neighbouring countries, Israel and Turkey Comparative Technology Transfer and Society. 3(3), 2005, 322-370.

[3] Lorentzen, J., Mollgaard, P., and Rojec, M.," Host-country absorption of technology: Evidence from automotive supply networks in Eastern Europe", Industry and Innovation. 10(4), 2003, 415-432.

[4] Van Wyk, R. 2004. Technology: A unifying code; A simple and coherent view of technology.SA:Stage Media Group.

[5] Dolinsek, S. and Strukelj, P., Technology, Wealth and Modern Management of Technology.Managing Global Transitions. 10(1), 2012, 29-49.

[6] Garcia-Muina, F. and Navas-Lopez, J., "Explaining and Measuring Success in New Business: The Effect of Technological Capabilities on Firm Results", Technovation. 27(1-2), 2007, 30-46.

[7] Marjolein C. and Romijn, H., Technological Learning in Small Enterprise Clusters:Conceptual Framework and Policy Implications, In: Mani, S. and Romijn, H. Eds. Innovation, Learning and Technological Dynamism of Developing Countries, UNU Press, Tokyo and New York, 2004, 135-157.

[8] Wang, E.T.G., Tai, J.C.F. and Wei, H.L., "A virtual integration theory of improved supply-chain performance", Journal of Management Information Systems. 13(2), 2006, 41-64.

[9] Kyriakou, D., Technology and sustainable growth: Towards a Synthesis, Technological Forecasting and Social Change. 69, 2002, 897–915.

[10] Sharif, N., The Evolution of Technology Management Studies: Techno-economics to Technometrics, Technology management: Strategies and applications for practitioners. 2(3), 1995, 113-148.

[11] Rush, H., Bessant, I. and Hobday, M., Assessing the technological capabilities of firms: Developing a policy tool. R&D Management. 37(3), 2007, 221-236.

[12] Lane, P., Salk, J. E., and Lyles, M. A., "Absorptive capacity, learning and performance in international joint ventures", Strategic Management Journal. 22(12), 2001, 1139-1157.

[13] Subramaniam, M. and Youndt, M.A, "The influence of intellectual capital on the types of innovative capabilities", Academy of Management Journal. 48, 2005, 450-463.

[14] Monappa, A. 2005. Liberalization and Human Resource Management: The new economic policy and human resource management. Challenges for the corporations of tomorrow. New Delhi: Sage Publication.

[15] Ashekele, H.M. and Matengu, K., Success factors in technology transfer to SME's: Rundu woodwork common facility center. Proceedings of the Portland International Conference on Management of Engineering & Technology 2008 (PICMET 2008),Cape Town, South Africa, 2008, 2190 – 2196.

[16] Mohamed, A. S., Sapuan, S. M., Megat Ahmad, M. M. H., Hamouda, A. M. S. and Hang Tuah, B. T., "The effect of technology transfer factors on performance: An empirical study of Libyan petroleum industry", American Journal of Applied Sciences. 6(9), 2009, 1763-1769.

[17] United Nations Commission, Technology transfer to small and medium enterprises and identifying opportunities for domestic and foreign direct investment in selected sector. Economic and Social Commission for Western Asia, 2005.

[18] Laursen, K. and Salter, A., Searching high and low : What types of firms use as a sourceof innovation? Research Policy. 33, 2004, 1201-1215.

[19] Bodas Freitas, I. M., Claussen, T, Fontana, R. and Verspagen, B., Formal and informal external linkages and firms' innovative strategy. A cross-country comparison. Paper presented at the Schumpeter Society Conference. Rio de Janeiro, 2008.

[20] Reichstein, T, and Salter, A., Investigating the sources of process innovation among UK manufacturing firms. Industrial and Corporate Change. 15(4), 2006, 653-682.

[21] Daft, R., Understanding the Theory and Design of Organizations. Mason, OH: Thomson South Western.

[22] Crossan, M.M. and Berdrow, I. 2003. "Organizational learning and strategic renewal", Strategic Management Journal. 24(11), 2007, 1087-1105.

[23] Fuchs, P.H., Mifflin, K.E. ,Miller, D. and Whitney, J.O., Strategic Integration: Competing in the age of capabilities. California Management Review. 42(3), 2000, 118-147.

[24] Beer, M., Voelpel, S.C., Leibold, M. and Tekie, E.B., Strategic management as organizational learning developing fit and alignment through a disciplined process. Long Range Planning. 38(5), 2005, 445-465.

[25] Zahra, S.A. and Bogner, W.C., "Technology strategy and software new ventures' performance: Exploring the moderating effect of the competitive environment", Journal of Business Venturing. 15(2), 1999, 135-173.

[26] Cooper, R.G. and Edgett, S.J., Developing a product innovation and technology strategy for your business. Research Technology Management. 53(3), 2010, 33-40.

[27] Sharma, S., "Technology strategy, contextual factors and business performance: An investigation of their relationship", South Asian Journal of Management. 15(3), 2008, 19-39.

[28] Hair, J. F., Anderson, R. E., Tatham, R. L., & Black, W. C., Multivariate data analysis. 6th ed. New Jersey: Prentice-Hall International Inc., 2006.

[29] Byrne, B.M., Structural Equation Modeling with AMOS: Basic concepts, applications and programming. Mahwah, NJ: Lawrence Erlbaum Associates, 2001.

[30] Ringle, C.M., Wende, S. and Will, A. 2005. SmartPLS 2.0 (beta), available at www.smartpls.de (assessed October, 2013).

[31] Sekaran, U., Research methods for business. A skill building approach. 4th ed. NY: John Wiley & Sons Inc., 2003.

[32] Gholami, R., Ainin, S., Ramayah, T. and Molla, A., "Senior manager's perception on green information system (IS) adoption and environmental performance: Results from a field survey", Information and Management Journal. 50, 2013, 431-438.

[33] Ringle, C.M., Sarstedt, M. and Straub, D.W., A critical look at the use of PLS-SEM. MIS Quarterly. 36, 2012, iii-xiv.

[34] Hair, J.F., Hult, G.T.M, Ringle, C.M. and Sarstedt, M., A primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). Thousand Oaks, California, 2013.

[35] Pallant, SPSS survival manual: A step by step guide to data analysis using SPSS. 4th ed. New York: McGraw Hill, 2010.

[36] Hair, J.F. Ringle, C.M. and Sarstedt, M., "PLS-SEM: Indeed a silver bullet", Journal of Marketing Theory and Practice. 19, 2011, 139-151.

Biographical Notes

Dr. Abdullah Ibrahim is working as a Professor in the Faculty of Engineering Technology, Universiti Malaysia Pahang, Malaysia.

Siti Aishah Md Hasan is presently pursuing PhD in the Faculty of Industrial Management, Universiti Malaysia Pahang, Malaysia.

APPROXIMATE LATERAL LOAD ANALYSIS OF TALL BUILDINGS- A COMPARATIVE STUDY

Nobin Samuel Philip[1], M.G. Rajendran[2]

[1]P.G Student, School of Civil Engineering Karunya University, Coimbatore, (India)

[2]Professor, School of Civil Engineering Karunya University, Coimbatore, (India)

ABSTRACT

For preliminary design of multistorey buildings, information regarding stress resultants due to lateral load are required even before arriving at member dimensions. Several alternatives have to be examined for arriving at member dimensions. Portal method and Cantilever method are commonly used for carrying out analysis as they do not require cross sectional dimensions. This paper discusses various other methods for approximate lateral load analysis of tall buildings. A 2D frame subjected to lateral load is chosen for the analysis. The results are then compared with exact solutions and the best alternative methods brought out. It is found that the methods discussed hereunder overcome the disadvantages of Portal method and Cantilever method. It is also highlighted that the solutions resulting from approximate methods are not realistic for those frames whose member dimensions are arbitrarily fixed without engineering judgement.

Keywords: Analysis, Approximate, Lateral load, Portal, Multistorey, Cantilever.

I. INTRODUCTION

Multistorey building design is an iterative procedure. The design is primarily governed by the lateral loads, viz., wind, earthquake and blast loads. For designing the columns, beams and beam-columns, to begin with knowledge regarding the stress resultants caused by these load is needed even before the cross sectional dimensions are known. Several alternatives have to be examined for evaluating best member dimensions. For arriving at the optimal member sizes, judicious choice of a method in preliminary analysis curtails the number of cycles facilitating easy reach of the final solution in one or two repetitions. Regular moment resisting framed building can be analysed as a plane frame building even though modern computers have the capability to perform three dimensional analyses. However, the restriction of computer use is that member properties (b, d, or I) and material properties i.e., Young’s modulus, Modulus of rigidity and Poisson’s ratio are necessary for use as input. Experienced analyst and architects will be in a position to predict member dimensions for the beams and columns. However, their estimation will be subjected to variation from time to time and may differ from person to person. In general, such empirical decisions may not be consistent. Hence, if a sound approximate method is used during early stages; personal errors will not creep in to the solution. To overcome these difficulties, preliminary analysis is adopted using the approximate methods. These approximate methods are based on some assumptions. For preliminary analysis of these frames subjected to lateral loads, approximate methods, i.e. portal and cantilever methods are used. The portal method is recommended for short frames and the cantilever method is advocated for tall frames. At present, there is no distinct guide line available to distinguish between tall and short frames. The analyst has to use his discretion to decide whether a given frame is tall or short.

II. OBJECTIVE

a) To analyze a multistorey frame subjected to lateral load by seven approximate methods.

b) To compare the results thus obtained and bring out the best method.

III. PROBLEM

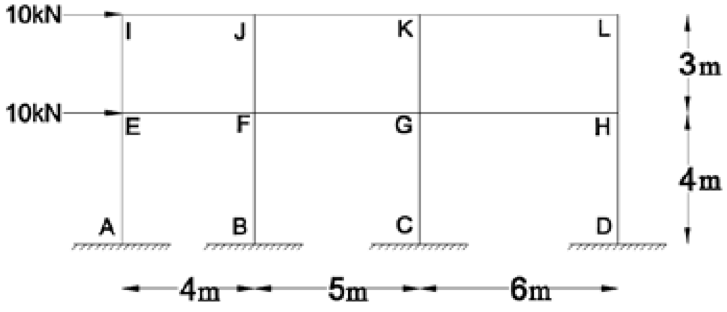


Figure 1: Frame Subjected To Lateral Load

IV. METHODOLOGY

4.1 Approximate Lateral Load Analysis by Load Index

A tentative assumption is made for the load distribution. The distribution of the load is shown in figure 2. The storey shear P is distributed between the rectangle and the parabola. For this purpose a parameter known as "load index" denoted as RXP is used. RXP means the rectangular portion carries X percent of total storey shear P. For example, R75P indicates, the rectangular section carries 75% of total storey shear P and 25% carries by the parabola. In the present study, three levels of load percentages are considered. They are R100P, R75P and R50P.

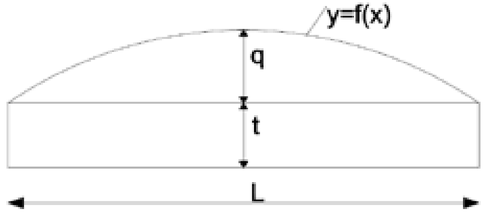


Figure 2: Distribution of Storey Shear

Procedure

a) Storey which consist of n bays is split into n aisles each carrying nodal load T_i.

b) Find the maximum ordinate for rectangle and parabola based on load index RXP

For rectangle

$txL=X\%$ of P

For parabola

$\frac{2}{3}qL=(100-X)\%$ of P

c) Calculate the nodal load for each aisle T_i.

$T_{1r} = \int_{li}^{li+1} f(x)\, dx$

$T_{1q} = \int_{li}^{li+1} f(x)\, dx$

$T_1 = T_{1r} + T_{1q}$

d) Calculate the column shear

$V_1 = 0.5T_1$

$V_2 = 0.5(T_1 + T_2)$

$V_3 = 0.5(T_2 + T_3)$

$V_4 = 0.5T_3$

e) Calculate the column terminal moment by multiplying column shear with lever arm.

f) Compute beam end moment by moment equilibrium i.e, sum of column moment at a joint is equal to the sum of beam end moment at the same joint.

Table 1: Comparison of Results of Load Index Method and Exact Analysis for Column Moments

Member (columns)	R100P kNm	R75P kNm	R50P kNm	Exact Analysis	Error% R100P	Error% R75P	Error% R50P
AE	5.33	4.88	4.42	6.48	17.75	11.75	31.79
EA	5.33	4.88	4.42	5.53	3.62	7.20	20.07
BF	12.0	12.24	12.48	13.19	9.02	6.25	5.38
FB	12.0	12.24	12.48	11.52	4.17	6.49	8.33
CG	14.67	15.12	15.58	16.17	9.28	9.96	3.65
GC	14.67	15.12	15.58	13.75	6.69	24.88	13.30
DH	8.0	7.76	7.52	10.33	22.56	18.49	27.20
HD	8.0	7.76	7.52	9.52	15.97	39.69	21.00
EI	2.03	1.83	1.66	1.31	54.96	24.07	26.72
IE	2.03	1.83	1.66	2.41	15.77	32.28	31.12
FJ	4.5	4.59	4.68	3.47	29.68	13.72	34.87
JF	4.5	4.59	4.68	5.32	15.41	69.76	12.03
GK	5.51	5.67	5.84	3.34	64.97	10.14	74.85
KG	5.51	5.67	5.84	6.31	12.67	21.56	7.45
HL	3.0	2.91	2.82	3.71	19.14	24.02	23.99
LH	3.0	2.91	2.82	3.83	21.67	11.75	26.37

R100P	R75P	R50P
Mean=15.63	Mean=14.52	Mean=16.29
SD= 7.31	SD= 7.22	SD=8.53

Table 2: Comparison of Results of Load Index Method and Exact Analysis for Beam Moments

Member (beams)	R100P kNm	R75P kNm	R50P kNm	Error % R100P	Error % R75P	Error% R50P
EF	7.36	6.71	6.08	7.60	1.90	11.11
FE	7.36	6.71	6.08	12.2	2.29	7.31
FG	9.14	10.12	11.08	8.42	20.05	31.43
GF	9.14	10.12	11.08	3.28	14.35	25.19
GH	11.03	10.67	10.34	6.06	2.6	0.57
HG	11.03	10.67	10.34	3.08	0.28	3.36
IJ	2.03	1.83	1.66	15.77	24.07	31.12
JI	2.03	1.83	1.66	14.71	23.11	30.25
JK	2.47	2.76	3.02	15.7	5.80	3.07
KJ	2.47	2.76	3.02	13.64	3.5	5.59
KL	3.03	2.91	2.82	15.36	18.72	21.22
LK	3.03	2.91	2.82	29.21	32.1	34.11

R100P	R75P	R50P
Mean=10.53	Mean=10.6	Mean=11.97
SD= 4.75	SD= 9.02	SD=10.22

4.2 Split Frame Method for Short Frames

Procedure:

a) The frame is split into n number of single bay frames each carrying nodal load R_i.

b) Find the areas of column in proportion to the tributary length and combined areas of two column of each split frame.

c) Compute the nodal load by

$R_i = \frac{R}{A} Q_i$

d) Compute the column shear of split frame. Since the hinge occur in the middle of beam, shear in column of any storey in a split frame will be same.

e) Calculate column terminal moment and beam terminal moment of all split frames.

f) To get back to the original structure, all the split frames are added.

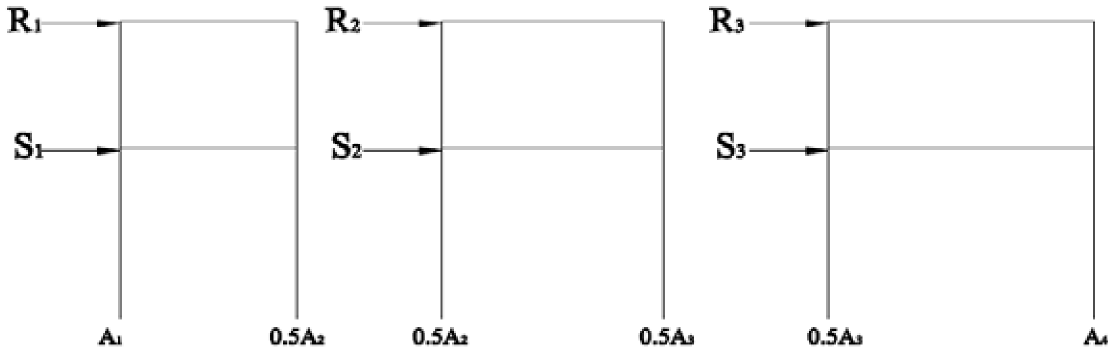


Fig 3: Split Frame with Nodal Load

Table 3: Comparison of Results of Split Frame Method for Short Frames and Exact Analysis

Members Beam	Split Frame Method (kNm)	Exact Analysis (kNm)	Error %
EF	7.77	6.84	13.59649
FE	7.77	6.56	18.44512
FG	9.185	8.43	8.956109
GF	9.185	8.85	3.785311
GH	10.56	10.4	1.538462
HG	10.56	10.7	1.308411
IJ	2.13	2.41	11.61826
JI	2.13	2.38	10.5042
JK	2.505	2.93	14.50512
KJ	2.505	2.86	12.41259
KL	2.88	3.58	19.55307
LK	2.88	4.28	32.71028

Members columns	Split frame method(kNm)	Exact Analysis (kNm)	Error %
AE	5.64	6.48	12.962
EA	5.64	5.53	1.98915
BF	12.32	13.19	6.595906
FB	12.32	11.52	6.944444
CG	14.36	16.17	11.19357
GC	14.36	13.75	4.436364
DH	7.68	10.33	25.65344
HD	7.68	9.52	19.32773
EI	2.13	1.31	62.59542
IE	2.13	2.41	11.61826
FJ	4.64	3.47	33.71758
JF	4.64	5.32	12.78195
GK	5.39	3.34	61.37725
KG	5.39	6.31	14.58003
HL	2.88	3.71	22.37197
LH	2.88	3.83	24.80418

Columns	Beams
Mean=11.5	Mean=10.6
SD= 7.62	SD= 5.94

4.3 Split Frame Method for Tall Frames

Procedure:

a) The frame is split into n number of single bay frames each carrying nodal load R_i.

b) Compute the nodal load R_i based on strength and displacement concept.

Displacement Concept:

$$\frac{R_1}{l_1^2}=\frac{R_2}{l_2^2}=\frac{R_3}{l_3^2}=\frac{P}{l_1^2+l_2^2+l_3^2}$$

Strength Concept:

$$\frac{R_1}{l_1}=\frac{R_2}{l_2}=\frac{R_3}{l_3}=\frac{P}{l_1+l_2+l_3}$$

c) The final nodal load is taken as the average of the two values.

d) Compute the column shear of split frame. Since the hinge occur in the middle of beam, shear in column of any storey in a split frame will be same.

e) Calculate column terminal moment and beam terminal moment of all split frames.

f) To get back to the original structure, all the split frames are added.

Table 4: Comparison of Results of Split Frame Method for Tall Frames and Exact Analysis

Members Columns	Split frame method(kNm)	Exact Analysis (kNm)	Error %
AE	4.74	6.48	26.85185
EA	4.74	5.53	14.28571
BF	11.32	13.19	14.17741
FB	11.32	11.52	1.736111
CG	15.24	16.17	5.751391
GC	15.24	13.75	10.83636
DH	8.66	10.33	16.16651
HD	8.66	9.52	9.033613
EI	1.78	1.31	35.87786
IE	1.78	2.41	26.14108
FJ	4.25	3.47	22.47839
JF	4.25	5.32	20.11278
GK	5.72	3.34	71.25749
KG	5.72	6.31	9.350238
HL	3.25	3.71	12.39892
LH	3.25	3.83	15.1436

Members beam	Split Frame Method (kNm)	Exact Analysis (kNm)	Error %
EF	6.52	6.84	4.678363
FE	6.52	6.56	0.609756
FG	9.05	8.43	7.354686
GF	9.05	8.85	2.259887
GH	11.91	10.4	14.51923
HG	11.91	10.7	11.30841
IJ	1.78	2.41	26.14108
JI	1.78	2.38	25.21008
JK	2.47	2.93	15.69966
KJ	2.47	2.86	13.63636
KL	3.25	3.58	9.217877
LK	3.25	4.28	24.06542

Columns	Beams
Mean=13.45	Mean=12.89
SD= 7.16	SD= 8.37

4.4 Variable Beam Shear Method

Procedure

a) Beam shear is proportioned according to bay length in terms of x.

$l_1 x : l_2 x : l_3 x$

b) Column shear is then written by joint equilibrium condition in terms of x.

Column shear=$\frac{Sum\ of\ beam\ moment\ at\ a\ joint}{Lever\ arm}$

c) The unknown value x is found by storey condition of the storey.

Sum of column shear = Storey shear.

d) Compute column shear and beam shear and column moment is then obtained by multiplying column shear with the lever arm.

Table 5: Comparison of Results of Variable Beam Shear Method and Exact Analysis

Members beam	Variable Beam Shear(kNm)	Exact Analysis (kNm)	Error %
EF	5.7136	6.84	16.46784
FE	5.7136	6.56	12.90244
FG	8.9275	8.43	5.901542
GF	8.9275	8.85	0.875706
GH	12.8556	10.4	23.61154
HG	12.8556	10.7	20.14579
IJ	1.58	2.41	34.43983
JI	1.58	2.38	33.61345
JK	2.435	2.93	16.8942
KJ	2.435	2.86	14.86014
KL	3.5064	3.58	2.055866
LK	3.5064	4.28	18.07477

Members columns	Variable Beam Shear(kNm)	Exact Analysis (kNm)	Error %
AE	4.15	6.48	35.95679
EA	4.15	5.53	24.95479
BF	10.65	13.19	19.25701
FB	10.65	11.52	7.552083
CG	15.84	16.17	2.040816
GC	15.84	13.75	15.2
DH	9.35	10.33	9.486931
HD	9.35	9.52	1.785714
EI	1.56	1.31	19.08397
IE	1.56	2.41	35.26971
FJ	3.99	3.47	14.98559
JF	3.99	5.32	25
GK	5.94	3.34	77.84431
KG	5.94	6.31	5.863708
HL	3.51	3.71	5.390836
LH	3.51	3.83	8.355091

Columns	Beams
Mean=11.45	Mean=13.18
SD= 7.5	SD= 7.33

4.5 Stationary Beam Shear Method

This method is suitable for short frame whose height-width ratio is less than five. Since the frame is short, panel distortion occurs due to shearing action. Hence the bending action is very small and axial deformation in the interior columns will be negligible. Therefore it is assumed that axial forces in the interior columns are zero. This is the key assumption which facilitates the analysis to be performed in a simple manner.

Assumptions:

a) Hinges occur in the middle of all the beams.

b) In the top most storey, hinges occur in the columns at 0.55h from top where h is the height of the storey.

c) In the bottom most storey, hinges occur in the columns at 0.55h from bottom where h is the height of the storey.

d) Axial forces in the interior columns are zero. From this assumption it is stated that in any horizontal plane passing through the hinges of the columns, the overturning moment produced by lateral load is resisted by couple produced by the axial forces in the two outer exterior columns. Because of this shear in all beams in a storey is same.

Procedure:

a) Compute moment in each storey due to storey shear and find the axial force in outer column of each storey by

Axial force in outer column = $\frac{\textit{Moment in each storey}}{\textit{Total bay length}}$

b) Compute the beam shear of each storey.

c) Calculate the beam terminal moment by multiplying beam shear with lever arm.

d) Compute column shear by moment equilibrium at a joint

Column shear= $\frac{\text{Sum of beam moment at a joint}}{\text{Lever arm}}$

e) Calculate column terminal moment by multiplying column shear with lever arm.

Table 6: Comparison of Results of Stationary Beam Shear Method and Exact Analysis

Members beam	Stationary Beam Shear(kNm)	Exact Analysis (kNm)	Error %
EF	6.6	6.84	3.508772
FE	6.6	6.56	0.609756
FG	8.25	8.43	2.135231
GF	8.25	8.85	6.779661
GH	9.9	10.4	4.807692
HG	9.9	10.7	7.476636
IJ	2.2	2.41	8.713693
JI	2.2	2.38	7.563025
JK	2.75	2.93	6.143345
KJ	2.75	2.86	3.846154
KL	3.3	3.58	7.821229
LK	3.3	4.28	22.8972

Columns	Beams
Mean=11.5	Mean=10.6
SD= 7.62	SD= 5.94

Member columns	Stationary Beam Shear (kNm)	Exact Analysis (kNm)	Error %
AE	5.872	6.48	9.38271
EA	4.8	5.53	13.2007
BF	13.2	13.19	0.07581
FB	10.8	11.52	6.25
CG	16.13	16.17	0.24737
GC	13.19	13.75	4.07272
DH	8.8	10.33	14.8112
HD	7.2	9.52	24.3697
EI	2.195	1.31	67.5572
IE	1.795	2.41	25.5186
FJ	4.05	3.47	16.7147
JF	4.95	5.32	6.95488
GK	4.954	3.34	48.3233
KG	6.05	6.31	4.12044
HL	2.7	3.71	27.2237
LH	3.3	3.83	13.8381

4.6 Distribution of Shear to Column for Short Multistorey Frames

Procedure:

a) Split the given frame into n number of single bay frames each carrying nodal load $R_{i.}$

b) Calculate the proportion based on Theorem 1 and Theorem 2

Theorem 1:

$$\frac{R_1}{(h+l_1)} : \frac{R_2}{(h+l_2)} : \frac{R_3}{(h+l_3)}$$

Theorem 2:

$$\frac{R_1}{l_1} \quad \frac{R_2}{l_2} \quad \frac{R_3}{l_3}$$

c) The storey shear is then distributed as nodal load for each split frame by taking the average of the above two proportions.

d) Knowing the value of R_i, shear in each column in any floor is found by just halving the shear force at the level of column hinges.

e) Compute column terminal moment by multiplying column shear with lever arm.

f) Beam end moment is calculated by applying moment equilibrium at a joint i.e, sum of column moment at a joint is equal to sum of beam moment at same joint.

Table 7: Comparison of Results of Distribution of Shear Method and Exact Analysis

Members Beam	Distribution of shear to column(kNm)	Exact Analysis (kNm)	Error %
EF	7.65	6.84	11.84211
FE	7.65	6.56	16.61585
FG	9.16	8.43	8.659549
GF	9.16	8.85	3.502825
GH	10.73	10.4	3.173077
HG	10.73	10.7	0.280374
IJ	2.09	2.41	13.27801
JI	2.09	2.38	12.18487
JK	2.5	2.93	14.67577
KJ	2.5	2.86	12.58741
KL	2.93	3.58	18.15642
LK	2.93	4.28	31.54206

Columns	Beams
Mean=13.26	Mean=10.45
SD= 6.99	SD= 5.32

Members columns	Distribution of shear to column(kNm)	Exact Analysis (kNm)	Error %
AE	5.56	6.48	14.19753
EA	5.56	5.53	0.542495
BF	12.22	13.19	7.354056
FB	12.22	11.52	6.076389
CG	14.47	16.17	10.5133
GC	14.47	13.75	5.236364
DH	7.8	10.33	24.49177
HD	7.8	9.52	18.06723
EI	2.09	1.31	59.54198
IE	2.09	2.41	13.27801
FJ	4.59	3.47	32.27666
JF	4.59	5.32	13.7218
GK	5.43	3.34	62.57485
KG	5.43	6.31	13.94612
HL	2.93	3.71	21.02426
LH	2.93	3.83	23.49869

4.7 Factor Method

The factor method is more accurate than either the portal method or the, cantilever method. The portal method and cantilever method depend on assumed location of hinges and column shears whereas the factor method is based on assumptions regarding the elastic action of the structure. For the application of Factor method, the relative stiffness (k = I/l), for each beam and column should be known or assumed, where, I is the moment of inertia of cross section and l is the length of the member

Procedure:

a) The girder factor g, is determined for each joint from the following expression.

$$g = \frac{\Sigma k_c}{\Sigma k}$$

where, Σk_c - Sum of relative stiffness of the column members meeting at that joint.

Σk - Sum of relative stiffness of all the members meeting at that joint.

Each value of girder factor is written at the near end of the girder meeting at the joint.

b) The column factor c, is found for each joint from the following expression

c = 1-g

Each value of column factor c is written at the near end of each column meeting at the joint. The column factor for the column fixed at the base is one. At each end of every member, there will be factors from step (a) or step (b). To these factors, half the values of those at the other end of the same member are added.

c) The sum obtained as per step (b) is multiplied by the relative stiffness of the respective members. This product is termed as column moment factor C, for the columns and the girder moment factor G, for girders.

d) Calculation of column end moments for a typical member ij - The column moment factors [C values] give approximate relative values of column end moments. The sum of column end moments is equal to horizontal shear of the storey multiplied by storey height. Column end moments are evaluated by using the following equation,

Mij = Cij A

where, Mij - moment at end i of the ij column

Cij - column moment factor at end i of column ij

A - storey constant given by

$$A=\frac{\text{Horizontal Shear} \times \text{Height of storey}}{\text{Sum of column end moment factor of the storey}}$$

e) Calculation of beam end moments - The girder moment factors [G values] give the approximate relative beam end moments. The sum of beam end moments at a joint is equal to the sum of column end moments at that joint. Beam end moments can be worked out by using following equation,

Mij= GijB

where, Mij - moment at end i of the ij beam

Gij- girder moment factor at end i of beam ij

B - joint constant given by

$$B=\frac{\text{Sum of column moments at that joint}}{\text{Sum of the girder end moment factors of that joint}}$$

Table 8: Comparison of Results of Factor Method and Exact Analysis

Members Beam	Factor Method (kNm)	Exact Analysis (kNm)	Error %
EF	6.914	6.84	1.081871
FE	6.371	6.56	2.881098
FG	8.07	8.43	4.270463
GF	8.628	8.85	2.508475
GH	9.36	10.4	10
HG	9.978	10.7	6.747664
IJ	2.197	2.41	8.838174
JI	2.057	2.38	13.57143
JK	2.613	2.93	10.81911
KJ	2.686	2.86	6.083916
KL	2.85	3.58	20.39106
LK	3.095	4.28	27.68692

Columns	Beams
Mean=13.23	Mean=7.93
SD= 7.36	SD= 5.16

Members columns	Factor Method (kNm)	Exact Analysis (kNm)	Error %
AE	6.17	6.48	4.783951
EA	4.867	5.53	11.98915
BF	12.504	13.19	5.20091
FB	10.06	11.52	12.67361
CG	15.567	16.17	3.729128
GC	15.805	13.75	14.94545
DH	10.904	10.33	5.556631
HD	7.118	9.52	25.23109
EI	2.047	1.31	56.25954
IE	2.197	2.41	8.838174
FJ	4.388	3.47	26.45533
JF	4.67	5.32	12.21805
GK	5.185	3.34	55.23952
KG	5.55	6.31	12.04437
HL	2.86	3.71	22.91105
LH	3.095	3.83	19.1906

4.8 K Values Method

Computer solutions are based on member cross sectional dimensions. The principal use of this method is to furnish answers to check the computer solution. Secondly any two storeys can be analyzed independent of the other storeys. This is a significant advantage of this method. The K-values method is based on relative I/l values. In case of frame the shear carried by each column is directly proportional to its K value, when beam are assumed to be infinitely rigid. Assumptions regarding hinge formations are same as that of in stationary beam shear method.

Procedure

a) 25% of storey shear is distributed among beams in proportion to their K values. Each value in the bay is then equally divided between 2 columns in the bay.

b) Remaining 75% of storey shear is distributed among columns in proportion to their K values.

c) Column shear is then computed by adding the above two contribution in each column.

d) Column terminal moment is obtained by multiplying column shear with lever arm.

e) Beam moments are obtained by moment equilibrium at a joint, i.e sum of column terminal moment at a joint should be equal to the sum of beam moment at the same joint.

Table 9: Comparison of Results of K Values Method and Exact Analysis

Members Beam	K Values Method (kNm)	Exact Analysis (kNm)	Error %
EF	6.746	6.84	1.374269
FE	5.33	6.56	18.75
FG	8.54	8.43	1.304864
GF	7.995	8.85	9.661017
GH	9.99	10.4	3.942308
HG	10.8795	10.7	1.67757
IJ	2.245	2.41	6.846473
JI	2.044	2.38	14.11765
JK	2.575	2.93	12.11604
KJ	2.664	2.86	6.853147
KL	3.33	3.58	6.98324
LK	3.62	4.28	15.42056

Columns	Beams
Mean=9.01	Mean=8.25
SD= 4.98	SD= 5.59

Members columns	K Values Method (kNm)	Exact Analysis (kNm)	Error %
AE	5.997	6.48	7.453704
EA	4.906	5.53	11.28391
BF	12.342	13.19	6.429113
FB	10.098	11.52	12.34375
CG	15.99	16.17	1.113173
GC	13.08	13.75	4.872727
DH	9.677	10.33	6.321394
HD	7.9176	9.52	16.83193
EI	1.84	1.31	40.45802
IE	2.245	2.41	6.846473
FJ	3.78	3.47	8.933718
JF	4.62	5.32	13.15789
GK	4.91	3.34	47.00599
KG	5.995	6.31	4.992076
HL	2.962	3.71	20.16173

V. DISCUSSIONS

The different approximate methods are compared with the exact analysis done by slope deflection method. For a linearly elastic structure, exact analysis is one which satisfies both equilibrium and compatibility conditions. On other hand, approximate methods used in lateral analysis fulfill only equilibrium requirement. If the assumptions used in the approximate analysis regarding hinge and shear force or axial force coincide with that of the hinge positions and hinge conditions of the exact method then both results will be alike. Theoretically there can be innumerable frames with different member cross sectional dimensions but with same structure dimensions and loading. The exact solution of each frame will be different even though the structure dimensions and loading are same. On the other hand the approximate solution will give only one solution which will closely match with only one of the exact solution. In general multistorey building design is an iterative process. Several trials are needed before arriving at the final dimensions of the members for a given structure dimensions and prescribed loading. A practical frame is arrived after satisfying serviceability and strength criteria. It is found that for such a practical frame the approximate method yield reasonable solution. Therefore the method will fail if applied to a frame in which the member dimensions are fixed in an arbitrary manner.

The simplified portal method is based on the assumption that axial forces in the interior columns are zero. The flaw of this method is that it predicts same magnitude of beam terminal moment in all the bays of storey which is contrary to the expectations. Thus moderate magnitude of axial force is produced in inner columns which is contrary to the assumptions. This two flaws are rectified in the methods described for short frames. In load index method, the results of load index R100P is almost close with the results obtained in improved portal method. Also the results of load index R50P is almost close with the results obtained by cantilever method.

VI. CONCLUSIONS

a) The different load index from load index method have been implemented for analyzing the following type of frame.
b) R100P- Short frames.
c) R75P- Medium rise frames.
d) R50P- Tall frames.

e) The results obtained by split frame method for short frames and split frame method for tall frames are in harmony with the solution of improved portal method and cantilever method respectively. This method does not involve much computational effort. For tall building it is better to deal with shear force as done in split frame method than axial forces in cantilever method which is prone to mistakes.

f) Variable beam shear method and stationary beam shear method can be used as a supplement method to overcome the disadvantage of simplified portal method.

g) K values method can be used for checking the solution obtained by computer analysis.

h) Approximate method solutions will fail for those frames whose member dimensions are arbitrarily fixed.

VII. ACKNOWLEDGEMENT

The authors are thankful to the management of Karunya University for providing necessary facilities to carry out the work reported above.

REFERENCES

[1] V.K Manicka Selvam, 'Multistorey buildings and yield line analysis of slabs', 1991.
[2] Bryan Stafford Smith and Alex Coull, "Tall building structures- Analysis and Design", 1991.
[3] V.K Manicka Selvam and K.R Bindhu, "Split frame method for the analysis of tall moment resisting frames subjected to lateral loads", International Journal of Civil and Structural Engineering, Vol. 4, No. 3, 2013, page 237-247.
[4] V.K Manicka Selvam and K.R Bindhu, "Split frame method for lateral load analysis of short frames", International Journal of Civil and Structural Engineering, Vol. 1, No. 4, 2011, page 835-843.
[5] V.K Manicka Selvam and K.R Bindhu, "Distribution of shear to the columns of short multistorey building frames subjected to lateral loads", International Journal of Civil and Structural Engineering, Vol. 2, No. 3, 2012, page 708-719.
[6] V.K Manicka Selvam and K.R Bindhu, "A novel general approximate method for lateral load analysis of multistorey building frames", International Journal of Earth Sciences and Engineering, Vol. 4, No. 1, 2011, page 104-111.

APPLICATION OF DIFFERENTIAL TRANSFORMATION METHOD FOR STABILITY ANALYSIS OF EULER BERNOULLI COLUMN

Muralikrishnan.K[1], C.S.C. Devadass[2], M.G. Rajendran[3]

[1] *P. G. Student, School of Civil Engineering Karunya University, Coimbatore, (India)*
[2, 3] *Professor, School of Civil Engineering Karunya University, Coimbatore, (India)*

ABSTRACT

In this paper, a relatively new approach called the Differential Transformation Method (DTM) is applied for stability analysis of Euler- Bernoulli column with uniform cross section. Buckling loads are calculated for different cases of boundary conditions. MATLAB code has been developed to solve the differential equation of the column using the Differential Transformation Method. It is found that the buckling loads for all the boundary conditions are in excellent agreement with published results.

Keywords: Differential Transformation Method, Eigen Value Problem, Euler Bernoulli Column, Stability Analysis, Taylor Series

I. INTRODUCTION

Many problems in science and engineering fields can be described by the partial differential equations. A variety of numerical and analytical methods has been developed to obtain accurate/ approximate solutions for the problems in the literature. The classical Taylor series method is one of the earliest analytic techniques to solve many problems, especially ordinary differential equations. However, since it requires a lot of symbolic calculations for the derivatives of functions, it takes a lot of computational time for higher order derivatives. Here, an updated version of the Taylor series method which is called the differential transform method (DTM) is introduced.

This method is useful to obtain the solutions of linear and nonlinear differential equations. There is no need to linearization or discretization. Large computational work and round-off errors are avoided. It has been used to solve effectively, easily and accurately a large class of linear and nonlinear problems with approximations.

For problems of complex nature, the exact solution cannot be obtained or is hard to obtain. In such cases, approximation method is resorted. But by applying differential transformation method, even for the complex problems, the exact solution can be obtained. The method is capable of modeling any beam whose cross-sectional area and moment of inertia vary along its length. Hence DTM can be effectively used in most of engineering applications.

DTM was first used by Zhou(1) to solve both linear and nonlinear initial value problems in electric circuit analysis. C.K chen(2) solved eigen value problems using DTM. Narhari Patil1 and Avinash Khambayat(3) used Differential Transform Method for system of Linear Differential Equations. Ülker Erdönmez, Ibrahim Özkol(5) solved Optimal shape analysis of a column structure under various loading conditions by using differential transform method. Chai, Y.H.; Wang, C.M(9) done stability analysis of heavy columns using DTM.

In this paper the stability analysis of uniform Euler Bernoulli columns has been done by using DTM and the buckling loads for various boundary conditions have been found.

II. DIFFERENTIAL TRANSFORMATION METHOD

In order to solve Eigenvalue problem by differential transformation its basic theory is started in brief in the section the differential transformation of the k^{th} derivative of function Y(x) is defined as follows,

$$Y(K) = \frac{1}{k!}\left[\frac{d^k Y(x)}{dx^k}\right] x = x_0 \tag{2.1}$$

In eq. (1) Y(x) is the original function and Y(K) is the transformed function, which is called the T- function in brief.

The differential inverse transformation of Y (k) is defined as follows:

$$y(x) = \sum_{k=0}^{\infty} Y(K)\,(x - x_0)^k \tag{2.2}$$

Combining Eqs. (1) and (2), we have

$$Y(K) = \sum_{k=0}^{\infty} \frac{(x-x_0)^k}{k!}\left[\frac{d^k Y(x)}{dx^k}\right] x = x_0 \tag{2.3}$$

Eqn (2.2) is the Taylor series of y(x) at x = x_0 Thus eq. (2.3) implies that the concept of differential transformation is derived from the Taylor series expansion. In this study lower-case letters are used to represent the original functions and upper-case letters to stand for the transformed functions (T functions).

From definitions of (2.1) and (2.2), it is very easy to prove that the transformed functions comply with the following basic mathematic operations. . It is easy to prove that the transformed functions comply with the basic

mathematical operations as shown in Table -1

Table-1 Some Basic Mathematical Operations of DTM

Original Function	*Transformed Function*	
$w(x) = y(x) \mp z(x)$	$W(k) = Y(k) \mp Z(k)$	(2.4)
$z(x) = \lambda y(x)$	$Z(k) = \propto Y(k)$	(2.5)
$w(x) = y(x)\,z(x)$	$W(k) = \sum_{l=0}^{k} Y(l)Z(k-l)$	(2.6)
$z(x) = \frac{dy(x)}{dx}$	$Z(k) = (k+1)Y(k+1)$	(2.7)
$w(x) = \frac{d^m y(x)}{dx^m}$	$W(k) = (k+1)(k+2)..(k+m)Y(k+m)$	(2.8)
$w(x) = x^m$	$W(k) = \delta(k-m) = \begin{cases} 1 & k = m \\ 0 & k \neq m \end{cases}$	(2.9)

In real applications, the function y(x) is expressed by a finite series and (2.2) can be written as

$$y(x) = \sum_{k=0}^{n} x^k Y(k) \tag{2.10}$$

Equation (2.10) implies that $\sum_{k=n+1}^{\infty} x^k Y(k)$ is negligibly small. In fact, n is decided by the convergence of the Eigen value in this study

III. BUCKLING OF EULER- BERNOULLI COLUMN

Consider a homogeneous column with flexural rigidity El, length L and end axial compressive load P. The governing Euler column buckling equation is given by,

$$EI\frac{d^4v}{dx^4} + \lambda\frac{d^2v}{dx^2} = 0\,, \quad \lambda = \frac{Pl^2}{EI} \tag{3.1}$$

Where, $x = \frac{x}{l}$ a non-dimensional co-ordinate varying from 0to 1

ie,

$$\frac{d^4v}{dx^4} = -\lambda^2\frac{d^2v}{dx^2} \tag{3.2}$$

DT of eq (3.2) is written as

$$\mathrm{V}\,(\mathrm{K}+4) = \frac{-\lambda^2\,(\mathrm{K}+1)\,(\mathrm{K}+2)\,\mathrm{V}\,(\mathrm{K}+2)}{(\mathrm{K}+1)\,(\mathrm{K}+2)\,(\mathrm{K}+3)\,(\mathrm{K}+4)} \tag{3.3}$$

3.1 Simply Supported At Both the Ends

The boundary conditions are v(0)=0 ; v”(0)=0 ; v(1)=0 ; v”(1)=0 (3.1.1)

The DT equivalents are

V[0]=0 ; V[1]=c ; V[2]=0 ; V[3]=d (3.1.2)

v(1)=0 leads to $\sum_{k=0}^{\infty} V(k) = 0$ (3.1.3)

v”(1)=0 leads to $\sum_{k=0}^{\infty} k(k-1)V(k) = 0$ (3.1.4)

By solving these equations, for a column with simply supported ends λ =9.86

That is buckling load for a column with simply supported ends is, $\mathrm{P} = \frac{9.86EI}{L^2}$

which agrees with closed form value.

3.2 Fixed and Roller Support

The boundary conditions are v(0)=0 ; v”(0)=0 ; v(1)=0 ; v’(1)=0 (3.2.1)

The DT equivalents are

V[0]=0 ; V[1]=c ; V[2]=0 ; V[3]=d (3.2.2)

v(1)=0 leads to $\sum_{k=0}^{\infty} V(k) = 0$ (3.2.3)

v’(1)=0 leads to $\sum_{k=0}^{\infty} kV(k) = 0$ (3.2.4)

By solving these equations, for a column with fixed and roller ends λ =20.19

That is buckling load for a column with fixed and roller ends is, $\mathrm{P} = \frac{20.19EI}{L^2}$

which agrees with closed form value.

3.3 Both End Fixed

The boundary conditions are v(0)=0 ; v'(0)=0 ; v(1)=0 ; v'(1)=0 (3.3.1)

The DT equivalents are

V[0]=0 ; V[1]=0 ; V[2]=c ; V[3]=d (3.3.2)

v(1)=0 leads to $\sum_{k=0}^{\infty} V(k) = 0$ (3.3.3)

v'(1)=0 leads to $\sum_{k=0}^{\infty} kV(k) = 0$ (3.3.4)

By solving these equations, for a column with fixed ends λ=39.47

That is buckling load for a column with fixed ends is, $P = \frac{39.47EI}{L^2}$

which agrees with closed form value.

3.4 One End Fixed Other End Free

The boundary conditions are

v(0)=0 ; v'(0)=0 ; v"(1)=0 ; v'"(1)=0 (3.4.1)

The DT equivalents are

V[0]=0 ; V[1]=0 ; V[2]=c ; V[3]=d (3.4.2)

V"(1)=0 leads to $\sum_{k=0}^{\infty} V(k) = 0$ (3.4.3)

v'"(1)=0 leads to $\sum_{k=0}^{\infty} k(k-1)(k-2)V(k) = 0$ (3.4.4)

By solving these equations, for a column with one end fixed other end free λ=2.45

That is buckling load for a column with one end fixed other end free, $P = \frac{2.45EI}{L^2}$

which agrees with closed form value.

IV. CONCLUSION

Buckling load of uniform Euler Bernoulli column for various boundary conditions are obtained using differential transformation method. The results obtained from mathematical analysis was found to be exactly same as closed form solutions. Comparison of buckling load obtained from DTM with closed form solution is shown in table- 2

Table- 2 Comparison of DTM with Closed Form Solution

Support condition	DTM solution	Closed form solution

Both end pinned	$P = \frac{9.86EI}{L^2}$	$P = \frac{\pi^2 EI}{L^2}$
Roller and fixed	$P = \frac{20.19EI}{L^2}$	$P = \frac{2.045\pi^2 EI}{L^2}$
Both end fixed	$P = \frac{39.47EI}{L^2}$	$P = \frac{4\pi^2 EI}{L^2}$
One end fixed other end free	$P = \frac{2.45EI}{L^2}$	$P = \frac{\pi^2 EI}{4L^2}$

In this paper, buckling load of a uniform Euler–Bernoulli column is analyzed using differential transformation technique. Buckling load for various boundary conditions are obtained. The method is successfully implemented in Matlab. Number of terms required for convergence is generally taken as 30. It is found that the Buckling load obtained, are in excellent agreement with published results. This method is better than numerical methods, since it is free from rounding off error. It is expected that DT will be more promising for further development into efficient and flexible numerical techniques for solving practical engineering problems in future.

V.ACKNOWLEDGEMENT

The authors are thankful to the Management of Karunya University for providing necessary facilities to carry out the work reported in this paper.

REFERENCE

[1] Zhou J.K and Pukhov, *Differential transformation and Application for electrical circuits*, Huazhong University Press, Wuhan, china (1986).

[2] C.K Chen , *Application of differential transformation to Eigen value problems,* Applied mathematics and computation, 173-188 (1996)

[3] Narhari Patil1 and Avinash Khambayat , *Differential Transform Method for system of Linear Differential Equations*, Research Journal of Mathematical and Statistical Sciences, (2014)

[4] I.H. Abdel-Halim Hassan, *Application to differential transformation method for solving systems of differential equations*, Applied Mathematical Modelling 32 (2008) 2552–2559

[5] Ülker Erdönmez, _Ibrahim Özkol , *Optimal shape analysis of a column structure under various loading conditions by using differential transform method (DTM),* Applied Mathematics and Computation 216 (2010) 3172–3183)

[6] Oktay Demirdaga, Yusuf Yesilceb, *Solution of free vibration equation of elastically supported Timoshenko columns with a tip mass by differential transform method*, Advances in Engineering Software 42 (2011) 860–867

[7] X.-F. Lia, L.-Y. Xia, Y. Huangb, *Stability analysis of composite columns and parameter optimization against buckling* Composites: Part B 42 (2011) 1337–1345

[8] Pedro D. Simãoa,b, Ana M. Girão Coelhoa,c,, Frans S.K. Bijlaardc, *Stability design of crane columns in mill buildings*, Engineering Structures 42 (2012) 51–82

[9] Chai, Y.H.; Wang, C.M, *An application of differential transformation to stability analysis of heavy columns*, International Journal of Structural Stability and Dynamics (2006)

[10] Sundaramoorthy Rajasekaran , *Static, stability and free vibration analysis of arches using a new differential transformation-based arch element*, International Journal of Mechanical Sciences 77 (2013) 82–97.

[11] Siu-Lai Chan, Gan-ping Shu, Zhi-tao Lu, *Stability analysis and parametric study of pre-stressed stayed columns*, Engineering Structures 24 (2002) 115–124.

[12] Aytac Arikoglu, Ibrahim Ozkol, *Solution of difference equations by using differential transform method*, Applied Mathematics and Computation 174 (2006) 1216–1228.

[13] Aytac Arikoglu, Ibrahim Ozkol, *Solution of differential–difference equations by using differential transform method*, Applied Mathematics and Computation 181 (2006) 153–162.

APPLICATION OF DIFFERENTIAL TRANSFORMATION METHOD FOR THE STATIC ANALYSIS OF EULER-BERNOULLI BEAM

Evin Varghese[1], C.S.C. Devadass[2], M.G. Rajendran[3]

[1] P G student, School of Civil Engineering, Karunya University, Coimbatore, (India)

[2, 3] Professor, School of Civil Engineering, Karunya University Coimbatore, (India)

ABSTRACT

This paper deals with the static analysis of uniform Euler-Bernoulli beam under various supporting condition using Differential Transformation Method (DTM). Deflection and bending moment are calculated for different cases of boundary conditions. MATLAB code has been developed to solve the differential equation of the beam. Comparison of results with the previous solutions has been made and found that the deflection and bending moment for all the boundary conditions are in excellent agreement with available results.

Keywords: DTM; Euler-Bernoulli Beam; Static Analysis; Taylor series method;

I. INTRODUCTION

Many problems in science and engineering fields can be described by the partial differential equations. A variety of numerical and analytical methods has been developed to obtain accurate approximate solutions for the problems in the literature. The classical Taylor series method is one of the earliest analytic techniques to many problems, especially ordinary differential equations. However, since it requires a lot of symbolic calculation for the derivatives of functions, it takes a lot of computational time for higher order derivatives. Here, an updated version of the Taylor series method is introduced which is called the Differential Transform Method (DTM).

This method is useful to obtain the solutions of linear and nonlinear differential equations. There is no need to linearization or discretization. Large computational work and round-off errors are avoided. It has been used to solve effectively, easily and accurately a large class of linear and nonlinear problems with approximations. For problems of complex nature, the exact solution cannot be obtained or is hard to obtain. In such cases, approximation method is resorted. But by applying differential transformation method, even for the complex problems, the exact solution can be obtained. The method is capable of modelling any beam whose cross-sectional area and moment of inertia vary along its length. Hence DTM can be effectively used in most of engineering applications.

DTM was first used by Zhou[(3)] to solve both linear and nonlinear initial value problems in electric circuit analysis. C.K chen[(1)] solved eigen value problems using DTM. Narhari Patil1 and Avinash Khambayat[(2)] used Differential Transform Method for system of Linear Differential Equations. Farshid Mirzaee[(4)] Solved Linear and Nonlinear Systems of Ordinary Differential Equations using DTM.Ibrahim Ozkol & Aytac Arikoglu[(5)] ,Solved the differential equations by using differential transform method.

In this paper, the static analysis of uniform Euler-Bernoulli beams has been done by using DTM for various boundary conditions.

II. DIFFERENTIAL TRANSFORMATION METHOD

The Differential transformation of function $y(x)$ is defined as follows:

$$Y(k) = \frac{1}{k!}\left[\frac{d^k y(x)}{dx^k}\right]_{x=0} \qquad (2.1)$$

In (2.1), $y(x)$ is the original function and $Y(k)$ is the transformed function, which is called the T-function in brief.
Differential inverse transformation of $Y(k)$ is defined as follows:

$$y(x) = \sum_{k=0}^{\infty} x^k Y(k) \qquad (2.2)$$

In fact, from (2.1) and (2.2), we obtain:

$$y(x) = \sum_{k=0}^{\infty} \frac{x^k}{k!}\left[\frac{d^k y(x)}{dx^k}\right]_{x=0} \qquad (2.3)$$

Equation (2.3) implies, that the concept of differential transformation is derived from the Taylor series expansion. In this study, lower-case letters are used to represent the original functions and upper-case letters to stand for the transformed function (T- functions).
From the definitions of (2.1) and (2.2), it is easy to prove that the transformed functions comply with the following basic mathematics operations:

Table 1: Some Basic Mathematical Operations of DTM

Original Function	*Transformed Function*	
$w(x) = y(x) \mp z(x)$	$W(k) = Y(k) \mp Z(k)$	(2.4)
$z(x) = \lambda y(x)$	$Z(k) = \propto Y(k)$	(2.5)
$w(x) = y(x)\, z(x)$	$W(k) = \sum_{l=0}^{k} Y(l) Z(k-l)$	(2.6)
$z(x) = \frac{dy(x)}{dx}$	$Z(k) = (k+1)Y(k+1)$	(2.7)
$w(x) = \frac{d^m y(x)}{dx^m}$	$W(k) = (k+1)(k+2)..(k+m)Y(k+m)$	(2.8)
$w(x) = x^m$	$W(k) = \delta(k-m) = \begin{cases} 1 & k = m \\ 0 & k \neq m \end{cases}$	(2.9)

In real applications, the function $y(x)$ is expressed by a finite series and (2) can be written as:

$$y(x) = \sum_{k=0}^{m} x^k Y(k) \qquad (2.10)$$

III. ANALYSIS OF EULER-BERNOULLI BEAM

The governing equation for Euler-Bernoulli beam:

$$EI\frac{d^4v}{dx^4} = q$$

Where $'v'$ is deflection of the beam. To make the equation to a non-dimensional value, x $\rightarrow \frac{x}{l}$.

The limits change from: $0 < x < l \text{ to } 0 < x < 1$

Thus the equation becomes:

$$\frac{d^4v}{dx^4} = \frac{ql^4}{EI}$$

Differential transformation is done according to the theorem given below:

$$V(k+4) = \frac{\delta(k)}{(k+1)(k+2)(k+3)(k+4)}$$

$putting\ k = 0,$

$$V[4] = \frac{1}{24}$$

$$v[5] = v[6] = \cdots v[n] = 0$$

3.1 Pinned-Pinned Support

The Boundary Conditions are:

$$v(0) = 0\ ;\ v''(0) = 0 \tag{3.1.1}$$

$$v(1) = 0\ ;\ v''(1) = 0 \tag{3.1.2}$$

The DT equivalents of (3.1.1) gives:

$V[0] = 0\ ; V[2] = 0$

Let $V[1] = A$; $V[3] = B$; Then,

$V[0] = 0;\ V[1] = A;\ V[2] = 0;\ V[3] = B$

The DT equivalents of (3.1.2) gives :

$$\sum_{k=0}^{\infty} V(k) = 0 \tag{3.1.3}$$

$$\sum_{k=0}^{\infty}(k)(k-1)V(k) = 0 \tag{3.1.4}$$

Solving (3.1.3) & (3.1.4), the value of ‘A’ & ‘B’ are obtained.

Substituting the value of $V(k)$ in the equation (3.1.5), the deflection of Euler-Bernoulli beam can be obtained.

$$v(x) = \sum_{k=0}^{\infty} V(k)\,x^k \tag{3.1.5}$$

3.2 Fixed-Fixed Support

The Boundary Conditions are :

$$v(0) = 0\ ;\ v'(0) = 0 \tag{3.2.1}$$

$$v(1) = 0\ ;\ v'(1) = 0 \tag{3.2.2}$$

The DT equivalents of (3.2.1) gives :

$V[0] = 0\ ; V[1] = 0$

Let $V[2] = A$; $V[3] = B$; Then,

$V[0] = 0;\ V[1] = 0;\ V[2] = A;\ V[3] = B$

The DT equivalents of (3.2.2) gives :

$$\sum_{k=0}^{\infty} V(k) = 0 \tag{3.2.3}$$

$$\sum_{k=0}^{\infty} (k)V(k) = 0 \tag{3.2.4}$$

Solving (3.2.3) & (3.2.4), the value of ‘A’ & ‘B’ are obtained.

Substituting the value of $V(k)$ in the equation (3.1.5), the deflection of Euler-Bernoulli beam can be obtained.

3.3 Fixed-Roller Support

The Boundary Conditions are:

$$v(0) = 0\ ;\ v'(0) = 0 \tag{3.3.1}$$

$$v(1) = 0\ ;\ v''(1) = 0 \tag{3.3.2}$$

The DT equivalents of (3.3.1) gives:

$V[0] = 0\ ;\ V[1] = 0$

Let $V[2] = A$; $V[3] = B$; Then,

$V[0] = 0;\ V[1] = 0;\ V[2] = A;\ V[3] = B$

The DT equivalents of (3.3.2) gives:

$$\sum_{k=0}^{\infty} V(k) = 0 \tag{3.3.3}$$

$$\sum_{k=0}^{\infty} (k)(k-1)V(k) = 0 \tag{3.3.4}$$

Solving (3.3.3) & (3.3.4), the value of ‘A’ & ‘B’ are obtained.

Substituting the value of $V(k)$ in the equation (3.1.5), the deflection of Euler-Bernoulli beam can be obtained.

3.4 Fixed-Free Supports

The Boundary Conditions are:

$$v(0) = 0\ ;\ v'(0) = 0 \tag{3.4.1}$$

$$v''(1) = 0\ ;\ v'''(1) = 0 \tag{3.4.2}$$

The DT equivalents of (3.4.1) gives:

$V(0) = 0\ ;\ V(1) = 0$

Let $V[2] = A$; $V[3] = B$; Then,

$V[0] = 0;\ V[1] = 0;\ V[2] = A;\ V[3] = B$

The DT equivalents of (3.4.2) gives:

$$\sum_{k=0}^{\infty} k(k-1)V(k) = 0 \tag{3.4.3}$$

$$\sum_{k=0}^{\infty} (k)(k-1)(k-2)V(k) = 0 \tag{3.4.4}$$

Solving (3.4.3) & (3.4.4), the value of ‘A’ & ‘B’ are obtained.

Substituting the value of $V(k)$ in the equation (3.1.5), the deflection of Euler-Bernoulli beam can be obtained.

IV. NUMERICAL RESULTS

The solution obtained from the Differential Transformation Method and the closed form solution are compared and are tabulated in Table 2.

Table 2: Comparison of DTM Solution with Closed Form Solution

Support conditions	DTM solution		Closed form solution	
	Max deflection	Max BM in span	Max deflection	Max BM in span
Pinned-pinned	$\frac{5wL^4}{384EI}$	$\frac{wL^2}{8}$	$\frac{5wL^4}{384EI}$	$\frac{wL^2}{8}$
Fixed-fixed	$\frac{wL^4}{384EI}$	$\frac{wL^2}{12}$	$\frac{wL^4}{384EI}$	$\frac{wL^2}{12}$
Roller-fixed	$\frac{wL^4}{185EI}$	$\frac{9wL^2}{128}$	$\frac{wL^4}{185EI}$	$\frac{9wL^2}{128}$

V. CONCLUSION

The static analysis of uniform Euler-Bernoulli beam is done using Differential Transformation Technique. Maximum value of deflection and bending moment for various boundary conditions are obtained. The method is successfully implemented in Mat lab. It is found that the deflections and bending moments obtained are in excellent agreement with the closed-form solutions. Based on the results presented, it can be demonstrated that the Differential Transformation Method is a convenient and efficient method for the static analysis of beams with good accuracy.

It is expected that DT will be more promising for further development into efficient and flexible numerical techniques for solving practical engineering problems in future.

VI. ACKNOWLEDGEMENT

The authors are thankful to the Management of Karunya University for providing necessary facilities to carry out the work reported in this paper.

REFERENCES

[1] C.K Chen, Application of differential transformation to Eigen value problems Applied math and computation, 173-188 (1996).

[2] Narhari Patil1 and Avinash Khambayat , Differential Transform Method for system of Linear Differential Equations, Research Journal of Mathematical and Statistical Sciences, (2014).

[3] Zhou J.K. and Pukhov: Differential transformation and Application for electrical circuits, Huazhong University Press, Wuhan, China 1986.

[4] Farshid Mirzaee, Differential Transform Method for Solving Linear and Nonlinear Systems of Ordinary Differential Equations, Applied Mathematical Sciences, Vol. 5, 2011, no. 70, 3465 – 3472.

[5] Ibrahim Ozkol & Aytac Arikoglu, Solution of difference equations by using differential transform method, Applied Mathematics and Computation 174 (2006) ,1216–1228.

[6] Chen CL, Liu YC. Solution of two-point boundary-value problems using the differential transformation method. J Optimum Theory Application 1998; 99: 23–35.

[7] Jang MJ, Chen CL, Liu YC. On solving the initial-value problems using differential transformation method. Applied Mathematics and Computation 2000; 115:145–60.

[8] Sundaramoorthy Rajasekaran, Differential transformation and differential quadrature methods for centrifugally stiffened axially functionally graded tapered beams, International Journal of Mechanical Sciences, April 2013, 15-31.

[9] J. Biazar, M. Eslami,Differential Transform Method for Quadratic Riccati Differential Equation, International Journal of Nonlinear Science,Vol.9(2010) No.4, March 2010, 444-447

VIBRATION ANALYSIS OF EULER AND TIMOSHENKO BEAMS USING DIFFERENTIAL TRANSFORMATION METHOD

Dona Varghese[1], M.G Rajendran[2]

[1]P G student, School of Civil Engineering, [2] Professor, School of Civil Engineering

Karunya University Coimbatore, Tamil Nadu, (India)

ABSTRACT

In this paper, a relatively new approach called the Differential Transformation Method (DTM) is applied for free vibration analysis of Euler beams and Timoshenko beams with uniform cross section. Natural frequencies are calculated for different cases of boundary conditions. MATLAB code has been developed to solve the differential equation of the beam using the Differential Transformation Method. It is found that the natural frequencies for all the boundary conditions are in excellent agreement with available solutions.

Keywords: DTM, Natural frequency, Taylor series, Vibration analysis, Euler-Timoshenko beams

I. INTRODUCTION

Many problems in science and engineering fields can be described by partial differential equations. The solution to these problems can be achieved by implementing any of the numerical and analytical methods available. The classical Taylor series method is one of the earliest analytic techniques to many problems, especially ordinary differential equations. However, for higher order derivatives, it requires a lot of symbolic calculation for the derivatives of functions and hence it takes a lot of time for computation. Here, an updated version of the Taylor series method is introduced which is called the differential transform method (DTM).

For problems of complex nature, the exact solution cannot be obtained or is hard to obtain. In such cases, approximation method is resorted. But by applying differential transformation method, even for the complex problems, the exact solution can be obtained. This method is capable of modeling any beam whose cross-sectional area and moment of inertia vary along beam with any two arbitrary functions and any type of cross-section with just one or few elements. Hence DTM can be effectively used in most of engineering applications.

DTM was first used by Zhou [1] to solve both linear and non-linear initial value problems in electric circuit analysis. C.K Chen [2] solved eigen value problems by using DTM. Fatma Ayaz[3] obtained numerical solution of linear differential equations by using DTM. Chen and Ho[4] solved eigenvalue problems for the free and transverse vibration problems of a rotating twisted Timoshenko beam under axial loading by using DTM. DTM was applied to solve a second order non-linear differential equation that describes the under damped and over damped motion of a system subject to external excitation by Jang and Chen [5]. Chen and Liu[6] considered the first order linear and non-linear two-point boundary value problems by using DTM. In the other study, Jang et al. [7] investigated the linear and non-linear initial value problems by using DTM. Hassan [8],[9] studied the solution of Sturm–Liouville eigenvalue problem and solved partial differential equations by using DTM. Bert and Zeng [10] used DTM to investigate the analysis of axial vibration of compound bars. Kurnaz et al.[11] studied n-dimensional DTM to solve the partial differential equations.

In this paper, the vibration analysis of uniform Euler-Bernoulli beams and Timoshenko Beams has been done by using DTM and the natural frequencies for various boundary conditions have been found.

II. DIFFERENTIAL TRANSFORMATION METHOD

The basic theory of Differential Transformation is stated in brief in this section.

Differential Transformation of function y(x) is defined as follows.

$$Y(k) = \frac{1}{k!}\left[\frac{d^k y(x)}{dx^k}\right]_{x=0} \tag{2.1}$$

In (2.1), y(x) is the original function and Y(k) is the transformed function, which is called the T-function in brief. Differential inverse transformation of Y(k) is defined as follows:

$$y(x) = \sum_{k=0}^{\infty} x^k Y(k) \tag{2.2}$$

In fact, from (2.1) and (2.2), we obtain,

$$y(x) = \sum_{k=0}^{\infty} \frac{x^k}{k!}\left[\frac{d^k y(x)}{dx^k}\right]_{x=0} \tag{2.3}$$

Equation (2.3) implies that the concept of differential transformation is derived from the Taylor series expansion. In this study we use lower-case letters to represent the original functions and upper-case letters to stand for the transformed functions (T-functions). From the definitions of (2.1) and (2.2), it is easy to prove that the transformed functions comply with the following basic mathematics operations.

Table 1: Some Basic Mathematical Operations of DTM

Original Function	*Transformed Function*	
$w(x) = y(x) \mp z(x)$	$W(k) = Y(k) \mp Z(k)$	(2.4)
$z(x) = \lambda y(x)$	$Z(k) = \lambda Y(k)$	(2.5)
$w(x) = y(x)\, z(x)$	$W(k) = \sum_{l=0}^{k} Y(l) Z(k-l)$	(2.6)
$z(x) = \frac{dy(x)}{dx}$	$Z(k) = (k+1)Y(k+1)$	(2.7)
$w(x) = \frac{d^m y(x)}{dx^m}$	$W(k) = (k+1)(k+2)..(k+m)Y(k+m)$	(2.8)
$w(x) = x^m$	$W(k) = \delta(k-m) = \begin{cases}1 & k = m\\ 0 & k \neq m\end{cases}$	(2.9)

In real applications, the function y (x) is expressed by a finite series and Eq. (2.2) can be written as

$$y(x) = \sum_{k=0}^{N} x^k Y(k) \tag{2.10}$$

Equation (2.10) implies that $\sum_{k=N+1}^{\infty} x^k Y(k)$ is negligibly small.

III. GOVERNING EQUATION FOR VIBRATION

3.1 Euler Beam

The governing differential equation of lateral vibration of uniform Euler beams is given by

$$EI\frac{\partial^4 v}{\partial x^4}+\bar{m}\frac{\partial^2 v}{\partial t^2}=0 \tag{3.1}$$

By assuming harmonic motion, Let $v(x,t)=y(x)sinpt$ and converting x to non-dimensional coordinate varying from 0 to 1 by substituting $x=\frac{\bar{x}}{L}$ we get:

$$\frac{EI}{L^4}\frac{d^4 y}{dx^4}sinpt-\bar{m}yp^2 sinpt=0 \tag{3.2}$$

Simplifying we get:

$$\frac{d^4 y}{dx^4}-\frac{\bar{m}p^2L^4}{EI}y=0 \tag{3.3}$$

Let, $a=\frac{\bar{m}p^2L^4}{EI}$

Then equation reduces to:

$$\frac{d^4 y}{dx^4}=ay \tag{3.4}$$

Which is the governing equation for the vibration of Euler beam of uniform crossection.

3.2 Timoshenko Beam

Governing equation for Timoshenko beam for free vibration is given by;

$$EI\frac{\partial^4 y}{\partial x^4}+\rho A\frac{\partial^2 y}{\partial t^2}-\rho \mathrm{I}\left(1+\frac{E}{kG}\right)\frac{\partial^4 y}{\partial x^2\partial t^2}+\frac{\rho^2 I}{kG}\frac{\partial^4 y}{\partial t^4}=0 \tag{3.5}$$

Using a non-dimensional coordinate by substituting $x=\frac{x}{L}$ and substituting

$w(x,t)=y(x)\,sin\omega t$, we get the governing equation as

$$\frac{d^4 y}{dx^4}-af_1 y+af_2\frac{dy^2}{dx^2}+a^2 f_1 y=0 \tag{3.6}$$

Where $\mathrm{a}=\omega^2$, $\mathrm{f}_1=\frac{\rho AL^4}{EI}$, $\mathrm{f}_2=\frac{\rho L^2}{E}\left(1+\frac{E}{kG}\right)$, $\mathrm{f}_3=\frac{\rho^2 AL^4}{kGE}$

IV. APPLYING DIFFERENTIAL TRANSFORMATION

For Euler Beam, using theorem (2.8), from Table1, differential transformation of

$$\frac{d^4 y}{dx^4}=(k+1)(k+2)(k+3)(k+4)Y[k+4]$$

Using theorem, the differential transformation of $ay=aY[k]$

Hence equation 3.4 becomes;

$$Y[k+4]=\frac{aY[k]}{(k+1)(k+2)(k+3)(k+4)} \tag{3.7}$$

Similiarly, for Timoshenko beam, Applying DTM, the governing equation 3.6 becomes

$$Y[k+4]=\frac{\{(af1-a^2f3)Y[k]-(k+1)(k+2)af2Y[k+2]\}}{(k+1)(k+2)(k+3)(k+4)} \tag{3.8}$$

V. APPLYING BOUNDARY CONDITIONS

5.1 Simply Supported At Both Ends

Deflection and curvature at both ends=0

$y(0) = 0; y''(0) = 0$ (3.9)

$y(1) = 0; y''(1) = 0$ (3.10)

The DT equivalents of (3.9) gives

$Y[0] = 0$

$Y[2] = 0$

Let $Y[1]=c$; $Y[3]=d$; Then,

$Y[0] = 0$

$Y[1] = c$

$Y[2] = 0$

$Y[3] = d$

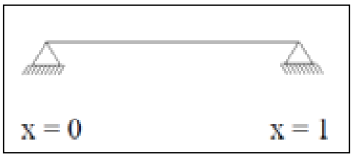


Figure 3.1 simply supported beam

Using the recursive relation of Eq.(3.7) for Euler Beam, Eq (3.8) for Timoshenko beam, we can get the remaining terms.

The DT equivalents of (3.10) gives

$\sum_{k=0}^{\infty} Y[k] = 0$ (3.11)

$\sum_{k=0}^{\infty} k(k-1)Y[k] = 0$ (3.12)

Both equations give nonlinear equation in terms of 'a' and linear in terms of 'c' and 'd'.

Putting the boundary conditions (3.11) and (3.12) in matrix form, we get,

$$\begin{bmatrix} aa & bb \\ cc & dd \end{bmatrix} \begin{Bmatrix} c \\ d \end{Bmatrix} = \{0\}$$

Where *aa* and *cc* are the coefficients of c, bb and dd are the coefficients of d

Since $\begin{Bmatrix} c \\ d \end{Bmatrix} \neq 0$, the determinant of matrix $\begin{bmatrix} aa & bb \\ cc & dd \end{bmatrix}$ must be equal to zero.

Hence,

$aa \times dd - bb \times cc = 0$

Which gives a polynomial in 'a'. Depending upon the number of terms N taken, we get a higher degree polynomial in 'a'. Solving for a the frequency is obtained as $p = \frac{1}{L^2}\sqrt{\frac{EIa}{m}}$. Same procedure is applied for different boundary conditions as below.

5.2 Fixed-Fixed Supports

Slope and deflection at both ends=0

$y(0) = 0; y'(0) = 0$ (3.13)

$y(1) = 0; y'(1) = 0$ (3.14)

The DT equivalents of (3.13) gives

Y[0] =0

Y[1]=0

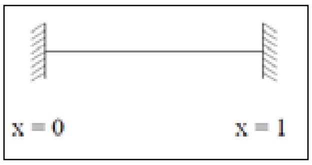


Figure3.2 Fixed-Fixed beam

Let Y[2]=c; Y[3]=d; Then,

Y[0] = 0

Y[1] = 0

Y[2] = c

Y[3] = d

The DT equivalents of (3.14) gives

$\sum_{k=0}^{\infty} Y[k] = 0$ (3.15)

$\sum_{k=0}^{\infty} kY[k] = 0$ (3.16)

5.3 Fixed-Roller Supports

Curvature and deflection at roller end =0

Slope and deflection at fixed end =0

y(0) = 0; y''(0) = 0 (3.17)

y(1) = 0; y' (1) = 0 (3.18)

The DT equivalents of (3.17) gives

Y[0] =0

Y[2]=0

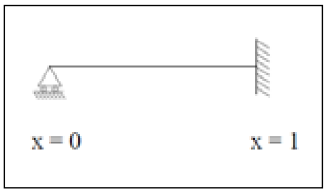


Figure3.3 Fixed-Roller beam

Let Y[1]=c; Y[3]=d; Then,

Y[0] = 0

Y[1] = c

Y[2] = 0

Y[3] = d

The DT equivalents of (3.18) gives

$\sum_{k=0}^{\infty} Y[k] = 0$ (3.19)

$\sum_{k=0}^{\infty} kY[k] = 0$ (3.20)

5.4 Fixed-Free Supports (Cantilever)

At fixed end,

Deflection and slope=0

y(0) = 0; y'(0) = 0 (3.21)

At the free end,

Bending moment= $EI\frac{\partial^2 v}{\partial x^2} = 0$

Shear force = $EI\frac{\partial^3 v}{\partial x^3} = 0$

\ DT equivalents of Bending moment & Shear force gives Y''(1) = 0; Y''' (1) = 0 (3.22)

The DT equivalents of (3.21) gives

Y[0] =0

Y[1]=0

Let Y[1]=c; Y[3]=d; Then,

Y[0] = 0

Y[1] = 0

Y[2] = c

Y[3] = d

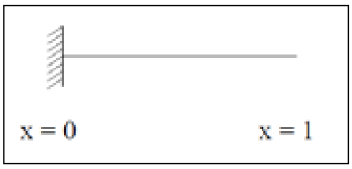


Figure3.4 Fixed-Free beam

The DT equivalents of (3.22) gives

$$\sum_{k=0}^{\infty} k(k-1)Y[k] = 0 \quad (3.23)$$

$$\sum_{k=0}^{\infty} k(k-1)(k-2)Y[k] = 0 \quad (3.24)$$

VI. NUMERICAL RESULTS

6.1 Euler Beam

Since $a = \frac{mp^2L^4}{EI}$, the frequency is obtained as $p = \frac{1}{L^2}\sqrt{\frac{EIa}{m}} = \frac{k}{L^2}\sqrt{\frac{EI}{m}}$ where $k = \sqrt{a}$

K value obtained for Euler beam is listed in Table 2.

Table2: Value of A and K Obtained For Different Boundary Conditions of an Euler Beam

Boundary conditions	'a' obtained	$k = \sqrt{a}$
Simply Supported at both ends	97.4090910	9.8696
fixed-fixed supports	500.563901	22.373
fixed-roller supports	237.721067	15.418
fixed-free supports	485.51881	22.034

6.2 Timoshenko Beam

Assuming unit width, Poisson's ratio $\nu = 0.3$ and the shear coefficient of the beam k=5/6, Modulus of Elasticity E = 200Gpa, length of the beam L =10m, mass density $\rho = 7800 kg/m3$, Moment of Inertia I =8.333e-5m^4, Area A= 0.1m^2 (h/L=0.01) we can find the value of nondimensional frequency parameter λ from the formula,

$$\lambda^2 = \omega L^2 \sqrt{\frac{\rho A}{EI}}, \quad \text{where } \omega = \sqrt{a}$$

λ value obtained for Timoshenko Beam is listed in Table 3.(Shear deformation at the ends being small, Euler beam boundary conditions have been adapted.)

Table3: Value of A and λ Obtained For Different Boundary Conditions of Timoshenko Beam

Boundary conditions	'a' obtained	λ
Simply Supported at both ends	208.09	3.1417
fixed-fixed supports	1069.311	4.730
fixed-roller supports	507.85	3.926
fixed-free supports	26.418	1.875

VII. CONCLUSION

Natural frequencies of uniform Euler and Timoshenko beam for various boundary conditions are obtained using DTM. The method is successfully implemented in MATLAB for convergence. Number of terms required for convergence is generally taken as 30. It is found that the natural frequencies obtained, are in excellent agreement with closed form solutions. Comparison of k obtained by DTM and closed form solutions for Euler Beam are listed in Table 3. Also comparison of nondimensionalized frequency parameter λ obtained by DTM and closed form solution for Timoshenko beam are listed in Table 5.

Table4: Comparison Of DTM With Closed Form Solution For Euler Beam

Boundary conditions	Closed form solution	DTM method
Simply supported	9.87	9.869
Fixed- Fixed	22.4	22.373
Fixed-roller	15.4	15.418
Fixed-free	3.52	3.516

Table 5: Comparison Of DTM With Closed Form Solution For Timoshenko Beam

Boundary conditions	Closed form solution	DTM method
Simply supported	3.141	3.141
Fixed- Fixed	4.73	4.73
Fixed-roller	3.927	3.926
Fixed-free	1.875	1.875

Based on the results presented, it can be demonstrated that the Differential Transformation Method is convenient and efficient in solving the vibrations of beams with good accuracy using fewer number of terms.

It is expected that DTM will be more promising for further development into efficient and flexible numerical techniques for solving practical engineering problems in future.

VIII. ACKNOWLEDGEMENT

The authors are thankful to the Management of Karunya University for providing necessary facilities to carry out the work reported in this paper.

REFERENCE

[1] Zhou J.K. and Pukhov, *Differential transformation and Application for electrical circuits*, Huazhong University Press, Wuhan, China, 1986.

[2] Chen CK, Ho SH., *Application of differential transformation to eigenvalue problem*. J Appl Math Comput 1996, 79:173–88.

[3] Fatma Ayaz, *Applications of differential transform method to differential-algebraic equations*, Applied Mathematics and Computation 2004, (152), 649–657.

[4] Chen CK, Ho SH., *Transverse vibration of a rotating twisted Timoshenko beams under axial loading using differential transform.*, Int J Mech Sci 1999, 41:1339–56.

[5] Jang MJ, Chen CL., *Analysis of the response of a strongly non-linear damped system using a differential transformation technique*., Appl Math Comput 1997, 88:137–51.

[6] Chen CL, Liu YC., *Solution of two-point boundary-value problems using the differential transformation method.*, J Optim Theory Appl 1998, 99: 23–35.

[7] Jang MJ, Chen CL, Liu YC, *On solving the initial-value problems using differential transformation method*. Appl Math Comput 2000, 115:145–60.

[8] Hassan IHAH., *On solving some eigenvalue problems by using differential transformation*,. Appl Math Comput 2002, 127:1–22.

[9] Hassan IHAH, *Different applications for the differential transformation in the differential equations.* Appl Math Comput 2002, 129:183–201.

[10] Bert CW, Zeng H. *"Analysis of axial vibration of compound bars by differential transformation method*,. J Sound Vib 2004, 275:641–7.

[11] Kurnaz A, Oturanç G, Kiris ME. *N-Dimensional differential transformation method for solving PDEs*,. Int J Comput Math 2005, 82(3):369–80.

[12] Lee J., Schultz W. W., *Eigenvalue analysis of Timoshenko beams and axisymmetric Mindlin plates by the pseudospectral method*, Journal of Sound and Vibration, 2004, 269, 609- 621.

[13] Rajasekaran S., *Structural Dynamics of Earthquake Engineering*, Woodhead Publishing Limited, (2009).

[14] Timoshenko S., Young D. H. "*Vibration Problems in Engineering*", Third edition, Van Nostrand Company, New York, 1955.

[15] Thomson WT, "*Theory of vibration with applications*" Unwin Hyman Ltd,. London, 1988.

[16] Chopra K. A, "*Dynamics of Structures*" Second edition, Prentice Hall, New Jersey, 2001.

[17] Craig R. R., "*Structural Dynamics*" John Wiley & Sons., United States of America, 1981.