Online ISSN : 2249-4596
Print ISSN : 0975-5861

Global Journal

of Researches in Engineering: G

Industrial Engineering

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Discovering Thoughts, Inventing Future

VOLUME 13 ISSUE 3 VERSION 1.0

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Global Journal of Researches in Engineering: G
Industrial Engineering

Global Journal of Researches in Engineering: G
Industrial Engineering
Volume 13 Issue 3 (Ver. 1.0)

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Offset Typesetting

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Contents of the Volume

Global Journal of Researches in Engineering
Industrial Engineering
Volume 13 Issue 3 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Life Cycle Cost Analysis of Small Wind Power Generation-A Case Study

By Smita G. Badgujar, Dr. Arun Kumar Dwivedi & Dr. Suresh Singh Kushwaha
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Abstract - The electrical energy is an integral utility not only in the in modern society, but also has become a basic need in the Indian rural culture too. In spite of the claim by central and state government that 80% of the rural population is facilitated by the electricity in India, still large portions is either facing a severe shortage or are not connected to grid system so far. The conventional energy sources are over stressed and the use of renewable energy sources is becoming technically and economically feasible due to advancement in technology. These renewable energy sources such as wind, solar and bio mass are creating an opportunity to develop an energy system, exclusively for a village to achieve the energy security.

This paper presents a feasibility study of a village for energy security through the wind energy. A wind energy generation system is proposed which will address the minimum energy needs including for household and street-lighting in a village. The life cycle cost analysis of a proposed wind energy generation system for a village is done. The unit cost of electricity is obtained for four phases in analysis period of 20 years, and it is found that the same tunes with the existing ones. A sensitivity analysis is also carried out for different rate of interest and different plant load factors.

Keywords : life cycle cost analysis, plant load factor, small wind turbine.

GJRE-G Classification : FOR Code: 850509, 090608

LIFE CYCLE COST ANALYSIS OF SMALL WIND POWER GENERATIONACASE STUDY

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Life Cycle Cost Analysis of Small Wind Power Generation–A Case Study

Smita G. Badgujar [α], Dr. Arun Kumar Dwivedi [σ] & Dr. Suresh Singh Kushwaha [ρ]

Abstract - The electrical energy is an integral utility not only in the in modern society, but also has become a basic need in the Indian rural culture too. In spite of the claim by central and state government that 80% of the rural population is facilitated by the electricity in India, still large portions is either facing a severe shortage or are not connected to grid system so far. The conventional energy sources are over stressed and the use of renewable energy sources is becoming technically and economically feasible due to advancement in technology. These renewable energy sources such as wind, solar and bio mass are creating an opportunity to develop an energy system, exclusively for a village to achieve the energy security.

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Keywords : life cycle cost analysis, plant load factor, small wind turbine.

I. Introduction

The electricity demand continued to rise despite of the slow pace of the global economy as observed in last five years i.e. 2007-2012. The demand of electricity in India is expected to be three fold in year 030 than it was in year 2005. The shortage of electricity is common and it is an established fact that even today around 40% of the population has no access to modern electric services. The gap between the supply and demand is mismatching despite of major capacity additions over recent decades [GoI (2012)].

The technologies fulfilling the rural electric demand may be classified by three approaches. The first one is conventional approach i.e. the centralized thermal generation combined with rural grid extensions. The second approach is the small scale de-centralized distributed generation, whereas the third approach is the use of renewable energy with household or village level technology such as use of solar photovoltaic cells or small wind turbines with set of battery for energy storage. However, this approach is useful only for low consumption activities and is viable with minimal unit investment costs [GWEC (2012)].

According to a survey by NSSO (2001), the rural households spend around 10% of their monthly income on basic fuel and energy services, which are primarily used for cooking and heating activities. The rural household spending on energy as % of their monthly per capita expenditure group is shown in Figure – 1 [CEA (2007)]. However, the willingness to pay depends upon income, existing energy mix and costs thereof, availability of electricity, quality of supply and appliance ownership.

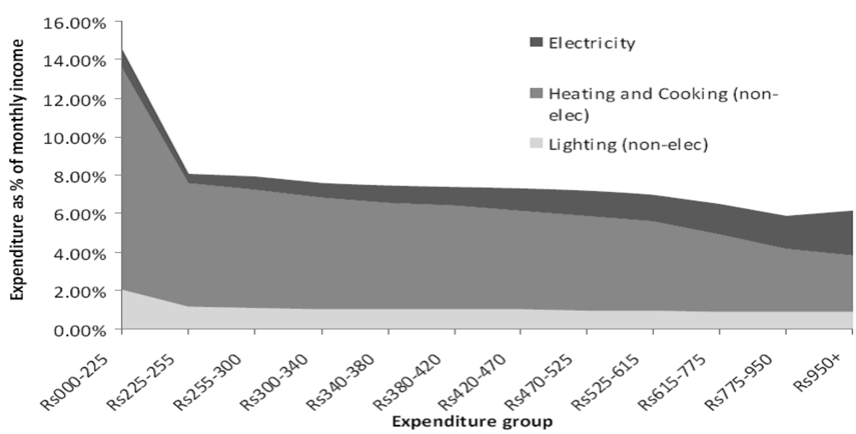

Figure 1 : Rural household spending on energy as % of monthly consumption, by monthly per capita expenditure group [NSSO (2001)] [Source : CEA(2007)]

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Global Journal of Researches in Engineering (G) Volume XIII Issue III Version I Year 2013

II. Significance

The reliable electric services are significant as these are the key driver behind the economic development of country as well raises the basic stand level of the people. The rural India home around 65% of the country's population and around 25% of the world's poor. Rural electricity supply in India has been lagging in terms of service (measured by hours of supply). Only 31% of the rural households have access to electricity, and the supply suffers from frequent power cuts and high fluctuations in voltage and frequency. The demand-supply gap is currently 7.8% of average load and 13% of peak demand [GWEC (2012)].

The reliable and affordable supply of electricity is essential in rural India, because it helps in income generating activities and allows the utilization of modern appliances and agricultural equipments. The electrification also increases the likelihood that women will read and earn income. At the same time its use replaces the use of inefficient and polluting sources of energy such as kerosene.

The non conventional energy sources excluding the large hydro electric power generation, constitutes around 5% of the total installed electric power generation capacity. The significant potential of non-conventional energy sources is still untapped. The various feasibility studies have demonstrated the technical and economical suitability of renewable energy at rural area in India. These studies have concluded that a use renewable energy technology, especially at rural area offers the environmental as well the social sustainability [WB (2008)].

III. Status of Wind Energy Conversion in India

Wind power is accepted as major complementary energy source for securing a sustainable and clean energy future for India. The total installed electrical power generation capacity in India is 207.80 GW as on start of financial year 2012-13. The share of the renewable energy is around 25 GW, out of which 67% is generated by the wind energy. As per an assessment by C-WET in 2011, the wind power potential in country is 102.78 GW at 80 m height above ground level and 49.13 GW at 50 m height above the ground level, both at 2% land availability. If the estimated wind power potential of 102.78 GW is fully developed, the wind electric power would fulfill 8% of the projected electrical demand in 2022 and 5% in 2032. The addition of wind power during the financial year 2011-12 is around 3.2 GW, which is highest addition in a year so far. The Government of India has fixed its target to add 15 GW of wind energy installations in 12th five year plan (2012~17). Currently, the 95% of the country's wind energy development is concentrated in five states i.e. Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra and Gujarat with their installed capacity 6987.6, 245.50, 1933.50, 2733.30 and 2966.30 MW respectively, as on start of financial year 2012-13. The two states i.e. Madhya Pradesh and Rajasthan have shown a considerable progress in spite of their poor potential. The total installed capacity in these two states is 376.40 and 2070.70 MW respectively.

The installation of wind mills in India has started in 21st century. The Figure -2 shows the year wise cumulative installation of wind mills in MW after year 2000 [Gomathinayagam (2012)].

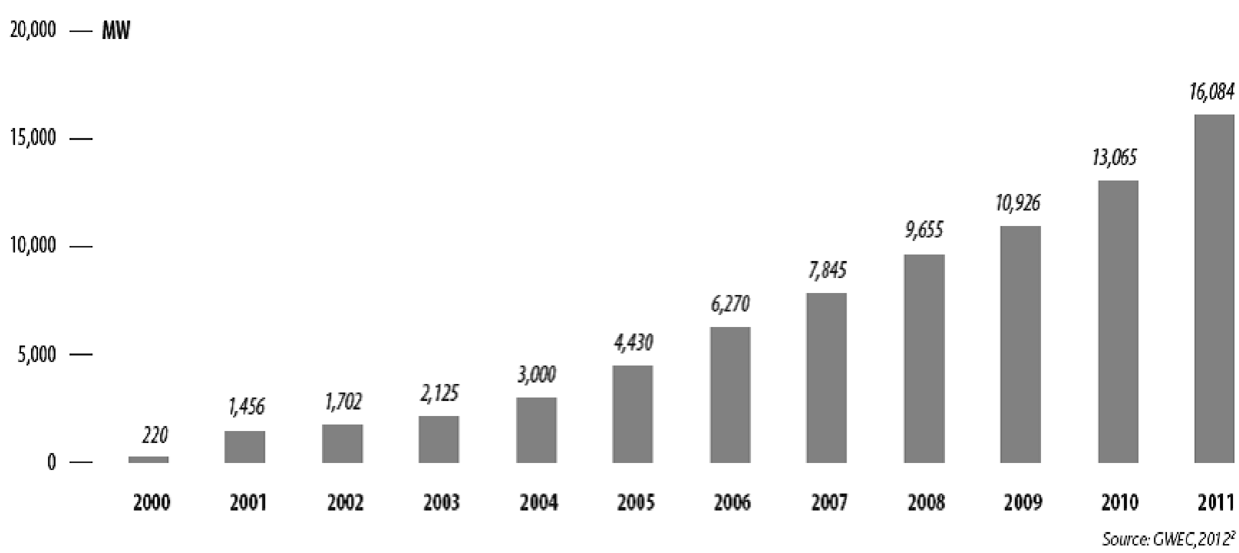

Figure 2 : India: Cumulative Wind Installation (MW)

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IV. Principle of Generation of Electricity from Wind Power

Some of the important components of the small wind turbines are rotor, generator/alternator, gear box, nacelle, tail vane, control system, tower, batteries and charger, inverter, and rectifier. The rotor consists of blades and shafts. The wind moves over the blades and converts the kinetic energy from moving wind into rotary motion of rotor, the diameter of circle formed by which determine the quantum of energy extracted from wind and thus the power generated by the system. The generator produces electricity i.e. direct current (DC) from the rotation of the turbine rotor whereas an alternator converts the DC into alternating current (AC). The purpose of a gearbox is to match the rotor speed to that of the generator. The Nacelle is the removable casing to protect the generator/alternator and gearbox. A yaw system is required to align a wind turbine in the direction of the wind. There are many micro and mini systems use a simple tail vane that directs the rotor in the direction of wind. The control systems vary from simple switches, fuses and battery charge regulators to computerized systems for control of yaw systems and brakes. The sophistication of the control and protection system varies depending on the application of the wind turbine and the energy system it supports. The main function of the tower is to hold the turbine in the path of the wind and is an integral part of a wind energy system. It is designed to support adverse conditions of atmosphere. The additional equipments are needed to support the balance-of-system such as batteries with charger, inverter, and rectifier along with some protective equipment.

The ratio of actual output to installed capacity is the plant load factor (PLF) of the wind mill of that year. The wind may not be available at the wind farm site with required intensity throughout the year and hence the wind turbine may not be operational as would be a conventional thermal power plant. Hence, the plant load factor is comparatively lesser for a wind turbine.

A modern wind turbine produces electricity 80~85% of the time however the output may be different depending upon the wind speed. The load factor of wind turbines ranges between 28~30%, whereas the average plant load factor of conventional power plant such as thermal power plant is around 50%. The best performing wind turbine have the plant load factor close to 50% [Eleanor (2007)].

V. Advantages of Wind Energy Conversion

Wind energy systems are one of the most cost-effective renewable energy systems. Depending on wind resource, a small wind energy system being lifetime energy source can lower load on other energy sources helps to avoid the high costs of extending utility power lines to remote locations, prevent power interruptions and it is non-polluting green energy. A modern wind farm, when installed on land, has one of the lowest environmental impacts of all energy sources:

- It occupies less land area per kilowatt-hour (kWh) of electricity generated than any other renewable energy conversion system, apart from rooftop solar energy.
- It generates the energy embodied in its construction within just months of operation.
- Greenhouse gas emissions and air pollution produced by its construction are small and declining. There are no emissions or pollution produced by its operation.
- Modern wind turbines rotate so slowly i.e. revolutions per minute, that they are rarely a hazard to birds.

VI. Energy Security of a Village Through Wind Energy – Case Study

A feasibility study of a village Bhod (Khurd) is done for energy security through the wind energy. The village lies under Dharangaon Taluka in district Jalgaon of Maharashtra state of India. The village is 28 kms from the district head quarter and is on the right bank of river Ajani, which is one of the tributary of west flowing Tapi river.

VII. Data Collected

a) Wind Resource at Village Bhod

A wind rose diagram is a graphical tool which gives a succinct view of distribution of wind speed and direction at a particular location. The wind rose diagram of the surrounding area is shown in Figure – 3.

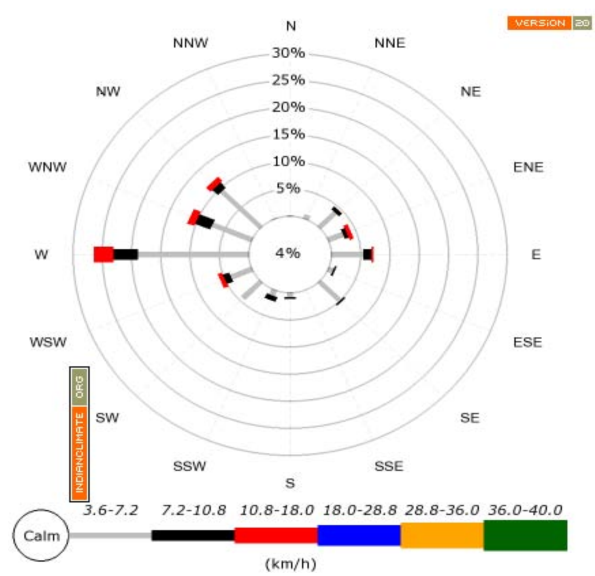

Figure 3 : Wind Rose Diagram

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The monthly average wind speeds are given in the Table - 1.

Table 1 : "Monthly Average Wind Speed"

Month	Wind speed m/s
January	4.4
February	4.1
March	4.5
April	5.3
May	6.8
June	8.5
July	10.1
August	9.8
September	6.2
October	4.8
November	4.3
December	4.4
Minimum	**4.1**
Maximum	**10.1**
Average	**6.3**

b) Demand of Electrical Energy

The village is surveyed for the energy requirement at household level in year 2012. The survey revealed that there is a load shedding of more than 10 hours in a day. This signifies the necessity of proposed projects at village level. Out of the 120 total numbers of houses in the village, 68 houses are electrified. In the demand calculation, it is considered that the non electrified houses shall be given one point connection for lighting. The current average monthly requirement of the electrical energy of the entire village as per survey is 2887.90 kWh.

The demand forecasting curve is plotted for the data available for last five decades for consumption of electricity in rural sector in country. The extended part of the curve is shown in Figure 4.

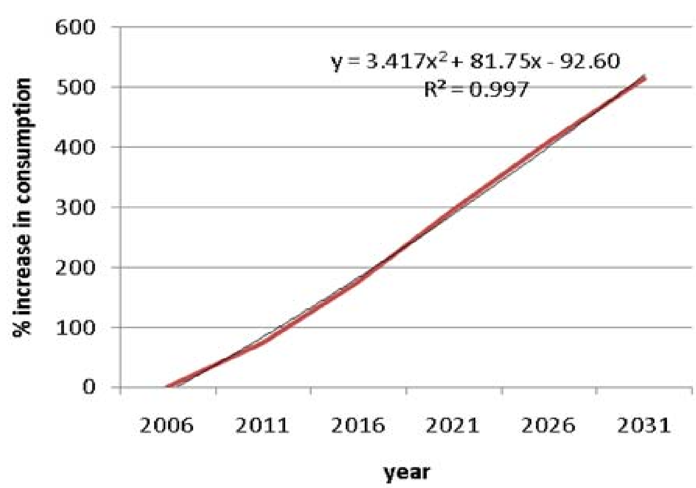

Figure 4 : "Demand Forecasting Curve"

The forecasted demand during the four phases of analysis period is calculated and is shown in Table – 2.

c) Proposal of Wind Turbine

It is found from the market survey and expert advice that the wind turbines of 5.00 kW capacities are suitable, economically and technically among all the ranges of small wind turbines. It is proposed to install the wind turbines of 5.00 kW capacities in four phases in a span of 5 year each, as per forecasted demand.

A plant load factor of 22.5% is considered as per usual practice and at this plant load factor, a turbine of 5.0 kW may generate 9855 electrical units (kWh). The number of turbines required in these four phases is 6, 8, 11 and 13 respectively. The base year is taken as 2012 and the service year is considered as end of year 2013.

d) Cost Estimation and Analysis

The life cycle cost analysis is done with the following assumptions -

i. The analysis period of the project is taken as 20 years.
ii. The rate of interest is considered as 8%.
iii. The plant load factor is taken as moderate i.e. 22.5%, which is the usual practice for turbines of 5 kW rating.
iv. Maintenance cost of small turbines is negligible and hence not taken into account, however provision of one mechanic and one helper at the monthly wage of Rs.8000.00 is considered for the maintenance of system.
v. The life of battery is considered as 5 years i.e. in the entire analysis period the batteries are placed three times.

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vi. Maintenance cost of battery is taken as 10% of cost of capital cost.

vii. Residual value of battery is taken as 20% of original cost.

The residual value of turbines installed at first phase is considered as 20%, correspondingly the residual value of turbines in second, third and fourth installation is taken as 30%, 40%, and 50% of capital cost of turbine.

The cash flow diagram with the above stated assumptions is shown in the Figure – 5 [Kishk, Al-Hajj, and Pollock (2003)].

The cost of items appearing in the analysis period of 20 years and the residual values of items at the end of the analysis period is given in Table - 3. The life cycle cost analysis is done and the unit cost of electricity produced is calculated in four phases of analysis period of the project, is shown in Table – 4.

Table 2 : Demand Calculations

Description	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	
Housewise daily consumption in units		0.07	0.07	1.13	1.57	0.53	1.87	4.77	3.07		
		0.07	0.07	1.43	1.27	0.57	1.50	0.97	3.40		
		0.17	2.00	1.37	0.27	1.30	0.80	1.00	3.87		
				1.30	0.30	1.30	0.93	1.07	4.17		
				1.13	0.37	0.60	0.67	1.07			
				1.13	0.27	0.53	0.07	2.07			
					0.3	1.67	0.93	2.10			
					0.43	1.40	0.83	2.23			
					0.53	1.60	1.63	1.13			
					0.57	0.63	1.50	1.13			
					1.37	0.73	1.77	1.13			
					1.57	0.73	1.80	1.13			
					1.7	0.70		2.37			
Actual	0.00	0.31	2.14	7.49	10.52	12.29	14.30	22.17	14.51	0.00	
Facilitated	2.10	0.00	0.00	1.20	0.00	0.00	0.00	0.00	0.00	4.65	
Total	2.10	0.31	2.14	8.69	10.52	12.29	14.3	22.17	14.51	4.65	
Transmission Losses @ 5%	0.105	0.016	0.107	0.435	0.526	0.615	0.715	1.11	0.73	0.23	
Total Consumption/ Day	2.21	0.33	2.25	9.125	11.046	12.90	15.015	23.28	15.24	4.88	
Total Consumption/ Month	66.15	9.77	67.41	273.74	331.38	387.14	450.45	698.35	457.07	146.48	
Total Consumption in 2012	793.80	117.18	808.92	3284.82	3976.56	4645.62	5405.4	8380.26	5484.78	1757.70	34655.04
Forecasted Consumption (2017)	1270.08	187.49	1294.27	5255.71	6362.50	7433.00	8648.64	13408.42	8775.65	2812.32	55448.06
Forecasted Consumption (2022)	1801.93	265.00	1836.25	7456.54	9026.79	10545.56	12270.26	19023.19	12450.45	3989.98	78666.94
Forecasted Consumption (2027)	2381.40	351.54	2426.76	9854.46	11929.68	13936.86	16216.2	25140.78	16454.34	5273.10	103965.10
Forecasted Consumption (2032)	2794.18	412.47	2847.40	11562.57	13997.49	16352.58	19027.01	29498.52	19306.43	6187.11	121985.70

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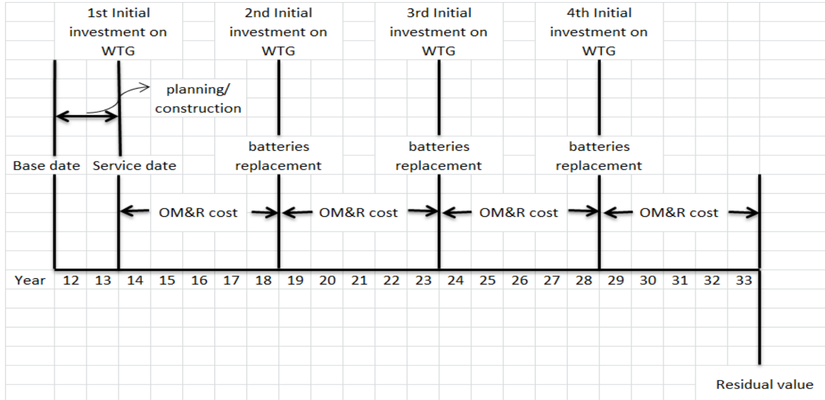

Figure 5 : "Cash Flow Diagram of Proposal"

Table 3 : Life Cycle Cost Estimation

Sr No	Description	Unit Cost	Unit	Quantity	Cost
		Rs			Rs
	Initial investment cost				
1	First installation of turbines (5KW)	508000.00	NO.	6	3048000.00
2	Second installation of turbines (5KW)	508000.00	NO.	2	1016000.00
3	Third installation of turbines (5KW)	508000.00	NO.	3	1524000.00
4	Forth installation of turbines (5KW)	508000.00	NO.	2	1016000.00
5	Batteries required in First installation	9000.00	NO.	60	540000.00
6	Batteries required in second installation	9000.00	NO.	20	180000.00
7	Batteries required in third installation	9000.00	NO.	30	270000.00
8	Batteries required in forth installation	9000.00	NO.	20	180000.00
9	Cable(with labour cost) at first installation	62.00	NO.	1500	93150.00
10	Sub meter (with labour cost) at first installation	1525.00	NO.	120	183000.00
	Capital Replacement of Batteries				
11	After 5 years	7200.00	NO.	60	432000.00
12	After 10 years	7200.00	NO.	80	576000.00
13	After 15 years	7200.00	NO.	110	792000.00
	Operation, Maintenance & Repair Cost				
14	Batteries maintenance first five years from first Installation	900.00	NO.	60	54000.00
15	Batteries maintenance 5 years after second installation	900.00	NO.	80	72000.00
16	Batteries maintenance 5 years after third installation	900.00	NO.	110	99000.00
17	Batteries maintenance 5 years after forth installation	900.00	NO.	130	117000.00
18	Salary of mechanic	5000.00	MONTH	12 months	60000.00
19	Salary of helper	3000.00	MONTH	12 months	36000.00
	Residual value				
20	20 % of turbine cost for first installation	101600.00	NO.	6	609600.00
21	30 % of turbine cost for second installation	152400.00	NO.	2	304800.00
22	40 % of turbine cost for third installation	203200.00	NO.	3	609600.00
23	50 % of turbine cost for forth installation	254000.00	NO.	2	508000.00
24	Batteries	1800.00	NO.	130	234000.00
	Residual Value at the end of Analysis Period				2266000.00

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Table 4 : Life Cycle Cost Analysis for Analysis Period 20 Years and Depreciation @ 8%

Year	CC (WTG)	CC(BATTERY)	RC (BATTERY)	TCC	EACCF	EACC(2)	EACC(7)	EACC(12)	EACC(17)	AO&MC	ALCC(GROSS)	ALCV	ALCC(NET)	APGC	UNIT COST
	(Rs)	(Rs)	(Rs)	(Rs)		(Rs)	(Rs)	(Rs)	(Rs)	(Rs)	(Rs)	(Rs)	(Rs)	(kWh)	(Rs)
0															
1															
2	3048000.00	540000.00		3588000.00	0.1019	365445.73				150000.00	515445.73	-230797.11	284648.62		
3						365445.73				150000.00	515445.73	-230797.11	284648.62		
4						365445.73				150000.00	515445.73	-230797.11	284648.62	59130	4.81
5						365445.73				150000.00	515445.73	-230797.11	284648.62		
6						365445.73				150000.00	515445.73	-230797.11	492847.12		
7	1016000.00	180000.00	432000.00	1628000.00	0.1168	365445.73	190198.50			168000.00	723644.22	-230797.11	492847.12		
8						365445.73	190198.50			168000.00	723644.22	-230797.11	492847.12		
9						365445.73	190198.50			168000.00	723644.22	-230797.11	492847.12	78840	6.25
10						365445.73	190198.50			168000.00	723644.22	-230797.11	492847.12		
11						365445.73	190198.50			168000.00	723644.22	-230797.11	492847.12		
12	1524000.00	270000.00	576000.00	2370000.00	0.1490	365445.73	190198.50	353199.89		195000.00	1103844.11	-230797.11	873047.01		
13						365445.73	190198.50	353199.89		195000.00	1103844.11	-230797.11	873047.01		
14						365445.73	190198.50	353199.89		195000.00	1103844.11	-230797.11	873047.01	108405	8.05
15						365445.73	190198.50	353199.89		195000.00	1103844.11	-230797.11	873047.01		
16						365445.73	190198.50	353199.89		195000.00	1103844.11	-230797.11	1388954.44		
17	1016000.00	180000.00	792000.00	1988000.00	0.2505	365445.73	190198.50	353199.89	497907.43	213000.00	1619751.54	-230797.11	1388954.44		
18						365445.73	190198.50	353199.89	497907.43	213000.00	1619751.54	-230797.11	1388954.44		
19						365445.73	190198.50	353199.89	497907.43	213000.00	1619751.54	-230797.11	1388954.44	128115	10.84
20						365445.73	190198.50	353199.89	497907.43	213000.00	1619751.54	-230797.11	1388954.44		
21						365445.73	190198.50	353199.89	497907.43	213000.00	1619751.54	-230797.11	1388954.44		
22	RESIDUAL VALUE OF WT & BATTERIES			2266000.00											

CC – Capital Cost, WTG – Wind Turbine, BATT – Battery, RC – Replacement Cost, TCC – Total Capital Cost, EACCF – Equivalent Annual Capital Cost Factor, EACC – Equivalent Annual Capital Cost,
AO&MC – Annual Operation & Maintenance Cost, ALCC – Annual Life Cycle Cost, ALCRV – Annual Life Cycle Residual Value, APGC - Annual Power Generation Capacity

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e) Sensitivity Analysis

The rate of interest is an important parameter in life cycle cost analysis of a project and thus the unit cost of generation. The variation in unit cost of electricity (Rs/kWh) with the rate of interest is calculated for all four phases of life cycle and is shown in Figure – 6.

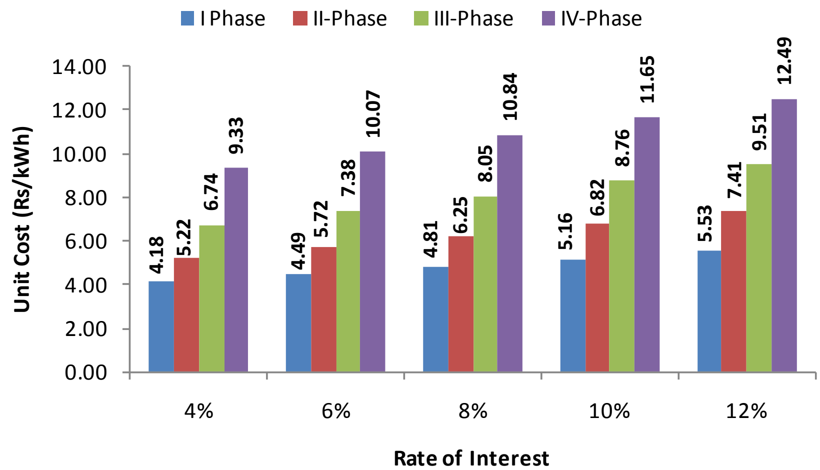


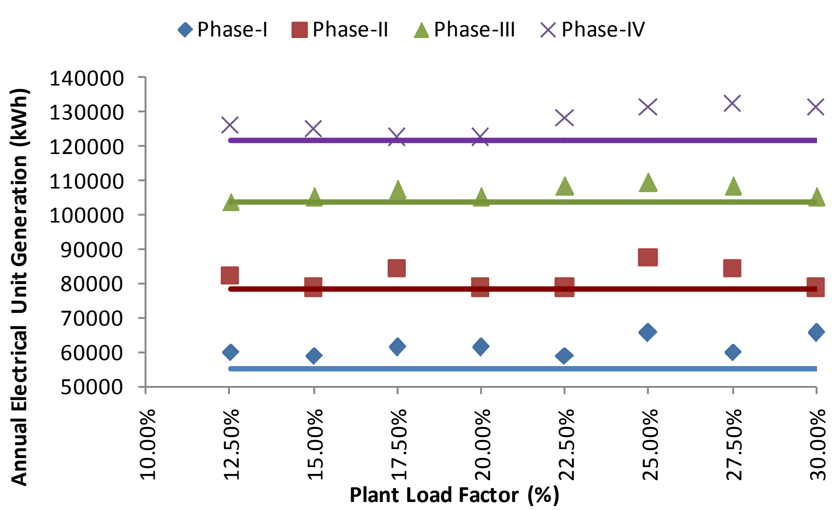
Figure 6 : "Variation in Unit Cost with Rate of Interest"

The another parameter which affects the life cycle cost is the plant load factor, which in turn depends upon many technical parameters of wind turbine generation and ambiance. The number of wind turbines required to fulfill the demand is a function of plant load factor. The numbers of wind turbines for different PLF are calculated and are shown in Table – 5.

Table 5 : "Wind Turbine for Different Plant Load Factors"

Phases	Plant Load Factor (%)							
	12.50%	15.00%	17.50%	20.00%	22.50%	25.00%	27.50%	30.00%
	Total Number of Wind Turbine							
Phase-I	11	9	8	7	6	6	5	5
Phase-II	15	12	11	9	8	8	7	6
Phase-III	19	16	14	12	11	10	9	8
Phase-IV	23	19	16	14	13	12	11	10

The demand in different phases corresponding annual generation of electrical units is shown in Figure – 7.



(Points & Lines indicate Generation and Demand respectively)

Figure 7 : "Annual Electrical Unit Generation (kWh) from WECS at Different Plant Load Factors"

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The unit cost of electricity (Rs/kWh) with the plant load factor is calculated for all four phases of life cycle and is shown in Figure – 8.

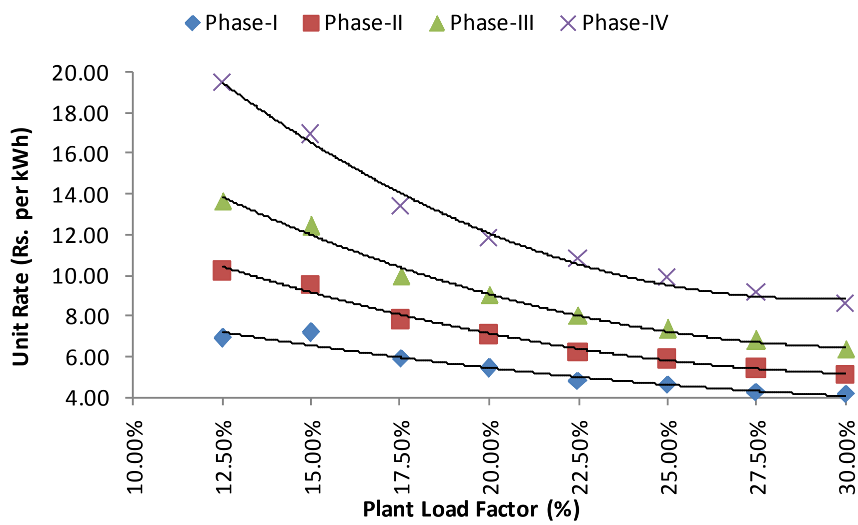

Figure 8 : "Variation in Unit Cost with Plant Load Factor"

The % variation in unit cost of electricity (Rs/kWh) with the plant load factor is calculated for all four phases of life cycle and is shown in Table – 6.

Table 6 : % Increase in Unit Cost with Plant Load Factor

PLF	% Increase in PLF	% Increase in Unit Cost with respect to PLF = 12.5%			
		Phase-I	Phase-II	Phase-III	Phase-IV
12.50%	0.00%	0.00	0.00	0.00	0.00
15.00%	20.00%	4.31	-6.39	-9.18	-13.04
17.50%	40.00%	-13.81	-23.44	-27.16	-31.42
20.00%	60.00%	-21.22	-30.43	-34.00	-39.47
22.50%	80.00%	-30.25	-38.83	-41.28	-44.47
25.00%	100.00%	-32.25	-42.43	-46.30	-49.16
27.50%	120.00%	-37.82	-46.82	-50.32	-52.90
30.00%	140.00%	-39.58	-49.87	-53.28	-55.74
PLF - Plant Load Factor					

VIII. Conclusions

The electrical has become a basic need in the Indian rural culture too. The conventional sources of energy have its limited life as the sources have finite quantum. These sources are distributed unevenly across the globe, and thus lead to a non uniform economy. At the same time, the transformation of these conventional energy sources into electrical energy affects the atmosphere adversely. The non conventional energy sources such as wind and solar are unlimited and mostly distributed by the nature across the globe evenly and need the attention of scientists and engineers to develop the technology to tap these sources economically. The economical feasibility of non-conventional sources for generation of electrical energy should be ascertained by life cycle cost analysis, instead of capital cost at initial level. The life cycle cost analysis of a proposed wind power generation system for a village is done, in which the unit cost of electricity is obtained for four phases in analysis period of 20 years. The following conclusions are drawn from the analysis -

- The current annual demand of electricity in the village as per survey is 34655 kWh, which is forecasted at the end of four phases during the analysis period of 20 years as 55448 kWh in 2017, 78667 kWh in 2022, 103965 kWh in 2027 and 121986 kWh in year 2032.

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- The small wind turbines each of 5.00 kW capacities with average plant load factor of 22.5 % are proposed for installation. The numbers of wind turbines required in four phases are 6, 8, 11 and 13.
- The life cycle cost analysis is done for analysis period of 20 years, considering the rate of interest 8%. The unit cost of electricity increases with capital investment in different phases and thus does not follow the economies of scale. It is Rs.4.81, Rs.6.25, Rs.8.05 and Rs.10.84 in four phases.
- The unit cost of the electricity of the proposed wind power generation in the first and second phase of analysis period tunes with the existing unit rates of Maharashtra Electric Supply and Distribution Company. The rates in third and fourth phases of analysis period are higher with respect to the current rates; however the same may be justified by considering the natural rise in the rates with time due to escalation in prices.
- The unit cost of generation is sensitive to rate of interest, which is demonstrated in Figure – 6. The unit rate of electricity varies from 23.46 to 30.51% in all phase of life cycle, for rate of interest 4% to 12%.
- The plant load factor of any generation depends on many technical and management factors. Any improvement in the plant load factor reduces the unit cost of generation. The sensitivity of unit cost with respect plant load factor is analysed and it is observed that improvement in plant load factor from 12.50% to 30.00% reduces the unit cost by 39.58 % & 55.74% for phases I & IV respectively.

IX. Limitations and Future Scope

The case study presented in this paper is an attempt to justify the economical feasibility of wind turbine at village level. The strength and characteristics of wind in the area plays an important role in success of wind power generation. At the same time efficiency of battery system also plays a vital role in an isolated door step supply. The renewable energy sources such as bio-mass and solar are available in the village, which can also be used for electric power generation. A hybrid system using biomass, solar and wind energy may be a more realistic solution for the energy security for the village.

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Global Journal of Researches in Engineering
Industrial Engineering
Volume 13 Issue 3 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Productivity Improvement through Process Analysis for Optimizing Assembly Line in Packaging Industries

By Naveen Kumar & Dalgobind Mahto
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Abstract - Assembly line balancing is to know how tasks are to be assigned to workstations, so that the predetermined goal is achieved. Minimization of the number of workstations and maximization of the production rate are the most common goals. This paper presents the actual case different components manufactured at industries in which productivity improvement is a prime concern and there is a necessity for balancing the operations at various strategic workstations in order to apply group technology and minimize the total production cost and number of workstations.

Keywords : *assembly line balancing, workstations, production cost.*

GJRE-G Classification : FOR Code: 290502

PRODUCTIVITY IMPROVEMENT THROUGH PROCESS ANALYSIS FOR OPTIMIZING ASSEMBLY LINE IN PACKAGING INDUSTRIES

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Productivity Improvement through Process Analysis for Optimizing Assembly Line in Packaging Industries

Naveen Kumar [α] & Dalgobind Mahto [σ]

Abstract - Assembly line balancing is to know how tasks are to be assigned to workstations, so that the predetermined goal is achieved. Minimization of the number of workstations and maximization of the production rate are the most common goals. This paper presents the actual case different components manufactured at industries in which productivity improvement is a prime concern and there is a necessity for balancing the operations at various strategic workstations in order to apply group technology and minimize the total production cost and number of workstations.

Keywords : assembly line balancing, workstations, production cost.

I. Introduction

Line Balancing means balancing the production line, or any assembly line. The main objective of line balancing is to distribute the task evenly over the work station so that idle time of man of machine can be minimized. Lime balancing aims at grouping the facilities or workers in an efficient pattern in order to obtain an optimum or most efficient balance of the capacities and flows of the production or assembly processes.

Assembly Line Balancing (ALB) is the term commonly used to refer to the decision process of assigning tasks to workstations in a serial production system. The task consists of elemental operations required to convert raw material in to finished goods. Line Balancing is a classic Operations Research optimization technique which has significant industrial importance in lean system. The concept of mass production essentially involves the Line Balancing in assembly of identical or interchangeable parts or components into the final product in various stages at different workstations. With the improvement in knowledge, the refinement in the application of line balancing procedure is also a must. Task allocation of each worker was achieved by assembly line balancing to increase an assembly efficiency and productivity.

i. Line Balancing
ii. Single-Model Assembly Line
iii. Mixed Model Assembly Line
iv. Multi Model Assembly Line
v. Non Value Added Costs

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Author σ : Professor Green Hills Engineering College, Solan, India.

This work is in continuous to the previous paper "**Assembly Line Balancing: A review of developments and trends in approach to industrial application**" which is published in "Global Journal of Researches in Engineering" of "Industrial Engineering", Vol. 13, Issue 2, Version 1.0, pp. 29-50, Year 2013.

a) Equations used in Line Balancing Technique

In assembly line balancing system, there are various equations and methods are prevalent. The following equations have been used to calculate the line efficiency and arrive at decision how and what are the requirements and area where action is needed for further improvement

(i) Cycle Time

$$Cycle\ time = \frac{Produ\ ction\ Time\ per\ day}{Unit\ required\ \ per\ day} \quad (1)$$

(ii) Lead Time

$$Lead\ time = \sum Production\ Time\ along\ the\ assembly\ time \quad (2)$$

(iii) Productivity

$$Productivity = \frac{Output}{Labour\ *Production\ \ time\ per\ day\ (hour\ )} \quad (3)$$

(iv) Smoothness Index

$$SI = \sqrt{\sum_{i=1}^{k}(STmax - STi)^2} \quad (4)$$

Where,

Stamp - maximum station time (in most cases cycle time),
STi - station time of station i.

(v) Balance Delay

$$BD = [\{(K)*(CT) - (\sum_{I=1}^{K} STi)\}/\{(K)*(CT)\}*100\%] \quad (5)$$

b) Definations used in Line Balancing

The definitions of the some of the terms used in the course of case studies have been illustrated below:

c) Time Study in Line Balancing

Time study is a technique used to establish a time standard to perform a given assembly operation. It is based on the measuring the work content of the selected assembly, including any personal allowances and unavoidable delays. It is the primary step required

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to determine the opportunities that improve assembly operations and set production standards.

i. *Operations Analysis*

The operation analysis is a method used to identify and analyze the productive and non-productive activities described above by deployment of Lean elements and is concerned with developing techniques to improve productivity and reduce unit costs. Any operation improvement is a continuing process and with sufficient study of all the operations, they can be practically improved.

II. Aims and Objectives of the Work

The aim of this work is to minimizing workloads and workers on the assembly line while meeting a required / maximum output. The aims and objectives of the present study are as follows:-

- To reduce production cost and improve productivity.
- To determine number of feasible workstation.
- To identify the location of bottleneck and eliminate them.
- To determine machinery and equipment according to assembly mechanism.
- To equally distribute the workloads among workmen to the assembly line.
- To optimize the production functions through construction of mix form of automation assembly and manual assembly.
- To minimize the total amount of idle time and equivalently minimizing the number of operators to do a given amount of work at a given assembly line speed.

III. Methodology: Steps for Improvement

Based in the study and works of other experts and authors, it has been observed that for the mixed model assembly line balancing, different steps and procedures have been planned, which have been shown in fig.1.

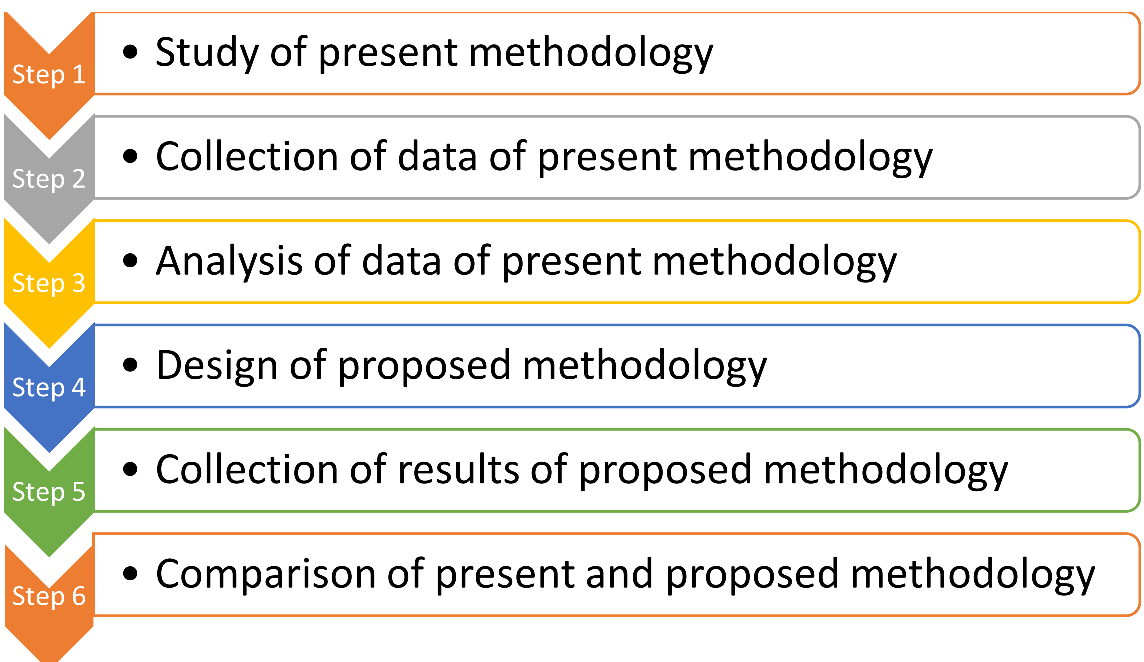

Figure 1 : Steps followed for study of line balancing case study

In the case of this work, the first step following methodology has been adopted for the study of line balancing under mixed model constant.

a) *Product Selection Criteria*

Product selection is critical as it provides focus to the project and produce tangible improvements in a timely manner. Trying to solve all problems at the same time creates confusion, inefficient use of resources and delays. Product selection refers to the process of identifying a “product” or “family” of similar products to be the target of an improvement project or study.

The selection of product was based on the following criteria:

- ➢ Customer importance and importance of the product to customer.
- ➢ Potential to improve overall operations.
- ➢ Potential to impact other products.

Different product family classification methods are available, the most dominant in usage being the following methods:

a) A-B-C Classification Method
b) Part-Process Matrix Method

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b) Time Study and Line Balancing

The time study was done in order to meet the key objectives of increasing productivity, determining the production capacities, evaluating standard cost and balancing the activities through proper planning and plant layout.

c) Operations Analysis

Operation analyses were performed by techniques of lean operations like Process Chart, Spaghetti chart, Value Added Mapping (VAM) etc. These analyzing tools help in effectively taking decision for material handling, plant layout, delay times, and storage. Operation analysis involves:

- Purpose of the Operation starts with analysis or study of any process or assembly operation for improving the same by eliminating or combining any operation.
- Material utilized for direct and indirect processes.
- Make ready Setup and Tools which involves procuring tools and materials, receiving instructions, preparing the workstation, cleaning up the work station and returning the tools to the tool crib.
- It involves working conditions, which should be good, safe, and comfortable. Good working conditions have positive impact on the overall productivity.
- Material handling involves motion, storage and quantity of materials throughout the process.
- Other important operation analysis approaches is to simplify the operator body motion i.e. analyzing the operator's physical activity and reduce the work content. This approach helps to eliminate wasted motion, make operator tasks easy and reduce operator fatigue.
- Line layout to establish a production system that allows producing the desired quantity of products with desired quality at minimum cost.

An ideal layout is considered to be the one that provides adequate output at each work station without causing bottlenecks and interruptions to the production flow. A variety of assembly line layouts, as shown in Fig.2, Fig.3 and Fig.4 are feasible for any given assembly process (Straight line layout, U shaped layout).

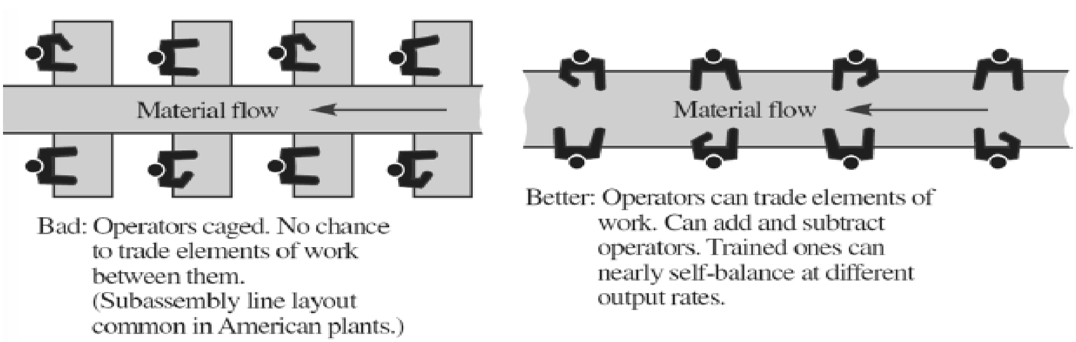

Figure 2 : Material Flow in Straight Line Layout

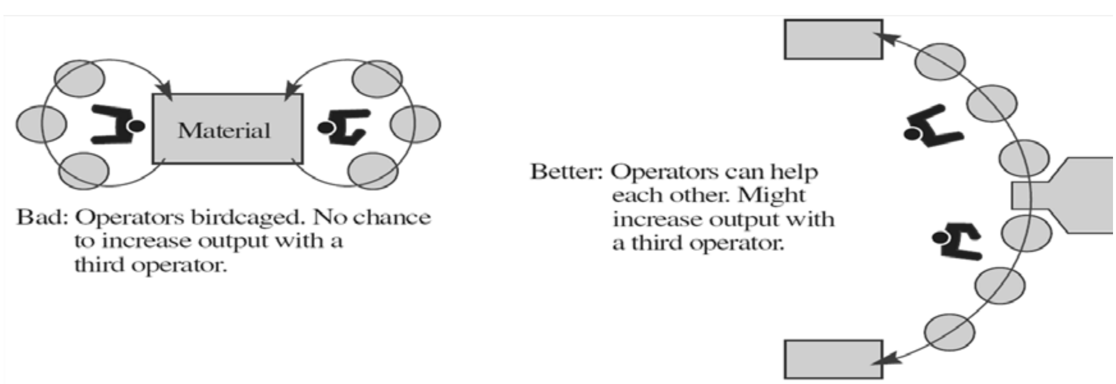

Figure 3 : Material Flow in Circular Layout

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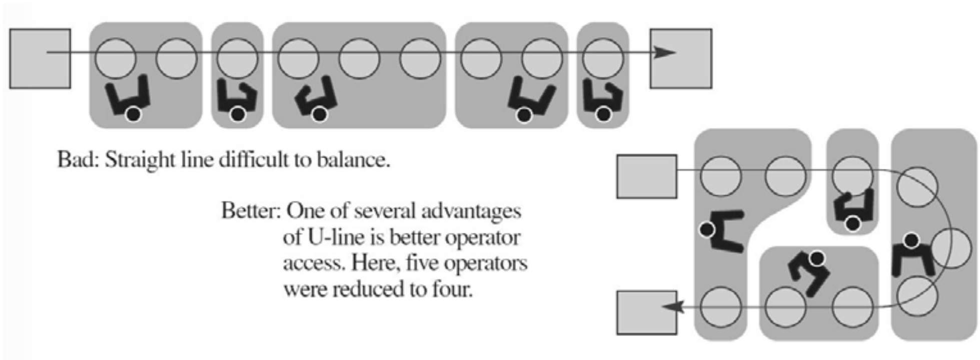

Figure 4 : Material Flow in U-shaped Layout

d) Assembly Line Balancing Problem

Applying Lean thinking, the first step in increasing the assembly line productivity was to analyze the production tasks and its integral motions. The next step was to record each motion, the physical effort it takes, and the time it takes, also known as time and motion study. Then motions that were not needed can be eliminated also known as non-value added activities and any process improvement opportunity exists must be identified. Then, all the standardized tasks required to finish the product must be established in a logical sequence and the tools must be redesigned. If required, multiple stations can be designed and the line must be balanced accordingly. The distribution of work on each of these stations must be uniform. The productivity can be improved by incorporating a dedicated material handling system. This allows assembly operators to concentrate on the essential tasks.

Some of the most critical components of an assembly line are given as follows:

- Process design or standardization
- Line balance
- Material handling
- Parts procurement and feeding
- Work-in-process management
- Man power
- Line size
- Line configuration

Then, the work elements will be assigned to these numbers of stations, one at a time, by meeting cycle time requirements and precedence constraints.

IV. Case Study

The three step productivity improvement methodology was applied to a real problem consisting of a manual assembly line. The assembly line contains mobile phone package assembly operations. The process involves initial disassembly, light assembly and inspection operations. Each package came in a master box which contains ten such packages as shown in Fig.5. Once all the packages are ready, were placed in an empty master box and the master box was moved to bar-coding area and then to the shipping area.

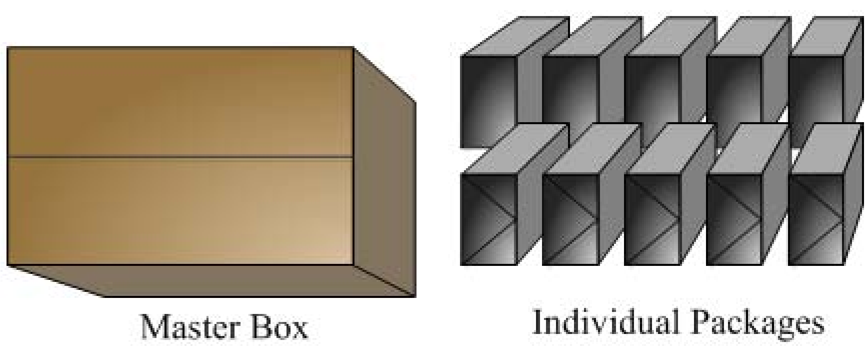

Figure 5 : Figure Showing Master Box and Individual Packages

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The process / component list for a single package is as follows:

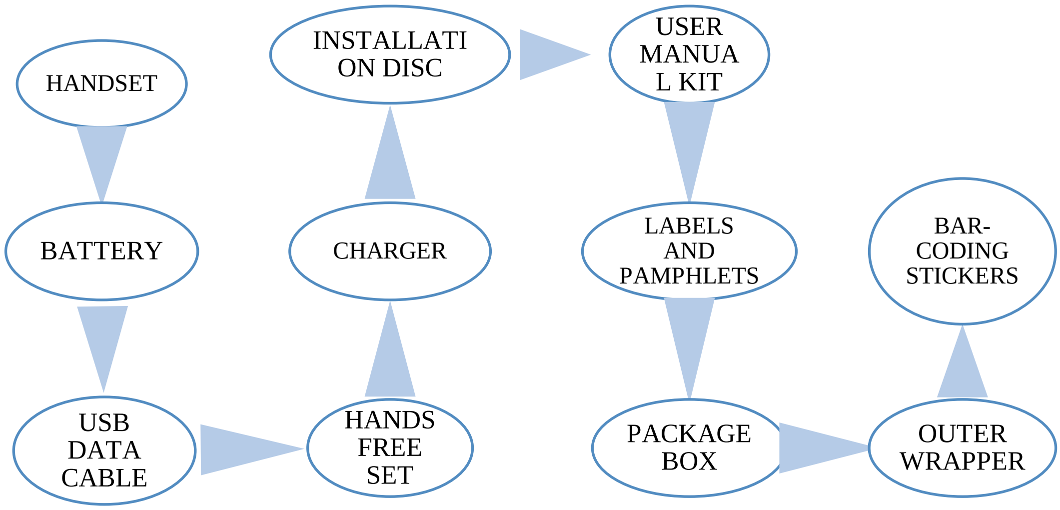

Figure 6 : Component in a single package

a) Current Assembly Method

In the original assembly method, the input buffer has no pre-specified capacity. The master boxes were piled at both input and output sides of the assembly table in stacks using storage pallets. Each pallet holds approximately 40 to 60 master boxes. The individual packages were then removed from the master box on to the table, all at a time, and the assembly is carried out on each package by four different operators. The subassemblies and the headset components were pushed from one person to the next person on the table without an appropriate material handling arrangement. Once the assembly was completed, the packages were arranged in an empty master box and placed on storage pallet. These finished master boxes were then carried to bar coding area manually by an operator.

b) Present Work Study

The first step in productivity improvement methodology was the present work study. For the current scenario, almost all the models produced have the similar processing steps. Hence, the product selection step has less significance in this context. In the next step, the current process was studied and all the assembly work elements were listed. Time studies were then carried out and the data obtained was analyzed to identify bottle neck situations and establish production standards. The precedence network diagram is drawn by the plant engineers for the original assembly process as shown in Fig.7.

The target given for this assembly line was 35 boxes/operator/hour. Due to the drawbacks associated with this method, the actual measured assembly output is observed to be 29.8 boxes/operator/hour. From the process study and the network diagram, it can be seen that the assembly line has large scope for improvement by careful analysis. The next step explores these opportunities and develops methods to perform the assembly better.

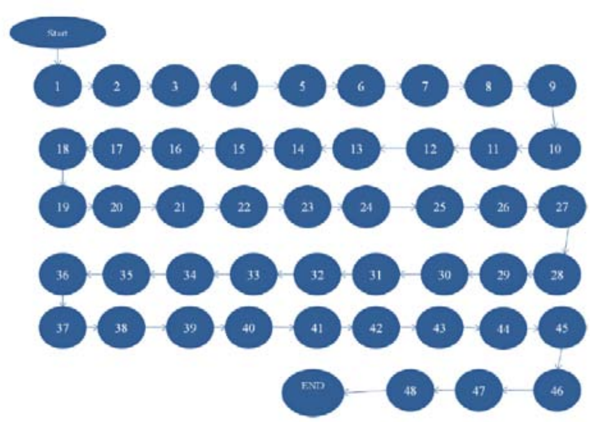

Figure 7 : Original Precedence Network Diagram

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c) Analysis and To-Be System

The next step, operations analysis, helps to identify improvement opportunities by highlighting productive and non-productive operations. This step also facilitates effective ways of doing things by suggesting alternate methods to perform operations to reduce operator fatigue and unnecessary movements to improve the overall performance. The operations analysis step adapts certain principles of Lean manufacturing such as standardization, visual management, 5-S and ergonomics, making the assembly line Lean.

For the assembly line, the operations analysis is carried out and the assembly operations are standardized by reducing the non-value added activities and the corresponding standard times are established. The precedence network diagram for the standardized assembly is given in Fig.8.

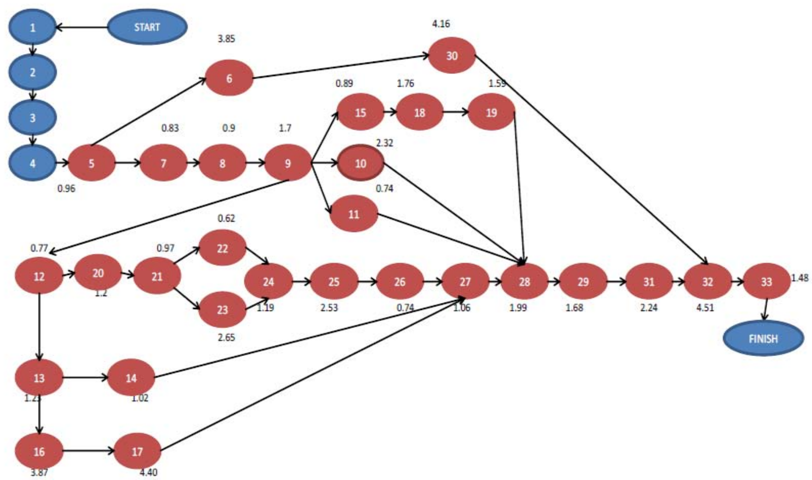

Figure 8 : Modified Precedence Network Diagram

Operations analysis step also results in selecting the most suitable assembly line layout, which further helps in planning a good material handling system. Taking into account the total assembly time required to produce one package (which is considerably small), the simplicity of the assembly operations, the feasibility to modify the existing layout without causing much effect on current production, the traditional straight line configuration is chosen. A straight line configuration is well suitable for assemblies involving operators perform a set of tasks continuously in a given sequence for all the products.

The two proposed assembly line configurations for the current assembly method are shown in Fig.8. The next step to improve the assembly line productivity is to design and balance the assembly line accordingly to satisfy the cycle time and demand requirements.

Both the configurations take into consideration Lean manufacturing principles such as Standard Work, 5-S, Visual Controls, Kaizen (Continuous Improvement) and knowledge sharing, to improve productivity, reduce work-in-process inventory, floor space reduction, minimize operator unnecessary motion and reworks. A brief description of each configuration with the workstation specifications follows.

i. *Single Stage Parallel Line Configuration*

The entire set of assembly operations required to produce one package will be performed by single operator at one workstation. The number of operators is reduced from four to one operator per assembly table from the original method. The completed package will be placed in a master box and the finished master box with ten of these packages is moved through conveyor to an output buffer. The master box is then transferred to bar coding area by a material handler.

ii. *Five-Stage Serial Line Configuration*

The assembly table consists of five work stations and each stage is assigned with a defined set of work elements. The work elements are assigned to each station using Ranked Positional Weight (RPW) heuristic method. The balanced line with five assembly stages is shown in Fig.9.

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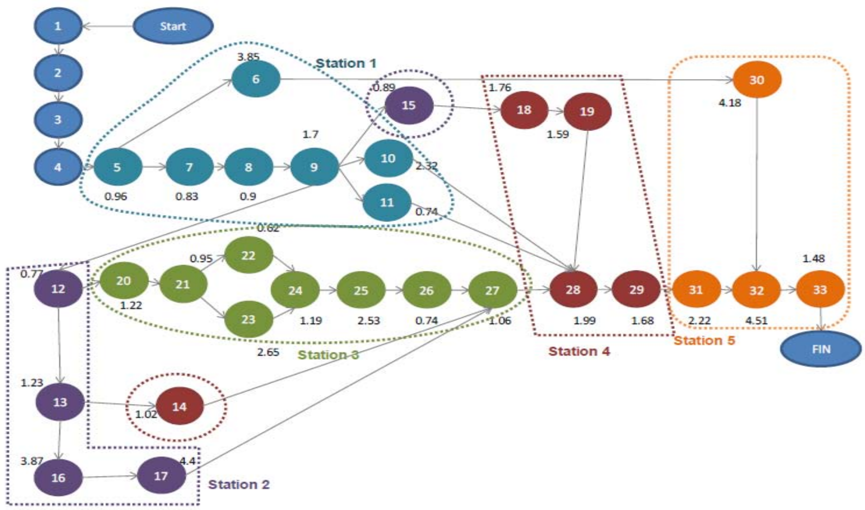

Figure 9 : Precedence Diagram Showing Five Assembly Stages

After the completion of tasks at each stage, the components or sub-assemblies are pushed on to a conveyor located along the center of work table by using a material tray. The operator at the next stage pulls the tray from the conveyor and completes the assembly. Once the package reaches the end of assembly table it is placed in the master box and then the master box is moved to bar-coding area by a material handler.

The conveyor at each assembly stage can hold only two material trays. This prevents excess work-in-process inventory in terms of packages. The stopper acts as mistake proofing tool by avoiding accidental tray movement to the next stage.

d) System Evaluation

Under ideal conditions, experimenting with the real assembly line would be excellent, but is not feasible always. The costs associated with manipulating the system, parameters, operators and workstations may be quite large. These costs can be in terms of capital required to bring about the changes and the output lost during this process. Simulation proves to be an exceptional tool in such scenario and efficiently provides an estimation of all the performance parameters.

i. *Objectives of the Simulation Analysis*

Simulation was used to analyze the assembly line and the associated material handling and distribution system for the proposed assembly layouts. The objectives of the simulation analysis to determined are:

- The number of master boxes to be loaded per material delivery cart.
- The input and output buffer sizes of the assembly tables.
- The number of material handling carts required to deliver the master boxes from storage area to assembly tables.
- To determine number of material handlers required to deliver finished boxes from assembly tables to bar-coding area.

ii. *Material Handling System - Proposed Operation*

Manually operated push carts are used to deliver master boxes from the pallet storage locations to the assembly tables. Input and output buffers located at each table ensure a constant and controlled work-in-process at the lines, and also appropriately protecting each station from possible material starvation. Labels and other documentation to be assembled with each product do not need frequent replenishment and will be stored at the point-of-use bins on the assembly table.

V. Data Collection and Analysis

From the study of assembly line balancing it is found that the product is moved from one workstation to other through the line, and is complete when it leaves the last workstation.

a) Material Handling Cart Capacity

For single stage line it can be seen from Fig.10 that at cart capacity as 6 boxes maximum utilization is achieved. The idle time for material carts increase when the capacity exceeds 6 units although utilization is 100%, which is not recommended. Similarly for five-stage line, maximum table utilization is observed at a capacity of 6 boxes. So, for both the configurations the material handling cart loads 6 boxes per trip.

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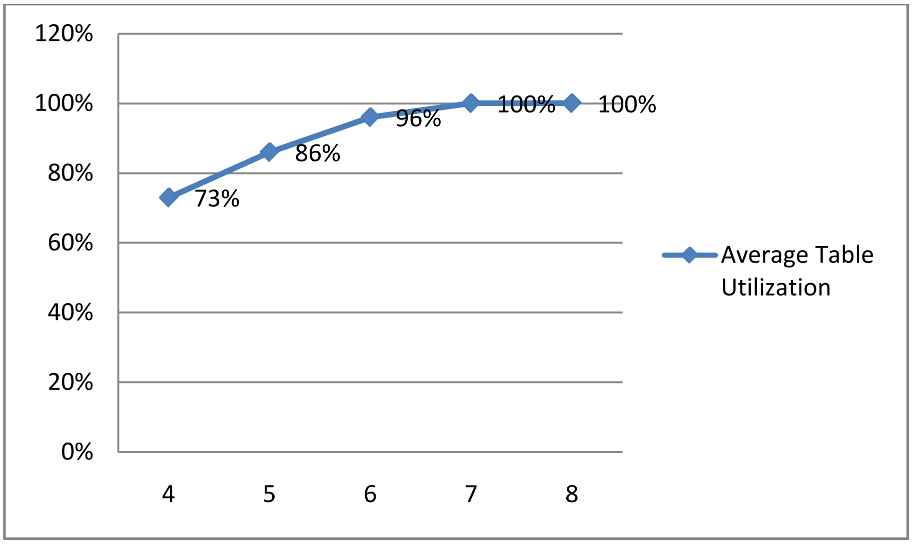
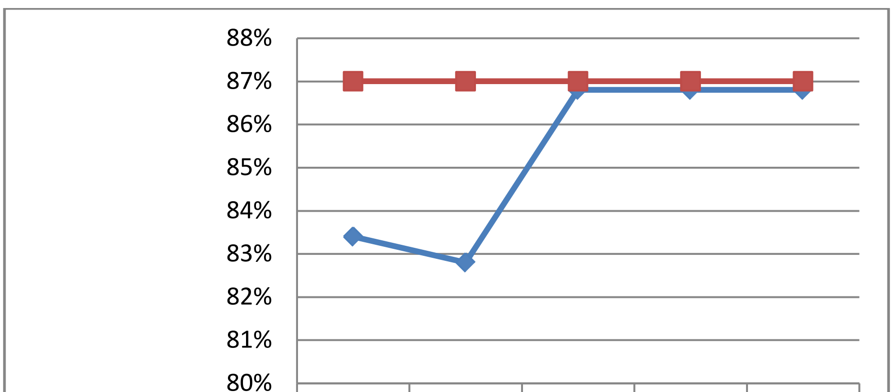


Figure 10 (a) : Single Stage Parallel Line Layouts



	4	5	6	7	8
Avg. Table Utilization	83.40%	82.80%	86.80%	86.80%	86.80%
Maximum Table Utilization	87%	87%	87%	87%	87%

Figure 10(b) : Five Stage Serial Line Layout

Figure 10 (a) & (b) : Cart Capacities for Parallel Line and Serial Line configurations

b) Material Handlers Required _ Supply Side

With the cart capacity fixed as 6 units, iterations are run by varying the cart quantities. For both the configurations, 2 carts are required to supply master boxes to input buffers.

c) Input Buffer Size

The assembly tables yield maximum utilization when the input buffer size is 2 units. Fig.11 gives the analysis of changing buffer sizes on the average table utilization.

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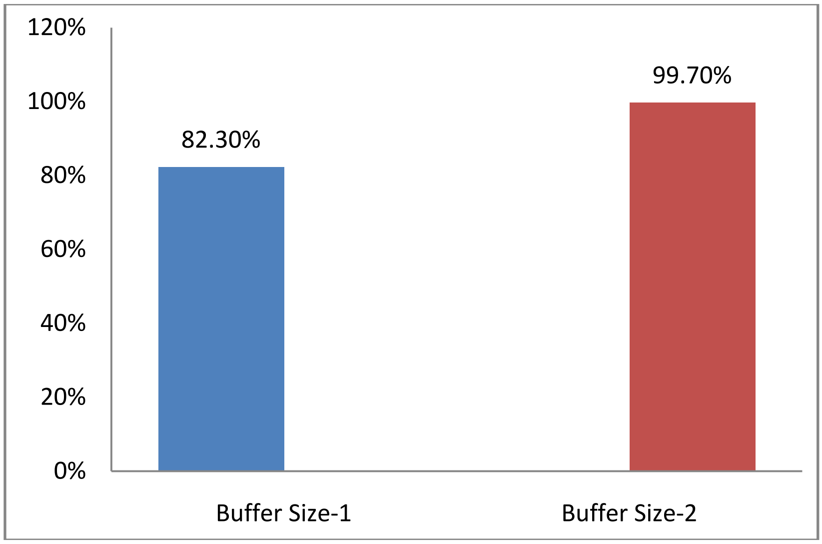

Figure11 (a) : Single Stage Parallel Line

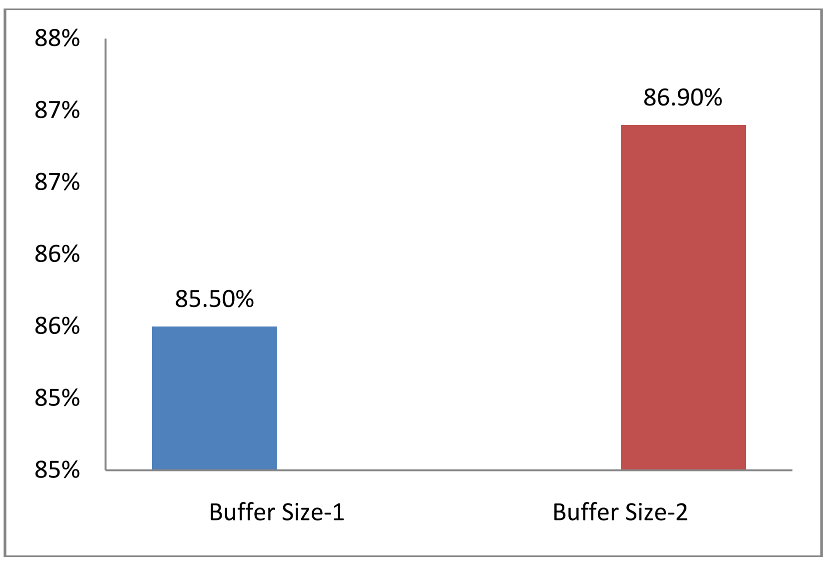

Figure11 (b) : Five Stage Serial Line

Figure 11(a) & (b) : Buffer Sizes for Parallel Line and Serial Line configurations

d) Output Buffer Size

The output buffer size is determined by performing iterations by varying the output buffer capacity for fixed input buffer sizes, cart capacity and quantity. The output buffer capacity is obtained for single stage line as 5 units and for five-stage line as 2 units per table.

e) Material Handlers Required – Bar Coding Side

The single stage line requires two operators to carry finished master boxes to bar coding area. The five-stage line requires three material handlers with carts to transfer master boxes to bar coding area. This is determined based on how the finished box removal from output buffer affects the assembly utilization. The material handling requirements based on the table utilization is shown in Fig. 12

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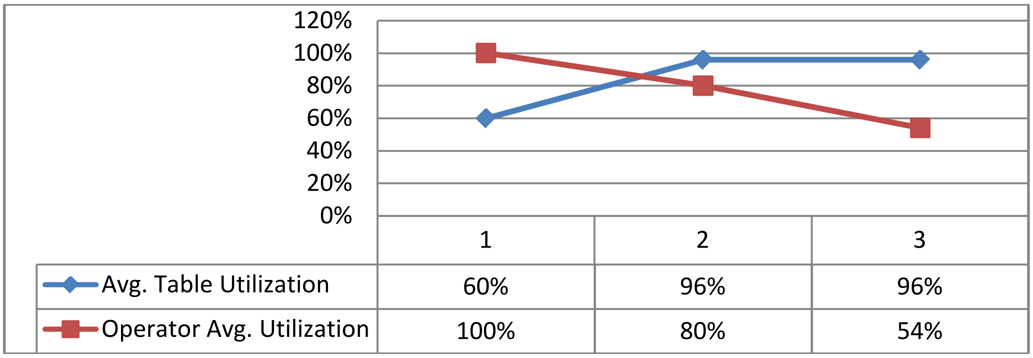

Figure 12 (a) : Single Stage Parallel Line

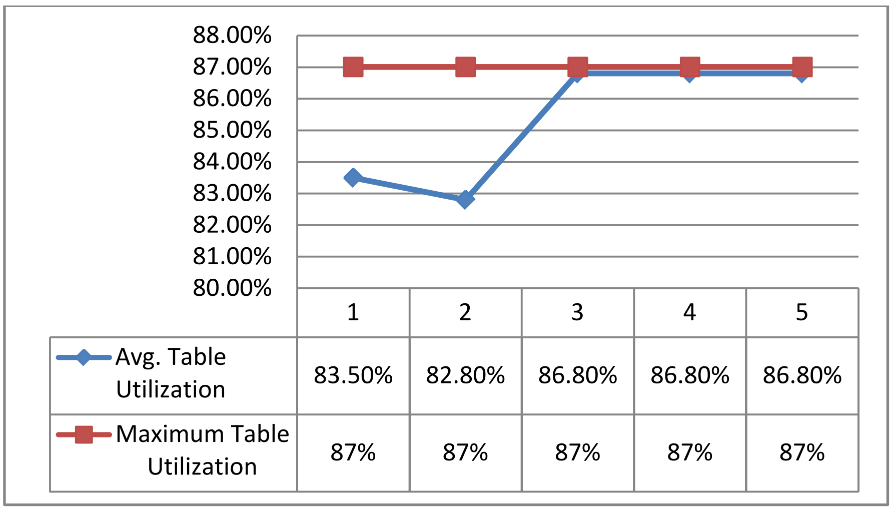

Figure 12 (b): Five Stage Serial Line

Figure 12 (a) & (b) : No. of Material Handlers Required

f) Analysis of Results

The Table 1 consolidates and compares the results for the two assembly configurations tested.

Table 1 : Consolidated Results

Parameter	Single Stage Parallel Line	Five Stage Serial Line
No. of material handlers required – supply side	2 Carts with operators	2 Carts with operators
No. of material handlers required- Bar coding side	2 Operators	3 Carts with operators
Cart capacity	6 Boxes	6 Boxes
Input buffer size	2 Boxes	2 Boxes
Output buffer size	5 Boxes	2 Boxes

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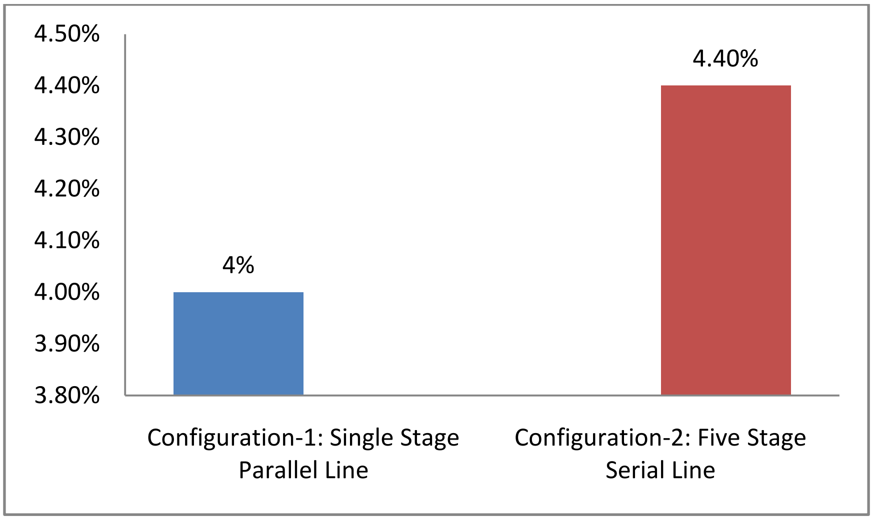

Figure 13 (a) : Avg. No. of Tables Served per Material Handler

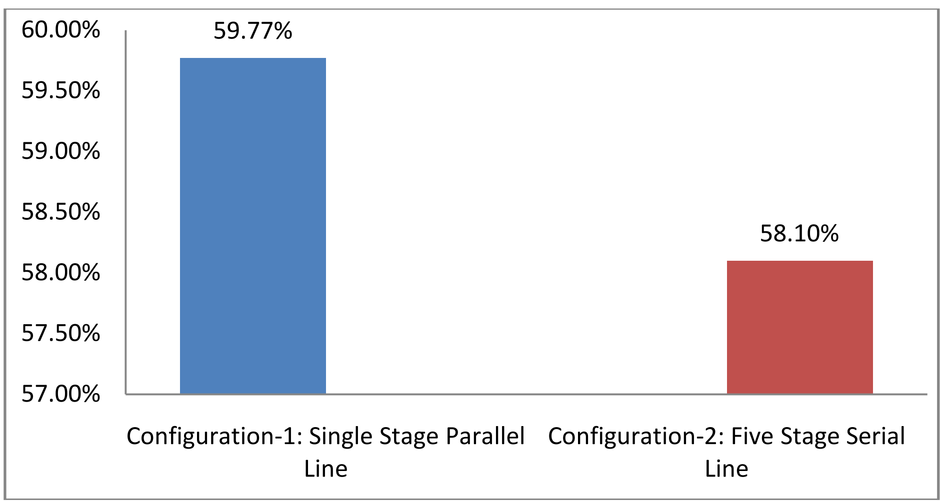

Figure 13 (b) : Box Output/Operator/Hour

Figure 13 (a) & (b) : Comparison of Results Parallel Line and Serial Line Configurations

The consolidated results comparing the two assembly line configurations are as follows.

- **Tables Served Per Material Handler:** Number of tables served by each material handling unit is higher for five stage serial line configuration.
- Fig.13 shows that the five stage serial line requires less material handlers than the single stage line. The number of tables to be served is lesser in five stage configuration compared to the single stage configuration. But it can be observed that the difference is not highly dominating.
- **Productivity**: The single stage configuration gives output as 59.7 boxes/operator/hour where as five stage line gives 58 boxes/operator/hour.
- There is a considerable improvement in productivity in both the assembly lines from the original method.
- **Operator Utilization:** Fig. 14 shows that the average operator utilization for single stage line is about 99% and for five stage line is 86.9%.

It can be seen that for a five-stage line all the operators at different stages of assembly line are not uniformly utilized.

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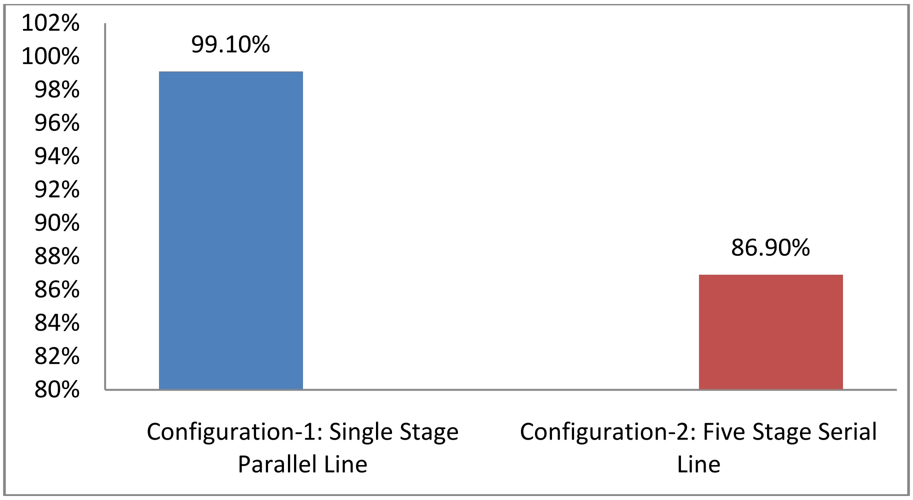

Figure 14 (a) : Operator Average Utilization

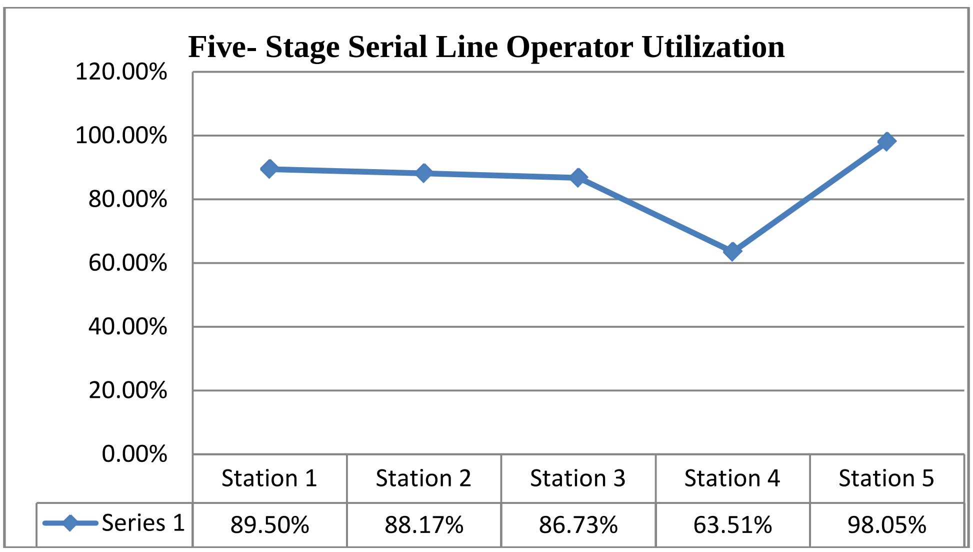

Figure 14 (b) : Operator Utilization

While solving an assembly line balancing problem, certain amount of imbalance in station times is inevitable. In this case, the level of imbalance shows a great impact on the assembly line utilization. The Table 2 shows the imbalances in station times for the five stage line.

Table 2 : Five Stage Assembly Line Balancing Showing the Imbalance Associated With Each Stage

S.No.	Operation	Average Time	Work Station	Station Time	Cycle Time	Imbalance
5	Take Individual Box	0.96	Stage 1	11.31	10.77	-0.54
6	Peel original Import label	3.85				
7	Breaking the seal of approval	0.83				
8	Open individual box	0.90				
9	Remove pamphlets and disc from the box	1.70				
10	Stick the label on disc manual	2.32				
11	Verify the internet address booklet	0.74				

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12	Check handset	0.77	Stage 2	11.16		-0.39
13	Remove handset tray from box	1.23				
15	Check full pamphlets	0.89				
16	Paste label on charger box	3.87				
17	Check charger	4.40				
20	Remove the Phone from bag	1.22	Stage 3	10.97		-0.20
21	Remove the flip	0.95				
22	Verify the sd card for handset	0.62				
23	Verify the serial number and logo of NOM	2.65				
24	Place lid back on the phone	1.19				
25	Save phone in the bag	2.53				
26	Arrange phone on tray	0.74				
27	Return the tray in the box	1.06				
14	Check complete accessories	1.02	Stage 4	8.04		2.73
18	Add user policy to the pamphlets	1.76				
19	Add user guide to pamphlets	1.59				
28	Returning pamphlets to the box	1.99				
29	Close Individual box	1.68				
30	Paste import tag	4.18	Stage 5	12.39		-1.62
31	Place security seal	2.22				
32	Place on individual box the outer wrapper	4.51				
33	Place individual box in master	1.48				

Hence, it is recommended to implement the single stage parallel line in order to achieve higher productivity and better overall assembly performance.

VI. Discussion

In the light of collection of data, findings and analysis, the following inferences can be made:

- Experiments in line balancing show that optimal solutions for small and medium-sized problem are possible in acceptable time.
- A new improvement in priority rule is discussed which shows that production cost is the result of both production time and cost rates.
- For maximizing the production rate of the line robot assembly line balancing problems are solved for optimal assignment of robots to line stations and a balanced distribution of work between different stations.
- Three terms i.e. the lowest standard deviation of operation efficiency, the highest production line efficiency and the least total operation efficiency waste are studied to find out the optimal solution of operator allocation.
- Simulation tools such as Fact- Model, to modeling the production line and the works estimated are used to reduce the line unbalancing causes and relocate the workforce associated to idle time, eliminating the bottleneck and improving the productivity.
- New criterion of posture diversity is defined which assigned workers encounter the opportunities of changing their body postures regularly.

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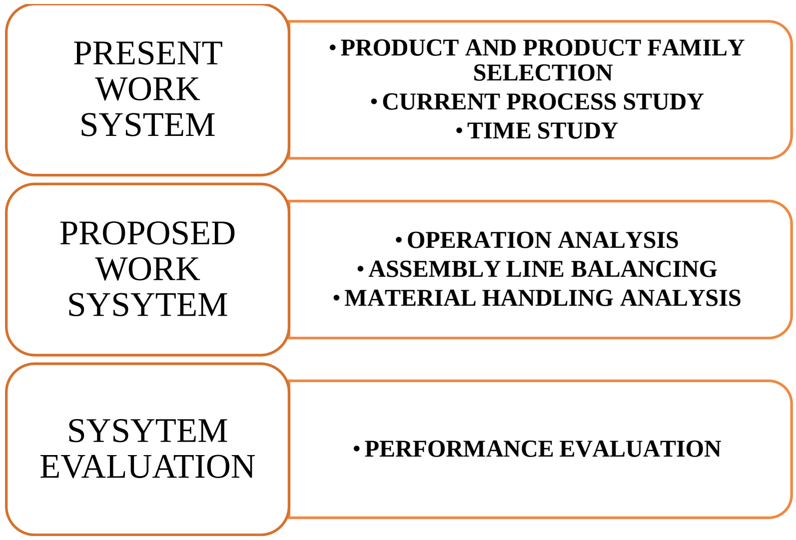

Figure 15 : Summary of comparison of present and proposed methodology

VII. Conclusion

From the analysis of data gathered from industry on assembly line balancing it is found that assembly lines are flow-line production systems, where a series of workstations, on which interchangeable parts are added to a product. The product is moved from one workstation to other through the line, and is complete when it leaves the last workstation. Ultimately, there is such workstation where the time study shows that the lines are not properly balanced. This is evident according to table 2 that item no 14, 18, 19, 28 and 29 have imbalance value of 2.73. So the priority of line balancing should start with these workstations in order to bring more improvement in productivity.

In the same way the second work stations of stage 3 needs attention for improvement.

In order to optimize line balancing from the results can be derived that

- A heuristic procedure for solving larger size of problems can be designed.
- Paralleling of workstations and tasks may be studied to improve the line efficiency.
- To select a single equipment to perform each task from a specified equipment set.
- Bee and ant colony algorithm to be adopted for finding number of workstations.

Further, for effectively implementing line balancing techniques one has to see the

- size of the operator,
- machineries availability & involved and
- Cost factors and storage capacity.

Side by side one has to see the throughput time before devising a mechanism for line balancing.

a) Scope of Future Work

The industrial situation of each and every industry differs on type of product manufactured, nature of machineries available, category of worker involved, methodology adopted and the management principles and policies in force in the industries. Therefore a particular case study carried out at package industry can further be reinvestigated in other process industries like automotive products sector, batch production industries, bottling plants or such industries where products are manufactured in lots.

Therefore the topic on line balancing can equally be implemented in manual assembly line as well as automotive assembly line. The further research therefore can be carried out on the same pattern in other nature of industries producing metallic products or non metallic products. However there may be different no. of workstations and predecessor but the basic mathematical modeling equation for calculating the cycle time, balance delay and smoothness index will be same in all types of industries.

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Global Journal of Researches in Engineering
Industrial Engineering
Volume 13 Issue 3 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Manual Lifting Task Methods and Low Back Pain among Construction Workers in the Southwestern Nigeria

By Oluwole Adeyemi, Samuel Adejuyigbe, Olusegun AkanbI
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Abstract - This study evaluated manual lifting tasks methods among construction workers in Southwestern Nigeria. The aim was to determine the level of inclusion of ergonomics in the work methods. Single-task lifting analysis based on National Institute for Occupational Safety and Health (NIOSH) was used to evaluate 32 jobs involving 250 healthy workers. The result shows single task lifting index (STLI) greater than 1.0 for more than 75% of the jobs. The result indicated that more than 70% of the total workers are at an increased risk of lifting-related discomfort. Level of ergonomics inclusion in the work methods is low. More than sixty three percent (63%) of the workers had no regular ergonomics training that could expose them to better method(s) of lifting. Redesigning of work methods is necessary. Managers in the industry need proactive measures to incorporate ergonomics into their job methods to achieve STLI values of 1.0 or less.

Keywords : manual; lifting; load; task; method; construction; workers; pains; injury; risk; ergonomics.

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MANUAL LIFTING TASK METHODS AND LOW BACK PAIN AMONG CONSTRUCTION WORKERS IN THE SOUTHWESTERN NIGERIA

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Manual Lifting Task Methods and Low Back Pain among Construction Workers in the Southwestern Nigeria

Oluwole Adeyemi [α], Samuel Adejuyigbe [σ], Olusegun Akanbl [ρ], Salami Ismaila [Ѡ] & Adebayo. F. Adekoya [¥]

Abstract - This study evaluated manual lifting tasks methods among construction workers in Southwestern Nigeria. The aim was to determine the level of inclusion of ergonomics in the work methods. Single-task lifting analysis based on National Institute for Occupational Safety and Health (NIOSH) was used to evaluate 32 jobs involving 250 healthy workers. The result shows single task lifting index (STLI) greater than 1.0 for more than 75% of the jobs. The result indicated that more than 70% of the total workers are at an increased risk of lifting-related discomfort. Level of ergonomics inclusion in the work methods is low. More than sixty three percent (63%) of the workers had no regular ergonomics training that could expose them to better method(s) of lifting. Redesigning of work methods is necessary. Managers in the industry need proactive measures to incorporate ergonomics into their job methods to achieve STLI values of 1.0 or less.

Keywords : manual; lifting; load; task; method; construction; workers; pains; injury; risk; ergonomics.

I. Introduction

Construction industry is one of the more hazardous and risky occupations in terms of safety and health. Workers in the industry work under tough conditions to perform the desired task. The workers are frequently exposed to awkward work postures, physical demands and different types of diseases and accidents. They are more than twice as likely to be killed at work, than the average worker. Among the most common diseases is Work related Musculoskeletal Disorders (WMSDs) (Helen et al. 2008; Aman et al., 2011; David et al., 2010; BLES, 2010). The physical hazards always leading to increased risk of Musculoskeletal Disorders (MSDs) (NIOSH, 2011). Tasks that are either physically demanding or require repetitive lifting are at a high risk for accident-injuries. One situation that regularly cause worker to report back pains or to actually sustain injury is where an event that is not anticipated cause an injury while performing the task, example is the straining of back muscles by improper lifting (Articlesbase, 2011). Task may be considered hazardous if the imposed loads (forces) exceed the individual's strength and endurance/ tolerance (Chafin and Andersson, 1991). It was noted that the risk of injury is largely determined by the weight lifted (MHOR, 1992).

Basra and Crawford (1995) observed variety of different handling techniques within the 131 employees in one brick manufacturing plant of which some of the techniques were considered potentially harmful. Construction Industry Advisory Committee (CONIAC, 1993) stated that there is a high risk of injury in the single-handed, and repetitive manual handling techniques of blocks heavier than 20 kilograms. As emphasized by Kerst (2003), effects of repetitive motions coupled with the performance of the same tasks are increased when awkward postures and forceful exertions are involved.

It was however stated that ergonomics involvement tends to lower the physical demands of work tasks, thereby lowering the incidence and severity of injuries (Ajimotokan, 2008). Ergonomics must be targeted to each individual worker and the tasks that he or she performs. It is also important to take into account the physical abilities of each worker as well as their personal limitations (Articlesbase, 2011). One way to minimize risk to health or safety in construction work is by changing the way the work is done (WHSR, 2011). The Work Health and Safety (WHS) regulations place obligations on administrators carrying out of high risk construction work to ensure that a Safe Work Method Statement (SWMS) is prepared before the proposed work commences. The document should state among others the health and safety hazards and risks arising from the work to be carried out and describe how the risk control measures will be implemented, monitored and reviewed (CWCP, 2012). All employers are to devise safe working methods and communicate to all of the necessary workers on site and which have to be updated as the construction work progresses (TS, 2013). It is therefore the responsibility of site supervisor to supervise the safe work procedures and workers also are trained to follow such safe work techniques.

There has been a number of research works after the limits established by International Labour Office

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(ILO, 1964) to reduce injuries, especially Low Back Pain (LBP) associated with manual load lifting. Work Practices Guide for Manual Lifting was published in 1981 (NIOSH, 191). Load that nearly all healthy workers could perform in a specific set of task conditions over a substantial period of time without an increased risk of developing lifting-related low back pain was highlighted as Recommended Weight Limit (RWL) (Waters et al., 1993). This limit as described (Waters et al., 1994), proved useful for identifying certain lifting jobs that posed a risk to the musculoskeletal system for developing lifting related low back pain.

Using NIOSH equation involves calculating Single task Recommended Weight Limit (STRWL) and Single–task Lifting Index (STLI) Waters et al., 1993) (APPENDIX A1) for the factors in the equation for a particular lifting and lowering task. If the magnitude of the lifting index (LI) increases, the level of the risk for the worker performing the job would be increased and a greater percentage of the workforce is likely to be at risk for developing lifting-related low back pain. The goal should be to design all lifting jobs to achieve a LI of 1.0 or less (Waters et al., 1994).

a) The aim and objectives of the study

The aim of this study is to determine the level of inclusion of ergonomics in the work methods of some selected lifting related tasks in construction industry.

The objectives of the study are too;

1. Determine the prevailing ergonomics risk factors contributing to lifting–related injuries among the group of tasks.
2. Determine the cause of prevalence of lifting related pains among the group of workers.

II. Material and Methods

a) Study Site and Task

A worker participatory approach was used in this study. Two hundred and fifty male workers from ten construction sites in the Southwestern Nigeria volunteered to participate in the study. All participants were experienced workers in manual material lifting jobs and the tasks selected for the study were tasks performed regularly, for a long time without major changes and that conform to the application of the RWL. Thirty two lifting-related jobs which involved two-handed and none required of significant amount of non-lifting physical demands were included in the study. Some of the tasks included; brick setting, kern setting, lowering bricks from truck bed, loading wheelbarrow with bricks, Lifting head pans filled with mortars, lifting and fixing window blade, ceiling fan, fluorescent holders, setting perforated bricks, wall tilling, lifting and fixing wooden doors, Stacking concrete bricks, among others. Weight of materials lifted ranged from 2kg to 42kg.

b) Data Collection

i. *Demographic Information and Assessment of Work Outcomes*

A structured interview which followed a set of standardized questionnaires was conducted at the workers by trained personnel. Data collection was conducted at the construction sites during the working period and at a time agreed by the workers and the site managers. Data collection procedures consist of the assessment of demographic information of the workers, data related to level of ergonomics training received by the workers and the health outcome for workers who spent at least 2 years on the current lifting jobs. Workers were asked of their age and the number of years spent on the current job. Inclusion of ergonomics in the job methods was verified by the frequency of ergonomics related information/training made available to workers through their supervisors. Workers' responses to introduction of new methods of lifting were also examined. Nordic Musculoskeletal Symptom Survey (Kuorinka et al.,1987) was also used, inform of a questionnaire, taking into consideration the information concerning the subjective pain/discomfort so as to record the presence or absence of any lifting related pains in lower back, upper back, hips/upper legs, knees/lower legs, ankles/feet, neck, shoulders, elbows/forearms, wrists /hands, and fingers within the past 12 months.

ii. *Assessment of Lifting Task Parameters*

Reliable measurements are obtained if standardized measurement methods are used(Kuorinka et al., 1987). For reliability, personnel trained to make measurement in a standardized manner were involved in the measurement of variables of the selected tasks. In each of the selected job the following variables were recorded: weight of the lifted object (kg) using a weighing scale, frequency of the lift (lift/min) with the use of stop watch, task duration (hour) with wrist watch, vertical and horizontal distances (cm) both at the origin and destination of the lift with meter rule, coupling rating by observation, asymmetry angle (degree) both at the origin and destination of the lift with the use of goniometer. The frequency of lift was counted within the sample period of 15minutes.

Data obtained from the workers were used for the calculations of STLI using the revised National Institute for Occupational Safety and Health (NIOSH) lifting equation. Horizontal Multiplier (HM), Vertical Multiplier (VM), Distance Multiplier (DM) and Asymmetric Multiplier (AM) were obtained with the use of equations as stated in APPENDIX A1 while Coupling Multiplier (CM) and Frequency Multiplier (FM) were derived using tables in APPENDIX A2 and A3 respectively. All the tasks were analyzed both at the origin of lift and at the destination.

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III. Results

Two hundred and thirty three (93.2%) of the two hundred and fifty (250) workers that participated in the study completed the questionnaire all of which have spent not less than 2 years on the current job. The demographics of the workers who participated in the studies are presented in Table 1.

Table 1 : Description of Demographic Information for Workers studied in ten constructions sites

	Lifting Index Category			
Demographic Variable	0<LI ≤1	1<LI≤ 2	2<LI ≤ 3	LI>3
Mean age (yr)	39.78	36	33.67	36.12
Mean time at current job (yr)	6.78	4.68	5.25	5.84
No. of workers	63	51	53	66

Table 2 presents the variables and multiplier values of the studied tasks. The outcome measure of STLI was greater than 1.0 for 23 (71.9%) out of 32 jobs analyzed and the highest value of the mean lifting index was 4.49 with a standard deviation of 2.19. All multipliers values are below the value of 1.0 with horizontal and frequency multipliers as worse cases.

It appears that the average STRWL values in the four categories of LI are similar in magnitude (6.86, 6.42, 7.83, and 6.23 kg) and there are wide variability in the magnitude of the weight lifted (3.50, 9.32, 19.73, and 25.42 kg).

Table 2 : Description of Mean (Standard Deviation) Lifting Equation Values for Jobs with Workers on Current Job ≥ 2 year, by Lifting Index (LI) category

	Lifting Index Category			
Demographic Variable	0<LI≤1	1<LI≤2	2<LI≤ 3	LI>3
No. of Jobs	9	7	8	8
Single Task Recommended Weight Limit (STRWL)	6.864(2.088)	6.42(2.24)	7.83(3.41)	6.23(2.34)
Mean Lifting index	0.52(0.27)	1.48(0.33)	2.64(0.27)	4.49(2.19)
Weight	3.50(2.14)	9.32(3.35)	19.73(7.96)	25.42(6.3 8)
Horizontal multiplier (HM)	0.65(0.16)	0.65(0.21)	0.61(0.24)	0.56(0.15)
Vertical multiplier (VM)	0.87(0.07)	0.93(0.06)	0.80(0.25)	0.87(0.09)
Distance multiplier (DM)	0.91(0.07)	0.91(0.03)	0.92(0.07)	0.94(0.07)
Asymmetric multiplier (AM)	0.86(0.06)	0.92(0.07)	0.92(0.08)	0.89(0.07)
Coupling multiplier (CM)	0.92(0.03)	0.90(0.01)	0.92(0.04)	0.92(0.03)
Frequency multiplier (FM)	0.70(0.17)	0.62(0.20)	0.63(0.13)	0.62(0.19)

a) Response of workers to ergonomics related training

Regarding ergonomics related training-/information organized by supervisors/managers to introduce workers to new method(s) of safe lifting (Figure 1), about 146 workers (63%) confirmed that there is no regular ergonomics training that could expose them to any better method(s) of lifting than the one they are used to. While 87 of the workers (37%) reported receiving regular training/information from their supervisors, 56 workers (64.4%) in this category could not confirm learning any new method of lifting during the said training.

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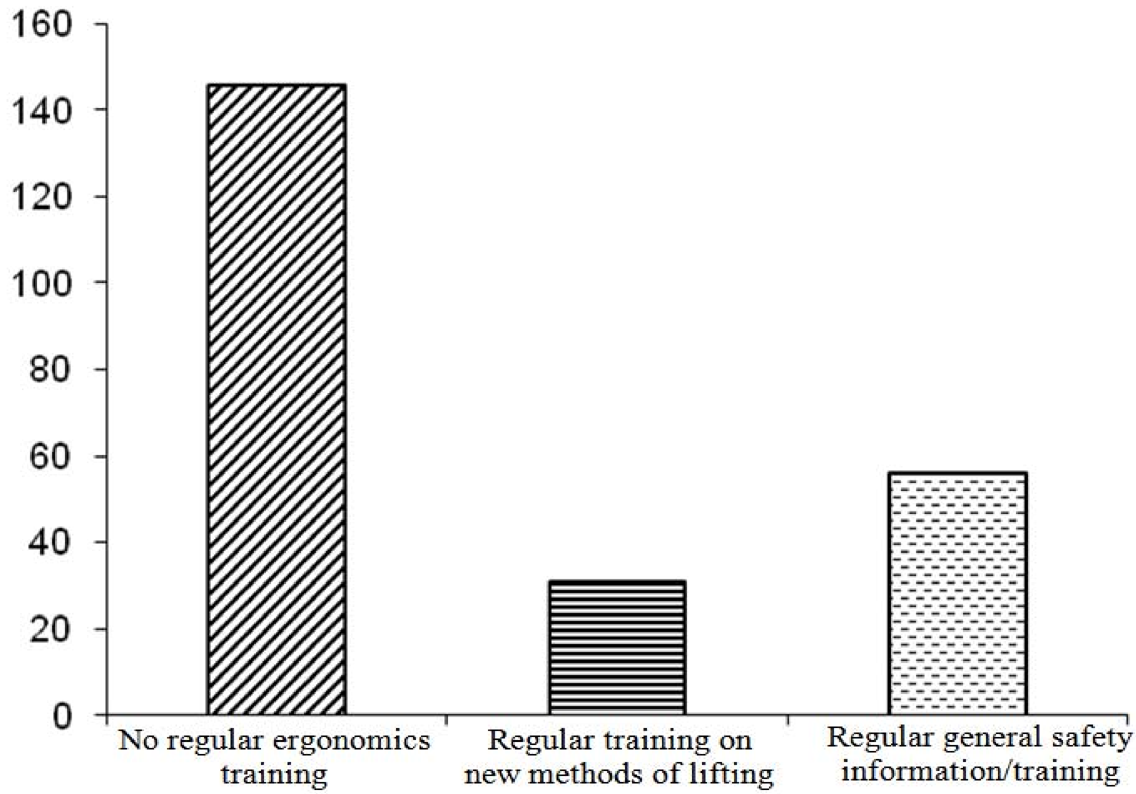

Figure 1 : Description of the Response of workers to ergonomics related training

Therefore through regular information/training, only thirty-one workers representing 13.3 percent of the total workers who participated in the study are probably exposed to ergonomics/ safe method of lifting.

b) Work-related pain prevalence among the workers

Regarding work-related pain prevalence among the workers, 170 workers (73%) out of 233 workers fall into categories of LI>1 (Table 3). In the study 40 (63.5%) out of 63 workers that fall into category of 0<LI≤1 complained of neck pain as compared to 11 (16.4%) out of 67 workers in the category of LI>3 who complained of pain in the same body region. Category of 0<LI≤1 workers have the least complaint of lower back pain with 8 (12.7 %) out of 63 workers. The major reported LBP are from workers in the category of LI>3 where 50 (74.6%) out of 67 workers reported having lower back pain lasting more than one week in the past 12months.

Table 3 : Description of Percentage (Number of workers) reported health outcome for Workers on current Job≥1 year, by Lifting Index (LI) Category

	Lifting Index Category			
Demographic Variable	0<LI≤1	1<LI≤2	2<LI≤ 3	LI>3
No. of workers	63	49	54	67
% Pain in the neck	63.6 (21)	19.0(4)	18.2(4)	16.7(6)
% Pain in the lower back	12.1(4)	47.6(10)	59.1(13)	75(27)
% Pain in the upper back	0	9.5(2)	18.2(4)	8.3(3)
% Pain in the hips/upper legs	0	0	9.1(2)	38.9(14)
% Pain in the knees/lower legs	0	0	0	22.2(8)
% Pain in the ankles/feet	0	0	0	0
% Pain in the shoulders	54.5(18)	33.3(7)	40.9(9)	30.6(11)
% Pain in the elbows/forearms	27.3(9)	23.8(5)	18.2(4)	8.3(3)
% Pain in the wrists /hands	0	0	0	0
% Pain in the fingers.	0	0	0	0
% Workers missed work due to back pain from repeated activities in the last 12months	0	4.8(1)	36.4(8)	58.3(21)

Global Journal of Researches in Engineering (G) Volume XIII Issue III Version I Year 2013

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Pains at the shoulder region of the body were reported by workers fixing window blade, ceiling fan and fluorescent holder with 54.5% of the workers in the category 0<LI≤1 complained of pain in the region and 40.9% of workers in the category 2<LI≤3, 33.3% of workers in the category 1<LI≤2 and 30.6% of workers in the category LI>3 were also reported suffering from shoulder pain as a result of the repetitive work. About twenty seven percent (27.3%) of workers in the category of 0<LI≤1 had pains in the elbows/forearms region of their body. Among all the complaints, lower back, shoulder and neck pain take predominant in decreasing order (Figure 2).

In all the categories, 62 (26.6%) out of the total 233 workers interviewed of which 39 (58.2%) out of 67 workers are in the category of LI>3 and 20 (37.0%) of 54 workers are in the category of 2<LI ≤3 reported to have missed work due to back pain in the last 12 months. When the reported pain was associated with their job, 55 (90.2%) of 61 workers who reported having LBP lasting more than a week in the past 12months thought that their back pain was caused by their works. Forty-six workers (68.7%) that fall into this group were from the category of LI>3. No worker in the categories of 0<LI≤1 and 1<LI≤2 however reported missing their job schedule in the past 12months because of back pain.

IV. Discussion

Workers in the category 0<LI≤1 had the longest tenure on the current job and followed closely by LI>3 category which were also the youngest among the group. Workers in the category of 0<LI≤1 were older than other categories. The outcome indicated that this group of workers stays longer in the job more than other groups. For the population included in this study, as the LI value increases, the mean age of the workers reduces.

The low values of HM recorded in the course of performing the tasks showed that the loads are not positioned where workers can conveniently access them. The values of FM obtained suggested that workers are subjected to a high frequency of lift to probably meet up with the demand of their service. This was common in mortar lifting jobs. High frequencies of lift as well as location of load are therefore suspected as potential factors capable of causing lifting related pain.

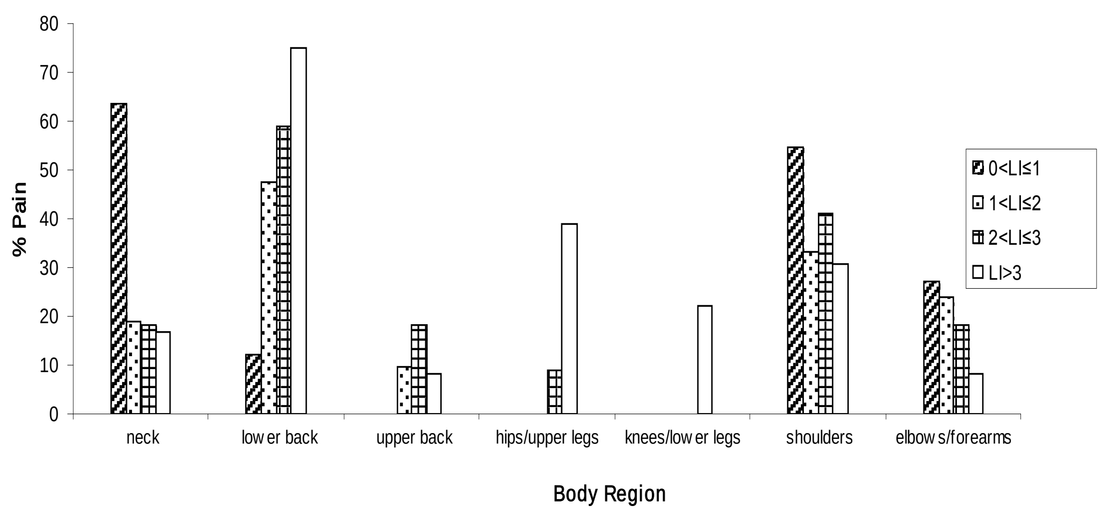

Figure 2 : Description of the reported pain in body regions within the past 12 months

Twisting and bending of body parts are also frequent in the lifting processes. Workers sometimes had to lift loads from the origin by bending sides asymmetrically and/or delivered the load at the destination at angles deviated from the natural as witnessed nearly in all the jobs studied. Most workers (in stacking and dies-stacking jobs) preferred quick lift from Sides instead of repositioning the body to lift directly from the front.

Though some times may be gained to complete their tasks earlier as envisaged by the workers, but the increases in frequency of lift in an awkward posture subjected the workers to more risks.

A larger percentage of the workers are ignorant of the negative effects of the awkward lifting because they were not properly informed/ trained by the concern supervisors on the ergonomics techniques of performing the tasks. It could also be suggested that LI are sensitive to the magnitude of weight lifted. Among other multipliers the horizontal and frequency multipliers had the greatest effects on the STRWL values in all the categories.

Though the calculated LIs for workers in the category 0<LI≤1 were less than 1.0, majority of the workers complained of neck pain most especially those who are involved in fixing wall tiles and fluorescent lamb

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holders. This could be as a result of prolonged inclination of head/neck during the tasks. This category of workers also had the least complaint of lower back pain. The major reported LBP among workers lasting more than one week in the past 12 months are from the category of LI>3, the same group also suffered from shoulder pain because the nature of their jobs required having the load sustained at hands for some times at a height above the head. Mortar lifting, brick lifting, brick setting and fixing wooding doors tasks are mostly affected in this group. The high LBP complaints could be as a result of the magnitude of load lifted and the low variable multiplies recorded among the category of workers.

One of the important proposed applications of the lifting equation is as a tool for estimating the percentage of workers involving in lifting related jobs that is likely to be at risk for developing lifting-related low back pain (LBP). It has been raised that most of the working population should be able to perform jobs with LIs less than 1.0 without a significant risk of LBP and that the risk begins to increase as the LI exceeds 1.0. It is therefore necessary to consider possible ways of reducing the values of LI for all the jobs evaluated. A total redesign of workplace and job methods is very essential. Administrators in the industry need to incorporate ergonomics into the job methods most especially by intensifying efforts in training the workers on safe methods of manual material lifting among other safety trainings. All the multipliers must be given attention most importantly HM and FM in all categories to bring the values to 1.0 and less. The weight lifted by workers can be reduced by ensuring the containers are not fully loaded at the lifting point. Possibility of resizing the lifting containers can be conceived. Vertical multiplier can be increased by raising the origin of lift most especially while working above. This will increase the VM making it better than lifting from the lowest layer. Bringing the load as close as between the workers' leg could make a significant positive change. The angle of twist should be reduced to increase AM by moving the origin and destination closer together. The physiological demands can decrease by reducing the frequency rate of lift. Increasing number of mortar carriers, for instance, can be helpful in this measure so that demand on one worker will reduce. These corrections will decrease the values of LI below 1.0, reduce the risk of work related injuries and increase the quality of the task.

V. Conclusion

Seventy-six percent (76%) of the lifting-related jobs studied had LI greater than 1.0 showing that the entire individual tasks in the groups have excessive physical stress that is connected with the jobs for nearly all healthy workers performing them and will result in physical fatigue. It is significant from this present study that most of the stress related complaints in construction works are engineered by poor work methods leading to high frequency of lift, lifting heavy loads at awkward postures among other factors.

It can be concluded that manual handling in construction industries still have a significant level of higher physical stress associated with the jobs. There is a wide gaps in information related to the prevention of construction site injuries and illnesses among the workers. The tasks analysis results indicated that the involvement of ergonomics in studied construction sites is very low. Most workers performing the manual lifting job will be at an increased risk of a work-related injury. Among all the jobs analyzed, the highest LI values were recorded in mortar lifting tasks.

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Appendix

Appendix A1: NIOSH Lifting Equation

Calculation for single-Task Recommended Weight Limit
STRWL = LC * HM * VM * DM * AM *FM * CM
(* indicates multiplication)
STLI = Laverage/STRWL
Hours: or≤8 hours assuming appropriate recovery allowances

Recommended Weight Limit	
Components	ic
LC = Load Constant	3kg
HM=Horizontal Multiplier	25/H
VM=Vertical Multiplier	1-0.003(|V– 75|)
DM=Distance Multiplier	0.82 + 4.5/D
AM=Asymmetric Multiplier	1-0.0032A
CM=Coupling Multiplier	From Table A2
FM=Frequency Multiplier	From Table A3

Appendix A2: Coupling Multiplier: NIOSH Lifting Equation

Couplings	Coupling Multiplier	
	V<75 cm	V>75cm
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Where
H= horizontal location of hands from midpoint between the ankles; measure at the origin and the destination of the lift (cm)
V = vertical location of the hands from the floor; measured at the origin and destination of the lift (cm)
D = vertical travel distance between the origin and the destination of the lift (cm)
A = angle of asymmetric-angular displacement of the load from the sagittal plane; measure at the origin and destination of the lift (degree)
F = average frequency rate of lifting measured in lift/min
Duration is defined to be: ≤1 hour: ≤2

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Appendix A3: Frequency Multiplier (FM): NIOSH Lifting Equation*

Frequency lift/min.	Work Duration					
	< 1 hour		<2 hours		<8 Hours	
	V<75	V>75	V<75	V>75	V<75	V>75
.2	.1.00	1.00	1.00	.95	.85	.85
.5	1.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.31	.00	.00	.00	.00
14	.00	.00	.00	.00	.00	.00
15	.00	.00	.00	.00	.00	.00

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Global Journal of Researches in Engineering
Industrial Engineering
Volume 13 Issue 3 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

A Study on the Amount of Free Silica in the Dusts of Stonecutting Factories and Offering Controlling Solutions

By Mohammad Hossein Moafi, Seyed Mostafa Khezri & Farideh Atabi

Abstract - This research aims at determining amount of dispersion of free silica and inhalant dusts and contents of free silica in the inhalant aerosol of stonecutting factories and offering engineering control strategies to omit or decrease distribution of the aerosol containing silica. Using standard method Niosh-7601, 40 samples of inhalant dusts were taken from 5 stonecutting factories and concentration of inhalant dusts was calculated by weighting. One sample of each stonecutting factory was analyzed by method of UV-VIS to figure out the amount of free silica. Two volume samples were provided and analyzed by X-ray dispersion to determine type of silica in the inhalant dusts. Concentration of inhalant dusts containing free silica in different worksites is 2.232 mg/m3 in average. The most amounts were found in grinding and polishing worksite amounted to 3.3293 with criteria deviation of 0.54 and the least amount was related to entrance door station, amounted to 1.1191 with criteria deviation of 0.25. The most amount of free silica in the worksites was related to worksite No.3, amounted to 12.15% and the least amount was related to worksite No.4 which was amounted to 4.25%. The most concentration of inhalant dusts was related to worksite No.2, i.e. 2.745 mg/m3 in average, and the least concentration of inhalant dusts was related to worksite No.5, i.e. 2.056 mg/m3 in average. Quartz was the result of analysis of volume samples by XRD method to determine type of silica.

Keywords : silica, stonecutting, dusts, niosh- 7601.

GJRE-G Classification : FOR Code: 290502p

A STUDY ON THE AMOUNT OF FREE SILICA IN THE DUSTS OF STONECUTTING FACTORIES AND OFFERING CONTROLLING SOLUTIONS

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Keywords : silica, stonecutting, dusts, niosh- 7601.

I. Introduction

Human has been faced too many problems and dangers in effort to earn a livelihood for centuries. Fortunately in step with the increasing perils, methods of their prevention and control are developing as well. So that in spite of using dangerous chemicals or physical or biological factors, work places could be turned into healthy places in which workers can benefit from health and long life as similar as other people. Certainly the main provision of controlling dangers and preventing them in the places of work is having full knowledge of those dangers and their quality.

Nowadays stonecutting industry makes the most important part of civil and construction affairs. It can be assuredly said that civil processes were completed by stonecutting industry. In the stonecutting factories, workers are exposed to several undesirable and detrimental factors and conditions which sometimes endanger their health seriously. Inhalation of free silica dusts is mentioned as one of those factors. Arising career diseases and complications like silicosis and other pulmonary damages are consequences of inhalation of free silica dusts. Importance of stonecutting and increasing need to its products in Iran, explains necessity of paying attention to the health of professionals of this industry.

On the other hand, noticeable number of workers, exposed or will be exposed to detrimental factors of place of work in stonecutting factories, reflects necessity of carrying out research to study on conditions of place of work and especially to precisely find type and amount of free silica dusts in this industry.

Considering the importance of effects resulted from inhalation of free silica dusts, environmental conditions of work in stonecutting industry from aspects of air pollution by this pollutant and the degree of workers' exposure to it were studied in this paper which was performed within fall of 20011 through spring of 2012 at stonecutting factories of Fadaeian Eslam Street of Tehran. We hope that the results can take effective steps toward improvement of the present status and more health of professionals of this industry.

II. Review of Previous Researches

* Banks et.al. figured out concentration of free silica in 2 mills of silica powder in 1981. Concentration of free silica was more than 0.05 mg/m^3 in 85% of inhalant dusts samples and it's silica was variable between 95 to 98% (banks&etal).

* Fulekar's study in stone-grinding factories of Rajasthan State of India indicated that the mean of total particles concentration in the air of these worksites was 22.5 mg/m^3 and the mean of inhalant particles concentration was 2.93 mg/m^3 and considering percentage of free silica in dusts (75%) rate of exposure of the professionals was reported as more than allowed limit of professional exposure: PEL=0.36 mg/m^3 (fulekar,1999).

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* In a research at Kashmar construction mine in 1998, Manouchehr Sakhaei studied on total dusts and free silica (quartz) in which 60 samples of inhalant dusts, 6 samples as control (check sample) and 12 environmental samples were taken from breathing area of the workers in 5 different worksites in order to analyze concentration of free silica and exposure rate of workers in the construction stone mine. Then the concentration was calculated according to Niosh method: the mean concentration of dusts was the highest in the 5th station and the 1st worksite showed the least amount and concentration of free silica in all worksites was less than allowed limit (Sakhaei, Manouchehr, 1998).

* Mr. Sajad Mousavi did study on workers of under construction subway tunnel of Tehran exposed to total dusts and crystal silica (quartz) as M.Sc. thesis of University of Tehran in 2009. In this research, performed by standard method of Niosh-7601, amounts of total dusts and inhalant dusts containing silica exceeded the standards of Iran and ACGIH in all worksites. (Mousavi, Sajad,2009)

III. Stonecutting Factories

In stonecutting factories, there are granite and other construction stones of porcelain type which are cut from larger mineral rocks and brought to stonecutting factories to be prepared for construction. In the stonecutting factories, the stones are cut in different sizes in order to be used in granite stairs and kitchen counter most of which, especially carving granite stairs and kitchen counters, are dry. In the worksites subject of the study, workers cut and carve these stones without using breathing masks and after carving or cutting, these stones are stored in depot or warehouse by the workers and they are finally delivered to the customers.

IV. Silica Forms

* Crystal form (Crysalln) which is seen as 3 forms of quartz, tridimite and crystobalite, depended on temperature of formation time.

* Microcrystal form (micro) including small crystals of quartz attached to each other by amorphous silica.

* Amorphous form (amorph) in which different molecules have dissimilar spatial relation with each other and as a result there is no specific regular pattern between the molecules (lanyer,1978).

V. Free Silica Dispersion Origins

Too many industries like tunnel construction, mining, foundry, buildings stone-working, earthwork, plastic production, glass-working industries, sandblast and ballasting, sand mines, pottery, construction operation, digging, agriculture, hammering, ceramic and brick making, stonecutting, Portland cement production, production of washing materials, etc. are origins of dispersion of free silica in the air.

VI. Materials & Methods

This study has been planned as descriptive-cross-sectional including the following stages:

1. Preliminary investigation and gathering necessary basic information of the research
2. Planning for number of required samples considering number of all worksites and work process in the worksites
3. Sampling according to standard method of Niosh-7601 and transferring samples to the laboratory
4. Weight analysis of the samples
5. Analysis of percentage and concentration of free silica by visible spectrophotometry according to method of Niosh-7601
6. Determination of type of free silica in volume samples for XRD analysis according to method of Niosh-7601

VII. Preliminary Study and Gathering Basic Information Required for the Research

a) Library and data study was performed to get information about process of the work and required instruments and samples analysis

Method of work in the worksites were examined as well which resulted to figuring out type of consuming stones and conditions of work and totally 8 worksites were identified in the stonecutting factories as a result of studying worksites of the factories including: entrance door stations, peak offload, raw stone depot, primary cut (single-cut), secondary cut, grinding and polishing, product depot, loading, locations of sampling were planned, the workers' breathing protection instruments, function of cutting machines, stonecutting factories air conditioners, and number of persons who are exposed to dusts and free silica were examined and it became clear that 8-10 persons were exposed to dusts in average.

b) Applied instruments and materials

Equipment and materials used in this research were as follows:

- Individual sampling pump of SKC LTD type, model EX96 D2120, made in UK with chargeable battery and 5 L/min Debi
- 10 mm Nylon silicon
- Digital calibration system, model 1/08DCL-MRE, made in USA to calibrate individual sampling pump
- Rotameter with 2 L/min flow to calibrate individual sampling pump
- Digital scale, mark sauter and weighting accuracy of 0.0001 gr., made in UK
- Visible Spectrophotometer
- Membranous filter with 37 mm in diameter and 0.8 micron powder

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c) Planning for number of required samples considering number of all worksites and work process in the worksites

After inspecting status of the worksites located at the region subject of study, 5 worksites were selected to be studied. Considering the mean and criteria deviation of concentration of aerosol containing free silica in other studies and using statistical relation, 40 samples should be gathered. Therefore 8 samples were taken from each worksite according to process of work in the worksites and one out of each 8 samples was analyzed for percentage of free silica.

d) Sampling according to Standard Method of Niosh-7601

According to aims of the study, sampling of inhalant dusts was performed in 8 regions of each worksite.

At first 37mm filters, with aperture size of 0.8μ, were weighted by a scale, with accuracy of 0.0001 gr. and then they were put in silicon support and sampling pump was fixed on a 1.5 m stand (at the same breathing height of the workers). According to method of Niosh-7601, the pump Debi was set on 1.7L/min and sampling was carried out during 8 hours.

At the beginning and by the end of sampling by the sampling pump, Debi monotony was watched. By the end, the sampling pump was removed from the stand and filters (real and check samples) were put in the support to be transferred to the laboratory and then the filters were weighted in the laboratory. It is worthy to note that to correct sampled air volume to volume in standard conditions, temperature and pressure quota were measured during sampling and the mean was calculated. Controls were treated like the real samples. In this way, the support of the controls was removed in the environment and quickly was placed on it without sampling. Then they were packed and transferred to the laboratory with real samples. Exactly the same stages were passed for real samples and controls. In the laboratory, controls were essentially used to estimate pollutants in the sampling filters. Results of controls should be deducted from results of tests performed on the real samples in order to get more accurate results. (6)

- Weight analysis of the samples

* Weighting filters:

In this research, visible spectrophotometer was used to calculate concentration of crystal silica in the samples. In this method, total weight of dusts should not be more than 2 mg. Sampling filters and control were weighted by digital scale before and after sampling.

VIII. Analysis of Percentage and Concentration of Free Silica by Spectrophotometer in Visible Limit According to Method of Niosh-7601

* Reagents:

1. Silica standard

A: Quartz (1958, 2951, 2950, 1878a SRMs), B: Crystobalite (957, 2960, 1879 SRMs) C: Tridimite

2. 2- Hydrofloricacide 48%
3. Autophosphoricacide 85%
4. Abebdonsilis
5. Hydrocloridricacide 1/10 in Abdionise
6. Solphoricacide 10N
7. Concentrated Nitric Acid
8. Concentrated Percloricacide for PVC filters
9. Boric Acid 5%

IX. Determination of Type of Free Silica in Volume Samples for XRD Analysis According to Method of Niosh-7601

a) Providing volume sample

To find type of free silica in the stones used in the stonecutting factories, volume sample should be prepared from the dusts taken from cutting operation in the stonecutting factories and considering that there are 2 types of granite stones in these factories, 2 volume samples were prepared. After preparation of these samples by 40μ sieve, they were delivered to XRD analysis laboratory in the Research Center of Inorganic Materials Process of Iran to determine type of silica using standard method of Niosh-7500.

b) Analysis by XRD

Generator of X-ray is set on 40 KV and 40 Ma. One standard sample is transferred to the sample support in the system by pincers and the support is placed in the container.

X. Results and Findings

a) The Results of Weight Analysis of Inhalant Dusts

Concentration of inhalant dusts were calculated and presented by weighting method for each sampling station separately. Some parameters used in the calculations are as follows:

V_{mes} : Volume of sampled air in Liter

P_{bar} : Barometric pressure in mmHg.

P_w : Saturated Vapor Pressure in mmHg

$$V_{stp} = V_{measurd} \times \frac{P_{bar} - p_w}{760} \times \frac{298}{273+t}$$

T: Environmental temperature in Centigrade degree

V_{stp} : Air volume in standard conditions in Liter

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W_1: Sampling filter's weight before sampling in mg.

W_2 : Sampling filter's weight after sampling in mg.

$\acute{W}_1$: Control filter's weight before sampling in mg.

$\acute{W}_2$: Control filter's weight after sampling in mg.

W: Weight of inhalant dusts on the filter in mg.

C: Concentration of the inhalant dusts in mg/m^3

$$w = (w_2 - w_1) - (w_2' - w_1')$$

Table 1 : Mean, Criteria Deviation, and Calculation of Confidence Limit 95% for Concentration of Inhalant Dusts of Different Worksites of Stonecutting Factories

Worksite	Number of Samples	Mean	Criteria Deviation	Confidence Limit 95%		Amplitude of Changes	
				Lower limit	Upper limit	Min.	Max.
Entrance Door	5	1.1191	0.25	1.12	1.51	0.77	1.64
Peak Offload	5	1.2192	0.27	1.02	1.41	0.87	1.74
Raw Stone Depot	5	2.353	0.41	2.18	2.82	1.91	3.37
Primary Cut	5	2.556	0.45	2.23	2.87	1.96	3.42
Secondary Cut	5	3.2912	0.52	2.91	3.70	2.57	4.02
Grinding & Polishing	5	3.3293	0.54	2.93	3.72	2.59	4.11
Product Depot	5	1.8254	0.42	1.52	2.12	1.10	2.61
Loading	5	1.6204	0.40	1.50	2.10	1.06	2.57

Total average of inhalant dusts concentration in different worksites is 2.232. Maximum average is related to Grinding & Polishing worksite which equals to 3.3293 with Criteria Deviation of 0.54 and the minimum average is related to Entrance Door worksite which equals to 1.1191 with Criteria Deviation of 0.25.

b) The Results of Instrumental Analysis by UV-VIS Spectrophotometry

Table 2-4 shows percentage of free silica in stonecutting factories in microgram. It is worthy to note that silica contents of 2 samples of each worksite were calculated by the following formula using UV-VIS device in Research Center of Inorganic Materials Process of Iran.

Sio2%= Silica Content (mg)/Content of inhalant dusts (mg)×100

Table 2 : Percentage of free silica in inhalant dusts of stonecutting factories

No. of Worksite	Name of Worksite	Content of Dusts (mg)	Contents of Silica (µg)	Percentage of free silica in inhalant dust
1	Product Depot	1	70	7
	Entrance Door	0.7	51	.285
2	Secondary Cut	1.7	124	7.30
	Peak Offload	0.5	21	4.30
3	Raw Stone Depot	1.1	73	6.636
	Grinding & Polishing	1.9	231	12.15
4	Loading	0.7	50	7.14
	Entrance Door	0.4	17	4.25
5	Peak Offload	0.6	40	6.66
	Primary Cut	1.2	76	6.33

Table 3 : Comparison of mean concentration of inhalant dusts with maximum allowed concentration in stonecutting factories

No. of Worksite	Mean concentration	Criteria Deviation	Amplitude of Changes in Concentration		Maximum allowed concentration of inhalant dusts
			Min.	Max.	
1	2.5685	1	1.3	4.05	1.11
2	2.745	0.93	1.526	4.851	1.077
3	2.3	0.84	1.3	3.617	1.075
4	2.193	0.84	1.075	3.2	1.61
5	2.056	0.71	1.1	3.01	1.158

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Table 4 : Concentration of free silica in stonecutting factories

No. of Worksite	Name of Worksite	Contents of Silica (µg)	Silica concentration	Silica concentration in professional standard of Iran
1	Product Depot	70	0.151	0.1
	Entrance Door	51	0.111	0.1
2	Secondary Cut	124	0.264	0.1
	Peak Offload	21	0.0451	0.1
3	Raw Stone Depot	73	0.157	0.1
	Grinding & Polishing	231	0.5	0.1
4	Loading	50	0.109	0.1
	Entrance Door	17	0.037	0.1
5	Peak Offload	40	0.0872	0.1
	Primary Cut	76	0.164	0.1

Table 5 : Maximum concentration of inhalant dusts containing free silica in stonecutting factories

No. of Worksite	Name of Worksite	Type of Silica (µg)		Maximum concentration of inhalant dusts (mg/m^3)
1	Product Depot	Quartz	7	1.11
	Entrance Door	Quartz	7.285	1.077
2	Secondary Cut	Quartz	7.3	1.075
	Peak Offload	Quartz	4.2	1.61
3	Raw Stone Depot	Quartz	6.636	1.158
	Grinding & Polishing	Quartz	12.15	0.706
4	Loading	Quartz	7.14	1.093
	Entrance Door	Quartz	4.25	1.60
5	Peak Offload	Quartz	6.66	1.153
	Primary Cut	Quartz	6.33	1.2

Table 6 : Comparison of mean and criteria deviation of concentration of inhalant dusts with maximum allowed concentration in different stonecutting worksites

Name of Worksite	Number of Worksite	Mean concentration	Criteria Deviation	Amplitude of Changes in Concentration		Maximum Allowed Concentration
				Min.	Max.	
Entrance Door	5	1.1191	0.25	0.77	1.64	1.315
Peak Offload	5	1.2192	0.27	0.87	1.74	1.336
Raw Stone Depot	5	2.353	0.41	1.91	3.37	1.178
Primary Cut	5	2.556	0.45	1.96	3.42	1.210
Secondary Cut	5	3.2912	0.52	2.57	4.02	0.8528
Grinding & Polishing	5	3.3293	0.54	2.59	4.11	0.9732
Product Depot	5	1.8254	0.42	1.10	2.61	1.1025
Loading	5	1.6204	0.40	1.06	2.57	1.152

Table 7 : Type, percentage and concentration of free silica in comparison with concentration of silica in professional standard of Iran

Name of Worksite	Contents of Dusts (mg)	Contents of silica (µg)	Type of silica	Percentage of silica%(sio2)	Maximum concentration of inhalant dusts	Concentration of silica (mg/m^3)	Concentration of Silica in professional standard of Iran
Entrance Door	0.7	51	Quartz	7.285	1.077	0.111	0.1
Peak Offload	0.5	21	Quartz	4.30	1.61	0.0451	0.1
Raw Stone Depot	1.1	73	Quartz	6.636	1.158	0.157	0.1

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Primary Cut	1.2	76	Quartz	6.33	1.2	0.164	0.1
Secondary Cut	1.7	124	Quartz	7.3	1.075	0.264	0.1
Grinding & Polishing	1.9	231	Quartz	12.15	0.706	0.5	0.1
Product Depot	1	70	Quartz	7	1.11	0.151	0.1
Loading	0.7	50	Quartz	7.14	1.093	0.109	0.1

According to table 7, contents of inhalant dusts and silica in µg, amount, type, percentage and concentration of free silica in µg in comparison with maximum concentration of inhalant dusts and silica are obtained in mg/m^3 in professional standard of Iran.

In this table, concentration of silica in professional standard of Iran in mg/m^3 is showed as 0.1 in all worksites and also maximum concentration of inhalant dusts is showed as fixed amount in mg/m^3 in each worksite of the stonecutting factories.

Figure 1 : Entrance Door Worksite

Figure 2 : Peak Offload Worksite

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Figure 3 : Raw Stone Depot Worksite

Figure 4 : Primary Cut Worksite

Figure 5 : Secondary Cut Worksite

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Figure 6 : Grinding & Polishing Worksite

Figure 7 : Product Depot Worksite

Figure 8 : Loading Worksite

XI. Discussion

In worksites No.1 to 5, maximum allowed concentration of inhalant dusts were measured as 1.11, 1.077, 1.075, 1.61 and 1.58 mg/m^3 respectively, however concentration of inhalant dusts in 85% of the subject worksites was more than allowed concentration standard and the remaining 15% of the worksites showed the maximum allowed limit of concentration.

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The highest concentration measured in this study was 3.910 mg/m^3 and the highest percentage of silica, i.e.12.5%, was related to grinding and polishing worksite No.3 and the least concentration was measured as 1.005 mg/m^3 and the least percentage of silica, i.e.4.25%, was related to entrance door worksite No.4.

According to the results of statistical test, there is significant difference between concentration of free silica in the samples and standard level. Allowed concentration of silica in professional standard of Iran is 0.1 mg/m^3.

In fact, free silica in inhalant dusts of these worksites turns them from ineffective and or annoying dusts to toxic dusts and increases change of suffering pulmonary problems in proportion to percentage of free silica and intensity and duration of exposure to such dusts.

Therefore more polluted worksites must be given priority in taking engineering control measures. Considering the results of tables 1 to 6, concentration of inhalant dusts in sampling worksite of grinding and polishing is more than other worksites. In other words, the most dispersion of aerosol containing free silica happens in grinding and polishing worksite and also secondary cut worksite.

The least concentration of aerosol is related to entrance door and peak offload worksites. Statistical relation shows that concentrations of inhalant aerosol among different worksites of a factory are significantly different from each other and prioritization of management and engineering control actions should be based on these findings. According to XRD analysis, the consumed stone contains free silica of quartz type which pathogenic effects are less than crystobalite. However it's pathogenic effects is emphasized as well because of increase, fashion and more application of crystal form of free silica than other forms. According to table 6, mean concentration of dusts resulted from free silica in all worksites of study is 2-3 times more than maximum allowed limit in stonecutting factories.

XII. Conclusion

Findings of this study indicate that air pollution as inhalant dusts dispersed in stonecutting factories contains free silica of crystal or quartz type and percentage of free silica in dusts of different worksites is measured so that concentration of dispersed dusts is more than allowed concentration. Meanwhile, dispersion of dusts in secondary cut worksites is noticeable from concentration and percentage of free silica aspects and it seems that there is probability of suffering from pulmonary problems among professionals and persons exposed for long term and work conditions of subject worksites are not appropriate from viewpoints of air pollution control and protection of workers' health against inhalation of aerosol containing free silica. Therefore taking appropriate control actions to decrease rate of dusts dispersion and also to decrease their concentration around the worksites seems to be necessary.

XIII. Proposals

According to the results and prioritization of control measurements among worksites of study and factories, preventive control actions should be predicted, planned and taken as management, engineering and individual in proportion to the work conditions in order to omit or decrease health risks resulted from inhalation of free silica dusts in the place of work. Principles of preventions may be summarized as follows:

In general, control methods including: process correction, engineering control, promotion of method of work, and using individual instruments may be used in 3 levels of control in the origin aiming at omission or decrease in producing pollution, control in dispersion path aiming at omission or minimizing pollution area, and finally control in exposure level aiming at omission or minimizing persons' exposure.

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Global Journal of Researches in Engineering
Industrial Engineering
Volume 13 Issue 3 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Water Distribution as a no Cooperative Game

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Abstract - The water distribution problem of the Mexican Valley is modeled as a three-person no uncooperative Game in which agriculture, industry, and domestic water users are the players and the total water Amounts supplied to the users are the payoff functions. The equilibrium is determined by solving a nonlinear optimization problem, which can be derived based on the Kuhn-Tucker necessary Conditions. All constraints are linear and the objective function is quadratic, so standard solution Algorithm and software can be used.

GJRE-G Classification : FOR Code: 090509

WATER DISTRIBUTION AS A NO COOPERATIVE GAME

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Water Distribution as a no Cooperative Game

Ardeshir Ahmadi

Abstract - The water distribution problem of the Mexican Valley is modeled as a three-person no uncooperative Game in which agriculture, industry, and domestic water users are the players and the total water Amounts supplied to the users are the payoff functions. The equilibrium is determined by solving a nonlinear optimization problem, which can be derived based on the Kuhn-Tucker necessary Conditions. All constraints are linear and the objective function is quadratic, so standard solution Algorithm and software can be used.

I. Introduction

The limited amount of natural resources creates conflicts between the users, since any user can Increase its supply only in the expense of the others. As it is well known, water shortage is one of the most worrying problems of our society. According to recent predictions, by 2010 we will need about 17% more water than available to feed the world. Therefore efficient usage of water and optimal water distribution schemes become necessities.

The Mexican Valley is one of the most critical areas, since Mexico City with its 19 million in habitants is the most populated city in the world, and agriculture is the main economic activity in the region which requires large amount of irrigation water. In addition there are industrial users, and the development of industrial employers is crucial for the welfare of the population. The water supply is divided into surface water, groundwater and treated water. The groundwater supply has the best quality, and treated water has the worst. So, treated water can have only limited usage.

The ground water resources are over exploited at a rate of 100% or more, which has the direct Cones quinces of drying springs and sinking ground up to 0.4m/year in some areas.

The current water shortage situation raises the necessity of importing surface and ground water from the neighboring watershed, which also might raise dispute over water resources.

The water distribution problem of the Mexican Valley is modeled as a three person game. Where the three users are the players and the total water amounts supplied to the users are the payoff functions.

There are many earlier works dealing with similar problems. The survey paper of Hype (1992) and the more recent paper of Kapelanet al. (2005),Donevska et al. (2003),Coppola and Szidarovszky(2004), Salazar et al. (2010) can be mentioned among others. As the game theoretical concepts and methods are concerned the books of Szidarovszky et al.(1986) and Forgo et al. (1999) give comprehensive summaries.

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II. Mathematical Model

The three players are agriculture (k=1), industry (k=2) and domestic users (k=3). For each player the Decision variables are

s_k =surface water supply from local source
$k\,g$ =ground water supply from local source
$k\,t$ =treated water supply
$k\,s$ =imported surface water supply
$k\,g$ =imported ground water supply

So, the straegy of player k is the 5-dimensional vector $\underline{x}_k = (s_k, g_k, t_k, s_k^*, g_k^*)$ The strategy set of the players are determined by feasibility constraints. The three users have two common constraints:

$$s_k + g_k + t_k + s_k^* + g_k^* \le D_k \qquad (1)$$

and

$$s_k + g_k + t_k + s_k^* + g_k^* \ge D_k^{\min} \quad (k=1, 2, 3), \qquad (2)$$

Where D_k^{min} is the minimum necessary amount and D_k is the total demand of player k. Constraint (1) is requested to avoid wasting water. In addition to these constraints each user has its own conditions.

Agriculture (k=1) has two special water quality related constraints. Some crops can use only ground water, since they are very sensitive to the quality of the water they are irrigated with. If 1 is the ratio of the water need of these sensitive crops to the total water amount used for irrigation, then it is required that

$$\frac{g_1 + g_1^*}{s_1 + g_1 + t_1 + s_1^* + g_1^*} \ge \alpha_1 . \qquad (3)$$

Some less sensitive crops can tolerate treated water, which has the worst quality. If 1 is ratio of the Water need of these less sensitive crops to the total water amount used for irrigation, then we have to assume that since treated water cannot be used to irrigate crops which cannot tolerate treated water.

$$\frac{t_1}{s_1 + g_1 + t_1 + s_1^* + g_1^*} \le \beta_1 \qquad (4)$$

Industry (k=2) has very similar constraints, since there are certain usages which can be supplied

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only by groundwater as well as some other usages can tolerate treated water:

$$\frac{g_2 + g_2^*}{s_2 + g_2 + t_2 + s_2^* + g_2^*} \geq \alpha_2 \quad (5)$$

and

$$\frac{t_2}{s_2 + g_2 + t_2 + s_2^* + g_2^*} \leq \beta_2 \,. \quad (6)$$

Domestic users (k=3) have limitations only on the amount of treated water, since it can be used only for limited purposes (such as irrigating parks, golf courses, etc). Hence this constraint can be given. As

$$\frac{t_3}{s_3 + g_3 + t_3 + s_3^* + g_3^*} \leq \beta_3 \quad (7)$$

Notice that all constraints (3)-(7) can be rewritten into linear forms.

The total water available in both local and imported surface and groundwater resources can be represented by the additional constraints:

$$s_1 + s_2 + s_3 = S_s \quad (8)$$

$$g_1 + g_2 + g_3 = S_g \quad (9)$$

$$s_1^* + s_2^* + s_3^* \leq S_s^* \quad (10)$$

$$g_1^* + g_2^* + g_3^* \leq S_g^* \quad (11)$$

Where the right hand sides are the maximum available amounts supplied from the different resources. We require equality in constraints (8) and (9) to be sure that all local resources have to be used before water is imported from other watersheds.

The payoff function for each player is the water supply:

$$\text{Maximize * * } \quad s_k + g_k + t_k + s_k^* + g_k^* \,. \quad (12)$$

Hence we have a three-player noncooperative game with linear payoffs and linear constraints defining the strategy sets of the players.

III. Solution Methodology

In our case the number of players is n=3, the strategy of player k is the five-dimensional vector x_k, and the strategy set of this player is defined by the individual constraints

$$\underline{A}_k \underline{x}_k \quad \underline{a}_k \quad (13)$$

Obtained from (1) through (7) and by the joint constraints (8) through (11):

$$\underline{B}_1 \underline{x}_1 + \underline{B}_2 \underline{x}_2 + \underline{B}_3 \underline{x}_3 \leq \underline{b} \,. \quad (14)$$

The payoff of player k can be written in general as

$$\text{Maximize} \quad \underline{c}_k^T \underline{x}_k \,. \quad (15)$$

Since the constraints are linear, the Kuhn-Tucker regularity conditions are satisfied, so there are Nonnegative vectors v_k and w_k such that

$$\begin{aligned} &\underline{A} \underline{x}_k \quad \underline{a}_k \\ &\underline{B}_1 \underline{x}_1 + \underline{B}_2 \underline{x}_2 + \underline{B}_3 \underline{x}_3 \leq \underline{b} \\ &\underline{c}_k^T - \underline{v}_k^T \underline{A}_k - \underline{w}_k^T \underline{B}_k = \underline{0}^T \\ &\underline{v}_k^T (\underline{a}_k - \underline{A}_k \underline{x}_k) + \underline{w}_k^T (\underline{b} - \underline{B}_1 \underline{x}_1 - \underline{B}_2 \underline{x}_2 - \underline{B}_3 \underline{x}_3) = 0. \end{aligned} \quad (16)$$

Because of the other constraints the left hand side of the last condition is always nonnegative, so its minimal value is zero. Consider now the following quadratic programming problem with linear constraints:

$$\text{Minimize} \sum_{k=1}^{3} \underline{v}_k^T (\underline{a}_k - \underline{A}_k \underline{x}_k) + \left(\sum_{k=1}^{3} \underline{w}_k^T \right) (\underline{b} - \underline{B}_1 \underline{x}_1 - \underline{B}_2 \underline{x}_2 - \underline{B}_3 \underline{x}_3) \quad (17)$$

The Nikaido-Isoda theorem implies the existence of at least one equilibrium, so there is at least one solution of system (16). So the optimal objective function value is zero, and all optimal solutions satisfy the Kuhn-Tucker necessary conditions (16). Because of the linearity of the game, conditions (16) are also sufficient, implying that all optimal solutions of problem (17) are Nash-equilibria of the three-person game. For the numerical solution of (17) standard methodology and software is available.

IV. Numerical Results

The data for our case study were given by a research group of the Universidad Autonoma Chapingo, who investigated the same problem by using different solution concept and methodology (Salazar et al., 2007).The input data are given in Table 1. In addition, the available water supplies from the

Table 1

	k=1	k=2	k=3
$D_k^{\min}$	594	177	1092.8
D_k	966	230	2123
α_k	0.41	0.066	-
β_k	0.33	0.20	0.06

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Different sources are limited as given in constraints (8) through (11) with S_s =58, S_g =1702, S^*_s =453 and S_s* =169. These quantities and min D_k and D_k are given in mill m3/year, the constants a_k and β_k are ratios, unit less quantities. The equilibrium was computed by solving the optimization problem (17).

The results are presented in Table 2. The objective function at the optimum was zero showing.

Table 2 : Numerical Results

	k=1	k=2	k=3	Total
s_k	0	0	58	58
g_k	966	205.353	530.647	1702
t_k	0	0	75.702	75.702
s^*_k	0	24.647	428.353	453
g^*_k	0	0	169	169
Total	966	230	1261.702	

That global optimum was reached. All demands of agriculture and industry can be satisfied, since there ceiled amounts are their total demands. The domestic demand can be satisfied only partially, on 59.43% level. All surface and groundwater resources are used. The restrictive constraints on treated water usage make the use of more treated water impossible. Importing the large amount of surface and groundwater into the Maxi can Valley will raise severe conflicts with the neighboring regions. In addition, a larger amount of treated water has to be used which raises the important issue of water quality, since under the given constraints the only way to increase water supply is to increase the treated water usage. In order to have larger water supply and avoid serious social conflicts further developments are needed in combination with more efficient water usage by the three sectors. May be a market-driven water pricing policy would give incentives to the users.

V. Conclusions

The water distribution problem in the Maxi can Valley was modeled as a three-person no cooperative game. The three users were the players, the supplied water amounts the payoffs, and the strategy set were determined by supply and water quality constraints. The Nash equilibrium of this game was determined by solving a special quadratic optimization problem with linear constraints, which was derived based on the Kuhn-Tucker conditions.

The numerical results indicate that a combination of investment for further developments in the infrastructure is needed in combination with more efficient water usage in order to avoid serious social conflicts and water shortages.

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4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

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27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Administration Rules Listed Before Submitting Your Research Paper to Global Journals Inc. (US)

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.

- Do not give permission to anyone else to "PROOFREAD" your manuscript.

- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

Criterion for Grading a Research Paper (Compilation) by Global Journals Inc. (US)

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals Inc. (US).

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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ISSN 9755861

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