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USE OF ENVIRONMENTAL INTELLIGENCE FOR GREEN ICT IN THE MANUFACTURING SECTOR

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Abstract: *The ICT industry has a very significant part to play in reducing carbon footprints. This is so because ICT is an integral part of business and, hence, has a direct correlation to overall greenhouse gas emissions by businesses. This paper explains how Green ICT can be used by organizations to reduce their carbon footprints and conduct their business in sustainable manner. The reduction of energy consumption, reduction of carbon footprints is termed as Environmental Intelligence. This research paper presents EI as a means to green usage of ICT, green procurement of ICT, green disposal of ICT and green data centres. The study was primarily based in the manufacturing business domain of organizations in Vadodara in India. This study employed the ordinal logistic regression to understand the impact of Green ICT on the collaborative business.*

Keywords: *Green ICT, Environmental Intelligence (EI), Carbon footprints, Green procurement, Green disposal, Green data centre*

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1. INTRODUCTION

ICT encompasses tools and processes aimed at handling data information by electronic means such as computers, mobile phones, satellite systems. The interaction between ICT and environment is complex and the environmental impacts of the ICT are not fully understood. Gartner's estimate [1] of the 2 percent of global CO_2 emissions that ICT is responsible for includes the in-use phase of PCs, servers, cooling, fixed and mobile telephony, local area network (LAN), office telecommunications and printers. Gartner has also included an estimate of the embodied (that used in design, manufacture and distribution) energy in large-volume devices, namely PCs and cell phones. The design, manufacture, deployment, operation, use, and disposal of information technology (ICT) have significant implications for the environment [2] [3]. For example, ICT (computers, networking, data and telecommunications technologies) consume significant amounts of energy when in use and contribute in no small way to the growth in greenhouse gas (GHG) emissions. Energy issues aside, ICT artifacts also contain regulated and hazardous materials. Accordingly, the influence of environmentally- oriented regulatory and social pressures are especially evident in the ICT sector [4], particularly in manufacturing, but also in adoption, operation and use [5]. ICT is increasingly viewed as a significant and growing part of the environmental problem— something that few people take seriously, particularly ICT executives.

Green ICT is about reducing the energy consumption and carbon footprint of the IT function within the organization [6]. Green ICT is the conscious implementation of technologies, techniques and policies designed to reduce the carbon footprint of the ICT function within the organization and the use of ICT to reduce the carbon footprint of the whole organization [7].

This research paper studies the impact of use of EI for Green ICT in the manufacturing business of Vadodara, where business and ICT move closer to a convergence than ever before. The manufacturing business surveyed access technology resources not just through a common infrastructure or application platform, but through the transparent business methodology. Vadodara is the third most populated city in the Indian state of Gujarat. In line with the 'Knowledge City' vision of the confederation of Indian Industry, Vadodara is gradually becoming a hub in Gujarat for IT and other development projects. The research

population consist of all the manufacturing units of Vadodara (with population size N = 73) which are using huge computer infrastructure and network in the organization and has an IT officer responsible for the IT department. A cross sectional approach using survey was conducted and a census study was conducted.

2. LITERATURE REVIEW

The environment has become one of the most significant issues of the current times. However, environmental considerations do not seem to appear as substantially as they should within the business strategies - especially in the climate of global financial crisis. The ICT sector has a profitable opportunity and a critical role to play with other sectors to design and deploy solutions needed to create a low carbon society [7]. This research explores the environmentally responsible strategies and practices for ICT in the current business setup. According to Forrester Research [8], the Green IT can be divided into four broad categories, referring to IT suppliers & users initiatives , these are design, manufacture, operations and disposal of IT systems.

The constant improvements in technology and software makes the electronic equipment quickly becomes obsolete and needs to be replaced by newer, faster models. Many computer components are highly toxic to the environment, and virtually all electronic equipment utilizes some form of computer technology. Mercury, chromium, and lead are a few of the hazardous materials found in batteries, cathode ray tubes, and circuit boards [9]. These toxins will be released into the environment if all this outdated equipment disposed of in traditional ways. Soil and water will be affected if this material is dumped in a landfill, and incineration releases toxic ash into the air.

Therefore, the very first attempt by an organization at Green ICT is to handle the emissions produced by the ICT devices themselves. This aims to reduce ICT's own emissions that are based on the end-user computer emissions as well as those from the data centers housing the servers and communication equipments.

The green assets and infrastructure comprise substantial part of long term approach to managing the carbon performance of the organization. The hardware aspect of ICT deals with the architecture and design of ICT hardware, the manner in which it is procured and operated [10]. While operational energy consumption is increasingly an important issue for computer manufacturers, what is even more interesting is the impact a good, energy

optimum design can have on the overall energy consumed by a piece of hardware over its entire life [11]. This requires the organization to devise standards around procuring new equipments or buying new services. The new procurement must be based on energy efficiency. While the efficient design and manufacturing of these end-user devices remains the perceiver of the hardware manufacturers, the efficient operation and disposal is with the user organization. Following is the more detailed description of these ICT hardware assets of an organization.

2.1 Green Use

Reducing the energy consumption of computers and other information systems as well as using them in an environmentally sound manner, to comprehensively and effectively address the environmental impacts of IT [5]. Listed below are the ways of using IT in green way.

2.1.1. Specify computers with high-efficiency Power Supply Units

2.1.2. Printer consolidation [12].

2.1.3. Device consolidation .

2.1.4. Optimize power-saving sleep mode on printers [13][14].

2.1.5. Set default green printing including duplex and grey scale [15].

2.1.6. Apply timer switches to non-networked technology and printers [16].

2.1.7. Enable active power management on desktops [17].

2.1.8. Reduce the use of paper and related material (eg. Ink or toner) [18].

2.2 Green Procurement

Procurement is arguably the most important aspect of green ICT in terms of making an overall impact on sustainability [14]. The research survey covers the criterion followed while purchasing the ICT equipments / services and turning existing services into green services. By this, organizations devise standards around procuring new equipments or buying new services from external parties. Environmentally responsible purchasing for IT products is being incorporated into purchasing programs of many private and public sectors. The criterions examined in the research survey are stated below:

2.2.1 *Purchase IT equipments only what is required*

2.2.2 *Extend asset life of ICT equipments*

2.2.3 *Consider leasing agreements that requires suppliers to take back equipment once the lease has expired.*

2.2.4 *Acquire energy efficient PCs (desktop & notebook computers) and monitors with high environmental rating.*

2.2.5 *Procure energy-efficient servers*

2.2.6 *Procure energy efficient imaging equipment, including ink and laser printers, multifunction devices, copiers, fax machines and scanners.*

2.2.7 *Buy eco printing software*

2.2.8 *Use solid state drives*

2.3 Green Disposal and Reuse

Green disposal is described as refurbishing and reusing old computers and properly recycling unwanted computers and other electronic [5]. Computer peripherals include printers, photocopiers, printer ink and so on. These electronic gadgets are of immense interest in Green ICT due to their large numbers, their potentially unnecessary overuse, the operational waste that is generated as a result and the carbon associated with the eventual disposal of these 'fast moving' items. The research survey interrogates the survey respondents regarding the disposal and recycling practices noted below:

2.3.1 Ensure re-use of equipment that is no longer required but is still serviceable. If re-use is not possible recycle or ensure green disposal.

2.3.2 Use of electronic recycled or second hand equipment.

2.3.3 Has a policy for recycling of electronic gadgets properly.

2.3.4 Safe disposal of ICT and electronic waste.

2.3.5 Adopting and implementing recycling of ICT equipments.

2.4 Green Data Centres

A green data center is a repository for the storage, management, processing, and dissemination of data in which the mechanical, lighting, electrical, and computer systems are designed for maximum energy efficiency and minimum environmental impact [19]. The factors considered in the research survey are:

2.4.1 Server Optimization in data centers.

2.4.2 Reduce cooling in the data centre to appropriate levels and increase the ambient room temperature.

2.4.3 Identify servers and data disks in the data centre that are running but not providing any services and decommission.

2.4.4 Specify low-power consumption, low voltage servers with high-efficiency Power Supply Units (80% conversion or better).

3. RESEARCH MODEL AND HYPOTHESIS DEVELOPMENT

Based on previous studies a questionnaire developed to understand the impact of Green ICT on the environmental goals of the business. The first section of the questionnaire consisted some items such as name of the organization, number of computers and peripherals, information about computer networking. The second section included the practices and strategies related to Green ICT factors (green use, green procurement, green disposal and green data centre) in an organization. The third section included variables which measure the dependent variable. An environmentally complaint business is identified by reduction of energy consumption, reduction of carbon footprints and reduction of operational cost [20] [21]. Finally all the three variables summarize into a single variable which a dependent variable (DV) is called 'Environmental Intelligence' of a business from expert's viewpoint. 25 independent variables can be categorized into four factors which are detailed along with the hypothesis in Table 1.

The hypothesis in Table 1 are detailed as -

H1: There is a significant relationship between EI (DV) and green use of ICT in manufacturing business.

H2: There is a significant relationship between green procurement and EI (DV) in manufacturing business.

H3: There is a significnat relationship between EI (DV) and green disposal of ICT equipments in manufacturing business.

H4: There is a significant impact of green data centres on EI (DV) of a manufacturing organization.

Table 1: Independent Variables (IV) and Research Hypothesis

Factors	Items	Hypothesis
Green Use (GU)	Specify computers with high efficiency power supply units (GU1), Implement and manage printer consolidation (GU2), Implement and manage device consolidation (GU3), Optimize power saving sleep mode on printers (GU4), Set default green printing including duplex and grey scale (GU5), Apply Timer switches to non networked technology and printers (GU6), Enable active power management on desktop (GU70, Reduce use of paper and related material (GU8)	H1
Green Procurement (GP)	Purchase the ICT equipment only what is required (GP1), Extend asset life of ICT devices (GP2), Consider leasing agreement that requires supplier to take equipment back once the lease has expired (GP3), Acquire energy efficient PC's and monitors with high environmental rating (GP4), Procure energy efficient servers (GP5), Procure energy efficient imaging equipment, including ink and laser printers, copiers, fax machines & scanners (GP6), Buy eco printing software (automatically reduce the no. of pages and reformats documents) (GP7), Use solid state drives (for less power usage and fast data access) (GP8)	H2
Green Disposal and Reuse (GD)	Ensure reuse of ICT equipment that is no longer required but is still serviceable (GD1), Use electronic recycled or second hand ICT equipment (GD2), Has policies for recycling the electronic gadgets properly (GD3), Safely disposes the electronic gadgets (GD4), Adopts and implements the recycling of electronic waste (GD5)	H3
Green Data Centre (GDC)	Implements server optimization (reduce energy consumption) (GDC1), Reduces cooling in data centers to appropriate levels and increase the ambient room temperature (GDC2), Identifies server and data disks in the data center that are running but not providing any services and decommission it (GDC3), Specifies low power consumption, low voltage servers with high efficiency power supply units (GDC4)	H4

4. METHODOLOGY

The research subject "*to investigate the use of EI for Green ICT practices and its impact in the manufacturing sector"* predetermines the choice of statistical test and analysis to be used in the study.

A 5–point likert scale ranging from 1 as strongly disagrees to 5 as strongly agree was used for the measurement. A test for the reliability of the instrument was conducted for each stratum population. The cronbach alpha for GU is 0.7466, for GP technologies is 0.7602, for GD is 0.8669 and for GDC is 0.7853, indicating high reliability of questionnaire.

This research employed the ordinal logistic regression to drive its results. An ordinal logistic regression is used to handle multiple ordinal dependent variables. Minitab 14 is a statistical software package that can fit an ordinal logistic regression to data. The output of the

software includes: 1) Response and Factor Information, which displays the number of observations and the response and factor categories; 2) Logistic Regression Table, which shows the estimated coefficients, p-values (related to a test that the corresponding coefficient is zero) and odds ratio (which shows the effect of variables on the model); 3) Goodness-of-Fit Tests which displays both Pearson goodness-of-fit test of the model to data. Final and appropriate model is chosen by entering variables which their coefficients are significant (p-value<0.05) and ordering effect of variables from their odds ratio (negative coefficient along smallest odds ratio indicates more impact of the variable on the dependent variable [22]). Finally, appropriative of model is evaluated by (i) a G test whose null hypothesis states all the coefficients associated with predictors equal zero versus at least one coefficient is not zero (we prefer to reject their null hypothesis, i.e., p-value <0.05) and (ii) Goodness-of-Fit Tests, (we prefer to accept their null hypothesis, i.e., p-value >0.05), of which more can be found [22]. The equation of ordinal logistic regression in this research model are given below.

$$\gamma_i = \frac{\exp(\alpha i + \text{coeff (GU)} + \text{coeff(GP)} + \text{coeff(GD)} + \text{coeff (GDC)})}{1 + \exp(\alpha i + \text{coeff(GU)} + \text{coeff(GP)} + \text{coeff(GD)} + \text{coeff (GDC)})}$$

where i= (1,2,3,4)

γ_i is the cumulative probability efficiency of the EI of i^{th} level , $\underline{\alpha_i}$ are the coefficients for each level.

5. RESULTS

The practices adopted by business with respect to the use of ICT in environmentally compliant manner are studied in this section. The impact of green use on the manufacturing units in Vadodara is shown in Table 2 using ordinal logistic regression.

Table 2: Impact of Green use on Manufacturing Units using Ordinal Logistic Regression

	Reduction of Energy Consumption				Reduction of Carbon Footprints				Reduction of Operational Cost			
	C	P	O	R	C	P	O	R	C	P	O	R
α1	0.545	0.593	-	-	1.65	0.67	-	-	-1.98	0.554	-	-
α2	-1.65	0.755	-	-	2.87	0.51	-	-	-0.76	0.271	-	-
α3	-0.67	0.060	-	-	0.72	0.077	-	-	-0.52	0.027	-	-
α4	-2.61	0.001	-	-	0.89	0.051	-	-	-0.72	0.005	-	-
GU1	-0.24	0.028	1.01	4	1.8	0.03	-	-	-0.56	0.035	0.71	3
GU2	-0.45	0.002	0.71	2	0.98	0.72	-	-	-2.74	0.009	0.59	2
GU3	-1.61	0.017	1.05	5	0.77	0.20	-	-	-0.67	0.026	1.06	5
GU4	0.561	0.050	1.31	6	-0.28	0.618	-	-	0.562	0.041	1.28	6
GU5	1.87	0.787	-	-	-1.78	0.710	-	-	2.81	0.63	-	-
GU6	0.71	0.672	-	-	0.88	0.32	-	-	0.82	0.89	-	-
GU7	-1.65	0.013	0.87	3	0.27	0.91	-	-	-0.87	0.017	0.86	4
GU8	-2.01	0.007	0.35	1	2.72	0.28	-	-	-1.87	0.006	0.56	1
P-value for the tests				0.002	P-value for the tests			0.074	P-value for the tests			0.017
P-value of the Goodness of Fit tests				0.867	P-value of the Goodness of Fit tests			0.024	P-value of the Goodness of Fit tests			0.671

The P-Value in Table 2 for the tests indicates that for 0.05 alpha-level, there is sufficient evidence to conclude that green use of ICT has a significant impact on reduction of energy consumption and reduction of operational cost but not on the reduction of carbon footprints of an organization.

P-value for Set default green printing including duplex (0.787;0.63) and p-value for grey scale and Apply Timer switches to non networked technology and printers (0.672;0.89), shows sufficient evidence to conclude that these factors are not significant, whereas other factors are ranked as per their significance according to ascending odd ones ratio.

The practices related to procure the energy efficient IT devices in manufacturing organizations are detailed in Table 3. The impact and ranking of practices for the procurement of the ICT with an aim to fulfill environmental considerations are listed in Table 3.

Table 3: Impact of Green Procurement on Manufacturing Units using Ordinal Logistic Regression

	Reduction of Energy Consumption				Reduction of Carbon Footprints				Reduction of Operational Cost			
	C	P	O	R	C	P	O	R	C	P	O	R
α1	1.82	0.761	-	-	-2.88	0.881	-	-	0.821	0.534	-	-
α2	2.435	0.052	-	-	0.672	0.071	-	-	0.721	0.987	-	-
α3	-0.642	0.045	-	-	0.87	0.028	-	-	1.772	0.006	-	-
α4	-0.056	0.018	-	-	-2.22	0.009	-	-	-2.87	0.000	-	-
GP1	-1.82	0.021	1.02	4	-0.28	0.018	0.35	2	-1.28	0.013	0.81	4
GP2	-0.42	0.017	0.87	3	-0.26	0.021	0.76	3	-0.25	0.027	0.67	2
GP3	1.22	0.781	-	-	2.17	0.86	-	-	2.11	0.76	-	-
GP4	-0.27	0.005	0.67	1	-0.67	0.010	0.23	1	-0.26	0.026	0.54	1
GP5	-0.772	0.008	0.82	2	1.87	0.29	1.32	6	-1.67	0.037	0.76	3
GP6	-1.67	0.041	1.62	5	-0.82	0.37	0.78	4	-2.66	0.015	0.98	5
GP7	-0.19	0.042	2.05	6	-0.66	0.041	1.03	5	0.776	0.026	1.15	6
GP8	2.781	0.051	-	-	2.16	0.27	-	-	0.982	0.182	-	-
P-value for the tests				0.004	P-value for the tests			0.009	P-value for the tests			0.004
P-value of the Goodness of Fit tests				0.706	P-value of the Goodness of Fit tests			0.061	P-value of the Goodness of Fit tests			0.621

Values in Table 3 shows that consider leasing agreement that requires supplier to take equipment back once the lease has expired (GP3) and Use solid state drives (GP8) do not have a significant impact on business. The other factors have significant impact and they are ranked one to six as shown in Table 3. The p-values for goodness of fit tests are greater than 0.05 (0.706; 0.061 & 0.621), indicating that ordinal logistic regression is an appropriate model to analyze.

Results shown in Table 5 (later in this paper) depicts that there is no correlation between the green disposal practices of ICT in manufacturing units and the environmental goals.

The impact of practices related to environment friendly data centers in manufacturing units are tabulated in Table 4.

Table 4: Impact of Green data centers on Manufacturing Units using Ordinal Logistic Regression

	Reduction of Energy Consumption				Reduction of Carbon Footprints				Reduction of Operational Cost			
	C	P	O	R	C	P	O	R	C	P	O	R
α1	0.82	0.065	-	-	1.28	0.92	-	-	0.23	0.025	-	-
α2	-0.282	0.025	-	-	2.88	0.98	-	-	1.28	0.020	-	-
α3	-1.212	0.008	-	-	-0.27	0.026	-	-	2.8	0.009	-	-
α4	0.673	0.003	-	-	-2.81	0.015	-	-	-0.56	0.016	-	-
GDC1	-0.37	0.006	0.56	1	-0.35	0.017	0.38	1	-0.27	0.006	0.36	1
GDC2	-1.27	0.041	1.22	2	-0.77	0.023	0.78	2	-2.2	0.016	0.66	2
GDC3	1.24	0.661	-	-	0.78	0.198	-	-	0.61	0.06	-	-
GDC4	0.22	0.054	-	-	0.45	0.72	-	-	0.11	0.031	0.79	3
P-value for the tests				0.003	P-value for the tests			0.012	P-value for the tests			0.009
P-value of the Goodness of Fit tests				0.239	P-value of the Goodness of Fit tests			0.078	P-value of the Goodness of Fit tests			0.129

The result of Table 4 can be summarized as - green data centers in manufacturing business has an impact on reducing energy consumption, reducing carbon footprints as well as reducing operational cost. Ensure reuse of ICT equipment that is no longer required but is still serviceable (GDC1) and Use of electronic recycled or second hand equipment (GDC2) have ranked one and two as per their odds ratio implying that these practices are significant in manufacturing units.

The p-values for GDC3 (Identifies server and data disks in the data center that are running but not providing any services and decommission it) and GDC4 (specifies low power consumption, low voltage servers with high efficiency power supply units) is greater than 0.05 so there is significant evidence that these factors have no impact on reduction of energy consumption , or carbon footprints, or operational costs.

The results of the above values are summarized in Table 5 using Ordinal Logistic Regression.

Table 5: Results of Ordinal Regression Analysis

Impact (Dependent Variables)	G	P-Value
Green Use		
Reduction of energy consumption in your business	24.926	0.002 *
Reduction of carbon footprints in your business	14.289	0. 074
Reduction of operational cost in your business	18.694	0.017*
Green Procurement		
Reduction of energy consumption in your business	22.507	0.004*
Reduction of carbon footprints in your business	20.279	0.009*
Reduction of operational cost in your business	22.779	0.004*
Green Disposal		
Reduction of energy consumption in your business	13.896	0.085
Reduction of carbon footprints in your business	10.696	0.220
Reduction of operational cost in your business	8.654	0.370
Green Data Centre		
Reduction of energy consumption in your business	23.032	0.003*
Reduction of carbon footprints in your business	19.543	0.012*
Reduction of operational cost in your business	20.387	0.009*

The G statistic tests the null hypothesis that all the coefficients associated with predictors equal zero versus these coefficients not all being equal to zero. For example, In Table 2 ,G = 24.927, with a p-value of 0.002 for the impact of GU on the reduction of energy consumption, indicating that there is sufficient evidence that at least one of the coefficients is different from zero, given that the accepted α-level is greater than 0.005.The *p-value < 0.05 in Table 2 suggests that the proposed hypothesis is accepted.

6. CONCLUSION

All the variables are ordinal; a median is employed to summarize a group of items into one single variable. The grouped in one variable called EI and the independent variables are grouped in four factors displayed in Table 6.

Table 6: Ordinal Logistic Regression for impact of Green ICT on EI

	Environmental Intelligence (DV)			
	Coefficient	p-value	Odds-ratio	Rank Order
α1	0.09	0.92		
α2	0.18	0.82		
α3	-1.9	0.07		
α4	-0.1	0.006		
GU	-0.6	0.022	1.02	3
GP	-0.2	0.008	0.77	1
GD	1.8	0.4	-	-
GDC	-0.82	0.016	0.81	2
P-value for the test that all coefficients are zero				0
P-value of the Goodness of Fit tests				0.59

In Table 6, the p-value for the Pearson test is 0.0, and the p-value for the goodness of fit test is 0.59, indicating that there is insufficient evidence to claim that the model fit the data adequately. If the p-value is less than the α-level (0.05), the test rejects the null hypothesis that the model does not fit the data adequately.

The values labeled α1, α2, α3 and α4 are estimated intercepts for the logits of the cumulative probabilities of agreement for strongly disagree (SD), SD + Disagree (D), SD + D + neutral (N) and for SD + D + N + Agree (A) respectively. Because the cumulative probability for the last response value is 1, there is no need to estimate an intercept for SD + D + N + A + SA.

The p-value for estimated coefficient of GD is 1.8, and p-value for GD is 0.4, there is insufficient evidence to conclude that Green Disposal has any impact upon EI of an organization.

There is one estimated coefficient for each covariate, which gives parallel lines for the factor levels. Here, the estimated coefficient for the covariate, GU is -0.6, with a p-value of < 0.05. The p-value indicates that for most a-levels, there is sufficient evidence to conclude that the GU has an impact on EI. Similarly, the estimated coefficient for the covariate, GP is -0.2, with a p-value of < 0.05. The p-value indicates that for most a-levels, there is sufficient evidence to conclude that the GP has an impact on EI. The estimated coefficient for the covariate, GDC is -0.82, with a p-value of < 0.05. The p-value indicates that for most a-levels, there is sufficient evidence to conclude that the GDC has an impact on EI. The negative coefficient and an odds ratio that is less than one indicate that higher GU, GP and

GDC tend to be associated with higher EI in business. Hypothesis H1, H2 and H4 are accepted whereas H3 is rejected. The ranks based on odds ratio shows that green procurement comes first in priority in manufacturing units, green data centre comes second and green use comes after wards, whereas green disposal is not adopted in most manufacturing organizations.

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