An Analysis of Interactions Among Barriers on the Implementation of Green Computing: Using Multi-objective Decision Modelling ISM

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Abstract. Green computing is the process of utilizing computer systems and their related resources in an ecological and environment friendly manner. It incorporates designing, building, utilizing and assembling of computing devices in a way that decreases their harmful ecological effect. In the past few years, green-computing concepts had been adopted by the industries due to increase in harmful effects of computing systems. This paper emphasizes on the important computing practices which are influencing on the environment. Significant practices and the essential barriers are recognized and analysed for the adoption of green systems. In this research, significant green barriers have been identified from the literature study and by the judgement of the specialists. The paper focuses on identifying and ranking the barriers for application, developing and studying the interrelationship between the identified barriers using the Interpretive Structural Modelling (ISM) and preparing a structure for the implementation of green computing.

Keywords: Green practices · Barriers · Interpretive system modelling (ISM)

1 Introduction

In the past few years, computer systems had been harming the environment rapidly in different ways like the increased power consumption, energy wastage, increased carbon footprint, lack of proper disposal, etc. The concept of green computing was introduced to deal with these effects [3]. The notion of green computing was brought up to reduce the effects of computers on the environment and enhancing the throughput of the computing systems. The main areas of focus of green computing are:

- To decrease the power consumed by systems.
- To increase the use of green energy.
- To make the systems more economical without sacrificing the productivity.
- To decrease the amount of electronic waste.

Although, green computing is an efficient way to provide services to the world as well as it also faces some barriers, such as: lack of resources, lack of techniques and eco-literacy etc. which hinder its performance [16, 18]. To further motivate the

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companies to embrace green computing, these barriers should be eliminated. These barriers impact each other and the knowledge of the common relationship they share is very important. These barriers can be independent, dependant or interrelated.

Different decision-making techniques are used to evaluate the relationship between different attributes [9]. In this paper, the "Interpretive Structural Modelling (ISM)" is used for establishing the relationship between the barriers. It is known to be a firmly established methodology to recognize and encapsulate relationships amongst explicit variables, which are used for defining an issue or a problem [15].

This paper tries to increase the amount of knowledge by following the given points:

- Identifying the relationship between the barriers.
- Developing a model for feasible implementation of green computing.

This paper is further categorized into the following subsections. Second section comprises of the barriers affecting green computing are defined. A brief description of ISM is given in the third section. Section four discusses the ISM model for the barriers. Finally, the fifth section comprises of the conclusion.

2 Literature Review

The whole concept behind green computing is to reduce carbon footprint and cost cutting. Various number of research work has been done focusing entirely on the availability of resources, overall cost, performance of the computing systems and the data centres in the long run.

Larumbe et al. [1] had given a way for improving the design of networks for providing improved performance while reducing the overall consumption of energy and cost of the system. It is a new energy awareness system which supports the new computer architecture while providing a low power consumption environment.

The Eco Value 21 model gave a 7-step environment credit rating (AAA-CCC), while the GCI (Green Competitive Index) model developed by Samsung and rates the competitiveness between countries based on low carbon index and green industry index [5, 6].

Gartner and Molla catches the whole concept of green in ICT but is only limited to the direct influences of ICT on the environment [2, 17].

Principles of virtualising server can help large industries to conserve the over usage of power by 80% and can help to increase the use of hardware resource to maximum. According to a research, in 1990's IBM company saved 4 billion of kilowatts in power [4]. The data centres are more responsible in power consumption and uses more than 50% of the office space.

ISM technique was used by Sharma et al. for developing a ranking of actions essential for achieving the upcoming motive of managing waste [14].

Diabat et al. utilized this methodology for developing a framework of the drivers which affected the application of green computing [10]. The enablers for supply chain agility were examined using the ISM technique by Faisal et al. [7].

Madaan et al. used ISM to provide a multi-objective decision model for enriching and initiating the green computing activities in an industry [8]. Mudgal et al. used this approach for modelling and analysing key barriers of Green Computing [11]. The relationships among the main barriers preventing the practise of energy saving were examined by Wan et al. in China [12].

3 Barriers Affecting Green Computing

- Privacy issues (security issues) (B1)
- Budget issues (B2)
- Adoption issues(B3)
- Reluctance to change (B4)
- Lack of management(B5)
- Lack of motivation (B6)
- Frequent changes in the technology (B7)
- Lack of technology (B8)
- Lack of resources (B9)
- Low eco-literacy (B10).

4 Interpretive Structural Modeling (ISM)

The ISM, created by J.W. Warfield, is a well-known technique to study the synergic impact of different variables over the whole system. The process of ISM comprises of finding the factors, defining their contextual relationships, and imposing a hierarchical rank order to eliminate complex problems from a system's point of view.

The ISM process helps in transforming uncertain, poorly segmented mental frameworks of systems into observable, distinct frameworks beneficial for various motives.

Many researchers have used ISM for understanding the interrelationships between different attributes in several organisations since it is a well-established methodology that can be used in different fields. Methodology for developing the model using ISM:

A step-to-step procedure is followed for developing the ISM framework. Ravi and Shankar defined some steps or stages which are listed below [13]:

- Stage 1: Variables affecting the system are taken into consideration.
- Stage 2: An interdependent relationship among the variables is defined.
- Stage 3: SSIM is created for the variables which defines the relationship of a variable with another.
- Stage 4: From the SSIM, reachability matrix is derived and examined for transitivity.
- Stage 5: Reachability matrix is divided into various levels.
- Stage 6: A directed graph is drawn and remove the transitive links.
- Stage 7: Subsequent digraph is then transformed into ISM.
- Stage 8: The developed ISM model is revised, and essential alterations are made.

5 ISM Model

5.1 Structural Self Interaction Matrix (SSIM)

Ten barriers are chosen from the literature and judgement of experts. The next point of focus is identifying and analysing the contextual relationship between the barriers. ISM encourages the usage of opinions of experts and minimum group discussion techniques for identifying the relationship. Four symbols are defined to understand the connection among the barriers.

V: B_I influences the barrier B_j
A: B_i is influenced by the barrier B_j
X: B_i and B_j influence each other
O: B_i and B_j are not inter-related

Based on the interrelationships between the variables, the final SSIM is created which is shown in Table 1.

Table 1. SSIM

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	1	A	A	A	V	V	V	A	A	A
B2	V	1	V	V	V	V	V	O	V	V
B3	V	A	1	A	V	V	V	O	V	V
B4	V	A	V	1	O	V	V	O	V	V
B5	A”	A	A	O	1	X	V	O	V	V
B6	A	A	A	A	X	1	A	o	O	A
B7	A	A	A	A	A	V	1	o	O	V
B8	V	O	O	O	O	O	O	1	O	V
B9	V	A	A	A	A	O	O	O	1	V
B10	V	A	A	A	A	V	A	A	A	1

5.2 Initial Reachability Matrix

This matrix is derived from the SSIM by substituting the values of A, V, O, X by binary digits (0, 1) according to the rules of transformation. The rules are listed below (Table 2):

Table 2. Rules of transformation

If the (i, j) entry in the SSIM is	Entry in the initial reachability matrix	
	(i, j)	(j, i)
V	1	0
A	0	1
X	1	1
O	0	0

The initial reachability matrix is organized following the above rule as shown in Table 3.

Table 3. Initial reachability matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	1	0	1	0	1	1	1	0	0	0
B2	1	1	0	1	1	1	1	0	1	1
B3	1	0	1	0	1	1	1	0	1	1
B4	1	0	1	1	0	1	1	0	1	1
B5	0	0	0	0	1	1	1	0	1	1
B6	0	0	0	0	1	1	0	0	0	0
B7	0	0	0	0	0	1	1	0	0	1
B8	1	0	0	0	0	0	0	1	0	1
B9	1	0	0	0	0	0	0	0	1	1
B10	1	0	0	0	0	1	0	0	0	1

5.3 Final Reachability Matrix

For creating the final reachability matrix, modify the initial reachability using the concept of transitivity. If an element ‘i’ affects an element ‘j’ and ‘j’ affects an element ‘k’ then transitivity states that ‘i’ should affect ‘k’. The final reachability matrix is represented in Table 4. In Table 4, transitivity is shown in cells marked by ‘*’.

Table 4. Final reachability matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Driving power
B1	1	0	1	0	1	1	1	0	1*	1*	7
B2	1	1	1*	1	1	1	1	0	1	1	9
B3	1	0	1	0	1	1	1	0	1	1	7
B4	1	0	1	1	1*	1	1	0	1	1	8
B5	1*	0	0	0	1	1	1	0	1	1	6
B6	0	0	0	0	1	1	1*	0	1*	1*	5
B7	1*	0	0	0	1*	1	1	0	0	1	5
B8	1	0	1*	0	1*	1*	1	1	0	1	7
B9	1	0	1*	0	1*	1*	1*	0	1	1	7
B10	1	0	1*	0	1*	1	1*	0	0	1	6
Dependencies	9	1	7	2	10	10	10	1	7	10	67

5.4 Level Partitioning

Firstly, the reachability and antecedent sets are derived from final reachability matrix. The reachability matrix is formed by the barrier itself and the different barriers which are influenced by it. The antecedent set is made up of the barrier and other barriers which might affect it. The intersection set comprises of the intersection of the reachability sets and antecedent sets for every barrier. Finally, the levels of various barriers are deduced. If the reachability sets and the antecedent sets of a barrier are identical, the highest level is allotted to that barrier in the ISM hierarchy. In the hierarchy, the highest-level barriers do not allow any other barriers above their own level (Table 5, 6, 7 and 8).

Table 5. Barriers of Level I

Barrier	Reachability set	Antecedent set	Intersection set	Level
Bl	B1, B3, B5, B6, B7, B9, B10	Bl, B2, B3, B4, B5, B7, B9, B10	Bl, B3, B5, B7, B9, B10	
B2	B1, B2, B3, B4, B5, B6, B7, B9, B10	B2	B2	
B3	Bl, B3, B5, B6, B7, B9, B10	Bl, B2, B3, B4,	Bl, B3	
B4	Bl, B3, B4, B5, B6, B7, B9, B10	Bl, B4	Bl, B4	
B5	Bl, B5, B6, B7, B9, B10	Bl, B2, B3, B4, B5, B6, B7, B8, B9, B10	Bl, B5, B6, B7, B9, B10	I
B6	B5, B6, B7, B9, B10	Bl, B2, B3, B4, B5, B6, B7, B8, B9, B10	B5, B6, B7, B9, B10	I
B7	B1, B5, B6, B7, B9, B10	B1, B2, B3, B4, B5, B6, B7, B8, B9, B10	Bl, B5, B6, B7, B9, B10	I
B8	Bl, B3, B5, B6, B7, B8, B10	B8	B8	
B9	Bl, B3, B5, B6, B7, B9, B10	Bl, B2, B3, B4, B5, B6, B9	Bl, B3, B5, B6, B9	
B10	Bl, B3, B5, B6, B7, B10	Bl, B2, B3, B4, B5, B6, B7, B8, B9, B10	Bl, B3, B5, B6, B7, B10	I

Table 6. Barriers of Level II

Barrier	Reachability set	Antecedent set	Intersection set	Level
B1	B1, B3, B9	B1, B2, B3, B4, B8, B9	Bl, B3, B9	II
B2	B1, B2, B3, B4, B9	B2	B2	
B3	B1, B3, B9	Bl, B2, B3, B4	Bl, B3	
B4	B1, B3, B4, B9	Bl, B2, B3, B4	Bl, B3, B4	
B8	B1, B3, B8	B8	B8	
B9	Bl, B3, B9	Bl, B2, B3, B4, B9	Bl, B3, B9	II

Table 7. Barriers of Level III

Barrier	Reachability set	antecedent set	Intersection set	Level
B2	B2, B3, B4	B2	B2	
B3	B3	B2, B3, B4	B3	III
B4	B3, B4	B2, B3, B4	B3, B4	III
B8	B3, B8	B8	B8	

Table 8. Barriers of Level IV

Barrier	Reachability set	Antecedent set	Intersection set	Level
B2	B2	B2	B2	IV
B8	B8	B8	B8	IV

5.5 Building the ISM Model

The model created with the known barriers in green computing is depicted in Figs. 1 and 2. It clearly shows that the successful elimination of barriers B2 and B8 (Budget issues and lack of technology respectively) would lead to better implementation of green computing as they form base level of ISM hierarchy whereas B5, B6, B7 and B10 (lack of management, lack of motivation, frequent changes in technology and low eco-literacy) leans on other barriers and appear highest in the hierarchy.

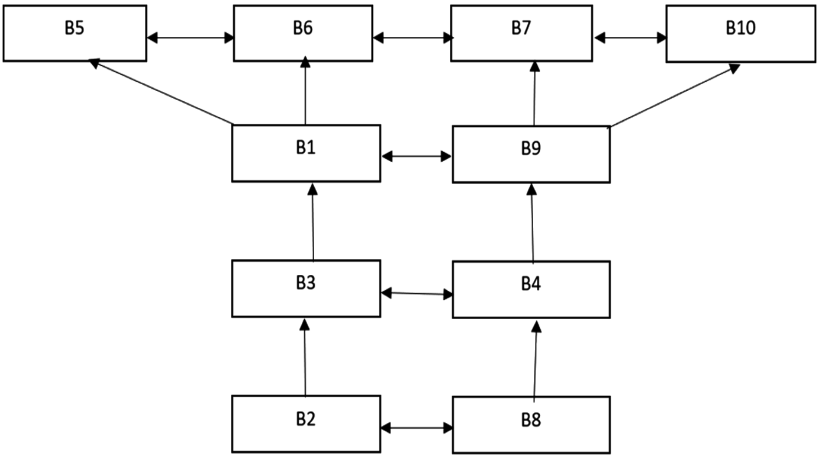

Fig. 1. Barriers

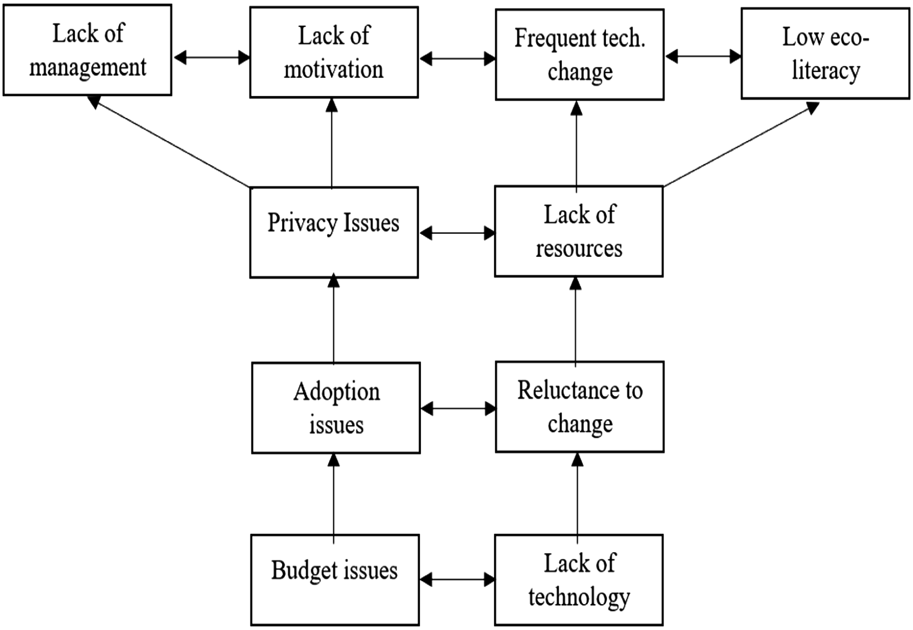

Fig. 2. ISM Model

6 Conclusion

This paper guides the practitioners in the successful implementation of green computing by eliminating the barriers in systematic way. This model provides a relationship between the barriers and it will help the practitioners and industries for understanding the connection. This research shows that barriers are modelled based on their driving power and dependencies. Barriers with weak dependence (or strong driving power) should be dealt firstly as they lead the other barriers.

Using the ISM model, successful management and utilization of resources will lead to the removal of barriers and a successful and profitable implementation of green computing. Proper study and research of this area may help in acting like a road map for the future in Green ICT. It would be a light house to researchers and industries.

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