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Transfer of Environmentally Sound Technologies

Identifying the Hierarchy and Interdependence of Barriers

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ABSTRACT

The application of new, resource efficient Environmentally Sound Technologies (ESTs) has become crucial for both development and the environment. Technology transfer is most fundamentally complex process of learning and the effective transfer is not possible until all the factors related to transfer process is well understood. Present paper aims to understand Hierarchy and inter-relationship among barriers to the process of adoption of environmentally sound technologies using an interpretive structural modelling (ISM) technique. The paper will reveal how ISM supports policy planners and implementing agencies in recognizing and exploring interdependencies among barriers to EST. The main findings of the paper contain the development of Hierarchy and inter-relationship of barriers to EST adoption with ISM model. The identified barriers are divided into five blocks of Hierarchy that display their inter-relationship depicting the driving-dependence relationship.

This academic exercise of ISM model development is expected to direct a way forward to the policy planners, makers and implementers to leverage their resources optimally with effective adoption of EST.

Keywords: *Interpretive Structural Modeling, Environmental Sound Technology, Barriers*

INTRODUCTION

Green Technology is increasingly seen as a major agent of environmental management and improvement. The "green technology" has become a topic of growing discussion in light of the environmental crisis. The "green technology" is not a concept that has yet to enjoy widespread agreement among economists or environmentalists or an international consensus. It is an extremely complex concept and it is unlikely there can be a consensus on its meaning, use and usefulness and policy implications, in the short term. A "green technology" gives the impression of a technology that is environmentally-friendly, sensitive to the need to conserve natural resources, minimizes pollution and emissions that damage the environment in the production process, and produces products and services the existence and consumption of which do not harm the environment.

It is against such a background that the use of environmentally sound technologies was recognized by the United Nations Conference on Environment and Development (UNCED) as crucial in achieving sustainable development. Chapter 34 of Agenda 21 which deals with environmentally sound technology stresses the 'need for favorable access to and transfer of environmentally sound technologies, in particular to developing countries, through supportive measures that promote technology co-operation and that should enable transfer of necessary technological know-how as well as building up of economic, technical, and managerial capabilities for the efficient use and further development of transferred technology'.

The basic technical possibilities for making this transition already exist. Whether these options are adopted will depend largely on the policies and practices as well as the range of incentives available in these countries to promote technological development. In the 1990s, and particularly with impetus from Our Common Future as well as the results of UNCED, the world community has recognized the importance of technological innovation in responding to environmental problems. This has made it possible for the private sector, to engage in the promotion of the sustainable development agenda. Technological innovation, which used to be seen largely as a threat to the environment, now offers new opportunities for reducing environmental degradation and promoting sustainable development. In the 1970s technology transfer was seen as a potential threat to the environment, thereby requiring regulation and control. In the 1990s technology transfer is being seen as a source of opportunities for promoting sustainable development. The challenge, therefore, is how to move from the traditional control of technological flow to new approaches of technology assessment that take environmental concerns into consideration. The transition towards greater application of environmentally sound technologies is being mediated mainly through research-and-development (R&D) activities.

The consumption of perishable natural resources in highly sustainable manner and release of toxic emissions has led to a great degradation to the environment. The pollution and degradation has also affected environment, economy and society as a whole (Sangwan, 2011). The rising world population and the improving living standards in developing countries have put pressure on the technology industry to grow and transform into a sustainable and green technology which will be at par with the efficiency and will has a low impact on the degradation of environment parallely. There is a strong need, particularly, in emerging and developing economies to improve technological performance so that there is less pollution, less material and energy consumption, less wastage, etc. One such potential system is environmentally sound technology (EST). It consists of methods and tools to achieve sustainable technology through process optimizations with environmental costs in mind (IEA, 2007). This paradigm shift to newer technology alternatives is urgently required in emerging countries like India to balance their economic growth vis-a`-vis ecological balance. The society is well aware of its responsibility toward environment but there are some factors that hinder the adoption of EST (Singh, 2010).

This study aims at finding EST barriers and developing a structural model to obtain hierarchy and inter-relationship among these barriers. These relationships are expected to help in mitigating these barriers strategically within limited resources. In this paper, twelve barriers to EST, found from literature, are modeled using interpretive structural modeling (ISM) technique to establish the hierarchy and inter-relationship among these barriers for successful adoption of EST.

LITERATURE REVIEW

In the last decade, several studies have investigated the barriers hindering the adoption of EST under various synonymous names like green manufacturing, sustainable manufacturing, cleaner production (CP), etc. Wang et al. (2008) identified 13 barriers to energy saving in India through the review of literature and opinion of experts from industry and academia. Veshagh and Li (2006) studied the status and feasibility of eco friendly technologies and it's manufacturing. The study was designed to identify the barriers in the adoption and sustainability in manufacturing such technologies. Further studies by Yu et al. (2008) found six barriers related to ease of use and reach of EST in northern states of India. However, these studies are conducted with limited scope of identifying barriers in various areas related to a specific sect of people rather than using a holistic approach of EST, which covers all the stakeholders in the successful diffusion of EST thereby covering the life cycle of the technology in general.

Several studies by Experts like Studer et al. (2006) have found out barriers in engagement of people and the implementation authorities for the successful diffusion of EST. Zhang et al. (2009) pointed out ten barriers to engage enterprises in environmental management initiatives in China through a questionnaire survey. Nevertheless, the strategies are limited either to a partial technology initiatives or compliance of either private or public venture initiatives only.

Recent studies by Shi et al. (2008) has found out a priority list of problems in their findings by applying an analytic hierarchy process in India from the perspectives of government, industry, and expert groups. Cooray (1999) has summarized a set of barriers related to the implementation specifically to summarize barriers to implement Green technology in Indian villages through an intensive survey of people in South India . Zhang (2000) has uniquely identified some barriers like lack of promotional activities and corruption as key set of barriers in successful implementation of EST in any geographical area. Montalvo (2008) has compiled an intensive literature from 1997 for almost a decade and presented his findings related to factors related to diffusion, adoption and exploitation of EST in South Asian sub continent wherein most of the studies were from India. Mitchell (2006) explored reasons in slow adoption of EST by people in the state of Karnataka despite the promotion of EST was sufficiently done by Government authorities, private organizations and by Public Private enterprises. Most of the literature has covered India as a sub continent or states of India as their geographical area of study.

Although all these studies were region specific, time centric and found out barriers at various phases of EST, none of them focused on creating a model of relationship among the barriers. This research paper focuses on the issue of building the model which can help in understanding the exact linkage of barriers. Interpretative Structral Modelling is one such approach of building a model. ISM provides a framework for delineation of a hierarchy amongst variables, influencers or elements of any project under consideration (Warfield 1974; Sage 1977). This kind of modelling is seen as a useful tool that helps logical thinking and carefully approaching complex issues and then communicating the results of that thinking to others. It would thus enable the policy makers and the implementing authorities to understand the proper hierarchy and dependence of each barrier on other. These barriers to EST are identified t hrough a review of literature on EST barriers as shown in Table 1.

Table 1: Description of Barriers of EST
(*Self Compiled*)

Sl. No.	*Barriers*	*Description*
1	High short-term costs	High costs of buying newer efficient technology and its implementation
2	Uncertain benefits	Uncertainty of achievable benefits after making huge investments in newer technologies
3	Technology risk	State of the art technologies, materials, operations, and industrial processes are often not easily and cheaply available to the company
4	Low top management commitment	Low top management commitment deterring ability to influence, support and champion the actual formulation and deployment of environmental initiatives across the organization
5	Lack of organizational resources	Limited technical and human resources affect the ability of firms to adopt new practices like environmentally conscious manufacturing
6	Lack of awareness/ information	Insufficient information about the available technology choices and limited access to green literature or the information diffusion
7	Weak legislation	Complete absence of environmental laws or complex and ineffective environmental legislations
8	Low enforcement	Ineffective enforcement of environmental laws because of lack of organizational infrastructure, lack of trained human resources, cost of monitoring, and dishonest officials, etc.
9	Uncertain future legislation	Possibility of upcoming legislations with unforeseen impacts on the huge investments on newer technologies
10	Trade-offs	Outsourcing of dirty manufacturing work to developing or emerging markets where environmental laws are less stringent which reduces company's share of emissions
11	Low public pressure	The absence of pressure by key social actors like local communities, media, NGOs, banks, insurance companies, or politicians
12	Low customer demand	Low customer demand for environment friendly products and processes because of price-sensitive and uninformed customers

METHODOLOGY AND MODEL DEVELOPMENT

Interpretive Structural Modeling (ISM) enables the individual or a group of them to manage the interrelations between two or more elements at a time without compromising and deviating from the actual properties of the original elements/issues (Morgado et al. 1999).

Term "interpretive structural modeling" (ISM) connotes systematic application of elementary notions of graph theory in such a way that theoretical, conceptual, and computation leverage is exploited to efficiently construct a directed graph, or network representation, of the complex pattern of a contextual relationship among a set of elements (Malone 1975). ISM is much more flexible than many conventional quantitative modeling approaches that require variables to be measured on ratio scales. It offers a qualitative modeling language for structuring complexity and thinking on an issue by building an agreed structural model (Morgado et al. 1999).

ISM as a tool is interpretive because it is based on interpretation and judgment of group members on whether and how elements are related and it is structural as it extracts overall hierarchy form a complex set of variables. It has a mathematical foundation, philosophical basis and a conceptual and analytical structure. It provides the means to transform unclear and poorly articulated mental hierarchies into visible, well-defined models for better planning of strategies (Barve et al. 2007; Faisal et al. 2006; Hasan et al. 2007; Kumar et al. 2008). Unlike a conventional questionnaire requiring respondents to merely rate the importance of key issues, Interpretive Structured Modeling (ISM) forces the managers to consider various linkages among key issues (Morgado et al. 1999).

ISM allows handling of several elemental classes under various structural types and varied relationships amongst those elements. It helps in understanding of several ill-defined elements that are related in systems (Bolan et al. 2005). It also helps in summarizing relationships among specific items and imposing an order and direction on the complex relationship among elements of the system (Thakkar et al. 2007).

Details of various steps involved in ISM are as follows

(a) Identify and list elements/variables relevant to the problem under consideration, through a literature review, field survey or any group activity for the purpose.

(b) Use expert opinion or group techniques to determine contextual relationships amongst identified variables, in line with the objectives of the study.

(c) Develop a Structural Self Interaction Matrix (SSIM) for variables, indicating pair-wise relationships among variables being studied.

(d) Convert the SSIM developed into a reachability matrix.

(e) Test the reachability matrix for transitivity (if A depends on B and B depends on C, then by principle of transitivity, A depends on C), make modifications to satisfy the transitivity requirements and derive the final reachability matrix.

(f) Delineate levels by iterative partitioning of the final reachability matrix.

(g) Translate the relationships of reachability matrix into a diagraph and convert it into an ISM (Interpretive Structural Model).

(h) Review the model for conceptual inconsistencies and make modifications in SSIM if necessary.

(i) Use the driving power and dependency of each influencer to map the driver-dependency grid for better insight into interdependencies.

Structural Self-interaction Matrix

For development of Structural Self interaction Matrix (SSIM) mentioned in Table 2, ISM methodology suggests that experts' views are used for defining contextual relationship among variables, in line with objectives of the study. In this research, entire list of influencers, barriers/hurdles identified from literature survey was presented to a group of eighty participants of 'Executive MBA Program'. Executives selected had 6~10 years of work experience in different fields were chosen. Group was explained the background of study and was asked to deliberate whether the list of barriers adequately covered all factors influencing EST or there was a need to include any other factor(s).

Four symbols were used to denote the type and direction of relationship between a pair of barriers 'i' and 'j' (referring to serial number of a barrier in row and column respectively).

V – barrier 'i' needs to be addressed before barrier 'j'

A – barrier 'j' needs to be addressed before barrier 'i'

X – both barriers 'i' and 'j' need to be addressed simultaneously and

O – barriers 'i' and 'j' can be addressed independent of each other

Table 2: Structural Self Interaction Matrix (SSIM) for EST Barriers (*Self Compiled*)

Sr. No.	*Brief Description of Barrier*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*
1	Weak legislation	V	V	X	V	V	X	V	X	V	V	A
2	Low enforcement		O	A	O	V	A	V	A	V	V	A
3	Uncertain future legislation			A	O	V	A	V	A	V	V	A
4	Low public pressure				V	V	X	V	X	V	V	A
5	High short-term costs					V	A	V	A	V	V	A
6	Uncertain benefits						A	X	A	X	V	A
7	Low customer demand							V	X	V	V	A
8	Trade-offs								A	X	V	A
9	Low top management commitment									V	V	A
10	Lack of organizational resources										V	A
11	Technological Risk											A
12	Lack of Awareness/information											

For enablers/drivers, the group was asked to deliberate a reinforcing/ameliorating type of contextual relationships amongst the factors. For instance, the group agreed that 'weak legislation' would be influenced by 'Lack of organizational resources' and 'Trade-offs' but would not impact those factors. These relationships are marked as "A".

Reachability Matrix

SSIM developed from contextual relationships were converted into binary matrices called initial reachability matrices as shwn in Table 3, by replacing V, A, X and O by a combination of 1s and 0s in accordance with the VAXO rules.

If entry (i,j) in SSIM = 'V', enter element (i,j) as '1' and (j. i) as '0' in initial reachability matrix

If entry (i,j) in SSIM = 'A', enter element (i,j) as '0' and (j. i) as '1' in initial reachability matrix

If entry (i,j) in SSIM = 'X', enter element (i,j) as '1' and (j. i) as '1' in initial reachability matrix

If entry (i,j) in SSIM = 'O', enter element (i,j) as '0' and (j. i) as '0' in initial reachability matrix

Table 3: Initial Reachability matrix for EST Barriers- (*Self Compiled*)

Sr. No.	*Brief Description of Barrier*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1	Weak legislation	1	1	1	1	1	1	1	1	1	1	1	0
2	Low enforcement	0	1	0	0	0	1	0	1	0	1	1	0
3	Uncertain future legislation	0	0	1	0	0	1	0	1	0	1	1	0
4	Low public pressure	1	1	1	1	1	1	1	1	1	1	1	0
5	High short-term costs	0	0	0	0	1	1	0	1	0	1	1	0
6	Uncertain benefits	0	0	0	0	0	1	0	1	0	1	1	0
7	Low customer demand	1	1	1	1	1	1	1	1	1	1	1	0
8	Trade-offs	0	0	0	0	0	1	0	1	0	1	1	0
9	Low top management commitment	1	1	1	1	1	1	1	1	1	1	1	0
10	Lack of organizational resources	0	0	0	0	0	1	0	1	0	1	1	0
11	Technological Risk	0	0	0	0	0	0	0	0	0	0	1	0
12	Lack of Awareness/information	1	1	1	1	1	1	1	1	1	1	1	1

Final reachability matrix was then obtained for barriers (Table 4) by incorporating the changes necessary to satisfy transitivity requirements detailed in step 5 of Structural modeling methodology. Driving power is defined as total number of variables, which it impacts including itself (equals the count of 1's in a row) and dependency is total number of variables, which have an impact on it including itself (equals the count of 1's in a column).

Table 4: Final Reachability Matrix for M-banking Barriers/hurdles (Self Compiled)

Sr. No.	*Brief Description of Barrier*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*Driving Power*
1	Weak legislation	1	1	1	1	1	1	1	1	1	1	1	0	11
2	Low enforcement	0	1	0	0	0	1	0	1	0	1	1	0	5
3	Uncertain future legislation	0	0	1	0	0	1	0	1	0	1	1	0	5
4	Low public pressure	1	1	1	1	1	1	1	1	1	1	1	0	11
5	High short-term costs	0	0	0	0	1	1	0	1	0	1	1	0	5
6	Uncertain benefits	0	0	0	0	0	1	0	1	0	1	1	0	4
7	Low customer demand	1	1	1	1	1	1	1	1	1	1	1	0	11
8	Trade-offs	0	0	0	0	0	1	0	1	0	1	1	0	4
9	Low top management commitment	1	1	1	1	1	1	1	1	1	1	1	0	11
10	Lack of organizational resources	0	0	0	0	0	1	0	1	0	1	1	0	4
11	Technological Risk	0	0	0	0	0	0	0	0	0	0	1	0	1
12	Lack of Awareness/information	1	1	1	1	1	1	1	1	1	1	1	1	12
	Dependency	5	6	6	5	6	11	5	11	5	11	12	1	84

Level Partitions and ISM Modelling

Final reachability matrix obtained after incorporating transitivity requirements is used for level partitioning. It involves comparing the 'recahability' and 'antecedent' sets of variables and delineating levels on the basis of intersection sets. It leads to a reachability set for a variable by considering the variable itself and other set of variables that causes an impact, whereas antecedent set comprises of the variable and a set of all those variables that have an impact on the primary variable. The hierarchy in ISM is decided by the level of similarity in reachability and intersection sets (Table 5). These variables would not impact any other variables

Table 5: Matrix of Reachability and Intersection Set (*Self Compiled*)

Iteration	*Barrier*	*Reachability set*	*Antecedent set*	*Interaction set*	*Level*
1	11	11	1,2,3,4,5,6,7,8,9,10,11,12	11	V
2	6	6,8,10	1,2,3,4,5,6,7,8,9,10,12	6,8,10	IV
2	8	6,8,10	1,2,3,4,5,6,7,8,9,10,12	6,8,10	IV
2	10	6,8,10	1,2,3,4,5,6,7,8,9,10,12	6,8,10	IV
3	2	2	1,2,4,7,9,12	2	III
3	3	3	1,3,4,7,9,12	3	III
3	5	5	1,4,5,7,9,12	5	III
4	1	1,4,7,9	1,4,7,9,12	1,4,7,9	II
4	4	1,4,7,9	1,4,7,9,12	1,4,7,9	II
4	7	1,4,7,9	1,4,7,9,12	1,4,7,9	II
4	9	1,4,7,9	1,4,7,9,12	1,4,7,9	II
5	12	1,4,7,9,12	12	12	I

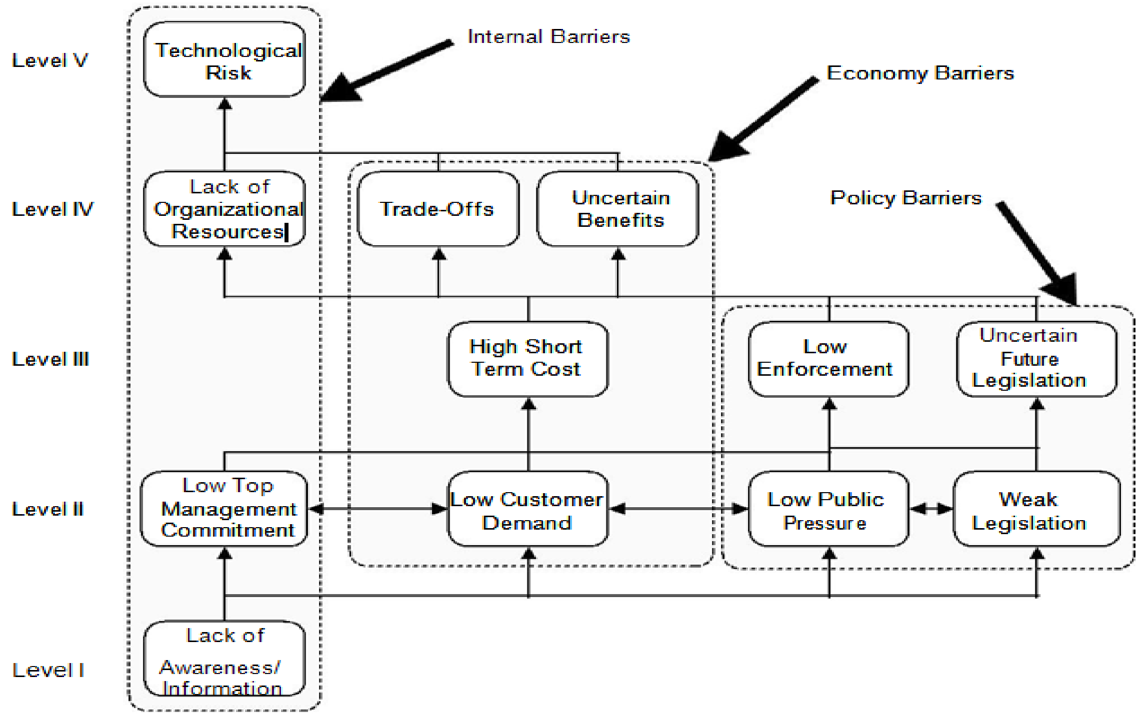

Figure 1: Hierarchy of Barriers of EST (*Self Compiled*)

RESULTS AND DISCUSSION

The developed ISM model consists of five levels of hierarchy as shown in Fig 1. The base level comprises of Lack of information and appropriate awareness among public and government agencies. It showcases that awareness plays a key role in problem solving. It indirectly affects four further levels. The next level of the pyramid then comprises of top management commitment, pressures from the peers, demand of the technology by the customers and structure of the legislation who implements these technologies. These four parameters strongly point out a public private mismatch in terms of expectations and deliverables. These barriers also point out the imbalance between land and lab ie. whether the technology generated is useful for the target audience or not. The feasibility of the technology and the usefulness has been a mismatch at this level of pyramid. Strangely these barriers have a weak dependency and a strong driving power. The inter-relationship between the two levels can be understood by the fact that Scarcity of general awareness enhances pressure from the public to demand for the right technology required for them. The lethargic approach by the end users give a chance to the government officials to produce and deliver the technologies in whatever form they have built. This indirectly causes a mismatch between the expectations and usefulness of the currently available EST in the market. The next upper level of the pyramid consists of three more levels named escalated short-term cost, low level of enforcement, and uncertainaity of legislation in the future. Short Term Costs involved in switching from the contemporary technology to the newer set of technology are generally high and usually the officials do not like to invest in this transition. The uncertainity amongst the producers and distributors of this new form of technology also forms a parallel level of concern. The resources available for generation of new efficient technology in terms of engineers, researchers and technology promoters are very few in the country. Thus a lack of trade off in terms of financial and technological factors creeps a new issue in this area. Lack of benefits and proper management of available resources forms the next cadre of the pyramid which is one of the least related factors yet are equally important. Any technology which is launched newly in the market brings along a set of risks depending upon its target audience and maturity level. This forms the apex of the pyramid.

DRIVER-DEPENDENCY MAP

A further insight into the hierarchy generated by ISM, variables can be classified using Cross-Impact Matrix Multiplication Applied to the Classification analysis (MICMAC) analysis into following four categories, viz. autonomous, independent, dependent and linkage. Such a juxtaposition of two plots brings all the barriers of autonomous and dependent types closer to dependency axis and puts independent and linkage variables on the extremes of driving power axis (Fig 2).

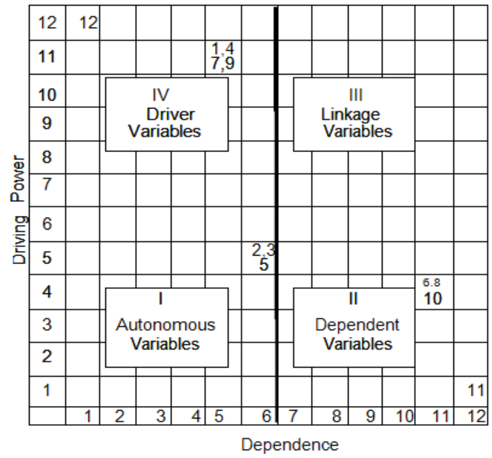

Figure 2: MICMAC Analysis of Barriers of EST (*Self Compiled*)

Although, three barriers, namely low enforcement, uncertain future legislation, and high short-term cost lies in autonomous cluster, but these barriers lie exactly on the line dividing the clusters 1 and 2, so these barriers have properties of the barriers of cluster 2 also. Higher value of "dependence" for a barriers means that other barriers in the network are to be addressed first. High value of "driving force" of a barriers means that these barriers are to be addressed before taking up the other barriers.

CONCLUSIONS

In this paper, a model of 12 barriers; identified from the review of literature; for the successful adoption of EST has been developed using ISM technique. The developed model divided the identified barriers into five levels of hierarchies showing their inter-relationship and depicting the driving-dependence relationship. These five levels have been further classified into three categories – internal, economy, and policy barriers. The developed ISM model is expected to provide a direction to the policy makers in the government and industry and the top management of the organizations to mitigate the barriers by focusing on few root barriers which directly or indirectly mitigate other barriers.

Although ISM is an interpretive modeling technique based on judgment of experts, Driver-dependency grid does evolve an overall mapping of EST influencers and helps in classification/categorization/prioritization of variables for optimum allocation of resources. The concept of plotting drivers and barriers on a common driver-dependency map, to gain strategic insights for implementation can be extended to projects/programs in any field/area.

However, the ISM model is developed through the input of experts from an emerging economy. The model needs to be tested by the input of experts from different countries under different situations. Further, the model can be tested for different segments of industry.

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