GEOGRAPHIC INFORMATION SYSTEM APPLIED IN TECHNOLOGY DIFFUSION: THE STUDY OF A HIGH POROSITY BRICK

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This paper studies technology diffusion generated in the red ceramics industry by using a Geographical Information System (GIS) to analyze the potential use of a novel brick material for energy reduction. For this purpose, simulations were carried out which compared the heat transfer information of the average temperature inside and the external average temperatures from a series of buildings, under the current environmental conditions of a previously defined locality. The results were spatially represented through GIS, and allowed a comparison between the use of novel bricks and normal bricks. Work was carried out in two phases: the collection and the treatment of the temperature data obtained from a measurement station in the city of Rio de Janeiro (1.5 km radius), and type-related data of the buildings (residential, commercial and territorial), which defined a standard unit of measurement. The analysis of the simulation of the energy consumption in the area of interest showed that GIS could be a powerful visual instrument to motivate investors of the productive chain, civil construction companies and society in general, to adopt technological innovations.

***Keywords**: geographical information system, technology diffusion and energy consumption*

1. Introduction

This paper presents an applied technology diffusion study within the scope of energy efficiency for construction, using the tools of a Geographical Information System - GIS. GIS is data visualization technology that relies on digitalized maps. It can be defined as a collection of hardware, software, geographic data and census data. The final purpose of this technology is to capture, catalogue, and allow updates on all forms of geographically referenced information (Hsiao and Sterling, 1992., ESRI, 1996). In other words, it allows each register or digital object to have its own identified geographic location (Turbam, 2003). The most important feature of a GIS is its geographical intelligence, or topology, which allows database searches based on a location in the map. With this in mind, end-users are allowed to generate graphical outputs quickly, and also summarize statistical information within a spatial geographical context.

Currently, GIS is considered the one of the best tools for solving data organization problems with spatial models, within the field of data visualization technology. Turban (2003) considers data visualization studies important assets for the understanding of the relationships between data and compacting information. As the saying goes "a picture is worth one thousand words", and as a consequence, visual technology provides a more attractive and user- friendly media for information technology (IT) decision makers. This property of GIS is particularly important when one considers the predictive nature of technology diffusion. This predictive nature is possible through simulations that employ complex architecture models with the objective of minimizing the associated uncertainties. These models began in the financial/derivative markets in the 1980´s, with the merging of computer science and telecommunications. At present, these models are configured as artificial environments (cyber-spaces) of invention and anticipation, where, according to Saints (2003), "wealth abandons the substance and the energy, valuing preferably the information".

In this context according to Turban (2003), large amounts of data can be analyzed through software visualization packages. These are based on self-driven exploration resources and visual representation tools, which allow detection of problems that cannot otherwise be identified by conventional methods alone. This also enables integrated analyses to be performed as well as the display of a variety of data formats. These software packages have an important role in a diverse spectrum of social, political and governmental institutions. In particular, when these tools are applied in governmental institutions in developing countries, the decision making process is simplified and this, in turn, allows for safer and more efficient implementations in innovation science (Katz 1987., Lall 1992).

In this work the use of GIS in technology diffusion is presented, focusing on a particular industrial segment: the red ceramic industry. This work is part of a more comprehensive project developed in the Centro Federal de Educação Tecnológica do Rio de Janeiro - Cefet/RJ which entails a diverse range of technological and economical innovation area studies within the red ceramic industry in Brazil. Specifically, this paper has used GIS to study the technical and commercial viability of the use of a high porosity novel structural brick developed in Germany. Cefet/RJ has appropriated this technology and has developed a prototype novel brick for use in research in Brazil (Brochado, 2001). These prototype novel bricks consist of various kinds of materials that allow the reduction of thermal conductivity energy that can improve energy efficiency. This work has simulated the reduction in energy consumption in residential buildings as a function of thermal conductivity variation resulting from the use of these novel bricks. The results were then spatially represented through GIS and this allowed for the comparison of the use of this novel brick as opposed to the more conventional normal bricks. It is hoped that this work will demonstrate the potential use of GIS in technological diffusion. In addition, it is envisaged that this methodology will allow easier implementation of energy efficiency strategies, thus becoming an attractive alternative for urban decision makers.

2. The GIS use

Geographic Information Systems allow for a multiplicity of uses and scientific visions due to the high explanatory power of spatial analysis, the simplified treatment of concrete data and the symbolic representation of subjective elements. This application entails tools to produce maps, used as support for spatial representation of phenomena and a geographic database, with functions of storage and recovery of this spatial information.

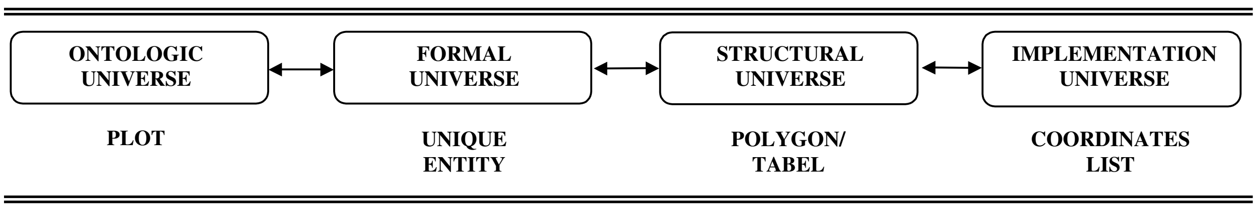
According to Rodrigues (1988), geoprocessing is the technology to collect and treat spatial information and develop interface systems. As outlined in Courseware in Cartographic Sciences of the UNESP (2002), it constitutes a valuable technological environment for the most diverse applications such as in the social and economical areas.

Huxhold (1991) stated that the focus of a traditional GIS was the spatial analysis. In addition, Tomlin (1990) stated that GIS was a useful source to prepare, present and interpret facts related to land surfaces. Therefore, its hardware and software configuration has developed specifically for the acquisition, maintenance and use of cartographic data. These properties define GIS as an instrument that interlinks database systems (specific capacities to deal with spatial referenced data) with a set of operations to work with it (Star and Estes, 1990).

Following this argument, it appears as an additional interface element, within the information systems area, promoting technology in an efficient manner with the purpose of acquiring, storing, updating, manipulating, analyzing and presenting all kinds of spatially referenced information (ESRI, 1990). Some additional advantages of GIS can be observed in the enhanced ability to integrate many kinds of information as well as displaying data, which facilitates the decision making process.

In these analyses, space becomes the arena where different actors interact to produces an intended social organization (Corrêa, 1997). This complexity of interactions is materialized in the space in urban or rural forms, characterized by different landscapes. These areas are usually homogeneous (same degrees of insertion in the work force, education, household income and property price) and internally different in neighboring areas (Almeida, 1982).

The spatial information will try to translate these spatial conditioning elements into trends, by establishing symbolic standards to be represented through a map (Chamber and Hunter, 2002). This is made possible because the spatial information is added to morphology landscape studies that are based on a phenomenological vision of science, which attributes forms to those spatial symbols. Spatial forms as residences, streets, neighbors, and others, when being mapped, express a virtual language that is subject to new interpretations, as showed in scheme 1.



Scheme 1 - Adapted from: The Process of Computational Representation. Source: Câmara and Monteiro (2002).

In order to better understand these dynamics, is it necessary to have prior knowledge of a systemic approach based on visual information technology, as well as the innovations on the information analysis theme.

Several authors in this area have stated that information is attributed to the data (numeric, alphabetic, alphanumeric and graphic values, or combinations) each has a particular meaning for each end-use or application. This is the basis of GIS inputs which convert these data registers into visual registers. Quoting Harvey (1989), "if a single image is worth more than a thousand words, the representation becomes more relevant than the spatial organization".

GIS therefore works as a technological information system, by integrating discrete technologies as well as supporting spatial analysis, with maps and modeling. As mentioned by Foot and Lynch (2002), GIS improves on the capacity of manual methods, enabling elaborate maps to be created and the analysis of large amounts of data in one single database.

3. The Modeling Approach

The model used in this work has been developed for the Red Ceramics Project by the Centro Tecnológico Federal *Celso Suckow da Fonseca* (Cefet/RJ). This was adapted from a model developed in Germany. The basis of this model is a structural novel red ceramics brick of high porosity, known as "*Dämmziegel*" (isolating brick). Several experiments have been carried out in this institution, including the development of a prototype brick financed by FAPERJ (Research Development Foundation of the State of Rio de Janeiro). More details can be found in the work of Monetto (2005).

Monetto (2005) presents the results of the analysis of the novel brick components and these were found to be mostly clays. Experiments were carried out to incorporate porous media in these bricks. The properties of these incorporated materials were tested using density, compressive strength and thermal conductivity measurements. Table 1 presents some results. It can be observed that the thermal conductivity index of these novel brick is less than 50% of the normal brick material.

	THERMAL CONDUCTIVITY INDEX *(W/m ºC)*
Traditional Bricks	1,0
High porosity brick - Sawdust moisture/ Cellulose's pope	0,406

Table1 - Thermal Conductivity Index for the Traditional Brick and for the High Porosity Brick
Source: ABNT - Project of Norm 02:135.07/001/3 and Ambrósio, 2003

A spatiallized model for the insertion of the high capacity structural brick (Scheme 2) was conceived to model this reduction in thermal conductivity. The described model (Scheme 2) represents the empirical application of this study based on the use of a georreferenced database. More specifically, the collection, treatment and analysis of data. The software package used was Arcview GIS, version 3.2.

The databases used for the first phase of this study, consist of:

- A cartographic base of public roads and avenues of the city of Rio de Janeiro disposed in blocks, where the information had been interpolated. The source of this was the urban zoning work developed by municipal department of urbanism (SMU) (1999). This database is currently being updated by aerial photography surveys as well as from the land use maps (1:10.000 scale). The radius of study specified for this work was a 1.5 km area having as center the Av. General Canabarro, which is precisely the location of the temperature measurement station of Cefet/RJ.

- The base of values and typologies for this work were taken from the Listings of Urban Land and Territorial Property Tax - IPTU, provided from the Municipal City hall of Rio de Janeiro and its Institute of Urban Planning - IPLAN, for the years 1991 to 1994 and 1997 to 1999. Typologies are defined as: residential, commercial and territorial. This database allowed the classification of standard properties defined according to total areas (ranging from 30 to 100 m^2). By using this assumption, it can be observed in Fig 1. that the area chosen for this study fall in the residential category (a majority of traditional bricks).

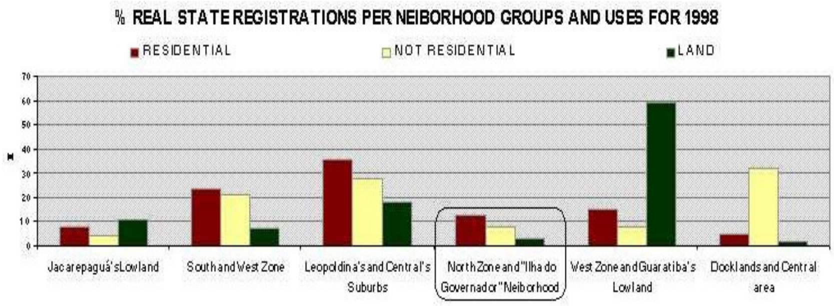
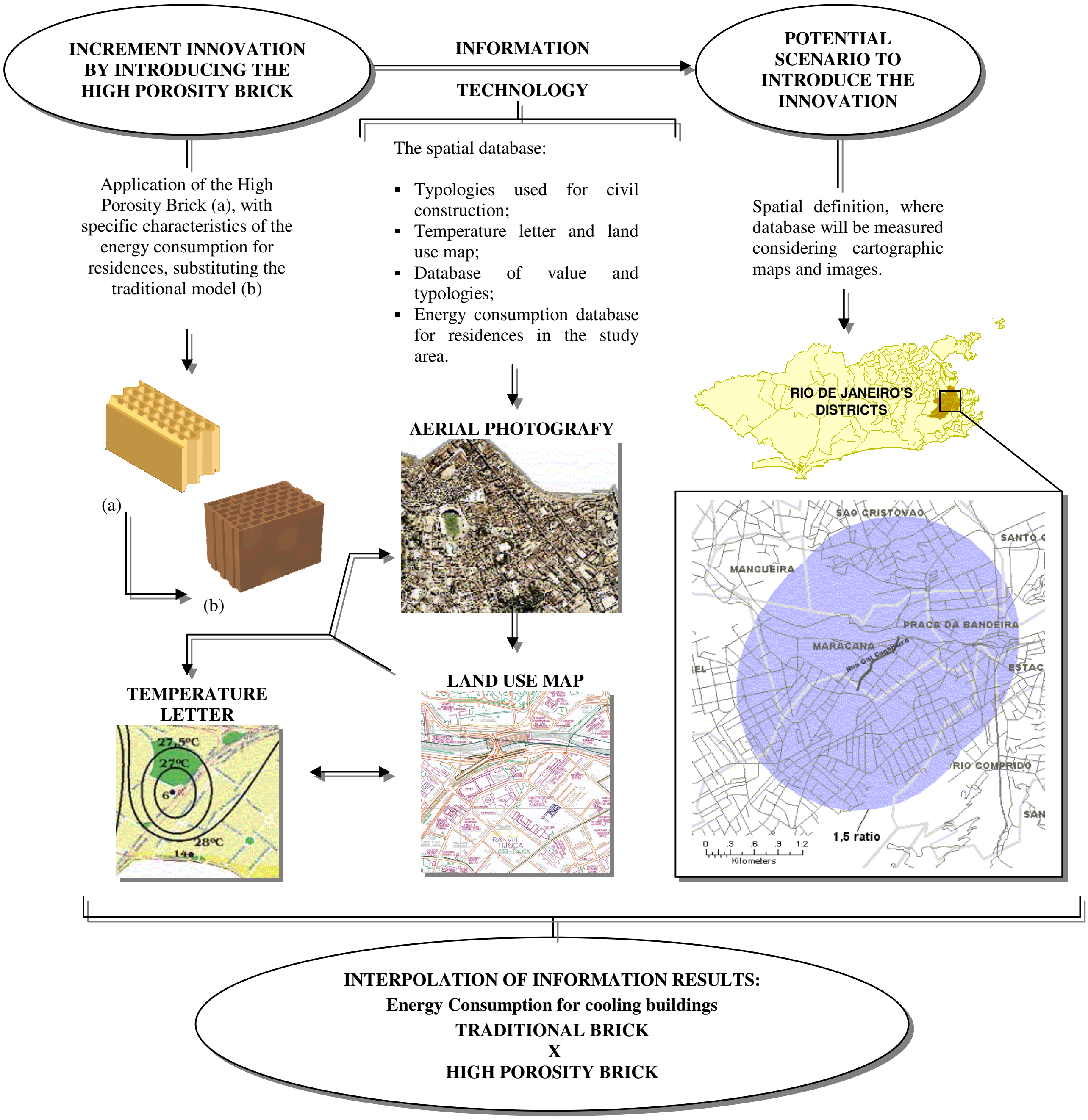


Fig. 1 – Percentage of real estate registrations for district categories Source: Statistical Yearbook of IPTU – 1998.



Scheme 2: Modeling approach

- The temperature map of the study area uses two sources of data: the Maracanã district climatic studies, developed by Climatologic and Environmental Analysis Laboratory (CLIMAGEO) from the Federal University of Rio de Janeiro - UFRJ; and the database generated by the Climatologic Station located in the campus of Cefet/RJ. Maracanã is considered a through-fare district, and receives an intense flow of vehicles during rush hours, forming heat islands that make this district one of the hottest places in the city. Data from the last 10 years was assembled by us in the course of this study. These will be used to compare the average temperatures inside a building and external average temperatures, for a range of buildings in a forecoming study. Temperatures which will be used include three annual average temperatures: maximum, average and minimum. However for this preliminary analysis, only a maximum temperature of 40º C was used.

- The energy consumption database consists of energy data for the residences located in the study area, taken by the Electricity Distribution Company - Light. In a forecoming study, this data will be used to simulate the energy consumption for the three average temperatures previously mentioned. In this preliminary work, the modeling used the energy consumption of two household equipments: the ceiling fan and the residential air conditioning (taken to be 7500 BTU). These household devices were chosen in order to maintain a temperature of 23º C in a single 12 m^2 room. The energy consumption of these equipments are listed in Table 2 (Creder, 1998 *apud* Monetto, 2005).

	POWER *(Pw/h)*	PERIOD OF USE *(Hours)*	MONTHLY CONSUMPTION *(Kw/h)*
Ceiling Fan	300	24	216.000
Air Conditioning	567	12	204.120

Table 2 - Consumption for household device. Source: Creder, 1998

The modeling approach uses methodology based on the computations using finite elements that calculates transient thermal behavior of the novel bricks in rooms with the specifications described above. According to Monetto (2005), the study has demonstrated the possibility of maintaining the internal temperature generated by air conditioning in building interiors for long periods of time, due to capacity of the brick to minimize the transmission of the external heat to the environment. As a result energy savings have been shown to compare favorably against the traditional bricks. Monetto (2005) also quantified the flow of heat through the analysis of the effect of the thermal transmittance in the constructions. These were found to reach less than 1,82 times that of a wall of conventional bricks.

4. The application of the modeling approach

For this preliminary analysis, the central public avenue analyzed was Av General Canabarro, where the meteorological station is located, as illustrated in Map 1.

Map 1 - Delineation of the study area using Arcview 3.2 .

Av General Canabarro is located in the Maracanã district. It presents some particularities : it comprises a commercial street in a residential zone. As a result, it possesses a total of 101 residential units, which can be further divided in: 68 apartments distributed for 9 buildings and 33 apartments with characteristics of multi-family buildings, (2 to 4 units). The residential units, after the standard buildings classification were reduced to a total of 75 units. These were distributed in 3 blocks (but the Av Maracana also contains an additional 5 blocks which are strictly commercial in nature). Unit groupings are presented in Table 3.

	Block 1	Block 2	Block 3
Units per block	55	4	16
Units areas *(m^2)*	54	45	63

Table 3 - Distribution of the units for blocks.

For the calculation of the monthly average energy consumption in the three blocks described in Table 3, an average unit size criteria was used as a means of establishing the number of electric devices, as illustrated in Table 4.

AVERAGE SIZE *(m^2)*	AIR CONDITIONING *(Units)*	CEILING FAN *(Units)*
45	1	1
54	1	1
63	1	2

Table 4 – Number of electric devices for average units areas as defined in Table 3.

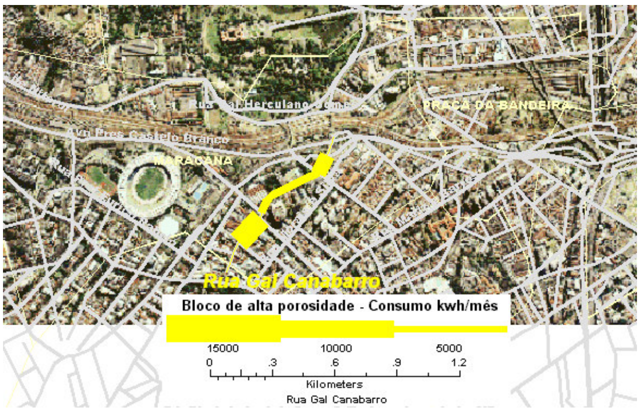
In turn, the data for each block was added, indicating the monthly consumption of energy in each block. The total consumption for the high porosity structural brick in each block could then be obtained from the analysis of thermal transmittance effects in the buildings (Monetto, 2005). As can be observed in Table 5, the data shows a reduction in energy consumption for all blocks where the novel brick was used.

BLOCKS / CONSUMPITION	1 *(kwh/m)*	2 *(kwh/m)*	3 *(kwh/m)*
Conventional Bricks (*Full consumption* **x** *nº of units*)	23.106.600	10.178.000	16.804.800
High Porosity Bricks - 1,82 (*Full consumption* **x** *nº of units*)	12.695.934	5.592.308	9.233.407

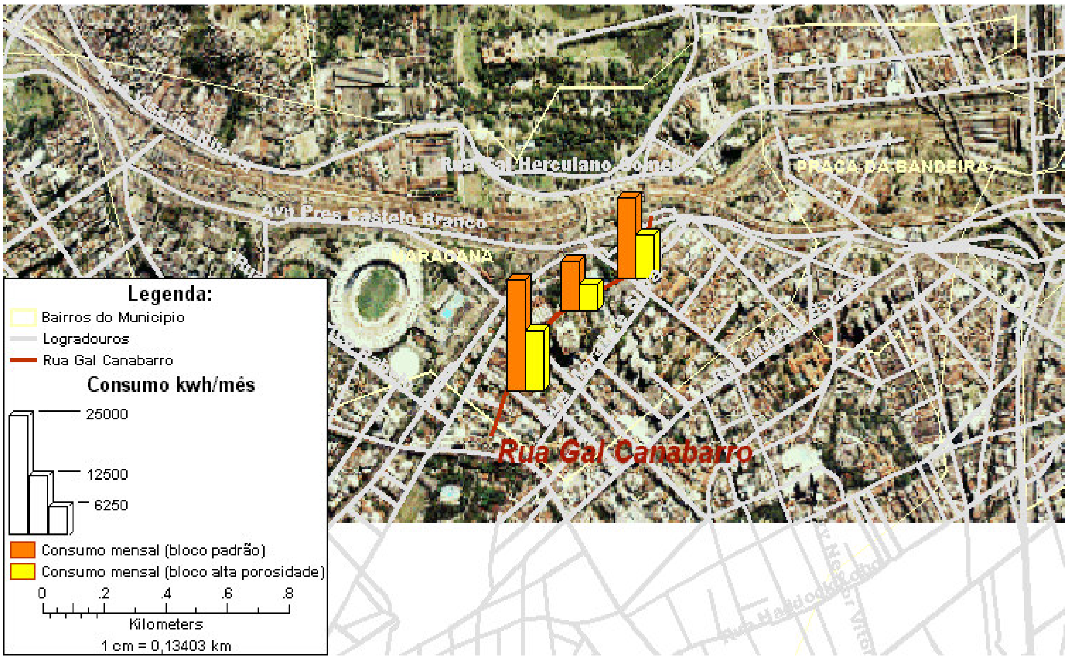
Table 5 - Monthly consumption of energy for block units. Comparison of conventional bricks with novel bricks.

The information was then spatiallized allowing for the interpretation of the distinct trends between the total consumed energy and the projected values as demonstrated in Maps 2, 3 and 4.

Map 2 - Monthly consumption for blocks using traditional bricks



Map 3 - Monthly consumption for blocks using novel bricks



Map 4 - Monthly consumption for blocks - comparative analysis.

5. Interim conclusions

This work has reached a number of interesting conclusions:

GIS was used to treat data from residential blocks from a street in Rio de Janeiro. The data was spatiallized with mapping and allowed a preliminary study of the economic viability of novel brick materials.

The simulated results showed that these novel materials led to a reduction in the energy needs for the residential buildings studied.

The adoption of this method, based on GIS, was used as a methodological reference for the diffusion of new projects. This tool allowed for the visualization of the innovation focused in the energy question.

Future work will apply this methodology to 150 public roads and avenues and will allow a more comprehensive visualization of the impact of the novel material. It is hoped that the results presented in this work will provide an instrument to motivate investors of the productive chain, civil construction companies and society in general to adopt technological innovations.

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