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A smart grids knowledge transfer paradigm supported by experts' throughput modeling artificial intelligence algorithmic processes

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ABSTRACT

This paper presents an artificial intelligence algorithmic knowledge transfer approach to the models that have been developed throughout the world for smart grid networks. Many nations are moving forward to implement smarter ways to generate, distribute and network energy, while others are expecting the leading countries to take the initiative and then follow suit. Therefore, we theoretically identify three dimensions of experts' competencies—perception, judgment, and decision choice supported by the Throughput Model algorithms for knowledge transfer. Integrating the Throughput Model algorithmic framework and Deming Cycle (i.e., plan, do, check, act), we propose that Information and Communication Technology (ICT) systems influence experts' decision making towards implementation of Smart Grids (SG). This model was backed up with the perspectives of 32 global experts as surveyed using Carnegie Mellon Maturity model questions and analyzed the results using PLS to validate the findings and compare them to our enhanced knowledge transfer developed from Deming's PDCA cycle. Our results suggest that these key algorithmic decision-making components are critical in explaining the successful application of planning, doing, checking/ acting, and planning of renewable energy technology as well as for a greener environment.

1. Introduction

The environment is receiving more emissions of CO_2 and other gases, utility companies and governments are urging the implementation of alternative sources of energy, while maintaining the control on the distribution because they own the current infrastructure (Benson et al., 2016). Many of the leading countries have implemented policies dictate on resource sustainability. Despite the fact that presented policies have increased level of awareness on the influence of resource sustainability, the implementation is challenging because the difficulties in transforming strategy policy targets thoroughly into feasible operational objectives (Koh et al., 2017). Electricity supply chains need to provide sustainable techniques that increase energy efficiency in an environment-friendly manner (Pagell and Wu, 2009). Aligning the business model and environmental elements of sustainability improves efficiency and effectiveness(Pagell and Wu, 2009). Considering the Deming Cycle of "Plan-Do-Check-Act" (PDCA) cycle (Du et al., 2008) we developed a artificial intelligence algorithmic knowledge management (i.e., knowledge transfer) model (Argote and Ingram, 2000; Chang et al., 2012) and based on literature survey (Cardenas et al., 2014) we selected relations between the identified elements. The Deming Cycle is put into operation by a cognitive model described as the Throughput Model (Rodgers, 1997a; Foss and Rodgers, 2011; Rodgers et al., 2019). This model demonstrates the relationship among the artificial intelligence algorithms depiction of individuals' perceptions and judgments impact on decision choices of Smart Grids (SG). Artificial intelligence algorithms have empowered individuals and organizations to make decisions and take actions on society behalf in these and many other domains due to the efficiency and speed gains that these tools make possible (Rodgers, 2020). As such, algorithms can be defined as a sequence of precise instructions that are implementable on computing systems (including but not limited to human brains) (Rodgers, 2020).

People often are unclear on the nature of the algorithms controlling large segments of their lives. What is more, decision-makers and policy analysts progressively more rely on algorithms as they try to make timely effective decisions in a data-rich world. A properly functioning

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algorithm frees up the decision-maker's cognitive capacity for other important deliberations (Rodgers, 2022). To this end, algorithms have driven the application of knowledge management concepts used in organizations (Rodgers and Al Fayi, 2019; Rodgers et al., 2022; Rodgers and Nguyen, 2022). Knowledge management is the name of a concept in which an individual/organization consciously and comprehensively gathers, organizes, shares, and analyzes its knowledge in terms of resources, documents, and people skills (Rodgers and Negash, 2007). Knowledge management involves training, teaching, and learning of individuals in terms of transferring and utilization of knowledge. This research paper emphasizes that the implementation of renewable and distributed energy can benefit from knowledge sharing of planning, checking/analysis, and re-planning for decision makers. We hypothesize that experts' "perception" (planning), influences it "judgment" (do/ checking/ acting) on "decision choices" (re-planning). The algorithmic model presented in this paper encapsulates these components in its influence of efficiencies in terms of success regarding the selection of energy sources.

Conducting a survey to worldwide experts, we received responses that provided the necessary data to validate the algorithmic knowledge transfer model. In order to identify any possible bias among the opinions, we conducted a clustering demographic analysis to determine if there was any bias among the respondents' characteristics. The responses represented 33 % of the 100 most influential individuals in Smart grid technologies as noted in the list of The Networked Grid 100 (Leeds and Thompson, 2010).

We investigated the level of implementation of SG to the eyes of the experts in the field via the transfer of knowledge through Information and Communication Technology (ICT) for energy efficiencies and for a greener environment. The trends of modernity in the distribution of electric energy have caught some people off guard. Just as the telephone companies were not expecting the major breakthrough that came into that area, utility companies do not seem to be vigorously implementing modern ICT for the distribution and generation of renewable resources' energy. The theory of knowledge management advocates that fruitful knowledge transfer is contingent on the characteristics of both the source and the knowledge recipient (Easterby-Smith et al., 2008). To this end, we selected experts (recipients of knowledge) around the world to survey them about their ICT knowledge (provider of knowledge) for the implementation of SG. To our knowledge, this is the first study that asserts that the artificial intelligence algorithms depicting knowledge transfer sources can be encapsulated in ICT for users (recipients of knowledge).

To measure how knowledgeable people are about energy in general, we analyzed published research of a survey conducted in the United States by the Harris-Interactive (2014) Interactive Polls. The results claim that almost two thirds (65 %) of Americans consider themselves knowledgeable about energy issues. This number is significantly better than the 61 % and 59 % results of Harris' surveys in 2009 and 2011. With regards to specific regions, 68 % of the respondents indicated that they were knowledgeable on energy issues in the West and 66 % were knowledgeable in the South—both regions scoring higher than the results from the Midwest and East. On an individual level, the most knowledgeable people in the 2011 poll were those older than 65, who graded themselves as 65 %, although the numbers were also high for those over 30 years. 75 % of men considered themselves knowledgeable about energy, compared to 47 % of women. When asked about sources of energy in general, 78 % and 76 % of the people considered that the benefits outweighed risks for the generation of energy using solar and wind power. 68 % and 52 % supported natural gas and geothermal generation. However, 53 % of the people considered coal as the worst source for the environment, and 40 % were concerned about nuclear energy being the worst one (Harris-Interactive, 2014).

As a result of the Tsunami that hit Japan on March 11, 2011, there have been some serious concerns about the use of nuclear energy in the world. Nonetheless, before this event, when the 2011 survey was conducted, less than half of Americans (42 %) said that the benefits outweighed the risks of nuclear energy; this proportion decreased to 37 % in 2014. 21 % of the respondents were not at all sure about nuclear energy, and 37 % said the risks outweigh the benefits. With regards to these new technologies, mostly represented by the "Smart Grid" (SG), people were asked if they were familiar with the term. 56 % of the Americans had not heard about "smart grids," while women were more unfamiliar with the term (66 %, compared to 46 % of men).

When people were asked if SG would increase the use of solar, wind and other renewable sources, 38 % agreed but 55 % weren't sure. Also, 60 % of Americans were not sure if SG will increase cost of the electricity—while 24 % were afraid that it will do just that (Harris-Interactive, 2011). Surveying people on how to optimize the use of energy, 79 % of Americans say that they conserve energy by turning off lights and devices when not in use. 55 % of Americans are changing incandescent light bulbs with fluorescent bulbs, 49 % are using power strips, 50 % are using lower-wattage bulbs, 50 % are buying Energy Star appliances, and 45 % are reducing hot water usage (Harris-Interactive, 2014). All these efforts are worthy examples of energy savings shared by both the consumers and the government through the American Recovery and Reinvesting Act of 2009 (ARRA) grant money; however, the problem that we are facing at a global scale is much more complex. A major scale shift of energy generation, transmission, distribution and consumption is necessary to optimize resources, use green energy and provoke collaboration of consumers with utility companies to achieve these goals. The knowledge transfer of ICT for energy distribution is important and based on the previously presented survey, most consumers are neither informed nor aware about the available options and prospective ways of distributing energy using Smart Grids for a greener environment.

2. Theory, model and hypotheses

2.1. Literature review

Based upon recent literature surveys, three very important goals for smart grid were identified as: (a) access for all, (b) environmental protection, and (c) efficiency. These goals are in line with the United Nations Conference on Sustainable Development (Rio + 20) that established the goal to achieve universal access to electricity by the year 2030, provide affordable energy by the year 2050, reduce air pollution in compliance with the World Health Organization by 2030, and to limit the global temperature change to 2 degrees celcius above the pre-industrial numbers (UN, 2012). From these three goals, we will use in the model efficiency and green energy only because the access of all population to electricity is more of a social responsibility than a goal for the implementation of smart grids. The social aspect of the model will be combined with the concept of green environment since they are both societal goals related to the well-being of the inhabitants. In an extensive literature survey to discover the trends and areas of growth for the smart grids (Cardenas et al., 2014), the results assisted us to identify the best possible definition of Smart Grids that can be implemented in this century. For the future technological advancements in energy, the office of Electricity Delivery and Energy Reliability developed a definition of a "smart grid" that generally refers to a class of technology people are using to bring utility electricity delivery systems into the 21st century, calling upon computer-based remote control and automation. The model developed by this governmental office consists of 7 major blocks: The Smart Grid, The Smart House, Renewable Energy, Consumer Engagement, Operation Centers, Distribution Intelligence, and Plug-In Electric Vehicles.

Yet another definition of Smart Grid technology was developed in 2010. This definition was proposed during the 1st IEEE/IFIP International Workshop on the Management of the Smart Grid (SG). This definition mixed both power delivery systems with an ICT layer in such a manner that allows the utility provider and the consumers to monitor and adjust electricity use. Gharavi and Ghafurian (2011, p. 918) claim that "The Smart Grid can be defined as an electric system that implements information, two-way, cyber-secure communication technologies, and computational intelligence in an integrated fashion across electricity generation, transmission, substations, distribution and consumption to achieve a system that is clean, safe, secure, reliable, resilient, efficient, and sustainable."

To better understand SG, a more recent definition was employed, which states that SG is "an approach to modernize electrical distribution that would transform the way that a utility interacted with its customers in order to provide a higher level of service and reliability, put the customer in control of their energy costs, and to achieve energy conservation and sustainability goals" (Sarfi et al., 2010).

Smart grid supply chain includes companies that operate in the fields of generation, transmission, distribution, and consumption of electric energy. With the developments of smart grids, new business models were introduced, new companies enter the market and the supply chain becomes more complex. This complexity of supply chain networks necessitates smart grids companies to adopt more innovative environmental supply networks (Nair et al., 2016). Therefore, smart grid companies need new supply chain intelligence systems that integrate business elements, concepts, tools, and smart grid technologies. These supply chain intelligence systems are required to standardize business processes, data warehouse and business intelligence through knowledge management techniques (Lukić et al., 2017).

Several studies have revealed that the current management information systems cannot meet the current needs of practitioners in the electricity supply chains. Obtaining the decision-making information is difficult; however, it is necessary to compete in the market (Rodgers, 1997b, 2016). In order to enhance the operation and management capacity of electric power supply chains it is essential to build an integrated business intelligence platform designed for process management, analysis, and forecasts. Moreover, many studies have shown that smart energy across the whole electricity supply chain is necessary for the effective coordination of business activities (Nair et al., 2016).

Attempting to go up on the ladder of abstraction, we wanted to use the term: "smart energy." Researching the term, we discovered that it comes from the philosophy of always using the most cost effective long-term approach to meeting energy needs, while maintaining the lowest environmental impact. Scholars have been relating the smart use of energy with safe environment energy. Hence, some organizations are pushing to clean and maintain the environment and the ecosystem while maintaining ecosystem health; although, this is not the entire issue. Based upon the aforementioned models and frameworks, we gather its elements and found that the most mentioned concept is "renewable energy" followed by secured communications, sustainability optimized flow and reduced costs. Using these elements we define the smart use of energy as: the use of optimized flow of sustainable energy via secured communications to enhance the use of renewable energy at reduced costs. To develop a more elaborate definition based on people's perceptions, we designed a survey to collect the opinions of professionals and further fine-tune our definition.

2.2. Knowledge transfer model development

The advocates of the knowledge-based theory contend that knowledge is the individuals/organizations foremost asset. These "assets" are assumed to enhanced future efficiency and effectiveness. Due to its complex nature knowledge is difficult to imitate and thus it provides organizations with sources for reasonable advantage in organizational performance (Alavi and Leidner, 2001) such as energy renewal. Researchers and practitioners have therefore started to investigate mechanisms to manage knowledge and to make it available for the organization as an asset (Rodgers and Negash, 2007). Research has identified perceptual planning (as well as judgment and decision choices) knowledge transfer as one of the main processes of knowledge management (Alavi and Leidner, 2001). That is, if appropriately transferred and implemented, knowledge can be meaningful to develop organizational strength and innovation.

The importance of enabling knowledge transfer, especially involving people, processes, and technology for organizations, has greatly increased in recent years. Information technology (e.g., renewable energy) has led to the rapid growth of knowledge transfer because of its capability to reach every corner of the globe and provide an unprecedented level of connectivity and the ability to communicate efficiently at a paltry cost. Therefore, energy renewal technology compels organizations to explore knowledge transfer tools to make them more competitive. The effective use of knowledge transfer enables organizations to enhance the use of energy by generating, distributing, and networking according to their needs as well as restructuring the way they share and utilize knowledge to provide an efficient and effective solution for the issue of energy renewal.

For example, leading countries have developed global road maps to aid in the implementation of Smart Grids. Although there are many proposals, the road maps focus on the basic blocks of technologies of electricity supply: generation, transmission, distribution, and consumption. Next is a detailed analysis on some of the available models to help us develop our own complimentary proposed model.

The first roadmap to analyze comes from the United Kingdom and the Electricity Networks Strategy Group (ENSG), which is chaired by the Department of Energy and Climate Change (DCC), and the Office of Gas and Electricity Markets (Ofgem). This roadmap along with a high-level smart grid vision was published in December 2009. The ENSG is fully aware of the technical, commercial, industrial, and regulatory impacts of the smart grid; therefore, any effort shall consider all these variables as well as their possible interactions. Their first activities are related to Distributed Generation and Demand Response expansion in the first stage. The second stage is the widespread of electrification of heating and transportation, as well as Distributed Generation and Storage. The last stage includes the activity to provide electricity to consumers at home. The road map outlines a potential smart grid end state with color coded activities classified as storage and demand response, electricity and heat generation, sensing, control and integration, and other infrastructure. This model seems to be a well-thought plan with a goal of deployment for all these technologies by the year 2050 (ENSG, 2010).

The Federal Minister of Economics and Technology, Rainer Brüderle presents the German model as an E-energy/Smart Grid Road Map; this road map includes recommendations on how to balance generation and consumption of energy in the future. The presentation of the model includes a large section focusing on developing standards for critical communications requiring cyber security, bandwidth, and latency regulations. The Deutsche Kommission Elektrotechnik Elektronik (DKE) is an important part of the road map developing team and is working on the specific technical aspects of the implementation. Nuclear energy is not included in this roadmap, although there is some speculation about reconsidering it back when experts feel that is safer than it was before. The model includes 4 major blocks: Standardization environment, smart meters, in-house automation, global standardization, and integration (VDE, 2009).

The China's model is called the "Strong Smart Grid" where the country is living an incredible growth of infrastructure. The implementation of SG over there is very important for the rest of the world, as most of the global emissions of CO_2 come from China and are mostly due to the generation of electricity. It is important to emphasize that China is still considering having large coal-based plants in the future, while the rest of the world is moving away from coal and oil burning. Another important difference is the use of renewable resources to generate electricity because in Europe and America, the focus is on having distributed generation while China is working on using this energy to be connected to the grid to supply whoever needs it with controlled prices and a unified power flow control (Jiandong, 2011). The cost that China is paying for this gigantic amount of energy generated is the highest pollution in the world since they use coal to generate most of this energy.

The Middle Eastern model comes from United Arab Emirates, where they have developed the city of Masdar: The Sustainable City, a city that is sustainable in energy without contaminating the environment. One of the challenges that our modern society is facing is the migration to cities. Over half the world's population is now living at urban concentrations, and these large cities are responsible for >70 % of the global CO_2 emissions. Masdar City is a beautiful place to live that achieves sustainability and no contamination in a viable financial manner. The energy part of the model is divided into two major blocks: Demand and Supply Chain. On the demand side, Masdar uses the best energy-efficient techniques along with strict guidelines for buildings that should consider special insulations, low-energy lighting, windows with glazing, using natural light as much as possible, and with the installation of smart devices. On the supply side, the city is fully powered with onsite renewable energy. It is expected that as the city grows, there will be some offsite renewable energy from several solar projects under construction (Masdar, 2011).

In North America, there is the Ontario Smart Grid Model from Canada (IESO, 2014). In this model, the Smart Grids use the power of ICT to monitor, control and optimize the use of the electricity system. The model shows efforts to increase efficiency, reduce blackouts, integrate distributed renewable generation, and empower consumers to control their energy use more effectively. The key elements of the model are Demand Response, Energy Storage, Distribution Automation, Data Access, Smart Energy Networks, Smart Homes, and Distributed Generation discussed as follow.

1. Demand Response (DR) provides customers with the ability to respond to price signals and system conditions using better monitoring, control, and automation processes.
2. Energy Storage (ES) varies from rechargeable batteries of electric vehicles to large sites that compress and release air to generate electricity as needed.
3. Distribution Automation (DA) uses controls and sensors to quickly detect and isolate faults on the grid and restore electricity faster and more efficiently.
4. Data Access. Utilities use the local distribution networks more efficiently and incorporate small-scale wind and solar generation onto the lines and into the grid. Going online to view their consumption data from their smart meters provides data access; This way, consumers better understand their energy usage as well as new ways to use energy more efficiently.
5. Smart Energy Networks help to better meet electricity needs and align the available sources to create a more efficient and sustainable system. Networks bring together several disciplines related to the electricity sector.
6. Smart Homes include new technologies like the Internet or network-connected smart appliances, energy storage and sophisticated home automation systems.
7. Distributed Generation (DG). Around the world, more consumers are choosing distributed generation where they can produce their own electrical energy, as the costs of renewable resources generating energy are going down in price. The challenge for the utility companies to integrate these new sources is supported by the Smart Grid technologies.

In the United States, the National Institute of Standards and Technology (NIST, 2010) presented a road map for developing standards in the eight most critical categories: Demands Response and Efficiency, Wide-area situational awareness, Energy Storage, Electric Transportation, Advanced Metering Infrastructure, Distribution Grid Management, Cyber Security and Networks Communications. The framework includes 4 major elements: Generation, Transmission, Distribution, and Consumption. This is an old school vertically integrated model that doesn't consider local generation or storage. The modern systems are trending towards distributed resources and this model does not consider them; hence, there is an important area of opportunity. Along with the previously presented four elements, the framework includes the markets, operations, and service providers. Along with the conceptual model there is a regulatory and legal framework that considers policies and requirements for various actors and applications as well as their interactions. The Federal Energy Regulatory Commission (FERC) adopts regulations at the federal level, and by state and local levels, there are public utility commissions, so that all of them govern some of the aspects of the Smart Grid.

Comparing the characteristics of the previously mentioned models, we can develop Table 1, which compares the models with regards to technologies and focus points. Although generation is the most mentioned category in the analyzed models, it is too general, so for this study, we consider Distributed Generation (DG) as the top one. Efficiency is surprisingly the next one since it is an expected output of the process.

2.3. *Throughput modeling employing artificial intelligence algorithms*

The *Throughput Model* provides a conceptual artificial intelligence algorithmic road map that represents the various stages that decision makers go through before rendering a decision. Such a model can provide significant insights regarding knowledge transfer to decision makers by: (1) capturing strategic decision processes, (2) by enabling individuals to track their processes to correct or modify information for future decision-making, and (3) helping individuals to understand and predict their processes and goals, especially for planning purposes.

The *Throughput Model* algorithmic pathways presented in this paper has shown to be useful in conceptualizing several different issues important to organizations (Rodgers, 1997a; Andersson, 2004; Rodgers and Negash, 2007; Foss and Rodgers, 2011; O'Shaughnessy, 2014; Rodgers and Al Fayi, 2019; Rodgers et al., 2019; Ishaque et al., 2022). This model is particularly relevant because it clarifies critical pathways for decision making purposes and eliminates rival alternative hypotheses (Rodgers, 1997a: 63).

The circles in Fig. 1 represent the theoretical constructs of perception (P), information (I), judgment (J), and decision choice (D). The central insight of this modeling approach is that knowledge inputs are necessarily embedded in a context representing cognitive, behavioral, individual, and social that constrains their discovery, their transfer from one set of actors to another, and their usefulness in different problems (Postrel, 2002). This insight we depict as "perception" in our model, implicitly or explicitly, drives path dependence in later stages of processing in the model. That is, what you already know biases or influences what you are likely to process next. Perception involves framing informational sources. The double-ended arrow connecting perception and information in Fig. 1 represents this relation. In addition, the perception←→information relationship denotes a general neural network system, which is a part of artificial intelligence. That is, perception inspires the types of information to be designated for further processing in the judgment stage (i.e., analysis). Furthermore, information impacts on perception, which is comparable to Bayesian statistics displaying a revision or updating of perception (Rodgers and Al Fayi, 2019). In other words, information and perception are interdependent because information is dependent on how individuals, influenced by their framing, interpret it and information can modify individuals' frames. In the *first algorithmic stage*, perception and information affect judgment; while in the *second algorithmic stage*, perception and judgment affect decision choice.

Judgment, the next step in the decision-making process, requires more analysis of the information and the perceptual processes. It is in the judgment stage where analytical tools and deeper insights are used for the interpretation of perception and information. Finally, a decision choice is made.

This study illustrates how the algorithmic process of decision choices

Table 1
Comparison of global smart grid models.

Category	UK	Canada	USA	China	Germany	Arab Emirates	Total
Generation	6	4	3	5	4	2	24
Distributed generation	4	3	4	3	3	1	18
Efficiency	2	3	2	2		1	10
Distribution automation	4		1				5
Distribution networks	1	2	1	1			5
Participatory	2	1	2				5
Transmission	1	1	1	1	1		5
Distribution	1	1	1		1		4
Distributed storage	1	1			2		4
Electric vehicle	1	1	1			1	4
Environmental	1					2	3
Demand response	1						1
Total	25	17	16	12	11	7	88

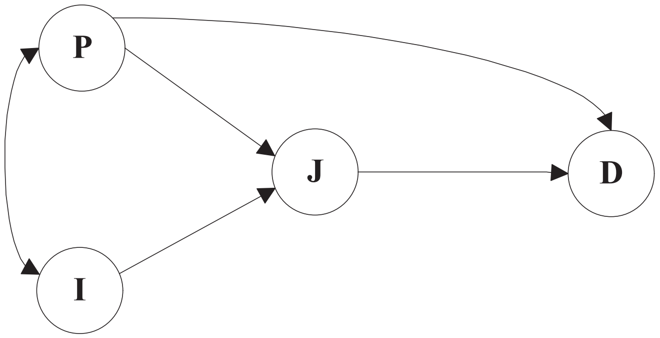

Fig. 1. Throughput Model
Where, P = perception, I = information, J = judgment, and D = decision choice.

are made. Whereby, knowledge sharing, and transfer attributes relate to the *perception* construct of planning; *information* relates to individuals' experiences in the model (and will not be tested in our model); knowledge transfer to *judgment* relates to do/check/act; and knowledge utilization in *decision choice* represented terms of re-planning (see Fig. 1).

The remainder of the manuscript is organized as follows. Reviews of relevant literature in the area that provides a theoretical foundation for the present research follows next. The subsequent section presents the research model used for this study and corresponding hypotheses. This is followed by an explanation of the methodology used for the research. The next section discusses the results. Contributions and implications for practice follow the discussion section. The manuscript concludes by providing future research ideas and limitations of the study.

We argue that knowledge transfer constitutes decision makers' judgments that is influenced by their perception of knowledge sharing. The interaction of the judgmental characteristics indicates the knowledge transfer of strategies, organizational efficiencies, and effectiveness. Further, each of the judgmental characteristics has an impact on the decision choice component of knowledge utilization success. The theoretical algorithmic model that is employed is the Throughput Model (Rodgers, 1997a; Foss and Rodgers, 2011) has been implemented in different decision-making business contexts (e.g., auditors, commercial loan officers, managers and executives). This model algorithms posit that perception and information influences judgment, while judgment influences decision choices. Moreover, the Throughput Model also depicts a direct influence of perception on decision choice.

2.4. Developing a throughput model for knowledge transfer

Expanding from the Throughput Model, to develop an artificial intelligence algorithmic knowledge transfer model, we selected the never-ending cycle for continuous improvement model. This model was originally developed by Dr. Walter Shewhart in the early half of the twentieth century (Du et al., 2008). Dr. W. Edwards Deming promoted this cycle during his historical conferences in Japan. The Japanese version of the cycle is nowadays known as the Plan-Do-Check-Act (PDCA) cycle (Du et al., 2008), which can be tested via the Throughput Model's perception (Planning), judgment (Do-Check-Act), and decision choice (Re-planning). That is, we expand the "judgment phase to incorporate three parts of do, check, and act. The **Plan** (i.e., perception) section focuses on strategies, instructions, and preparation for knowledge transfer. This part of the knowledge transfer cycle includes the distributed generation and storage elements, as they are part of the preparation for the electricity distribution process. This element is in line with the category listed by EPRI and all the analyzed models that include a point of focus for renewable resources energy generation. Although Electric Vehicles are normally related to environmental protection activities, in our model we are going to put this element in the knowledge transfer process because most of the papers in the literature survey are addressing the upcoming possibility, although at this time may look difficult to achieve, of providing consumers with electricity from the vehicles batteries while at home, that concept is named vehicle to grid (V2G).

The **Do** element (i.e., judgment) in the cycle refers to the activity itself conducted by the doer. In our model we are introducing the main actor: a computer or Information and Communication Technology (ICT) device. This knowledge transfer process includes both transmission (by ICT, in this study) and receipt (by doers) of knowledge (Grant, 1996). The introduction of ICT is shown in most models discussed before, but the benefits of this shift are critical because ICT devices can transfer knowledge based on programmed conditions that can be even unnoticeable for humans. Among the elements listed in the literature survey we consider Distribution Automation the main driver for this element because it represents the automated decision-making process using artificial intelligence.

The **Check** and **Act** (i.e., judgment) of the cycle go together, because if we do not provide accurate information, the reaction might be incorrect. For our model, we implement both elements under a new section that groups them together: Stakeholders' Participation. To have accurate information, we need to ensure the existence of proper knowledge transfer communication channels to all stakeholders, not only to the key actors in the process. In this branch of the model, we are placing the Distribution Networks that ensure the proper and secure lines of communication among all participants. The reaction to the provided knowledge transfer is going to depend on the training, awareness, experience and even audacity of the participants. In this branch of the model, we are also placing the Demand Response element from the literature survey. Based on the tariffs, peak hours, flexible pricing or other information, the participants will make decisions that will influence the performance of the distribution process. Devices could be programmed to make these decisions, but the consumers shall have the last word about allowing those devices to work or not. This section also includes cyber security concerns because the more participants in the process, the more vulnerable the system will be—as more people will enter in the system.

The last part of the knowledge transfer model is the output (decision choice), which is later going to become the PLAN section again, with the added knowledge, as Dr. Deming stated it. Two outputs are going to be considered in the model. The first output is going to be the Green Energy element, which represents environmentally friendly energy generation and/or distribution. Although this element is mentioned continuously throughout the world, its importance is not that evident. The other element is the one referring to Efficient Energy, which is the result of the optimized use of resources, resulting also in economic benefits.

Figs. 2 and 3 show the model represented in blocks and by element, along with the expected relationships among them. The purpose of this model is to show the relationship among the elements and so provide a path for others to follow in the implementation of Smart Grids.

2.5. Hypotheses

The new advancements on energy supply such as the distributed generation and vehicle-to-grid (V2G) depend a lot on the progress on distributed storage (Srivastava et al., 2010; Taylor et al., 2011) because renewable resources generated energy cannot be readily available at all times, so the same as for the electric vehicles, a battery to store energy is required in order to dispatch power when needed (Sathyanarayana and Heydt, 2010; Görbe et al., 2011). Another possible alternative is that electric vehicles might be used as energy storage devices for some households (Pang et al., 2012). Thus, our first hypotheses within the perceptual planning stage are:

H1. Electric Vehicles have an important influence on Distributed Storage.

The electric vehicles (EVs) increase the limit of the penetration of renewables in the electric power system. Because of that, using the same capacity installed, the share of renewables can increase, and the amount of energy spilled is reduced. (Díaz et al., 2015). A main function of a smart grid is to utilize EV batteries as storage devices (vehicle-to-grid connectivity) in order to reduce the volatility in demand for electricity between peak and off-peak times(Naor et al., 2015). EVs fleet can also feed energy into the network during peak periods to increase power capacity and to reduce the usage of traditional gas turbines that are more costly and ineffective. Centralized and distributed generation, intermittent renewable power generation, and multi-directional power flow are characters of smart grid networks. In these networks, consumers not only use energy, but they also produce it.

H2. Distributed Generation has an important influence on Distributed Storage.

Distributed generation requires the use of energy routers to be used as the foundation of the system; these routers are part of the distribution automation system (Huang et al., 2011). Researchers are finding that PV and other renewable resources generation are going to have an important impact on the distribution feeders' section of the grid (Steffel et al., 2012). New Distributed Generation concepts are providing innovations into electrical power generation. These concepts are influencing all partners of the electricity supply chain. Application of these new approaches are altering the market structure and changing business models and services (Lukić et al., 2017). Therefore, we are expecting that knowledge transfer of distributed generation in general to have an impact on the DA systems.

H3. Perception of Distributed Generation has an important influence on judgment of Distribution Automation.

Once the energy has been generated and efficiently stored, the whole infrastructure needs to be fully integrated into the distribution automation system (Belkacemi et al., 2011) to deliver energy as needed and not only at the moments when it is being generated. If distributions storage decisions are made without coordination between different network partners, the sustainability of other connected resources could be affected, and this could have extensive environmental, economic, and social consequences for supply chains and the broader society Mindful of the importance of efficient storage, we suggest that the knowledge transfer process of distributed storage will have an impact on distribution automation, and it might even handicap the automation process if there is no strong storage method. As stated by Vaz and Shakshuki (2012), integrating energy storage to the grid, to reduce the provision of energy demand variations, can be the main goal of researchers and practitioners for a successful future of sustainable energy.

H4. Perception of Distributed Storage has an important influence on "Distribution Automation" judgments.

For a strong and reliable distribution of energy, the need of a network is critical for success. The network is going to be the way to integrate the behaviors of generators, consumers, and "prosumers" (Gudžius et al., 2011). We expect that, to achieve an efficient distribution, the automation mechanisms must be connected to a network of well-functioning ICT systems (König et al., 2010); therefore, our next hypothesis suggests a strong knowledge transfer impact among networks and automation of energy.

H5. The first stage of judgment, "Distribution Automation" has an important influence on the second judgment stage of "Distribution

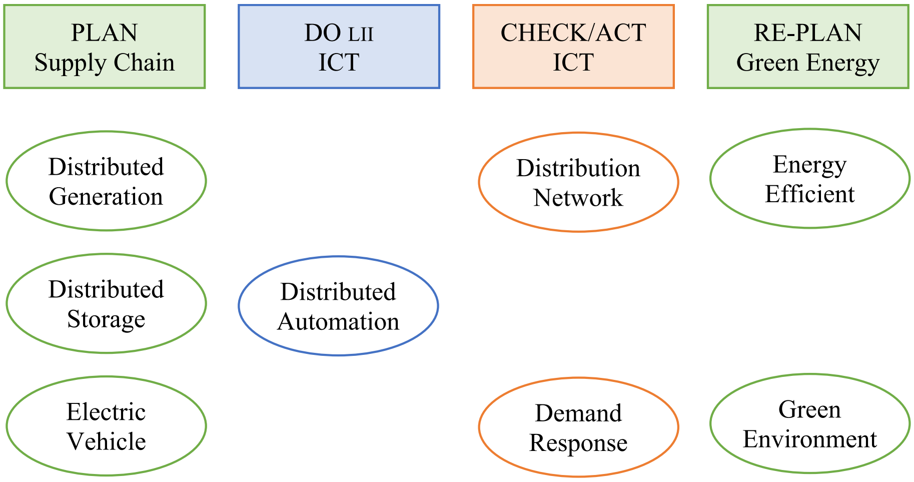

Fig. 2. Enhanced Model by Blocks related to PDCA Cycle.

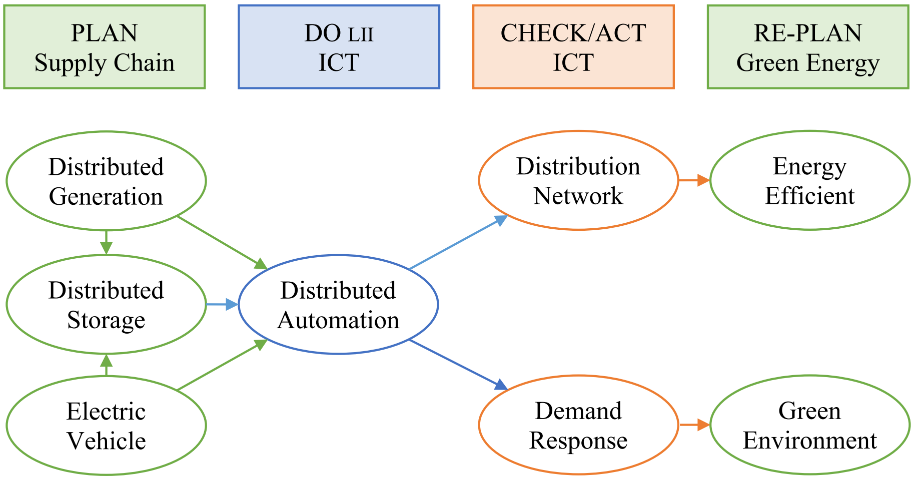

Fig. 3. Proposed enhanced model.

Network."

Smart grid supply chains can efficiently integrate huge amounts of data and support to handle various difficult and challenging problems within electricity market including forecasting, pattern identification and modeling. Because of its ability to manage large volumes of real-time data automatically, smart grids application is an essential solution to different issues in the complex electricity networks (Argotte et al., 2009). This enables consumers to have informative decision-making process. Demand Response (DR) is enabled using distribution automation and Advanced Metering Infrastructure, so the advanced system automation is going to be primary for the Smart Grid enabling technologies (Zuliang and So, 2010). Based on this statement, we expect distribution automation to have a strong knowledge transfer influence on demand response, because the more communication the easier the stakeholders' response to any real-time issue, mainly during the peak hours period (Solanki et al., 2012). As each node becomes a point of access, responses to demand in smart grids increase the permeability to cyber-attacks (Pearson, 2011).

H6. The first stage of judgment, "Distribution Automation" exerts an important influence on the second judgment stage of "Demand Response."

Via the knowledge transfer networking communication and electricity distribution, we expect that SG will improve the economics and efficiency of the electricity delivery process. Smart Grids are a highly efficient intelligent electricity network allowing two-way communications among consumers and suppliers with the utilization of ICT in the electricity production, transmission, distribution, and consumption process (Moon et al., 2011). Smart meters grouped as networks also provide support for interoperability capability to facilitate technology that is consumer and environmentally friendly and at the same time secured (Rahman and Mto, 2011).

H7. The second judgment stage, "Distribution Networks" have a strong influence on efficiency of decision choice of "SG Distribution—energy efficient" (re-planning).

The knowledge transfer of new technologies allows consumers the opportunity of knowing and reacting to the real-time status of energy provision, to make informed and efficient decisions that will surely have an impact on the environment via reduction of contamination. Demand response or stakeholders' participation is an important factor in achieving the goals of smart grid energy because the goals require environmental protection and efficiency throughout the entire process of energy distribution (Law et al., 2012). By reducing the amount of electricity generated we may replace all imported electricity with attractive economic payback, which suggests that we might have a cost-effective method to achieve reduction of greenhouse gas emissions at some industries (Klemeš et al., 2012). Attending to the last hypotheses in this paper, we tested the effect of demand response on efficiency and environmental protection.

H8. The second judgment stage, "Demand Response" has an important effect on decision choice of the "model efficiency" (replanning).

Demand response plays a key role in the smart grid supply chains and operational performance and market efficiency. It can be applied for overall load reductions in response to peak power concerns and for ancillary services for frequency regulation with faster scale response times (Siano, 2014).

H9. The second judgment stage, Demand Response has an important effect on decision choice of the "environmental protection" (re-planning).

3. Methods

3.1. Questionnaire, sample and procedure

To determine the level of maturity in the implementation of Smart Grids, Carnegie Mellon developed a survey in 2009 (SGMM Team, 2011). Internal consistency for the survey instrument was estimated using Cronbach's alpha, which is an appropriate method in the context of software process assessment and is commonly used in empirical software engineering (Dooley et al., 2001). For the Carnegie Mellon's Smart Grids' models, the values of Cronbach's alpha coefficient of internal consistency are higher than the recommended value of 0.9 (Ho-Won Jung and Goldenson, 2002).

The survey includes 180 questions, divided into 4 major sections, as shown in Table 2. For our purposes, we considered that the number of questions was too high for the professional level that we were planning to survey, so we reduced the number of questions to 55 and separated them into the six main groups of the literature survey based on Chicco (2010). Because the numbers of questions for social and environmental

Table 2
SGMM survey's questions.

Carnegie Mellon SG Maturity Model Survey	Qty.
Strategy, Mgt. & Regulatory	41
Grid Operations	41
Technology	57
Value Chain	41

areas were less than the other categories, we grouped them into one, so we had five groups with eleven questions each. Five practitioners' questions were added at the end of the survey to capture the status of maturity of technologies that were not addressed in the survey. (See Table 3.)

All 60 questions were related to the section that they belonged to, as shown in Table 4. Distribution Network was the area with the most related questions, while distributed storage had only one question.

After adding demographics questions, the survey was completed and submitted for approval before distributing the survey publicly. The target included the 100 most influential persons in Smart grid technologies as noted in the list of The Networked Grid 100: The Movers and Shakers of the Smart Grid in 2012 (Leeds and Thompson, 2010). We also included in the list those professors and researchers that are publishing about smart grids in journals, as well as college professors with this area of specialty, national laboratories scientists and utility company's experts. The survey was sent out on July 5, 2014, and fifteen experts responded immediately within a week. Unfortunately, not all questions were answered, so we re-sent the survey in several occasions until we received 32 completed surveys to use PLS with statistical validity according to Wixom and Watson (2001). One of the reasons the PLS model was implemented is due to its robustness to small samples.

PLS Model for the SGMM Modified Survey.

The PLS model was developed based on Fig. 3, and then fifty out-of-sixty questions were added as MVs to the eight LVs. The model is shown as well as the relationships of all variables. We expect Distributed Generation and Electric Vehicles to be the supply chain for the process; therefore, they are the independent exogenous variables of the model. The endogenous dependent variables are going to be the targets of the SGD model: Environment and efficiency (economics). Distribution Automation, Distribution Networks, and Demand Response are going to be influencing while being influenced by other factors. The model latent and measurable variables are shown in Table 4.

It looks very busy, but it provides a good perspective of the complexity of the model and all the different relationships. In Table 4 we can see that the model contains eight latent variables (LVs), and fifty manifest variables (MVs), which are the questions of the survey. The model contains two exogenous latent variables, Prosumer and PHEV, which are independent variables affecting the model. There are two endogenous variables, environmental protection and efficiency, which are the dependent variables affected by the independent variables of the model.

The ten questions that were not used in the model were analyzed and t tested. It is interesting that the results show the lowest average for the investment on SG for those parties that did not receive ARRA funds. The governance model of SG also had an average as low as the previous question. The highest averages are for those sections cautioning about cyber-security issues, followed by the question considering SG as important management sensors. The Cronbach's Alpha for the ten questions was 0.788, which is acceptable.

4. Results

Table 3
Our survey's questions.

Our survey	Qty.
Physical	11
Regulatory	11
Environmental / Social	11
Economic	11
ICT	11
Extra	5

Table 4
Elements and questions for the PLS analysis.

Element	Q#	Element	Q#	Element	Q#
Distributed Generation (DG)	20	Distribution Network (DN)	10	Demand Response (DR)	17
	24		15		23
	36		45		25
	39		46		27
	40		47		28
			48		29
Electric Vehicle (PHEV, PEV)	11		49		35
	56		50		55
			51		58
Distribution Automation (DA)	3		52		
	4		53	Efficiency	26
	5		54		30
	6				31
	8	Dist. Storage (DS)	44		32
	9				41
	12	Environment	22		42
	13		33		43
	16		34		60
			38		

There were 32 respondents who completed all the questions, so we used the provided information from expert sources on this subject to prove the proposed model. This first analysis is directed towards the analysis of demographics of the responders. The first demographic question is related to the gender, and because of the technicality and gender bias of the electrical sector, we received responses from 7 females and 25 males. Comparing the results by the LVs in the model we find some interesting facts in Table 6. The females' response is more optimistic and consistent as their means are always higher, with an average of 0.91, and also their standard deviations were smaller with an average of 0.59. One point to consider at this moment is that women's perception of the future technologies is more positive and consistent than that of males.

The second demographic question separates the academics from the practitioners to compare their perceptions. Although some are both practitioners and academics, we asked the respondents to identify as only one. We received responses from 19 academics and 13 practitioners, so we feel confident about the representation of both sectors (Table 7). The two areas with the major differences are related to Distribution Storage and Electric Vehicles, where academics are more optimistic about storage and electric vehicles, while practitioners are more optimistic about demand response. In general, academics are more positive than practitioners.

The third question is related to the years of experience to identify if the perception of the younger generations is either more positive or negative than the more mature respondents. Most respondents, as expected, have more than ten years of experience.

There were three rookies with less than five years of experience, only one individual with more than five and less than ten years, and the rest have more than ten years of experience in this field (Table 8). The most optimistic group is that of professionals, with more than fifteen and less than twenty-five years. Surprisingly, the less optimistic were consistently the rookies who have a very low perception regarding distributed storage and efficiency. The group with more than twenty-five years of experience is the most consistent one in their responses, as their standard deviation is the smallest in most cases. The senior group seems to be slightly less optimistic but more consistent.

The fourth question is related to the highest level of education completed. Five respondents have only a bachelor's degree, eleven have a master's and sixteen hold a PhD. Our expectation was that the highest the education level the more optimistic about these technologies.

The group with bachelor's degrees proved to be the most optimistic and consistent one, followed by the doctors, although their standard deviation was high. Finally, the masters are the less optimistic, although moderately consistent. The group holding bachelor's degrees are very positive and consistent about the environment, which is a modern theme, while the doctors are more optimistic about electric vehicles, although not as consistent. The Masters' group is concerned about most subjects, but their perception of efficiency-distributed storage is low.

The fifth question is related to the location of the respondent. Sixteen respondents are from America while eight are from Asia and eight from Europe. Our expectation is that America will be more optimistic than the rest of the world regarding Smart Grid technologies, due in no small part to the implementation of the process.

Surprisingly the most optimistic and consistent group is the one from Asia, while the least optimistic group is from Europe. The Asian group has the most optimistic opinion in most categories, except on environment and DA, where they are lower than the US. On the electric vehicles' topic there's an interesting finding as the European group is the second most optimistic group while the Americans are the ones with the least confidence. We see that in Asia the groups are optimistic and working on implementing these technologies. Based on the prior analysis, we feel confident that the sample will present a good representation of the experts' perceptions about the maturity level of the Smart Grid Distribution. There is gender, occupation, educational level, years of experience, and location representations. Something that we need to emphasize is that there are more males, academics, PhDs, and representatives from America, but this was expected due to the nature of the selected universe of experts on the field of Smart Grid Distribution and electricity supply in general.

4.1. PLS model results

Running Warp PLS 4.0 software, the model fit was calculated as shown in Table 12 where all coefficients are acceptable. Examining the loadings of the manifest variables, shown in Table 15. Most of the loadings are above the recommended level of 0.7 (Hair et al., 2011). But not all cross-loadings were below the desired 0.2 levels.

To complete the convergent validity, analysis was conducted on both composite reliability and Cronbach's alpha in Table 16, which are above the 0.7 desired levels with the only exception of the participation Cronbach's alpha for the electric vehicle PHEV, which is 0.2 with only two questions. This low Cronbach's alpha score is probably attributed to the low sample size of experts. It was then concluded that the items converge towards the latent variable. The second part of the analysis is the discriminant validation, where we analyzed how the items reflect their construct differently from the relation with others. The square root of the average variance extracted (AVE) was analyzed and expected to be larger than any correlation among any other pair of constructs. The results of the model have average variance extracted (AVE) values >0.5, as recommended by Chiang (2013) (see Table 17).

P-values show significant correlations, except from DS to DA, which is 0.022 significant, but with a negative value. The result of these analyses provides confidence on the validity of the model.

Although the R^2 for DA, DN and DR came under the 0.6 target, we can support the model because DR and DN are very close to 0.5, which is still considered a moderate endogenous latent variable. The rule of thumb for R^2 is that values of 0.75 represent substantial latent variables; values of 0.50 are moderate; and values of 0.25 are described as weak (Hair et al., 2011).

4.2. Hypotheses results

Hypothesis 1 is supported as the path coefficient is 0.496 and the average variance extracted (AVE) of 0.687. The results state that there is indeed a moderate influence of electrical vehicles on distributed storage. This point has been one of the major concerns why PHEV is not considered part of the Smart Grid technology, because the relationship of the vehicle and the charging and discharging of batteries is still a concern. One of the major concerns on the implementation of Smart Grids on regards to cyber systems that include electric vehicles has been identified as facilitating efficient energy storage (Erol-Kantarci and Mouftah, 2010) and this relationship is supported within the analyzed model (Fig. 4, Tables 5, 9-11, 13, 14 and 18).

Hypothesis 2 suggesting an important influence has a path coefficient of 0.459 and an AVE of 0.674. The results show a moderate influence of distributed generation on distributed storage supporting this hypothesis. The energy costs of DGs and distributed storage devices are more competitive than those of the former energy grid because of "encouragement factors" (Heydt et al., 2012). We expect that until the distributed storage is fine-tuned, this relationship is going to be moderate at most, but once that these devices are developed, the relationship is going to be very strong.

Hypothesis 3 suggesting an important influence has a path coefficient of 0.493 and an AVE of 0.595, hence supporting this hypothesis. The results show a moderate influence of distributed generation on distribution automation. The benefits of DGs are evident for our modern technological society, but the distribution automation supports a very large amount of access points coming from DG devices (Du et al., 2012). Without this technological distribution, it would be very difficult to integrate DG into any grid.

Hypothesis 4 suggesting an important influence has a path coefficient of −0.201 and an AVE of 0.397. The results show an opposite and weak influence of distributed storage on distribution automation. This hypothesis is not supported because the Smart Grid Operators (SGO's) are supposed to own and operate the new energy storage systems, instead of the other way around (Carpinelli et al., 2013). Under this perception the relation is negative while insignificant.

Hypothesis 5 suggesting an important influence has a path coefficient of 0.706 and an AVE of 0.677. The path coefficient is among the largest ones in this study as the relationship between automation and networks is natural because Distribution Automation needs a well-organized and integrated network in order to isolate issues and restore power whenever necessary (Mekic et al., 2009).

Hypothesis 6 suggesting an important influence has a path coefficient of 0.744 and an AVE of 0.737. The results show a stronger influence of distribution automation on demand response. With the advancements in technology and automation, it is not surprising the contribution of demand response by the consumer or the utility company. DA searches for energy management technologies to make efficient and intelligent decision-making processes to provide immediate demand response (Lu et al., 2012).

Hypothesis 7 suggesting an important influence has a path coefficient of 0.531 and an AVE of 0.779. The outcome suggests a moderate influence of distribution networks on efficiency. The mere inclusion of networks for distribution of energy does not warrant an efficiency improvement, but as more distributed resources are interconnected, the resulting networks become smarter (Rodriguez-calvo et al., 2012) thus achieving efficiency more frequently and consistently.

Hypothesis 8 suggesting an important influence has a path coefficient of 0.471 and an AVE of 0.769. The numbers of the calculated relation present a moderate influence of demand response on efficiency. We expected that by responding to demand, the results would be efficient, but there are some factors to consider. To achieve an efficient use of electricity, utilities should also consider the needs of reliability and optimization on top of efficiency while responding to demand (Petinrin and Shaaban, 2012).

Hypothesis 9 suggesting an important influence has a path coefficient of 0.825 and an AVE of 0.768. The results show the strong influence of the study on demand response affecting the environment. Responding to demand, there shall be energy savings that will definitively result in reduced harm to the environment, so this relation was expected to be strong. A way to reduce the severe environmental harm resulting from the generation of energy is low carbon development; a project was implemented at Jiangxi, in China (Zhou et al., 2012).

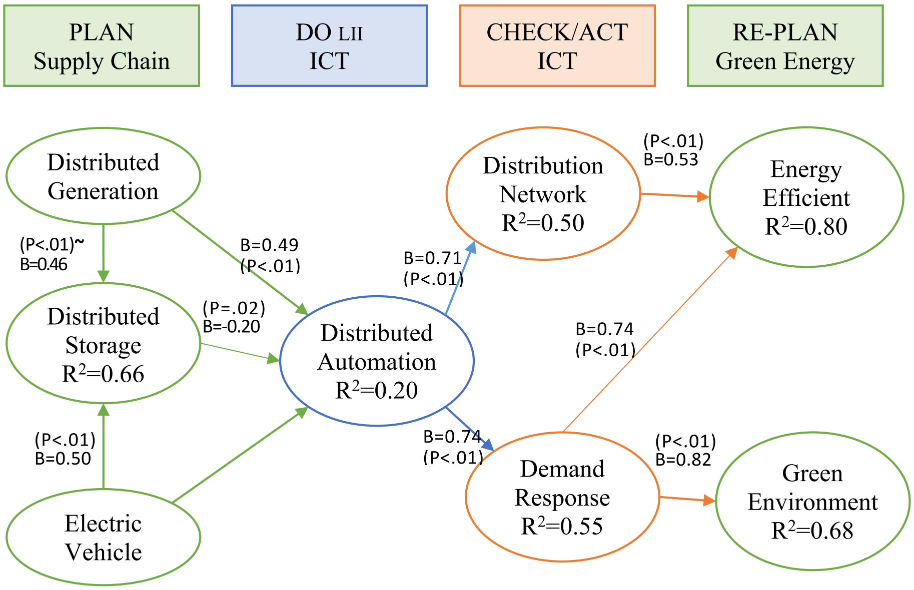

Fig. 4. PLS Model with Results.

Table 5

Means and *t*-tests for questions not used in the model.

	N	Mean	Std. Deviation	Std. Error Mean	Test Value = 0					
					t	df	Sig. (2-tailed)	Mean Difference	95 % Confidence Interval of the Difference	
									Lower	Upper
Smart meters are important grid management sensors	32	5.5313	1.21773	0.21527	25.695	31	0.000	5.53125	5.0922	5.9703
Outage and distribution management systems linked to substation automation are being explored and evaluated	32	5.3125	1.14828	0.20299	26.171	31	0.000	5.31250	4.8985	5.7265
Pilots of remote AMI/AMR are being explored or have been deployed	32	5.2588	1.54435	0.27301	19.263	31	0.000	5.25879	4.7020	5.8156
Grid data is used by an organization's security functions	32	4.8125	1.30600	0.23087	20.845	31	0.000	4.81250	4.3416	5.2834
Security and privacy implications of smart grid are being investigated	32	5.3750	1.53979	0.27220	19.747	31	0.000	5.37500	4.8198	5.9302
Pilots to support a diverse resource portfolio have been conducted	32	5.1250	1.49731	0.26469	19.362	31	0.000	5.12500	4.5852	5.6648
A smart grid governance model has been established	32	3.8750	1.56060	0.27588	14.046	31	0.000	3.87500	3.3123	4.4377
Smart grid vision and strategy drive the utility companies' strategy and direction	32	4.2188	1.79128	0.31666	13.323	31	0.000	4.21875	3.7529	4.8646
There is a widespread adoption of the Smart Grid to American Recovery & Reinvestment Acts (ARRA) non-recipients	32	3.8750	1.43122	0.25301	15.316	31	0.000	3.87500	3.3590	4.3910
Regulators are pre-funding Smart Grid initiatives	32	4.3226	1.71120	0.30250	14.289	31	0.000	4.32256	3.7056	4.9395

Table 6

Gender differences on SG technology (Means & Std. Dev.)

	Female	Male	Avg.		Female	Male	Avg.
	(7)	(25)	(32)		(7)	(25)	(32)
DS	5.14	3.60	3.94	Env	0.42	1.27	1.18
Eff	5.14	3.76	4.07	PHEV	0.48	1.29	1.16
DG	5.15	4.10	4.33	DG	0.76	1.44	1.38
DR	5.36	4.42	4.63	DR	0.64	1.29	1.23
DN	5.00	4.10	4.30	Eff	0.91	1.51	1.50
Env	5.71	4.92	5.09	DN	0.82	1.23	1.20
DA	5.29	4.68	4.81	DS	1.46	1.63	1.70
PHEV	5.36	5.09	5.15	DA	1.02	1.13	1.12
Avg.	5.27	4.36	4.54	Avg.	0.84	1.43	1.37

Table 7

Occupation driven differences on SG technology (Means & Std. Dev.).

	Academic	Practitioner	Avg.		Academic	Practitioner	Avg.
	(19)	(13)	(32)		(19)	(13)	(32)
PHEV	5.50	4.63	5.15	DR	1.34	1.05	1.23
DS	4.26	3.46	3.94	DA	1.23	0.98	1.12
DN	4.50	4.00	4.30	DN	1.09	1.33	1.20
DR	4.43	4.91	4.63	DG	1.49	1.27	1.38
Env	4.91	5.36	5.09	Env	1.26	1.04	1.18
Eff	4.19	3.88	4.07	DS	1.63	1.76	1.70
DA	4.75	4.90	4.81	Eff	1.56	1.44	1.50
DG	4.33	4.34	4.33	PHEV	1.05	1.14	1.16
Avg.	4.61	4.43	4.54	Avg.	1.38	1.37	1.37

5. Discussion

As our reliance on artificial intelligence algorithms continues to grow, so does the risk. A better understanding of modeling perceptions, information and judgments with algorithms is essential precisely because of the aura of objectivity and infallibility the global community ascribes to algorithms. In addition, errant algorithms in smart grid

Table 8
Year of experience driven differences on SG technology (Means & Std. Dev.)

	0–5 yrs (3)	5–10 yrs (1)	10–15 yrs (7)	15–25 yrs (10)	>25 yrs (11)	Avg (32)		0–5 yrs (3)	5–10 yrs (1)	10–15 yrs (7)	15–25 yrs (10)	>25 yrs (11)	Avg (32)
Eff	3.50	5.71	4.09	4.51	3.65	4.07	DS	2.31		1.95	1.69	1.36	1.70
DN	4.02	5.55	4.74	4.57	3.73	4.30	Env	1.61		1.72	0.83	1.02	1.18
DA	4.27	6.00	4.76	4.76	4.93	4.81	DN	1.78		1.06	1.25	0.99	1.20
DS	3.33	3.94	3.86	4.80	3.36	3.94	Eff	1.74		1.84	1.60	1.13	1.50
DR	4.29	5.70	4.51	4.70	4.63	4.63	DA	0.87		1.45	1.34	0.79	1.12
Env	5.58	5.46	4.57	5.32	5.05	5.09	DG	1.81		1.62	1.44	1.20	1.38
DG	4.07	5.00	4.23	4.78	4.00	4.33	DR	1.61		1.48	1.26	1.13	1.23
PHEV	5.17	5.15	4.86	5.30	5.18	5.15	PHEV	1.04		1.21	1.42	1.08	1.16
Avg.	4.28	5.31	4.45	4.84	4.32	4.54	Avg.	1.56	0.64	1.50	1.35	1.25	1.37

Table 9
Education driven differences on SG technology (Means & Std. Dev.).

	Bachelor Master PhD Avg.					Bachelor Master		PhD	Avg.
	(5)	(11)	(16)	(32)		(5)	(11)	(16)	(32)
DR	5.50	4.05	4.75	4.63	DG	0.77	1.05	1.68	1.38
DA	5.33	4.24	5.04	4.81	DR	0.46	1.02	1.37	1.23
DG	5.08	4.09	4.26	4.33	PHEV	0.55	1.28	1.18	1.16
Env	5.85	4.88	5.00	5.09	Env	0.72	0.99	1.36	1.18
Eff	4.50	3.56	4.27	4.07	DN	1.45	1.08	1.23	1.20
PHEV	4.90	4.79	5.47	5.15	Eff	1.43	1.31	1.64	1.50
DS	4.20	3.63	4.06	3.94	DA	0.86	1.05	1.13	1.12
DN	4.40	3.97	4.49	4.30	DS	1.79	1.63	1.81	1.70
Avg.	4.97	4.15	4.67	4.54	Avg.	1.14	1.23	1.47	1.37

Table 10
Location Driven Differences on SG Technology (Means & Std. Dev.).

	America (16)	Asia (8)	Europe (8)	Avg. (32)		America (16)	Asia (8)	Europe (8)	Avg. (32)
DS	3.43	5.25	3.63	3.94	Env	0.94	0.80	1.67	1.18
Eff	3.91	4.89	3.55	4.07	DG	1.12	1.34	1.78	1.38
DG	4.44	4.80	3.65	4.33	DA	0.87	1.21	1.50	1.12
DN	4.02	5.15	4.00	4.30	DN	1.18	0.73	1.33	1.20
DR	4.85	4.98	3.83	4.63	PHEV	1.25	0.75	1.07	1.16
PHEV	4.76	5.81	5.25	5.15	DR	1.05	1.15	1.44	1.23
Env	5.37	5.25	4.38	5.09	Eff	1.35	1.42	1.70	1.50
DA	4.96	4.92	4.40	4.81	DS	1.63	1.39	1.60	1.70
Avg.	4.47	5.13	4.09	4.54	Avg.	1.31	1.11	1.54	1.37

Table 11
Survey's sample analysis.

	Female	Male	Academic	Practitioner	Bachelor	Master	PhD	America	Asia	Europe
0–5 yrs	1	2	1	2	1	2	0	1	2	0
5–10 yrs	0	1	0	1	0	0	1	1	0	0
10–15 yrs	2	5	6	1	0	1	6	2	3	2
15–25 yrs	2	8	8	2	1	4	5	4	3	3
>25 yrs	2	9	4	7	3	3	5	8	0	3
Avg	1.4	5	3.8	2.6	1	2	3.4	3.2	1.6	1.6

infrastructures could contain potentially high global security risk.

Based on the literature, three very important goals for smart grid were identified: Access for all, environmental protection, and efficiency. These goals are in line with the United Nations Conference on Sustainable Development (Rio + 20) that established the goal to achieve universal access to electricity by the year 2030, provide affordable energy by the year 2050, reduce air pollution in compliance with the World Health Organization by 2030, and to limit the global temperature change to 2^{o} C above the pre-industrial numbers (UN, 2012). From these three goals, we implemented in the model efficiency and green energy only because the access of all population to electricity is more of a social responsibility than a goal for the implementation of smart grids. The social aspect of the model will be combined with the concept of green environment because they are both societal goals related to the well-being of the inhabitants.

We theoretically identified three dimensions of experts' decision-making processes of perceptions (planning) and judgments (doing, checking/acting), before arriving at a decision choice (re-planning). Further, we discussed the knowledge transfer apparatus of the Throughput Model and empirically showed that they were distinct both from each other and from knowledge received by experts. ICT devices in knowledge transfer enhanced experts' performance through knowledge

Table 12
Model fit results.

Model fit measure		Results	
Average path coefficient	(APC)=	0.547	$P < 0.001$
Average R-squared	(ARS)=	0.566	$P < 0.001$
Average adjusted R-squared	(AARS)=	0.544	$P < 0.001$
Average block VIF	(AVIF)=	1.403	acceptable if ≤ 5, ideally ≤ 3.6
Average full collinearity VIF	(AFVIF)=	4.134	acceptable if ≤ 5, ideally ≤ 3.6
Tenenhaus GoF	(GoF)=	0.629	small ≥ 0.1, medium ≥ 0.25, large ≥ 0.39
Sympson's paradox ratio	(SPR)=	0.889	acceptable if ≥ 0.7, ideally = 4
R-squared contribution ratio	(RSCR)=	0.974	acceptable if ≥ 0.9, ideally = 4
Statistical suppression ratio	(SSR)=	1.000	acceptable if ≥ 0.10
Nonlinear bivariate causality direction ratio	(NLBCDR)=	1.000	acceptable if ≥ 0.10

received by experts for a greener environment.

The result of the PLS-SEM is that supply exerts a moderate influence on ICT, which is an important driver for participation. That is, without ICT the consumers' participation, hence the cyber risks, will be minimal. With the participation of stakeholders, it is also possible to reach the green energy, or Smart Grid environmentally friendly energy. As shown in the analysis, the most important elements in the new business model for Smart Grid seem to be technology (ICT) and participation to achieve the cost (Efficiency), environmental (conservation) and social (access). Environmental protection has been a flag for years where scientists and academics have been looking forward to renewable resources, but the main drivers now seem to be the involvement of consumers to optimize and even generate energy.

5.1. *Limitations of study*

This study has at least six limitations that point out future research directions. First, we did not establish causality for the relationships examined. For instance, greater knowledge received by an expert may have appeared that ICT apparatus can be well understood by other individuals and stakeholders. Second, the experts' motivation measure in this study may not be well represented for all stakeholders. Third, this study focused on knowledge transfer to experts. An interesting future line of research would be to examine how other stakeholders facilitate knowledge transfer. Fourth, this study focused on experts from Asia, Europe, and the United States; and not including the Africa, Middle East, and South America. Although there is no theoretical reason to believe that our model would work differently for Africa, Middle East, and South America, it would be useful to replicate the study in those continents. Fifth, in this research, questionnaire responses were collected after decisions had been made. That is, typically, with most previous research that deals with knowledge transfer issues, the data are typically cross-sectional and after decisions have been formulated. Finally, the Smart Grid approach depicts processes with predetermined outputs, assuming that there is a "shortest description" of the knowledge required to change inputs into outputs. Nonetheless, since there is conceptually no shortest description, this approach requires a review of the rationale for using the shortest process description of the knowledge required to produce the processes outputs.

5.2. *Practical implications*

According to Gharavi and Ghafurian (2011), SG has the following requirements: (a) Integration of renewable energy resources to address global climate change (green energy); (b) Active customer participation for better energy conservation (demand response); (c) Secure communications (cybersecurity). (d) Better asset utilization for sustainability (smart cities); (e) Optimized flow to reduce losses and lower the cost of energy (efficiency); (f) Integration of electric vehicles to reduce dependence on fuels (PHEV/PEV); (g) Management of distributed generation & energy storage to reduce overall cost (distributed generation and distributed storage); (h) Integration of communication & control to increase safety and operational flexibility (distribution networks).

The United States Department of Energy states that SG represents an opportunity to move into a new era of reliability, availability, and efficiency. These results shall contribute to the improvement of economic and environmental health. To prepare for this transition, focus should be on testing, technology improvements, consumer education, development of standards and regulations, and information sharing between projects (DoE (United States Department of Energy), 2003).

The benefits associated with the Smart Grid include:

(a) More efficient transmission of electricity (efficiency).

Table 13
Model's path coefficients.

	DG	DS	PHEV	DA	DN	DR	Green E	Efficien
DG								
DS	0.459		0.496					
PHEV								
DA	0.493	−0.201						
DN				0.706				
DR				0.744				
Green E						0.825		
Efficien					0.531	0.471		

Table 14
Model's path coefficients p-values.

	DG	DS	PHEV	DA	DN	DR	Green E	Efficien
DG								
DS	<0.001		<0.001					
PHEV								
DA	<0.001	0.022						
DN				<0.001				
DR				<0.001				
Green E						<0.001		
Efficien					<0.001	<0.001		

Table 15
Loading and cross-loading results.

	DG	DS	PHEV	DA	DN	DR	Green E Efficienc		SE	*P* value
Q20	(0.896)	−0.316	0.166	0.108	−0.060	0.171	−0.379	0.123	0.096	<0.001
Q24	(0.759)	−0.004	0.395	0.510	−0.339	−0.108	−0.180	0.001	0.096	<0.001
Q36	(0.726)	0.729	−0.539	0.249	0.023	−0.125	0.502	−0.725	0.096	<0.001
Q39	(0.914)	−0.433	0.108	−0.456	0.123	0.087	0.042	0.169	0.096	<0.001
Q40	(0.903)	0.170	−0.171	−0.275	0.202	−0.066	0.081	0.288	0.096	<0.001
Q44	0.000	(1.000)	0.000	0.000	0.000	0.000	0.000	0.000	0.096	<0.001
Q11	0.426	−0.241	(0.745)	−0.025	0.092	−0.354	−0.255	0.213	0.096	<0.001
Q56	-0.426	0.241	(0.745)	0.025	−0.092	0.354	0.255	−0.213	0.096	<0.001
Q3	-0.541	0.225	−0.332	(0.574)	−0.238	−0.616	0.990	0.527	0.096	<0.001
Q4	-0.383	−0.311	0.285	(0.837)	0.097	0.052	−0.028	0.163	0.096	<0.001
Q5	-0.058	−0.431	0.204	(0.772)	−0.036	−0.237	0.191	−0.070	0.096	<0.001
Q60	-0.045	−0.531	−0.121	(0.634)	−0.126	−0.541	0.636	0.218	0.096	<0.001
Q8	-0.217	0.134	−0.117	(0.796)	0.432	0.254	0.093	−0.247	0.096	<0.001
Q9	0.173	0.464	−0.030	(0.781)	0.002	0.099	−0.060	−0.416	0.096	<0.001
Q12	-0.020	0.410	−0.107	(0.797)	−0.090	0.294	−0.312	0.070	0.096	<0.001
Q13	0.189	−0.213	0.016	(0.813)	0.014	0.572	−0.668	0.207	0.096	<0.001
Q16	0.763	0.225	0.075	(0.792)	−0.153	−0.180	−0.419	−0.284	0.096	<0.001
Q10	-0.347	0.396	−0.310	0.150	(0.750)	0.409	−0.184	−0.137	0.096	<0.001
Q15	0.377	−0.266	0.277	0.463	(0.786)	0.000	−0.527	0.330	0.096	<0.001
Q45	0.194	−0.025	0.076	0.190	(0.834)	−0.269	−0.198	0.093	0.096	<0.001
Q46	-0.252	0.039	−0.064	0.135	(0.860)	0.152	0.009	−0.155	0.096	<0.001
Q47	0.003	0.056	0.017	0.031	(0.864)	−0.583	0.372	−0.063	0.096	<0.001
Q48	0.197	0.036	0.156	0.199	(0.871)	−0.262	−0.255	−0.050	0.096	<0.001
Q49	0.519	−0.518	0.041	−0.447	(0.821)	−0.098	0.100	0.430	0.096	<0.001
Q50	-0.123	0.215	−0.090	−0.077	(0.877)	−0.040	0.043	−0.198	0.096	<0.001
Q51	0.042	0.105	−0.137	−0.304	(0.791)	−0.288	0.033	0.479	0.096	<0.001
Q52	0.199	−0.337	0.265	−0.146	(0.862)	0.550	−0.376	−0.397	0.096	<0.001
Q54	-0.483	0.249	−0.269	−0.100	(0.786)	0.243	0.509	−0.094	0.096	<0.001
Q53	-0.383	0.087	−0.008	−0.092	(0.784)	0.252	0.496	−0.185	0.096	<0.001
Q17	0.541	−0.109	0.108	0.196	0.292	(0.838)	−0.220	−0.995	0.096	<0.001
Q23	0.348	0.459	−0.141	0.127	−0.320	(0.792)	−0.305	−0.155	0.096	<0.001
Q25	-0.143	−0.190	0.124	−0.194	0.126	(0.909)	0.134	0.082	0.096	<0.001
Q27	-0.316	−0.228	−0.074	0.223	−0.428	(0.745)	0.211	0.984	0.096	<0.001
Q28	-0.573	0.053	0.235	0.000	−0.027	(0.770)	0.432	0.442	0.096	<0.001
Q29	-0.021	−0.269	0.005	0.070	−0.431	(0.829)	−0.127	0.571	0.096	<0.001
Q55	0.072	0.048	0.269	−0.029	0.416	(0.770)	−0.070	−0.804	0.096	<0.001
Q58	0.059	−0.281	−0.414	−0.698	0.485	(0.567)	−0.313	0.204	0.096	<0.001
Q35	0.007	0.488	−0.251	0.134	−0.005	(0.771)	0.194	−0.208	0.096	<0.001

Table 16
Loading and cross-loading results.

	DG	DS	PHEV	DA	DN	DR	Green E Efficien	
DG	(0.843)	0.674	0.427	0.595	0.702	0.682	0.644	0.807
DS	0.674	(1.000)	0.687	0.397	0.624	0.503	0.39	0.770
PHEV	0.427	0.687	(0.745)	0.292	0.418	0.432	0.411	0.600
DA	0.595	0.397	0.292	(0.760)	0.677	0.737	0.519	0.742
DN	0.702	0.624	0.418	0.677	(0.825)	0.580	0.395	0.779
DR	0.682	0.503	0.432	0.737	0.580	(0.782)	0.768	0.769
Green E	0.644	0.390	0.411	0.519	0.395	0.768	(0.851)	0.567
Efficien	0.807	0.770	0.600	0.742	0.779	0.769	0.567	(0.858)

Table 17
Model's latent variable coefficients.

	DG	DS	PHEV	DA	DN	DR	Green E Efficien	
R-squared		0.658		0.202	0.499	0.553	0.680	0.803
Adj. R-squared		0.634		0.147	0.482	0.538	0.670	0.790
Composite reliab.	0.924	1.000	0.714	0.924	0.962	0.933	0.913	0.957
Cronbach's alpha	0.896	1.000	0.199	0.906	0.957	0.918	0.871	0.948
Avg. var. extrac.	0.711	1.000	0.555	0.577	0.680	0.611	0.724	0.736
Full collin. VIF	4.126	3.785	2.260	3.430	3.056	4.755	3.130	8.528
Q-squared		0.662		0.401	0.500	0.565	0.680	0.811

(b) Quicker restoration of electricity after power disturbances (distribution automation).
(c) Reduced operations and management costs, and lower power costs for consumers.
(d) Reduced peak demand, which will also help lower electricity rates (demand response).
(e) Increased integration of large-scale renewable energy systems (distribution networks).

Table 18
Hypotheses results.

Result	Path coefficient	Square root of AVE
Supported	0.496	0.687
Supported	0.459	0.674
Supported	0.493	0.595
Not Supported	−0.201	0.397
Supported	0.706	0.677
Supported	0.744	0.737
Supported	0.531	0.779
Supported	0.471	0.769
Supported	0.825	0.768

(f) Better integration of customer-owner power generation systems (distribution generation).
(g) Improved security (cyber security).

6. Conclusions

Artificial intelligence algorithmic decision choices are not mechanically equitable just by virtue of being the products of complex processes. Moreover, the procedural consistency of algorithms is not equivalent to objectivity. Hopefully, by implementing the Throughput Model to the algorithmic pathways of decision choices may provide researchers and practitioners more clarity regarding Smart Grids. While human decision-making is also rife with comparable biases that AI algorithms might display, the accountability issue is strengthened when employing a model such as the Throughput Model.

In sum, Smart Grids typically denotes a class of technology that individuals implement to bring utility electricity delivery systems into the 21st century, using ICT for a greener environment. These systems are made possible by two-way communication technology and computer processing that has been utilized for decades in other industries. They are starting to be employed on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. In essence, they provide various benefits to utilities and consumers. Finally, they are mostly observed in large improvements in energy efficiency on the electricity grid and in the energy consumers' homes and offices.

We have identified ICT competencies in knowledge transfer and examined their indirect effects, via knowledge received, on experts' planning moderated by an artificial intelligence algorithmic decision-making process of perceptions (planning) and judgments (doing, checking/acting). Theoretically, we suggest that ICT can be implemented more effectively as a knowledge transfer mechanism when certain conditions are met. Empirically, we have found that ICT apparatus must have the capabilities to transfer knowledge and experts must have the capacity to absorb such knowledge. In conclusion, when implementing systems with efficient energy capability and green environment structures, individuals and stakeholders should go beyond the focus on technical features and consider competencies in knowledge transfer. Individuals and stakeholders should consider developing Smart Grids capacity with green environment structures at the same time.

CRediT authorship contribution statement

Waymond Rodgers: Conceptualization, Writing, Reviewing and Editing, Methodology, Visualization.

Jesus A. Cardenas: Conceptualization, Writing- Original draft preparation, Visualization, Methodology, Data curation, Formal analysis.

Leopoldo A. Gemoets: Conceptualization, Visualization, Investigation.

Robert J. Sarfi:: Methodology, Investigation, Visualization.

Data availability

Data will be made available on request.

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