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Designing a Socio-Technical System for Groundwater Resources Management, Applying Smart Energy and Water Meter

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Abstract**—**World, nowadays, encounters serious water scarcity problem. During the past few years, by advent of Smart Energy and Water Meter (SEWM) and its installation at the electro-pumps of the water wells, one had believed that it could be the golden key to address the groundwater resources over-pumping issue. In fact, implementation of these Smart Meters managed to control the water table drawdown for short; but it was not a sustainable approach. SEWM has been considered as law enforcement facility at first; however, for solving a complex socioeconomic problem like shared groundwater resources management, more than just enforcement is required: participation to conserve common resources. The well owners or farmers, as water consumers, are the main and direct stakeholders of this system and other stakeholders could be government sectors, investors, technology providers, privet sectors or ordinary people. Designing a socio-technical system not only defines the role of each stakeholder but also can lubricate the communication to reach the system goals while benefits of each are considered and provided. Farmers, as the key participators for solving groundwater problem, do not trust governments but they would trust a fair system in which responsibilities, privileges and benefits are clear. Technology could help this system remained impartial and productive. Social aspects provide rules, regulations, social objects and etc. for the system and help it to be more human-centered. As the design methodology, Design Thinking provides probable solutions for the challenging problems and ongoing conflicts; it could enlighten the way in which the final system could be designed. Using Human Centered Design approach of IDEO helps to keep farmers in the center of the solution and provides a vision by which stakeholders' requirements and needs are addressed effectively. Farmers would be considered to trust the system and participate in their groundwater resources management if they find the rules and tools of the system fair and effective. Besides, implementation of the socio-technical system could change farmers' behavior in order that they concern more about their valuable shared water resources as well as their farm profit. This socio-technical system contains nine main subsystems: 1) Measurement and Monitoring system, 2) Legislation and Governmental system, 3) Information Sharing system, 4) Knowledge based NGOs, 5) Integrated Farm Management system (using IoT), 6) Water Market and Water Banking system, 7) Gamification, 8) Agribusiness ecosystem, 9) Investment system.

Keywords**—**Design Thinking, Human Centered Design, participatory management, Smart Energy and Water Meter (SEWM), socio-technical system, water table drawdown, Internet of Things, Gamification

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I. Introduction

DROUGHT and shortage of water resources has been a major issue in many parts of the world. Just ahead of Davos gathering, the World Economic Forum (WEF) published its tenth annual Global Risk Report for 2015 [1], which includes a yearly probe on the globes most acute problems from about 900 heads of states in business, politics and economics. World economic forum portrays this global threat as: an unsteady phenomenon that, if it takes place, major negative effects may follow within the period of 10 years in numerous countries [2]. Accordingly, in 11th Global Risk Report of World Economic Forum in 2016 [3], although the water crisis issue was not place at the top of the list in terms of impact, it still places the third.

According to WWAP record, around 20% of total consumed water worldwide is from groundwater resources, and this split is growing up rapidly, particularly in dry areas [4]. The Middle East and North Africa (MENA) is a region with the scarcest water resources in the world. To get a better picture of the water problem, considering this region can help anyone to get a better understanding of the complexity of the situation that includes different aspects and to give way to a more promising solution. As shown by the World Bank, of all the water resources in MENA region is being used for means of agriculture thus limiting the availability of water resources to be used for other means, most importantly of which drinking water. Groundwater resources can be exploited by anyone who has the ability to dig a well, and this is being done in such excessive manner that these resources are way lower than their yield levels that can be considered safe [5].

To tackle the water scarcity in the MENA region, as the most stressed region regarding the water scarcity, it is important to understand that agriculture has the highest potential to reduce overexploitation. The greatest portion of groundwater in the region is being spent on agriculture. Approaching domestic or industry usage in order to alleviate the problem would require millions of users who are already under heavy pressure to take action to reduce their water usage. Comparing that to the lower number of agricultural users (farmers) who use the greater proportion, the decision to monitor them seems inevitable. As the water fees for domestic and industry are billed at higher tariffs, more investment has been done to improve the management of water in cities and industries. However, poor groundwater management by governmental institutions and a general disrespect and disregard by farmers for groundwater legislation and regulations have resulted in an excessive overexploitation across the entire MENA region [6].

In the past, regulation was assured by local communities themselves and the limitations of previous exploitation methods meant that the resources were essentially renewable. However, the introduction of modern pumping and irrigation methods, the disruption of traditional society, and the failure of government administration to step into the gap in regulation, have led to the present situation of overexploitation across the region.

The other factor that has worsened the situation is that the trust among the stakeholders is broken. On one hand, governments accuse farmers of a huge waste of groundwater; on the other hand, farmers believe that their governments are not competent enough to secure their access to water. Farmers believe that, in saving water, the first priority of governments is to provide more resources to cities and industries as they pay higher tariffs — by saving water the governments will make more money. With that in mind, it is not easy to convince a farmer to reduce his water withdrawal in order to secure the sustainability of water for his neighbors because there is no mechanism to guarantee that his neighbors will do the same for him.

In most countries across the MENA region, illegal wells and over-exploitation have been addressed in regional laws; pricing water and energy at higher tariffs, closing illegal wells, placing fines, limiting farmers' access to water, and other managerial instruments have been considered for authorities to put pressure on wrongdoers. Without producing and monitoring vivid abstraction data and building the capacity to use these instruments, it will be very hard to bring farmers to table and oblige them to change their consumption patterns. The region has a long history of mistrust between people and the government and among people themselves; technology can help to repair this trust — even if they cannot trust each other, they can trust impartial data. Data transparency can help people supervise each other and monitor the system to ensure that all parties are respecting the terms of a collaborative agreement [6]. In this way, it is expected that this participation, could unlock the collaboration potential among all the stakeholders to consume and conserve groundwater resources sustainably.

Technically speaking, various types of measurement and monitoring systems have been implemented by far, to control groundwater resources. Among all these system and measurement technologies, a new class of water meter called Smart Energy Water Meter (SEWM) is a cutting-edge electronic device with advanced processing features. It measures the electrical consumption of an electro-pump and accurately calculates its output water flow. It is a water meter that is not in direct contact with water; so, sand, stone, salt or other suspended particles in the water do not damage or affect its operation or accuracy. This device is an energy meter, plus a water meter, plus a smart controller all integrated in one single package. Because the electricity of the pump is passed through the SEWM, the meter can turn the pump ON or OFF. Using a modem, SEWM is in direct communication with a control center to send energy and water consumption data and receive commands. For regions where there is no coverage for mobile networks, smart cards or hand held units (such as Pocket PCs) can be used as a median to transfer data and commands between the meters and the control center. Various security features have been embedded in the design of SEWM. Any unauthorized access to the meter will be detected, logged and reported to the authorities instantly. The meter can be set to stop the pump if it is being tampered with so that the wrongdoer will be faced with the consequences of his irresponsible acts immediately [6]. According to the aforementioned points, SEWM could be considered as a "smart, connected product" in the literature of Internet of Things, as Michel E. Porter mentioned in his HBR paper [7].

Smart Energy and Water Meter (SEWM), in the form of a monitoring or controlling system, which was mentioned above, has been installed in various countries in the region like Oman, Jordan, Pakistan, China, and mainly all across Iran. Groundwater scarcity problem is totally related to the social aspects -especially those for the agriculture sector. The aforementioned technological system for groundwater resources management, considered as a network of "smart, connected products" including SEWM, had a great potential to provide the technical infrastructure(s) for the final solution; however, the social and human aspects of this complex problem will not address effectively. Hence, this technological facility by itself would not be the answer for the groundwater resources management problem; at least, it is not the complete one. Law enforcement by some controlling or enforcing policies was not a sustainable approach, too. In fact, implementation of SEWM as the tool for law enforcement in practice has suffered from lack of social and economic aspects and some historical roots. It requires to put together different needs of various stakeholders, including farmers, and design a novel mechanism in which all stakeholders are encouraged to participate in groundwater resources management and to stop water resources uncontrolled consumption; this would be a design of a "socio-technical system".

This paper aims to develop the concept of participatory management for groundwater resources through designing a giant socio-technical system in which the correlation between technological breakthroughs, like SEWM or other "smart, connected products", and social concerns is observed. Management of groundwater goes beyond just looking after the water; it related to the farm management system, agriculture issues, agriculture economy and businesses, law and regulations establishment, and etc. These all are to be considered to pave the path to consume groundwater resources sustainably and manage it with farmers', let's say the real owners', engagement. This paper is talking about the appropriate designed socio-technical system and its sub-systems generally; however, some of the technical or social ingredients are noticed to clarify the way the system operates.

In this paper, the concept and features of a socio-technical system and its differentiation from other systems or technical products are discussed [8]. Then, complexities and places to intervene a system, called: "leverage points", are explained and some useful leverage points for the groundwater resources socio-technical system are examined [9]. To show the breakthrough related technologies and to place SEWM in its suitable context, the Internet of Things concept is briefly reviewed [7]. Social aspects, people's behavior and the cultural roots of Iranian, as a case, are implicitly considered [10]. Meanwhile, some evidence is brought from governing the commons theory [11] to support the social behaviors of the society. Design Thinking approach and Human-Centered-Design method of IDEO [12] was applied in the design process to find out the users' essential needs and requirements, approach the problem and extract the proper solution based on the local observation. Moreover, the system benefits from Gamification rules and principles at the implementation phase [13]; hence, they are described briefly. Taking into account all the aforementioned consideration, the socio-technical system is designed and the relations among sub-systems and ingredients are defined separately, based on the quality of the relation. The results are shown in the form of schematic diagrams.

II. Materials

A. Socio-Technical System

Technical artifacts such as airplanes, scooters, computers and screw drivers differ from both physical objects and social objects in that they consist something of both. Technical artifacts are tangible objects with physical properties, but they are also objects with a function, which they have the quality or advantage of their embeddedness in use plans aimed at the achievement of human purposes. Looking at technology as just a 'collection' of technical artifacts would be an enormous oversimplification [8].

1. Introducing Hybrid Systems

Pieter Vermaas and his friends in their book- A Philosophy of Technology- explained the concept of socio-technical system through an example [8]. Imagine that you are in an airport and want to travel to a faraway destination. You will probably be using a lot of objects such trolleys and other things in cafes and departure lounges. A few of these objects will be quite simply designed by one person, others however would probably be the work of teams and engineers who have spent a very long time to design them. As an example, think of the computerized check-in system or the plane itself you would be flying in. However, alongside all these separate things something much more encompassing will be made use of, invented, developed and maintained by human hands as the very typical artifacts just mentioned, but at the same time, it is much more abstract and difficult to work out. That 'thing' is the world civil aviation system.

The parts that where mentioned beforehand were just a fraction of the things that make up a much larger system. Some of these parts are stationary such as the buildings in which the passengers have to go through certain procedures such as going through passport control. It's notable that there are various people involved in the airport as well such as the cabin and crew and other components that are abstract in nature such as the air corridors. All of these are very different in nature. Also, treaties between countries that make flying one country to another possible, and there are also companies that are involved in inuring these systems. So, the simple act of traveling from one place to another is much more complex than just buying tickets or sitting in a plane. This world civil aviation system is an example of a socio-technical system.

Exactly like this example, if we consider the whole agriculture value chain as a system, its target is to plant crops, fertilize them - includes watering them, harvest them and deliver them to the customers (people). Simple tools or handicrafts like shovel, or scarecrow, are artifacts; electro-pumps by which groundwater is exploited, meters, tractors, power panels, packaging boxes and etc. are incredibly complicated, designed by whole teams of engineers who will probably have worked on them for years; it is possible to compare the role or position of airplanes with some agriculture advanced machineries like planters, fertilizers, various kinds of harvesters, or irrigation systems. Moreover, organizations and authorities like water, electrical and agriculture authorities or law and regulations for consuming water, planting the right and appropriate crops, or electricity tariffs, water quota, license of a well, and etc. are some of the abstract components of this socio-technical system.

Every system as an entity includes separated parts which are at the same time linked to each other in a specific way. The aviation system and integrated agriculture system are examples of special sort of systems with different kinds of components that are of different natures; components which no natural science can include them in any sort of system, because some of these components are of abstract nature, such as condition and rules, whilst others are not.

The people who work in these systems have the ability to understand instructions and put them into practice; they also understand the importance and purposes of these instructions. Rules and regulations and institutions and organizations that are a part of aviation system assume for all people who are involved the status of persons. Rules can be obeyed by humans or disobeyed. Organizations and institutions are made and kept afloat by people. The way people do things is stemmed from their knowledge of psychology and sociology. And it is safe to say that it is a hybrid system because none of the natural sciences has the capability to describe the aforementioned matter. Hybrid systems have some components which can only be explained using natural sciences and other components that need social sciences to be described with are called socio-technical systems.

Socio-technical systems are very complex technical artifacts that have the dual nature of a technical artifact, meaning that while having their specific function also a human use plans as non-physical features.

2. Roles of People in System: User and Operator

What is special about socio-technical systems is that, first a lot of people are using them, and second people have the role of users and operators of these systems at the same time.

All socio-technical systems involve people fulfilling these two roles. Because it would nearly impossible to make systems that are only made of hardware devices and would work properly. The only way these systems will function is their hardware to be in line and functioning together with their users' behavior and moreover the coordination of its many other users. For this coordination to be successful we need laws and rules and agreements, specifically stemming from social sciences and not natural sciences [8]. In groundwater resources management case, we face different types of many users – call them farmers or well owners- with different taste, background knowledge, demands, needs and characteristics who not only play a role of users, but also stand as the operator of the system in some way. This makes groundwater management socio-technical system more complicated.

3. Technology Has A Great Impact on Society

Every invention that is made is not just a new object but rather a new way acting function. Every single socio-technical system that has been made dictates a new human action in short, they add some novel acting functions and some substitute given human function. In other words, every invention is an act of intervention and that is exactly why technical development amounts to social change. [14].

4. Mechanisms for Rules and Harmony

If anyone wants to make people do anything it has to be through instructions and rules and not through signals and casual encouragement. A rule is a directive or norm that aims deeply to change a behavioral pattern, regardless of whether that pattern actually occurs. A rule can be obeyed or ignored depending on the circumstances or time. If a rule is not followed in a particular case, this means that it is apparently not in optimal points of everyone's best interests to behave according to what rule says [8].

The particular characteristic of a rule is the ability to impose sanctions relating to the breaking of the rule. The nature of rules dictates that it needs to be implemented in a group because a person cannot enforce sanctions on his own, and it also, naturally, dictates that there should sanctions for people in a group if they do not adhere to these rules.

For a socio-technical system to work, then we need to think of and make and impose rules for coordination to happen. As a result, these systems have the complexity that technical systems lack. An operator's role is thus determined by a set of rules and instructions that dictate what needs to be done in a particular situation by the operator. These instructions include use plans for components that are controlled by the operators. Moreover, these use plans then tell the users how they should use these components so that they would keep functioning for others.

With this information, people who are in charge of the implementation and the maintenance of these systems face two problems that can be approached from two angles. Firstly, the problem of establishing the system boundaries and the extent of it, secondly the problem of the predictability of the system and how much can it be controlled. When it comes to designing systems, the major question is not the boundaries that need to be drawn but the place which the system would be taking in real life.

5. Design of System and Controllability

The traditional engineering approach to design has a problem with socio-technical systems by namely loss of predictability and control. The thorough social system within which every socio-technical system functions as a component is in a state of continues change. If we imagine that a specific socio-technical system that involves a lot of people such as the world civil aviation is made in a single effort, it would still be unimaginable to think of the scope within which that system would operate precisely. This problem can only be addressed with difficulty by broadening the meaning of design and expanding the borders of the system by including the institutional context.

International and national regulations and legislations in their institutional context have been made and function in a completely different way from technical artifacts. This is totally inevitable because society cannot be put away to make way for new design, designing happens within the context of society. As a metaphor introduced by Otto Neurath, society is like a ship that needs to be maintained and repaired while being sailed in high seas and kept afloat at the same time.

Socio-technical systems have inevitable developing properties, properties that come the properties of the components and how the system is built but which are not foreseeable, for the very reason that if we want to foresee them we need to have access to knowledge that is inapproachable, or if approachable, cannot be approached in the time available.

Considering all, socio-technical systems, because of their lack of predictability compared to traditional technical artifacts, they can show unforeseeable behavior even in situations where the end user uses them tidily. Even though the mere thought of a use plan for such systems is problematic, for the reason that they are made and designed on a board, it is instinctively clear that there are ways in which we could benefit from them.

B. Leverage Points in a System

People who are system analysts have a great belief in "leverage points." These are places within a complex system where a little modification in one thing can produce big changes in everything [9]. Studying these leverage points is helpful to know where the most effective places are in the groundwater resources management system to intervene.

Places to intervene in a system, as Meadows classified them in increasing order of effectiveness:

- The parameters and invariants; such as taxes, subsidies, etc. and their impact(s) on the tariffs of water.
- The relation of the amount of something as a buffer; such as the quantity of water in an aquifer to its flows.
- The composition of material; such as groundwater transmission network among the farmers.
- The delays related to the changes in a system; such as the

time needed to give a feedback by a society.

- The power of negative feedback cycles to solve the problems; such as water table drawdown in result of over-extraction
- The profits of positive feedback cycles; such as allocating less amount of water to the same unit area with the same crop yield level by using modern irrigation technology; which results in expanding cultivation area excessively
- The information architecture related to its flow and sharing rules; such as access to water extraction info.
- The system rules; such as punishments, constraints, etc.
- The capability of self-organizing system structure.
- The system goals; such as for what groundwater system was designed and what achievement will be demanded.
- The paradigm out of goals, structure, rules and parameters of system.
- The force and intention to surpass paradigm.

Taking into account all of the twelve points mentioned in the list, for improving groundwater resources management system or agriculture value chain, one should take advantages of all. However, in this paper the study is confined to only some more important of them including numbers 6 to 2 in the list in increasing order of effectiveness.

1.No.6: The Information Architecture, Its Flow and Sharing Rules

Most of the time, missing feedback in a system, causes malfunction. Moreover, adding information as an influential intervention can be much easier than reconstructing physical structure. The concept of "tragedy of the commons" is helpful here to analyze the problem. For example, when the users of an aquifer are only informed about the groundwater table dropdown, it seems it would be enough to work; but it is not. The tragic race to depletion will be started. Nevertheless, it would be more effective to set a rising water price or taxes that increases as over-pumping begins [9].

It is very important to define what kind of information should deliver to whom and when. This is the heart of the design concept through which information transparency among stakeholders in groundwater resources management system, including farmers, is directed in a right way. The information flow of the socio-technical system is shown in Fig. 3.

2. The Essence of Tragedy of the Commons

"The tragedy of the commons" is an expression that has come into use since Garrett Hardin published his article in 1968 for representing the degeneration of the environment when its scarce resources are being exploited by many individuals together. To depict his model, he asks to imagine a pasture that is available for all. He then looks at the situation from the perspective of a rational herder. Every herder benefits from their own animals and sustains delayed costs from others deterioration at the time which his or others' cattle overgraze [15] – exactly like the situation between farmers and over-extraction of an aquifer. Each farmer is motivated to exploit more water because he receives the direct benefit of his own farm and bears only a share of the costs in consequence of over-exploitation. Hardin concludes:

> "There in is the tragedy. Each man is locked into a system that compels him to increase his herd without limit -in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons." [11].

In groundwater resources the same tragedy happens. Farmers tend to consume water of a reservoir freely and without any limit in order to expand their cultivation land as much as they could to increase their profit level.

There seems to be some shred of truth in this conservative saying that everybody's property is nobody's property. Something that is free for all tends to be valued by none, because somebody who doesn't care enough and waits his turn to claim something will find that that something is taken by others. As in the metaphor of a fisherman who doesn't value the fish in the sea solely because there is no guarantee that the fish that are left behind would be there for him tomorrow, Gordon believes [11]. The same occurs in exploitation of groundwater resources, especially in a water year.

Analysis in modern economics show that wherever there is a common resource people sharing that resource will withdraw more than that it is optimal economically [16].

Based on the tragedy of commons, the prisoner's dilemma and the logic behind collective action which are interconnected concepts we can view and explain many problems of individuals in achieving collective benefits. At the most important part of these concepts there is the free-rider concept that argues that any contribution of single individuals is in turn for the benefit of the collective benefits. If a person cannot be left out from the common advantages, each person tends to have his/her benefits without making any effort or contribution. If all the engaged people do the same, there would be no collective advantages at all [15]. These models are of important when it comes to groundwater common resources which are shared among many farmers. When the aim of the management system is to set limits or incentives to conserve water resources, behavior of an individual is as essential to be considered as the behavior of the farmers' society.

A similar view related to the hardships of getting individuals to follow their benefits collectively, in contrast to pursuing their benefits individually, was generated by Mancur Olson (1965) in The Logic of Collective Action [17]. Olson especially challenged the optimism that surrounded the group theory: individuals in a group with common interests would willingly take action to help develop those interests. On the first page of his book, he summarized that common view:

If the members of a group have common interests and if they all benefited from that goal being achieved, then it is logically believed that they would all work together so that that goal is achieved. That is of course if that they are all rational and self-interested [17].

Olson made the presumption that, the mere probability of generating collective action based on solely benefit of the group, seem uncertain and insufficient. His argument was on the foundation that somebody who cannot be put away from getting the merits of a collective good when that good is made will most likely not be willing to act voluntarily in the process of making that good produced.

3. No.5: The System Rules

The scope, the boundaries and the degree of freedom of a system are expressed by the rules of that system. Contracts need to be fulfilled once agreed upon. The red card in football match means that the player should stay out of the game.

One of most powerful social rules is the constitutions. To explain more explicit, there are absolute rules, like physical laws, which are no matter we understand them or not or communicate with them or not; they work inherently. However, all types of punishments, laws, social agreements which are being made by human in a society and improving through the time are weaker rules.

They are leverage points. Real power is power that casts shadow over rules. If you want to understand the flaws of a system you need to pay close attention to the rules, and more powerful position whose power over shadows them [9].

Many countries in the MENA region, like Iran, Oman, Iraq, Jordan, Lebanon, Egypt, Algeria and etc, have their bylaw about groundwater consumption or share among all the stakeholders. However, some of the bylaws in the region are required to be revised based on the new conditions. Many of them are just written laws and there is not any practical measure to implement the rules or to adopt it to the real life of the people. Sometimes, conservative politicians prefer to neglect challenging parts of the law in which some uncontrolled social conditions may arise.

Based on the rules of the groundwater resources management system, various incentives, outreaches or constraint could be set. According to the history of dissatisfactions among the farmers when the authorities try to enforce the law through punishment actions, it is clear that in this way farmers' behavior, as the groundwater consumers, will not change in a right way. In this new era of communication, we require to hire modern and developed approaches to settle the rules of a system. We take advantages of Gamification rules and theory to implement rules of the groundwater resources management system. It should not be neglected that concept behind the tragedy of the common, is helpful here, too.

4. Gamification

In his recently published white paper Pete Jenkins evaluated the science involved in driving engagement and how marketers can influence insight, gamification, proximity marketing and social media to make outstanding engagement and influence the way someone would behave [13].

Pete has summarized gamified marketing to just 6 critical strategies, and he explained the 6 C's of gamified marketing and the practical steps to gain the highest levels of customer engagement and participation 6C Framework [18]:

1) *Captivate:* With a story, epic or legend and powerful long-term goals, with numerous short-term activities that move in the direction on that;
2) *Challenge*: Users, to learns new things, study new skills and master them, give feedback and reward success;
3) *Cherish*: By finding out more about the customers via tests and competitions, deploy the subsequent data to increase relevance of communications software;
4) *Connect:* The customers with each other and help them make stronger ties to rise to challenges /get rewards;
5) *Create:* An atmosphere for people to generate and develop their own content and rewards;
6) *Champion*: The most engaged users or customers, open opportunities for them. Give them power to do the more of marketing.

These six steps, could interpret in groundwater resources socio-technical system's lingo as well. Through fair Gamification rules and plan, regulation and rules of system could be implemented by encouraged stakeholders themselves, including farmers.

5. No.4: The Capability of Self-Organizing System Structure

The force of self-organizing a system is also called technical advance or social revolution in human economies. It's the strongest form and ability of a system to organize, evolve and improve itself facing of any change.

There are the good examples in the nature that show the capability of many natural systems to be self-organized according to the intelligent rules implemented in them. These rules define how, where and what a system can change or add or subtract from itself under which circumstances. Self-organizing puts a system into an evolutionary development state; it's a tool for experimentation, choosing and evaluating new patterns.

The fact is that, although this leverage point is clearly effective, it is not well-liked. It may consider as a cause of "losing control' if diversity, experimentation and freely change are encouraged. Accountable people prefer to keep it safe and push this leverage point in the wrong direction by removing biological, cultural, social, and market diversity [9].

In socio-technical groundwater resources management system, through engagement of farmers or other stakeholders in the system, they will participate in management of their common resources by optimizing their common interests. This engagement cycle and participatory management may lead to the state of self-organization. Moreover, the role of Gamification in this regard is inevitable.

6. No.3: The System Goals.

Even people within systems aren't often aware of what whole-system goal they are working for. Donella Meadows mentioned that replacing the players in the system is a low-level intervention, as long as the players fit into the same old system. There is an exception; a single player at the top can have the power or ability to change the system's goal [9].

What is the key goal of groundwater resources socio-technical system? Is it to conserve groundwater resources or to facilitate the agriculture value chain among the farmers? Replying to these kind of deep questions, helps one to set the right goal for the socio-technical system and share it among the players. According to the previously experienced approach toward groundwater resources management, it is clear that to absorb farmers' participation in water conservation; we have to pay attention of their profit or benefits out of agricultural activities. Each of these two interrelates with the other. Neglecting farmers' profit out of harvesting agri-product – which is a consequence of consuming the water- cause a malfunction in any groundwater resources management system which aims to control water consumption.

7. No.2: The Paradigm Out of Goals, Structure, Rules and Parameters of System

The common idea or notion in the minds of society, the great big unstated assumptions— unstated because it is clear to everyone – include society's general attitude and paradigm about how the world works. The sources of systems are paradigms.

Although paradigms are harder to change than anything else about a system, there doesn't seem to be anything expensive, slow or even physical in the process involved in paradigm change. It can happen in a millisecond in a single individual. All it requires is a trigger in the mind, putting the previous aside, a new and bright perspective. Whole societies are different —they don't like their paradigms changed at any cost. [9].

In short, if one is into changing paradigms, the anomalies and failures in the old paradigm should be continuously pointed at, loudly and with confidence from the new one, people should be inserted with the new outlook in places of public visibility and power. Have to forget reactionaries; rather to work with active change agents and with the vast middle ground of people who are open-minded and unbiased [9].

Training and awareness plan for all the stakeholder – including legislation parties, authorities, managers and experts, various systems staff, farmers, workers, land owners, and etc. could shift the paradigm or mindset to the better posing in which the sustainability of groundwater resources is as of a vivid concern. NGOs or some social activists are playing a significant role in this action; as the model in Fig. 7 illustrates.

The aforementioned four leverage points could be the most effective places to intervene groundwater resources management socio-technical system. It does not mean that the other leverage points are not useful or of a less important, but it seems that the impact of these four mentioned one is higher and more accessible than those.

III. Methods and Methodology

Every design project must ultimately go through three spaces. Tim Brown, the CEO of the "innovation and design" firm IDEO, named and described these "inspiration," for the condition and situation (if they are an opportunity, a problem, or both) that trigger the search for solution; "ideation," for the procedure of generating, developing and testing ideas that might result in solutions; and "implementation," for putting it to the practice and a real ecosystem[19]. Projects will loop back through these spaces –particularly the first two – more than once as ideas are refined and new directions taken.

In this paper, we benefit from taking Design Thinking approach in which by the power of empathy, designers can imagine the world from multiple perspectives – those of stakeholders like colleagues, clients, end users, and customers (current and prospective). By taking a "people first" approach, designers can think of solutions that are desirable by itself own and meet explicit or dormant needs [19].

As a tool, Human-Centered- Design Toolkit of IDEO [12] and The Field Guide to Human-Centered Design [20], which are practical ways of implementing Design Thinking approach, are applied. Based on the approach and the tools, researches and field studies about the challenges of groundwater resources management, have been conducted. The field studies have been enriched by several years of experiences in some MENA countries and regions where water issue is in the highest priority; like Iran, Jordan, Oman, Iraq, Pakistan, Algeria and etc. Traveling through the region and negotiation with the top responsible persons in charge, gave us the overview of the common root and reasons behind the groundwater conservation problems. Besides, traveling to the field directly and shadowing farmers -traditional or up-to-date-, well owners, and ordinary people who consume groundwater resources, help us to understand their needs and empathize with them. From this interviews and visits, some of the design factors have been extracted.

To illustrate the whole groundwater resources management socio-technical system and its component, and schematic prototype diagram was designed. By this illustration, the discussion between us and various experts were started: technical, academic, on- the-field and etc. experts. We took advantages of prototyping to learn from our audience and correct our ideas.

Farm, as an entity of the system, plays a significant role in groundwater resources management socio-technical system. It is necessary that farm management integrates to its interconnected supporting systems like irrigation, seed optimization, farm equipment and etc. Productivity on the farm is strongly affected farmers' behavior toward the whole system. Thus, we take advantages of Internet of Things concept and especially Michel E. Porter's paper in HBR [7].

A. Internet of Things

When it come to the smart systems and internet of things, we can't help talking about Smart, connected products which have three core elements: *physical components*, *"smart" components*, and *connectivity components*. Smart components augment the capabilities and value of the physical components, while connectivity augments the capabilities and value of the smart components and let some of them join to the physical product while they are not with it. It leads to a virtuous cycle of effectiveness and value improvement [7].

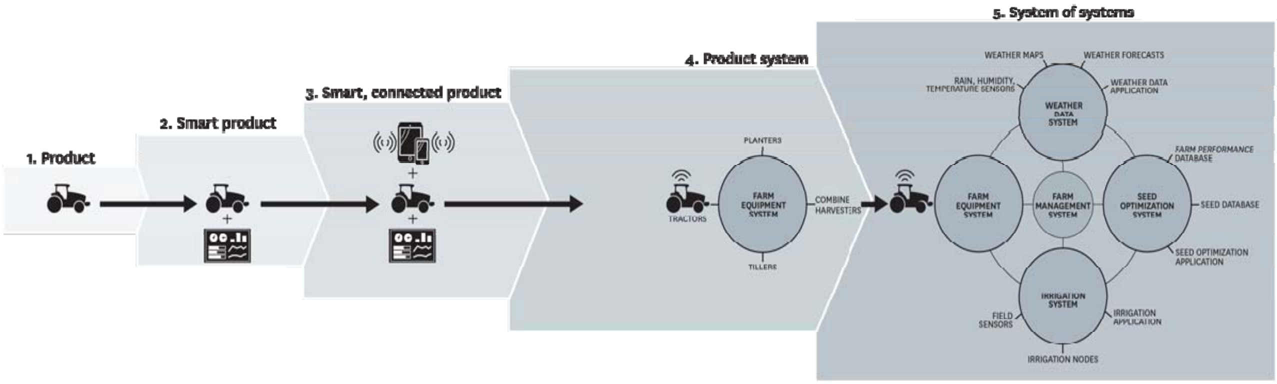

Fig. 1 Smart, connected product; Internet of Things [7]

Physical components consist of the product's mechanical and electrical parts. In groundwater management system, for example, these include the electricity panel, pipes, shovels.

Smart components consist of the sensors, microprocessors, data storage, controls, software, and, usually, an inbuilt operating system and improved user interface. In our system, for example, these include Smart Energy and Water Meters, moisture sensors and etc.

Connectivity components consist of the ports, antennae, and protocols enabling wired or wireless connections with the product. Connectivity takes three forms, which can be present together: One-to-one, One-to-many, Many-to-many. In the groundwater system, for example, a modem could connect SEWM to the control center through a telecommunication network and could support all three forms.

Intelligence and connectivity provide a completely new set of product functions and capabilities, which can be set in four categories: *monitoring*, *control*, *optimization*, and *autonomy*. Each capability is of value because of its own special qualities and makes the next level possible. [7].

The increasing capabilities of smart, connected products expand industry boundaries. This makes the situation shift from discrete products, to product systems consisting of closely related products, to systems of systems that link an impressive group of product systems together.

The state of *system of systems* (step 5 mentioned in the Fig. 1) is a basic idea of creating an integrated farm management smart system just as a sub-system of groundwater resources management socio-technical system. The examination could be found in the results section.

IV. Results

Through inspiration phase of Design Thinking process and shadowing different parties regarding the problem, following factors or requirements are extracted. However, these are some of the most common and important ones. Users' requirements or design factors:

1) Farmers, especially who work traditionally, cannot communicate with smart products like Smart Meters
2) They need to clear reliable information about the groundwater reservoirs or consumption,
3) They tend to improve themselves and learn about the whole system and environment (paradigm could change).
4) They need supporting rules or conditions (financial, legislative and etc.) to improve their agricultural activities contain crop management, irrigation systems, integrated farm management and etc.
5) They cannot help consuming water for irrigation in the growing seasons. There has been always a challenge between authority and farmers' community regarding the resources management. Punishment, fine or penalty, enforcement and etc. were not stopped farmers from exploiting the water they need. They did not address the goal of the system.
6) They do not trust to the government to save their own groundwater resources. (some historical evidence is existed)
7) The system, as a socio-technical system, does not have somebody or some unit as an accountable who would be in charge of system operation. (inconsistency)
8) Farmers are looking for a fair solution in which all of the consumers obey the same rules and conditions.

A schematic prototype diagram was designed to illustrate the whole groundwater resources management socio-technical system and its component and to communicate to stakeholders. As it is shown in Fig. 2, it contains nine sub-systems each of them has its own component.

The nine main subsystems which build the whole socio-technical system:

1) Groundwater Measurement and Monitoring system,
2) Legislation and Governmental system,
3) Information Sharing system,
4) Knowledge based NGOs,
5) Integrated Farm Management system (using IoT),
6) Water Market and Water Banking system,
7) Gamification.
8) Agribusiness ecosystem,
9) Investment system,

Besides, the relations between the entities in the socio-technical system are complicated; hence, they were divided into separate conceptual layers of relations based on their diversity and correlation. The five layers of relations are listed as following, which are shown in Figs. 3-8.

1) Information flow,
2) Rules, regulations, instructions and etc. flow,
3) Technology flow,
4) Money and finances flow,
5) Knowledge-based Support flow,

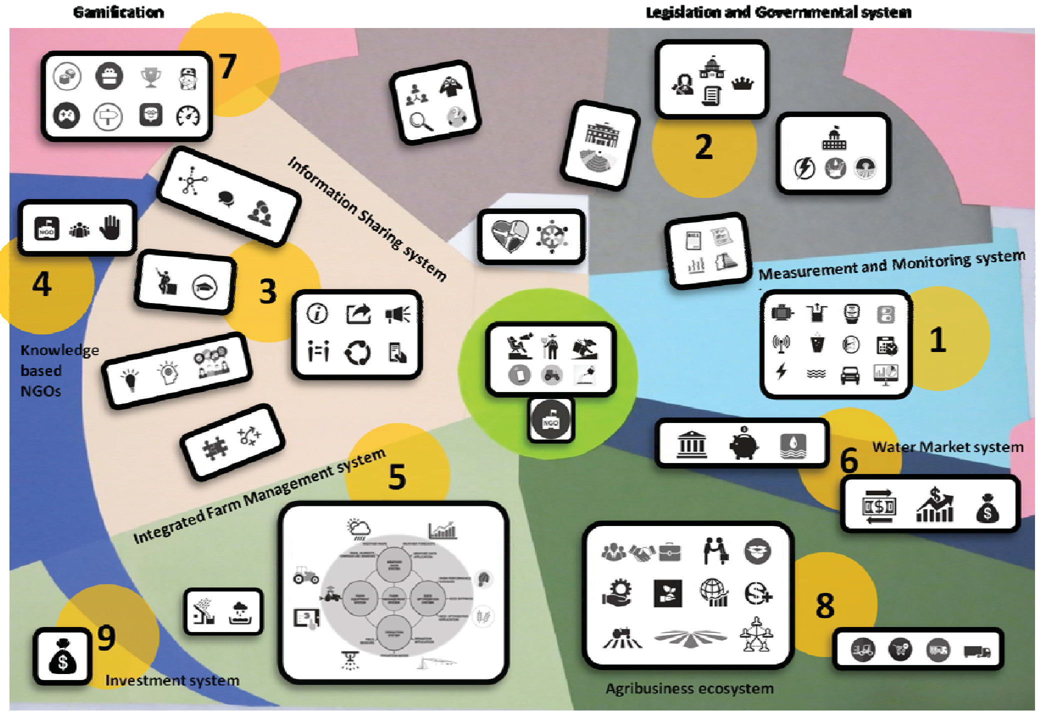

Fig. 2 Socio-technical system model

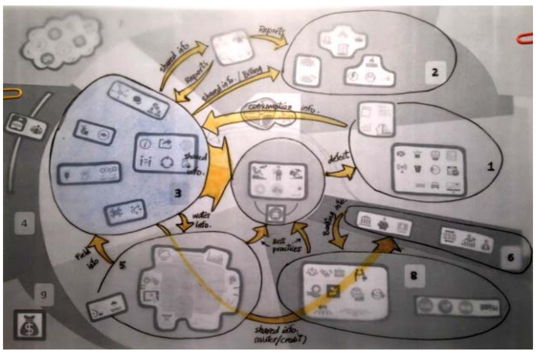

Fig. 3 Information flow

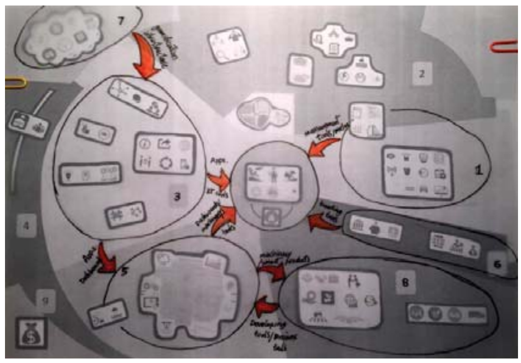

Fig. 5 Technology flow

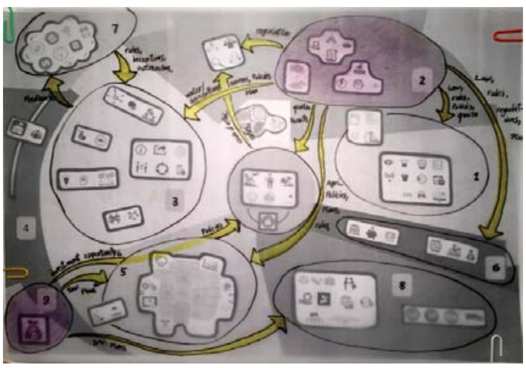

Fig. 4 Rules, regulations, instructions etc. flow

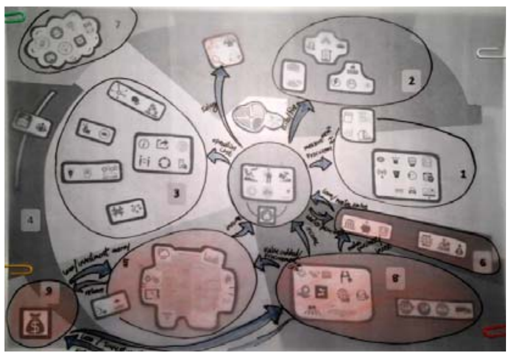

Fig. 6 Money and finances flow

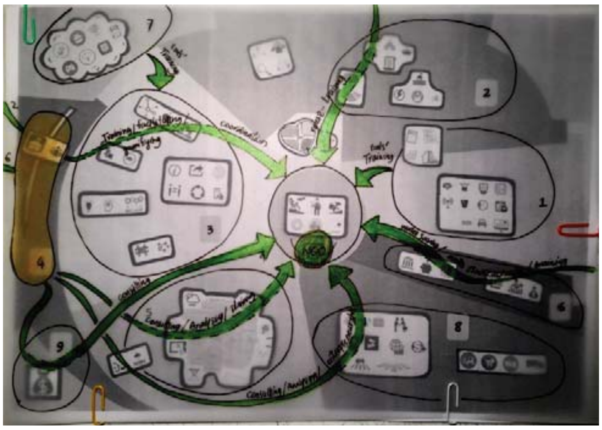

Fig. 7 Knowledge-based Support flow

V. Discussion

Groundwater resources management is a complicated and vast issue these days. It connects to many different divisions. Technical solutions or systems by themselves were not the answer; it needs to practically consider social aspects of the issue. This led us to perceive the groundwater resources management system as a socio-technical system. Design Thinking steps could guarantee that the final designed system will map its stakeholders' needs and requirements in a more sustainable way. However, we designed just the initial model of this socio-technical system; designing a giant complicated socio-technical system is just at the beginning. More precise and applicable ideas could be developed through implementation and testing phase. Like any of running socio-technical system, it will be evolved over the time.

The model needs to be developed deeply to a more effective level of decision making; regarding laws, regulations, instructions, organizations, communities, and etc. Furthermore, it has a great potential for designing tangible outcomes like products, services, experiences, social objects and etc. Without design of these concrete and abstract things, the groundwater resources management socio-technical system will not function properly and act maturely.

The last but not list is that historical roots and cultural concerns of the society, makes it serious to pay more attention on localization advantages of the system.

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