A Novel Business Model for a Cyber Physical System(CPS)-Based Smart Irrigation Network

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ABSTRACT:

Industry4.0 plays a significant role in the strategy making to take the opportunities of digital transformation of all stages of the production and the service systems in water management. This paper examines how the digital technologies and cyber physical system facilitate business model innovations in smart irrigation network. We choose the smart irrigation network as the case study; because the smart irrigation network is the first instance of a cyber physical system in practice for water management. That is, a successful instance of the digital transformation in water management. We determine the components and the building blocks of the business model of the smart irrigation network. The Industrial Internet of Things (IIoT) business model of the smart irrigation network that we propose in this paper focuses on creating new markets, new services/product/platform and the enhancement of the efficiency of transaction. This framework is developed from bottom-up approach practical case study and top-down from the theoretical perspective of business model and the digital transformation of smart irrigation network. The finding of this paper shows that the value proposition of smart irrigation network for the customers ranges from shorter order, near to demand supply, equity in irrigation water allocation between all customers including upstream and downstream, better planning and water allocation to extracting extra fresh water for the restoration of wetlands and urban usage.

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1- Introduction

The emergence of digital technologies has dramatically transformed businesses (van Tonder et al., 2020). With the advent of the Industry 4.0., businesses are adapting to the digital transformation and redesigning their existing business models. As a result, a significant emerging trend is the increasing adoption of Industrial Internet of Things (IIoT)-based business model (Ustundag, &

Cevikcan, 2017). However, there is limited empirical research on this phenomenon. Especially, to the best of our knowledge, there is no research about business model of smart irrigation network as an example of cyber physical system in Industry 4.0. This paper intends to fill this gap. The aim of this paper is to develop a conceptual model that indicates how the traditional irrigation system can digitally transform the existing business model elements. The primary research question can therefore be formulated as follows: what is the digital transformation business model of the smart irrigation network?

This paper is organized as follows. The introduction was given in Section1. The literature review and the theoretical background is given in Section2. In Section 3, we describe methodology and the automated irrigation network management system as the case study. In Section 4, the finding and business model of smart irrigation network and the changes resulted from digitalization is provided. In Section 5, the paper is concluded by summarizing the main contributions of the paper and describing the future research.

2. Literature Review and Theoretical Background

2.1. Cyber Physical System and Digital Transformation

The key technology of industry 4.0 is cyber physical system (Ustundag, & Cevikcan, 2017). A cyber physical system is a seamless automatic network between the material world, e.g., sensors, actuators, microcontrollers and generally speaking physical layer and smart components, e.g., cyber resources (Prem, 2015). At the physical layer, sensors, actuators and microcontroller work together to detect changes in an object or the environment and cyber/digital layer store, analysis and process the huge amount of data that comes from the physical layers (Prem, 2015). Smart irrigation network is the first instance of a cyber physical system in practice for water management. Knowledge management plays an important role in cyber-physical systems as there is a need for an integrated framework to represent the myriad types of data, information and application contexts in different physical areas, and interpret them under the proper context (Shafiq etal., 2015).

Digital transformation is defined as the alteration of the business models by the use of innovative and technological processes that leads to major changes in the behavior of the society and the customer (Sundaram, et al.,). At the core of digital transformation is the customer; hence processes must be developed in such a way that customer needs are understood and satisfied by digitalizing the customer experience (van Tonder et al., 2020). Digitalization provides many benefits in a variety of ways, one of which is the better use of customer knowledge.

2.2. Customer Knowledge Management

In knowledge based economy, knowledge is regarded as a key asset and only sustainable source of competitive advantage and businesses have to realize the critical importance of organizational knowledge (Zanjani et al., 2008). However many firms overlook Customer Knowledge (CK) as a brilliant resource (Zanjani et al., 2008). In fact, Customer knowledge is an important resource for all businesses and industries. Customer knowledge management is concerned with the management and exploitation of customer knowledge (Rowley, 2002). Customer Knowledge Management (CKM) is defined as tools, practices and soft skills to create and transfer customer-related knowledge. CKM becomes a strategic asset in order to create customer value (Gomez, et al., 2020). The implementation and use of CKM can bring benefits, such as customer satisfaction, company’s profitability, cost reduction, more effective marketing strategy and improved customer service and support (Gomez, et al., 2020). Nowadays, many companies know a lot about the attitude and behavior of their customers but little about how the company should make good use of this knowledge (Campbell, 2003).

2.3. Business Model of Smart and IIOT Industry

Business models are a complex, multi-dimensional concept (Li, 2020). Business models are the management tools or cognitive configurations that facilitate creating, enlarging and retaining business value (Prem, 2015). Only the companies developing the proper business model are successful in competitive era of business.

The IIoT uses recent advances in sensing, networking, and computing technologies to enable novel applications and services for water management. With the rise of IIOT, there is significant interest in business model of smart and IIOT industry (Ustundag, & Cevikcan, 2017). IIOT business model focuses on creating new markets, new services/product/platform and increasing the efficiency of transaction. The value proposition is considered as the key component of a business model. In the value proposition, the firm decides which product/services to offer to customers; and they have which customer segment (Ustundag, & Cevikcan, 2017).

3. Methodology

The design of the business model proposed in this research is based on the following categories:

- General business model framework presented in the literature
- Case study of smart irrigation network (bottom-up)
- Theoretical reasoning (top-down) about IIoT-based business model and the impact of digital transformation on business model

For new phenomena where no prior literature is available, qualitative research can help to found patterns and framework for future research. Hence; due to this exploratory approach of this paper, a case study is chosen as the research method. In this research, data was collected from interview, customer's survey results and governmental reports, website and etc.

We choose the smart irrigation network as the case study; because the smart irrigation network is the first instance of a cyber physical system in practice for water management. That is, a successful instance of the digital transformation in water management. Therefore; we take the real world case study of smart irrigation as a successful cyber physical system to analysis the impact of digital transformation on business model.

3.1. Case Study: Smart Irrigation Network

Today’s, one of the world's major problems and challenges is lack of water and water is consumed abundantly in agriculture. Hence, the key purpose of smart irrigation network is to reduce manpower, water resources and power consumption (Srivastava et., 2018). Especially, there was a ground breaking reform on Australia's irrigation industry 20 years ago as the nation battled with sever dry out, water scarcity and the global warming effects. Due to the sharp rise in demand for water in many parts of the country, water became an increasingly scarce resource. Over extraction from murray-darling river had resulted in drying out six wetlands located in the northern region of the state of Victoria in Australia. This massive dry out had caused severe environmental damage. The government responded with a major drive to modernize its irrigation supply infrastructures and improve their efficiency. This applies particularly to agricultural irrigation canals, where large amounts of water are wasted due to poor management and control. In fact, water losses in irrigation network, which consumes 70 percent of Australia's fresh water, was around 25% (Mareels et al., 2005). Distribution losses were mainly due to traditionally upstream water management, which resulted in oversupply and irrecoverable outfalls at the end of irrigation canals. Digitalization of irrigation supply infrastructure results in downstream water management and near to demand supply, which have resulted customers' satisfaction. The TCC pilot project report (Luscombe, C. 2004) published in 2004 by the government after the digitalization of a pilot canal reports that:

- the customer service has been improved to supply water on one hour notice compared to the previous 72 to 96 hours notice required,
- supply to all customers, no matter where they are located on the canal network has been achieved,
- supply to all customers can be maintained at a constant flow rate from start to end of an order delivery,

- through accurate measurement of flow at each regulating structure, losses can be better understood and located, providing an opportunity to reduce losses from leakage, seepage and poor operation of flow control devices, previously considered too difficult or out of reach, and
- the same volume of water can be delivered onto farms with less water released from storage.

Another survey result taken in 2011 from 25 customers living in the Shepparton area after modernization of its irrigation network reports that (Rubicon report 2011):

- 100% of customers agrees that they get more constant flows through their farm service point,
- 100% of customers agrees that upgrading to automated service points benefits their business,
- 92% of customers agrees that reduced order times benefits their business,
- 100% of customers agrees that instant confirmation of orders benefits their business.

The 2013 annual report published by the government indicated that "the survey result of 750 randomly selected customers from the across region shows that the overall satisfaction has increased by 11% from the previous year, moving from 52% to 63%" (GMW-AR 2013). The annual customer satisfaction survey conducted in June 2014 from 750 randomly selected customers out of 39073 customers also showed 85% customer's satisfaction (GMW-AR (2014)); while the last year report showed only 63% customer's satisfaction (GMW-AR 2013).

Similarly, a domestic pilot of Iran's smart irrigation network was developed in 2018 in Khuzestan province.

4. Finding

4.1. IIoT Value Creation Layers and Technologies of Smart Irrigation

Table1 provides the main attributes and IIoT value creation layers and technologies of the business model of smart irrigation network as a cyber physical system.

At the physical layer, sensors, actuators, and microcontrollers work together to detect changes in an object or the environment, allowing for capture of relevant data for real-time or post-processing. Digital layer of smart irrigation network employs many technologies, such as databases, cloud computing, and big data processing modules. It is also responsible for delivering application specific services to the user.

Table1: IIoT Value Creation Layers and Technologies of Smart Irrigation

Business	Value proposition	Physical layer	Digital layer
B2C	-Delivering near to demand supply - Efficiency enhancement by sharing demand-related customer knowledge and using customer knowledge management -Equity in irrigation water allocation between all customers including upstream and downstream -Real time monitoring of the irrigation network for pointing out leakage and illegal exploitation -Extracting extra fresh water for the restoration of wetlands and urban usage	Sensors, actuators, IIoT wireless communication modules, cloud computing and microcontrollers	-Analyzed data at cloud platform -Via mobile phone app, SMS, email, user can monitor, control and order water online

4.2. The Digital Framework of the Business Model of Smart Irrigation Network

A range of business model framework has been presented in the literature. We choose the canvas business model framework for the ease of use, comprehensiveness, and graphical format (Osterwalder & Pigneur, 2010).

Business model is divided into nine Building blocks (Osterwalder & Pigneur, 2010):

• Customer segments • Customer relationships • Channels • Value proposition • Revenue streams • Key resources • Key activities • Key partners • Cost structure • Revenue streams.

In Fig. 1, we propose the digitalization business model innovation framework of smart irrigation network, as a cyber physical system.

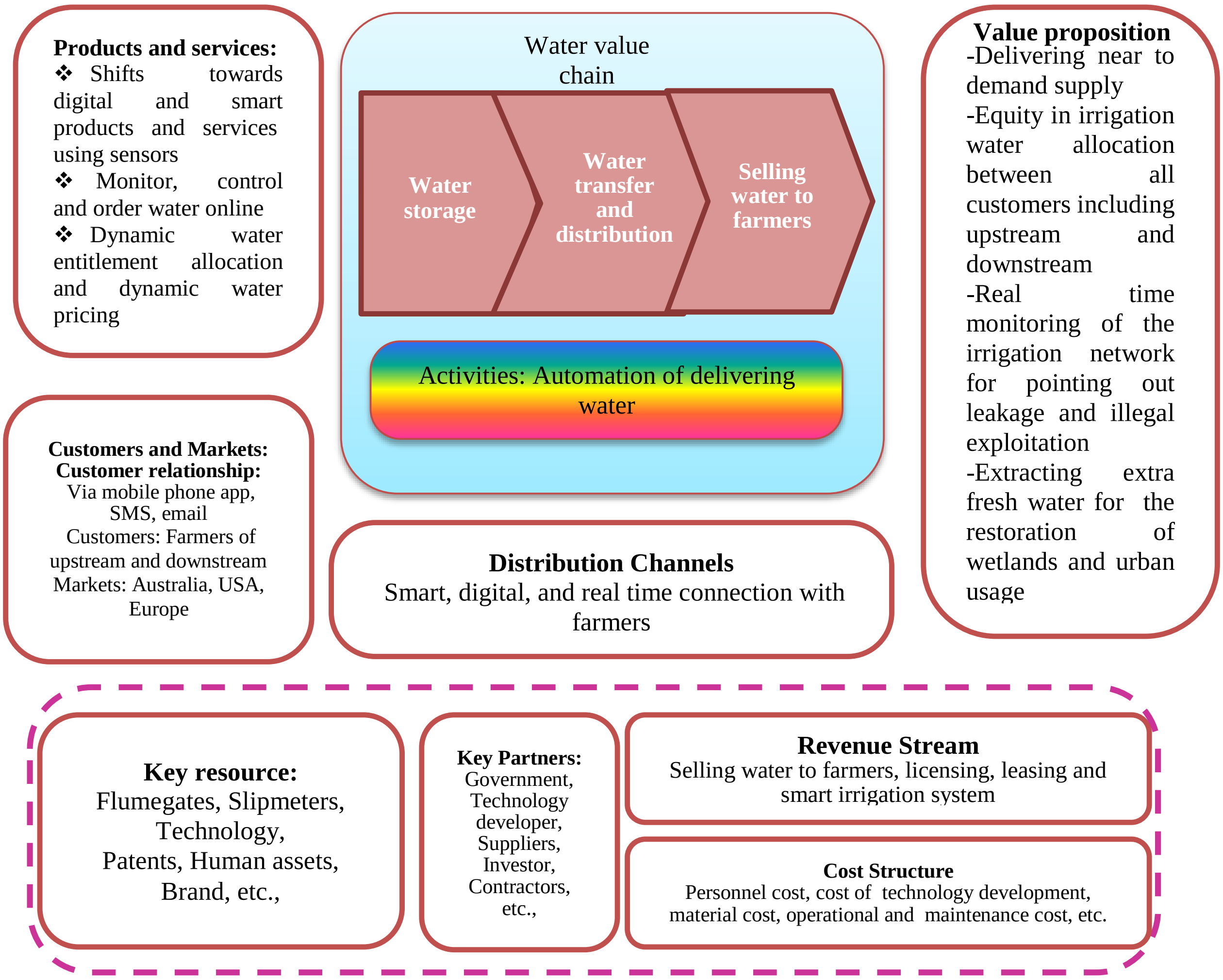

Fig. 1: The proposed business model innovation framework of smart irrigation network

5-Value propositions

The value proposition is identified as a critical issue of smart irrigation network, as it highlights the value of a technological innovation to the potential customer. The business model of traditional irrigation system suffered from some drawbacks, such as oversupply, inequity in irrigation water allocation to customer, long delay between water ordering and delivering, poor efficiency and performance, etc. Smart irrigation and equipping irrigation network with new sensors, IIoT modules and cloud computing resources implies the generation and consequently the collection of data and information. Most of this data is new and could not previously be collected and studied. This has the potential to offer new value based on insights into big data. Another source of value creation is better personalization, customization and individualization of products and services with smart irrigation and digital components.

Downstream supply management that proposed by smart irrigation network can significantly enhances the efficiency of this network. The value proposed by smart irrigation for the customers ranges from shorter delay between water ordering and delivering, near to demand supply, improved accuracy of measurement, better planning and water allocation to extracting extra fresh water for the restoration of wetlands and urban usage. In smart irrigation, value is created in changeable and dynamic networks of business, customers and consumers.

In sum, the value proposed by smart irrigation network can be categorized in economic, technical, environmental and social value (Fig. 2). Note that economic and environmental sustainability are an intertwined challenge for businesses.

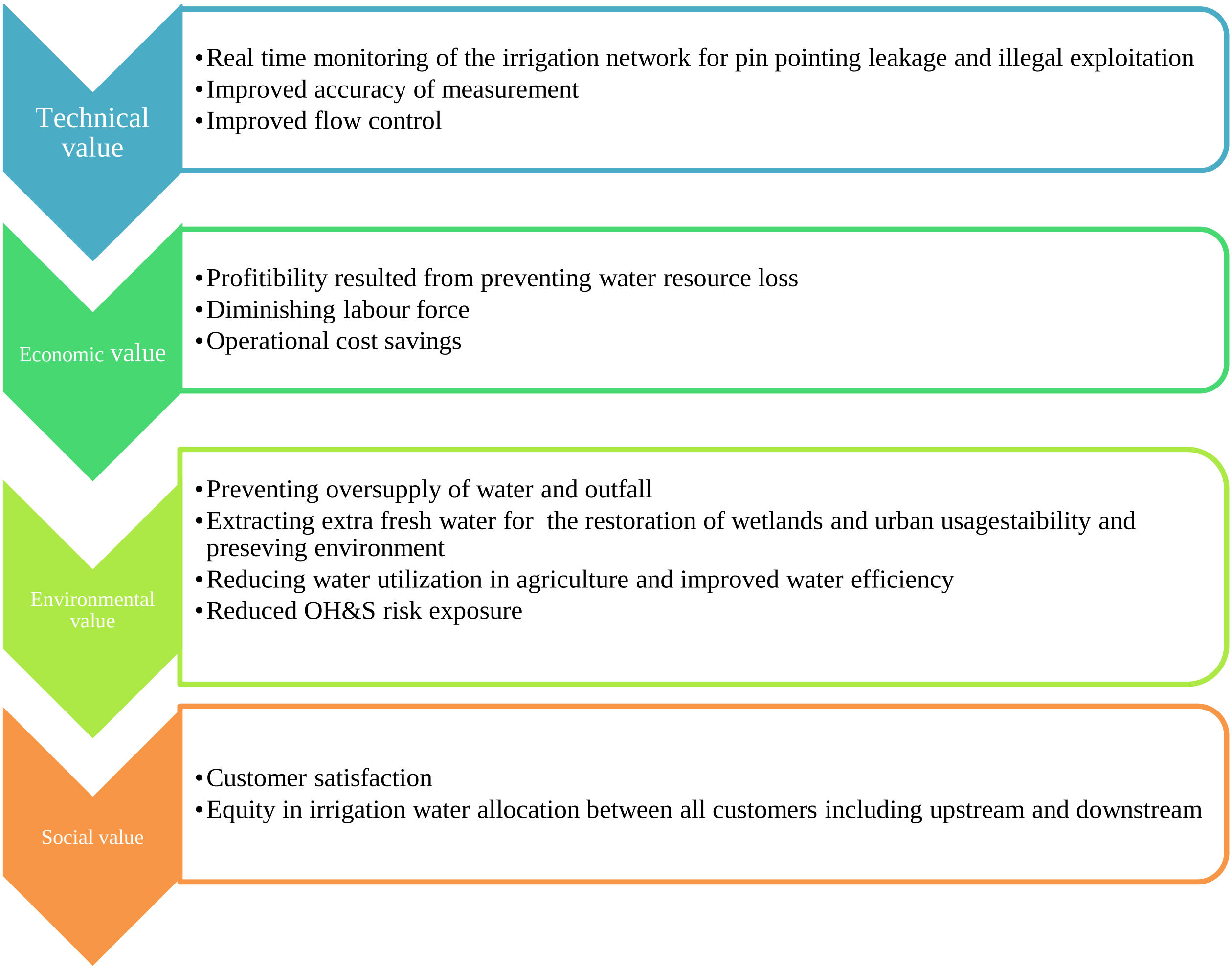

Figure2: The value proposition of smart irrigation network

6- Products and Services

The smart irrigation network shifts towards digital and smart products using sensors, actuators and cyber resources. The smart irrigation system has water flow sensor, temperature sensor and soil moisture sensor that measure these items. Main products and services of this network are monitoring, control and ordering water online. Before using this cyber physical system, customers had to order water at least three days in advance.

Other services that can be provided by smart irrigation are as follows:

- Dynamic water entitlement allocation based on farm's water needs
- Real time detection of customers with high water consumption
- Penalizing high-consumption customers
- Rewarding low-consumption customers in order to encourage saving water

- Dynamic water pricing for peak shaving and saving water
- Near to demand supply
- Real time response to customer's demands
- Immediate response to turbulences in irrigation network
- Providing a digital twin management dashboard to help top managers to come up with better planning and execution strategies
- Pin pointing leakage and seepage in irrigation channels
- Real time detection and prevention of the unauthorized withdrawal of water from irrigation network

In many middle-east countries, such as Iran, there is no basically any water entitlement allocation and farmers can pick up water from irrigation network without any restriction. This is the case, for example, in Khuzestan province located in the south-west of Iran. Farmers in Khuzestan can pick up water as much as they want; and in return they pay 3% - 5% of their farms products to authorities as water price for this generous entitlement. Therefore, farmers can grow up any plants and crops that they want, including rice which needs a lot of water and it is not suitable for Khuzestan's environment. FAO published a document known as the FAO's 56 (Allen et al., 1998). In this document, the water needs of every plants and crops are calculated accurately. Therefore, the actual water needs for each farm can be determined based on the size of farm land, type of plants or crops in the farm and the weather history and data. Now, by upgrading the traditional irrigation network of this province to a smart irrigation network, the actual water need of each farm can be determined by the cyber layer of this system via implementing the information about farms and weather history and data on it. Consequently, we can have a fair water entitlement allocation for each farm. Also, using this smart irrigation network, the amount of water that is picked up by each farmer from irrigation network is accurately measured real time. Subsequently, authorities can determine whether farmers are picking up water more than their entitlements or not? In this way, high-consumption customers are determined and in order to encourage them to save water, authorities may penalize them by asking them a higher price for water that they have consumed more than their entitlements. Moreover, authorities can reward low-consumption customers by asking them a lower price for water. Due to the real time capability of this smart system, in the peak hours, authorities can implement a peak shaving strategy for saving water by asking higher price of water from those customers that have picked up water during peak hours.

The above valuable services cannot be provided by the traditional irrigation system; and they are the by-products of the smart irrigation system. Considering the above emerging services of smart irrigation network, the digitalization of irrigation network can shift this network from a product-based system to a service-based system. These new services can be provided to several stakeholders including policy makers, regulators, farmers, technology developers and etc.,

7-Channel

The smart irrigation network makes it possible to directly access customers and trade and support them without any intermediaries. Hence; there is a shift towards mobile and real time channels to trade water resource and services to customers.

7-1-Revenue Stream/Cost Structure

Digitalization and using smart irrigation leads to service fees, generating income from lease and licensing of this IIOT-based high tech. rather than just selling products and services. Therefore; the shift from a product-based to digital service resulting from using smart irrigation induces a change in revenue structure from purchase- based to recurrent lease-based payment.

The ‘cost structure’ should be minimized, maximizing the chance for profit. However, the design of implementing of smart irrigation network is too expensive and it has overly long pay-back periods.

7-2-Key Activities

Digitalization and smart irrigation network has facilitated highly automated process and accelerated speeds, water resource efficiency, flexibility of irrigation system.

7-3-Key Partner

Regulatory and policy maker, spinoff company developing technology, and suppliers are the key partners in smart irrigation network. Due to the multidisciplinary nature of smart irrigation, key partners are from a variety of disciplines, such as water management, technology development/transfer, environment, automation, etc,.

7-4-Key Resource

Capital, finance, human asset, and technology can be conceptualized as the key resources required to provide the value proposition of smart irrigation duo to the emerging and cutting edge nature of technology.

In addition, during the digitalization, customer knowledge is one of the most important resources of smart irrigation. In this system, the knowledge is mainly related to the forecast of water demand of user that is a key resource for improving the performance of system. A continuous knowledge stream from the management team to customer is crucial to support this system. The customer’s needs and complaints can be integrated into the value-adding process of designing, developing and implementing of smart irrigation network.

7-5-Customer and Customer Relationship

Customers are the farmer of upstream and downstream irrigation network. Customer can order water via mobile phone app, SMS, email, etc.

6. Conclusion

To answer the main research question of the paper, a conceptual framework was constructed following an extensive search on the literature. That leaded to a framework for smart irrigation business model. Using an extensive literature review, we defined the main determinants and components of a business model and specific types of these main determinants. In the literature, few studies focus on smart irrigation network business models. This paper filled the gap by defining the key features, value propositions, revenue streams, and technologies of the smart irrigation network.

The findings of this paper can support managers in understanding and navigating the digital business model of smart irrigation network.

However, this research has some limitation. One limitation is the fact that this research is based on a single case study of smart irrigation network. Further research might be needed in order to expand the business framework developed in this paper to other smart systems. In addition, the business model components are causally interacting with each other so that a change towards digitalization in one component has impact in other components in turn. This phenomenon in smart irrigation network can be studied in future research. Finally, it would also be interesting to analyze failure cases of digital transformation in a smart network.

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