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DEVELOPMENT OF A CONCEPTUAL MODEL FOR APPLICATION OF HYDRO-MECHANICAL GATES IN IRRIGATION NETWORKS BY A SYSTEM DYNAMIC APPROACH[†]

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ABSTRACT

Poor performance of irrigation networks necessitates their improvement. One of the measures for performance improvement is application of automatic systems such as hydro-mechanical gates. The decision-making process for application of automatic systems is a complicated task. Reasons for this complexity are the wide range of existing technologies to be selected from, interactions between components and economic and social short- and long-term impacts. Development of a suitable model which addresses all aspects of automation is needed. One suitable technique for coping with this is a system dynamic approach.

In this research, the dynamic behaviour of irrigation networks using automated control systems is investigated and its conceptual model is developed as a first step of a system dynamic model. A questionnaire based on system dynamic archetypes was designed and completed by irrigation experts from six irrigation networks in Iran. In addition, interview techniques were used to collect data. The conceptual model was developed by a system dynamic approach. The conceptual model includes fixes that fail, limits to growth, eroding goals, success to the successful, and shifting the burden archetypes. The interactions between social, managerial, economic, technical and water resources in the long term, which play a significant role, are well elaborated in the developed conceptual model. Copyright © 2017 John Wiley & Sons, Ltd.

KEY WORDS: canal automation; conceptual model; irrigation network; system dynamics

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RÉSUMÉ

La mauvaise performance des réseaux d'irrigation nécessite des mesures correctives. L'une des mesures est l'installation des portes automatiques hydro-mécaniques. La prise de décision pour l'application des systèmes automatiques est une tâche compliquée: large gamme et complexité des équipements, interactions entre les équipements. Le développement d'un modèle approprié qui aborde tous les aspects de l'automatisation est nécessaire, et nous avons privilégié l'approche de système dynamique.

Dans cette recherche, le comportement dynamique des réseaux d'irrigation utilisant des systèmes automatisés est enquêté et son modèle conceptuel est développé comme une première étape. Un questionnaire basé sur des archétypes du système dynamique est conçu et rempli par des experts d'irrigation de six réseaux d'irrigation en Iran. Le modèle conceptuel inclut des correctifs comme la réparation qui échoue, une limite à la croissance, l'érosion des objectifs, le succès de la réussite, la suppression du fardeau des archétypes. Les interactions sociales, managériales, techniques, les ressources en eau à long terme, qui jouent un rôle important, sont bien élaborées dans le modèle conceptuel développé. Copyright © 2017 John Wiley & Sons, Ltd.

MOTS CLÉS: automatisation du canal; modèle conceptuel; réseau d'irrigation; dynamique du système

INTRODUCTION

In the context of scarce water resources and increasing competition from other sectors such as the environment, industry and the urban sphere, the efficient management of water

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resources in irrigation networks, as the largest user of water, is very important. Iran is located in an arid and semi-arid region and has non-uniform temporal and spatial distribution of rainfall. Iranian irrigation networks use more than 90% of water, but the performance of the irrigation networks is lower than expected. Therefore, optimal water management in Iranian irrigation networks is necessary. Applications of automated control systems are capable of achieving this goal (Hosseinzadeh *et al.,* 2014).

Application of automated control systems in Iranian irrigation networks has recently attracted the attention of the authorities; for example, the installation of automatic discharge measurement equipment in important canals of Iranian irrigation networks by the Iran Water Resource Management Company, and using hydro-mechanical gates (Amil gates) for automatic control of water levels in some Iranian irrigation networks (Qazvin, Sefid Rood and Fomanat irrigation networks). Investigation of the success and failure of these systems and their systematic manner could help to make better decisions that could reduce economic, social and technical risks.

Many control systems have been developed and applied in irrigation networks to improve their performance (Litrico and Fromion, 2005; Stringam and Esplin, 2006; Ooi and Weyer, 2008; Isa *et al.,* 2011; Li -fang, 2012; Figueiredo *et al.,* 2013); some of them have succeeded and some have failed.

Some successful cases are the following. Figueiredo applied the MPC algorithm to control an experimental irrigation canal located at the University of E'vora, Portugal. PLC (programmable logic controller) technology supervised by a SCADA system was applied. The result shows that the MPC algorithm could regulate the water level properly when there were disturbances. Also, using canal geometric characteristics is necessary in modelling (Figueiredo *et al.,* 2013).

Old canal automation facilities in the East Bench Irrigation District in Dillon, Montana, were removed and replaced with new ones. Such as replacement of the directional antennas with omnidirectional antennas at the installation stage, and replacement of the bubbler sensor with a pressure transducer because of inaccurate data reading. Also, the technician's skill is a very important factor in solving problems and maintaining the systems (Stringam and Esplin, 2006).

Litrico applied a combinatorial upstream and downstream method to design a PI controller for irrigation canals. To evaluate the controller, a developed model was tested on a canal with two reaches. The trapezoidal canal was 3 km in length, 7 m wide and with a 1.5 side slope. The results show that the controller could regulate water level reasonably (Litrico and Fromion, 2005). Hydro-mechanical automatic control systems such as Amil and Nyrpic gates regulate the water level correctly in some Iranian irrigation networks such as Sefid Rood and Fomanat.

Some unsuccessful cases of automatic control systems are the following. In 2009 the Iran Water & Power Resource Development Company installed an automatic discharge measurement and communication platform in the important places of most Iranian irrigation networks such as Dez, Gotvand, Qazvin, Sefid Rood and Fomanat. After some time, some of them stopped working because the technical and social conditions were ignored. One of USBR's experiences in automatic control of irrigation canals was to develop, install and evaluate the low-cost SCADA system in the USA (Servire River in Utah), China (Jingtai and R.R. China) and Malaysia (Rerian Irrigation District). These systems exhibit some drawbacks in small irrigation networks, as they are expensive and time-consuming (Hansen *et al.,* 2001).

Decision making is usually based on the current situation of selection criteria without enough attention being paid to long-term impacts. Some solutions could solve the problem in the short term, but might make it worse in the long term. Application of automated control systems and the interaction between components have effects on irrigation networks. With the availability of various technologies and their interactions with irrigation network components, they have different technical, managerial, economic and social drawbacks in the short and long term. Therefore decision making in this regard is a difficult task, requiring a comprehensive, systematic and provident standpoint.

Based on our knowledge, the interaction between irrigation network elements and automated control systems has not been considered in detail. Some research has been done into modernization of irrigation networks. Vaez Tehrani studied the general rehabilitation of irrigation networks using a system dynamic approach (Vaez Tehrani *et al.,* 2012, 2013). This paper focuses on automatic control systems application which is an important option for rehabilitation of an irrigation network which requires separate and detailed treatment. Moreover, integrated models with respect to social, managerial, economic and technical aspects of application of automated control systems in irrigation networks have not been developed. In this paper, irrigation network behaviour with application of an automated system has been investigated and its conceptual model developed. A system dynamic approach is a suitable methodology capable of achieving this goal.

Each system has various components. In linear systems, components affect each other hierarchically and there is no feedback between components. But a system dynamic (SD) approach uses feedback loops. It is simple and user-friendly (Sušnik *et al.,* 2012). SD has been applied in water resources research studies (Atanasova *et al.,* 2006; Khan *et al.,* 2009; Balali *et al.,* 2011; Guan *et al.,* 2011; Vaez Tehrani *et al.,* 2013).

The first step in the development of an SD model is to develop a conceptual model which describes the casual relation between components. The quantitative model is developed afterwards, based on the conceptual model (Baker, 2007). The main goals of this paper are to consider the effective variables and dynamic processes of automated control system application in irrigation networks in order to pay attention to the long-term consequences of this application in irrigation systems. The decision maker could select the best control system based on irrigation system performance in the long term. As the first step, the conceptual model of application of automated control systems in irrigation networks was developed in an SD approach (VENSIM software). To show the casual relation between components and define them, a questionnaire was prepared based on standard archetype structures of an SD approach. After that, the questionnaire was completed in six irrigation networks and accompanied with interviews with experts from the Ministry of Power in Iran. Finally, the conceptual model for application of these systems was developed.

MATERIALS AND METHOD

System dynamic (SD) approach

System dynamics (SD) is one of the most effective approaches to investigate a dynamic system. This approach introduced by Forrester in 1961, is able to consider the feedback between the system elements and various scenarios could be easily simulated (Guan *et al.,* 2011). Figure 1 shows the schematic of a feedback loop used in an SD approach. In a feedback loop, elements of a system interact with each other in a closed path (Ooi and Weyer, 2008).

A, B, and C in Figure 1 are effective factors in a system which have feedback on each other. There are two kinds of feedback loop, including balancing and reinforcing loops which form the system's dynamic behaviour.

SD models rely on two feedback loops, one balancing and one reinforcing loop. A reinforcing loop describes systems where elements reinforce one another, creating either a virtuous or a vicious cycle. Reinforcing loops have inherent limits to growth, usually because one of the elements interacts with another loop to eventually slow growth. A balancing loop describes efforts to solve a problem or close a gap between a desired state and a current state (Baker, 2007).

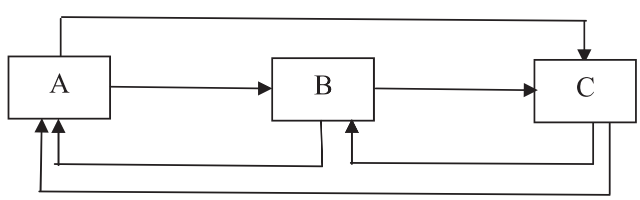


Figure 1. Feedback structures in the system

A map of the feedback structure of a system is a starting point for analysing what is causing a particular pattern of behaviour. Archetypes are useful for gaining insight into the 'nature' of the underlying problem and for offering a basic structure or foundation upon which a model can be further developed and constructed. The archetypes are rarely sufficient models in and of themselves. They are generic in nature and generally fail to reveal important variables that are part of a real system. Without an explicit awareness of these real variables, it is difficult for managers to pinpoint specific leverage points where changes in structure can achieve sustainable changes in system behaviour (Braun, 2002).

There are various archetypes such as limits to growth, eroding goals, success to the successful, fixes that fail, etc. that will be explained.

Method of research

There is a main variable in each system. The goal of SD modelling is to investigate the effect of other variables and processes on the main variable. In this paper, the main variable is the utility of irrigation network which consists of variables such as adequacy, fairness, efficiency and flexibility. The aim of this research is to identify the effective variable and process, in particular an automated control system in an irrigation network utility, in order to determine the behaviour of the irrigation network. To achieve this, first, a possible effective variable and related processes were assumed by the authors. To ensure the existence of assumed processes, a questionnaire was designed and completed, and then six Iranian irrigation networks including Qazvin, Sefidrood, Moghan, Gotvand, Rajaee, and Zohre and Jarahi, the Iranian Ministry of Power and the Iran Water Resource Management company experts were interviewed. Figure 2 shows the location of the irrigation networks.

The questionnaire consisted of seven major questions including:

- side effects of application of automated control systems in irrigation canals classified into managerial, social, economic and technical categories;
- basic and sectional measures required to apply these systems;
- substitution of the main goals of application of automated control systems with the side goals;
- restrictive factors to apply automated control systems;

Figure 2. Location of the six irrigation networks in Iran. [Colour figure can be viewed at wileyonlinelibrary.com]

- are there influential water users who can allocate automation services toward themselves?
- what can be done to improve available systems performance?
- what problems exist in implementing volumetric delivery in irrigation networks?
- have other modernization measures been investigated before application of automated systems?

For most of the questions several subquestions with a ranking of low, average and high were prepared. After completing the questionnaires, the processes which had been approved by 70% of questioners were assumed as the behaviour of application of automated control systems in irrigation networks. The conceptual model of application of automated control systems in irrigation networks was developed based on approved processes.

Introduction of the mechanisms of automated system in irrigation networks

Various mechanisms had been assumed by the authors at first. After completing the developed questionnaire in different irrigation networks and governmental organizations, the approved mechanisms about application of automated control systems in irrigation networks were determined.

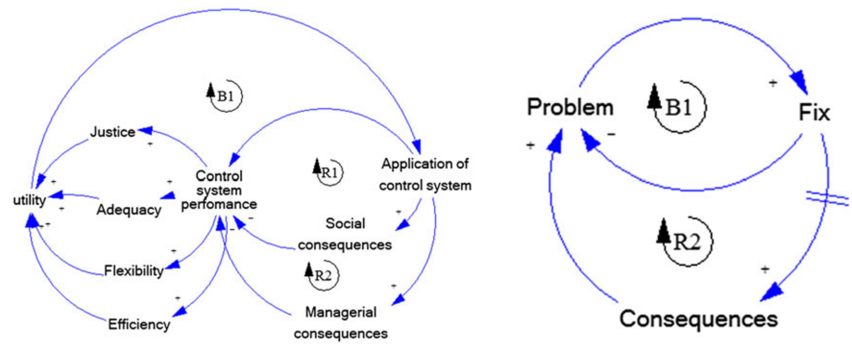
In this model the utility of an irrigation network is defined in terms of adequacy, fairness, efficiency and flexibility.

The assumed mechanisms are the following:

- *Mechanism of fixes that fail* (*application of a control system*). As shown in Figures 3(a) and (b), the fixes that fail archetype display a long-term worsening scenario, where the initial problem symptoms (utility) are improved by the fix (application of control system), but the consequences worsen the problem. The reinforcing loop (R1 and R2 in Figure 3b), which contains a delay, contributes to a long-term deteriorating problem symptom.

Another fixes that fail mechanism assumed by the authors is about volumetric water delivery, which is shown in Figure 4.

Based on the mechanism shown in Figure 4, there is a difference between actual water price and the farmers' water bill. At most delivery points in Iranian irrigation networks, there is no (or no suitable) discharge measurement to calculate actual water delivered to farmers. Nowadays, the water price (which farmers should pay) is calculated based on water release in the upstream of networks that may be less or more than the water needs (scheduled water delivery). To reduce this difference, automated control systems are



a. Fixes that fail mechanism in application of automated systems in irrigation networks

b. Fixes that fail mechanism

Figure 3. a. Fixes that fail mechanism. b. Fixes that fail mechanism in application of automated systems in irrigation network. [Colour figure can be viewed at wileyonlinelibrary.com]

applied which could improve volumetric water delivery and actual water price (R9 loop). The actual water price calculation reduces water delivery to farmers which could lead to managers' satisfaction with application control systems (R11 loop) and decrease the farmers' adaptability to use control systems (B16 loop). On the other hand, the actual water delivery results in ease of operation and management of irrigation networks and more operators adaptability (R10 loop).

- *Mechanism of limit to growth* (*agriculture development and water resources limitations*).

The limits to growth mechanism consists of reinforcing and balancing loops (Figure 5a). The reinforcing loop (R3 in Figure 5b) is linked to a balancing loop (B2, B3 and B4 in Figure 5b). On the other hand, some resource limitations could affect growth. In a classic growth engine (agricultural development with improved utility), more effort produces better performance, and in turn better performance spurs even greater efforts (application of the control system). However, this growth engine is linked to a balancing loop that limits its growth. As performance increases, some limiting factors such as lack of experts, training, repair and maintenance of automatic systems and limitation of water resources (surface and underground water) reduce performance. Thus, despite an organization's increasing efforts, it is unable to drive its performance past a certain point which is imposed by the constraints. The real breakthrough in limits to growth lies in identifying and removing the constraint that is limiting growth while there are still sufficient resources to do so (Novak and Levine, 2010).

- *Mechanism of eroding goals* (*gap between current and desired utility and control system performance*). Eroding goals describes the tension between two

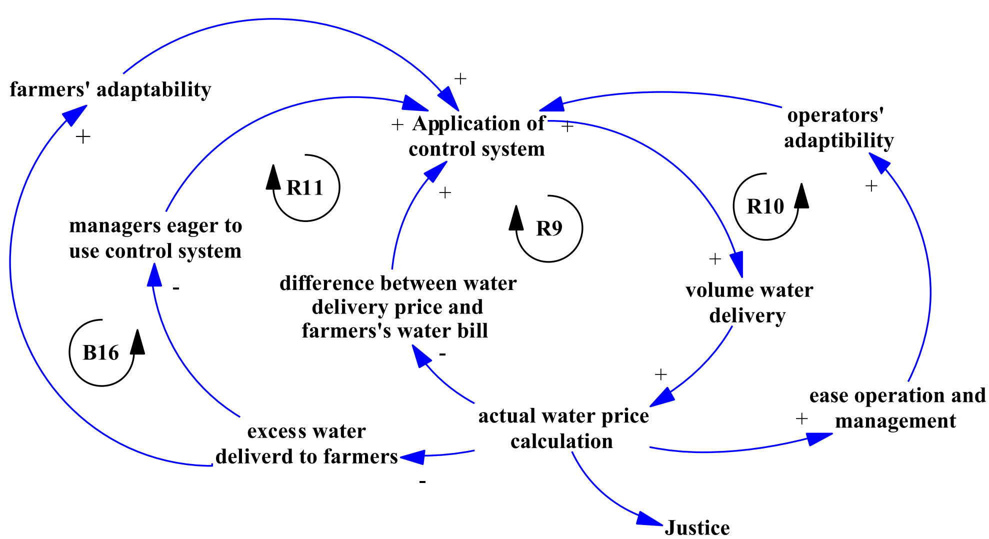
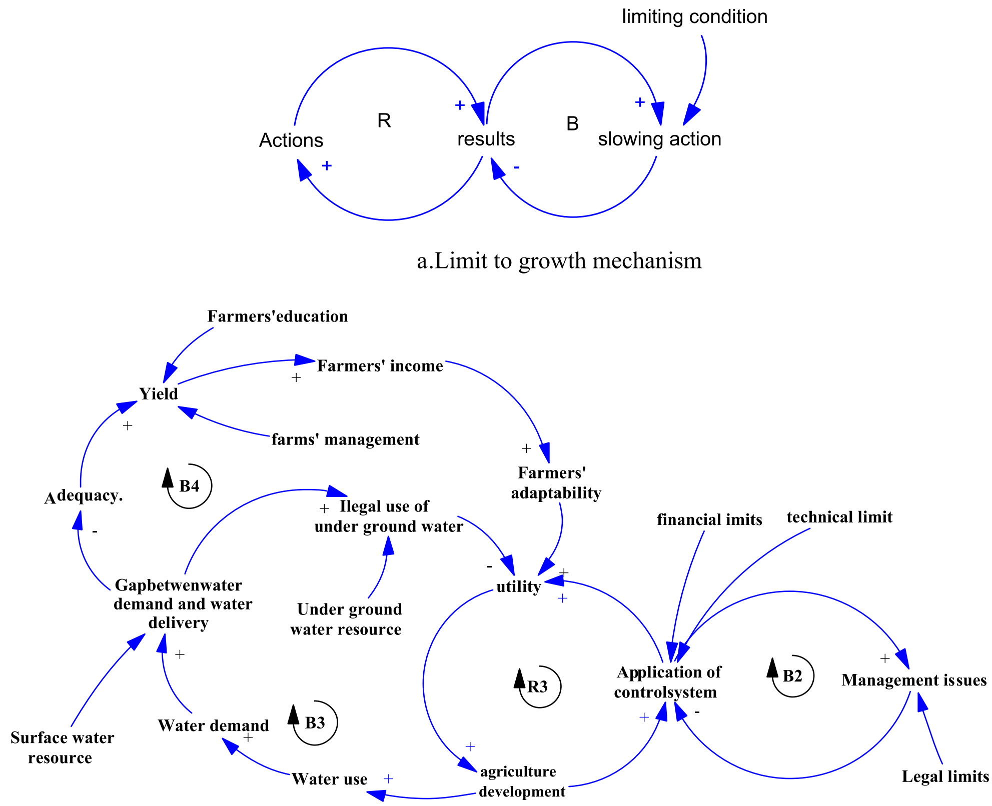


Figure 4. The assumed volumetric water delivery mechanism in irrigation canal in point of view application control systems. [Colour figure can be viewed at wileyonlinelibrary.com]



a.Limit to growth mechanism

b. Limit to growth mechanism in application of control systems in irrigation networks

Figure 5. a. Limit to growth mechanism. b. Limit to growth mechanism in application of control system in irrigation networks. [Colour figure can be viewed at wileyonlinelibrary.com]

balancing loops that represent two competing pressures. A gap between the goal and the current state (desired and current utility) can be addressed either by taking corrective action (B7 in Figure 6a, and B1 in Figure 6b) or by lowering the goal (B6 in Figure 6a, and B8 in Figure 6b).

- *Mechanism of shifting the burden* (*other modernization measures*). Shifting the burden starts with a problem symptom (low utility in the irrigation network). A choice exists between applying the symptomatic solution (application of automatic control systems) or the fundamental solution (other modernization measures) to address the problem symptom (Figure 7a). The fundamental solution has a time delay before it has an effect on the original problem symptom, which leads to a preference for using the more immediate symptomatic solution. The problem is supposedly solved by using the symptomatic solution (B1 in Figure 7b) and attention is diverted away from a more fundamental solution. Neglecting the fundamental solution and application of the symptomatic solution causes a decrease in the original problem symptom, keeping it in balance. However, increasing the use of the symptomatic solution causes more unintended side effects (such as unsuitable operation, destruction of the system, etc.) (R12 in Figure 7b) to be produced, which in turn decreases the ability to use the fundamental solution, making the organization more dependent on the symptomatic solution, and ultimately being trapped into using only the symptomatic solution. If the fundamental solution had been chosen (B16 in Figure 7b), as the problem symptom increased, the use of the fundamental solution would also have increased, and after a time delay there would be a decrease in the original problem symptom, again keeping them in balance (Novak and Levine, 2010).

As mentioned before, the utility of irrigation network is defined in terms of adequacy, fairness, efficiency and flexibility. Each of these parameters could have a specific mechanism which is described in the next section.

- *Agreed upon delivery and flexibility mechanism.* This is the combination of the eroding goal and fixes that fail

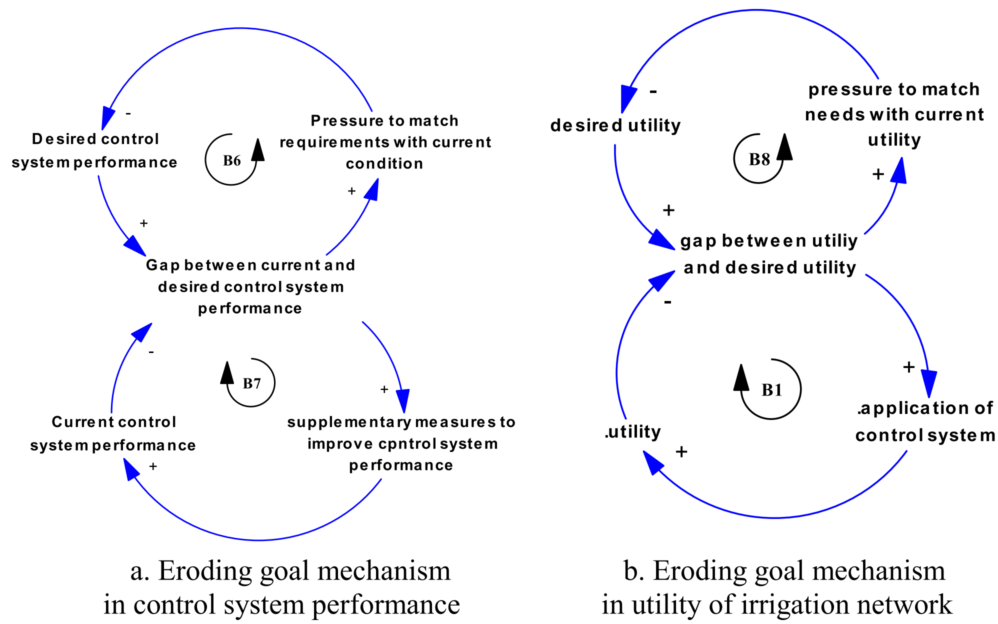


Figure 6. a. Eroding goal mechanism in control system. b. Eroding goal mechanism in performance utility of irrigation network. [Colour figure can be viewed at wileyonlinelibrary.com]

archetypes. In this mechanism, there is a gap between agreed upon delivery and current flexibility. Two solutions could be applied to reduce this gap:

- maintain the current flexibility and adjusting the delivery method which means that the current flexibility is acceptable (B10 in Figure 8);
- to reduce the gap by applying a better control system, which increases the flexibility level up to the agreed upon delivery flexibility (B11 in Figure 8).

On the other hand, increasing flexibility means more structure setting that results in more fluctuations of the discharge and water level which decrease the performance of control system in canals (R5 in Figure 8).

- *Allocation of service mechanism.* This follows the success to successful archetype. Several services are provided through application of the control system. Usually there are some influential farmers who receive greater services compared to other farmers.

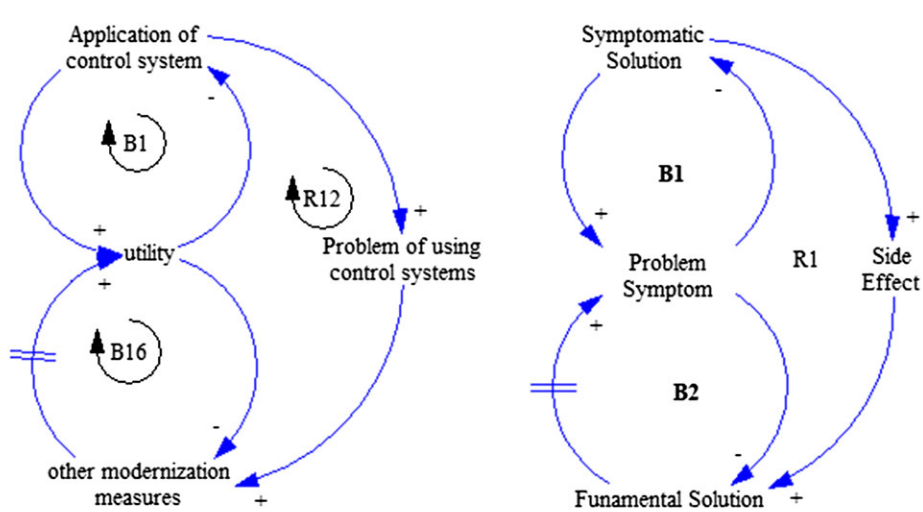


Figure 7. a. Shifting the burden mechanism. b. Shifting the burden mechanism in other modernization measures application. [Colour figure can be viewed at wileyonlinelibrary.com]

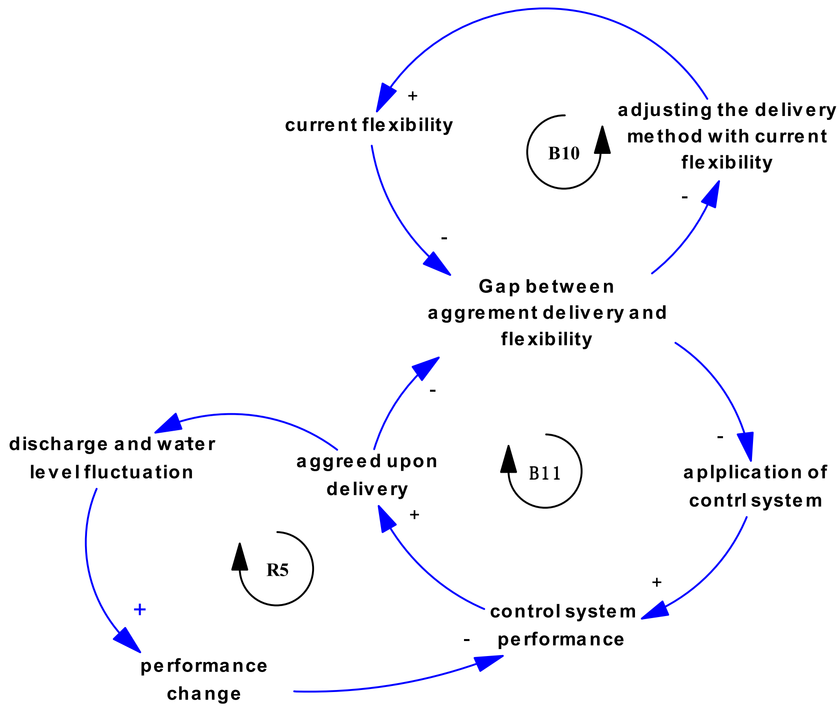


Figure 8. Agreed upon delivery and flexibility mechanism. [Colour figure can be viewed at wileyonlinelibrary.com]

When influential farmers receive greater services, other farmers receive lower services, therefore their income will be decreased. Decreasing income of other farmers results in more power for influential farmers and an increase in their income (R7 and R8 in Figure 9).

DISCUSSION AND RESULTS

After extraction of the assumed mechanisms of application of control systems in irrigation networks, a questionnaire was designed to verify these mechanisms and completed in interviews with six Iranian irrigation networks including Qazvin, Sefidrood, Moghan, Gotvand, Rajaee, and Zohre and Jarahi, and with Iranian Ministry of Power and Iran Water Resource Management Company experts. Except for two assumed mechanisms, other mechanisms were verified. The two unapproved mechanisms were fixes that fail of the volumetric water delivery mechanism, and the shifting the burden mechanism for other modernization measures application which are modified according to the interview results.

The modified water volumetric delivery mechanism

This mechanism includes the eroding the goal and fixes that fail archetypes. There is a gap between actual delivered water (delivered adequacy) and scheduled water (programmed adequacy). There are two solutions for reducing this gap. One is that irrigation network administrators put pressure on farmers to follow the designed crop pattern. This

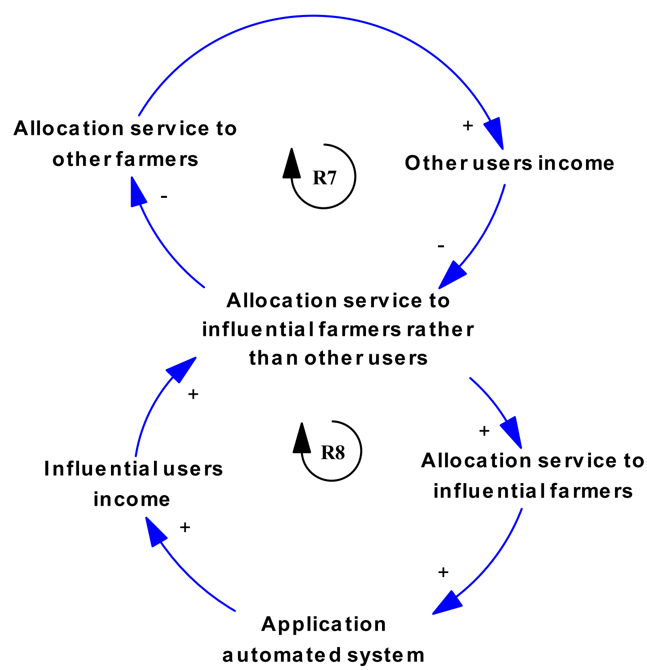


Figure 9. Allocation of service mechanism. [Colour figure can be viewed at wileyonlinelibrary.com]

solution results in keeping the actual water delivery (delivered adequacy) closer to the scheduled water (programmed adequacy) and reduces the gap (B12 loop in Figure 10). On the other hand, because of the social, political and economic situation, there is a pressure on irrigation network administrators to try to deliver the actual water demand, and not the scheduled water (B13 loop in Figure 10).

Application of an automatic control system could improve the difference between delivered and programmed adequacy. These systems could improve the volumetric water delivery (B15 loop in Figure 10). Increase of the water volumetric delivery decreases excess water delivery to users which reduces some farmers' adaptability and has a negative impact on automation (B14 loop in Figure 10). Excess water increases water managers' adaptability which is in favour of automation (R6 loop in Figure 10).

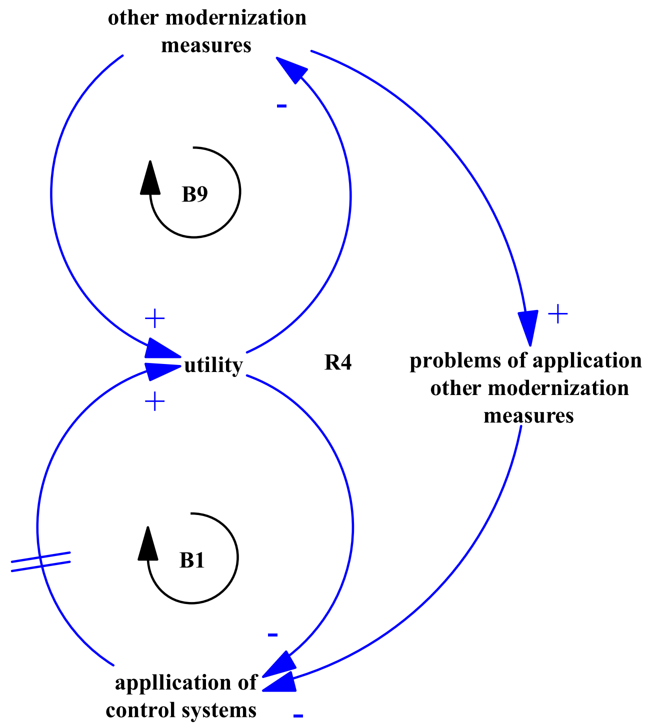


Figure 11. The other modernization measures application modified mechanism. [Colour figure can be viewed at wileyonlinelibrary.com]

The modified mechanism of other modernization measures application

During surveying the questionnaire, the other modernization measures application was modified based on interviewer results. In the initial mechanism, the application of control systems had been considered as the symptomatic solution and the other modernization measures considered as the fundamental solution. Interviewees believed that the other modernization measures (such as canal lining) are the symptomatic solution, because they could be easily implemented at lower cost, therefore managers prefer these solutions at the first stage (B9 loop in Figure 11). After some time, the problem will reappear (R4 loop in Figure 11) because the main problems—old structures, increasing irrigated land, and unsuitable water control to deliver the required water—are untouched. Therefore, in the next stages managers consider the application of control systems as the fundamental solution which could improve irrigation network utility in the long term (B1 loop in Figure 11).

Based on the mechanisms described, the conceptual model of automation system application in irrigation networks has been developed using the SD method (Figures 12 and 13).

The following section describes the conceptual model which is shown in Figures 12 and 13.

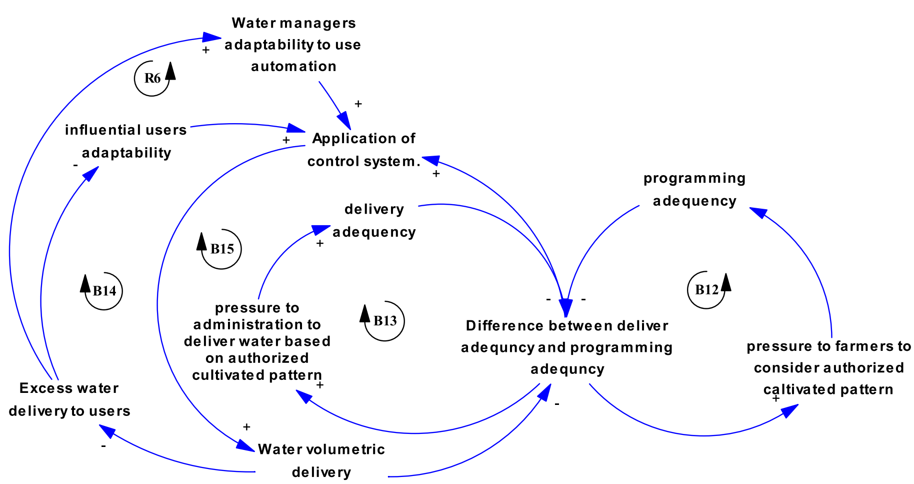


Figure 10. The modified water volumetric delivery mechanism. [Colour figure can be viewed at wileyonlinelibrary.com]

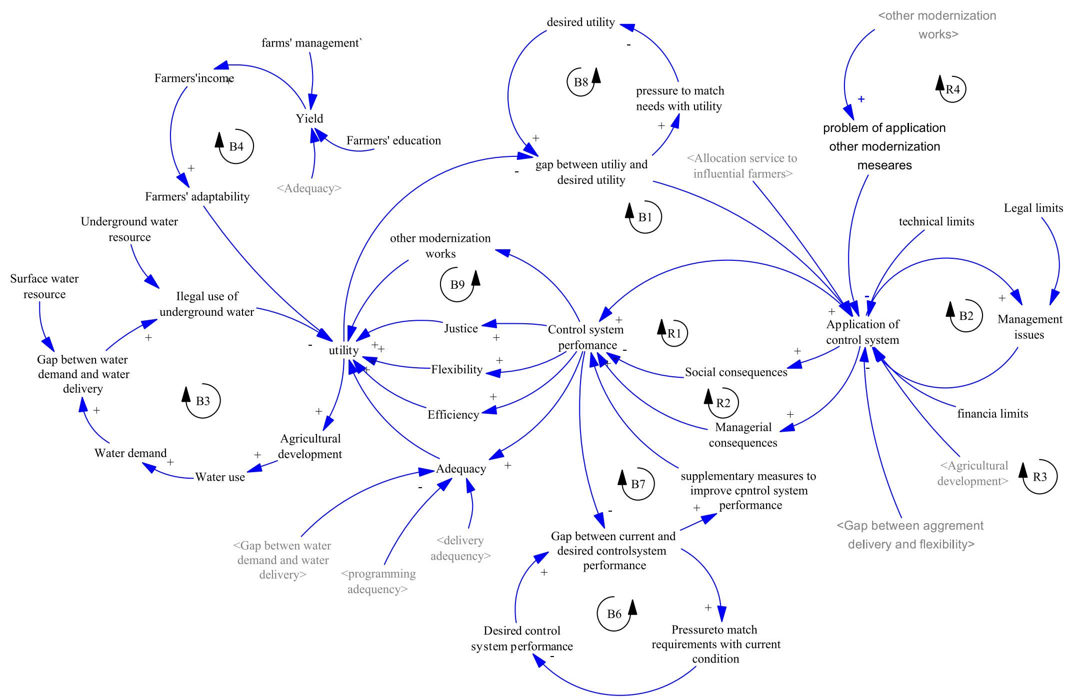


Figure 12. The conceptual model of automation system application in irrigation networks. [Colour figure can be viewed at wileyonlinelibrary.com]

B1, R1 and R2 loops. To solve the existing problem (low utility in the irrigation network), a fix has been applied (application of control systems) (B1 loop). Each control system has a specified performance. The application of control systems produces the desired correction in the short term to improve utility in irrigation network. The application

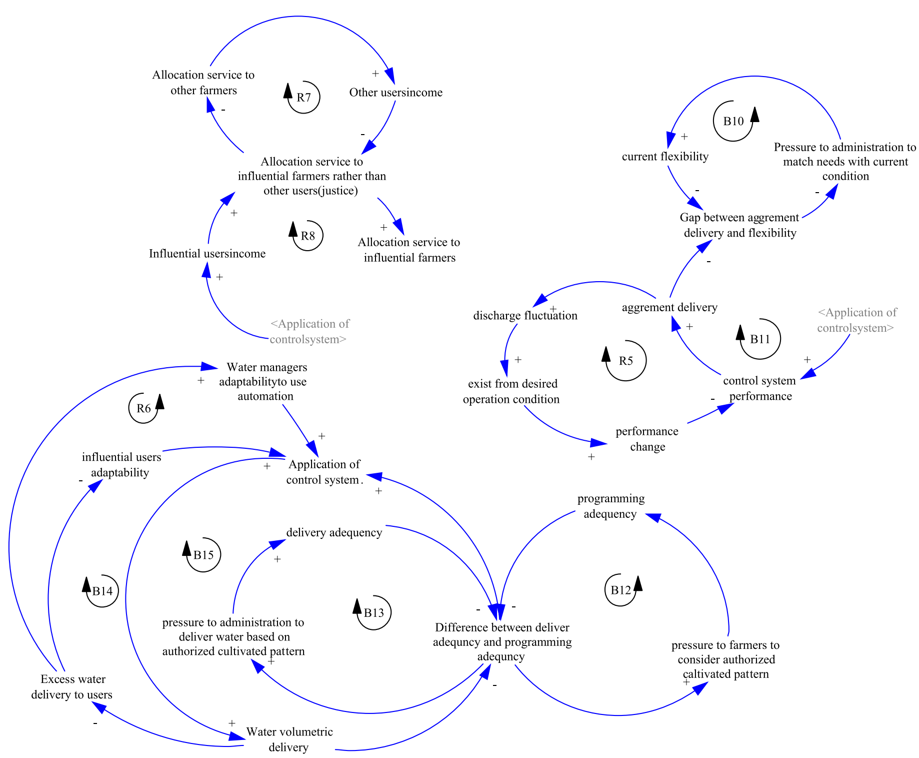


Figure 13. The conceptual model of automation system application in irrigation networks (continue). [Colour figure can be viewed at wileyonlinelibrary.com]

of control systems has some undesired social and managerial consequences such as destruction of control systems and unsuitable maintenance and repair measures. These consequences have a negative effect on control system performance (R1 and R2 loops) and consequently on utility.

B3 and R3 loops. High utility could result in agricultural development by farmers which means they increase the cultivated area or change the crop pattern. Therefore, a water demand increase and some of the water demand could not be answered by current water resources (unanswered demand). Farmers try to supply the needed water illegally either from underground water or by stealing water which reduces overall utility (B3 loop). On the other hand, more agricultural development could lead to more application of control systems (R3).

B4 loop. The gap between water demand and water delivery could affect adequacy and yield performance. Improvement options such as farmer training or better management could increase yield performance and farmers' adaptability which in turn increase the utility (B4 loop).

B1 and B8 loops. The problem in irrigation networks is the gap between desired and current utility. To reduce this gap, measures such as application of automated systems or other modernization options could be taken (B1). If these measures have a good performance, utility will increase and the gap reduces. On the other hand, when the gap is great, there is pressure on administrations to try to match needs with the current condition (utility) (B8). This means that the current condition satisfies managers and no more effort is made to attain greater utility.

B6 and B7 loops. Each control system has a certain desired performance. After application of the control system, control system performance could be changed as a result of limiting factors such as maintenance, operation, etc. Therefore, there will be a gap between current and desired control system performance. To reduce this gap, two solutions could be applied:

- applying pressure to match needs with the current condition means that lower performance is accepted as the desired control system performance (B6);
- applying supplementary measures to improve control system performance which could increase current control system performance and reduce the gap (B7).

R4 and B9 loops. Based on the shifting the burden mechanism, after some time the problems of application of control systems such as lack of maintenance and operation, and destruction of control systems, will appear. Managers try to apply some other simpler modernization measures to increase utility when faced with these problems (R4). The other modernization measures could increase utility (B9).

Important issues in the developed conceptual model are social, managerial, economic, technical and water resources. The model has been developed for Iranian irrigation networks. This means that the quantified SD model of each irrigation network could be developed based on the proposed conceptual model, and the irrigation networks could be investigated under different scenarios which helps better decision making for automated control system application in the networks.

CONCLUSION

In this paper, the conceptual model of automation system application in irrigation networks was developed using an SD approach. First, possible mechanisms in the application of automated control systems were assumed by the authors, including the social and managerial consequences of application of automated systems (Figure 3b), a volumetric water delivery mechanism as a capability of the automatic control system (Figure 4), limit to growth mechanisms regarding legal, financial, technical and water resource limitations (Figure 5b), an eroding goal mechanism in control system performance (Figure 6a), an eroding goal mechanism in the utility of the irrigation network (Figure 6b), a mechanism of other modernization measures application (Figure 7a), an agreed upon delivery and flexibility mechanism (Figure 8) and an allocation of service mechanism (Figure 9). In the next step, both questionnaire and interview techniques were used in order to collect data in six irrigation networks in Iran. The interviewees were experts from the Iranian Power Ministry and managers and operators of irrigation networks. Except for two assumed mechanisms, other mechanisms are approved. The two unapproved mechanisms were the volumetric water delivery mechanism in irrigation canals as a consequence of application of an automatic control system (Figure 4), and the mechanism of other modernization measures application (Figure 7a). The two mechanisms were modified based on interview results as shown in Figures 10 and 11. The finalized conceptual model includes the fixes that fail, limits to growth, eroding the goal, success to successful and shifting the burden archetypes. The most important issues in the developed conceptual model are to consider the interactions between the social, managerial, economic and technical components of the system in the long term. The developed model could be used to test different policies for application of automated control systems and to quantify their consequences in the next steps. Because the conceptual model has been developed based on various Iranian irrigation networks with different situations (such as climate, management, culture, water resources, etc.), the developed model could be applied to all Iranian irrigation networks.

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