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Combining Soft Systems Methodology with Interpretive Structural Modeling and System Dynamics for Network Orchestration: Case Study of the Formal Science and Technology Collaborative Networks in Iran

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Abstract
The orchestration of collaborative networks plays a fundamental role in shaping and configuring network cooperation and ensuring the success of a network. Despite a notable number of studies conducted, the issue of orchestrating collaborative networks and establishing a relationship among their diverse and dispersed components has not been designed and developed in the form of a coherent model. The purpose of the present study is to cast light on the process of determining the dimensions of formal science and technology collaborative networks in Iran. Soft Systems Methodology (SSM) was utilized due to its high capability to deal with the dynamic complexity of the problem, the various stakeholders and actors involved, and the conflicting interests of these stakeholders. Accordingly, in addition to investigating and interviewing the informants and obtaining a rich picture of the situation, interpretive structural modeling (ISM) was used to design a conceptual model. The results show that in order to improve the problem condition and achieve an effective output of the network, the communication processes of the founding organization, Steering Board, the network leaderboard, and the members should all be subject to proper changes at the right time. Finally, in order to facilitate the analysis of effective variables and the role of the orchestrator in the formal science and technology collaborative networks in Iran by using System Dynamics (SD), a dynamic model was proposed. According to the obtained results, the orchestrator's ability, trust and motivation of network members, the socialization process of members, and network sustainability are among the most important factors in network orchestration.

Keywords Collaborative network · Network orchestration · Soft systems methodology · Interpretive structural modelling · System dynamics

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Introduction

Designed to bring about innovation, networks have become a widespread phenomenon with the advent of evolutionary economics (Nelson and Winter 1982). Networking is considered as one of the main functions of an innovative system (Hekkert and Negro 2009). Many industrial countries have recognized the importance of such networks in the development of innovative capacity, international competitiveness, and wealth creation (Rampersad et al. 2010). In the formation process of official networks, potential network members are so distant that they cannot realize how many interests they share, especially when they do not develop strategic relationships with each other prior to forming a network of members. Therefore, a new entity or role is required to inform potential network members about the degree of codependency and the level of common interests; in doing so, the establishment of a network formation is contextualized and becomes clear to all. Managing networks is the key to collaboration and learning. Hence, an in-depth analysis of different aspects of the orchestration process of these networks can provide policymakers and science and technology executives with important insights.

In developing countries like Iran, limited information and statistics on the status of networks is available. On the other hand, most studies conducted in the field of network orchestration are limited to recognizing the tasks and capabilities of the network orchestrator and to analyzing network orchestration with a comprehensive approach. Therefore, a more exhaustive study is required to analyze the main elements of the network and relationships among its components. In this regard, there are three categories of analytical levels regarding networks: dyad, node, and network (Borgatti et al. 2013). Most studies have addressed the problem from an organization's perspective. Therefore, a general view of the network level that encompasses a broad spectrum of participants in the network is overlooked (Provan and Milward 1995).

Three orchestration processes that a hub firm must perform include managing knowledge mobility, innovation appropriability, and network stability (Dhanaraj and Parkhe 2006). Levén et al. (2014) examined the challenges of network orchestration. Introducing the concept of cooperation in the field of ecosystem innovation network orchestration, Mankevich (2014) presented a number of suggestions for the development of network management practices by examining existing challenges.

Hurmelinna-Laukkanen and Nätti (2017) examined a number of capabilities such as operational role-implementation, role-switching, and role-augmentation capabilities of an orchestrator. Parks et al. (2017) investigated the failure of network orchestration blocked by peripheral actors like governments. Hara et al. (2017) shed light on the anti-diesel car campaign led by the Tokyo Metropolitan Government (TMG) in Japan. More importantly, due to this campaign, the network orchestration concerning diesel cars faced extreme difficulty. To carry out the analysis, this study employs persuasion strategies (different types of theorization) offered from an institutional perspective. The novelty of this study lies in proposing the necessity to reconsider the existing treatment of boundary concerning the whole picture of network orchestration.

It is important to note that networking is not simply done by physically combining the components of a network; proper placement of the components, their interaction and collaboration, and the continuous growth of components by the synergies achieved through these interactions are the main characteristics of a real network. Therefore, network management should be equipped with special capabilities that are different from organization management and must be able to overcome network challenges. These challenges have been addressed by some authors. Provan and Kenis (2008) proposed that network managers operating within each section must recognize and respond to three basic tensions, or contradictory logic: efficiency versus inclusiveness, internal versus external legitimacy, and flexibility versus stability. McGuire and Agranoff (2011) stated that the constraints and challenges of network management included operational constraints, performance constraints, and bureaucratic restrictions. Aarikka-Stenroos and Ritala (2017) identified the challenges of network management as follows: the changes in (a) wider cooperation, (b) the processes of exchange management, (c) methods and management tools, (d) the speed of interactions, and (e) increased dynamism.

Generally, network management challenges are more complex and different than the challenges facing enterprise management (Kleindorfer and Wind 2009). To overcome these challenges, it is required to know the position and structure of the network. However, in developing countries like Iran, information and statistics about the network are limited. Thus, despite the passage of two decades following the emergence of networks in Iran, the network management structure has been underestimated, which is the reason why there is a considerable research gap in this regard.

Contrary to the studies conducted in the field of collaborative networks, the issue of network orchestration has not been considered as a system, taking into account all stakeholders and dynamics in this field. Therefore, in this research, by applying a Soft Systems Methodology based on appropriate structures to the network orchestration problem, which has different stakeholders and dimensions, it is required to find more precise solutions to this problem.

Lastly, we offer suggestions for structural reforms and the dynamic model of network orchestration.

In order to analyze the orchestration system of formal science and technology collaborative networks in Iran, the following questions are raised:

A: What are the components of the orchestration system of formal collaborative networks in Iran?
B: What is the definition of the orchestration system of formal collaborative networks?
C: How should the relationship between these components be defined for functional coherence and achievement of optimal efficiency?
D: How does the macro implementation process of the functions of the orchestration system of formal collaborative networks play out?

Therefore, answering research questions can help reduce the research gap existing in the field of formal science and technology collaborative networks and guide managers and policymakers.

Formal Science and Technology Collaborative Networks

According to Tidd and Bessant (2009), networks are composed of a set of ties or nodes to which individuals, companies, business units, universities, governments, and customers can be assigned. In addition, they argued that based on a resource-based approach, the purpose of a network is to engage companies in building a network that yields a common profitable result.

According to INT, a network of companies represents any group of related companies or actors that are interconnected (Hakanson and Snehota 1995). The networking approach in the field of science and technology activities has also been addressed in various sectors, including the creation of networks of experts, laboratories, libraries, etc. Collaborative networks represent a heterogeneous set of organizations with different, yet dependent, competencies. They effectively combine the most appropriate set of skills and resources for a period of time in order to achieve a common goal and utilize the information and communication technology to coordinate and support their activities (Chituc et al. 2008). The formation of science and technology collaborative networks has been one of the main strategies of advanced and developing countries for presenting new technologies that aim to develop networking infrastructure and reinforce national capacity-building measures so that science and technology development can be ensured (Asadifard et al. 2017).

The networking approach can be used in all science and technology chain loops, starting from a basic idea and ending with the production of wealth in the market. For example, networking in the research phase is described as “scientific parks”. In the industrial stage, especially for small- and medium-sized enterprises, it is described as “industrial clusters.” Cluster development and networking play a pivotal role in improving collaborative science and technology (Mihajlovic 2014). Small- and medium-sized enterprises can upgrade their capabilities through networking or cluster development because of financial and marketing constraints (Herliana 2015). Governments play a key role in the success of clusters and networks (Porter 2000). In Iran, efforts have been made to develop clusters and networking in the field of science and technology; however, more effort is still required.

Generally, networks are divided into structured and unstructured networks (Inkpen and Tsang 2005). Tidd and Bessant (2009) divided networks into formal or informal ones. In a structured network, the role of network members and their relationships are clearly defined, and they are organized to achieve a specific goal, while it is not the case for the unstructured networks. Science and technology collaborative networks, which are also the subject of our study, can be classified according to two types of formation patterns. In the first model, networks are formed spontaneously and informally (from bottom to up) based on the need for the participation of participants; in the other model, networks act as a policy-making tool, which are subject to the government’s interventions (often a policy-maker) as in an official organization (From top to bottom). In Iran, science and technology collaborative networks have often followed the second model. In this project, studied networks are of structural and formal nature. Formal collaborative networks are usually configured and formed by a larger public or private organization (Wixted and Holbrook 2008).

Network Orchestration

In networks, the orchestrator should possess enough capabilities to act decisively in different situations; therefore, the orchestrator should be prepared to play diffrent roles such as (a) being a key actor, (b) a startup organization manager, (c) a network orchestrator (Dhanaraj and Parkhe 2006), and (d) a network governance character (Dal Molin and Masella 2016). In general, the shaping and configuration of the network depend on how members are selected, their relationship with the orchestrator, and the relationship of each member and the orchestrator (Levén et al. 2014).

In this research, the model of Dhanaraj and Parkhe (2006) is considered as the base model for the network orchestration. This model is one of the most comprehensive models in this field and has many references (Hurmelinna-Laukkanen et al. 2012; Hu and Sørensen 2012; Gardet and Mothe 2012; Klerkx and Aarts 2013; Levén et al. 2014; Mankevich 2014; Milwood and Roehl 2018).

Figure 1 shows the orchestration process of the networks.

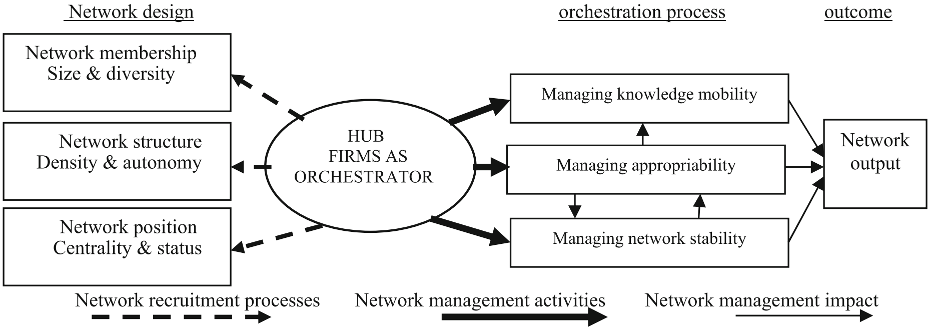


Fig. 1 A Framework for orchestration in innovative networks (Dhanaraj and Parkhe 2006)

The orchestrator plays a crucial role in the abovementioned two main stages, ultimately yielding the output. The initial stage consists of three main roles: a) the selection of members and type of network connections b) network structure, and c) network position. In the second stage, after creating the network (when network is running), the orchestrator is responsible for (a) managing knowledge mobility, (b) innovation appropriability, and (c) network stability.

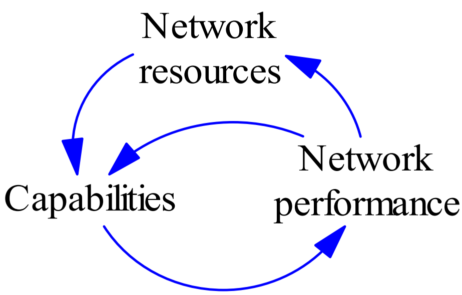
The Role of the Orchestrator in a Collaborative Network

With regard to the orchestrator's role in the networks, it is noteworthy to point out that network management is greatly different from the organizations' management. The first task of orchestration is to ensure the transfer of knowledge (Dhanaraj and Parkhe 2006). Knowledge mobility implies ease of sharing, acquiring, and deploying knowledge within the network. The orchestrator can enhance knowledge mobility by strengthening the identity of the members of the network.

Another function of the network is appropriability as an environmental feature, which is related to the ability to control an innovator in order to capture the profits generated by innovation and reduce the potential of illegal imitation by tools such as patents, copyrights, and trademarks. The orchestrator must ensure that the activities of the members of the network are developed within a broad and agreed-upon framework, in which there is no attempt to cheat by the partners.

The other task of the network is stability management. Gardner (2011) considered network resources, network capabilities, and its performance as necessary elements in a cycle to ensure the success and sustainability of the network (Fig. 2).

Fig. 2 Balancing resources, capabilities, and performance (Gardner 2011)



Considering the strategic choice of partners and members, the orchestrator can significantly control network membership (size and variety) and network structure. If network members are abused, they will stop supporting the network and end their relationship with abusive members.

Methodology

The Methodology of the Research

In order to carry out the analytical stages of this research, it is necessary to identify a new methodology. The plurality of views and the social structures involved are identified and taken into account in certain steps. This paper introduces a multi-methodology composed of soft systems methodology, ISM, and SD for analyzing the orchestration model of formal science and technology collaborative networks in Iran. Based on the reviews of operations reserach paradigms, the optimization paradigm is the origin of the rigorous hard approach to operations research, while the interpretive/learning paradigm is the origin of the soft approach to operations research. The learning process that SSM suggests can be implemented through complex social processes such as management processes. In this approach, processes are mostly of learning such that attempts are made to present technical solutions to the problem.

Soft system methodology is one of the most important approaches of soft systems thinking (Louis Flood 2010).

The findings show that the application of SSM has expanded to a new extent such as sustainable development, knowledge management, and project management (Hanafizadeh and Mehrabioun 2018).

The soft system method is presented in seven steps, as shown below (Fig. 3).

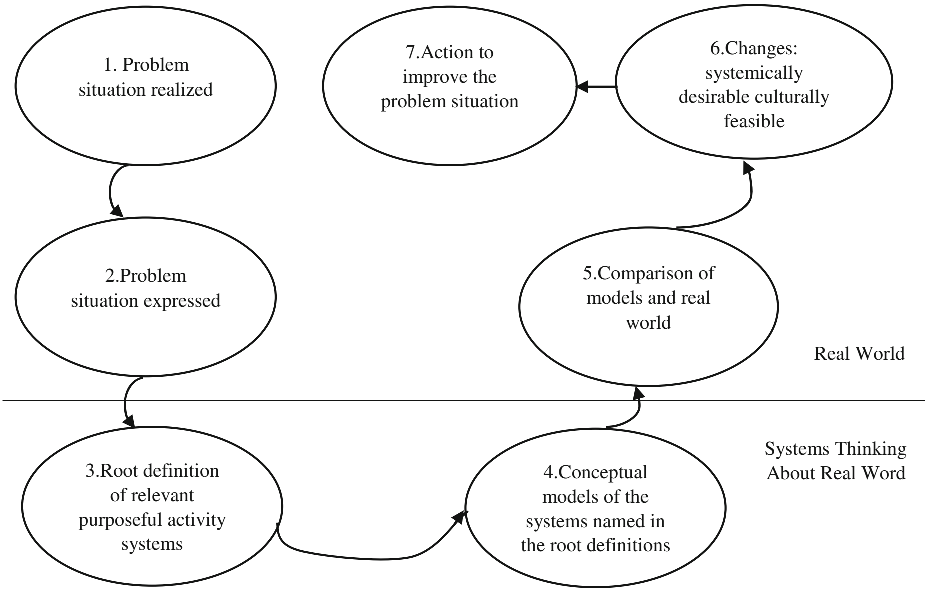


Fig. 3 The conventional seven-stage model of SSM (Checkland and Scholes 1990)

Soft Systems Methodology (SSM) has been criticized for lacking guidelines necessary to make rich pictures (Rosenkopf et al. 2001). Failure to provide instruction for managing the implementation process of real-world changes is another aspect of SSM that requires to be reworked (Rodriguez-Ulloa et al. 2011). According to Holwell (2000), the SSM method should be developed by further research. Due to the lack of information on the variables of the network orchestration system in Iran and the weakness of SSM in providing a specific framework for modeling, in this research, the ISM method has been used to identify the variables and compose the model. This provides a more specific framework for composing the model. ISM transforms the weak and vague mental models of systems into well-defined transparent models that are beneficial for many purposes (Warfield 1974). ISM enables individuals and groups to establish complex relationships among a large number of elements in a complex decision-making situation and acts as a tool for organizing and directing the complexity of relationships among variables. This technique begins by identifying those variables associated with the problem, determining the underlying relationships between the variables based on the experience and practical knowledge of the experts, and ultimately identifying the multi-level structural model (Faisal et al. 2006).

The multimethodology is designed according to the objectives of this research and available information on the formal networks of cooperation in Iran (Table 1). The main framework is SSM; ISM is used to compose a conceptual model (problem-driven model), and SD is used to produce the final model (Solution-focused model).

Case Study

The sample was selected on the basis of the definition of a formal science and technology collaborative network and judgment sampling. These networks have been created by a governmental institution in the field of scientific and technological cooperation and are currently among the most active networks in Iran, with all their components and processes being formed. In general, the most active official networks of cooperation in Iran have been formed in the Ministry of Health, the Ministry of Science, and the Vice Presidency for Science and Technology (Table 2).

The interviewees consist of three groups of managers and informants of 5 formal science and technology collaborative networks in Iran:

Group 1: Informant of the founding organization who has been present from the beginning of the formation of the studied networks in the formulating and policy-making process to the end.

Group 2: Heads of studied networks.

Group 3: Managers of member organizations in each network (based on judgment sampling, managers of organizations active in the network who, in addition to the experimental work, have also scientifically mastered the subject).

Generally, data collection about networks was conducted through primary and secondary sources. In the primary data, we directly asked the informant or studied the actual behavior of the networks. In our secondary data, we collected data that were already available. Secondary data were often simpler and faster to collect, yet limited in scope (Borgatti et al. 2013).

In this research, necessary information has been collected in two ways. First, in the library study, books, articles, theses, and internet texts and documents were reviewed. While identifying, studying, and developing theoretical foundations, literature and subject matter were

Table 1 The steps of the proposed multi-methodology

Steps	SSM	ISM	SD	Explanation
Problem Situation and Problem Expressed	Analyze the problem and identify stakeholders and their relationships			SSM analyzes the problem with an interpretive and phenomenological approach
Rich Picture & Root Definition	Provide root definitions based on the SSM structure and CATWOE analysis			SSM has a specific framework for this section
Conceptual Model		Identify and level variables and, then, present the final model		SSM does not express the exact construction of a system; however, ISM provides a complete method for composing a conceptual model. The hybrid model provides a comprehensive view of the problem situation in all stages of the modeling process (Problem-driven model)
Comparison of the concept model and the real world	Describe the reality by using epistemological terms			The combined approach in this study ensures that, in reality, the system gives meaning to the systems
Necessary action			Establish causal relationships and dynamics and network orchestration system	SSM does not describe how changes are made in real terms and are unable to evaluate possible changes over time in the system. However, SD is more suitable for the implementation stage and is able to measure and evaluate changes over time. (Solution-focused model)

Table 2 Profiles of the investigated networks

Network	Established year	Founding organization	Modes of network orchestration	No. of interviewees
Molecular medicine network	1999	Ministry of Health and Medical Education of Iran	Lead Organization	5
Medical biotechnology network	2000	Ministry of Health and Medical Education of Iran	Lead Organization	7
National network of medical plants research and Technology	2004	Ministry of Science, Research and Technology of Iran	Shared participant orchestration	6
Sha'aa	2010	Ministry of Science, Research and Technology of Iran	NAO	6
Iran high-tech laboratory network	2014	Science, and Technology Vice-Presidency of Iran	NAO	8
Total	–	–		32

studied, too. In order to access the data and information to draw illustrative pictures, informants and network officials and members were given questionnaires to fill and, then, interviewed. Questionnaires, completed by various stakeholders, were used to answer open questions. Those people who have had some influence on the network orchestration system and possessed complete information were interviewed in particular.

Questions About the Founding Organization

What is the current process of network orchestration based on high-level documents?

What are the problems and challenges of formal science and technology collaborative networks in Iran?

What criteria will improve the network orchestration?

Questions About the Network Orchestration

What is the current process of network orchestration and what does an orchestrator do?

What are the problems and challenges of the network orchestrator in network management?

What are your suggestions for improving the network orchestration system?

Membership Questions

What are the overall problems of collaborative network orchestration?

What problems do you encounter in receiving network services and communicating with the orchestrator and other members, knowledge mobility, etc.?

What are your preferences for improving the network orchestration system?

Afterwards, by analyzing the information obtained from the questionnaires and interviews, a rich picture that represents the current status of the system and all of the processes, stages, and problems has been illustrated.

The Application of the SSM Method to the Analysis of the Network Orchestration System

Stages 1, 2: Situation and Expression of the Problem

In the first step, the problem is analyzed and, then, by considering the analysis results of the problem, a better grasp of all the factors involved in the problem is obtained, and the views associated with the problem position are considered.

In Iran, science and technology collaborative networks have often been engineered and considered in the country's macro policies and plans in the mid-1990s. Initially, the National Research Laboratories Network of the country was established by the National Council for Scientific Research. Then, networking in the field of science and technology in the country was formed in the Ministry of Health and Medical Education. In the 2000s, a molecular medicine network, a medical biotechnology network, and a a Medicinal Plants and Natural Products Research Center were established in this ministry.

The National Network of Research and Technology in Medicinal Plants was established in 2004 by the Ministry of Science, Research and Technology, and the Nanotechnology Lab Network was established in 2004 by the National Nanotechnology Initiative. The comprehensive development plan for medical research networks was developed in 2013. According to the statute of the research networks, by the end of 2012, the permit for the establishment of 27 research networks was issued by the Council for the Development of Medical Sciences Universities.

In the fifth and sixth development plans and in science and technology comprehensive map, supporting the science and technology collaboration between universities and research centers both at home and abroad has been emphasized. In 2010, the network of scientific laboratories of Iran started its work in compliance with the policies of the Ministry of Science, Research and Technology. In 2014, the laboratory Network of Strategic Technologies of Iran began its activities with the aim of synergizing the country's laboratory capabilities in various fields of advanced and strategic technologies. This network is currently under development. The country's science and technology network was launched in 2016. The software of this network was titled "Sha'aa" "Science and Technology Network" and was offered to the science and technology parks.

The field of policy and management of science and technology in Iran has witnessed the emergence of collaborative networks over the last two decades. Policy-makers and managers have shown great interest in this topic and have always tried to use the concept for optimal management of human resources, finances, and equipment of the country. The inclusion of the law in the Fourth Development Plan Act (Section C, Article 46) to support the networks has reinforced the mentioned claim. In the budget rules for the implementation of this program (2005–2010), a line was dedicated to supporting networks, and Management and Planning Organization codified and communicated the style guide for cooperation networks of science and technology in 2016. However, with the announcement of this style sheet, many requests for networking have been sent to the planning and management organization; however, in practice, the number of emerging and successful networks has not increased significantly.

Due to the growing spread of science and technology collaborative networks in Iran, some of these networks have successfully developed, some have been disbanded at the beginning, and some others have been fully or partially unsuccessful.

It can be pointed out that there is no proper understanding of the issues of management and orchestration of networks in Iran. Issues that require further study include how the two sides of a relationship adapt themselves to the changing environment, or what motivation one requires to adapt to the links so as to maintain growth and continuous improvement. Other issues include how network members adapt to the changing environment and the preservation of the members' motivation for continuous collaboration.

Sometimes, in Iranian networks, it is mistakenly assumed that the participants reach their goals as long as the relationship exists, and failure of the network is considered as a termination of the relationship. In some networks, despite the lack of cooperation, members' relationships continue in the network. Creating collaboration can be difficult and costly; therefore, when it comes to collaboration, the parties may be reluctant to cause disturbance.

Another challenge of collaborative networks in Iran occurs when a number of network members are very close to each other so that information circulates only within a small group, which will weaken the knowledge mobility in the network. Information that only passes through the same members may result in 'locking' in the network. The opportunistic behavior of some network members is another serious challenge (Belussi and Arcangeli 1998).

The success of collaborative networks is dependent on the orchestration system, which is always faced with various challenges, and this is particularly noticeable in developing countries, especially Iran where networks have not yet reached maturity.

In this regard, the two following questions arise: How do the differences in management structures affect the orchestration of science and technology networks in Iran? and what are the challenges of the orchestration of formal science and technology collaborative networks in Iran? Therefore, it is necessary to study the orchestration problem of collaborative networks and their main elements and existing relationships.

Rich Picture

Rich pictures are large drawings that provide images of the nature of the problem as they are perceived to the senses (Jackson 2003). The drawing of a rich picture provides a forum that gives one several moments to ponder over about a given situation. Researchers are allowed to use various graphic signs to help the reader by explaining the essential parts of an image (Bell and Morse 2013). In the production of a rich picture, the informal goal is to discover the original elements, structures, and views in a single position. One of the most important factors in managing effective organizational processes is identifying the needs of stakeholders. Stakeholders are individuals or groups that make any decision in line with their desires and expectations.

The rich picture of the present study is based on a visual representation of actors and their relationship at three levels of supervisory, intelligence, and financial relationships. In other research studies, the communicative relation is usually considered at a single level. Sepehrirad et al. (2017) depicted their rich picture as a cycle of stakeholder relationships. Many studies illustrated their own version of a rich picture as a general picture of the communication among stakeholders (Karake Shalhoub and AlQasimi 2005; West and Braganca 2012; Torlak and Müceldili 2014; Hanafizadeh and ValiZadeh 2015).

In the present research, based on the conducted interviews and analysis of various networks, the main elements of the orchestration system of formal science and technology collaborative networks in Iran are as follows: (Fig. 4)

1. The founding organization (the relevant government agency): According to the high-level documents, the task of establishing a network is to formulate and monitor network policies and budget and specify network position at a macro level.
2. Network Orchestrator: Selected by the Steering Board as Network Administrator and tasked with implementing policies and reporting, appointing network secretary, contracting with members, resolving conflicts, managing communication, managing innovative output, offering guidance, and handling network navigation.
3. Network members: Individuals and organizations that are members of the network in accordance with the network's statutes and operate in line with the network's goals,

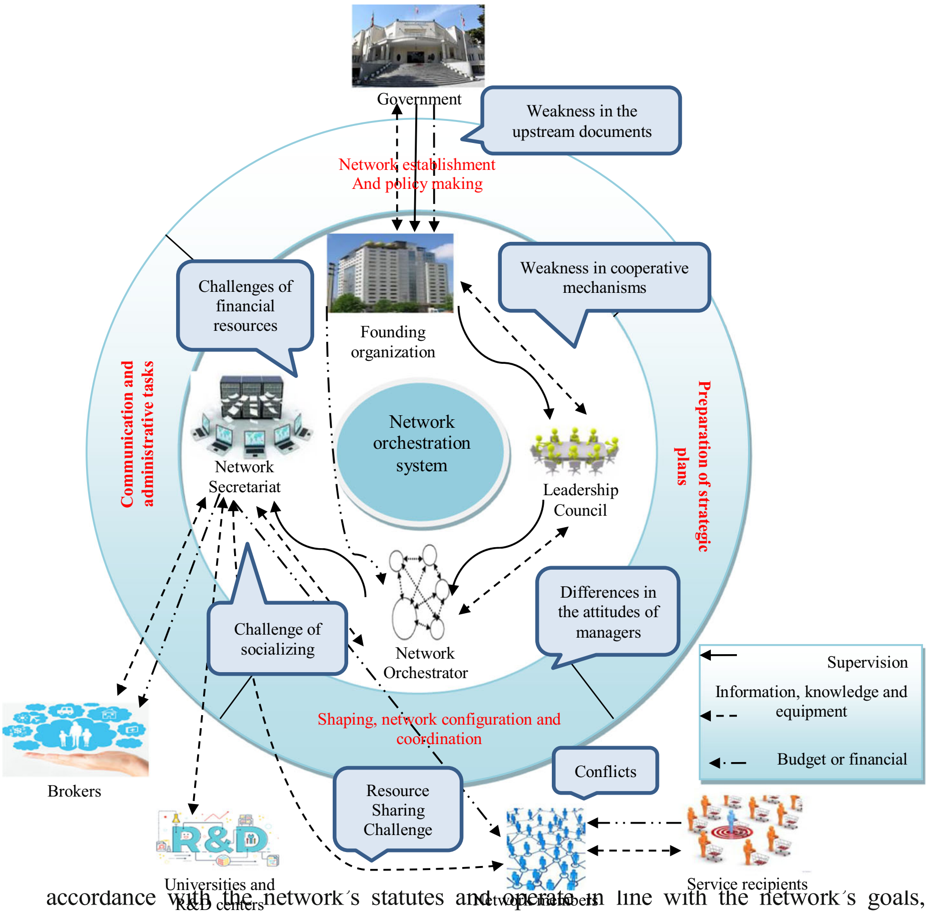


Fig. 4 Rich picture of the current situation of network orchestration system

communication, and collaboration with other members, sharing supplementary capabilities (information, knowledge, and equipment), and common projects.

The other following elements are also defined in this system:

Government: The role of policymaking in Iran's National System of Innovation
Network Steering Board: Developing strategic plans, choosing a network orchestrator, monitoring the network orchestrator, and setting priorities for work.
Secretariat: The intermediary between the orchestrator and the members who performs administrative, communication, and financial affairs.
Network Broker (agent): An organization that serves the network and its members in response to network requests.
Service recipients: Individuals or organizations that use the services and outputs of the network.
Universities and research centers: The organizations providing research advice to the network.

Stage 3: CATWOE Analysis & Root Definition

In the current stage, the soft system methodology is detached from the real world and is instead applied to the world of systems, thus explaining the root definition from various perspectives. The root definition represents the problem, and any root definition is indicative of a particular worldview (of each stakeholder). Then, the validity of the root definitions is examined by the CATWOE analysis.

PQR Formula

The PQR formula stems from the Soft Systems Methodology (SSM) in which it is used as an aid to express a root definition: a statement written in a few sentences capturing the intention of someone's worldview (Checkland 2000). The table below shows the factors analyzed by the PQR formula (Table 3).

Table 3 PQR formula

Attitudes PQR formula	Founder	Orchestrator	Members
What (P)	Network guidance	Network Orchestration	Network membership
How (Q)	Through macroeconomic policy-making, infrastructure development, financing and budget, intellectual property, and definition and sense-making of network status at a national level	By managing the network	Through network membership and Network Cooperation
Why(R)	Growing and developing network cooperation for high-level goals	Network development and evolution	Benefiting from Network Advantages

Table 4 CARWOE elements and their definition

CATWOE	Founder's view	Orchestrator view	Network members' view
Customers	Strategic Council and Network Orchestrator	Network members	Service recipients Other members
Actors	Minister and Founders Organization	Network Orchestrator and Strategic Council	Directors and members of member organizations
Transformation process	Compilation of macro policies and budgeting	Execution of codified policies	Activities in line with network programs
World view	Founder: Large policies increase efficiency and effectiveness	Orchestrator's capabilities to manage the network and solve related challenges	The existence of a networked orchestration system with defined relationships can increase the trust and motivation of members and their collaboration.
Owner	Government	Government	From one standpoint, while retaining independence for each member, the company's owner is the owner of the system; however, in the network, the government is the owner of the network.
Environmental constrains	Values and structure of the National System of Innovation, a variety of upstream documents, government attitudes, limitations on financial resources, legal problems, and legislative institutions	Laws, economic and cultural problems, norms, attitudes of managers and members, and a variety of upstream documents	Opportunistic behavior by other members, Poor cultural perspectives on network collaboration in Iran, The weakness of system and platform for network collaboration

CATWOE Analysis

According to the conducted interviews, the six following elements that should be considered in each root definition are extracted from the standpoint of all three perspectives (Table 4):

A better perception of the six elements helps us reach the root definition. The root definition is actually a statement that describes the ideal state of the system. This is a strong base definition for another output called a model of targeted activity or a conceptual model (Jackson 2003).

Root Definition

Root Definition 1 (Viewpoint of the Relevant Governmental Bodies - Founding Organization) An organization or a government agency that acts legally and on the basis of high-level records to establish a specific network and appoint a manager. From the standpoint of the founding organization, the most important challenge is taking the correct direction of the network toward the pre-set macro goals. In this regard, large-scale policy-making, budget system schematization, network performance examination by network chiefs are among the most important factors.

Root definition 2 (orchestrator view): The person or persons responsible for the orchestration of the networks. Obviously, the quality and level of authority and responsibilities vary in different networks. The orchestrator of the network acts as the executor of the high-level goals set within the framework of a regular and coherent program. Therefore, the orchestrator must manage everything from recruiting to accessing innovation, maintaining network sustainability, facilitating the knowledge mobility in the network, solving conflicts and opportunistic behaviors, creating an atmosphere of acceptance and building trust in the network, etc.

The network's orchestrator must have sufficient knowledge of the set goals, networking, and notable capabilities. Orchestrating a network is very different from running an organization. Therefore, the network orchestrator should constantly add the most appropriate decision-making methods to ensure the effectiveness of the process by mastering and improving technical knowledge in various fields.

In Iran, three types of network orchestration structures have been identified. Thanks to the detailed study of the networks and based on experts' opinion presented in this research, the type of orchestration structure of each of the studied networks is specified (Table 2).

> Shared participant orchestration: This form is orchestrated by the network members themselves with no separate and unique entity governance.
> Lead Organization: When one organization has sufficient resources and legitimacy to play a lead role.
> Network Administrative Organization: Separate administrative entity is set up specifically to orchestrate the network and its activities.

The capabilities of the orchestrator are identified as in a causal loop diagram (CLD) in the dynamic model (Fig. 7).

Root definition 3 (member organizations view): The individuals from all the companies who are members of the network according to the rules and regulations of the network while maintaining their independence within the framework of the network. In terms of member organizations, receiving network services, enhancing supplementary capabilities, and participating in network-level decision-making are the most important issues. According to the concluding results, one of the research questions will be answered as follows:

> **What is the root definition of the orchestration system of formal science and technology collaborative networks in Iran?**

The orchestration system of the formal collaborative network includes sub-systems of the founding organization, the Steering Board, Network Head, Secretariat, and network members, which are a set of targeted actions to create value and effective output for the network. Therefore, in the orchestration process of collaborative networks, the following issues are considered:

- How does the process of recruiting a diverse set of members in the network take place?
- How is collaborations for shaping new relationships and strengthening existing relationships managed?
- How is a legitimate and convenient position for the network created?
- How are members motivated to share resources and transfer information and knowledge?
- How is the financial and intellectual benefits of networking among stakeholders shared?
- How is a long-term commitment and cooperation established?
- How is network stability maintained and total or partial failure prevented?

Conceptual Model

In the previous step, the analyst utilized the root definitions to understand the current system and express "what it is". In this step, the analyst uses the results of the previous step to answer "what the system should do". In order to achieve this goal, a conceptual model must be created for each of the root definitions. Since the soft system methodology has drawbacks and weak points in the conceptual model, the application of a combined (hybrid) method and soft systems can help map the model more accurately. Some researchers have used a combination method in their research. For instance, Soft System Dynamics Methodology (SSDM): Combination of Soft Systems Methodology (SSM) and System Dynamics (SD)) (Rodrıguez-Ulloa and Paucar-Caceres 2005; Rodriguez-Ulloa et al. 2011), Combination of Soft Systems Methodology (SSM) Techniques and Data Envelopment Analysis (Hoga et al. 2003), Combination of discrete event simulations and soft systems methodology (Holm 2013).

In this research, interpretive structural modeling has been used to map the model. Interpretive structural modeling is a method for creating and understanding the relationships between the elements of a complex system.

ISM contributes greatly to arranging complex relationships between elements of a system and helps identify the internal relationships of variables. In addition, it is an appropriate technique for representing the interrelationships among various elements associated with the issue.

Different stages of the ISM are presented as follows:

Step One: the criteria and/or elements (the governance variables of the collaborative network) are listed. By studying the previous research and opinions of experts and conducting open-ended interviews and several screenings, 16 final factors are identified as follows (Table 5):

Initial Reachability Matrix

Step one:

The first step involves obtaining an initial reachability matrix from the SSIM format by transforming the information of each cell of SSIM into binary digits (i.e., 1 s or 0 s). This transformation has been done by substituting V, A, X, O by 1 and 0 as per the following rules.

Table 5 Factors affecting the collaborative network orchestration

Factors	Variable number	Factors	Variable number
C_1	Capabilities of Orchestrator	C_9	The motivation of network members
C_2	Design of cooperation mechanism	C_{10}	Network Cooperation
C_3	Management of resource absorption and sharing	C_{11}	Joint project operation
C_4	relations management	C_{12}	Network stability
C_5	Sharing resources	C_{13}	Internal and external legitimacy of the Orchestrator
C_6	Socialization	C_{14}	Equitable distribution of network output
C_7	Supplementary capabilities	C_{15}	Learning capacity
C_8	building trust	C_{16}	Network output

Table 6 Rules for transformation

If the (i, j) entry in the SSIM is	Entry in the initial reachability matrix	
	(i, j)	(j, i)
V	1	0
A	0	1
X	1	1
O	0	0

Rules for transformation are given in Table 6:

Step Two: In this stage, by applying the criteria or variables identified in the first step, the relationship between them is defined according to each pair of criteria. The content relationship represents a conceptual content link between the components of the system that correlates with the objectives of the system. Then, an SSIM (structural self-interaction matrix) for agents is developed that reveals paired relationships between the factors that affect the orchestration system of collaborative networks in Iran (Table 7).

Step Three: The reachability matrix is evaluated by the structural self-interaction matrix, and the matrix is used for the basic hypothesis transitivity in interpretive structural modeling. Transitivity means that if variable "A" is associated with variable "B" and variable "B" is also related to "C", then variable "A" is also associated with variable "C".

Step Four: By using the final reachability matrix, factorization is performed.

Table 7 Structural self-interaction matrix (SSIM)

	Variables	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
C_1	Capabilities of Orchestrator		V	V	V	V	V	X	V	V	V	V	V	X	V	X	V
C_2	Design of cooperation mechanism			X	X	V	X	O	V	X	O	O	V	X	X	O	O
C_3	Management of resource absorption and sharing				A	V	O	V	X	X	X	X	X	V	O	X	X
C_4	relations management					V	X	O	V	X	V	V	X	X	X	O	O
C_5	Sharing resources						A	X	X	X	V	V	X	O	O	X	O
C_6	Socialization							O	X	X	X	X	V	X	X	O	O
C_7	Supplementary capabilities								X	V	X	X	V	O	O	V	O
C_8	Trust/confidence building									V	X	X	X	A	A	O	A
C_9	The motivation of network members										V	V	A	A	X	X	A
C_{10}	Network Cooperation											V	V	V	O	X	V
C_{11}	Joint project operation												X	O	A	X	V
C_{12}	Network stability													V	A	X	X
C_{13}	Internal and external legitimacy of the Orchestrator														A	O	V
C_{14}	Equitable distribution of network output															V	A
C_{15}	Learning capacity																A
C_{16}	Network output																

Table 8 Final list of level partitions

Variables	Reachability set	Antecedent set	Intersection set	Levels
C_1	1	1	1	V
C_2	1,2,3,4,6,9,14	2,3,4,6,9,14	2,3,4,6,9,14	IV
C_3	1,2,3,4,6,9,14	1,3,4,6,9,14	1,3,4,6,9,14	IV
C_4	1,2,3,4,6,9,14	1,3,4,6,9,14	1,3,4,6,9,14	IV
C_5	1–12	1,3–12	1,3–12	II
C_6	1,2,3,4,6,9,13	1,2,3,4,6,9,13	1,2,3,4,6,9,13	IV
C_7	1–12	1,3–12	1,3–12	II
C_8	1,2,3,4,6,8,9,12,13,14	3,4,6,8,9,12,13	3,4,6,8,9,12,13	III
C_9	1,2,3,4,6,8,9,12,13,14	1,3,4,6,8,9,12,13	1,3,4,6,8,9,12,13	III
C_{10}	1–14	1,3–14	1,3–14	II
C_{11}	1–14	1,3–14	1,3–14	II
C_{12}	1,2,3,4,6,8,9,12,13,14	1,3,4,6,8,9,12,13,14	1,3,4,6,8,9,12,13,14	III
C_{13}	1,2,3,4,6,8,9,12,13,14	1,3,4,6,8,9,12,13,14	1,3,4,6,8,9,12,13,14	III
C_{14}	1,2,3,6,9,14	1,3,4,6,9,14	1,3,4,6,9,14	IV
C_{15}	1–16	1,3,5,9,10,11,12,15	1,3,5,9,10,11,12,15	I
C_{16}	1–13,16	3,8,9,12,16	3,8,9,12,16	I

The leveling is done in the table below (Table 8).

Step Five: The reachability matrix in the fourth step is divided into different levels.
Step Six: Based on the relationships defined in the reachability matrix, the directed graph is drawn and the transitive relationships are deleted.
Step seven: The final diagram transforms into interpretive structural modeling by replacing the node numbers by the variable description written in text boxes.

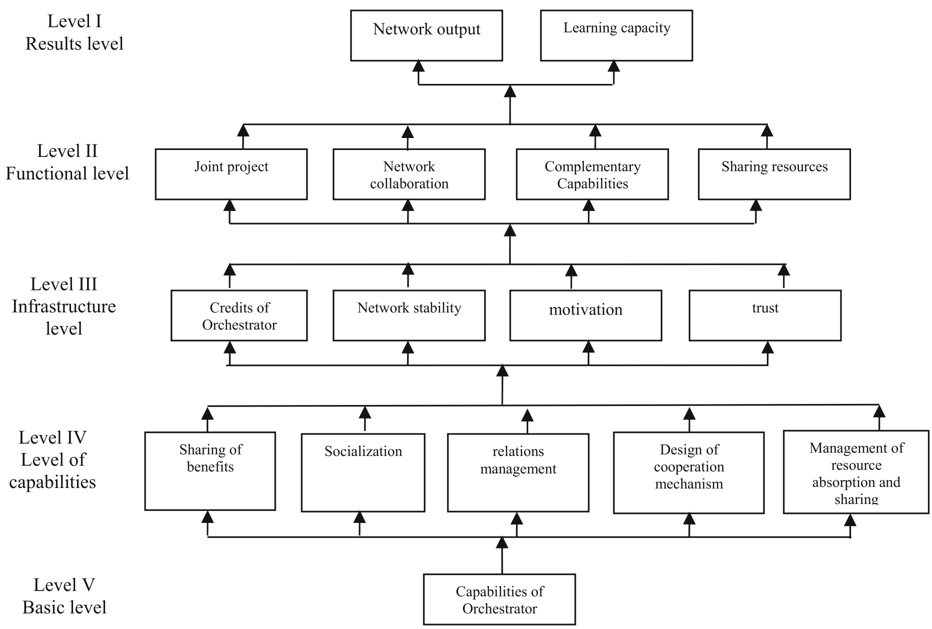


Fig. 5 ISM of network orchestration

Finally, the interpretive structural modeling is developed to prevent inconsistencies in the content. In case of incompatibility, necessary corrections will be made (Fig. 5).

The above-mentioned model illustrates the orchestration process of the formal science and technology collaborative networks in Iran, as illustrated in 5 levels.

The 'Basic' and 'Capabilities' levels represent the capabilities of an orchestrator, which is a substrate for higher levels. At Level III, there are infrastructure variables required for the functional variables and, finally, for network output and Learning capacity. The relationships among these variables are presented as a system in the dynamic model (Fig. 7).

MICMAC Analysis

After determining the priority and status of the driving or dependence power of variables, all involved factors can be categorized into four clusters of Cross-Impact matrix multiplication applied to classification (MICMAC) analysis. Based on the calculation results, the following table briefly shows the driving power and the dependence power of each variable (Table 9).

Finally, the clustering matrix of the effective factors in the network orchestration system is obtained by the MICMAC method, as shown below (Fig. 6):

In this analysis, the variables are divided into four categories in terms of driving and dependence power.

1. Autonomous variables: They have both weak driving and dependence power. These variables are relatively not compliant with the system and have low and poor connections with the system. In this study, none of the variables is in this category. In addition, it is indicated that the indicators are interconnected.
2. Dependent variables: They have weak driving power, yet strong dependence. In other words, many variables are involved in the process. In this research, learning capacity and network output variables are in this category.
3. Linkage variables: These variables have strong driving and dependence power. These variables are very sensitive and unstable because any change in them can affect the whole system. Orchestral function variables, recruitment and subscription management, relationship management, resource sharing, socialization, complementary ability, trust building, network members' motivation, network cooperation, joint project operation, network sustainability, internal and external legitimacy of the orchestrator, equitable distribution of network output, learning capacity, and network outlet fall into this category.
4. Independent variables: They have strong driving power, yet weak dependence power. This category acts as the building block of the model. In the present research, the design variable is a collaborative mechanism in this category.

Table 9 Driving-dependence power

Variable	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
Driving power	16	10	15	15	14	14	14	13	14	14	14	15	10	12	8	**7**
Dependence power	14	8	16	14	14	13	12	15	16	14	15	16	14	9	16	**14**

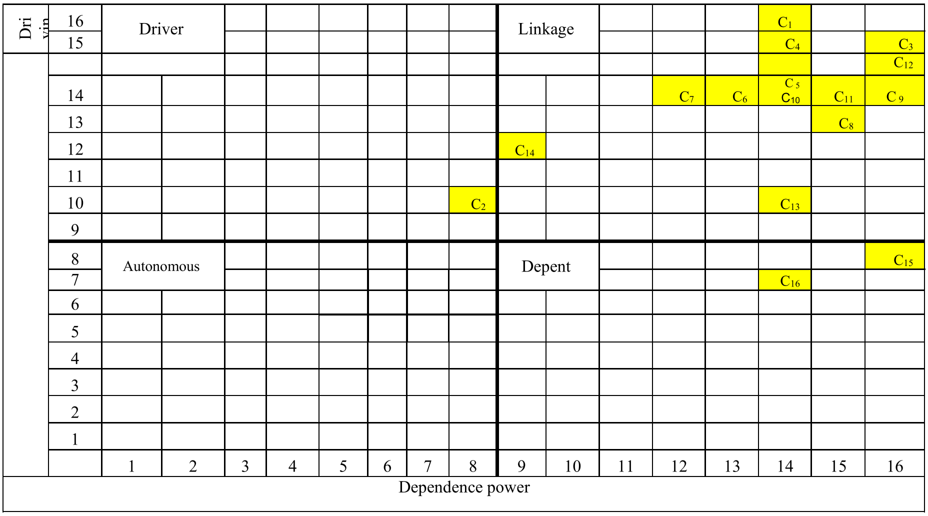


Fig. 6 Driving & dependence power matrix

After designing the model and analyzing the variables of the orchestration of the network, the following steps of the soft system method are performed as follows:

Comparison of the Concept Model and the Real World and Implementation of Necessary Steps

In this stage, the methodology is focused on the real world and analyzes the differences between the conceptual model and the real world. The analyst must propose measures that are socially and culturally feasible to change the situation.

A number of studies have been carried out after gaining knowledge of the current orchestration processes of formal networks and their comparison with the orchestration system (Fig. 5).

The analysis shows that some communications have been formed; however, they need to be improved and strengthened.

One of the weaknesses of the orchestration system of the formal science and technology collaborative networks in Iran is that despite the definition of a financial channel, there is no specific budget line for networks in the country's budget plan; surprisingly, in practice, this financial channel is not active. The high rate of changes in the orchestrator of networks, the lack of a comprehensive map for network evolution, and the low number of meetings of network members together are among the other weaknesses.

In addition, in some networks, members are not motivated to cooperate, and some opportunistic behaviors are also observed. In order to solve the challenges, two proposals are presented:

1. applying changes to the existing process; 2. identifying the capabilities of the network orchestrator that can overcome the challenges.

1-The requirements for designing an optimal system are as follows (Table 10):

The orchestration system of the network has three main components: the founder, the chairman, and members of the network. In addition to these components, there are the Steering Board of

Table 10 Suggested changes for the main components of the network orchestration system

Row	System	Required change	Desired output
1	Network founder	• The need for macro-scale policymaking and mapping of network road map based on specific timeframes and designing a comprehensive network performance assessment system • Budgeting system design • Development of a comprehensive system for recording and analyzing network reports • Considering the specific budget for networks	• Internal and external legitimacy of the Orchestrator • Providing a clear pattern of expected system allowance to help the orchestrator make decisions and perform tasks • Creating internal and external legitimacy for the network • Maintaining network completeness
2	Network orchestrator	• Designing the pattern of the formation and evolution of the network from recruitment to implementation based on the supplementary capabilities of the members and in line with high-level goals. • Single job network head to handle full-time network administration • Designing a two-way communication system between the network orchestrator and the founding organization • Designing a precise cooperation mechanism in the network to create a collaborative atmosphere • Outsourcing network affairs to agents	• Proper and effective communication with the Steering Board and the founder • Effective communication with the secretariat • Socialization • Equitable distribution management of network output • Improving Networked learning • Avoiding stagnations in the members' work and recruitment process • Resolving intra-network conflicts and preventing opportunistic behaviors • Agility of the administrative team of the network
3	Network members	• Establishing effective communication between the members and the network secretariat by certain methods such as joint conferences, breakthrough exhibitions, customer clubs, etc. • Establishing a proper and flexible mechanism to facilitate the reception of network services • Engaging more network members in network-level decision-making and manager meetings • Selecting and encouraging top network members	• Creating and maintaining members' motivation and building trust and, eventually, increasing the willingness to share resources and create additional functionality in the network. • Increasing willingness of members to carry out joint project operations • Network stability

Network, the Network Secretariat, and network service users, which are interconnected with the main components. Therefore, the proposed changes are in line with the main components.

Network Orchestrator Capabilities

Because the orchestration of formal cooperation networks is a process that takes shape over time and involves complex variables and dynamics, a dynamic system is used to draw the model.

The problem is examined by the system dynamic modeling, and the causal diagram is used to identify and highlight the dynamic relationships existing in the problem (Sterman 2000).

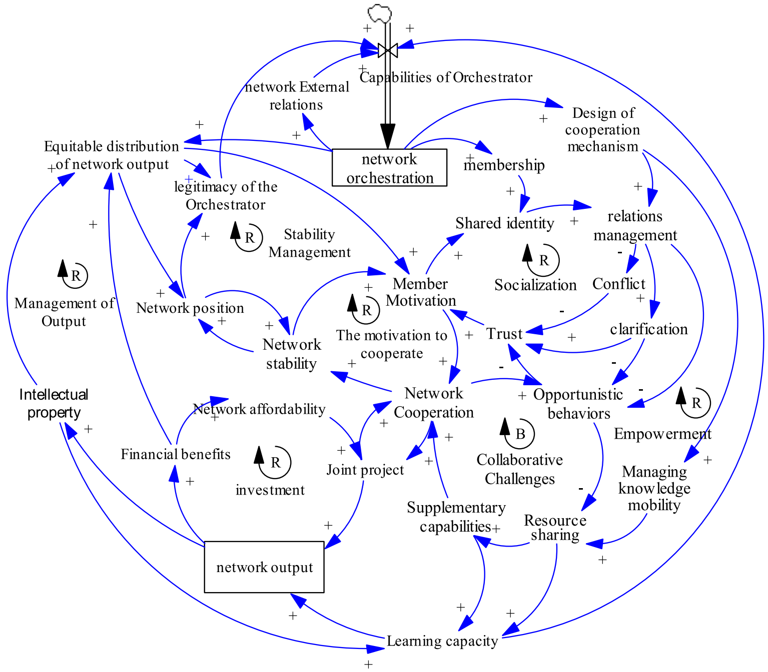


Fig. 7 Dynamic model of network orchestration

A dynamic model of network orchestration is depicted in the form of cause-and-effect loops (Fig. 7). These circles include socialization loop, empowerment, collaborative challenges, motivation to cooperate, investment, management stability, and management of output.

Conclusion

The purpose of this study was to analyze the orchestration system of formal science and technology collaborative networks in Iran. To study the various stakeholders existing in this problem systematically, the soft systems method was utilized to provide a method for structuring complex problems. Based on a variety of stakeholders' perceptions and root definitions, a rich picture of the system was obtained that illustrated the relationships and dynamics among the stakeholders of the network orchestration system.

Afterwards, in accordance with the experts' opinion, 16 main factors were confirmed and selected to design the model, and interpretive structural modeling was used to analyze the relationships between them and present their structural model. These factors were categorized into five levels:basics, capabilities, context, performance, and outcomes.

Based on the results of the ISM, the substructure of formal science and technology collaborative networks in Iran was identified as "orchestrator capabilities" index, which itself included five main capabilities: resource sharing and recruiting management, designing a collaboration mechanism, managing relationships, socializing, and equitable distribution of network output. By conducting the MICMAC analysis, the innovative network output and network learning variables in the domain of dependent variables indicate that they are strongly influenced by other elements of the network orchestration system. In addition, it was shown that in order to achieve the optimal output in the network that leads to network learning, infrastructure and functional variables need to be formed properly.

According to the comparison results of the conceptual model and the real world, it became evident that in order to facilitate the implementation of the orchestrator's tasks in collaborative networks and achieve a common perspective, a multi-dimensional and effective interconnection should be established between the various components of the orchestrator network system. This connection involves the relations of the founder with the Steering Board and the head of the network, as well as the head of the network with the secretariat and members. Möller and Halinen (1999) proposed that to handle a network, the management must understand the interrelationships of the network and provide a general perspective and vision for all stakeholders. The network's vision plan capability represents the ability of the orchestrator to create credible viewpoints and future plans for the network and its potential evolution.

The network orchestration system should make a trade-off between the issues such as pragmatism or the result-orientedness and the flexibility, as well as agility and long-term stability and consistency.

Further, McGuire and Agranoff (2011) considered the challenge of the process versus the results of networks as one of the important challenges for network managers. Kapucu and Montgomery (2006) and Provan and Kenis (2008) considered the issue of flexibility versus stability.

This study recommends that the orchestrator must have enough capabilities to manage the network from recruiting and socializing to achieving network output. In doing so, the needs and challenges that are derived from SSM analysis can be met. These capabilities are located in level IV of the ISM output, whose relationships and dynamics are presented in the form of a conceptual model with SD (Fig. 7).

Therefore, the final model of research is the result of applying the multimethodology presented in this research. In the orchestration of collaborative networks, the orchestrator's capabilities are very important. These capabilities can be developed through network learning. According to experts, an orchestrator should have the ability to design a collaboration and design mechanism to create a climate of trust and collaboration to share knowledge. On the other hand, after forming this collaboration, the orchestrator must increase the members' incentive to continue collaborating with a fair and transparent distribution of network output that includes financial and intellectual assets. Wu (2010) stated the most important task of the network manager was to convert resources into more efficient performance, learning, and sharing. Network stability management is another important factor for continuing cooperation in collaborative networks, which is one of the main loops of the model. Other relationships are visible in the dynamic model (Fig. 7). Due to the rather grand scale of this study regarding the design of a formal collaborative network orchestration system, a detailed design of the system can be studied in further research.

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