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A model for investigating the stability factors in formal science and technology collaborative networks: A case study of Iran

Reza Asadifard [a,]*, Seyed Habiboallah Tabatabaeian [b], Jahanyar Bamdad Sofi [b], Mohammad Reza Taghva [b]

[a] *Technology Study Institute (TSI), Tehran, Iran*
[b] *Allame Tabatabaei University, Tehran, Iran*

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ABSTRACT

In spite of vast studies performed on Science and Technology Collaborative Networks (STCNs) in recent decades, factors affecting the stability of these networks have rarely been investigated. In this study, 6 collaborative networks established between 1995 and 2005 in Iran, in the fields of nanotechnology, biotechnology, molecular medicine and herbal medicine, were evaluated. Conducting a qualitative research, and using multiple-case study method, we collected related data adequately from in-depth interviews with key informants, survey, and archived documents, and identified the stability factors of STCNs. In this paper, a tentative conceptual model is proposed for classification of stability factors in formal STCNs. Employing this model, 27 identified and screened stability factors were classified into 2 main categories; including internal factors (network management, network formation processes, collaboration mechanisms in the network and characteristics of network members) and external factors (collaboration infrastructures and network environment). Designed model was evaluated by conducting an extensive survey which provides feedbacks from the representatives of network members and other informed people on the primary model. In total, 112 individuals from 83 affiliated organizations of 6 selected networks participated in this survey. Confirmatory factor analysis (CFA) method was used to evaluate the goodness of fit of the proposed model which indicated that each structural component of the model has suitable fit, separately. In addition, the whole model offers a good fitting and it can be reliably used to achieve the research goal only by omitting two of considered factors.

1. Introduction

Collaborative networks have been acknowledged as an efficient tool for optimized management of resources (Musiolik and Markard, 2011), knowledge transfer between entities, sharing of assets and reduction of development risks in the industrial, business and economic sectors (Kapucu and Garayev, 2012; Cowan et al., 2004). In the public sector, the implementation and management of public programs through networks have now become more of the rule than the exception (Turrini et al., 2010). It is also useful in science, technology and innovation management domains (Ozcan and Islam, 2014; Musiolik et al., 2012; Musiolik and Markard, 2011). Evidences indicate that since the 1980s, rapid increase in networking at organizational level has been occurred, particularly in high-tech sectors including communications, computations and biotechnology (Hagedoorn and Schakenraad, 1992). In countries such as the United States, Australia and UK, innovation policies have a marked shift from the provision of financial incentives for R&D to the encouragement of multi-sector innovation networks (Corley et al., 2006).

In the available literature on networks, there are major weaknesses in the theories related to network formation and evolution processes (Hoang and Antoncic, 2003), as well as considerations necessary in these processes to obtain adequate network stability. This is because the researchers often presumed that networks have been pre-existed before their investigations (Powell and Gordal, 2004; Jack, 2010). In addition, they rarely discussed about the changes and adjustments took place in a network during its lifetime (Knoben et al., 2006), and most of the studies have been focused on structural aspects of the networks (Turrini et al., 2010). Network studies have been mostly dedicated to more stable networks, and, fewer studies have been conducted regarding failed networks (DeBreeson and Amesse, 1991). For this reason, significant theoretical imperfections can be observed in the context of stability risks and failure factors in the existing network literature.

Literature implies that most papers and books available on networks correspond to “informal” networks. They discuss the different types of collaboration in science and technology domain, including collaboration in research and development projects (for instance see; Rowley, 1997; Schilling and Phelps, 2007). As a fact, a great number of scholars have dealt with networks as virtual structures. Therefore, formal inter-organization (inter-firm) collaborative networks have seldom been investigated (Freeman, 1991; Wixted and Holbrook, 2012). In addition, a great deal of papers on collaborative networks correspond to the industry and business domains which have been evolved in the exchange market; hence, collaborative schemes in science and technology sector have been scarcely investigated (Chompalov et al., 2002). Collaboration driving forces and stability factors in STCNs - frequently supported by public funding - are probably different from business networks.

* Corresponding author.
Email address: reza_asadifard@yahoo.com, reza_asadifard@nano.ir (R. Asadifard)

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Social context is recognized as an important aspect in studying the collaborative networks (Turrini et al., 2010; Zacocs and Edwards, 2006; Jack and Anderson, 2002), so, it seems that the different social contexts lead to differences in network characteristics and functions across various countries. The literature on collaborative networks is mostly restricted to the networking experiences in developed countries (Bignami-Van, 2005; Bangens, 1993), whereas, to our knowledge, the properties and context of these networks in developing economies are generally remained uncovered. This might be related to the fact that, there are few numbers of successful collaborative networks reported from developing countries (Bianchi and Bellini, 1991) and examples of successful networks frequently correspond to the developed countries (Salazar and Holbrook, 2007). The social context of developed countries is more in favor of collaborative networks than developing economies. There are no strong infrastructures (e.g. ICT technologies), enough financial supports, proper organizational culture, and supporting S&T policies (like what exists in EU region) to stimulate collaborative networks in developing countries (Van Dijk and Sverrisson, 2003). Therefore, differences regarding the social context and economic structure of developing countries (such as Iran), must be taken into account more in future network studies. This issue is of vital importance because, as White and Watkins (2000, p. 338) correctly point out, "it is hazardous to generalize from populations with considerable social and economic differentiation [in developed countries] to the less stratified contexts of developing countries". Hence, the present study may contribute to the network literature to add some insights about the real collaborative networks in developing countries.

Therefore, there is a significant gap in theories related to the stability of formal S&T collaborative networks, especially in the context of developing countries.

Since the Islamic Revolution of 1979, the higher educational system of Iran has gone through quantum leaps, both qualitatively and quantitatively. The system enrolls 3 million students every year, 65% of whom are female. In the last two decades, Iran has shown one of the world's highest scientific growth rates, particularly in advanced technologies including nano- and bio-technologies. The number of researchers in the country, which was around 82 per one million in the 1980s, has reached to 1500 per million now. Also, the number of articles written by authors who reside in Iran that are published in ISI journals has increased considerably in recent years, from 682 in 1997 up to 13,568 in 2008, a 20-fold increase in 11 years (Soofi and Ghazinoory, 2011). In order to maintain this growth rate and translation of scientific achievements into implementable technological innovations and also due to the country's limitations in resources, the country is in need of using networking approach for science and technology infrastructures. However, despite great interests in networks and relatively good financial and legal supports, experiences of the past two decades indicate that networks have not been successful enough. Most of the networks in the S&T field in Iran have failed in the early years of their formation. So this question has arisen in the mind of authorities in the field of science and technology that is why these collaborative networks lack desired stability? Therefore, a deep understanding of the factors affecting the stability of the networks seems necessary for policy makers and administrators of science and technology.

In this study, we have evaluated six major collaborative networks established in science and technology domain in I. Rep. of Iran between 1995 and 2005 in the fields of nanotechnology, biotechnology, molecular medicine and herbal medicine. All of these networks had been established formally with government support to address a national mission; so, their stability in the long run was a main concern of founding organizations. In this work, we have tried to develop a well-defined model for evaluation of the factors affecting the stability of collaborative networks in S&T domain. In this regard, a combination of qualitative and quantitative research methods was used in order to create and evaluate the desired model. We focused on the study of inter-organizational networks at the network level rather than at the organizational level of analysis. Some researchers have considered it as "whole network" studies (Kilduff and Tsai, 2003; Provan et al., 2007). In this research, we also focused on formal inter-organizational collaborations, while most of social network studies have addressed inter-individual relationships. This limited us to borrow much from social network theories and literature, whereas we employed existing literature on inter-organizational networks in a large extent.

2. Theoretical background

2.1. What is meant by the term "network" in this research?

"Network" is a general concept that is widely used nowadays in sociology, politics, economics and management. The broad extent of this concept sometimes results in wrong impressions; hence, it seems necessary to determine the exact definition of the word "network" preferred in this investigation before further discussion.

Barringer and Harrison (2000) define networks as constellations of organizations that come together through the establishment of social contracts or agreements rather than legally binding contracts. Legally binding contracts may exist within a network, but the organization of the relationship is primarily based on the social contracts. In the field of public administration, networks are defined either as inter-organizational collaboration arrangements or as new governance structures designed to achieve a common goal that cannot be achieved (effectively) by one single organization (Koliba et al., 2010). Provan et al. (2007) believe that despite differences, nearly all definitions of "network" refer to certain common themes, including social interaction (of individuals acting on behalf of their organizations), relationships, connectedness, collaboration, collective action, trust, and cooperation.

The definition of the "network" considered in this work is very similar to that proposed by Ceglie and Dini (1999). According to these researchers, "a group of firms can be recognized as a "network" if they; cooperate on a joint development project, complement each other, specialize in order to overcome common problems, achieve collective efficiency and conquer markets beyond their individual reach". We believe that in an inter-organizational collaborative network, some of the main features are; "having a common goal", "supplementary membership", "collaboration in joint projects", "voluntarily participation", "and "retaining members' autonomy".

2.2. Formal collaborative networks

Generally, one can classify networks into two main types including; formal (or mandated) and informal networks. These two groups of networks have been differentiated in several studies such as the investigations performed by Kapucu and Garayev (2012), Wixted and Holbrook (2012), Tidd and Bessant (2009), Powell and Gordal (2004), and Buchel and Raub (2002).

Based on the definition given by Tidd and Bessant (2009), formal or "engineered" networks are specifically created to facilitate the innovation. Musiolik et al. (2012), define a formal network as an organizational structure with clearly identifiable members where firms and other organizations come together to achieve common aims or to solve specific tasks.

The closest definition of formal networks in the sense used in this study is the description proposed by Wixted and Holbrook (2012) to classify two types of formal and informal networks. According to their definition, informal networks consist of research collaborators working on any research project or co-authors in any article or book. Most projects having a level of collaboration can be considered as informal networks. On the other hand, formal networks are described as organizations that are often established by governments to encourage researches in novel promising areas or to achieve a critical mass in areas with geographically scattered researchers. Formal networks usually pursue one or several specific policy goals and frequently have a kind of administration structures (Wixted and Holbrook, 2012). In recent decades, especially since the 1990s, formal inter-organizational networks have attracted government attention (in countries such as OECD members) as an instrument for implementation of local, national or regional S&T policies. Usually, the main responsibility of these government supported networks is to organize the researches funded by government particularly in the field of emerging technologies (Wixted and Holbrook, 2012; Musiolik and Markard, 2011). The number of these networks is much less compared to informal networks (considering the extensive definition of informal networks).

2.3. Stability in formal S&T collaborative networks

Stability is known as a key determinant for effectiveness of collaborative networks particularly in formal government supported and public networks (Enkel and Gassmann, 2006; Provan and Milward, 1995). A number of researchers believe that networks are more effective, if they are maintained and sustained, namely, when network relationships are stable over time (Ansell and Gash, 2008; Milward and Provan, 2000). Although some progress has been made in the existing literature on network stability, there is hardly any well-established and generalizable theory (Turrini et al., 2010; Kapucu and Garayev, 2012).

There are several perspectives regarding network stability; ranging from a “dyadic” to a “holistic (or whole network)” approach and/or from “internal” to “external” views. Kapucu and Garayev (2012) used the term sustainability instead of stability and defined it in networks as the continuation and/or evolution of network relationships in the absence of triggering factors for network collaboration. Turrini et al. (2010) and Junke (2005) used the term “network inner (internal) stability” which refers basically to the stability of the personnel working in the network. For these researchers, an important sign of internal stability in a network refers to the length of management tenure, which in terms facilitates trust building, knowledge diffusion, and continuity in relationships in a network. All these factors are likely to be encouraging to a higher level of integration and therefore to network stability and effectiveness. In Jackson and Wolinsky's opinion, a network can be called stable when “no pair of members (individuals/organizations) tends to establish a new connection and no individual benefits from failure of an existing connection” (Jackson and Wolinsky, 1996). Wang (2015) defines network stability as the degree of stability of the environments in which networks are embedded. Baum et al. (2003) found that the stability of the whole network is in part dependent on the types of relationships occurring within sub-networks, based on their small world properties. Core organizations and their sub-networks will tend to stabilize the entire network, whereas actors that are more peripheral will destabilize it.

In this paper, stability does not necessarily mean maintaining a long-term relationship between two specific members of a collaborative network or even the relationship between the network manager and a member. In other words, we believe in a holistic view about network stability in which two specific members can break their relationship and establish new linkages with others without threatening network's stability. In this approach, the whole network should be stable and active in pursuing its policy goals, while inside the network a number of bilateral links could be built up or end at any time. By contrast, in Jackson and Wolinsky (1996) dyadic perspective, if two members end their relationship, the network would be unstable, even if these members benefit from the linkage disruption. We think that pairwise or dyadic stability is a poor interpretation of network's stability and cannot effectively describe the stability of the whole network. This is because the dyadic approach is only concerned with creation or elimination of one single connection at a time while it is possible that some members (individuals or centers) benefit from changes in paired connections.

In this research, stability of an S&T collaborative networks - STCNs - has been defined as long-term stability of a whole network and its commitment to reach a number of pre-determined policy goals. Based on the definition proposed by Wixted and Holbrook (2012), most of the active networks in S&T domain (including all 6 STCNs studied in this research) are formal networks with formal management structure and are often funded by public (government) budgets. Therefore, long-term operation of S&T networks is one of the main expectations of their founders. Policy-making organizations in S&T area - who establish these collaborative networks - perceive the network stability as a prerequisite for fulfilling network level goals (Hasnain-Wynia et al., 2003; Zacocs and Edwards, 2006) such as development of new knowledge, formation of a knowledge flow and nationwide sharing of human, equipment and scientific resources (Wixted and Holbrook, 2012).

We believe that gradual changes made for improving the structure and processes of the whole network as well as enhancing its flexibility to respond to new requirements induced over time, not only does not contradict with their stability, but also serve as innovations in networks (Turrini et al., 2010) which guarantee their long-term stability. These changes may include setting a new mission for the network, quitting of some members due to their lack of collaboration or joining of several new members to complement network capability map. The risks that can result in complete dissolution of a network, significant disruption of its activities or hinder moving toward the policy goals (set by network founders) are the real threats to network stability. Consequently, when no collaboration occurs between members of a network, it can be assumed that network stability has been drastically diminished even if the network's managing structures are preserved apparently. The recent definition of stability in collaborative networks has been previously suggested and approved by other researchers such as Kapucu and Garayev (2012) and Enkel and Gassmann (2006), and has been used throughout this paper.

Some researchers recently bring about a discussion on dormant ties in social networks and their effect on network stability (Levin et al., 2011; Walter et al., 2015; Mariotti and Delbridge, 2012; Bliemel, 2011). The idea is that networks need constant effort from all actors forming the network to maintain the value of the ties to keep the network stable. This discussion is mostly raised in the context of inter-individual social networks rather than formal inter-organizational networks. However, in the holistic perspective of the current research about network stability, every stable network includes both active and dormant ties at any time. Each member organization may reactivate some of its dormant tie with other members and disable some of its existing links. So there is continuous interchange of active and dormant ties inside a stable network. The overall sum-up of these ties should be active enough to stabilize the whole network.

Some scholars believe that the value of networks is somehow limited, and network actors can only benefit from a limited subset of ties (McFadyen and Cannella, 2004). We think that in an inter-individual egocentric network, the benefits of a network depend on the values created by dyadic ties of individuals. While, in an inter-organizational formal network, in addition to efforts of member organizations, there is a managing structure which is responsible to evaluate the network effectiveness regarding its national tasks (Wixted and Holbrook, 2012). The network management is also responsible for modifications and improvements in network in terms of its configuration, procedures and even its national mission to assure about network effectiveness. Therefore stability is a desirable and expected characteristic especially for network founders and policy makers in formal S&T networks.

Kilduff et al. (2006), discussed about the coexistence of changes and stability in networks and labeled it as "dynamic stability". When they explain dynamic stability, they mean that organizational networks change constantly in some respects and yet can remain stable in other respects, just as organizations can be considered both "rapidly changing engines of creativity" and "stable bundles of routines". The notion of dynamic stability is in a good harmony with the holistic view of the present study about network stability. In both perspectives, it is accepted that inside a stable network there is a non-stop evolution of mutual ties and endless number of changes in member's relationships.

2.4. Factors affecting the stability of STCNs

Although a few studies have been concentrated on the stability issue in formal science and technology collaborative networks (Kapucu and Garayev, 2012; Turrini et al., 2010), however some factors related to the stability in these networks have been addressed in previous studies on networks. In this context, various approaches have been used. A number of researchers believe that a network would be stable and successful if the initial motivations for participation have been fulfilled in majority of network members (Hasnain-Wynia et al., 2003; Zacocs and Edwards, 2006). In fact, they have stated that these fulfilled motivations are the factors with positive impact on network stability. Some of these motivations include; provision of complementary assets (Kapucu and Garayev, 2012), access to a large pool of knowledge and experience (Teece, 1990), and reducing the R&D risks for developing new products through collaboration in the network (Mowery et al., 1996). Other researchers believe that in order to study the factors affecting the stability in S&T networks, one needs to consider the risks relevant to the formation and development of the networks. Divergence in the objectives of network members (DeBreeson and Amesse, 1991), grasping the intangible assets of one member by other members (Szarka, 1990), opportunistic behavior of some members (Belussi and Arcangeli, 1998) are examples of risks for network stability. Table 1, shows a list of factors influencing network stability (including motives and risks) collected from the network literature.

Given the main subject of the present paper, i.e. investigating the network stability factors, no comprehensive theory is available in the literature being capable of describing the status of S&T collaborative networks in Iran. However, there are a couple of researches and theories which are partially helpful in dealing with this issue. Some of the useful theories and models for supporting our argument will be introduced and discussed below.

Kapucu and Garayev (2012), in their study on collaborative emergency management networks, examine how network sustainability (or stability) is affected by three factors namely; interdependent network relationships, network complexity, and utilization of information and communication technology (ICT). This research introduces one of the few models which are directly related to network stability. Although these factors may be of importance for the stability of STCNs in developing countries like Iran, but there are many other factors that this research is silent on them.

One of the main duties of STCNs is to create and flow knowledge through inter-individual and inter-organizational interactions (Marrocu et al., 2013; Owen-Smith and Powell, 2004). "Knowledge-creating company" theory proposed by Nonaka and Takeuchi (2005) demonstrates the different stages of knowledge creation cycle by using four-stage SECI[1] model. The inspiring point of this theory is the dynamic nature of knowledge creation

Table 1
List of factors influencing network stability collected from the literature.

No.	Factor	References in literature
	Factors with positive effect on network stability (motives)	
1	Interdependency of members' organizational goals	Kapucu and Garayev (2012)
2	Continuous support of founding organizations during network evolution and growth	Enkel and Gassmann (2006)
3	Stability in network managing board (and its secretariat)	Junke (2005), O'Toole and Meier (2004)
4	Providing sustainable financial support for the network (through public resources)	Conrad et al. (2003)
5	Ability to solve tensions (conflict management)	O'Toole and Meier (2004), Zacocs and Edwards (2006)
6	Management support for participation of representatives of organizations in network	Page (2003), Buchel and Raub (2002)
7	Formation of complementary assets in the network	Musiolik et al. (2012), Mowery et al. (1996)
8	Success of the network in achieving network level goals	Hasnain-Wynia et al. (2003), Zacocs and Edwards (2006),
9	Use explicit ongoing outcome measurement	Conrad et al. (2003), Page (2003),
10	Convergence of network activities with strategic interests and needs of members	Buchel and Raub (2002)
11	Formation of common (physical/software) infrastructure in the network	Bianchi and Bellini (1991)
12	Adequate communication\collaboration among network members at different levels	Danilovic and Winroth (2005), Starkey et al. (2000)
13	Success of the network in implementing win-win partnerships between its members	Lasker et al. (2001), Teece (1990)
14	Utilization of information and communication technology (ICT)	Kapucu and Garayev (2012)
15	Interactive spirit and active performance of network management (manager/secretariat)	Danilovic and Winroth (2005)
16	Proper perception of organizational differences of members by network management	Buchel and Raub (2002)
	Factors with negative effect on network stability (risks)	
17	Dependency of network relationships of member organizations to a certain individual	Danilovic and Winroth (2005)
18	Opportunistic behavior (free-riding) of some members (individual/organization)	Belussi and Arcangeli (1998)
19	Rapid growth (instead of gradual growth) in the number of members particularly in the beginning	Brown et al. (1998), Bianchi and Bellini (1991)
20	High degree of centrality of secretariat or some members of the networks	Miles and Snow (1992)
21	Heterogeneity in size and composition of network members	Zacocs and Edwards (2006)
22	Divergence in the objectives of network members	DeBreeson and Amesse (1991)
23	Grasping the intangible assets of one member by other members	Szarka (1990)

[1] Socialization-Externalization-Combination-Internalization.

via trans-organizational interactions. They also came up with the concept of "Ba" as a physical or virtual environment to exchange and combine knowledge by involved individuals. More interactive environments (or Ba) and more effective knowledge exchange mechanisms which consequently lead to more benefits for participating members as well as more stability in the network.

One of the few models available for network evolution is the "knowledge network" model proposed by Buchel and Raub (2002) which determines factors affecting network stability in each stage of network development. According to this model, for attaining a more stable network, its activities must be closely aligned with the strategic corporate priorities of the member institutions, particularly at the network establishment stage. Based on this model, the network coordinator must attempt to create a network context which enables the sharing of knowledge. A trusted environment will encourage network members to share more resource and build long-term relationship in the network which in turn reinforces network stability. Gaining the continuous support of the members requires demonstration of network tangible outcomes (Buchel and Raub, 2002).

As it could be seen in Table 1, there are too many factors introduced through several researchers as influencing factors on network stability. There are some efforts in the literature to classify these network stability factors. One helpful method in this regard is the model developed by Enkel and Gassmann (2006) to evaluate the EURADOS network performance in the European Union. In their study, the factors with positive and negative impacts on network success have been resembled with centripetal and centrifugal forces, respectively. They have stated that if the positive issues (motivation for participation in network) and negative factors (collaboration risks in the network) are recognized as "centripetal" and "centrifugal" forces, the network is stable only when the resultant force is positive and in favor of centripetal forces. In spite of some valuable advantages, there is still a problem in using this model for classifying network stability factors which is different and sometimes contradictory opinions about the impact of some factors on the network stability. For instance, many researchers have argued whether the difference in the size of the network members is an advantage or a threat in terms of network stability.

As a concluding statement of the discussion on network stability, we believe that to date, literature on the subject has developed in a fragmentary way. It has generally taken the form of multiple explanations of network stability and factors affecting it. It has also concentrated mainly on network success factors to identify outcomes of network functioning and has lacked sound empirical findings and underlying theories related to network stability. On this basis, the present article aims to review the literature on factors influencing inter-organizational networks stability and mix them with factors extracted from 6 case studies conducted in I. R. of Iran. Then, we will draw all items together, evaluate them in the Iran S&T atmosphere, and classify them into a unitary framework. Our goal is not to provide an overall theory about determinants of network stability, but we aim to develop a tentative model on that.

3. Studied networks and corresponding stability issues

In 1995, National Research Program (NRP) was initiated by the Iranian Council of Scientific Researches (ICSR). In this program, 1700 of about 8000 proposed research projects were approved. In order to support this huge number of research projects, in 1995, the council decided to create a network of laboratories - SHAMTAK - in different areas (including materials, biotechnology, medicine, earthquake, etc.). The research team encountered difficulties in gathering required information about SHAMTEC since the network was dissolved about a decade before starting the present research. However, because of practical failure of SHAMTEC network, investigating its stability risks seems very useful. Because of the mentioned limitations, this network was only used in the qualitative stage of the present research. Our investigations showed that stability had been an important issue in the minds of the SHAMTEC network developers. This can be clearly understood from the statements of SHAMTEC network designers. For instance, the former deputy secretary of the ICSR council has said that "... Although SHAMTEC network was a great idea, it did not last for some reasons. The main problem in the country is the lack of long-term plans" (Olyaei and Rahmani, 2007). The results of our research showed that SHAMTEC failed for a number of reasons including; dissolution of founding organization (i.e. ICSR), weak managing structure, and diverse expectations of network founders.

The Ministry of Health and Medical Education of Iran (MoHMEI) might be acknowledged as the most active ministry in the country in terms of the number of developed collaborative networks in S&T domain during last two decades. In 1999, the department of science and technology of this ministry began to design research networks in medical fields with the aim to properly organize the researches in this area and align them with the national priorities (Medical Biotechnology Network Website, 2000). Molecular Medicine, Medical Biotechnology and Herbal Medicine research networks were established in 1999, 2000 and 2001, respectively. All government supported medical universities and research centers with active research teams and labs were invited to be a member of these networks. The main goal of the medical research networks was to define and manage collaborative multidisciplinary research projects. Most of the networks goals were long-term objectives. Some of these goals include; capacity building, reinforcing teamwork spirit, and accelerating the commercialization process of research results (Website of Medical Biotechnology Network, 2000). In addition, all of the interviewed key informants of these networks recognized them as long-term infrastructures rather than temporary programs. They also expressed their concerns regarding the stability of the networks in the long run. Herbal Medicine research network (HMN) dissolved just after 5 years of operation. The present study shows that the main reasons for the failure of HMN network were the opportunistic behavior of some members, different expectation of the founding organizations, and lack of win-win collaboration mechanisms. Although the two other medical research networks were operational at the time of conducting the present research, they were less successful in terms of pre-determined national/network level objectives.

National Network of Medical Plants Research and Technology (NNMPRT) was developed by the ministry of Science, Research and Technology MoSRT in 2004. All universities, research centers and private companies that are involved in any kind of activities from education and research to production and marketing related to medial plants could apply for membership in NNMPRT network. Several evidences imply that stability has been an important issue for founders of the network since the beginning. One of the committee members has said that "stability and effectiveness can be regarded as two main indicators of network success". Furthermore, it is stated in the scope of the network "strategic plan" that "in the 20-year national vision of the Islamic Republic of Iran (2025), NNMPRT network is a unique network for efficient communication of units involving in medical plants research and technology and an effective mean for providing intellectual support for them" (Website of NNMPRT, 2004). So, stability could be recognized as a main concern and network level objective of the network founders.

Iran Nanotechnology Laboratory Network (INLN) is one of the first efforts of Iran Nanotechnology Initiative Council (INIC) to provide required infrastructure for development of this technology in Iran. INLN began recruiting its first members in 2004, and 34 laboratories from different universities, research centers and private companies were accepted as network members. Network related documents suggest that the intention of network founders has not been conducting a short-term and temporary program and network stability has been a major issue of concern to them (Website of INLN, 2004). INLN was one of the most successful networking experiences in Iran by the time we were conducting the current research.

4. Research methodology

In this research, we utilized a multi-case study approach with a combination of qualitative and quantitative methods. At the first step, factors affecting the stability of 6 selected S&T collaborative networks were identified and screened using qualitative evaluations. We collected related data adequately from in-depth interviews with key informants, survey, and archived documents for the purpose of identifying the stability factors of STCNs. Then; a conceptual model was developed to categorize these factors. At the final step, we used confirmatory factor analyses (CFA) method to verify the proposed model. Fig. 1 shows the three main steps of the current research. We will elaborate more on each step later in this section.

4.1. Step 1: preparing a list of network stability factors

Table 2 shows the profiles of 6 investigated S&T collaborative networks. This table reveals that selected networks were established from 1995 to 2004; hence all of them had a minimum history of activities to make it possible to study these networks. Based on the definition of network suggested by Wixted and Holbrook (2012), all of the 6 studied networks were formal and were created by a governmental institute to achieve one or more policy objectives. This similarity of networks makes the comparison of the studied cases significant. At the time of this study, among 6 selected networks, 2 networks were active, 2 networks were relatively active and 2 of them were inactive (or dissolved). This evaluation is an overall (and not precise) assessment made by each network's key informants which is supported by available documents on studied networks. Variation in actual status of investigated networks enriches the obtained results; in particular, dissolved and inactive ones are suitable cases to study the failure factors or in other words risks to the stability of the networks. Moreover, considering 6 different networks (not just one network) as case studies increases the validity and reliability of the investigations.

Exploratory interviews with the involved persons in the establishment and developing process of studied networks, were the main source of information in the qualitative stage of this investigation. A total number of 20 key informants from the studied networks were interviewed. Distribution of interviewees in 6 investigated networks is shown in Table 2. Key informants include members of networks councils, network directors, secretariat officials, managers of member organizations, and influential individuals in the founding institutes. Efforts were made to interview more than one person in each network. Fortunately, it was the case in all of 6 networks. Using semi-structured interviews allows an individual's opinion to be well-perceived due to the possibility of getting feedbacks from interviewee which in turn improves the validity of the qualitative research (Johnson, 1997). In this work, active interview approach was also implemented (Holstein and Gubrium, 1995). In this approach, interviewees participate in the theory developing process and interpretation of the events. In all cases, data obtained from interviews was compared with information collected from other sources (such as statutes, annual reports, and information available on websites), so that no significant inconsistencies existed in gathered data. Triangulation approach employed for gathering the information ensures the required validity of the investigations.

The initial list of network stability factors must be investigated according to the actual situation of studied networks because experts believe that social context has a substantial role in research on networks (Zacocs and Edwards, 2006; Jack and Anderson, 2002). To prepare the final list of network stability factors, preliminary list of factors obtained from the literature (Table 1), was reviewed by key informants of chosen networks and their comments on whether these factors are effective in Iran environment were received. They were also asked to add new factors; this procedure was continued by snow-ball effect technique until no new factor was added to the list. By means of this procedure the initial list encompassed 34 factors. Furthermore, interviewee's viewpoint about how to classify the stability factors was questioned.

4.2. Step 2: refining and classification of the network stability factors and designing the preliminary research model

In order to design the conceptual framework (or research model), it was necessary to screen and modify the initial list of factors affecting the stability of the networks (Table 1). Two main actions (according to expert opinions) were made to refine the preliminary list of factors. First, some of the factors with overlap were merged. Second, some minor factors were omitted. To enter the final list, a factor identified using literature must be approved or suggested by at least one key informant of the studied networks. On the other hand, factors added to the initial list only through exploratory interviews, must be suggested by at least two key informants. At the end, 27 factors among 34 initial factors were chosen to be entered to the final list. At the next step, a model was proposed for the graphic illustration of factors classification. According to Miles and Huberman (1994), p. 18), a conceptual framework illustrates a graphical or textual representation of important issues to be studied such as key factors, structure and variables and their relations. In this work, the conceptual framework or research model classifies the factors affecting the stability of the STCNs and displays how they are related. We will explain more the process of designing the research model and its rationales in the next section of this article.

4.3. Step 3: assessment of validity of the designed research model using CFA method

In the second stage of data gathering process in present study, a quantitative approach was used. At this stage, a survey was planned to obtain the views of active members of each network excluding SHAMTEC.[2] A questionnaire was designed based on the results of literature review and exploratory interviews. The aim of the surveys was to acquire experimental templates for classification of the factors affecting the stability of the S&T collaborative networks. In other words, it was conducted to evaluate the importance of listed factors by the representatives of networks members and to test the classification model (or the research model) from the perspective of the stakeholders of the studied networks. Likert 5-de-

[2] See Note 1 in Table 2.

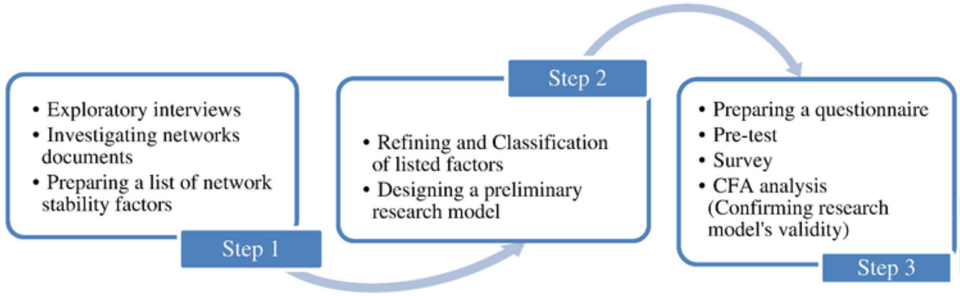

Fig. 1. Three main steps of this research.

Table 2
Profiles of the investigated networks.

Network	Founding year	No. of members in 2102	No. of interviewees	Founding organization	Network status in 2012
SHAMTEC	1995	-*	3	Iranian Council of Scientific Researches	Inactive (dissolved)
Molecular medicine network	1999	14	3	Ministry of Health and Medical Education of Iran	Relatively active
Medical biotechnology network	2000	37	3	Ministry of Health and Medical Education of Iran	Relatively active
Herbal medicine network	2001	14**	2	Ministry of Health and Medical Education of Iran	Inactive (dissolved)
National network of medical plants research and technology	2004	46	5	Ministry of Science, Research and Technology of Iran	Active
Iran nanotechnology laboratory network	2004	45	4	Iran nanotechnology initiative council	Active
Total	–	157	20	–	–

* Note 1 The research team could not find reliable data regarding the member organizations of SHAMTEC network due to its dissolution long time before the present research, so this network was excluded from the quantitative section of this study.

** Note 2 Herbal medicine network was dissolved in 2006, so the number of members was for the last year before the closure of this network (i.e. 2005).

gree spectrum was utilized to answer the questions. The preliminary questionnaire was reviewed to identify and resolve possible ambiguities and unnecessary repetitions in the questions. Expert judgment is a recommended method to measure and increase the validity of the survey tool. For convenience, e-questionnaires (electronic questionnaires) were prepared. Questionnaire was designed to be responded anonymously so it allows respondents to put their privacy concerns at ease and answer all questions truthfully. Before sending the survey tool to the potential audience, a pre-test with a limited group of respondents (22 people) were carried out to assess the reliability of the investigation tool as well as resolving the ambiguities. In this study, reliability of the survey tool was assessed using Cronbach's alpha method. This method is used to calculate internal consistency within a survey tool such as a questionnaire. The total value of Cronbach's alpha was 0.881. This value indicates the high reliability of our survey tool.

Statistical population for survey comprised the representatives of studied networks members (directors/representatives) and other influential people in the networks founding organizations. Total number of the potential audience was about 200 individuals. Due to the restriction of this statistical population, questionnaires were sent to all of the population (like a census). In total, 112 individuals of 83 institutions affiliated with the studied networks participated in this survey. The response rate of member organizations was about 52%.

Given that many factors were identified as factors affecting the stability of the collaborative networks in the research model, it was necessary to choose a proper statistical method based on the results of the conducted survey to validate the factors and designed model (structural validity). Due to the difficulty of determining the independent and dependent variables among identified factors, inter-correlation methods such as factor analysis must be applied. Confirmatory factor analysis (CFA) seems a suitable candidate because by using this method we could validate the proposed research model (Yong and Pearce, 2013; Child, 2006). When there is a pre-designed factorial model based on literature and/or experimental work, CFA method could be utilized to check its structural validity and "goodness of fit". To examine the goodness of fit of the proposed model, confirmatory factor analysis (CFA) test was performed using LISREL 8.7 software.

5. Results and analysis

In the following section firstly; we will explain more about the process of developing the conceptual framework (research model) of the current research and secondly; we will discuss the results that we obtained from CFA analysis of the preliminary research model using our survey data set.

5.1. Developing the conceptual framework (research model)

After identification and refining the network stability factors, a conceptual framework is required to assess the issue of stability in STCNs. An efficient way to design such a framework is to classify the identified factors into internal and external groups of factors. A number of researchers introduced an imaginary boundary between inside and outside of the network when they defined a formal inter-organizational collaborative network (Musiolik et al., 2012; Wixted and Holbrook, 2012). This boundary separates elements constructing a network (i.e. its members, management, secretariat office) from its environment. This imaginary boundary can also be used to classify the factors affecting the network stability. In other words, factors originating from inside of the network (including members, management and interactions) can be considered as internal stability factors and those affecting the network stability from outside of it (such as factors rooted in national and international environment) can be recognized as external stability factors. We classified 27 stability factors which remained in the final list into two internal and external types which were further categorized into 6 subgroups, as can be seen in Table 3.

Table 3 demonstrates the final list of identified and screened factors affecting the stability of STCNs in Iran along with their grouping based on the mentioned classification scheme. In this table, a specific code has been assigned to each factor which will be used in the following sections. In the fourth column from left, it shows whether the factor mentioned in the literature and in the fifth column (from left) the number of the interviewees suggesting this particular factor has been included. We developed a preliminary conceptual framework using above-mentioned idea which is shown in Fig. 2.

Different theories and ideas employed to design the conceptual model, are summarized in Annex 1. Furthermore, several correcting issues were suggested during exploratory interview with the key informants, which improved the research model. These comments are also included in the form of approval or correction points in Annex 1.

6. Evaluation of the research model by confirmatory factor analysis (CFA)

In order to ensure the reliability of the designed model for investigating the stability of collaborative networks in Iran and other developing countries with similar conditions, method of classification as well as the designed model must be validated by using an appropriate statistical method. Here, a well-developed statistical tool i.e. confirmatory factor analysis (CFA) method was used for closer evaluation of the conceptual model designed in previous sections.

Since a pre-experimental model had been built in this study using literatures and exploratory interview with key informants, confirmatory factor analysis (CFA) method was used. The main aim is purifying the measures of variables as well as confirming the relationships between experimental data and designed model. LISREL 8.7 software was used to perform confirmatory factor analysis with the maximum likelihood estimation method. Experts have already insisted that the result of factor analysis doesn't confirm the model and only evaluate its goodness of fit. In this research, 8 fit indices (as it shown in the first row of Table 4) were used to assess the goodness of fit. We also plotted a path diagram according to significant level. In this diagram, numbers assigned to arrows drawn from latent variables (classification of stability factors) to observed ones (stability factors) show t-values and with a probability of 95%, values larger than 1.96 are significant and corresponding factors are not removed from the model.

6.1. Evaluation of the goodness of fit indices for components of the proposed model

Table 4 shows the value of fit indices calculated separately for each of 6 structural components of the proposed model and the cut-off value for each indices. As it is seen in this table, goodness of fit for 5 of 6 six structural components of the model are con-

Table 3
Final list of factors affecting the stability of the STCNs and their classification.

Category	Factor code	Factor	Literature	Frequency in Interviewees
Characteristics of network management	MgChr1	Credibility and acceptability of network manager in the eyes of the network members	–	3
	MgChr2	Discrimination by network manager (instead of taking into account nationwide interests)	–	10
	MgChr3	Interactive spirit and active performance of network management (manager/secretariat)	√	4
	MgChr4	Proper perception of organizational differences of members by network management	√	3
	MgChr5	Stability in network managing board (and its secretariat)	√	5
	MgChr6	Network manager's preoccupation outside network activates	–	5
Characteristics of network members	MebChr1	Balance in the capabilities of different members	–	2
	MebChr2	Dependency of network relationships of member organizations to a certain individual	√	4
	MebChr3	Opportunistic behavior (Free-riding) of some members (individual/organization)	√	8
	MebChr4	Encouraging member organizations to participate in network affairs by their managers	√	1
	MebChr5	Network comprehensiveness (the extent to which main beneficiaries Participate in network)	–	6
Network development and evolution processes	NetEvol 1	Formation of complementary assets in the network	√	9
	NetEvol 2	Success of the network in achieving network level goals	√	5
	NetEvol 3	Rapid growth (instead of gradual growth) in the number of members particularly in the beginning	√	7
	NetEvol 4	Convergence of network activities with strategic interest and needs of member organizations	√	3
	NetEvol 5	Formation of collective (physical/software) infrastructure in the network	√	3
	NetEvol 6	Centrality of the secretariat or some members of the networks	√	1
Mechanisms of collaboration in network	ColabMch1	Adequate communication\collaboration between member organizations at different levels	√	6
	ColabMch2	Success of the network in implementing win-win collaborative programs between members	√	11
	ColabMch3	A systematic plan to assess the level of collaboration between members	–	5
Country's networking infrastructures	Infra1	Collaboration culture of the country (social networking infrastructure)	–	5
	Infra2	Continuous supports of the networks founding organization during its operation	√	10
	Infra3	Sustainable Provision of financial support for the network (through public resources)	√	9
	Infra4	Availability of legislative supporting acts for networks	–	6
Country's S&T environment	Environt1	Existence of appropriate environment in the country for international interactions	–	3
	Environt2	Existence of rival networks in related scientific domains	–	4
	Environt3	Alignment of the country's S&T policies/programs with collaborative networks	–	3

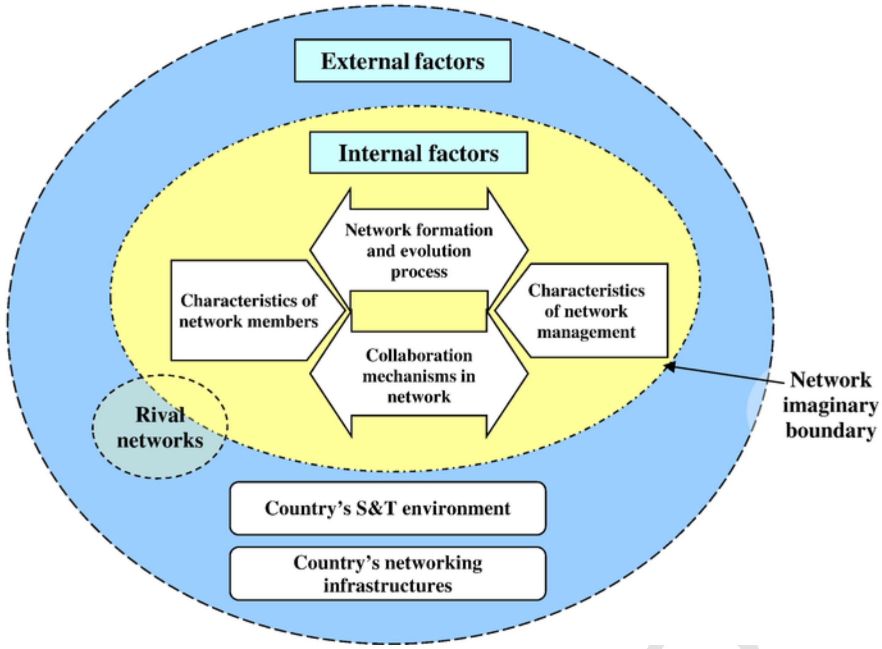

Fig. 2. Conceptual framework (research model) proposed for classification of network stability factors in this study.

Table 4
Value of fit indices for each of 6 structural components of the research model.

Component title in the research model	Indic	χ2/df	RMSEA	RMR	NFI	AGFI	GFI	CFI	NNFI
	Cut-off value	< 4	< 0.08	< 0.08	≈ 1	≈ 1	≈ 1	≈ 1	≈ 1
Characteristics of network management	Calculated value	0.961	0.000	0.027	0.93	0.94	0.97	1.00	1.00
	Result	√	√	√	√	√	√	√	√
Characteristics of network members	Calculated value	2.961	0.121	–	–	–	–	–	–
	Result	×	×	×	×	×	×	×	×
Network formation and evolution processes	Calculated value	2.95	0.133	0,056	0.79	0.83	0.93	0.94	0.79
	Result	√	×	√~	√~	√~	√	√	√~
Mechanisms of collaboration in network	Calculated value	–	0.00	–	–	–	–	–	–
	Result	The model is saturated, the fit is perfect.							
Country's Network infrastructures	Calculated value	1.40	0.061	0.026	0.99	0.94	0.99	1.00	0.99
	Result	√	√	√	√	√	√	√	√
Characteristics of Network environment	Calculated value	–	0.00	–	–	–	–	–	–
	Result	The model is saturated, the fit is perfect.							

√ Confirmed × Not confirmed.

firmed in the initial designed form (Table 3) and only the "characteristics of network members" component is not confirmed and required revision. According to Table 4, fit indices for two components i.e. "mechanisms of collaboration in the network" and "characteristics of network environment" have reached saturation. All fit indices related to "characteristics of network management" and "Country's networking infrastructures" are in the allowed range and their goodness of fit are confirmed. For the "network formation and evolution processes" component, some of the fit indices are in the acceptable limits and some of them are not; however, all of them lie very close to the cut-off values, therefore this component is also confirmed.

From the perspective of the internal factors of the research model, the results of confirmatory factor analysis for "characteristics of network members" component (Fig. 3) imply that the t-values for two of indices are < 1.96. Therefore, these indices have not been confirmed by the experimental data obtained from the survey and they are not significant. Furthermore, as it is clear from Table 4, the value of RMSEA index equals 0.121 while it should be < 0.08. Hence, it can be said that this component of the research model requires major revision. Two unconfirmed factors of this component include "Dependency of network relationships of member organizations to a certain individuals" (*MebChr2*) and "Opportunistic behavior of some network members (organizations/individuals)" (*MebChr3*). We removed these two unconfirmed variables, then, the designed model attained appropriate fit and all paths gained significance.

6.2. Factor analysis of the research model as a whole model

In previous sections (Table 4), goodness of fit of the model was investigated separately for each structural component of the research model by using LISREL factor analysis software. To evaluate the fitness of research model for all of the components as a whole model (represented in Fig. 2), all 6 components (along with their 27 factors) were simultaneously entered in the LISREL software. Fig. 3(a) demonstrates the software output. As it is seen in

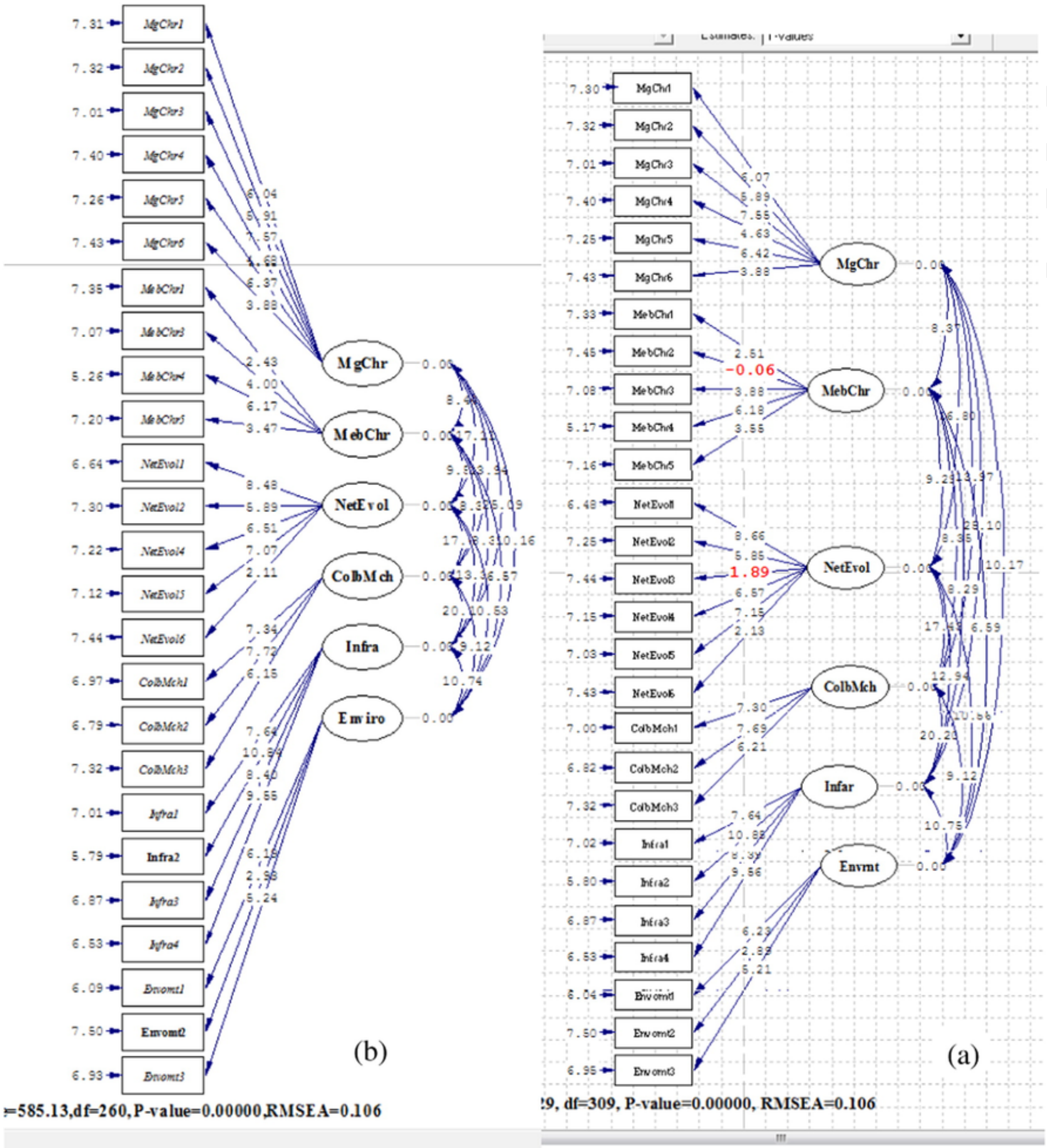

Fig. 3. The outputs of LISREL software for t-values and significance of the relationships in the whole research model; (a) initial output and (b) modified output.

this figure, most of the paths related to the components and their factors (all of them except 2) having a t-value higher than + 1.96 and are confirmed. Our investigations showed that proper goodness of fit is achieved for the whole model by omitting two unconfirmed paths namely; *MebChr2* and *NetEvol 3*.

7. Conclusion

In formal collaborative networks in science and technology domain which are frequently inter-organizational networks, long-term stability is one of the main expectations of network founders. Our interviews with key informants (founders, policy-makers, managers, etc.) of 6 Iranian S&T networks in this research highlighted the crucial importance of long-term stability of studied networks for their stakeholders. Network stability also is recognized as an important indicator of its success and effectiveness (Enkel and Gassmann, 2006; Provan and Milward, 1995).

In developing countries such as Iran, where government and public institutions are the main contributors in investment on research and R&D, this issue has more importance because S&T networks are unique tools for nationwide sharing of infrastructures and capabilities.

In this study, at the first step, we prepared an initial list of network stability factors using available literature on S&T collaborative networks. Then, given the importance of social context in the networks, this initial list of factors was presented to key informants of 6 selected S&T collaborative networks in Iran. In addition, to provide useful comments about listed factors according to particular circumstances in Iran, they approved most of the factors and added new ones to the initial list. After preparing the final list of network stability factors, these factors were classified as a conceptual model based on available theories and opinions of key informants of studied networks. At the final step, we used confirmatory factor analysis (CFA) method to validate the proposed model. This study showed that by removing only two factors (of 27 finalized factors), 6 structural components of the model separately, and the whole model are confirmed in term of goodness of fit. Therefore, this model and its components can be employed to successfully investigate the formal inter-organizational S&T collaborative networks in Iran and probably countries with similar circumstances. This study showed that classifying network stability factors to two main categories namely; internal and external factors would be helpful for investigating stability issue in S&T collaborative networks.

The authors call for more research on network stability. More contributions are required to develop a robust underlying theory on this issue and so far it seems that there is a considerable shortcoming in the existing literature regarding network stability and its components and origins.

8. Policy implications

Here we summarized a number of practical implications that our research could have for network founders and S&T policymakers in Iran and probably in countries with similar socio-economic situations. In most of the studied networks in Iran, the managing person has often been appointed among one of the network's member organizations. Hence, he/she should not sacrifice national/network level interests in exchange for benefits of his/her belonging organization. In other words, the discrimination of network manager and taking advantage of his position (*MgChr2* factor), could destabilize the whole network. In addition, if network management is not the first priority of a manager with several responsibilities, a collaborative atmosphere won't be created among members in the network, especially in the initial stages of network formation and development (*Mgchr6* factor).

Another important factor in developing countries like Iran is fostering collaborative culture and providing suitable condition for network collaboration (*Infra1* factor). Supporting legislative acts for collaboration (*Infra4*), appropriate and supportive environment for network operation (network ecosystem) (*Infra2*) and alignment of network activities with national policies and priorities (*Environt3*) could be acknowledged as the most important factors affecting the formation and development of stable S&T collaborative networks in developing countries with similar circumstances to Iran.

In terms of internal factors, characteristics of network members as its main players and network governors (i.e. managing or coordinating people and system) need to be taken into account. Two other important groups of factors are related to the collaboration mechanisms inside the network and the formation and evolution process of the network. In order to have a stable S&T network, collaboration mechanisms need to be fostered among network members through designing and promoting win-win bilateral/multilateral partnership arrangements. Network management should take the leading role in this regard. The more collaboration fostering and network-friendly social context (ecosystem) one country has, the more stable networks in that country would emerge and evolve.

9. Limitation of the research

Since the unit of analysis in this research is a science and technology collaborative network (STCN), direct assessment of the networks would be better; however, the small number of the networks was one of the main limitations of this study. Focusing on a higher level with simultaneous measurement at lower levels is an important tool for focused case studies (Yin, 2003). In summary, the level of theory and analysis was at the network level, and the survey was also focused on issues at the network level, while measurement was done through surveying of the informed people (individuals) within the networks (member organizations). Regarding the abstract nature of the networks, this was done to facilitate testability and tangibility.

Acknowledgment

We need to sincerely appreciate many people who assisted us to conduct this research, particularly the secretaries and officials of the six studied networks.

Annex 1.

Table 5 Ideas adopted by the authors from the existing literature on networks and exploratory interviews to design the conceptual model of the current research.

Relevant issues in proposed conceptual framework (Fig. 2)		Ideas adopted from the network literature	Comments made by key informants of studied networks
Classification of stability factors into two general categories including internal and external factors		Definition proposed by Wixted and Holbrook (2012) and somehow Musiolik et al. (2012) for formal inter-organizational networks was considered for determining the (imaginary) boundary between inside and outside of collaborative networks.	Most of the interviewees confirmed the classification of stability factors into two main categories including internal and external factors.
Internal factors	Characteristics of network management	“Knowledge network” model developed by Buchel and Raub (2002) emphasizes on specific coordinating features of the network. Junke (2005), O'Toole and Meier (2004) and many others recognized network management as an important factor for network stability.	- This subcategory confirmed by interviewees. - Some of the experts believed that for Iranian collaborative networks which have been founded and developed by a governmental organization, this group of factors are very important.
	Characteristics of network members	Kapucu and Garayev (2012) highlighted the effect of interdependency of network members on its stability. Buchel and Raub (2002) have determined the characteristics required in members organization for the success of the network.	- This subcategory confirmed by interviewees.
	Network formation and development processes	Buchel and Raub (2002) have determined the important factors in the development and evolution processes for network successfulness. Musiolik et al. (2012) emphasizes on formation of complementary assets in the network as a main stability factor.	- This subcategory confirmed by interviewees.
	Mechanisms of collaboration in network	According to Nonaka and Takeuchi (2005), the major purpose of network collaboration is knowledge transfer, especially tacit knowledge. Brannback (2003) have emphasized on the effect of interactive and collaborative environments on knowledge flow between members.	- This subcategory confirmed by interviewees.

External factors	Characteristics of S&T environment of the country (network environment)	Turrini et al. (2010), Zacocs and Edwards (2006), Jack and Anderson (2002) and many others have emphasized on the importance of the social context in studying collaborative networks. This should be considered for studying network stability.	- This subcategory confirmed by interviewees.
	Country's networking infrastructures	–	Considering the poor collaboration infrastructures in Iran, addition of this case was suggested by some of interviewees.

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Reza Asadifard (PhD) is an Innovation Policy researcher at Technology Studies Institute (TSI) (Tehran-Iran). He completed his PhD research on science, technology and innovation networks at Allame Tabtabei University of Tehran, Iran. He specializes in innovation policy, with a special interest in new technology commercialization, innovation networks and technology transfer.