Journal of Information Systems and Telecommunication
Vol.11, No.4, October-December 2023, 368-382
http://jist.acecr.org
ISSN 2322-1437 / EISSN:2345-2773

# Software-Defined Networking Adoption Model: Dimensions and Determinants

Elham Ziaeipour[1], Ali Rajabzadeh Gatari[2*], Alireza Taghizadeh[3]

[1].Department of Management of Information Technology, Faculty of Management and Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran
[2].Faculty of Management and Economics, Tarbiat Modares University, Tehran, Iran. (Visiting Professor at SRb)
[3].Faculty of Computer Science, Parand Branch, Islamic Azad University, Tehran, Iran

Received: 21 Nov 2022/ Revised: 4 Feb 2023/ Accepted: 20 Feb 2023

## Abstract

The recent technical trend in the field of communication networks shows a paradigm change from hardware to software. Software Defined Networking as one of the enablers of digital transformation could have prominent role in this paradigm shift and migration to Knowledge-based network. In this regard, telecom operators are interested in deploying SDN to migrate their infrastructure from a static architecture to a dynamic and programmable platform. However, it seems that they do not consider SDN as one of their priorities and still depend on traditional methods to manage their network (especially in some developing countries such as Iran). Since the first step in applying new technologies is to accept them, we have proposed a comprehensive SDN adoption model with the mixed-method research methodology. At first, the theoretical foundations related to the research problem were examined. Then, based on Grounded theory, in-depth interviews were conducted with 12 experts (including university professors and managers of the major telecom operators).
In result, more than a thousand initial codes were determined, which in the review stages and based on semantic commonalities, a total of 112 final codes, 14 categories and 6 themes have been extracted using open, axial and selective coding. Next, in order to confirm the indicators extracted from the qualitative part, the fuzzy Delphi method has been used. In the end, SPSS and Smart-PLSv.3 software were used to analyze the data collected from the questionnaire and to evaluate the fit of the model as well as confirm and reject the hypotheses.

**Keywords:** Adoption; Fuzzy Delphi; Grounded Theory; Service provider; Software Defined Network; Technology.

## 1- Introduction

The trend of technology in communication networks clearly shows that the different sectors of this industry are transforming from hardware to software [1]. In this regard, in addition to witnessing the development of software in various sectors, the architecture and overall image of the communication network space will also undergo transformation and change [1].
The importance of software development in telecommunications industry was highlighted during the international conference which was held at St. Louis University by the IEEE Organization in 2018. In this conference, SDN technology was identified as the most vital part among 11 key aspects of this trend [1].
By separating the control plane, SDN redefines network architecture and provides a flexible way to manage and control complex networks through efficient management of resources [3].
SDN will provide some important benefits such as new model of service creation and delivery, efficient and software-based management of resource and energy, agility and quick response to changes, operation automation and customization. In addition, SDN manages all domains, layers and vendors in an integrated fashion, which is able to analyze traffic, detect failures, respond promptly to user needs and reduce downtime. It also provides the possibility of using cognitive techniques, optimization and virtualization, reducing implementation costs, independence of services from the underlying hardware layer, faster procurement and equipment configuration time, increasing network intelligence [4]. Software Defined Networks will not only facilitate the fulfillment of the promises of other technologies such as 5G and Cloud computing, but also as an enabler [4][5], it will play a key role in providing concepts such as digital transformation, knowledge-based networks and business intelligence [6].
The importance of this research is due to the benefits of SDN and the global trend towards this technology, although telecom operators in some developing countries

✉ **Ali Rajabzadeh Gatari**
alirajabzadeh@modares.ac.ir

such as Iran are still hesitant to use this technology. It seems that the administrators prefer to manually configure and set up their networks instead of getting rid of their legacy networks and using new technology [4]. However, according to Martec's law, the main challenge of managing organizations is that technological changes are exponential and very fast, while the internal changes of organizations are slow. In this way, this distance becomes more and more over time, so that finally organizations must adjust themselves and align with new technologies [7].
The first step in applying new technologies is to accept them. Identifying the key factors of the information technology adoption is an important research area. In other words, the question why people accept and use a technology or conversely do not, is one of the most important issues in information systems [8].
Technology adoption is a multidimensional phenomenon that includes a wide range of key variables such as values, perceptions, personal perspectives, intellectual preferences, beliefs, attitudes, desires and the degree of their involvement with technology as well as the ability to change on adopting new technology [9][10]. In recent decades, in accordance with the development of information technology, several models have been introduced in the area of technology adoption [10]. According to [12], each of these models has its shortcoming and boundaries and does not complementary to the rest of the models [13]. There are two important concerns with these theories. First, each theory uses distinct term in its constructs, although they are basically under the same concepts. Secondly, there is not even a single theory that covers all behavioral variables [12][13][13]. In General, the research shows that these models can be developed according to different technologies, context and situation of each country.
To the best of our knowledge, In Iran there has not been any previous proper activity to SDN adoption to date. However, a few studies have been done on SDN from "technical point of view".
One of the reasons for the lack of appropriate research in this field is mainly due to its multidisciplinary nature.
This study intends to fill the existing theoretical gap by identifying the aspects of SDN adoption and examining the different dimensions of this process. In this regard, in literature review, three main topics have been studied:1) the theoretical foundations of SDN technology 2) the theoretical foundations of technology acceptance models and 3) researches on SDN adoption models (Fig.1).
In the first stage, all parameters extracted from the literature review were considered as a basis for preparing the initial questionnaire. Next, based on Grounded theory, an in-depth interview was conducted with 12 experts, which with using open, axial and selective coding the factors affecting SDN adoption have been recognized. Therefore, a proposed model for SDN adoption was presented based on the extracted codes and the Strauss and Corbin's paradigm model [14].
The methodology of research, data collection and analysis in addition to the identified dimensions and categories are presented in the relevant sections.
Then, in order to confirm the indicators extracted from the qualitative part, the fuzzy Delphi method has been used.

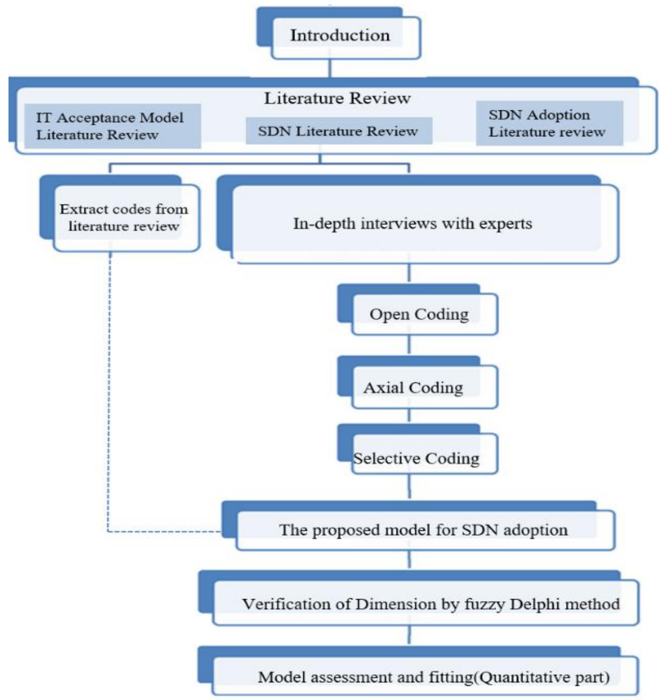

Fig.1: Steps of conducting research

In the quantitative part, by analyzing the data extracted from the questionnaire (with a Likert scale), the structure and fit of the model has been checked. Also, CFA[1], confirmation and rejection of hypotheses has also been done using PLS[2] software. Finally, after the validation, conclusions and suggestions for future research are given.
The expected outcome of current research can be also useful for countries that have similar telecom and geopolitical context. Also, same as the adoption of other technologies such as cloud, 5G, IOT, Big data, etc. it will be useful for telecommunication operators and all entities in the SDN ecosystem (Fig.1).

## 2- Literature Review

In literature review, three main topics have been studied:1) the theoretical foundations of SDN technology 2) The theoretical foundations of technology acceptance models and 3) researches on SDN adoption models.

[1] Confirmatory Factor Analysis
[2] partial least squares

## 2-1- Theoretical Foundations of SDN Technology

Software Defined networks are an alternative architecture to common inflexible networks. Generally, SDN can be simply defined as "a new generation of networks that uses software-based switches and controllers alongside high-level APIs to control and manage network infrastructure" [15].
The SDN architecture separates the control plane from the transmission plane and provides an abstraction of the network infrastructure for services and applications. It also allows network programming using the open APIs [16].
SDN networks consist of three main layers with north and south interfaces for communication between layers, as well as western and eastern interfaces for communication with other SDN networks or non-SDN networks [15][17].
Standard architectures for SDN have been provided by standardization organizations such as ITU[1], OIF[2], IETF[3], ETSI[4], ONF[5], etc., the most common of which is the architecture provided by ONF.

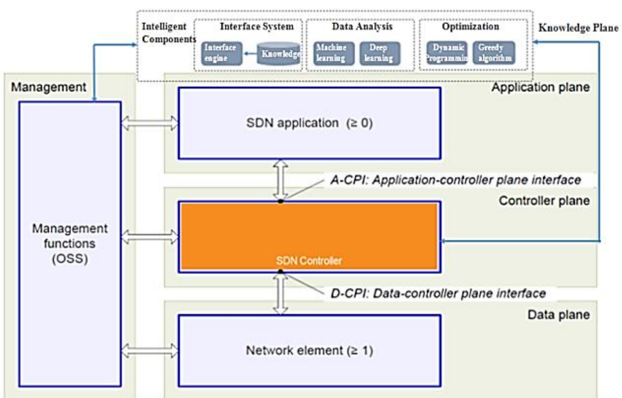

Fig.2: ETSI/ONF SDN architecture (ETSI, 2017) [17]

ETSI has also used ONF reference model and added the knowledge layer to it [17]. In this way, machine learning and cognitive techniques will be used along with neural networks, and operations such as learning, normalization, analysis, decision making, forecasting, judgment, and knowledge extraction will be performed in this intelligent layer (Fig.2) [17].
The new SDN architecture was introduced in 2019 to bring open-source architecture to SDN [18], and work is ongoing to operationalize it by standards-setting organizations.
In 2019, the SDN share was $9.995 million from the global market. Its value could be up to $72.630 million by 2027 (growing at a CAGR of 28.2% from 2020 to 2027) [3] and at $112.95 million by 2028 [19].
The software defined networking market has different sectors based on components, organization size, end users, industry vertical and regions. Telecom service providers, cloud service providers and companies are considered as the end users of this technology [3]. Also, from regional point of view, North America is a major SDN market due to ever increasing network traffic, mobility solutions and cloud applications [19].
Meanwhile, shift toward cloud by various organizations would increase the adoption of SDN among cloud providers and brings new opportunity for the market [3].
Thus, many students, research centers and leading vendors are working on various aspects of this technology. The main concern of the current research is lack of desire to implement SDN in practice.

## 2-2- Theoretical Foundations of IT Acceptance

Since the 80's, in parallel with the development of information technology in organizations, numerous researches in the field of technology adoption have been done. The foundation of all technology adoption models is shown in (Fig.3) [20].

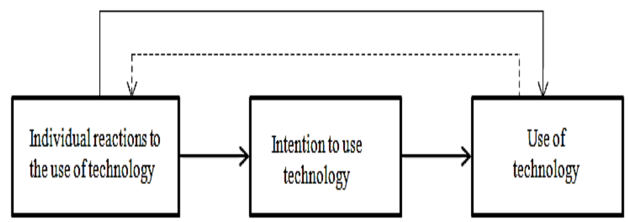

Fig.3: fundamentals of technology adoption models [20]

Technology adoption is a process that begins with the user's awareness of the technology and ends with the user embracing the technology and its full use [21]. According to Rogers (1995), the adoption of a technology involves a rational process in which investment decisions are made about the use of that new technology. Technology acceptance is an Individual's attitude towards a technology [21]. It looks more like acceptance would refer to the intentions towards use and adoption refers to the degree of actual use. Therefore, Technology acceptance is the first step of technology adoption (Fig.4) [21] [22].

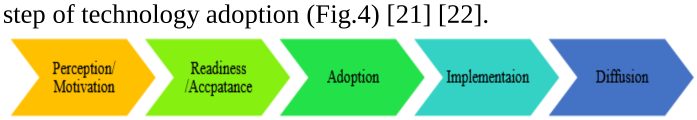

Fig.4.Innovation Diffusion Process [22]

Table 1 lists some of the common information technology acceptance models and their determinants of IT adoption [23][11]. The last column of the table shows peer categories of our suggested model which are based on the Strauss-Corbin model.

Table1: Evolution of Theories and Models of Technology Adoption

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[1] International Telecommunication Union-Telecommunications Standardization
[2] Organization international de la Francophone
[3] Internet Engineering Task Force
[4] European Telecommunications Standards Institute
[5] Open Networking Foundation

| *Year* | *Theory/Model* | *Developed By* | *Determinants of IT adoption* | *categories* |
|---|---|---|---|---|
| 1975 | Theory of Reasoned Action (TRA) | Ajzen & Fishbein | Attitude, Subjective Norm, Behavioral Intention, Behavior | Causal, Phenomenon, Factors |
| 1991 | Theory of Planned Behavior (TPB) | Ajzen | Attitude, Subjective Norm, Perceived Behavioral Control, Intention | Causal, Phenomenon, Factors |
| 1989 | Social Cognitive Theory (SCT) | Bandura | Personal Factors (Cognitive, affective and biological events), Environmental Factors, Behavior | Causal, Phenomenon, Contextual Factors |
| 1992 | Motivation Model (MM) | Davis et al. | Extrinsic Motivation, Intrinsic Motivation, Emotional style | Casual Factors |
| 1983 | DOI | Rogers & Shoemaker | Knowledge, Persuasion, Decision, Implementation, Confirmation | Causal, Phenomenon, Strategies Factors |
| 1990 | TOE | Tornatzky& Fleischer | Technological Context (Availability, Characteristics, Internal and External)<br>Environment Context (Industry Characteristics, Government Role, Completion, Structure)<br>Organizational Context (Size, Process and Practices, Linking structures (formal and informal) | Causal, Intervening, Contextual Factors |
| 1989 | TAM | Davis | External Variables, Perceived Usefulness, Perceived Ease of Use, Attitude, Intension to use, Actual Use | Causal, Phenomenon, Factors |
| 2000 | TAM2 | Venkatesh & Davis | Subjective Norm, Experience, Image, Job Relevance, Output Quality, Perceived Usefulness, Perceived Ease of Use, Intension to use, Usage Behavior | Causal, Phenomenon, Factors |
| 2008 | TAM3 | Venkatesh etal. | Subjective Norm, Experience, Image, Job Relevance, Output Quality, Perceived Usefulness, Perceived Ease of Use, Intension to use, Usage Behavior<br>Computer Anxiety, Computer playfulness, Perception of external control, Computer self-efficiency | Causal, Phenomenon, Factors |
| 2003 | UTAUT | Venkatesh, Morris, Davis | Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions, Gender, Age, Experience, Voluntariness of Use, Behavioral Intention, Use Behavior | Causal, Phenomenon, Factors |
| 2012 | UTAUT2 | Venkatesh,Thong & Xu | Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions, Price Value, Habit, Hedonic Motivation,<br>Gender, Age, Experience, Behavioral Intention, Use Behavior | Causal, Phenomenon, Factors |

## 2-3- Literature Review of SDN Adoption Models

Numerous articles have addressed SDN technology from different dimensions such as optimization, simulation, implementation, development, etc. This amount of study on SDN clearly shows its important from the perspective of academic societies. Table 2 shows a brief review of articles related to the research topic and the parameters extracted from them. The last column of the table shows peer categories of our suggested model which are based on the Strauss-Corbin model.

All the options considered in this section have examined the acceptance parameters, development process, advantages, opportunities and challenges of SDN technology. Some of them are the adoption parameters of similar technologies such as virtualization (NFV), cloud computing, big data, Internet of Things and blockchain. This group of research is intended for application in the field of SDN.

Table2: Summary of previous studies regarding SDN adoption

| *Reference* | *Purpose/ Domain* | *Method* | *Findings* | *categories* |
|---|---|---|---|---|
| [24] | SDN Adoption /IT cloud integrators | Quantitative method (SPSS, PLS)<br>+<br>Questionary (167 cloud integrators) | -Examine the relationship between IT cloud integrators' perceptions of performance expectancy, effort expectancy, social influence, facilitating conditions, and their intention to use SDN by using “UTAUT”.<br>-social influence and facilitating conditions were statistically significant; performance expectancy and effort expectancy were not. | Phenomenon, Causal Factors |
| [25] | Factors affecting Cloud Computing adoption / companies in Turkey | Combination of DOI and TOE<br>+<br>Quantitative method (Smart PLS V.3) | -parameters are: Comparative advantage (including security, cost savings), complexity, compatibility from DOI model and technical parameters (including technical readiness), organizational context (support of senior managers, company size), environmental context (competitive pressure, rule support) from TEO model. | Causal, Intervening, Contextual Factors |
| [26] | Factors influencing SDN adoption/ Research and Educational Networks (REN) | Qualitative method (Combination DOI and TOE models) | 1-Human resources (Leaders' opinion, Team skills)<br>2-SDN technology (advantages, compatibility, complexity, testability, security)<br>3-Organization (REN size and Resources, REN Global scope, Network users)<br>4-Environment (Regulation Policies, technology support) | Causal, Intervening, Contextual Factors |
| [27] | SDN Adoption Motivations/Telecom Networks | N/A | -Motivations for SDN market: complexity in Data Centers and Enterprises, inability of traditional network architecture to support migration to the cloud and the need for improving application performance.<br>-Some technology trends propelling the adoption of SDN are 5G, IoT, Cloud native, edge computing and Big Data.<br>-IDC enumerates top 6 motivations for SDN adoption: policy-based control and WAN optimization, network agility and flexibility, Optimized cost, Consistent security, Enhanced operational efficiency and Faster deployment. | Causal, Phenomenon, Intervening, Consequences Factors |
| [28] | Reasons for not accepting SDNs and reviewing studies/ Telecom Networks | Literature review | -SDN adoption limitations: Budget constraints, Performance and reliability, Scalability, maturity, Lack of experts and certification programs.<br>-network operators can incrementally deploy SDN and avoid replacing legacy equipment at once. | Causal, Intervening Factors |
| [29] | SDN Adoption/Telecom Service Provider | Mixed Method<br>+<br>Interview (14 Service Provider) | -The most important motivate for using SDN is agility, unlike previous research that has shown cost reductions.<br>-Proposed SDN adoption solution: technology evolution with 29%, innovative services with 21%, organizational transformation with 50% impact on SDN adoption | Causal, Consequences Factors |

| ***Reference*** | ***Purpose/ Domain*** | ***Method*** | ***Findings*** | ***categories*** |
|---|---|---|---|---|
| [30] | Cloud Computing Adoption / SMEs in Malaysia | Combination of DOI and TAM + Quantitative method (SPSS, SmartPLS) + Questionary (114 responses) | -The parameters are: Comparative advantage parameters (including security issues, cost savings), complexity, compatibility of the DOI model and perceived usefulness and perceived ease of use from TAM model that has strong influence on the user intention to adapt new technology.<br>-Three predictors of relative advantage, compatibility and complexity yielded a significant influence on perceived usefulness.<br>-Relative advantage revealed no significant relationship in cloud computing adoption.<br>-Perceived usefulness was found to have a mediating effect between compatibility and adoption attention, while perceived ease of use yielded a mediating effect between complexity and adoption attention. | Causal Factors |
| [31] | The impact of TOE Parameters on BDA adoption and its effect on the financial performance and marketing performance/SMEs | Combination of DOI, TOE and RBV[1] models + Quantitative method (PLS) + Questionary (171responses) | -Technological Factors (Relative Advantage, Compatibility, Complexity, Uncertainty and Insecurity, Trial ability, Observability), Organizational Factors (Top management Support, Organizational Readiness), Environmental Factors (Competitive Pressure, External Support from Vendors, High degree of regulatory)<br>-Complexity and uncertainty and insecurity have negative effect, while trial ability and observability affect oppositely. Relative advantage and compatibility show no effect. Top management support and Organizational resources, positively influence on BDA adoption. | Causal, Intervening, Contextual Factors |
| [32] | IoT Adoption (IoTAM) | Quantitative method (IoTAM) + Questionary (812 survey participant) + Quantitative method (SPSS, SEM [2], PLS) | -Model parameters: User character, Cyber resilience, social influence, Cognitive instrumentals, Trust, Long-term orientation, Flexibility, Perceived Usefulness, Perceived Ease of Use, Attitude, Behavioral intention.<br>-It was demonstrated that facilitated appropriation, Perceived Usefulness and Perceived Ease of Use significantly influence consumers' attitude and BI. User character, cyber resilience, cognitive instrumentals, social influence and trust exhibited a significantly indirect effect on attitude and Behavioral intention, through the three main mediators. | Causal, Phenomenon Factors |
| [33] | SDN adoption factors / Telecom Networks | Qualitative and Quantitative method + Semi-structured interviews | -Barriers to SDN adoption:<br>a) challenges to integrating SDNs with legacy networks<br>b) the immaturity of vendor solutions<br>c) Technology shortcomings (proper Interfaces)<br>-Top SDN adoption Drivers:<br>a) the simplification of network provisioning<br>b) the better utilization of network resources | Intervening Factors |
| [34] | SDN Adoption Factors | Questionnaire (Intel experts) | -benefits of SDN: speeding up service provision, creating services automatically, reducing costs<br>-Factors affecting SDN adoption: a proper understanding of SDN performance, adaptability, remove obstacles | Causal, Intervening, Consequences Factors |
| [35] | Application of SDN on network security/ Telecom Networks | Literature Review | -Benefits such as network security, attack detection and troubleshooting, traffic control, configuration and policy management, and service change | Causal, Intervening, Consequences |
| [36] | Block chain Adoption | qualitative Method + semi-structured interviews | Model: Technical parameters (comparative advantage, uncertainty), organizational parameters (managerial support, organizational readiness), environmental parameters (competitive pressure, regulatory environment, industry) and trust are added to the TOE framework. | Causal, Intervening, Contextual Factors |

[1] Resource Based View
[2] Structural Equation Modeling

The motivating factors for conducting this research are:

- Need for a comprehensive and integrated framework that focuses on all levels (national, organizational, individual, etc.)
- Dispersion of activities and the need to complete previous activities.
- Combining the strengths of the models presented for SDN adoption and the adoption model of similar technologies.
- Update the existing knowledge about SDN, especially in the field of its adoption and express management problems.
- Considering management processes, strategies, contextual conditions and Consequences that previous models had not addressed nor had very little reference to.
- Few researches have used the qualitative-quantitative mixed method. Most of them have extracted factors affecting the acceptance of this technology through content analysis, literature review, questionnaires and interviews.

## 3- Method

The review of previous studies indicates the weakness of existing theories and models regarding the adoption of SDN technology. Thus, at the beginning, the theoretical foundations related to the research problem were examined. Then, based on the Grounded theory, in-depth interviews have been conducted with the managers and experts of the country's major telecom operators.

In result, dimensions and categories have been extracted using open, axial and selective coding. In order to confirm the indicators extracted from the qualitative part, the fuzzy Delphi method has been used. Then by analyzing the data extracted from the questionnaire (with a Likert scale), the structure and fit of the model has been checked. Also, CFA, confirmation and rejection of hypotheses has also been done using Smart PLS.3 software.

### 3-1- Data Collection Process

In order to collect the initial data in the qualitative section, three different sources have been considered: 1) Interviews 2) Articles and documents 3) Technical reports, meetings.

A community of experts have been purposefully selected who have rich information about the research topic and are working individually or organizationally in this field.

According to the research methodology and considering the available time and resources, between 10 to 15 interviews would be enough, as the purpose of the interview is to explore the ideas and attitudes of the interviewee. Thus, in order to extract the initial data, current study has been done by 12 interviews (6 university professors and 6 senior managers and experts with PhD in computer, telecommunications, industry and management). Data collection has continued until the research reaches the saturation limit in the data and the concepts related to SDN adoption and there was no new one to be added to the model. Finally, at each stage, the codes were finalized with 5 of interviewees who had the following expertise (Table 3):

Table3: Characteristics of the Interviewed Experts

| *Expert* | *Degree* | *Skills* |
|---|---|---|
| Expert1 | PHD-Computer | Communication Net-SDN |
| Expert2 | PHD-Telecomm | Telecomm -5G- SDN |
| Expert3 | PHD-Electricity | Telecomm-Cloud/NFV/SDN |
| Expert4 | PHD-Industrial | MCDM-E. Readiness-Technology Adoption-Management |
| Expert5 | PHD-Management | Organizational-Public Administration |

In the quantitative section**,** the statistical population includes experts and managers of various Iranian telecommunication Sectors, including: ITRC[1], TIC[2], TCI[3], MCI[4], etc. In this section, the sample size was calculated using Cochran's formula. The statistical population was about 140 individuals, and considering Cochran's formula, a total of 101 experts were selected as a statistical sample. Demographic information of respondents illustrated in table 4.

Table4: Demographic Information of Respondents

| *Characteristic* | *Frequency* | *Percentage* |
|---|---|---|
| **Age** | | |
| 30-40 years old | 34 | 33.7% |
| 40-50 years old | 43 | 42.6% |
| 50 years old or older | 24 | 23.8% |
| **Gender** | | |
| Male | 75 | 74.3% |
| Female | 26 | 25.7% |
| **Degree of education** | | |
| Bachelor's degree | 9 | 8.9% |
| Master degree | 55 | 54.5% |
| PHD | 37 | 36.6% |
| **Field of education** | | |
| Telecommunications | 19 | 18.8% |
| Management | 24 | 23.8% |
| Computer | 23 | 22.8% |
| IT | 21 | 20.8% |
| Industrial Engineering | 9 | 8.9% |
| other | 5 | 5.0% |
| **Position** | | |
| Executive/Senior manager | 22 | 21.8% |
| Junior manager | 70 | 69.3% |
| University professor | 9 | 8.9% |

[1] Iran Telecommunication Research Center
[2] Telecommunication Infrastructure Company
[3] Telecommunication Company of Iran
[4] Mobile Telecommunication Company of Iran

## 3-2- Data Analysis Process in Qualitative Section

In this section the major steps of qualitative part of the research are explained.

- Review of research background:

Before conducting the interview, the background of the research was investigated (table 2) so that the findings of the initial stages were the basis for preparing the questionnaire and the interview.

In this regard, databases such as IEEE, Science Direct, Emerald Insight and etc. have been examined and it is important that the contents were not repeated and have been done in the last 15 years.

- Conducting research according to Grounded Theory:

By conducting the interviews and analyzing the data, a deeper understanding of the interviewees' experience and knowledge was gained. In this way, qualitative data analysis was performed in three stages: open, axial and selective coding [41].

**Open Coding:** Open coding was done in two stages. Initial coding was done by line-by-line coding of the data, and a concept or code was attached to each of them. Thus, more than a thousand initial codes were extracted. In secondary coding by comparing all extracted open codes, the items that had semantic similarity were placed in one category [40]. Then, in order to make the results validate, it has been reviewed by 5 experts who were highly specialized in this field. At the end, a set of 112 final codes is extracted.

**Axial Coding:** The data decomposed into concepts and categories are examined in a new way so that a link can be made between a category and the concepts in it and even other categories [40].

**Selective Coding:** Selective coding uses the results of the previous coding steps, selects the main category and links it systematically to other categories, validates the connections, and develops the categories that need further refinement and development [40] [41]. Fig.5 shows the final coding done by MAXQDA software.

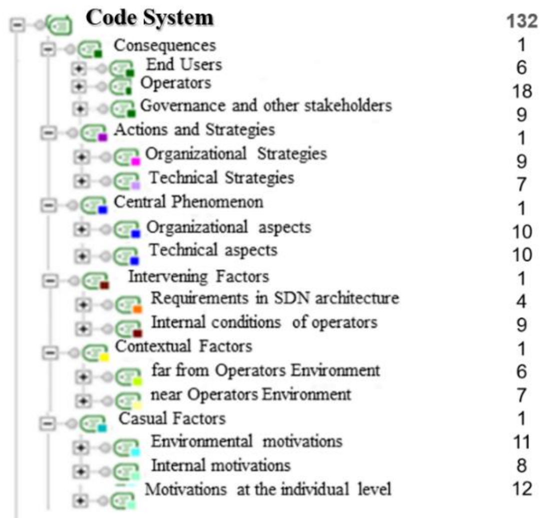


Fig.5: Final coding done by MAXQDA software

- Writing theory and theorizing:

Finally, with the help of the developed theory, 6 hypotheses have been extracted for testing in the research. In order to confirm the indicators extracted from the qualitative part, the fuzzy Delphi method has been used.

## 3-3- Data Analysis Process in Quantitative Section

After extracting the conceptual model, the model itself and the research hypotheses are tested in order to obtain deeper information about the research model in the statistical population. After collecting information with a questionnaire, the data was analyzed with SPSS and PLS software. Frequency distribution, mean and variance were used to describe the opinions of the statistical sample regarding the questions. This process was carried out at a significance level of 0.05. For data analysis, using Smart PLS.V3, the fit of the model and then the research hypotheses were evaluated. Before using the statistical tests, the normality of the data should be evaluated, and for this purpose, the Kolmogorov-Smirnov test was used.

# 4- Findings and Results

In order to present the SDN adoption model, the Strauss-Corbin paradigm has been used, which is based on a systemic approach and includes [14] [41]:

**Causal Condition:** Causal conditions are the motivating factors to encourage organizations to adopt SDN technology. Three categories of motivation identified includes: Environmental motivations of operators, internal motivations of operators [42] and motivations at the individual level.

**Contextual Conditions:** special conditions that affect strategies and are not under the control of organizations, but awareness of them can lead to appropriate response and understanding why some events related to the process of accepting SDN technology. Far and close environment of the operators is considered in this category [42]. The far environment is a situation that the operator has no control over that. The close environment of operators includes the competitors and other stakeholders [42].

**Phenomenon:** the main phenomenon refers to the adoption of SDN technology and its dimensions, which has been the main topic of this research. Use of SDN has been identified in two categories: organizational and technical.

**Intervening Conditions:** unlike Contextual conditions, intervening conditions are under the control of organizations and network administrators that affect the strategies. The internal conditions of the operators and the requirements of the SDN architecture were considered as intervening conditions [42].

**Strategies:** special actions that result from the main phenomenon and can be helpful in promoting SDN adoption. The difference between this and phenomenon is that the strategies are not process but action type and help execute processes. Technical and organizational strategies have been considered [42].

**Consequences:** the outcomes that emerge as a result of strategies. There are three levels of consequences for users, operators, government and other stakeholders [42]. These consequences include positive and negative impacts. Thus, 112 final codes, 14 concepts and 6 main categories were obtained, which is a total of 132 options. The SDN adoption model proposed by the research is shown in the (fig.6).

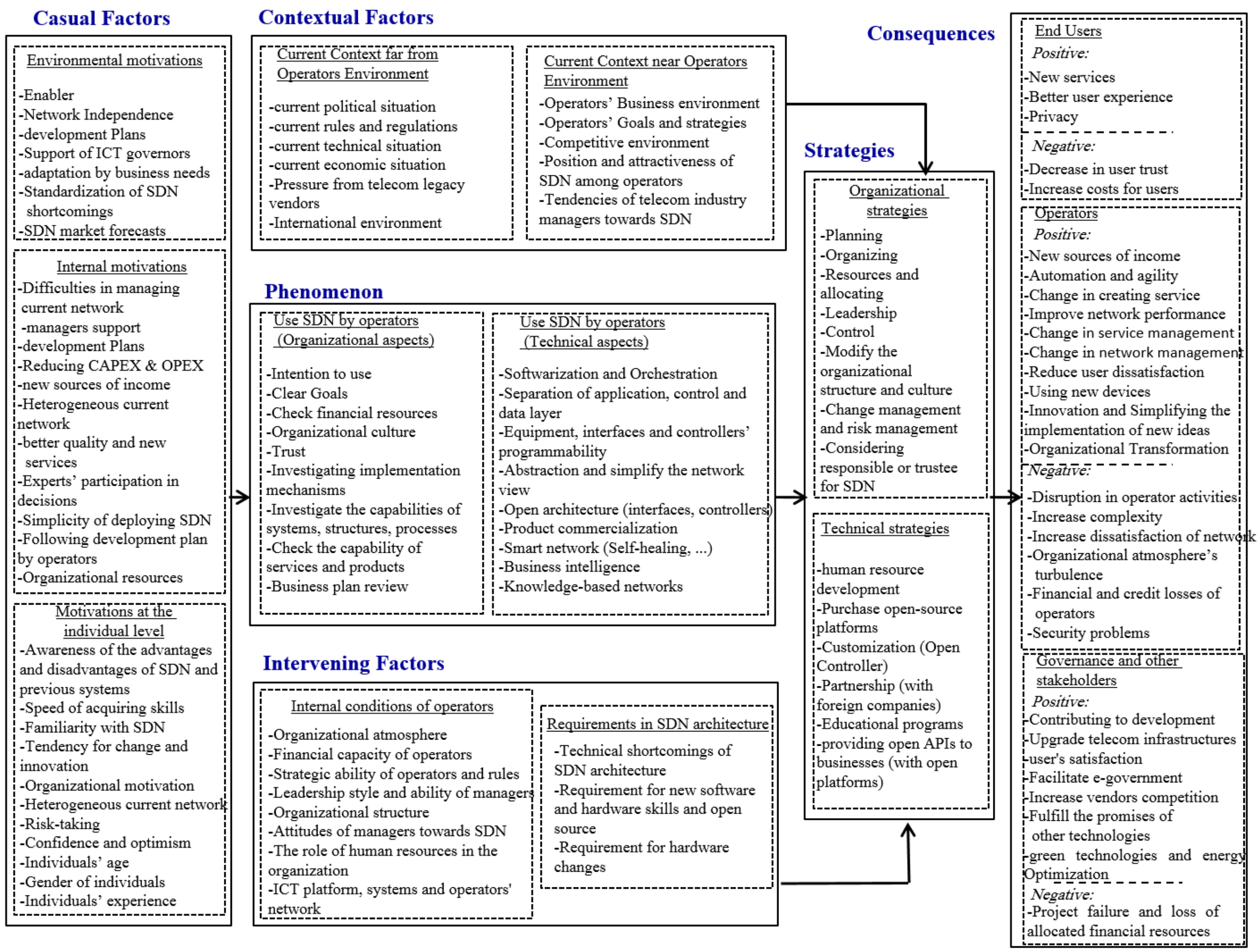


Fig.6: The proposed model for SDN adoption

### 4-1- Hypothesis

Based on the conceptual model and the main research questions, the following hypotheses are extracted:

- **H1:** Causal Factors have a significant effect on the Phenomenon, which is the use of SDN by operators (organizational and technical).
- **H2:** The Phenomenon, that is, the use of SDN by operators has a significant effect on the strategies.
- **H3:** The Contextual Factors (Current Context far from and near Operators Environment) has a significant effect on the strategies.
- **H4:** The Intervening Factors (internal conditions of operators and requirements in SDN architecture) has effect on the strategies.
- **H5:** The strategies have a significant effect on the consequences (for users, operators, governance and other stakeholders).

### 4-2- Fuzzy Delphi Method

At this stage, a questionnaire consisting of 112 indicators of the proposed SDN adoption model with the focus on large telecommunications operators, which was extracted from literature review and interviews, was provided to expert members [43]. In order to do fuzzy, the opinions of experts, triangular fuzzy numbers have been used. Experts' views on the importance of each indicator are collected with a 5-point fuzzy Likert spectrum. Then the fuzzy mean is taken from the scores and converted to a definite number according to the relation belong to the fuzzy mean. In the next step, the Delphi first stage questionnaire was given to the experts again. Also, in this round, the definite average of the first round is provided so that the experts are informed about the average of each index in the previous stage. In this round, the fuzzy mean of the scores was calculated in a similar way using the above-mentioned equation [43].
According to Cheng, if the difference between the two stages of the poll is less than the threshold (0.1), the polling process will stop, we have reached a consensus [43]. In the first phase of fuzzy Delphi, considering the threshold number of 0.7 [44], the results show the confirmation of all indicators (Table 5.a).
In the next round, considering the same threshold number of 0.7 [44], the results still show the confirmation of all indicators (Table 5.b).
Considering that the difference between the two stages of the survey is less than the threshold (0.1), the survey process has been stopped, we have reached a consensus.

Table5: Results of the first and second phase of fuzzy Delphi (23 out of 112 codes)

| row | Indicator | Fuzzy weight | Non fuzzy weight | status |
|---|---|---|---|---|
| 1 | Enabler (For other technologies or other concepts) | (0.5,0.75,0.917) | 0.722 | √ |
| 2 | National Network Independence | (0.521,0.771,0.958) | 0.750 | √ |
| 3 | development Plan and migration towards digital transformation | (0.542,0.792,0.917) | 0.750 | √ |
| 4 | Support of ICT governors | (0.5,0.75,0.938) | 0.729 | √ |
| 5 | Faster adaptation by changing business needs | (0.5,0.75,0.875) | 0.708 | √ |
| 6 | Standardization and elimination of SDN shortcomings | (0.5,0.75,0.875) | 0.708 | √ |
| 7 | SDN market forecasts | (0.521,0.771,0.896) | 0.729 | √ |
| 8 | Difficulties in managing and controlling the current network | (0.5,0.75,0.917) | 0.722 | √ |
| 9 | Positive attitude and managers support from SDN | (0.521,0.771,0.938) | 0.743 | √ |
| 10 | Reducing CAPEX & OPEX Costs | (0.479,0.729,0.917) | 0.708 | √ |
| 11 | Requirement for new sources of income | (0.542,0.792,0.938) | 0.757 | √ |
| 12 | Heterogeneous current network | (0.604,0.854,0.958) | 0.806 | √ |
| 13 | Requirement for better quality and new services | (0.604,0.854,0.958) | 0.806 | √ |
| 14 | Experts' participation in decisions and giving positive feedback from SDN | (0.521,0.771,0.917) | 0.736 | √ |
| 15 | Simplicity of implementing SDN architecture | (0.5,0.75,0.917) | 0.722 | √ |
| 16 | Operators follow the development plan and digital transformation | (0.625,0.875,0.958) | 0.819 | √ |
| 17 | Ability of organizational resources | (0.625,0.875,1) | 0.833 | √ |
| 18 | Awareness and understanding of the advantages and disadvantages of SDN and previous systems | (0.521,0.771,0.917) | 0.736 | √ |
| 19 | Familiarity of individuals involved with SDN in English, software skills and networking | (0.542,0.792,0.958) | 0.764 | √ |
| 20 | Speed of acquiring skills | (0.5,0.75,0.938) | 0.729 | √ |
| 21 | Tendency for change and innovation | (0.5,0.75,0.896) | 0.715 | √ |
| 22 | Organizational motivation and commitment | (0.542,0.792,0.917) | 0.750 | √ |
| 23 | Risk-taking | (0.583,0.833,0.938) | 0.785 | √ |

a) Results of the first phase of fuzzy Delphi (23 out of 112 codes)

| row | Indicator | Fuzzy weight | Non-fuzzy weight | status |
|---|---|---|---|---|
| 1 | Enabler (For other technologies or other concepts) | (0.563,0.813,0.938) | 0.771 | √ |
| 2 | National Network Independence | (0.5,0.75,0.958) | 0.736 | √ |
| 3 | development Plan and migration towards digital transformation | (0.5,0.75,0.917) | 0.722 | √ |
| 4 | Support of ICT governors | (0.521,0.771,0.958) | 0.750 | √ |
| 5 | Faster adaptation by changing business needs | (0.583,0.833,0.958) | 0.792 | √ |
| 6 | Standardization and elimination of SDN shortcomings | (0.521,0.771,0.917) | 0.736 | √ |
| 7 | SDN market forecasts | (0.521,0.771,0.896) | 0.729 | √ |
| 8 | Difficulties in managing and controlling the current network | (0.542,0.792,0.938) | 0.757 | √ |
| 9 | Positive attitude and managers support from SDN | (0.521,0.771,0.958) | 0.750 | √ |
| 10 | Reducing CAPEX & OPEX Costs | (0.542,0.792,0.938) | 0.757 | √ |
| 11 | Requirement for new sources of income | (0.542,0.792,0.938) | 0.757 | √ |
| 12 | Heterogeneous current network | (0.563,0.813,0.958) | 0.778 | √ |
| 13 | Requirement for better quality and new services | (0.604,0.854,0.958) | 0.806 | √ |
| 14 | Experts' participation in decisions and giving positive feedback from SDN | (0.5,0.75,0.917) | 0.722 | √ |
| 15 | Simplicity of implementing SDN architecture | (0.521,0.771,0.917) | 0.736 | √ |
| 16 | Operators follow the development plan and digital transformation | (0.583,0.833,0.958) | 0.792 | √ |
| 17 | Ability of organizational resources | (0.604,0.854,1) | 0.819 | √ |
| 18 | Awareness and understanding of the advantages and disadvantages of SDN and previous systems | (0.583,0.833,0.958) | 0.792 | √ |
| 19 | Familiarity of individuals involved with SDN in English, software skills and networking | (0.542,0.792,0.958) | 0.764 | √ |
| 20 | Speed of acquiring skills | (0.5,0.75,0.938) | 0.729 | √ |
| 21 | Tendency for change and innovation | (0.5,0.75,0.896) | 0.715 | √ |
| 22 | Organizational motivation and commitment | (0.5,0.75,0.917) | 0.722 | √ |
| 23 | Risk-taking | (0.583,0.833,0.938) | 0.785 | √ |

b) Results of the second phase of fuzzy Delphi (23 out of 112 codes)

## 5- Model Analysis

### 5-1- Data Preprocessing and Data Normality Test

Since the researcher used an electronic questionnaire, there were no missing and no outlier data, and all questionnaires were fully answered. To identify indifferent cases, they were identified by the formula STDEV.P>. /3 in Excel and the answers of 13 experts were removed.
Kolmogorov-Smirnov test was used to check the normality of research variables. If the significance level is greater than 5%, the variables are normal.

Table6: Assessing the Normality of the data

| *Variables* | *Causal Factors* | *Phenomenon* | *Contextual Factors* | *Intervening Factors* | *strategies* | *consequences* |
|---|---|---|---|---|---|---|
| Kolmogorov- Smirnov z | .113 | .202 | .098 | .137 | .173 | .098 |
| Sig | .003 | .000 | .017 | .000 | .000 | .017 |

According to Table 6, the data are not normal, and thus the PLS approach should be used [45][46]. Also, the normality test of each question has been evaluated with mean and variance. The average of the questions was more than 3 and the variance was more than 0.5, and their significance level was less than 0.05.

### 5-2- Evaluation of the Proposed Model

The factor load test for each question (112 final indicators) was higher than 0.4 and thus none of the questions were removed. The reliability of this measurement model is acceptable. The significance of the factor load was checked with the t-value statistic, none of the 112 questions was smaller than 1.96 and were not removed. Cronbach's alpha, CR[1], SR[2] and rho-a tests were also used to evaluate reliability (Table 7).

[1] Combined Reliability
[2] Shared Reliability

Table7: Reliability of constructs (Cronbach's alpha, CR, SR, rho-a) [46] [47]

| *Variable* | *Cronbach's alpha > 0.7* | *CR > 0.7* | *SR > 0.5* | *rho-a 0.7 or 0.6* |
|---|---|---|---|---|
| Use SDN by operators (Organizational) | 0.890 | 0.912 | 0.542 | 0.910 |
| Telecom Operator | 0.971 | 0.973 | 0.682 | 0.971 |
| Current Context far from Operators Environment | 0.907 | 0.931 | 0.696 | 0.927 |
| Current Context near Operators Environment | 0.890 | 0.919 | 0.698 | 0.914 |
| Use SDN by operators (Technical) | 0.889 | 0.910 | 0.534 | 0.900 |
| Governance and other stakeholders | 0.888 | 0.911 | 0.562 | 0.898 |
| Strategies | 0.955 | 0.947 | 0.899 | 0.960 |
| Organizational strategies | 0.914 | 0.930 | 0.625 | 0.919 |
| Technical strategies | 0.959 | 0.967 | 0.830 | 0.960 |
| Internal conditions of operators | 0.918 | 0.934 | 0.640 | 0.926 |
| Contextual Factors | 0.924 | 0.912 | 0.838 | 0.938 |
| Casual Factors | 0.960 | 0.939 | 0.839 | 0.964 |
| Intervening Factors | 0.938 | 0.950 | 0.905 | 0.944 |
| Motivations at the individual level | 0.927 | 0.938 | 0.583 | 0.936 |
| Internal motivations of operators | 0.918 | 0.932 | 0.577 | 0.921 |
| Environmental motivations of operators | 0.881 | 0.908 | 0.586 | 0.890 |
| Requirements in SDN architecture | 0.836 | 0.902 | 0.754 | 0.841 |
| Phenomenon | 0.923 | 0.909 | 0.834 | 0.934 |
| Consequences | 0.980 | 0.972 | 0.921 | 0.982 |
| End users | 0.958 | 0.967 | 0.855 | 0.958 |

Convergent validity was extracted with AVE [1] and divergent validity was done by Fornell and Larker method [48]. The AVE for all variables is higher than 0.5 which indicates the appropriate convergent validity of the constructs. Also, the divergent validity was at a reasonable level [45].

[1] Average Value of Extracted variance

## 5-3- Evaluation of the Structural Part of the Model

To evaluate the structure of the model, R Squares, CV Red and CV Com have been used. As the table 8 shows, the endogenous constructs of the model (strategies, consequences, and Phenomenon) with their exogenous constructs (causal, contextual, and intervention factors) with a value of more than 0.76, 0.80 and 0.699, It has a strong structural relationship and this indicates the strength of the structural part of the model. The CV Red index for all variables was higher than the average and in the strong range. Also, the CV Com index for all variables was within the acceptable range [45] (table8).

Table8: Evaluation of the Structural Part of the Model

| *Variable* | *R Squares > 0.19* | *CVRed $Q^2$> 0.01* | *CV Com $Q^2$> 0.001* |
|---|---|---|---|
| Use SDN by operators (Organizational) | 0.856 | 0.426 | - |
| Telecom Operator | 0.972 | 0.609 | 0.422 |
| Current Context far from Operators Environment | 0.870 | 0.547 | 0.601 |
| Current Context near Operators Environment | 0.806 | 0.516 | 0.378 |
| Use SDN by operators (Technical) | 0.813 | 0.396 | 0.457 |
| Governance and other stakeholders | 0.895 | 0.463 | 0.461 |
| Strategies | 0.762 | 0.431 | 0.362 |
| Organizational strategies | 0.896 | 0.503 | 0.532 |
| Technical strategies | 0.903 | 0.692 | - |
| Internal conditions of operators | 0.969 | 0.577 | 0.485 |
| Contextual Factors | - | - | - |
| Casual Factors | - | - | 0.385 |
| Intervening Factors | - | - | 0.653 |
| Motivations at the individuals | 0.898 | 0.478 | 0.682 |
| Internal motivations of operators | 0.827 | 0.440 | 0.430 |
| Environmental motivations of operators | 0.790 | 0.403 | 0.522 |
| Requirements in SDN architecture | 0.843 | 0.597 | 0.575 |
| Phenomenon | 0.807 | 0.326 | 0.613 |
| Consequences | 0.699 | 0.403 | 0.649 |
| End users | 0.895 | 0.710 | 0.577 |

# 6- Conclusions

Today’s telecommunication networks are intensively expensive, manual and inflexible. To transform to SDN, which could lead to cost reductions, automation, greater processing capacity, and service orchestration through programmability, system developers and industry leaders must perceive its necessity and adjust to the intricacies of its adoption.

Although some researches have been done in this regard, most of them have reviewed the advantages, challenges and development process of this technology. In this research, using Grounded theory, the adoption model of SDN technology has been extracted, focusing on the country's telecommunication sectors. The proposed Model include 112 codes, 14 categories and 6 themes which extracted in the qualitative section and confirmed by fuzzy Delphi method.

A comprehensive and integrated framework focusing on all levels (national, organizational, individual, etc.) has been presented, which includes, actions and consequences in addition to environmental factors, input, processing and output.

Among the advantages of the proposed model, we can mention the combination of the strengths of the models presented in adoption of SDN, adoption of similar technologies such as Cloud, and adoption of information technology. Also, attention to management processes, strategies, contextual factors that were not considered in the previous models or were mentioned very little.

The use of grounded theory (Strauss and Corbin model) along with the fuzzy Delphi method and quantitative analysis were very helpful and effective in conducting the research. It is also important to use SPSS and Smart-PLS 3 software to analyze the data collected from the questionnaire and evaluate the fit of the model as well as confirm and reject the hypotheses.

Gall has suggested that there is not much agreement among researchers on determining the criteria for validity and reliability in qualitative research. This disagreement arises from the fact that in the qualitative approach, the findings are based on the researcher's mental reflection and his interpretation of events. Therefore, in the qualitative approach, the definition of validity and reliability a little bit is different [49]. Maxwell has defined different types of validity [52]: Descriptive, Interpretative and Theoretical validity. Goulding believes that the theoretical saturation point indicates the reliability of the grounded theory research method. Theoretical saturation occurs when the data that helps to define the characteristics of a class is no longer included in the research and all the desired comparisons have taken place [51]. in this research these tactics have been used to achieve validity and reliability in qualitative part [50]:

- Data collection from several sources.
- Long-term observation.
- Preventing subjective assumptions in drawing conclusions and ensuring results through feedback. In fact, the researcher presented his interpretations to the participants and identified and corrected the misunderstood areas.
- Using experts with management and human resource experience along with IT.
- Providing various Presentations on SDN technology
- The collection and analysis process have been regularly modified by several experts, and the initial draft of the research findings was provided to research colleagues (supervisors and consultants).
- Quality analysis software (MAXQDA 2012) has been used and thus no data has been ignored in this process.
- In order to confirm the indicators extracted from the qualitative part, the fuzzy Delphi method has been used.
- Issues such as comprehensibility and accuracy of components, adaptation of the result with the phenomenon under study, control of new conditions, inclusion of different dimensions, have been considered in different stages.

In Quantitative part, in order to analyze the collected data, descriptive statistics of demographic variables were presented using SPSS software. Reliability (with factor loading, Cronbach's alpha, composite reliability), convergent and divergent validity (with AVE and Fornell-Larcker method) and measurement of model structure (with R2, CVRed and CV Com (Q2) criteria) were evaluated in inferential statistics. All these criteria were evaluated at a reasonable and acceptable level.

Finally, the fitting of the model was done through the GOF[1] and SRMR[2] criterion. $\sqrt{\overline{\text{communality}}}$ is the average of the shared values of each structure. $\sqrt{\overline{R^2}}$ is the average of the R Squares just for endogenous structures of the model. Wetzles (2009) introduced three values of 0.01, 0.25 and 0.36 as weak, medium and strong values for the overall fit of the model.

$$\sqrt{\overline{\text{communality}}} \times \sqrt{\overline{R^2}} = \sqrt{\overline{0.8629}} \times \sqrt{\overline{0.720}} = ./7878 \tag{1}$$

Obtaining 0.787 for the overall fit of the model indicates a strong overall fit of the model. Also, the value of SRMR index is equal to 0.979, which is less than the value of 0.1. Thus, the model has a suitable fit.

The output of the model shows that the coefficient of significance regarding research hypotheses is out of the range of $\pm 1.96$, which means that all research variables are confirmed at the 95% confidence level in the statistical sample.

Table9: Summary of the Findings

| ***Hypothesis*** | ***Path coefficient*** | ***t-value*** | ***Result*** |
|---|---|---|---|

[1] Goodness Of Fit

[2] Standardized Root Mean Residual

| | | | |
|---|---|---|---|
| H1 | 0.898 | 33.170 | Confirm |
| H2 | 0.298 | 2.826 | Confirm |
| H3 | 0.695 | 7.994 | Confirm |
| H4 | 0.302 | 3.305 | Confirm |
| H5 | 0.836 | 24.696 | Confirm |

In future, the proposed model can develop further by including SDN technology diffusion models. Also, prioritizing the identified categories to understand the importance of each, as well as model simulation to determine the effect of different policies on changing system behavior are among the important items that are proposed to complete the research. In Table 10, some suggestions are presented at three levels: governance, administrators of telecommunication operators and the experts. To avoid this risk, the assessing of company's E-Readiness before starting main project is necessary [53].

Table 10: research Suggestions

| ***Level*** | ***suggestions*** |
|---|---|
| **Macro level (Governance)** | ▪ Support and create motivation for operators.<br>▪ Increasing competitiveness between operators.<br>▪ Persuading investors to invest in infrastructure technologies.<br>▪ Establishing cooperation systems between research centers, industry and government.<br>▪ Creating a trustee in the country for SDN deployment and preparing a detailed roadmap for the operationalization of SDN implementation.<br>▪ Guiding the industry towards the commercialization and export the products of this technology.<br>▪ Reducing the impact of the country's macro changes on the implementation of projects. |
| **Telecom Operator (Manager)** | ▪ Preparing an accurate business plan<br>▪ Clarify clear goals<br>▪ Identify the main risks ahead<br>▪ Increasing awareness and training personnel<br>▪ providing a roadmap for SDN deployment<br>▪ Creating alignment between the country's ICT plans with their business activities (operators)<br>▪ Considering change management<br>▪ Upgrade hardware and software infrastructure<br>▪ Plan and resource allocation to deploy SDN<br>▪ Cultivating expert human resources in the field of SDN technology and related technologies<br>▪ Increasing the agility of operators<br>▪ Participation of experts in international scientific forums and standard-setting organizations |
| **Industry Experts** | ▪ Acquisition of network, software, hardware skills<br>▪ Trying to disambiguate the shortcomings of this technology<br>▪ Providing correct feedback based on study and knowledge and trying to create the right attitude of technology to senior managers<br>▪ Creating partnership and cooperation with other experts<br>▪ Enhance flexibility and acceptance of changes<br>▪ Improving the international language level<br>▪ Communication with academic centers, conferences, domestic and international associations |

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