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Holistic and Reductionist Thinker

A Comparison Study Based on Individuals' Skillset and Personality Types

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Preface

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Holistic and reductionist thinker: a comparison study based on individuals' skillset and personality types

Abstract: As organisations operate in turbulent and complex environments, it has become a necessity to assess the systems thinking (ST) skills, personality types (PTs), and demographics of practitioners. In this study, we investigated the relationship between practitioners' ST profile, their PTs profiles and demographic characteristics in the domain of complex system problems. The objective of this study is to address the current gap in the literature – lack of studies dedicated to predicting practitioners' ST profile based on their PTs and demographics characteristics. A total of 258 practitioners with different demographics and PTs provided the data. The results show that (1) practitioners can be classified based on their ST skills scores into two clusters: holistic and reductionist (that is, ST profile), (2) each cluster has different PTs profiles and demographic characteristics, and (3) practitioner's ST profile can be predicted, with good accuracy, based on their PTs profile and demographic characteristics.

1 Introduction

Nowadays, the socio-technical systems impose many challenges for practitioners, notably systems engineers, in reaching the required objectives. According to Whitworth and Sylla (2012), the socio-technical systems have the ability to succeed regardless of circumstances, such as being free of charge. It is likely that the risk associated with these systems appears to increase as the complexity rises. The complexity of the socio-technical systems is mainly caused by the high level of integration, ambiguity, uncertainty, and interdependence (Ackoff, 1995; Boardman and Sauser, 2006; Keating, 2008; Jaradat and Keating, 2016). These systems usually depict emergent behaviour, which might be hard to comprehend, examine, predict, and manage (Reymondet, 2016). The complexity associated with these systems has always existed even if its perception is recent. However, with the advancement of technologies and creation of interdisciplinary systems, the management of such systems becomes a challenging task (Boardman and Sauser, 2006; Churchman, 1968, 1971, 1979; Deming, 1982; DeLaurentis, 2005; Drucker, 1954, 2012a, 2012b; Gorod et al., 2008; Jaradat et al., 2018, 2019a, 2019b). This awareness arouses a growing interest in the Systems Thinking (ST) studies.

Systems thinking (ST) is an essential paradigm in understanding and resolving real-world dilemmas. It is a discipline that embraces theoretical approaches and practices targeting complex systems problems that cannot be tackled using traditional engineering reductionist approaches. In this sense, ST treats the system as a whole unit instead of individual parts, which is beneficial in dealing with complexity (Ackoff, 1971, 1995). In his book '*The Systems Approach*', Churchman (1968) emphasised the importance of using more holistic systemic approaches to better cope with complex problems. Individuals with high ST skills/capacity tend to comprehend the connectivity between the sub-systems to one whole system and solve multi-disciplinary projects efficiently.

Several standalone research studied the concept of personality traits, preferences, cognition, and behaviour as important elements that impact the way individuals deal with complex system problems (Brown and Moskowitz, 1998; Freeman et al., 2011; Schmidt and Richardson, 2008; Schuldberg and Gottlieb, 2002; Spivey, 2007; Vallacher et al., 2002; Warren, 2006). According to Allport (1961, p.28), "personality is the dynamic organisation in the individual of the psychophysical systems that determine his singular adjustments to his environment". It has been noticed that individuals' PTs might affect their tendency and ability to cope with complex systems such as socio-technical systems (Mumford et al., 2000). The socio-technical system is defined as a highly interconnected system that combines the social and technical entities in an organisation or a workplace, and it is exposed to the external environment (Appelbaum, 1997). According to Appelbaum (1997), organisations require a solid optimisation design to handle properly and effectively the complexity, emergence, and turbulence in the workplace. Failure in understanding and controlling the socio-technical systems can result from technical and/or social aspects including policy, culture, and politics (Ackoff, 1971, 1994, 1995;

Hossain et al., 2019; Jaradat et al., 2018; Katina et al., 2014; Clegg, 2000; Checkland, 1981). To minimise human failures and obtain a better understanding of complex systems, it is necessary to assess individuals' ST skills/capacity. The study of practitioners' ST skills is beneficial in the sense that it provides an efficient management structure. For instance, the identification of individuals' ST skillset would help in matching their skillset with the appropriate problem-solving technique and then minimise the waste of resources. Deming (1982) proposed a system thinking approach, composed of 14 principles, to assist managers in controlling the waste of resources in American companies. Systems thinking approaches have been used in different areas, including virtual teaching module, healthcare, energy-saving, financial service, and supply chain management (Dayarathna et al., 2019, 2020; Faezipour and Ferreira, 2016; Khansari et al., 2017; Lawrence et al., 2019; Nagahisarchoghaei et al., 2018). Regardless of the significant amount of ST studies conducted, few research outlined the impact of PTs profiles and demographic characteristics on practitioners' ST profile (main gap in the literature). The main contribution of this study is to investigate the impact of practitioners' PTs and demographic characteristics on their ST profile. Initially, we test whether we can cluster practitioners based on their seven ST skills scores. Based on the sample size, the clustering result showed that practitioners could be categorised into two clusters of holistic and reductionist. Then, we investigated the differences between PTs profiles and the demographic characteristics of the two clusters. At last, we test whether we can predict a practitioner's ST profile based on the PTs profile and demographic characteristics.

In the following section, we highlight the existing literature review related to ST and its predicting factors. The study design and methodology are described in Section 2. In Section 3, we present the different analysis techniques, including the clustering, post-hoc tests, and prediction analyses, namely, two steps clustering, K-means, Silhouette clustering, one-way ANOVA, artificial neural network (ANN), and binary logistic regression (BLR). Finally, the paper ends with discussion, followed by the conclusion, limitations, and future research.

2 Study background

The existing literature review associated with ST is summarised in the following section.

2.1 Systems thinking (ST): an overview

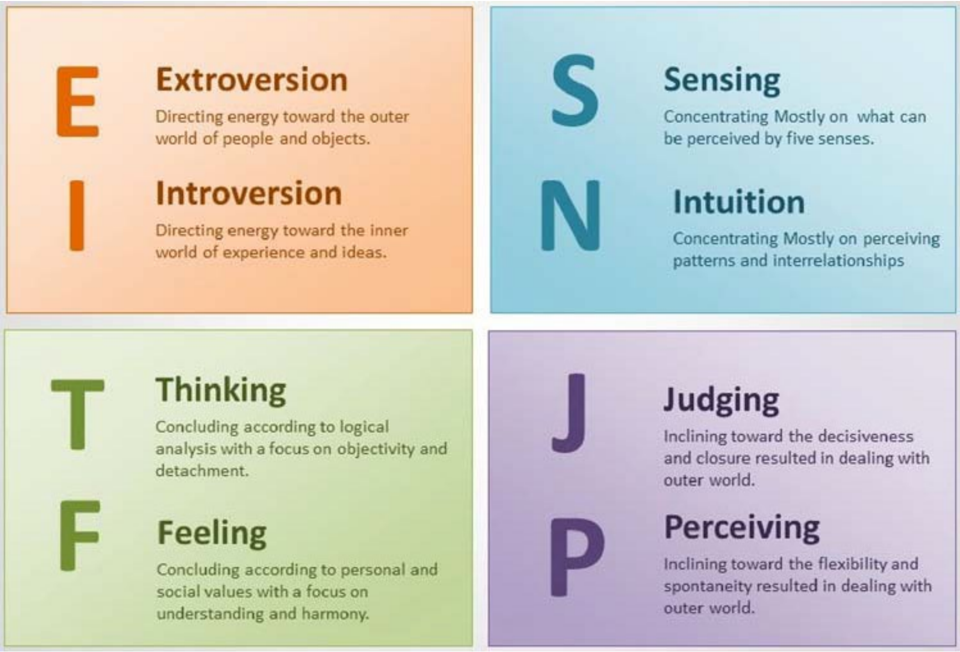
Systems thinking (ST) is a conceptual framework that takes into consideration the different parts of complex systems as integral parts of a set whose elements are interdependent (Monat and Gannon, 2015). ST paradigm allows individuals to comprehend their acts and their impacts on reality and thus learn how to detect the systemic forces and modify the system properly (Sterman, 2010). Bertalanffy (1968), one of the ST pioneers, introduced ST as an approach that emphasises treating systems as a whole and focusing on the interconnection among the systems' components. Along with the same context, Sterman (2010) described ST as the capability to view the entire world as a complex system whose components are interconnected. Senge (1991, p.7) defined ST as "a conceptual framework, a body of knowledge and tools that have been developed over the past fifty years, to make the full patterns clearer, and to help us see how to change them effectively”. In other words, ST targets the entire system as well as the interrelationships between its components. ST concept has been the spotlight of several researchers from the 1980s to 2020. Its literature encompasses systems theory, systems dynamics, complex systems and ST, systems approach, and the different ST tools, techniques, and approaches adopted in different fields (Ackoff, 1994, 1995; Checkland, 1981, 1999; Churchman, 1979; Deming, 1982; Drucker, 2012; Frank, 2006; Gorod et al., 2008; Hossain and Jaradat, 2018; Jaradat et al., 2018; Karam et al., 2020; Keating et al., 2003; Senge, 1991, 2004); along with a wide range of areas including economics (Lamperti et al., 2019), sustainability (Anastas, 2019), banking (Akhtar et al., 2018) and others. Literature shows that practitioners with high ST are more able to depict the big picture of a certain project without wasting time on small details. Literature in ST also shows that to better obtain qualified practitioners, it is essential to determine their personality traits along with their ST capacities (Koral Kordova et al., 2018).

2.2 Personality types (PTs) and systems thinking (ST)

In the early 19th century, the identification of personality traits in the workplace was a dilemma. The classification of psychological types was developed by the Swiss psychiatrist C.G. Jung to illustrate the psychological differences. The Jungian approach (1920, 1933) highlighted three basic bipolar dimensions of the personality: the orientation of energy, perception, and judgement. A fourth dimension was proposed by Myers (1962) based on Jung’s auxiliary function, which is related to the individuals’ preferences. Myers’s development produced what is known as the Myers-Briggs Typological Indicator (MBTI). MBTI instrument is the operational implementation of Jung’s thinking about the human mindset and most comprehensive theory developed by two American women, mother and daughter, Katharine Briggs and Isabel Briggs-Myers (Tucker and Kroeger, 2010, p.22; Myers, 1962; Myers and McCaulley, 1985). The instrument consists of four bipolar scales. The first scale, known as the *Extraversion-Introversion*, depicts the energy utilities. The *Sensing-Intuition* scale represents the perception while the third scale, *Thinking-Feeling* refers to the judgement. The last scale is known as the *Judging-Perceiving* scale and illustrates the orientation. Figure 1 presents the general definition of the four dimensions of the MBTI instrument adopted from Quenk’s (2009) book.

Engineering and practitioners are supposed to address complex systems problems and enhance system performance. These systems are multi-disciplinary and multi-task (Eppinger, 1991). According to Ed-daoui et al. (2019), these systems are defined as system of systems (SoS). Efatmaneshnik and Ryan (2016, p1) defined SoS as “an ensemble of complex systems, which have the potential for an extraordinary amount of structural complexity, even temporarily, as a result of interconnections and couplings that can vary in strength”. In 1954, Drucker introduced a strategic management model known as management by the objective to assist managers and improve the performance of an organisation. Along with the same context, Arass et al. (2019) proposed a paradigm to minimise the complexity of cycle management. According to Steward (1981) and Keating et al. (2003), conventional planning tools do not deal with these problems effectively, and there is a need to have more systemic approaches to better address socio-technical systems. ST paradigm might be an effective approach in addressing such systems. For instance, Chen and Unewisse (2017) employed SoS thinking to conceptualise, comprehend, and evaluate the military SoS efficiently.

Figure 1 Definition of four dimensions of the MBTI instrument (see online version for colours)



The proposed relationship between ST and PTs has arisen in the literature. For instance, Toshima (1993) conducted a study using 264 system engineers working in the Japanese industry to develop a standardised test for systems engineering. The study results indicated the existence of a significant relationship between systems engineers' personality traits, intellectual abilities, and their level of performance. Along with this context, Linder and Frakes (2011) mentioned that individuals' personality type and ST are correlated. The study was based on MBTI and 17 ST practices among members of professional organisations, professionals, and graduate-level students. Nagahi et al. (2020b) utilised a structural equation modelling method to assess the relationship between practitioners' systems-thinking (ST) skills preferences and their personality traits (PTs) in the domain of complex system problems. The study findings demonstrated that the PTs of practitioners positively impact their level of ST skills preferences. Nagahi et al. (2020c, 2020d) found relationships between ST skills and proactive personality of engineering students with their academic performance in the domain of complex system problems.

Buffinton et al. (2002) conducted a study in which they addressed team productivity. Results showed that the personality traits of team members have a significant role in problem-solving styles and interpersonal dynamics of project teams. In another study, Williamson et al. (2013) analysed the personality traits of 4876 engineers and 75,892 non-engineers in the context of innovation and technology development. The comparison showed that engineers recorded a higher score in only 2 out of 13 personality traits. In the same context, Abbas et al. (2018) examined the effect of the personality traits on the innovation performance among engineers. The findings emphasised the existence of a noteworthy relationship between personality traits and innovation. Balkis and Isiker (2005) explored the relationship between the thinking styles and PTs of

367 third-year undergraduate students. The authors found that the two concepts are remarkably related. Similarly, a set of studies carried out by Zhang (2000, 2001, 2002) emphasised the close relationship between thinking styles and PTs. Dragoni et al. (2011) investigated the relationship between cognitive abilities and strategic thinking competency among executives. The study results indicated that there is a highly positive correlation between these laters. Similarly, Soleimani et al. (2018) examined the liaison between MBTI personality type and cognitive metacognitive strategies usage of undergraduate students in the reading and comprehension test. The same conclusion is resolved. In another study, Davidz and Nightingale (2008) showed that participants' personality characteristics positively affect the development of systemic thinking. Since thinking styles and strategic thinking dimensions are in some aspects similar to ST skills dimensions, we hypothesise that a potential relationship between ST skills and PTs of practitioners might exist.

Table 1 Seven dimensions of the ST skills instrument

Less systemic (*reductionist*)	*Dimension*	*More systemic* (*holistic*)
Simplicity (S): Avoid uncertainty, work on linear problems, prefer the best solution, and prefer small-scale problems.	***Level of complexity***: Comfort with multidimensional problems and limited system understanding.	**Complexity (C):** Expect uncertainty, work on multidimensional problems, prefer a working solution, and explore the surrounding environment.
Autonomy (A): Preserve local autonomy, a trend more toward an independent decision and local performance level.	***Level of Independence***: Balance between local-level autonomy vs. system integration.	**Integration (G):** Preserve global integration, a trend more toward dependent decisions and global performance.
Isolation (N): Inclined to local interaction, follow a detailed plan, prefer to work individually, enjoy working in small systems, and interested more in cause-effect solution.	***Level of interaction***: Interconnectedness in coordination and communication among multiple systems.	**Interconnectivity (I):** Inclined to global interactions, follow the general plan, work within a team, and interested less in identifiable cause-effect relationships
Resistance to change (V): Prefer considering few perspectives, over-specify requirements, focus more on internal forces, like short-range plans, tend to settle things, and work best in a stable environment.	***Level of change***: Comfort with rapidly shifting systems and situations.	**Tolerant of change (Y):** Prefer considering multiple perspectives, underspecify requirements, focus more on external forces, like long-range plans, keep options open, and work best in a changing environment.
Stability (T): Prepare detailed plans beforehand, focus on the details, uncomfortable with uncertainty, believe the work environment is under control, and enjoy objectivity and technical problems.	***Level of uncertainty***: Acceptance of unpredictable situations with limited control.	**Emergence (E):** React to situations as they occur, focus on the whole, comfortable with uncertainty, believe the work environment is difficult to control and enjoy subjectivity and non-technical problems.
Reductionism (R): Focus on particulars and prefer analysing the parts for better performance.	***Systems worldview***: Understanding system behaviour at the whole vs. part level.	**Holism (H):** Focus on the whole, interested more in the big picture, and interested in concepts and abstract meaning of ideas.
Rigidity (D): Prefer not to change, like determined plans, not open to new ideas, and motivated by routine.	***Level of flexibility***: Accommodation of change or modifications in systems or approaches.	**Flexibility (F):** Accommodating to change, like a flexible plan, open to new ideas, and unmotivated by routine.

Source: Jaradat (2015, p.65)

In the system thinking field, several tools and techniques were proposed to evaluate system thinking. However, few instruments have been purposefully developed for modern complex system problem domains (i.e., socio-technical systems). Therefore, in this study, we have adopted Jaradat (2015) and Jaradat et al. (2018) ST skills instrument. The adopted instrument measures individuals' ST skills while dealing with complex system problems, using seven dimensions (see Table 1). The instrument is composed of 39 binary questions curtailed in seven preferential categories, which enable the identification of an individual's inclination towards holistic or reductionist thinking. The seven ST skills dimensions correspond to seven letters that represent the ST scores. Comparing the ST skills dimensions (illustrated in Table 1) and the four MBTI dimensions, it can be noticed that the *Extraversion-Introversion* scale has a hypothetical correlation with the *Interaction* and *Independence* dimensions of the ST instrument. The *Sensing-Intuition* scale and the *Systems worldview*, *Complexity,* and *Uncertainty* dimensions of the ST skills instrument reflect a similarity. A hypothetical correlation can be noticed between the *Thinking-Feeling* scale and *Systems worldview* and *Uncertainty* dimensions and between the *Judging-Perceiving* scale and *Flexibility* and *Change* dimensions.

2.3 Demographic variables and ST

By reviewing the literature, it has been noticed that demographic variables, including employer type, organisation sector, the field of degree, education level, managerial and work experience, occupation type, and gender, has a noticeable liaison with ST. For instance, concerning the employer type, Jaradat et al. (2019a, 2019b) investigated the correlation between employment domains and an individual's ST skills. The study results showed the difference in ST skills across different employment domains and how these domains react to changes according to their system's worldview. For instance, Dagli and Kilicay-Ergin (2008) stated that the military domain involves more holistic individuals, which is due to the high awareness and integration required in this domain.

In this study, the second demographic variable is the organisation sector. Complex problems are embedded in organisations, including the organisation's management, organisational performance, organisational configuration, subjective forecasting, and others. These problems vary from one organisational structure to another, which affects the ST paradigm of managers. It has been shown that the public sector managers' ST is different from those in the private sector (Cats-Baril and Thompson, 1995; Boyne, 2002; Gomes et al., 2012; Kwak et al., 2009; PMI, 2014; Gasik, 2016; Nagahi et al., 2020a). Gasik (2016) emphasised that public project management is more complex compared to the private project management. This is due to the political and external forces applied to the public project, the high number of stakeholders, and the persistent management changes. The level of education is one of the important demographic factors that indicate individuals' skillset and productivity (Benson et al., 2004; Chowning et al., 2012). A stream of studies showed that higher education improves the critical reasoning ability of individuals while dealing with complex systems problems (Priyaadharshini and Vinayaga Sundaram, 2018; Ramsden, 2003; Svanström et al., 2008; Stirgus et al., 2019; Yang and Wu, 2012). ST has a strong relationship with education in the sense that students' ST capacities can be enhanced through project-based courses and programs (Frank and Waks, 2001; Frank and Elata, 2005; Frank and Kordova, 2009). A study conducted by Richmond (1993) showed the significant impact of ST on the thinking models, educational development, and learning implements in the learning systems. Along with this context, Betts (1992) illustrated the importance of systemic policy in elementary and secondary education. Assaraf and Orion (2005) conducted a study at the Israeli junior high school. The purpose of the study was to evaluate the development of students' ST capacity in an urban class. Results showed the possibility of improving students' ST capacity despite their moderate abilities.

The following factor is managerial experience. In a study conducted by Ackoff (1994), it has been mentioned that managers with experience are capable of solving 'messes'. Ackoff (1994) introduced the word 'messes', referring to the complex systems problems. In another study, Mumford et al. (2000) investigated the effect of a leader's business experience on dealing with complex social problems in an organisation. Likewise, the work experience plays a major role in the individuals' ST profile. Porter (2008) declared that the work experience is beneficial for the level of managers' systems approach, especially in the social responsibility concerns. Nagahi et al. (2019a) showed that managerial and job experience of practitioners have a positive influence on the level of ST skills of practitioners.

A set of studies emphasised the importance of ST in different domains. Frank (2001) stated that different qualities and abilities are needed to tackle efficiently complex systems problems. Later on, Wasson (2015) affirmed this statement. According to Eisner (2008), a specialist such as systems engineering, engineering managers, and project managers have different distinct ways of dealing with complex systems.

Sladek et al. (2010) examined the relationship between gender differences in thinking disposition among healthcare workers. Results showed that male workers tend to be more rationale compared to females who tend to be more experiential than males. Along with this context, Stephens (2013) proposed a systemic framework called feminist-ST to evaluate ST and gender differences in project design, social policy, project management fields, and other areas. Nagahi et al. (2019b) assessed the moderation impact of gender on an individual's ST skills when engaging in a complex systems problem. The study results indicated that male and female practitioners differ in terms of some ST skills.

Since the above-mentioned demographics investigated in the ST literature, we assume that a potential relationship between ST skills and demographic characteristics and PTs of practitioners might exist. The purpose of the study is to use the MBTI instrument to measure practitioners' PTs and the ST skills instrument to evaluate practitioners' ST profile. The demographic factors were also used in this study, as additional predictors, to develop the theoretical model. In the following sub-section, the development of the theoretical model is described in detail.

2.4 The proposed theoretical model

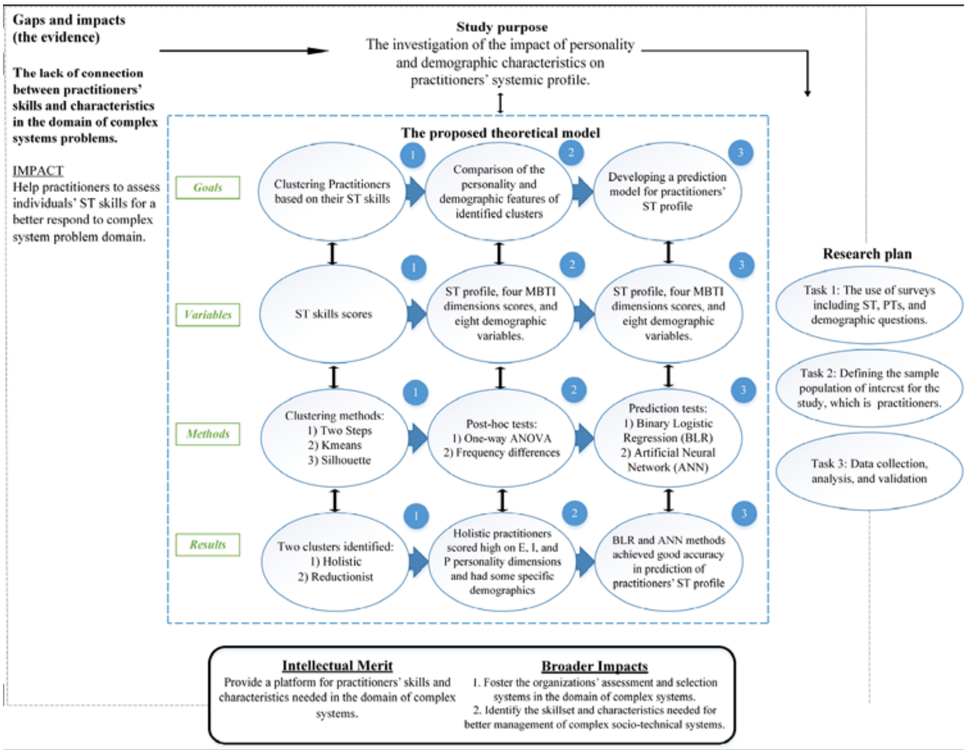
The literature is replete with several studies focused on the effects of personality theory and ST on organisational outputs (Abbas et al., 2018; Bradley and Hebert, 1997; Toshima, 1993; Williamson et al., 2013); however, there is a lack of studies addressing the following essential gaps:

- Evaluation of the relationship between practitioners' personality types (PTs) and their level of systems thinking (ST) profile in the domain of complex systems.

- Investigation of the impact of demographic factors including education level, current occupation type, managerial experience, and work experience and practitioners' PTs on their ST profile in the domain of complex systems. To our best knowledge, there is no study in the literature that simultaneously examine the impact of demographic variables and PTs profiles on practitioners' ST profile.

To address these cited gaps, we have based the analysis on the study framework depicted in Figure 2. The intent of this study is to enrich the current body of knowledge and orient practitioners by investigating the impact of PTs and demographic characteristics on their systemic profiles. Moreover, the study aims to identify the effect of this liaison on practitioners' tendencies in solving socio-technical system problems.

Figure 2 The study methodology framework (see online version for colours)



3 Methodology

The methodology section consists of four phases:

1 identification of the study sample and data collection procedure

2 presentation of study variables

3 summary of descriptive statistics

4 the introduction of the analytical methods used for clustering and prediction (see Figure 2).

3.1 *Sample and data collection procedure*

The data was collected from several organisations, including military and defence agencies (n = 5), manufacturing (n = 3), service (n = 2), and systems engineering consultants (n = 2). The organisations were selected based on one criterion – the complexity of their work environment, which has been determined through short interviews with senior managers. An email invitation to participate in the study was sent to the selected organisations, along with a web-link survey. The respondents filled out the demographic questions and the 39-question ST skills instrument in approximately 10 minutes. It took participants approximately 17 minutes to complete the 70-question MBTI instrument adopted by Keirsey and Bates (1984). The response rate was 55%, with a data size of 258. Responses were recorded using Qualtrics, and identity confidentiality was assured according to the IRB protocol.

3.2 *Study variables*

The variables listed below are developed in the proposed theoretical model of the study.

3.2.1 *Dependent variable*

A score is calculated for each of seven ST skills dimensions, as shown in Table 1. The seven ST dimensions are

1 level of complexity

2 level of independence

3 level of interaction

4 level of change

5 level of uncertainty

6 level of interaction

7 level of flexibility.

3.2.2 *Independent variable*

Personality types (PTs): The assessment of practitioners' PTs is conducted using MBTI. This instrument consists of four bipolar dimensions:

1 level of extraversion (E)

2 level of intuition (I)

3 level of feeling (F)

4 level of perceiving (P).

Initially, a numeric score is calculated for each of the four dimensions. Then, the scores in each of the four dimensions that were more toward the extreme are assigned a corresponding letter. For example, if an individual scored 9 out of 10 in the extroversion dimension, he is assigned a letter 'E' in the first dimension of the MBTI scale.

On the other hand, if an individual receives a score of 2 out of 10 in the Extraversion dimension, he is assigned an opposite letter '*I*' in the Extraversion dimension. After we assigned each person with four letters associated with dominating letter profiles, they received an aggregate four-letter profile as the personality type. The combinations of the four MBTI dimensions give 16 different personality profiles.

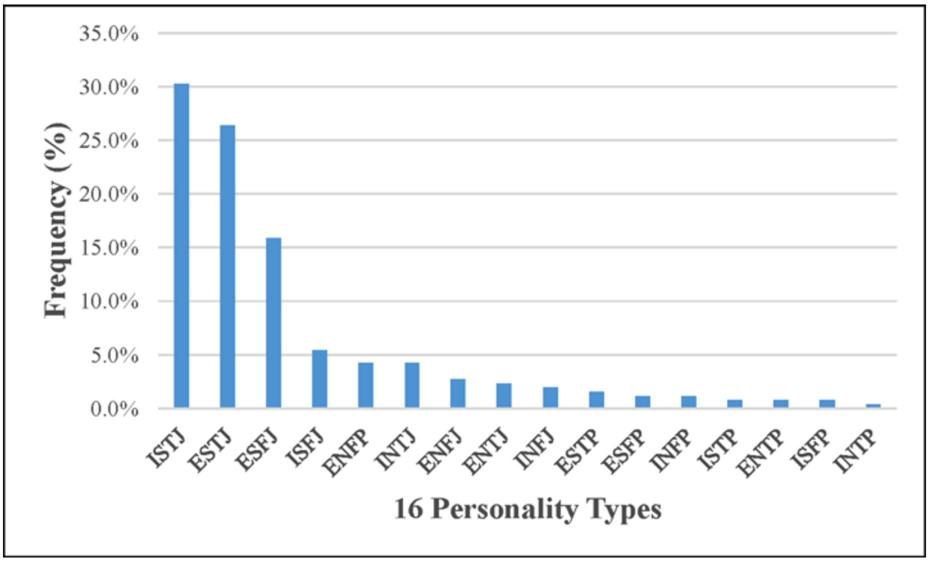
3.2.3 Demographic variables

The demographic variables refer to eight independent variables. The first variable, which is gender, is divided into two sub-variables: male and female. The organisation sector is the second variable folds three dummy variables related to the three types of the sector–private, non-profit, and public organisations. The third variable, employer type, indicates the field to which the practitioner belongs. He or she might be part of the industry, academics, military, government, or other fields. The field of degree is the fourth demographic variable. This variable is also decomposed into four dummy variables associated with practitioners' backgrounds; engineering background, management background, both engineering and management background, and other different backgrounds. The fifth variable, education level, is broken down into four coded dummy variables related to individuals' degree. The first dummy variable is dedicated to practitioners with a diploma degree, and the same logic is applied for other degrees (bachelor's degree, master's degree, and doctoral degree). The managerial and work experiences are the sixth and seventh variables. The final variable stands for the occupation type, consists of three sub-variables: engineers, managers, and others.

3.3 Descriptive statistics

Two-hundred and fifty-eight participants with different demographic characteristics provided data for the study. For the gender factor, males represent 80% of the practitioners, while 20% are females. 46% of practitioners work in private organisations, 42% in public organisations, and 12% in non-profit organisations. 41% of the participants belong to the industry sector, 15% to the academic sector, 16% to the military sector, 13% to the government sector, and the rest 15% to other sectors. Regarding the field of degree, 43% of participants have an engineering background, 22% with management backgrounds, 12% with both cited backgrounds, and 23% with different backgrounds. For the education level factor, participants with master's degrees represent the majority (55%), while others with diploma degrees, bachelor's degrees, and doctorate degrees represent 13%, 19%, and 13%, respectively. Participants with managerial experience above 21 years dominate (47%) the dataset whereas those with managerial experience below five years, between six and 11 years, between 12 and 15 years, and between 16 and 20 years exhibit respectively 17%, 14%, 9%, and 13%. Similar to the managerial experience, in the work experience factor, participants with 21 years of experience and above dominate (80%). Participants with work experience less than five years represent 7% of the dataset while those with work experience between six and 11 years, 12 and 15 years, 15 and 20 years represent 6%, 4%, 3%, respectively. For the last factor which the occupation type, the dataset includes 40% of engineers, 39% of managers, and 21% other occupations. Figure 3 presents the participants' overall personality type profiles based on the MBTI instrument results.

Figure 3 Overall personality type profiles of all participants (see online version for colours)



3.4 Analytical methods

In this section, a review of the different analytical methods used in this study is presented.

3.4.1 Two steps cluster

The SPSS two steps cluster is an analysis of the automatic classification algorithm developed to handle large datasets that are composed of continuous and categorical variables or attributes. It is based on a likelihood distance measure that considers the data variables to be independent variables. The two steps cluster consists of two consecutive steps. In the first step, the data is decomposed into many small clusters. The second step consists of grouping the pre-clustered small data into the desired number of clusters using an agglomerative clustering algorithm. The main advantage of this method is that it can help to identify the adequate number of the clusters in the case that the number is unknown using Schwarz's Bayesian Criterion (BIC) or the Akaike Information Criterion (AIC) (SPSS, 2001). The results of the analysis are usually precise, scalable, and fast in terms of performance (SPSS, 2001).

3.4.2 K-means clustering

K-means clustering is a popular unsupervised learning method used in data mining. The function of K-means clustering is the detection of a number k of clusters in a dataset composed on n observations. In the K-means algorithm, each cluster is defined by a centroid, which is a point at the centre of the cluster. The logic behind this technique is to identify k number of centroids and assign the dataset variables to the nearest cluster using the Euclidean distance. The next step consists of computing the mean values of all variables for each centroid. Each mean value evolves into the new value of the centroid.

This process repeats over and over until the centroid values became almost constant. This method aims to keep the centroids small.

3.4.3 Clustering Silhouette (complementary method for K-means)

Silhouette analysis is used for the interpretation and validation of clusters' consistency. This analysis assesses the distance separating the clusters and provides a plot that displays how well the classification of the samples (Rousseeuw, 1987). Silhouette value is a measure that provides a way to evaluate the similarity of a sample to its own cluster compared to other clusters. This measure ranges from –1 to +1, where +1 indicates that the sample very close to its own cluster but far away from the neighbouring clusters. A value of –1 indicates that the samples are in the wrong cluster. If the majority of samples have a value of +1, then the clustering structure is convenient. Otherwise, the clustering structure is inappropriate. The silhouette value is measured with any distance metric, including Euclidean or Manhattan distances.

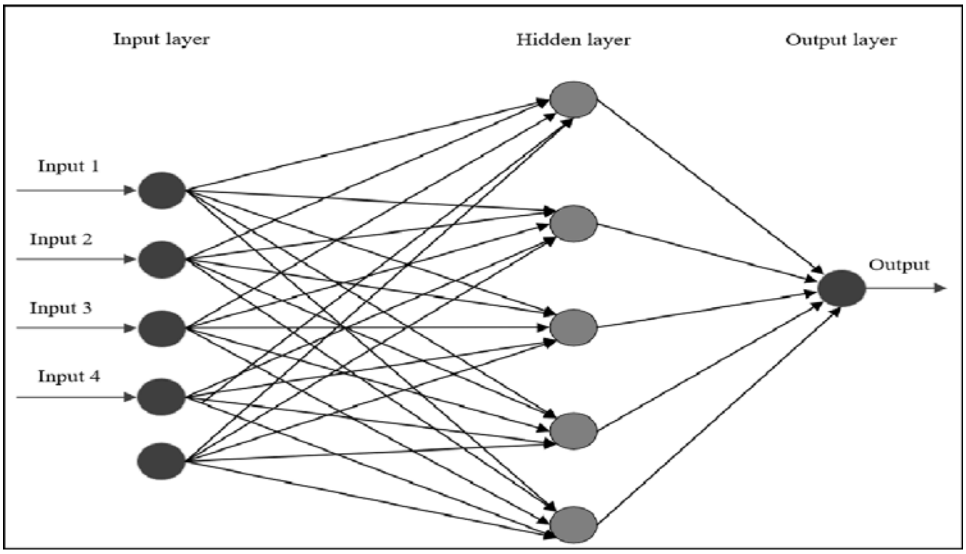
3.4.4 Binary logistic regression (BLR)

The BLR is a powerful regression analysis that is associated with binary or dichotomous dependent variables. According to Lee (2005), BLR analysis is greatly helpful in the sense that it can predict the presence or absence of an output based on a set of independent variables. This analysis is mainly based on the maximum likelihood estimation that opposes the violation of normality (Garson, 2012). As a result, data distribution does not impact the estimation of regression parameters (Mathew et al., 2008).

3.4.5 Artificial neural network (ANN)

An artificial neural network (ANN) is a powerful computational model that is inspired by the functioning of neurons in the human brain (Cross et al., 1995). The model belongs to a branch of machine learning named deep learning. ANN configuration is based on three main components: an input layer, one or more hidden layers, and an output layer. In the input layer, the network is fed with samples of the dataset through a layer with N neurons. The number of neurons is equal to the number of independent samples. The data proceeds then to the first hidden layer in which nodes are multiplied by specified weights. In the hidden layer, neurons are fully or partially related to each other through a series of weight vectors. The same logic is applied for the last hidden layer and the output layer. In the output layer, the outcome of the network is produced. ANN is an iterative process: initially, the weight vectors are given randomly. To evaluate the accuracy of the model predictions, a loss function is used, and based on it, the weight vectors will be updated using the backpropagation method. This will decrease the model's error in the following iterations. The process is repeated over and over until the loss function becomes small. To better compare the results of different methods, other mathematical models, such as optimal control and object-oriented modelling, can be used in conjunction with ANN (Dorodchi et al., 2019; Ghanbari and Farahi, 2013, 2014). Figure 4 illustrates an example structure of an ANN model.

Figure 4 A designed ANN structure



4 Results

Two clustering methods, namely, K-means and two steps, are performed using SPSS version 25.0. Clustering methods are used to show the differences between the ST skills scores of practitioners. Clustering is an unsupervised learning method in which there is no predefined label for data. This section includes results obtained from the clustering, post-hoc comparison, and prediction of practitioners' ST profile based on demographic factors and PTs profiles.

4.1 Practitioners ST profile

In this section, we describe the two clustering techniques used in this study: two steps cluster and K-means clustering.

4.1.1 Two steps cluster

We used the two steps clustering using SPSS software version 25.0 to group the practitioners based on their ST skills scores. Initially, we calculated an average score for each of seven ST skills dimensions as well as an aggregated total ST score. The result showed that the 2-cluster solution achieved the lowest Schwarz's Bayesian criterion (BIC) of 1305.6, which indicates the 2-cluster solution is the most appropriate solution, among others. Based on the ST scores of each cluster, we found out one cluster belongs to practitioners with relatively higher ST scores. Consequently, this cluster is called the holistic cluster. On the other hand, the other cluster consisted of practitioners with relatively lower ST scores, and it is called the reductionist cluster.

4.1.2 K-means clustering (validity check)

K-means clustering using SPSS software version 25.0 was performed to group the practitioners based on their ST skills scores. K-means in SPSS does not provide any test of the best clustering solution. As a result, we used the clustering Silhouette to validate and find the best clustering solution for K-means. The clustering Silhouette result showed that the 2-cluster solution is the best solution for the data. Table 2 shows the result of Silhouette analysis based on the comparison of K-means clustering results. The 2-cluster solution has the highest mean value, among other solutions, indicating the 2-cluster solution by K-means is the best clustering solution. The distances between the two cluster centres were 72.2, and all the ST scores were significant according to the ANOVA result of the analysis. It means that the two identified clusters have a significant difference from each other, which shows the adequacy of clustering.

Table 2 The Silhouette result for K-means clustering

Number of tested clusters	*2*	*3*	*4*	*5*	*6*	*7*
Mean	0.225	0.158	0.169	0.160	0.155	0.148
Std. error of mean	0.007	0.006	0.006	0.007	0.006	0.006

About 97% of cases (250 out of 258 cases) clustered identical by two different clustering methods (two steps and K-means clustering), which shows the good consistency and accuracy for clustering based on the ST skills scores of practitioners. We compared the individual cases (eight out of 258) that were clustered differently by two methods and found the result of two steps cluster more consistent. Therefore, the result of the two steps cluster is considered as the reference for further analysis. As it shows in the result of two steps cluster, this method categorised practitioners with two distinct groups of holistic and reductionist systems thinkers. The holistic group scored higher than 50% on almost all the ST skills dimensions, while the reductionist group scored lower than 45% in all the ST skills dimensions. Tables 3 and 4 show the descriptive statics for two identified clusters based on two steps clustering method.

Table 3 Descriptive statistics for holistic cluster (two steps method)

ST Dimension	*N*	*Mean*	*SE*	*SD*
Interaction	150	77.77	1.41	17.33
Independence		54.53	2.02	24.83
Change		54.44	1.58	19.46
Uncertainty		45.77	1.83	22.53
Complexity		68.88	1.65	20.31
Systems worldview		61.06	2.03	24.93
Flexibility		63.33	2.29	28.13
Aggregate ST score		60.83	0.81	9.94

Table 4 Descriptive statistics for reductionist cluster (two steps method)

ST Dimension	*N*	*Mean*	*SE*	*SD*
Interaction	108	38.88	2.12	22.08
Independence		42.59	2.64	27.49
Change		41.19	1.67	17.42
Uncertainty		23.76	1.72	17.96
Complexity		38.58	1.91	19.94
Systems worldview		29.44	2.06	21.43
Flexibility		44.62	2.61	27.15
Aggregate ST score		37.01	0.84	8.79

4.2 PTs and demographic characteristics

The personality type profiles and the demographic characteristics distributions, along with the two clusters, are discussed and compared.

4.2.1 PTs profiles across two clusters

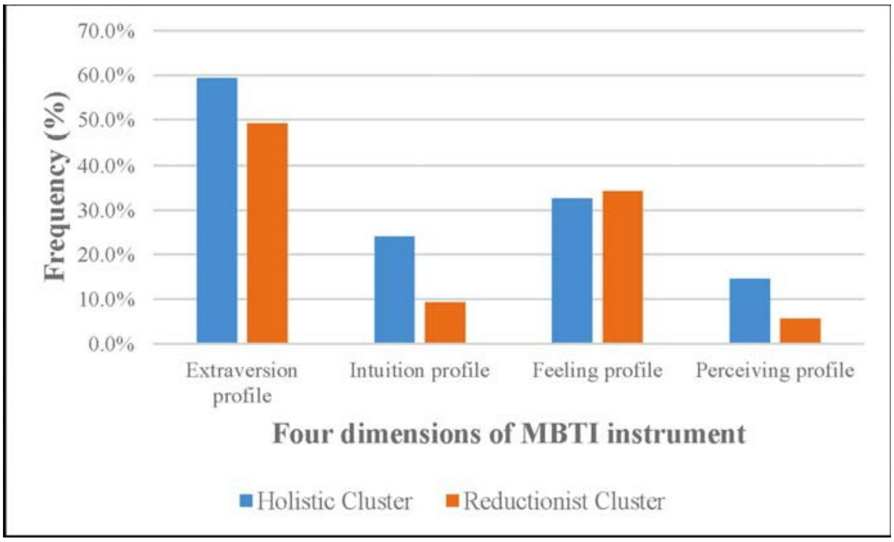
After the identification of two clusters of systems thinkers, namely, holistic practitioners and reductionist practitioners, we investigated the differences between PTs of these two clusters. As a result, a one-way ANOVA using SPSS version 25.0 was performed, and the results show that the differences between holistic and reductionist practitioners are significant in regards to Introversion-Extroversion score ($F(1,256) = 5.06$, $p = 0.025$), Intuition-Sensing score ($F(1,256) = 18.77$, $p < 0.001$), and Perceiving-Judging score ($F(1,256) = 8.96$, $p = 0.003$). Additionally, no significant difference between the two groups found in regards to the Feeling-Thinking score. Table 5 shows the differences between holistic and reductionist practitioners regarding the average scores of four dimensions of the MBTI instrument. Based on Table 5, it can be noticed that the holistic practitioners record a higher score in the extraversion numeric score, while reductionist practitioners record a higher score in the other three MBTI scores (sensing, thinking, and judging scores).

Table 5 The average scores of four MBTI dimensions across two clusters

Cluster		*Extraversion numeric score*	*Intuition numeric score*	*Feeling numeric score*	*Perceiving numeric score*
Holistic	M	55.7	35.9	40.2	26.3
	SD	26.7	24.6	25.6	20.8
Reductionist	M	48.1	23.7	39.5	19.1
	SD	27.5	18.9	24.1	16.2

Figure 5 indicates the percentage frequency of the four dichotomous profile letters across two clusters. It can be deduced from Figure 5 that the holistic cluster has more Extraversion, Intuition, and Perceiving type profile compared to the reductionist cluster. While the reductionist cluster has a slightly more Feeling type profile than the holistic cluster.

Figure 5 Frequency of the four dichotomous profile letter across two clusters (see online version for colours)



4.2.2 Demographic characteristics across two clusters

After the identification of two clusters, we investigated the differences between demographic characteristics among the two clusters. It has been noticed that the holistic cluster has a higher number of practitioners working in private and public organisations. However, the reductionist cluster has a higher number of practitioners working in non-profit organisations. For the following factor, it can be deduced that practitioners in the industry, military, government, and other employers are frequently found in the holistic cluster. On the other hand, practitioners in the academic field are more found to be in the reductionist cluster. Moreover, practitioners with engineering, management, or both backgrounds have a higher frequency in the holistic cluster compared to the reductionist one. For the level of education, the frequency of practitioners with diploma degrees is higher in the reductionist cluster, while the frequency of the ones with master's degrees is higher in the holistic cluster. It has also been noticed that the frequency of practitioners with managerial and work experiences less than five years is relatively higher in the reductionist cluster in comparison to the holistic cluster, whereas others with managerial experience above 11 years belong to the holistic cluster. The occupation type factor indicates that the holistic cluster has more engineers and managers compared to the reductionist cluster. Finally, we noticed that the frequency of male practitioners is higher in the holistic cluster, while the female practitioners' frequency is the same in both clusters.

4.3 The prediction model of ST profile

A prediction model is developed to predict the ST profile of practitioners based on their PTs and demographics characteristics using the two techniques presented below. The intent is if the information of a new practitioner given, the prediction models can predict the ST profile of the new practitioner with high accuracy.

4.3.1 Binary logistic regression (BLR)

We tested how accurately the personality type and demographic variables can predict the system thinking profile – holistic vs. reductionist – of a practitioner using BLR (with SPSS version 25.0). BLR calculates the likelihood of a specific case falling into a binary option by obtaining a set of independent variables. Chi-square of 50.3 with 13 degrees of freedom and p-value < 0.001 shows that the personality type and demographic variables can predict the outcome variable of the ST profile (holistic vs. reductionist). Additionally, the value of '-2 log-likelihood' is 300.5, and the Nagelkerke's (1991) R-square is 0.24. In sum, BLR can predict the ST profile of a practitioner with 69.8% accuracy based on personality and demographic variables. In other words, the personality and demographic features influence the ST profiles of practitioners. Table 6 shows the confusion matrix for the BLR.

Table 6 Accuracy of BLR prediction for practitioners' ST profile

		Predicted		
		ST profile		
Observed		*Holistic*	*Reductionist*	*Percentage correct*
ST profile	Holistic	119	31	79.3
	Reductionist	47	61	56.5
Overall accuracy percentage				69.8

4.3.2 Artificial neural network (ANN)

To show the prediction power possibility and classification between holistic and reductionist practitioners, the ANN method using SPSS software version 25.0 has been performed. To run ANN some initial setup has been set including,

- two hidden layers
- seven neurons in the first hidden layer and three neurons in the second hidden layer
- 13 neuron in input layer as the predictors which includes four PTs dimension scores, one personality profile indicator, and eight demographic variables
- one neuron in output layer as the dependent variable, which is a binary classification of practitioners' ST profile, namely, holistic and reductionist profiles
- partitions setup: we set 80% of the samples for the network training's purpose and 20% of the samples for the network testing's purpose (predicting, and no holdout)
- automatic architecture selection: minimum and maximum number of hidden layers have been set respectively one and 50
- batch method as the type of training and as the optimisation algorithm
- initial Lambda = 0.0000005, initial Sigma = 0.00005, interval centre = 0, and interval offset = 0.5.

According to Table 7, the average prediction accuracy of the testing dataset varied between 78.8% to 79.5% with SD varying from .041 to .052 among different iterations, which shows a good prediction power of the proposed classification between holistic and reductionist clusters. In other words, ANN can predict the ST profile of a new practitioner (a new data added to the dataset) with around 79% accuracy based on his/her PTs and demographic information.

Table 7 ANN classification's results – accuracy and reliability

Number of Iteration		*10*	*20*	*30*	*40*	*50*
Training overall (%)	Average accuracy (%)	77.3%	76.6%	74.7%	74.1%	73.2%
	SD (a measure of reliability)	0.078	0.071	0.069	0.066	0.073
Testing overall (%)	Average accuracy	79.4%	79.5%	79.0%	78.8%	79.3%
	SD (a measure of reliability)	0.049	0.052	0.045	0.041	0.044

5 Discussion

Several standalone studies have depicted the role of ST in enhancing the management of complex systems problems (Checkland, 1999; Flood and Carson, 2013; Keating et al., 2003; Steward, 1981). By reviewing the literature, we have noticed that no study has been conducted to investigate the effect of practitioners' PTs and demographic factors on their ST profile. Comprehending the liaison between PTs and ST profile is beneficial in assigning individuals to a suitable work environment that requires more holistic thinkers or more reductionist thinkers. In the same context, Linder and Frakes (2011) demonstrated the relationship between respondents' PTs and their preferences for using ST practices. This finding has been emphasised by Balkis and Isiker (2005), who showed the existence of a close correlation between PTs and different thinking styles among students. In another study, Davidz and Nightingale (2008) concluded that personality characteristics impact the development of systemic thinking positively.

Using the seven ST skills dimension, the relationship between PTs and ST profile indicates that holistic practitioners scored relatively higher in extraversion, intuition, and perceiving dimensions of MBTI instrument than reductionist practitioners (see Table 5). The score recorded for holistic practitioners is slightly higher in the Feeling dimension compared to the reductionist cluster. This emphasises that extroverted, intuitive, and perceiving practitioners are more comfortable in dealing with complex systems problems. The study result is consistent with the study conducted by Linder and Frakes (2011). Linder and Frakes (2011) showed that intuitive and perceiving respondents have more tendency toward ST practices than respondents with other PTs.

According to Tables 1 and 5, we can deduce that practitioners in the holistic cluster have more inclination toward extroversion, intuition, and perceiving preferences, since they:

- tend to be more interested in discovering the environment, expecting uncertainty, handling complexity
- are concerned with the global performance
- prefer developing general plans and being part of a team

- tend to be comfortable while dealing with dynamic systems
- perceive the system as a whole, take into consideration many perspectives when they make decisions
- tend to be more flexible in adapting quickly to emergent situations
- tend to work in more SoS (multidimensional) problems where integration and interaction are major elements
- understand problems by using a more holistic approach.

Following the same logic, we can notice that practitioners belonging to the reductionist cluster tend toward introversion, sensing, and judging preferences; they:

- prefer working on linear problems and close to the free-uncertainty environment
- prefer making independent decisions
- develop detailed plans and enjoy working by themselves in small systems or with a small group
- take few perspectives into consideration
- perceive the system as parts and break the system into managerial elements to understand the problem
- prefer working in a stable environment
- prefer working on more technical problems.

Referring to the results, we can say that the private and public sectors have more holistic practitioners (65% and 57%). In the non-profit sector, the majority of practitioners belong to the reductionist cluster. Among the employer type, only the industry/business employer has a significant difference between holistic and reductionist clusters; 64% of practitioners are holistic. This result is consistent with Jaradat et al.'s study that showed the ST skills/preferences of practitioners in the industry differ from other employers such as military, academic, and government. In the field of degree factor, we can recognise that the proportion of holistic practitioners are higher in the management field and engineering and management field. About 60% of practitioners with an engineering degree are part of the holistic cluster, while practitioners with other fields of degree are reductionists. For the education level factor, holistic practitioners are those with a master's degree. Results also showed that practitioners who have more than 11 years of managerial experience are classified in the holistic cluster while those with managerial experience less than five years are in the reductionist cluster. Regarding the work experience, we can notice that practitioners with more than 21 years of experience are categorised in the holistic cluster, whereas those with work experience less than five years belong to the reductionist cluster. Moreover, we can deduce that 62% of managers and 58% of engineers are holistic practitioners. For the gender factor, we can say that about 60% of male practitioners are classified in the holistic cluster while female practitioners have the same proportion in both clusters.

Another finding of this study is related to the frequency of 16 overall PTs of practitioners. According to Figure 3, practitioners with the highest frequency are ISTJ (30.5%), ESTJ (26.5%), and ESFJ (16%). These profiles represent 73% of the practitioners' PT profiles. It has been noticed that the study results are consistent with the findings of other researchers. For instance, Keirsey and Bates (1984) and Wideman (1998) suggested that ESTJ managers can be leaders, and ESFJ managers can be leaders and followers. According to McCaulley (1990), Schneider et al. (1998), and Krumwiede and Lavelle (2000), one of the most frequent PTs among managers in the USA is the ISTJ profile.

6 Conclusion, limitations and future studies

6.1 Conclusion

The work presented in this study is essential from an academic and research perspective. The study addresses three critical gaps in the existing literature. The first gap stands for the clustering of practitioners based on their ST skills scores into two clusters. To cluster practitioners, we have used the two steps cluster, K-means, and Silhouette techniques, and having two main clusters named holistic practitioners and reductionist practitioners. The second gap indicates the comparison of practitioners' ST skills and demographic characteristics with respect to their ST profile to identify the existing relationship among them. The comparison has been conducted using One-way ANOVA and the frequency differences technique. Results showed that holistic practitioners have a high score on *E*, *I*, and *P* personality dimensions, and also they have different demographic characteristics than reductionist practitioners. The third gap refers to the testing of the predictability of practitioners' ST profiles based on their PTs and demographic characteristics. The proposed prediction model is validated using BLR and ANN techniques. Both BLR and ANN techniques produced a good accuracy for the prediction of practitioners' ST profile. As a result, the proposed model could serve as a potential framework for predicting the ST profile in similar settings and populations, based on the PTs and demographic information.

6.2 Limitations

Sample size is a typical limitation for survey studies. Based on the central limit theorem, increasing the sample size increases the probability of normal sampling distribution, which leads to a more robust and generalisable research finding (Nunnally, 1994). Although the sample size of this research is very appropriate according to Nunnally's (1994) sample size rule of 10, larger sample sizes might be more accurate (10 observations for each predictor variable, which we have 20 observations for each predictor variable in this study). There are other impacting variables that might impact practitioners' ST profile in the domain of complex systems. We believe that the proposed model can be tailored further to include more impacting variables such as practitioners' complex problem-solving skills, cognitive skills such as reasoning, creativity, process skills such as critical thinking and monitoring self, and demographic variables, such as the level and position of practitioners in the organisation, and other potential variables (World Economic Forum, 2016). Clustering methods categorise data into clusters based on the distance between data-points, and consequently, these methods don not measure how holistic (or how reductionist) a practitioner is, which is a common limitation of clustering methods.

6.3 Future studies

This implies that the developed model can be applied in different academic disciplines in future studies. To enrich the body knowledge, future studies could base their analysis on the NEO-PI five-factor model (FFM) and proactive personality instruments as the personality predictors. The theoretical model can also be validated through the use of various populations during different periods of time. In sum, this study has significance in the domain of complex systems in the sense that the insights derived from it could be used in real-life situations for any socio-technical system.

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14. ABSTRACT

As organisations operate in turbulent and complex environments, it has become a necessity to assess the systems thinking (ST) skills, personality types (PTs), and demographics of practitioners. In this study, we investigated the relationship between practitioners' ST profile, their PTs profiles and demographic characteristics in the domain of complex system problems. The objective of this study is to address the current gap in the literature – lack of studies dedicated to predicting practitioners' ST profile based on their PTs and demographics characteristics. A total of 258 practitioners with different demographics and PTs provided the data. The results show that (1) practitioners can be classified based on their ST skills scores into two clusters: holistic and reductionist (that is, ST profile), (2) each cluster has different PTs profiles and demographic characteristics, and (3) practitioner's ST profile can be predicted, with good accuracy, based on their PTs profile and demographic characteristics.

15. SUBJECT TERMS

Systems thinking skills; systems thinking profile; personality types; complex systems; practitioners; clustering; prediction

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