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An Innovative Methodology to Make a Questionnaire "Positive Definite" by the Statistical Software of Spss

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Abstract: Questionnaires have advantages over some other types of surveys in that they are cheap, do not require as much effort from the questioner as verbal or telephone surveys and often have standardized answers that make it simple to compile data. However, such standardized answers may have some mathematical particularly statistical problems that dealing with them is complicated and only statistics experts can handle them. In this paper a simple methodology by SPSS is presented alongside a case study in an Iranian research and development organization. In the proposed methodology the parts that need deep knowledge of mathematics or statistics are posed on SPSS while the remained parts that can be handled by general skills are allocated to the human analyzer. This point makes the methodology very practical.

Key words: Questionnaire · Positive definite matrix · Knowledge management · Intellectual capital

INTRODUCTION

Neoclassical economics brings up the importance of knowledge and capital to the business processes. Followed the stream of the importance of knowledge and capital, there is a research in our organization that attempts to clarify the intertwined properties between intellectual capital (IC) and knowledge management (KM) by examining the effects of human capital, structural capital and innovation capital on organizational performance, accounting for the mediation of cultural capital, knowledge achievement and sharing and learning and knowledge application with organizational performance (Fig. 1).

A number of KM studies have conceptually established different dimensions of knowledge issues, e.g. Nonaka [1,2] on knowledge creation; Gold *et al.* [3] on knowledge process capabilities; Alavi and Leidner [4] on KM systems, Jarvenpaa and Staples [5] on knowledge ownerships/rewards systems; Massey *et al.* [6] and Davenport *et al.* [7-10] on interpretive case studies; and Teece [11], Bontis [12,13,] and Pike *et al.* [14] on positivist quality research (e.g. classification or frameworks establishment) but it is very rare to find questionnaire-based KM studies. A questionnaire is a research instrument consisting of a series of questions and other prompts for the purpose of gathering information from respondents. Although they are often designed for statistical analysis of the responses, this is not always the case [15].

In better words the studies on the concept of questionnaire are either very managerial or mathematical without a combinatorial discussion. The questionnaire-based KM studies are believed to contribute to the literature by presenting methods or methodologies to make the questionnaires statistically more standardized without being involved in the associated mathematical complexities. This study tries to contribute in this field and as far as the literature has been read, no analogous study was seen. In sum, this research focused on this point: How can we make a questionnaire positive definite without being involved in mathematical complexities?

The Concept of Positive Definiteness: In linear algebra, a positive-definite matrix is a matrix that in many ways is analogous to a positive real number. The notion is closely related to a positive-definite symmetric bilinear form.

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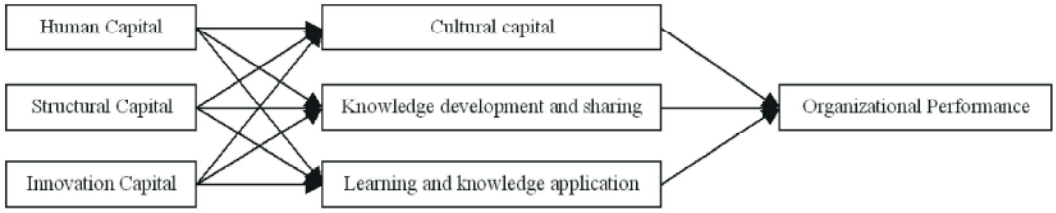

Fig. 1: The structural model of the underlying research

The proper definition of positive-definite is unambiguous for Hermitian matrices, but there is no agreement in the literature on how this should be extended for non-Hermitian matrices, if *at al* [16]. The mathematical definition according to Horn [17] is as follows:

- An $n \times n$ real matrix M is positive definite if $z^T Mz > 0$ for all non-zero vectors z with real entries ($z \in R^n$), where z^T denotes the transpose of z.
- An $n \times n$ complex matrix M is positive definite if $\vartheta\left(z^* Mz\right) > 0$ for all non-zero complex vectors z, where z^* denotes the conjugate transpose of z and $\vartheta(c)$ is the real part of a complex number c.
- An $n \times n$ complex Hermitian matrix M is positive definite if $z^*Mz>0$ for all non-zero complex vectors z. The quantity z^*Mz is always real because M is a Hermitian matrix.

On the basis of the above definitions, making a non positive definite questionnaire a positive definite one seems too complicated to be done by a non-expert KM worker. But many of these complexities are embedded in SPSS (that we can take advantage of) and the user need not knowing any of them. Just like a car driver that need not knowing the complex mechanism of the engine for driving the car. S/he needs only to know some simple points.

It is to be noted that SPSS for Windows provides a powerful statistical analysis and data management system in many fields in a graphical environment, using descriptive menus and simple dialog boxes to do most of the work for you. Most tasks can be accomplished simply by pointing and clicking the mouse.

The methodology: In development of a good questionnaire for our research, after considering the points and constraints like:

- Using clear and comprehensible wording, easily understandable for all educational levels.
- Using only one aspect of the interested construct per item.
- Using statements which are interpreted in the same way by members of different subpopulations of the population of interest.
- Applying the experts' comments.
- Doing a comprehensive review on the credible related questionnaires of the literature.

Our final questionnaire in 53 questions has been achieved as is brought completely in the appendix. As a matter of fact the questionnaire of this study is not exactly the same as the references but have seen some recisions. In this regard seventy five questionnaires were collected while the respondents were middle to top mangers who worked in the related companies of the organization. Now on the basis of the filled questionnaires, the proposed methodology can be applied. Two important practical points about the methodology are as follows:

- From the perspective of positive definiteness, even the most professionally designed questionnaires after being filled by participants, maybe need some kind of processing. So as a rule in the proposed methodology the number of participants is not important and it may not interfere with the rightness of the results. But it is better that the questionnaire become filled by all the potential participants and then the methodology being applied.
- A distinction can be made between questionnaires with questions that measure separate variables and questionnaires with questions that are aggregated into either a scale or index [18]. The proposed methodology can be applied only for the latter category that is commonly part of tests.

Alpha Factor Analysis: The most statistical part of the methodology is conducting alpha factor analysis by SPSS. The alpha factor analysis will attempt to create factors, which are linear combinations of the variables (the fifty three items on the questionnaire) that estimate the latent variables or constructs. The alpha method of

creating factors attempts to create them in such a way that alpha (reliability) is maximized. We could create as many factors as there are variables, but this is not the intention. Because of the fact that the structural model (Fig. 1) has three layers, the analysis must be done for each layer separately.

Since for example the model in the first layer claimed that this instrument measures three constructs, we shall ask SPSS to create only three factors. The output (as usual) is disappointing and the SPSS can do nothing with the filled questionnaire. The program said that "This matrix is not positive definite" and "Extraction can not be done. Extraction is skipped." The same thing happens to the second layer.

Apparently being not positive definite is because of some paradoxes that SPSS identifies. For example some of the questions are not compatible with their construct and should be omitted or moved to another construct or as another example two different constructs should be combined into one. None of these recognitions can be covered by a human analyzer.

There is a categorization on the constructs that helps us on our intention. They can be divided into two groups of 1- independent constructs and 2- dependent constructs. Identifying these two kinds of constructs from each other needs an expert knowledge of mathematics and statistics while by SPSS the mission can be done very simply.

Independent Constructs: In terms of SPSS, independent constructs are the ones that SPSS can calculate their factor matrix. The factor matrix gives the loadings, that is, the correlations between each variable and each factor. To achieve the goal of a positive definite matrix each construct must be represented by only one factor. For example consider the construct of human capital that covers questions of 1-10 on the questionnaire. After doing the alpha factor analysis the rotated factor matrix is achieved as Table 1, in which QUE 01, 05 and 06 are troublesome items because they do not load well on factor 1 and as was discussed before should be omitted. In better words the mentioned questions are positively and more strongly correlated with Factor 2.

After omitting the three incompatible questions and an alpha factor analysis on the new construct of human capital, Tables 2 and 3 are achieved with only one factor that is completely satisfactory in terms of positive definiteness.

Table 3 shows the eigenvalues for the factor analysis. It is worthy to say that SPSS started out by creating seven factors, each a weighted linear

Table 1: The rotated factor matrix

	Factor	
	1	2
QUE04	.864	-.113
QUE10	.630	.593
QUE.09	.624	.430
QUE02	.605	-.025
QUE08	.559	.541
QUE03	.529	.247
QUE07	.516	.200
QUE05	-.146	.660
QUE01	.108	.560
QUE06	.302	.439

Table 2: The factor matrix of the new human capital

	Factor
	1
QUE10	.817
QUE08	.756
QUE04	.747
QUE09	.720
QUE07	.560
QUE03	.559
QUE02	.529

Table 3: The explanation of total variance by eigenvalues

	Initial Eigenvalues		
Factor	Total	% of Variance	Cumulative %
1	3.700	52.857	52.857
2	.964	13.777	66.634
3	.891	12.730	79.364
4	.696	9.948	89.313
5	.436	6.224	95.537
6	.177	2.535	98.072
7	.135	1.928	100.000

Table 4: Communalities of the items on structural capital

	Initial
QUE11	.269
QUE12	.411
QUE13	.714
QUE14	.696
QUE15	.708
QUE16	.771
QUE17	.510

Table 5: The rotated factor matrix of QUE 11-22

	Factor		
	1	2	3
QUE14	.900	-.094	-.055
QUE13	.835	-.115	-.125
QUE15	.796	-.204	.073
QUE16	.750	.437	-.144
QUE22	.639	.415	-.003
QUE12	.463	-.117	.034
QUE21	-.176	.826	.291
QUE17	.230	.786	-.029
QUE20	.185	.701	.387
QUE19	-.453	.627	-.004
QUE18	.333	.415	-.656
QUE11	.498	-.201	.556

Table 6: The rotated factor matrix after omitting QUEs 11 and 18

	Factor	
	1	2
QUE14	.897	.001
QUE13	.833	-.035
QUE15	.829	-.091
QUE16	.689	.489
QUE22	.596	.494
QUE12	.480	-.050
QUE21	-.278	.849
QUE17	.141	.799
QUE20	.067	.730
QUE19	-.503	.547

Table 7: The new structural capital Eigenvalues

	Initial Eigenvalues		
Factor	Total	% of Variance	Cumulative %
1	3.629	60.484	60.484
2	.992	16.539	77.023
3	.619	10.315	87.338
4	.345	5.753	93.091
5	.235	3.919	97.011
6	.179	2.989	100.000

Table 8: The new innovation capital Eigenvalues

	Initial Eigenvalues		
Factor	Total	% of Variance	Cumulative %
1	2.629	65.721	65.721
2	.898	22.457	88.178
3	.352	8.803	96.981
4	.121	3.019	100.000

Table 9: The alpha factor analysis result of human, structural and innovation capital

	Initial Eigenvalues		
Factor	Total	% of Variance	Cumulative %
1	3.949	39.487	39.487
2	3.004	30.041	69.528
3	.973	9.733	79.261
4	.746	7.464	86.725
5	.486	4.855	91.580
6	.302	3.017	94.597
7	.259	2.593	97.190
8	.164	1.638	98.828
9	.091	.907	99.734
10	.027	.266	100.000

Table 10: The rotated factor matrix of human, structural and innovation capital

	Factor		
	1	2	3
QUE14	.845	-.172	.018
QUE16	.788	.320	-.070
QUE15	.760	-.251	.061
QUE13	.759	-.200	.099
QUE22	.727	.368	-.251
QUE12	.527	-.191	.504
QUE21	-.092	.881	.275
QUE17	.327	.766	-.227
QUE19	-.426	.722	.470
QUE20	.216	.683	-.022

Table 11: The rotated factor matrix of the new two-construct first level

	Factor	
	1	2
QUE14	.892	-.094
QUE13	.825	-.123
QUE15	.814	-.178
QUE16	.737	.413
QUE22	.645	.428
QUE12	.472	-.101
QUE21	-.187	.873
QUE17	.224	.780
QUE20	.144	.719
QUE19	-.442	.597

Table 12: The alpha factor analysis results of the second level

	Initial Eigenvalues		
Factor	Total	% of Variance	Cumulative %
1	5.115	46.500	46.500
2	2.122	19.293	65.793
3	1.571	14.282	80.075
4	.912	8.288	88.363
5	.488	4.437	92.800
6	.340	3.089	95.888
7	.210	1.908	97.796
8	.126	1.141	98.937
9	.069	.631	99.569
10	.036	.324	99.893
11	.012	.107	100.000

Table 13: The Cronbach's alpha for the seven constructs of the new questionnaire

Construct	Human capital	Structural capital	Cultural capital	Knowledge achievement and sharing	Learning and knowledge application	Organizational performance
Number of items	7	10	5	2	4	6
Cronbach's alpha	0.8478	0.7551	0.8644	0.8015	0.8733	0.9003

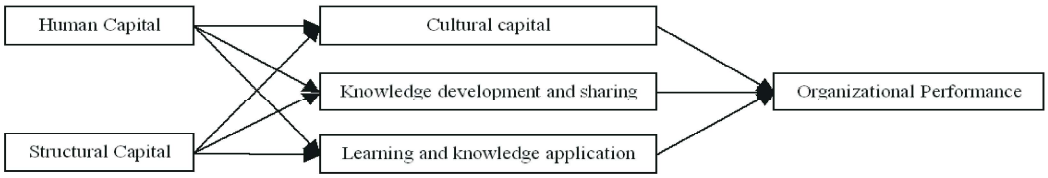

Fig. 2 : The new structural model after making the questionnaire definite positive

combination of the seven items. The initial eigenvalues tell us, for each of those seven factors, how much of the variance in the seven items was captured by that factor. A factor with an eigenvalue of 1 has captured as much variance as there is in one variable.

Dependent Constructs: In terms of SPSS, independent constructs are the ones that SPSS can not calculate their factor matrix and the only output is calculation of the communalities. These constructs must be combined with another construct of their layer.

After running the alpha factor analysis on the construct of structural capital (QUE 11-17), the SPSS output was only Table 4 that implies dependency of the construct. It is worthy to say that communalities tells what proportion of each variable's variance is shared with the factors which have been created. In the Initial column these are based on all seven factors (one per variable) which were created. Accordingly, the values in this column tell us how much variance each variable shared with all the other variables. For example QUE 11 has disturbingly low values here.

Based on what has been discussed the structural capital should be combined with the innovation capital, while in this condition should there be some replacements between their questions. After the combination (QUE 11-22) and running of the alpha factor analysis, Table 5 is achieved.

Since the combinatorial items of 11-22 cover two construct, the resulted factor matrix in terms of positive definiteness must have exactly two factors. For a two factor model, according to Table 5 the two following changes should be applied:

- QUE18 and QUE11 should be omitted.
- QUE17 (The organization structure prohibits the personnel from splitting.) and QUE22 (The existing know-how can convert easily to adapt to the environmental changes.) should be replaced. That is QUEs 22 and 17 are considered as the item of structural and innovation capital respectively; while even logically this change can be acceptable.

After the above changes and running the alpha factor analysis, Table 6 is achieved with pleasing result of two factors.

The new versions of structural and innovation capital according to Tables 7 and 8 assure good state of independent constructs.

The New Questionnaire and Cronbach's Alpha: After running same procedures on the 5 remaining independent constructs the following changes are applied. QUEs 27-29, 31 and 32 from cultural capital; QUEs 33 and 36-38 from Knowledge achievement and sharing; QUEs 39, 40 and 43 from Learning and knowledge application; and QUE 50 and 53 from Organizational performance are omitted to come to a new questionnaire with 34 questions. For the first layer of the model Tables 9 and 10 shows the results.

The results in the last two tables on one hand assure that the corrected questionnaire first layer is positive definite and on the other hand implies a possibility for another promotion in the questionnaire quality. As can be seen in Table 10 only the items of human capital are seen conspicuously and it seems that it would be better to combine structural and innovation capital into a single construct. The resulted factor matrix after the combination is shown by Table 11.

Apparently on the basis of Table 11 with conspicuous factor combination of the constructs, combination seems wise to come to the new structural model of Fig. 2.

The result for the three constructs of the second layer is all right again as is shown by Table 12.

At last the Cronbach's alpha is calculated for different parts of the questionnaire as is shown by Table 13. As can be seen for all the parts the Cronbach's alpha is greater than 0.75 that is an up to standard value for a research instrument.

CONCLUSION

Development of instruments by which a general worker can do an expert's job has always been considered as a good contribution. For example the most

conspicuous contribution of Frederick Winslow Taylor was development of a system by which every one can analyze the production system excellently [19].

In this study, whereas no empirical studies examining the efficient methods and methodologies for interpreting the questionnaire simpler but mathematically, a same work has been done. By an innovative application of the general statistical software of SPSS, a questionnaire can be checked from the perspective of positive definiteness. For better demonstration, alongside the methodology a case study in a research and development organization is presented with acceptable results.

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Appendix

Dear colleague,

The purpose of this research is collecting some information about intellectual capitals and knowledge management in your organization. Here through 53 questions your valuable opinions about "human capital", "structural capital", "innovation capital", "cultural capital", "Knowledge development and sharing", "Learning and knowledge application" and "organizational performance" are enquired.

Thank you very much for helping us in doing the research

With figures of 1 to 5, please indicate how agreeable you are with the following statements.

1: Absolutely disagree; 2: Semi disagree; 3: Moderate; 4: Semi agree and 5: Absolutely agree

Individual characteristic:

A)Age: ……. B) Education: ……. C) Experience (in year): …….

Human capital [20]

No.	Question	Score
1	The organization personnel are looked at as creative and intelligent workers.	
2	The personnel are satisfied with the organization.	
3	The personnel do their best in fulfillment of their duties.	
4	The organization has a comprehensive employment plan to employ the best available applicants.	
5	If one of the personnel leaves the organization unexpectedly, big difficulties will arise.	
6	The employees learn from each other.	
7	The personnel are motivated to give their opinions in group discussions.	
8	The personnel do not consider the others levels lower than themselves.	
9	The personnel competency is at maximum ideal level.	
10	The personnel do their best in differentiating their organization from others of the industry.	

Structural capital [20]

No.	Question	Score
1	The organization income per employee has increased during last years.	
2	An operation time has been decreased during last years.	
3	The organization supports new ideas and products.	
4	A considerable part of new ideas will be applied and become practical.	
5	If an employee has a new idea; the organization shares with her/him the necessary knowledge.	
6	The systems and procedures of the organization support the innovation.	
7	The organization structure prohibits the personnel from splitting.	

Innovation capital [21]

No.	Question	Score
1	The intellectual properties are hard to imitate by the competitors.	
2	The intellectual property can obtain certain financial gains for the company.	
3	The intellectual property can be possibly used by many other trading partners.	
4	The intellectual property has the strength to help achieve competitive changes.	
5	The existing know-how can convert easily to adapt to the environmental changes.	

Cultural capital [22]

No.	Question	Score
1	Organizational culture discusses the organization perspective, strategy and policy apparently.	
2	Organizational culture supports team working and knowledge sharing.	
3	Organizational culture supports cooperation.	
4	Organizational culture supports trust and open approach.	
5	Top managers declare openly their decision of applying the system of knowledge management.	
6	Top managers support the knowledge management projects and policies.	
7	The organization supports the personnel cooperation actively.	
8	There is an organizational commitment to strengthen the personnel.	
9	The personnel are motivated to benchmark the best practices of other organizations.	
10	The personnel are motivated to cooperate in planning and assessment of works.	

Knowledge development and sharing [23,24]

No.	Question	Score
1	The managers know where to find the necessary knowledge, expertise and information.	
2	The personnel are not afraid of less charisma after sharing of knowledge with others.	
3	Knowledge is distributed widely among personnel not only on the basis of their needs.	
4	Knowledge sharing between apart departments of organization happens regularly.	
5	Much the knowledge is in documents and data bases rather than the employees' brains.	
6	I have access to employees with the needed implicit knowledge regardless of hierarchy.	

Learning and knowledge application [25,26]

No.	Question	Score
1	There are informal places in the organization for meetings and appointments in which the problems are dealt with creatively.	
2	The aggregated knowledge of the organization is applied to solve the new problems.	
3	The lessons of organization previous mistakes have always been emphasized.	
4	After project consummation, the team gathers to analyze the mistakes and the parts that could have been done better.	
5	At the time of loss the first reflex is not finding the guilty people.	
6	Thinking about lessons of past experiences is completely usual in the organization.	
7	At the time of great achievements, the affairs that have been done very well are discussed.	

Organizational performance [21]

No.	Question	Score
1	The development efforts of different units are now more coordinated.	
2	The organization has a quick adaptiveness to the unanticipated changes.	
3	The market response time has been decreased.	
4	The redundancy of information and knowledge has been decreased.	
5	The overlapping development of corporate initiatives is avoided more.	
6	The organization ability in anticipation of surprises and crises has been increased.	
7	More potential markets are now ruled by the organization products/services.	
8	KM provides the positioning that competitors are forced to adopt less favorable postures.	