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Predictive modelling of social capital among library workers: a machine learning approach

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ABSTRACT
Social capital is an important asset for the development of communities, including communities linked to specific types of libraries. Despite numerous studies, no models dedicated to measuring this specific area have been developed yet. The paper proposes a model predicting the level of social capital among library workers with the use of machine learning methods. Its purpose is to identify the attributes that determine the level of social capital in a given community in order to enable the development of key areas. The model may be adapted for use in other groups, e.g. among library users or library non-users, in order to analyse social capital in the entire local community.

Keywords: Social capital; Library personnel; Libraries; Community development; Predictive model.

INTRODUCTION

Social capital, defined as a network of connections and social norms that enable individuals to collaborate in order to improve their life situation as well as prevent and solve social problems (Putnam, 2010), is a broad concept that covers various kinds of phenomena. Because of its multidimensionality, different theories, analyses and tools may be applied to study social capital. It can also be reviewed in different contexts: in association with social norms and principles (so-called regulatory component of social capital), social structures (structural component) or group or individual behaviour (behavioural component). The way social capital is diagnosed depends on how it is defined and what types of social capital sources are subject to analysis. The heterogeneity and multidimensionality of social capital make it difficult to develop universal measuring and analysis tools.

In the case of libraries, there is a pending need to study their actual role in the processes of building and solidifying social capital to stimulate the development of local communities (Vårheim, 2007). The existing studies, based on different methodologies and lacking comprehensiveness, failed to produce an optimal measuring method, one that would be supported by solid evidence and could be reused in order to compare results (Kranich,

2001; Hillenbrand, 2005; Aabø et al., 2010; Gong et al., 2008; Pors, 2008; Johnson, 2010; Lind & Svendsen, 2013; Griffis & Johnson, 2014). In this paper, we propose a research method to predict the level of individual social capital of librarians, who play an important role in the development of the social functions of libraries.

LITERATURE REVIEW

Social capital, with its significant impact on the functioning of the entire society, smaller social groups, groups of friends or colleagues and families, is frequently defined and discussed in literature. In the most general terms, it is the value arising from social relationships and trust that yields social and economic benefits to individuals.

According to the research concept outlined by Herbst (2007), social capital can be derived from six main sources as identified by the World Bank:

a) Families;
b) Communities characterized by varying levels of neighborly integration and social circles;
c) Institutionalized collaborations, such as different types of organizations;
d) Civil society, which relies on the ability of individuals to actively participate in public life, impacting decisions and expressing opinions;
e) The public sector, encompassing governmental authorities and institutions at local, regional, and national levels;
f) Ethnic ties, observable even in developed societies, such as nepotism within business environments.

Interestingly, libraries are linked to most of those spheres, i.e. to the functioning of local communities centred around libraries, institutionalised forms of activity, civic activity stimulated, among other things, by library projects or the public sector, in which most of the libraries operate.

Because of its multidimensionality and heterogeneity, social capital is difficult to study, yet researchers from various disciplines measure and evaluate social capital, which suggests that it is an important resource and plays a significant role in multiple social phenomena. Each individual study requires operationalisation of the concept of social capital and choice of a specific study model and assumptions. Usually, authors define the level of sociological analysis (a study of individuals, social groups, organisations or nations), the nature of external effects (positive or negative social capital), the type of bonds comprising social capital (the bonds of a family, association, power and formal subordination) and the strength and frequency of bonds (strong and frequent contacts – i.e. the most immediate family vs. weak and infrequent contacts – e.g. distant acquaintances). In other words, studies may focus on various dimensions of social capital: structural dimension (social networks, groups, structures and institutions, information channels and connections), regulatory dimension (social norms, especially those associated with interaction, models for pursuing values and interests, trust, solidarity, customs and practices) and behavioural dimension (concerning specific manifestations of interaction: collaboration, help, volunteerism, joint projects and exchange of information) (Markowska-Przybyła, 2017, p. 86).

Researchers usually develop their own indicators to measure social capital, there being no single, generally accepted model. The existing indicators may be grouped into three main categories:

a) Associated with social capital as such, measured on the basis of data on memberships in organised groups, shared norms, sense of bonding, sociability, neighbourly collaboration, volunteering activity and interpersonal trust;
b) Measuring the determinants of social capital, such as a sense of identity, and pride or access to information, e.g. through newspapers;
c) Evaluating the various (positive) effects of social capital: trust in institutions, honesty, low crime rate or political participation (Kamińska, 2011, p. 69).

Studies on social capital may focus on individuals, societies, regions, entire states or organisations. They may show the state of social capital in action (so-called utilised capital) or "mobilised" capital – that may potentially be used be members of a social network. Most often, researchers make the preliminary assumption that social capital is a source of benefits, i.e. it enables access to other resources or, to the contrary – that it is a source of dysfunctional or even pathological behaviour. Then, they formulate specific theses depending on the community they have selected for their study.

The choice of the environment where the study is conducted determines the use of study tools. In smaller groups that are willing to cooperate, interviews, questionnaires and source document analyses are useful, whereas in the case of large communities – e.g. country-wide or international studies, it is better to use data collected by specific offices or institutions and available in reports or databases.

Social capital research may be quantitative or qualitative. Quantitative research methods include a broad range of indicators that are each time tailored to the specific goals, conditions and nature of research (e.g. monographic, cross-sectional or dynamic research) and the functions of social capital that are analysed (economic, social, political, cultural). Since social capital is multi-dimensional, many studies (especially those focusing on the development of local communities or entire regions) are accompanied by social capital analyses or even cultural capital analyses. This enables complex evaluation. For example, the number of books borrowed per registered member of a public library is used in some studies as supplementary indicator (measuring the human capital, which is the basis for social capital) of average rank and significance. It indicates acquisition of knowledge, skills, information about the country and region. This indicator does not take into account readership among members of school or private libraries or acquisition of information from other sources: the radio, newspapers, the Internet. It also disregards the quality of readership. Yet, it is easy to process, being based on ready-made data (Kamińska, 2011).

Social capital research is conducted in many countries across the world, using different model and tools (questionnaires, interviews or experiments). The most important are: the World Values Survey and the European Values Survey, surveys in the United States (Social Capital Community Benchmark Survey; Living Standards Measurement Survey) and in the United Kingdom (General Household Survey; Home Office Citizenship), models developed by the World Bank (the Social Capital Assessment Tool and the Integrated Questionnaire for Measurement of Social Capital) and other studies focusing on leisure activities or engagement in democratisation processes, e.g. Citizenship, Involvement, Democracy Network; Adult Literacy and Lifeskills Survey; European Household Community Panel. Surveys usually use a universal set of questions concerning generalised trust, readiness to

help others, engagement in social life, civic and volunteering activity, attitude to the authorities and local or religious community.

Robert Putnam's social capital index

Robert Putnam – the leading social capital researcher – in one of his publications proposed a ready-made tool to measure social capital, which he called the Social Capital Index (Putnam, 2000). His Index contains fourteen indicators that measure the main five dimensions of social capital, namely: community organisational life, engagement in public affairs, community volunteerism, informal sociability and social trust. The Index measures the general social capital resources available to the studied community. Putnam's tool makes it possible to explore more thoroughly the areas that are of interest to a researcher by asking detailed questions in order to analyse social capital in different contexts, regions and social groups. Table 1 presents the components of general social capital and the respective indicators associated with each component.

Table 1: Robert Putnam's Social Capital Index[1]

Social capital dimension	Indicator
Community organisational life	• Served on committee of local organisation in last year (percentage of population) • Served as officer of some club or organisation in last year (percentage of population) • Civic and social organisations per 1,000 population • Mean number of club meetings attended in last year • Mean number of group membership
Engagement in public affairs	• Turnout in presidential elections • Attended public meeting on town or school affairs (percentage of population)
Community volunteerism	• Number of nonprofit organisations per 1,000 population • Mean number of times worked on community project in last year • Mean number of times did volunteer work in last year
Informal sociability	• Agree that "I spend a lot of time visiting friends" • Mean number of times entertained at home in last year
Social trust	• Agree that "Most people can be trusted" • Agree that "Most people are honest"

The World Bank model

Social capital research is also conducted by national governments and international organisations with the aim of determining and possibly improving the quality of life. Among the most valued are the analyses the World Bank conducts in almost all countries of the world. The World Bank's analytical model may be used to study entire communities (societies) and it is frequently applied by governments, politicians and researchers interested in the macro dimension of social capital. It is a simple and explicit tool for social practitioners to diagnose the political, economic and psychosocial aspects of reality. Yet, the model has some drawbacks, for example, it oversimplifies certain social mechanisms (e.g. it assumes that if people trust each other, the quality of their life improves, i.e. they have better lives) (Mikiewicz, 2014, p. 150). Table 2 presents the respective dimensions of social capital analysis proposed by the World Bank.

[1] On the basis of: Robert Putnam, Bowling alone: The Collapse and Revival of American Community (New York, NY: Simon&Schuster, 2000): 291.

Table 2: Basic Social Capital Dimensions According to the World Bank[2]

Groups and networks
The most important attributes of formal groups: density of membership, diversity of membership, extent of democratic functioning, extent of connections to other groups. How to measure it: by asking questions concerning specific hypothetical situations: if you suddenly needed a small amount of money, how many people beyond your immediate household could you turn to?
Trust
Within specific relations and networks, trust extended towards strangers (often on the basis of expected behaviour or a sense of sharing the same norms), trust towards government institutions (including integrity of principles, official procedures, solutions and allocation of resources). How to measure it: if you have to go out for a short while, would you ask your neighbour to look after your child? Generally speaking, would you say that most people can be trusted, or that you can't be too careful in your dealings with other people?
Collective action
The extent to which collective action occurs, provided it is not imposed by external force, as an indirect indicator of underlying social capital. How to measure it: Do you help in a local group as a volunteer? Did you participate in an event in the local community in the last 6 months (e.g. a church feast, school concert, handicraft exhibition)?
Social inclusion
Determining who in a given community is included in collective action, decision-making and access to services – from general questions concerning social cohesion and sense of community to specific experiences concerning exclusion from decision-making and/or benefiting from certain services/projects. How to measure it: are there any services from which your household is sometimes excluded (services that are denied to you) or that you can use only temporarily?
Information and communication
Maintaining and enhancing social capital depends critically on the ability of the members of a community to communicate among each other, with other communities and with members of their networks that live outside the community. How to measure it: questions about the availability of a number of important sources of information: telephone, newspaper, radio and television.

Other researchers, Christiaan Grootaert, Deepa Narayan, Veronica Nyhan Jones and Michael Woolcock, who collaborated as expert with the World Bank, used the following six basic categories of social capital indicators:

a) Networks and membership in organisations, especially various kinds of associations in which an individual is involved in a more or less formal way.
b) Trust and solidarity measured, in particular, by personal trust.
c) Collective action and cooperation measured by activity and cooperation in daily life and in crisis situations (e.g. natural disasters).
d) Information and communication, which explores, for example, readership of newspapers and use of other sources of information.
e) Social cohesion and inclusion associated with openness towards or discrimination of minority groups as well as conflicts and tensions on account of social differences.
f) Empowerment and political action concerning attitude to and influence on the political system (Grootaert et al., 2004).

[2] On the basis of: Piotr Mikiewicz, *Kapitał społeczny i edukacja* (Warszawa: Wydawnictwo Naukowe PWN, 2014): 149.

In fact, all of the above somehow concern libraries, their workers and the communities they collaborate with. Accordingly, the indicators proposed by Grootaert are more or less relevant to studies on social capital in the operation and functioning of libraries.

Level of social capital vs nature of research

Many researchers note that it is necessary to use different research tools depending on the examined level of the social capital. For example, Małgorzata Gajowiak (Gajowiak, 2012) proposed to group social capital indicators on the basis of the criterion of the scope of research, as presented in Table 3.

Table 3: Classification of Social Capital Indicators on the Basis of the Scope of Research According to Gajowiak (2012)

Level	Description
Household	Quantitative and qualitative analyses of relationships within a family (family social capital), with neighbours and acquaintances (neighbourhood social capital), and indicators: • Intensity and form of mutual assistance between individuals related by blood or marriage • Form and intensity of investments in own children • Membership of household members in social organisations • Scale and frequency of contacts with relatives, acquaintances and residents of the neighbourhood • Trust in the family, neighbours and residents • Divorce rate
Local and regional community	• Trust in local residents and authorities • Participation in local life • Frequency of contacts with local authorities • Social activity • Participation in local elections • Membership in social organisations • Number of NGOs per resident
Country	• Diagnosing social capital resources, e.g. in the context of national authorities, courts or political parties • Secondary analysis of data (e.g. from the National Electoral Commission, Statistics Poland, opinion polls)

In the case of library research, the most useful will undoubtedly be local and regional level indicators, such as participation in local life or social activity, though central data from statistical offices concerning the status and condition of libraries and readership in respective countries as well as results of opinion polls on culture, in the broad meaning of the term, social life and preferred leisure time activities might also be helpful.

On the national level, analyses may concern social capital resources of entire societies or national strategies for the development of those resources. Such analyses may contain proposals for the actors of public life of what actions to take and how to influence the social life sphere, in the broad meaning of the term. They may discuss such areas as:

a) Social attitudes and competencies (including: attributes of the competencies required to build social capital, dissemination of social attitudes and competencies in the education system, civic education, media and IT education, cultural and artistic education, human resource training);

b) Social collaboration and participation (including: civic activity, organised forms of civic activity, cooperation between public administration and NGOs, civic dialogue and social dialogue, quality and availability of public information, philanthropy and corporate social responsibility, social economy, legal and civic counselling, the problem of social exclusion);
c) Social Communication (including: changing patterns of the use of media, social consequences of changes in digital media, public domain and publicly available resources, financing of public media, audiovisual policy);
d) Cultural and creative potential (including: identity as inherited norms and patterns of behaviour, cultural resources, financing of culture, participation in culture, creative potential, promoting national culture and promoting the country through culture) (Ministerstwo Kultury i Dziedzictwa Narodowego, 2011).

The above is a very broad description of social capital, defined as the ability, resulting from trust as well as existing norms and patterns of behaviour, to mobilise and combine resources, which stimulates creativity and strengthens the role of collaboration and understanding in pursuit of common goals (Ministerstwo Kultury i Dziedzictwa Narodowego, 2011). Libraries as institutions that perform not only cultural but also educational and social functions, may operate in each of the four areas: education, culture, communication and participation. Depending on their type, libraries may perform all of the abovementioned functions, contributing to the creation of social capital in the national scale. They may offer after-school education, teach civic attitudes, prevent social exclusion, moderate civic dialogue, mediate information processes, in the broad meaning of the term, and provide communities with access to culture. Also, they belong to the group of institutions through which the State may develop social capital. Most typically, their role is recognised in the following priorities:

a) Supporting teaching methods that stimulate cooperation, creativity and communication and develop democratic school culture in formal education;
b) Supporting non-formal education that stimulates cooperation, creativity and social communication;
c) Making information more available and improving the quality of public communication;
d) Strengthening the role of culture in developing social cohesion (Ministerstwo Kultury i Dziedzictwa Narodowego, 2012).

Another interesting classification of the dimensions and components of social capital was proposed by Wojciech Dyduch (Dyduch, 2004) (cf. Table 4). Unlike the indices identified by Putnam (see Table 1) or the World Bank (see Table 2), he focused on the organisational dimension of social capital. Thus, his classification may be useful in diagnosing the social capital of libraries.

The organisational dimension of social capital is also examined using social network analyses. The purpose of those analyses is to identify the communication systems of members of an organisation and to evaluate their methods of collaboration other than the ones resulting from the formal organisational structure. Networks are usually analysed by means of indicators of network density, distance between employees, degree of centralisation and evaluation of communication hubs. One such tool is the Social Network Analysis (SNA) – an interdisciplinary method that uses elements of the graph theory, statistics, matrix algebra, psychology, sociology and anthropology to investigate multiplex and multidimensional structures of relationships between different social actors (employees, teams, organisational units), developed and promoted, among others, by Rob

Cross, Andrew Parker and David Knoke (Jędrych & Berniak-Woźny, 2018; Cross & Parker, 2004; Knoke, 2008).

Table 4: Dimensions and Components of the Social Capital of an Organisation According to Dyduch (2004)

Social capital dimension	Social capital component	Description of the component
The dimension of mutual relationships	Positive behaviour in networks	Reciprocity of actions Altruism Help and assistance Courage, openness, assertiveness Risk taking Acceptance and tolerance Initiative
	Team work	Working on projects and proposals together Brainstorming Formal and informal meetings
	Trust	Trust building Openness Exchange of information Taking risky actions
Structural dimension	Networks	Social bonds within an organisation Bonds with stakeholders Organisation's bonds with other entities Customer databases
Cognitive dimension	Norms	Mission and vision awareness Degree of representation by the organisation Organisational culture and identity Conflict solving
	Community	Supportive and empowering environment Positive group dynamics Organisational community Degree of representation by the organisation
	Productivity	Engagement of the members of organisation Independence Initiative Sense of responsibility Open communication Collaboration

Others evaluate organisational social capital on the basis of trust measurements. One such method is the Organizational Trust Inventory (OTI) developed by L.L. Cummings and Philip Bromiley that measures the dimensions of reliability, honesty and belief in partners (Cummings & Bromiley, 1996). This particular research trend is quickly developing now and further publications are to be expected in the coming years, some of which may also be dedicated specifically to libraries.

Individual social capital research

A separate group of studies concern individual social capital, which is the source of personal development and potentially of the development of the network in which an individual functions. The individualistic dimension of social capital was emphasised in particular by Pierre Bourdieu (Bourdieu, 1979), but it was also investigated by Zbigniew

Zagała (Zagała, 2000). In his in-depth interviews with local leaders representing cultural, educational, economic and church groups as well as local governments and activists promoting various kinds of associations, Zagała tried to determine which of the resources available to individuals and communities contribute to social development. He regarded sociocultural capital as pertaining to individuals and communities. The problem with Zagała's studies is that they are very subjective, i.e. their conclusions are based on personal and unstandardised opinions of local leaders. On the other hand, they give an insight into unconstrained opinions of individuals who are important innovators and agents of social changes in local communities. According to those leaders, a person with a high level of sociocultural capital:

a) Has a high morale, is truthful, dependable, honest, responsible and unselfish;
b) Is trustworthy and trusts others (without being naive), has the ability to convince and win the loyalty of others, has knowledge about social relations;
c) Is open-minded and tolerant (but does not tolerate the evil) and able and willing to collaborate;
d) Is knowledgeable (but not necessarily highly educated), which includes knowledge about the surrounding world, customs, procedures and rules, is competent and aware of the limits of their competencies;
e) Is "rooted" in the environment and knows their "little homeland", habits and customs;
f) Participates in and contributes to culture (Zagała, 2000, p. 96).

The question is, then, whether librarians have the abovementioned attributes and could be described as persons with a high level of sociocultural capital? According to studies conducted in 2018 and 2019 in libraries in 20 countries of the world, most librarians have an average level of social capital, though higher than the mean score in the society of their respective countries (Wojciechowska, 2019; 2020; 2021; 2022; 2023).

Research on the social impact of libraries

Research on the impact of libraries on their social environment started at the beginning of this century. The issue was systematically investigated by Andreas Vårheim (Vårheim et al., 2008; Vårheim 2009; 2011), Niels Ole Pors (Pors, 2007; 2008), Catherine A. Johnson (Johnson, 2010; Johnson & Griffis, 2009; Griffis & Johnson, 2014) and Timothy M. Schlak (Schlak, 2015; 2016). They focused, among other things, on the role of the library as a meeting place that supports the local community, contributes to integration and removal of barriers and social exclusion and assists in developing individual social and intellectual capital. In their studies, the authors mainly analysed the facilities and equipment of libraries, their sociocultural offering, the use of the Internet to establish and maintain relationships, the use of library services by various social groups (ethnic, religious, immigrants, disabled, senior citizens, etc.). To this end, they conducted interviews (with users, employees, managers), observations and analyses of library documents (e.g. statutory, project and other kinds of documents).

Recent library studies suggest that future research into the intangible resources of libraries should use additional frameworks to evaluate their operation, including social capital models (Corrall, 2014).

To sum up the deliberations on diagnosing social capital, it should be emphasised that social capital is a very complex value and a source of social benefits that, unlike the classical tangible capital or human capital, is very difficult to investigate and develop through conscious and planned activities. Many of the indicators used by researchers to

measure the phenomenon are dubious (Markowska-Przybyła, 2017) and the diversity of research techniques applied makes it difficult to aggregate data and compare results. Probably, social capital studies lack solid theoretical foundations, their tradition being quite short.

OBJECTIVES AND METHOD

The research was based on the assumption that libraries, apart from providing information services, may also perform various social roles – by integrating and engaging local communities. However, to do this, libraries must fulfil the following three conditions:

a) Have relevant facilities and equipment to make the library appear as a quiet, friendly and open meeting place;

b) Train library personnel to work with the local communities (provide personnel with knowledge and competencies, teach them the tools and techniques of work);

c) Have a team of personnel who are open-minded and eager to collaborate, trust other people and have an adequate level of individual social capital.

The third condition seems to be the most difficult to satisfy. Attitudes, beliefs and nature of social relationships depend on a number of factors, such as upbringing or previous experiences that affect the entire life of an individual. Thus, they are not easy to change or develop through ad hoc activities (training, managing methods, etc.).

The authors of this study intended to develop a statistical model to predict the level of individual social capital, which constitutes an important value for libraries that wish to perform social functions. The model was developed on the basis of data from a large survey conducted in 2018-2019 among the personnel of various kinds of libraries in 20 countries across the world. The survey yielded data on the social capital resources available to as well as the level of trust and the attitude towards others of the personnel of different kinds of libraries in different countries. Individual social capital was measured using the Questionnaire for the Measurement of Individual Social Capital (KPIKS) developed by the Polish psychologist Rafał Styła (Styła, 2009), based on so-called resource generator drafted by Martin van der Gaag and Tom Snijders (Van der Gaag & Snijders, 2004; 2005) – the Dutch researchers of individual social capital. Feedback from 6,593 respondents made it possible to conduct a statistical analysis and develop a research model.

The purpose of the research was to apply the selection of attributes in the task of building social capital level structures. In traditional methods, the dependent variable is predicted on the basis of the independent variable in one set of predictors. Each of such attributes has certain discriminatory power. Such set contains weak variables that may lower the discrimination of the entire model. To prevent this, the attributes were first selected using different methods and then, a classifier was built for every set. This way, a committee of classifiers was created. Each of the classifiers explains a different percentage of total variance. The choice of the attribute selection method and the type of base classifier was not random.

In order to choose the strongest model, different attribute selection methods were used. The Principal Component Analysis (PCA) is based on the maximisation of value of the explained variance by using linear function of the kernel of mapping (Ringnér, 2008). An extension of the PCA method is the Kernel Principal Component Analysis (KPCA), which

uses non-linear mapping (Schölkopf, 2001). Another method that was used is the Linear Discriminant Analysis (LDA), which uses linear functions to determine frontier areas (Leśkiewicz et al.,2016). The last two models used were the class centroid Principal Component Analysis (CCPCA), which rotates factors by class centroid (Topolski, 2020a; 2020c; Topolski & Topolska, 2019) and the Gradient Component Analysis (GPCA), which uses the stochastic gradient to determine the best angle of rotation and search step (Topolski, 2020b).

The CCPCA method is a supervised linear transformation technique that may be used in many different areas, in particular to select and reduce the dimensionality of attributes. The CCPCA analysis identifies data patterns on the basis of correlations between attributes with respect to a dependent variable on the nominal or ordinal scale. The purpose of the principal component analysis based on class centroids is to identify the directions of maximum variance in multidimensional space and to project them on a new subspace with the same number of (or fewer) dimensions as the original attribute space. Orthogonal axes (principal components) projected in the new subspace symbolise the directions of maximum variance with the limiting condition that new attribute axes must be parallel. In the CCPCA model, we associate every class, e.g. social capital level, with clusters of all attributes and then rotate sets around those clusters, grouping together the attributes that, in interaction with one another, discriminate/differentiate the abovementioned social capital level the most strongly.

Various studies have shown that attribute selection and reduction methods significantly improve the quality of classification and prediction not only by reducing multidimensionality but also by forming clusters of attributes that strongly determine the value of dependent variables. Such clusters make it easier to predict the dependent variable, as they frequently provide pieces of information that individually complement the predictive model. Together, they may result in abundance of information and overtraining, leading to overfitting to data and errors in the model.

Pre-selected attributes may be used to build high-quality structural models, using, for example, AMOS software. Such presentation of results satisfactorily explains the interactions between variables or moderation to dependent variable. Interaction in the structural model concerns coexistence of selected groups of variables (components). The literature on the subject presents interactive mechanisms, such as Anova, yet, in structural modelling, continuous interaction factor testing is still not strong enough. CCPCA models and bootstrap simulations enable modelling of quantitative and categorical variables in one model with high interactive strength. This method makes it possible to develop a good cause-and-effect model that, apart from simple dependencies, analyses causes and effects as well as mediators and moderators between variables.

Different machine learning algorithms were used in the research to evaluate the quality of prediction. They were purposefully selected to represent different algorithms. The aim was to verify the quality of prediction for different variants of the main components selected using the CCPCA method. KNN, i.e. k Nearest Neighbors, is the algorithm searching for the nearest neighbors of the identified objects (patterns) (Destercke, 2012). For the purpose of model optimization, different parameters were used (number of neighbors: 3, 5, 7, metrics: Minkowski, Euclidean, Manhattan). Another algorithm was the SVM (Support Vector Machine) (Vladimir & Corinna, 1995). The SVM was applied to the perdition task for the purpose of model optimization using different parameters (parameter C: 0.1, 1, 10, 100, kernel: linear, rbf, poly, sigmoid, gamma: scale, auto). The next machine learning algorithm

was the CART (Classification and Regression Trees) (Breiman et al., 1984). The optimization criteria were (criterion: gini, entropy, splitter: best, random, maximum depth: 1, 2, 3, . . ., 10). Yet another machine learning mechanism used in the research was the GNB (Gaussian Naive Bayes—without parameters) (Bayindir et al., 2017). This particular method does not analyze optimization parameters. Finally, there was also the MLP (Multi-layer perceptron) (Arena et al., 1998). In order to optimize the neuron network, a number of parameters were used (number of hidden layers: 3,4,5,. . .,10, activation function: identity, logistic, entropy, SOS, Tanh, Linear, Softmax, Exponent, parameter alpha: 0.00001, 0.0001, 0.001, 0.01, 0.1, momentum: 0, 0.2, 0.4, 0.6, 0.8, 1). All hyperparameters were tuned automatically with statistical software. For the sake of avoiding overfitting, the fivefold cross validation experimental protocol was applied, in which the set of data is divided into five equal folds, of which four are used for learning and one for testing. Next, the testing fold becomes a learning one and one of the learning folds becomes the testing one.

RESULTS

The results of comparing five selection models – by the percentage of the total explained variance – are presented in Table 5. As was explained in the previous chapter, attribute selection and extraction methods make some transformations in the original attribute space in order to maximise variance. In order to select the best differentiation of attributes in terms of selected clusters, the PCA, KPCA, GPCA, CCPCA and LDA methods were used. The value of maximum explained variance is the basis for the selection of the strongest model.

Table 5: The Results of Attribute Selection for Five Methods by % of Total Explained Variance for the Four Main Components

Method	% of explained variance
PCA	78.43%
KPCA	79.32%
GPCA	80.23%
CCPCA	82.41%
LDA	76.76%

The CCPCA method yielded the best percentage of the total explained variance – 82.41%, and accordingly, this method was used to build the model. The tests were conducted on 1,964 employees in one of the 20 countries covered by the research. The CCPCA identified three components that combine into the best model in terms of the discrimination of that specific country. The results of own value and total explained variance are presented in Table 6. It shows three separate components that form groups of variables, and the total variance explained by the set of those components is 82.41%. The maximum result of simple linear regression was R^2=0.544 = 54.4%. This shows how much information is lost in a holistic approach to variables.

Three components were identified on the basis of the results presented in Table 6. The result is the same as in Table 5. The three groups of variables together explain 82.41% of total variance. The results also show the percentage of variance explained by each of the identified components. The next step was to select the best classifier for the task of

developing classifier sets in social capital prediction, as is shown in Table 7. In order to avoid overfitting of the model, cross validation was applied.

Table 6: Basic Statistics for Each of the Three Main Components Identified by the CCPCA Method

Component	Own value	% of total variance	Accumulated own value	Accumulated %
1	3.67	33.21	3.67	33.21
2	2.09	29.65	5.76	62.86
3	1.81	19.55	7.57	82.41

Table 7: Statistics of Correct Classification of Librarian Nationalities Based on Different Sets (main components) of Attributes

		CCPCA (number of main components)						
	NO	1	2	3	4	5	6	
Regg	0.589	-	-	-	-	-	-	
k-NN	0.711	0.713	0.732	0.747	0.737	0.712	0.701	
SVM	0.726	0.748	0.763	0.754	0.744	0.723	0.708	
MLP	0.732	0.741	0.750	0.789	0.779	0.766	0.744	
CART	0.728	0.725	0.743	0.781	0.767	0.750	0.712	
GNB	0.705	0.715	0.721	0.741	0.721	0.690	0.678	

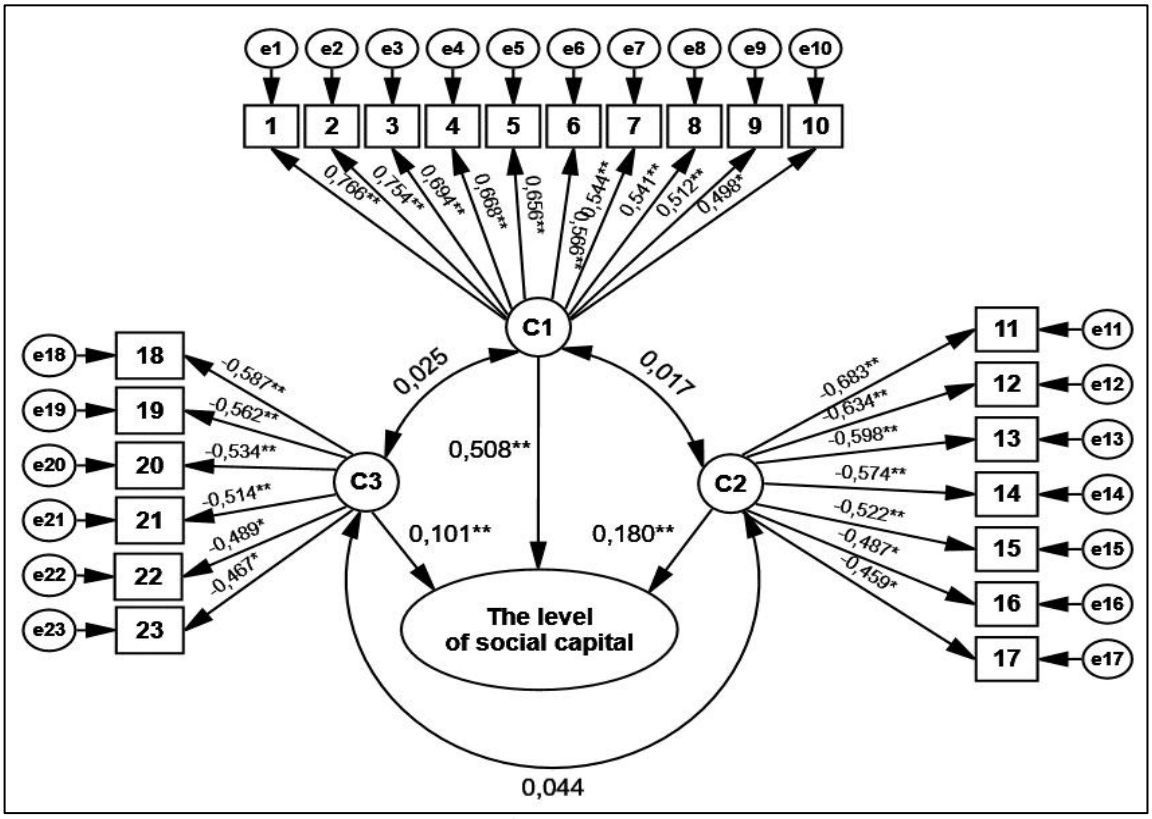
k-NN (k-Nearest Neighbours); *SVM* (Support Vector Machine) *MLP* (Multilayer Perceptron); *CART* (Classification and Regression Trees); *GNB* (Naive Bayes classifier)

The experiment was carried out in different sets of components. The purpose was to verify whether the discriminatory power is the strongest for the three identified components. For each classifier, the three main components yielded the best quality of social capital prediction. The experiments confirm that the prediction model is the strongest with the three components for the MPE neural network that were used in the prediction task for the CCPCA. The neural network – i.e. the multilayer perceptron (MLP) was applied as the base classifier in the classifier set.

Very interestingly, this method improves the quality of prediction by almost 20% compared to the multiple regression method. It is a definite advantage. CCPCA makes it possible to reduce the probability of the curse of dimensionality that concerns a relevant number of cases confronted with the vector of attributes.

Figure 1 presents the strongest three components of attributes identified using the CCPCA method. This is the final prediction model. In the model, attributes 1 to 10 exist in the first component, attributes 11 to 17 – in the second component and attributes 18 to 23 – in the third component.

The CCPA model identified three main groups of variables C1, C2 and C3, which are not correlated and may constitute separate groups comprising the level of social capital.



C1, C2, C3 – main components of the CCPCA, $R^2=0.674$ method

Figure 1: Results of the Selection of Attributes for the Three Main Components of the CCPCA

1 What matters in life is to always have friends
2 What matters in life is to have a loving family
3 The size of the settlement where the library is located [village, town with up to 100,000 residents, city with 100,000 to 500,000 residents, city with more than 500,000 residents]
4 Would you agree to have your salary reduced [in order to help another person or library]
5 How many times in the last year did you attend a public meeting not related to your work?
6 How many times in the last year did you sign a petition or protest, or attend a demonstration?
7 The type of library [public, university, school, scientific (non-university), other]
8 How many times in the last year did you attend a public meeting for residents concerning practical issues in the place where you live?
9 How many times in the last year did you inform a newspaper, radio or TV station, school management, police or other authorities about a problem (verbally or in writing)?
10 The appearance of the library and its immediate surroundings is the responsibility of [managers/employees/users]
11 Age [up to 30 years, 31 to 50 years, 50 years or older]
12 Does the mangers of your library promote pro-social activities?
13 Is the library an institution that can be trusted?
14 Have you ever volunteered for your community, church, district, village or town, or have you ever done social work for the needy?
15 Do you agree that “Most people can be trusted”?
16 What matters in life is to help the needy
17 What matters in life is to be able to do only what one wants to do
18 Do you know a librarian who volunteers for the community, church, district, village or town, or does social work for the needy?
19 Do you agree that “I can trust most of my colleagues at work”?
20 What matters in life is to be professionally successful
21 What matters in life is to be someone or with someone who is popular and admired
22 Gender
23 What do you think is the impact of people like you on the life of the local community?

The level of social capital is the most significantly (50.8%; $p<0.01$) influenced by having friends, having a loving family, the size of the settlement where a library is located and the fact that a person is willing to have their salary reduced in order to support some idea (a person in need, an institution). The level of social capital is influenced by less frequent attendance in meetings not related to work as well as by not signing petitions. Employees of libraries other than public, university, school or scientific libraries are more probable to have a higher level of social capital. Higher level of social capital is also conditioned by more frequent participation in meetings for residents on important local issues in the place where the respondent lives and by the fact of informing the media about problems. The level of social capital is also influenced by the opinion on who is responsible for the appearance of the library – only the managers or the employees and users, too.

When the attributes listed in the above groups interact, they are the strongest predictors of the level of social capital. The second group on its own explains social capital in 18%. Together with the first group, they constitute 68.8% of the total variance. In this group, age, the fact that managers support social activities, having volunteered for the needy, trust in people, helping the needy and being able to do in life what one wants to do result in increased social capital.

The third group of variables, C3, explains the total variance of social capital in 10.1%, corresponding to 78.9% for the entire model. Social capital is increased by knowing a librarian who volunteers for the community, trusting most colleagues at work, being professionally successful, being someone or with someone popular and admired and a having sense of impact on the life of the local community. Importantly, in this group, the above mechanisms are more probable for women rather than men.

In order to verify the proposed model, the CCPCA method was validated on a separate set of data for Ukrainian library personnel. The total of 572 Ukrainian library personnel participated in the research. The results in Table 1 suggest that Ukrainian library personnel most typically represent average social capital (41.8%). The majority of respondents were female (96.7%). Their most typical age range was 31-50 years (49.7%). Most of them worked in public libraries (51.4%) as librarians (line workers) (49%). The majority of respondents worked in cities with over 500k residents (49.8%).

Table 8 presents the results for 5 attribute extraction methods. They are comparable to the results in Table 5.

Table 8: The Results of Attribute Selection for Five Methods by % of Total Explained Variance for the Four Main Components for the Ukraine Data Set

Method	**% of explained variance**
PCA	76.43%
KPCA	77.12%
GPCA	81.18%
CCPCA	84.65%
LDA	79.26%

It was also verified whether the Ukraine sample would yield a similar set of components. To this end, 6 machine learning methods were applied to assess the best number of components producing the best prediction results. The results (Table 9) confirm those in

Table 7. For the Ukraine data, the best variant yielding the best classification quality is the one composed of 3 main components, which are the best for the MLP.

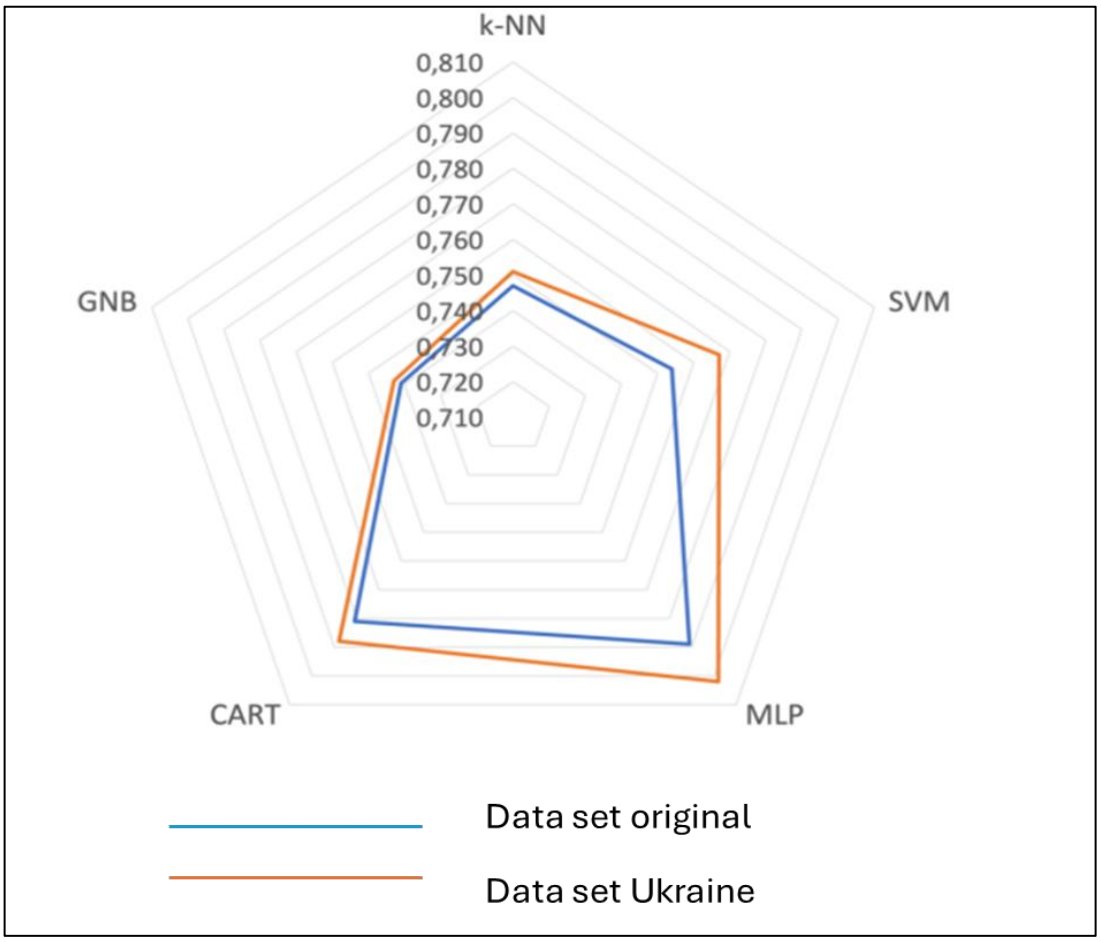
Table 9: Statistics of Correct Classification of Librarian Nationalities Based on Different Sets (main components) of Attributes for the Ukraine Data Set

		CCPCA (number of main components)						
	NO	1	2	3	4	5	6	
Regg	0.545	-	-	-	-	-	-	
k-NN	0.702	0.715	0.725	0.751	0.744	0.711	0.706	
SVM	0.703	0.744	0.757	0.767	0.748	0.731	0.721	
MLP	0.722	0.747	0.750	0.802	0.787	0.772	0.754	
CART	0.721	0.743	0.748	0.788	0.783	0.767	0.747	
GNB	0.699	0.712	0.721	0.743	0.731	0.693	0.671	

k-NN (k-Nearest Neighbours); *SVM* (Support Vector Machine) *MLP* (Multilayer Perceptron); *CART* (Classification and Regression Trees); *GNB* (Naive Bayes classifier)

Finally, it can be concluded that the model may be used for other libraries in different countries. Figure 2 presents a chart with the best division of attributes for three components for different classifiers and data sets.

Figure 2: Prediction Quality Results for the Best Division of Attributes into Three Main Components for Different Data Sets



DISCUSSION AND CONCLUSIONS

The paper presents a method to predict the level of individual social capital among librarians in 20 countries. The model divides a set of data into three components using the method of main components by class centroid. For each component, a neural network classifier was built in the form of multilayer perceptron, which proved to be the most precise in prediction. Since three components were identified, three classifiers, together comprising a committee, were applied. Knowledge of a given classifier is strengthened by knowledge of another classifier on the condition that prediction for the two classifiers increases, in a statistically significant way, the discriminatory power in terms of percentage of the explained variable. Importantly, by selecting attributes, we are able to separate to other components the attributes that have lower discriminatory power in a model. Consequently, we can strengthen the model based on various components, i.e. sets of attributes that are very strongly linked with one another in a given component. This model has a major advantage over other attributes selection models, because the set of independent variables may consist of quantitative as well as qualitative variables. Rotation by variables in the CCPCA yields good adjustment of the other quantitative variables to those attributes. This, in turn, significantly increases predictive capacity. In the classical regression models, the task of prediction is limited to one group of properties only, which, as studies suggest, may result in lower quality of prediction.

The attribute selection method applied to build classifier sets in the prediction task has its limitations. The first is the linear dependence of attributes. The CCPCA, PCA and GPCA models cannot be used for non-linear dependencies. In the case of non-linear dependencies, the KPCA model should be used for non-linear functions of the kernel of mapping. The CCPCA model, because of rotation by class centroid, requires at least 30 patterns, i.e. cases, for each categorical variable. Smaller classes may result in overfitting to data, making prediction less precise. Another limitation of the model is that there may be dependencies between attributes. Thus, it is important in the first place to evaluate independence and exclude any redundant variables at the selection stage. In order to avoid overfitting, cross validation needs to be applied. A good example is 5x2 validation. In the case of incomplete data, cases, i.e. patterns, are removed, as they cannot serve as complete data vectors. To avoid that, gaps may be filled, e.g. by an average, a median, using regression or other methods. Where there are many attributes and components, a model may be very complex and difficult to understand. Thus, in the final selection, components with own value < 1 may also be rejected.

To sum up, the proposed method may be used to predict social capital in libraries. Although the method was developed on the basis of data collected from library employees, it may be adapted for use in other groups, too, e.g. library users or library non-users, in order to analyse social capital in the entire local community. Identifying the attributes that are the most influential on the level of social capital will make it possible to focus on the development of key areas.

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AUTHORS DECLARATION

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AUTHORS CONTRIBUTION

Conceptualization: [all authors], Methodology: [all authors], Formal analysis and investigation: [all authors], Writing - original draft preparation: [M.Wojciechowska]; Writing - review and editing: [all authors]

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