Strategic management

International Journal of Strategic Management and Decision Support Systems in Strategic Management

Vol. 29, No. 3
2024
ISSN 2334-6191 (Online)
UDC 005.21
University of Novi Sad
Faculty of Economics in Subotica

Strategic Management

International Journal of Strategic Management and
Decision Support Systems in Strategic Management

ISSN 1821-3448, UDC 005.21

Strategic Management is a quarterly journal addressing issues concerned with all aspects of strategic management. It is devoted to the improvement and further development of the theory and practice of strategic management and it is designed to appeal to both practicing managers and academics. Specially, Journal publishes original refereed material in decision support systems in strategic management.

Thematic Fields

- Mission and Philosophy of the Organization
- Culture and Climate of the Organization
- Effectiveness and Efficiency of the Organization
- Structure and Form of the Organization
- Strategic Analysis
- Aims and Strategies
- Process of Strategic Management
- Characteristics of Strategic Management in the New Economy
- Contemporary Ontological, Epistemological and Axiological Suppositions on the Organization and its Environment
- Analysis of the Organization and its Interaction with the Environment
- Structure and Dynamics of the Organizational Environment
- Uncertainty and Indistinctiveness of the Organizational Environment
- Synchronic and Diachronic Analysis of the Organizational Environment
- Analysis Techniques of the Organization
- Business Processes, Learning and Development within the Context of Strategic Management
- Evaluation and Measuring of the Potential and Realization of the Organization within the
- Context of Strategic Management
- Strategic Control in Contemporary Management
- Information Technologies in Strategic Management
- Business Intelligence and Strategic Management
- Decision Support Systems and Artificial Intelligence in Strategic Management
- Performance Management Process
- Performance Management System
- Improving Performance
- Strategic Marketing Management
- Strategic Global Marketing Management
- Strategic Services Marketing
- Leadership and Ethics in Strategic Management
- Human Resource Management and Strategy
- Organizational Behaviour, Strategy, and Performance

All scientific articles submitted for publication in Journal are double-blind reviewed by at least two academics appointed by the Editor's Board: one from the Editorial Board and one independent scientist of the language of origin - English. Reviewers stay anonymous. Authors will timely receive written notification of acceptance, remarks, comments and evaluation of their articles.

Strategic Management

International Journal of Strategic Management and
Decision Support Systems in Strategic Management

www.smjournal.rs

Publisher

University of Novi Sad, Faculty of Economics in Subotica

9 - 11 Segedinski put, Subotica 24000, Serbia

Tel: +381 24 628 000

Fax: +381 24 546 486

http://www.ef.uns.ac.rs

e-mail: smjournal@ef.uns.ac.rs

Proofreading
Željko Buljovčić

Prepress
Aleksandar Vugdelija

Print
Donat Graf d.o.o. Beograd

Circulation
100

The Journal is published quarterly.

Strategic Management

International Journal of Strategic Management and
Decision Support Systems in Strategic Management

www.smjournal.rs

ISSN 1821-3448
UDC 005.21
2024, Vol. 29, No. 3

Contents

STRATEGIC MANAGEMENT, Vol. 29 (2024), No. 3, pp. 005-027

DOI: 10.5937/StraMan2400003G

Received: September 07, 2023
Revised: February 04, 2024
Accepted: February 09, 2024
Published online: March 26, 2024

Uncertainty decomposed: understanding levels of contingency to enable effective decision-making[1]

Sebastian L. Grüner

RheinMain University of Applied Sciences, Wiesbaden, Germany
https://orcid.org/0009-0002-3285-103X

Abstract

Background: Uncertainty is a common challenge in managerial decision-making, especially when it comes to predicting future states, establishing cause-effect relationships, and having knowledge about relevant variables. However, it is difficult to deliberately address different types of uncertainty by applying specific decision-making strategies and hence enable reduction of uncertainty due to overlapping definitions and conflicting operationalization of the uncertainty construct.

Purpose: The paper aims to delineate types of uncertainty along their epistemological configurations in terms of specific knowledge contexts to enable choices of suitable strategies for specific decision-making situations.

Study design/methodology/approach: A literature review revises and discusses concepts of (un)certainty based on (im)perfect information and objectively/subjectively available assemblages of knowledge.

Findings/conclusions: The paper provides a framework that encompasses and differentiates configurations of available information and knowledge applicable to decision-making situations. In order to achieve construct clarity and to free the original concept of uncertainty from conflicting definitions and heterogeneous operationalizations, the umbrella term contingency is introduced. It encompasses all states of (im)perfect information and variations in their epistemological configurations. Finally, the presented epistemological framework delineates levels of contingency along specific qualities of available information. The identified and discussed levels of contingency are certainty, risk, uncertainty in the narrow sense (i.n.s.), complexity, ambiguity/equivocality, and isotropy/radical uncertainty. The delineated levels of contingency help to tailor decision-making situation to specific epistemological configurations and hence may serve as a starting point for concluding and developing appropriate strategies to reduce contingency.

Limitations/future research: A holistic understanding how to deal with and solve contingency requires further research focusing on aligning levels of contingency with strategies for decision-making (algorithms, causation, effectuation, bricolage, improvisation, trial & error) by taking types of knowledge (structural, procedural, conceptual) and contextual factors (e. g. time, [origin of] resources) into account.

Keywords

uncertainty, contingency, decision-making, strategic management, knowledge, epistemology

[1] Extended version of the paper presented at Strategic Management and Decision Support Systems in Strategic Management SM 2023 scientific conference

Introduction

The notion of uncertainty has continually been a catalyst for theory-building in metaphysical sciences such as philosophy, as well as in non-metaphysical sciences including formal, or social sciences such as mathematics, sociology, or economics. Dealing with uncertainty has led to epistemological question about what is knowledge (Aristotle & Sachs, 2002; Descartes, 1996; Townsend, Hunt, McMullen & Sarasvathy, 2018), what are types of knowledge (Polanyi, 1966), how to accumulate knowledge (e. g. Hume, 2021) and how to apply knowledge in order to make decisions or predictions (Tversky & Kahneman, 1992). In line with that, research on decision-making under uncertainty has a long tradition among management scholars. Avenues have pointed out a rational perspective that assumes perfect information available to agents (Ariely, 2010; Kahneman & Tversky, 1979; Tversky & Kahneman, 1981). Others have rather focused on dealing with situational constraints (e. g. scarcity of resources and time) (Hmieleski & Corbett, 2006; Shepherd, Williams & Patzelt, 2015) or heuristic strategies (e. g. *effectuation*) (Dew, Read, Sarasvathy & Wiltbank, 2009; Sarasvathy, 2001) to tackle imperfect information.

Knowledge has been identified as a critical variable in dealing with and conceptualizing uncertainty. Agents' knowledge and experience influence how they make decisions and how they perceive and exploit business opportunities (Shepherd et al., 2015). It favors the identification of future states and outcomes in general (Shepherd & Patzelt, 2018) and in special fields (e. g. identifying financing opportunities) Seghers, Manigart & Vanacker, 2012). Knowledge represents "structures that people use to make assessments, judgments or decisions involving opportunity evaluation and venture creation and growth" (Mitchell et al., 2002, p. 97) on individual level.

At the organizational level, knowledge, as a bundle of intangible resources, is considered a sustainable and effective tool for gaining and maintaining competitive advantages (Wiklund & Shepherd, 2003). It is declared to be the basis of competencies, whereas competencies mean the ability to establish and repeat knowledge-based regular (not random) processes to achieve future market action and maintenance (Freiling, 2008). In summary, knowledge and knowledge-generating routines or strategies help deal with uncertainty.

Activatability and availability of knowledge in decision-making situations determine the choice of decision heuristics. Current research in the field investigates how strategists address incomplete knowledge problems (Rindova & Courtney, 2020), which typically incorporate microfoundations of decision-making such as which information is available, what are current/future states of development, by which variables are those states defined and how are they interrelated? "When should managers and entrepreneurs forecast and plan, and when should they adopt a more dynamic, adaptive strategy?" ask Packard and Clark (2020, p. 766) and conclude depending on the context and the extend of uncertainty in the given situation. However, the conceptualization of uncertainty remains inconsistent (Berglund, Bousfiha & Mansoori, 2020; Ramoglou, 2021). Widely debated levels and types of uncertainty are neither clearly distinct nor selectively defined, which makes it difficult to conclude specific (practical) and generalizable solutions (e. g. decision-making strategies) from specific contexts and extend of uncertainty. In addition to neglecting the role of individual actors, the current debate has not yet produced a concept that incorporates a unified understanding of recognized types of uncertainty (Sniazhko, 2019).

The motivation for this paper lies in the importance of decision-making for organizations in general and for entrepreneurial ventures in particular, which are confronted with liabilities of smallness, newness etc.. 50 % of new ventures fail within 5 years, 75% within the 10 years (U.S. Bureau of Labor Statistics, 2023). This leads to the question if failure rates are caused by exogenous reasons (e. g. market dynamics) or endogenous reasons (e. g. poor resource base, poor strategy) and hence how far failure is influenced by decision-making strategies or the agent's competences in handling decision-making situations. Similar challenges affect established organizations operating and striving toward survival in vivid and fast-growing markets. Despite major companies' failures (e. g. Lehman Brothers in 2008 or Enron in 2007) is effective decision-making also crucial and existential to successful companies such as Alphabet, who meanwhile have long lists of suspended products and services (Ogden, n.d.)? The paper can contribute to the aspects named above by attributing qualities of information to decision-making situations and hence enabling effective decision-making by

applying appropriate strategies (e. g. to create additional information) .

By reviewing the literature and existing concepts, the paper aims to delineate types of uncertainty to provide a holistic framework of contingency defined by specific epistemological configurations for particular levels of contingency. First, existing uncertainty constructs are reviewed and briefly discussed. Second, the idea of *contingency* is introduced to free the concept of uncertainty from conflicting definitions and heterogeneous operationalization. Third, types and levels of contingency are discussed. Therefore, initially the concept of *certainty* is explored first in order to delineate further levels of contingency. The concept of *uncertainty in the broader sense (i.b.s.)* remains of central importance and will therefore be treated and dissected in more detail. Levels of contingency (*certainty, risk, uncertainty in the narrow sense [i.n.s.]*, *complexity*, *ambiguity/equivocality*, *isotropy/radical uncertainty*) become concluded and presented successively. Forth, the discussed levels of contingency are aggregated to a contingency framework based on epistemological configurations and fifth, implications for further research avenues towards strategies to reduce contingency enabling effective decision-making are concluded.

1. Revision of existing uncertainty constructs

Undoubtedly, the concept of uncertainty has been used and applied in countless academic papers. However, the development of holistic frameworks for the understanding and differentiation of uncertainty levels has been limited. This section is an overview of the major contributions to the topic. The seminal literature is reviewed and the identified constructs are briefly discussed. They are organized chronologically and substantively (Table 1).

Knight (1964) distinguishes between *risk* and *uncertainty* (*Knightian uncertainty*). Both dimensions depend on given knowledge about outcomes and probabilities. Risk is present in decision-making situations where the outcomes can be estimated stochastically as the consequences of taking certain actions. For example, the relatively new field of extreme event attribution estimates that the risk of heavy rainfall recurring in the 2020s in Kyushu, Japan, increased by 15% due to climate change (Otto, 2023). Risk situations involve precise knowledge of outcomes and associated probabilities. Decision-making situations characterized by uncertainty also involve knowledge of eventual outcomes resulting from actions taken, but lack precise stochastic estimation. This is especially true when the number of known/comparable cases is too small to derive patterns and/or when the interdependencies and interactions of the variables involved are too high and nonlinear. In such situations, Knight concludes that actions based on judgmental decision-making because probabilistic estimates of the consequences of acting are not available or attainable. An archetypal case is that of an entrepreneur who is faced with uncertainty in deciding how to allocate, activate, and utilize resources in order to enter and succeed in an unknown market (Audretsch & Belitski, 2021). Because the consequences of actions and future states are not objectively probabilistically distinguishable, action in situations of Knightian uncertainty requires intuition, experience, and gut feeling.

In contrast to Knight, who distinguishes between risk and uncertainty according to rational and objective probabilities, Savage (1972) emphasizes a more subjective point of view. He understands actions to be driven by expected utility maximization and based on probabilities, although estimates may be subjectively (incorrect) and subsequently updated (Packard, Clark & Klein, 2017). His formulated *Savage Axioms* include individual risk preferences. They are limited to cases where sets of options and outcomes/future states are closed, which means that complete knowledge is objectively present.

Shubik (1954) focuses on information (and its costs) in his discussion of uncertainty. Agents faced with a closed set of outcomes and knowledge of the relationships among relevant variables find themselves in situations of *certainty* (e. g., custom-made products with all necessary resources available and processes known). Knowing a closed set of outcomes, but being faced with probabilities regarding the relationships between relevant variables, is considered a situation of risk (e. g., custom-made products with either not all necessary resources available yet, or not all processes yet known). When the set of outcomes is closed, but both the set of relevant variables and the probabilities of their relationships are not closed, *indeterminacy* occurs. It is exemplified by firms in competitive markets where there is incomplete information about the action-reaction relationships among competitors. Finally, *ignorance* of

information is identified by Shubik. Ignorance ranges from individual unwillingness to generate knowledge (e. g. due to high costs) to general impossibility (e. g. due to epistemological constraints). Thus, both a subjective and an objective perspective are considered in the level of ignorance. Further research on the subjective perspective is being conducted by Sharot and Sunstein (2020) who ask the question "How do people decide what they want to know?"

Ellsberg (1961) confirms the Savage Axioms (Savage, 1972) by showing that decision-making is highly subjective: Agents may deselect one of two options that are objectively equal, but select options that are unequal. However, Ellsberg also challenges Savage's Axioms by showing that risk is dominantly preferred over what he calls uncertainty or ambiguity. Ellsberg substantiates his finding by experimenting with 2 urns. One contains a fixed number of balls in certain colors. The first contains a known proportion (50 red, 50 black). The second urn has an unknown proportion of black and red balls. Participants are asked first to choose the color they would bet on and then to choose the urn from which the ball will be drawn. As a result, most participants choose the first urn with the known 50/50 proportion. However, drawings from the second urn have the same probability, given that any color from the initial set can be included. Ellsberg's approach is strictly formal while working with a closed set of outcomes (2 colors of balls). It leaves the set of relevant variables and the probabilities of their relationships subjectively open to the agents. Although the experiment actually represents a situation of risk, it points to the possibility that information may not only be hidden but actually non-existent.

In the tradition of systems theory thinking, Thompson (2017) views uncertainty from the subjective perspective of organizations. Organizations are understood as semi-open systems, which develop their identity and operations based on self-selected information from their environment. They deal with issues that they can control, but they have incomplete information about them. *Incompleteness* requires awareness of what is missing. Furthermore, they deal with contingent issues (*contingency*) that they cannot yet control because they are not yet relevant to or recognized by the organization. In order to achieve and maintain internal efficiency but structural openness, Thompson suggests the implementation of autonomous organizational subdivisions. This enables subsystems to develop (their own) complexity and increases the organization´s capacity to deal with incomplete information. According to Thompson, incompleteness and contingency are subjective and different for each organization. Both depend on specific internal and external variables and lead to contingent future states. Subjective contingency then means that for organizations, some things are not yet known and have not yet been decided, and that this has to be resolved in a distinctive way by individual organizational capabilities (e. g., through acceptance and preparation for contingency). Thompson (2017, p. 24) summarizes: "some of the factors involved in organizational action become constraints, for some meaningful period of time they are not variables but fixed conditions to which the organization must adapt. Some of the factors become contingencies, which may or may not vary, but are not subject to arbitrary control by the organization. Organizational rationality therefore is some result of (a) constraints which the organization must face, (b) contingencies which the organization must meet, and (c) variables which the organization can control."

Milliken (1987) presents an approach that focuses not on probabilities but on the absence of certain types of information. She distinguishes between three types of uncertainty: *state*, *response*, and *effect uncertainty*. State uncertainty reflects the inability of agents to predict developments in an organization's environment. This is due to the dynamism and complexity of the environment. Response uncertainty occurs when agents have no known specific actions to address state uncertainty. Finally, effect uncertainty is present when the consequences of actions are not known to the agents or cannot be predicted. Milliken leaves open the question of whether there are information gaps in an objective sense or whether they exist only on a subjective level. Her approach mainly tackles operational capabilities aiming at fulfilling certain organizational tasks (including dealing with lack of knowledge).

Spender (1989) adds Shubik's (1954) distinction. Besides risk and indeterminacy, he identifies the uncertainty states of *incompleteness*, *irrelevance* and *incommensurability*. Incompleteness means, a little more precise than Thompson (2017), situations of decision-making in which information can be known, but it is not gathered. Indeterminacy remains defined by situations in which there is a closed set of outcomes but there is no information about their probabilities

(e.g., the reactions of a firm's competitors). Up to that point, outcomes of actions and causal relationships can be clearly identified by collecting enough information. However, not for the level of *irrelevance*. It represents decision-making situations where the outcomes and causal relationships of relevant variables cannot be arbitrarily determined. A set of outcomes may be given, but the formation of the outcomes is not clear, nor are the causal relationships of the formative elements (e.g., one outcome may have several causes). Finally, cases of *incommensurability* identified by Spender convey some information and relationships between formative elements lie beyond the epistemological boundary. Some things may be unknowable to agents or to society as a whole in a subjective and objective sense.

Building on that objectivity/subjectivity perspective , Dosi and Egidi (1991) relabel and combine existing levels of uncertainty. For them, *weak substantive uncertainty* is similar to risk according to Knight (1964), represented by a) a closed set of outcomes, b) the knowability of probability distributions, but c) the lack of information about "the occurrence of a particular event […] in principle representable as a random drawing by 'nature'" (Dosi & Egidi, 1991, p. 148). Conversely, *strong substantive uncertainty* presupposes an open set of outcomes, not allowing inference to probability distributions. This type of uncertainty is pretty similar to Shubik's (1954) and Shackle´s (2010) concept of ignorance or Spender´s (1989) concept of incommensurability. Finally, in their conceptualization, Dosi and Egidi (1991, p. 146) also consider subjective perspectives of agents by identifying *procedural uncertainty* as "competence gap in problem-solving" to deal with substantive uncertainty.

Closely related to Dosi and Egidi (1991), Campos, Neves, & Campello de Souza, (2007) distinguish between resolvable uncertainty (Type B) and insolvable uncertainty (Type A). Solvability means that additional empirical effort, such as research, will generate knowledge about relevant variables, relationships, and thus probabilities. Type A uncertainty is characterized by more or less aleatoric elements that cannot (yet) be resolved by further research.

Dequech (2011) adds ambiguity and *fundamental* uncertainty to the idea of Dosi and Egidi (1991). Ambiguity is defined in the meaning of Ellsberg (1961), which is that outcomes are closed, information about probabilities is missing but could be known. This limits the understanding of ambiguity to a subjective problem. By fundamental uncertainty (also procedural uncertainty) Dequech (2011, p. 623) means unknowability. It is present when sets of outcomes and options are "not predetermined or knowable ex ante, regardless of what people do, as the future is yet to be created". The focus on processes and knowledge makes Dequech's approach compatible with research on epistemological configurations, or types of knowledge from Barr, Doyle, Clifford, Leo, & Dubeau. (2003), Berge and Hezewijk (1999), Nonaka and Takeuchi (1995), Nonaka and Toyama (2007), Sanchez (2005).

Recent research on the dimensions of uncertainty expands on the findings of earlier studies by consolidating them and bringing them together. In addition to further detailing epistemology (knowledge-related dimensions), they also focus more on incorporating subjective and objective perceptions of uncertainty (Angus, Packard & Clark, 2023). Packard et al. (2017) distinguish earlier discussed states of risk and ambiguity from *environmental*, *creative*, and *absolute uncertainty*. In line with Knight (1964), risk remains understood by the current level of knowledge about the outcomes and the probability of occurrence. Ambiguity does the same but considers the subjectivity/objectivity distinction emphasized by Ellsberg (1961). It must be borne in mind that the Ellsberg experiment objectively represents risk although this does not necessarily reflect the subjective perspective leading to irrational decisions. Creative uncertainty is represented by knowledge of outcomes but not of underlying causes or processes. This way, creative uncertainty is technically solvable if enough experience and/ or data would be available. Environmental uncertainty is defined similar to Milliken´s (1987) state uncertainty reflecting decision situations where individual outcomes of actions are not/cannot (yet) be fully known due to dynamism and complexity of the environment. Last but not least, absolute uncertainty which is present when neither outcomes nor underlying causes or processes are known. The classification of Packard et al. (2017) represents a relatively new classification for types of uncertainty that include earlier discussed concepts aligning them in a holistic framework.

A matrix to classify uncertainty according to the existing knowledge about sets of outcomes (possibilities) and options (probabilities) is

presented by Stirling (2010), Oehmen and Kwakkel (2020). A high level of both is referred to as risk. Low knowledge of options but high knowledge of outcomes occurs in situations of uncertainty. The reverse configuration represents ambiguity. Finally, low knowledge in both categories represents ignorance. The more open-ended (low knowledge) the set of outcomes, relevant variables, and the causal relationships between them, the higher the level of uncertainty. Apart from their genuinely handy distinction, the authors do not offer a holistic classification of knowledge beyond known probabilities, or, to put it differently, what "high" and "low" actually means.

Building on earlier research in the area of uncertainty, Dequech (2011) presents a holistic framework that aims to include various different types of uncertainty. He defines weak uncertainty (also substantive uncertainty) including both risk according to Knight (1964) (knowledge of objective probabilities) and uncertainty according to Savage (1972) (no information/knowledge of objective probabilities but given subjective, not quantifiable probabilities). Dequech also adopts the idea of procedural uncertainty from of Dosi and Egidi (1991) as an overarching concept that can be ascribed not only to the objective non-existence of information, but also to the subjective non-existence to agents when available information is not processed or used. However, procedural uncertainty becomes unfolded now when differentiating between risk, ambiguity and fundamental uncertainty. A good example of procedural uncertainty in the situation of risk would be chess. The game contains a closed set of outcomes, variables, relations, and probabilities, but mostly imperfect move execution due to players' cognitive limitations. Dequech's understanding of ambiguity is for the most part similar to that of Ellsberg (1961) but different from of Stirling (2010). For Stirling, ambiguity occurs when knowledge of probabilities of known outcomes (set of option) are complete but knowledge of set of outcomes and future states are incomplete. Dequech and Ellsberg understand ambiguity inversely, with knowledge of outcomes and future states complete (red/black ball urn experiment) but probabilities of subjectively known outcomes incomplete (urn 2 with unknown distribution). From an objective point of view, the Ellsberg experiment is only risky, but from a subjective point of view, the second urn seems more ambiguous to the participants. Dequech refers to ambiguity as being characterized by information that is hidden rather than non-existent; just like Camerer and Weber (1992, p. 330) state "ambiguity is uncertainty about probability, created by missing information that is relevant and could be known." In order to take into account situations in which information cannot yet be known, Dequech defines the sphere of fundamental uncertainty. This state is represented by situations in which future knowledge does not yet exist. It cannot be confirmed ex ante without hindsight bias, nor can its time of emergence be predicted. Fundamental uncertainty contains information that has not yet been declared to be missing because agents are unaware of its existence.

Packard et al. (2017) emphasize the (in)completeness of information about consequences of actions (set of options) and outcomes/future states (set of outcomes), building on Dequech´s (2011) approach. The set of outcomes reflects existing knowledge/information about all possible future states. The set of options reflects existing knowledge/information about courses of action to achieve the respective outcomes/future states. When both sets are closed, with full information about outcomes and options, situations are called risky or ambiguous. This understanding of ambiguity, where information is only hidden to agents but objectively exists, is consistent with that of Ellsberg (1961). In situations with a closed set of outcomes and an open set of options, *creative uncertainty* exists. This means that there is full information/knowledge about outcomes and future states. However, there is limited knowledge about their probabilities of occurrence. Examples of creative uncertainty are mainly found at the subjective level. They occur when the outcome of a task is known, but the processes and actions are not. Situations with open outcomes but closed sets of options are called *environmental uncertainty*. These situations contain complexity because the system and environment interact. Agents make decisions based on information about their environment (e.g., competitors). At the same time, their actions affect the environment. This cybernetic effect of feedback generates imperfect information about outcomes and future states (open set of outcomes). However, sets of options can be closed because they can be constantly updated depending on information about the environment. Ultimately, when both the sets options and outcomes are open, absolute uncertainty exists. Packard et al. (2017) illustrate this state from the

perspective of entrepreneurs with a radically disruptive business idea because they do not yet know what their outcomes may be, and thus they cannot predict the causal relationships between the actions they take.

Townsend, Hunt, McMullen & Sarasvathy. (2018) differentiate somewhat more clearly and with a clarified understanding from previous scholars between uncertainty, complexity, ambiguity and something he calls *equivocality*. Uncertainty (like risk) is understood as a typical knowledge problem and can be solved by collecting more information, e.g. through repetition. *Complexity* is introduced as a distinct level for uncertainty taking into account that the number of relevant variables and their interactions is high. Complexity leads to similar outcomes as a result of different actions, or similar actions leading to different, indeterminable outcomes. In situations of complexity, causal relationships are nonlinear and cause-effect relationships are not clear. Other than for earlier scholars, in the understanding of Townsend et al. (2018), ambiguity is present in an objectively vague decision environment. Fractured relationships between outcomes and options may be present, but they are incompletely known, and there are questions about the rules that should be applied in particular situations. Finally, there is equivocality in situations where more information is not sufficient for resolution. Information is so scarce that there is no objective, universal answer. Society must compete to make sense of the situation. Townsend et al. (2018) mention the climate change debate for an example of equivocality.

The effects of subjective uncertainty and external unpredictability on entrepreneurial actions are further explored in a recent study Angus et al. (2023). The authors follow the understanding of Packard et al. (2017), which implicitly assumes that open and closed sets of options and outcomes determine the actions taken. They conclude that situations of uncertainty have a closed set of outcomes but an open set of options. In contrast, situations of complexity and unpredictability have open sets of outcomes and a more or less closed set of options. Their research represents the actual status quo of the discipline.

The above-mentioned conceptualizations of uncertainty and are summarized in

Table 1. The table shows only those constructs that were actually discussed by the authors. Some gaps remain due to neglect. Some constructs overlap. Some constructs are defined and/or labeled differently by different authors although conceptual similarities. In order to contribute to more construct clarity around the term uncertainty, the paper takes this as a starting point.

Table 1 Existing conceptualizations of uncertainty levels

Author(s)					
Knight (1964)	Risk	Uncertainty			
Savage (1972)	Risk	Uncertainty			
Shubik (1954)	Risk		Indeterminacy		
	Ignorance				
Ellsberg (1961)	Risk		Ambiguity		
Thompson (2017)		Incompleteness		Contingency	
Milliken (1987)				State uncertainty	
				Effect uncertainty	
				Response uncertainty	
Spender (1989)		Incompleteness	Indeterminacy	Irrelevance	Incommensurability
Dosi and Egidi (1991)	Weak substantive uncertainty			Strong substantive uncertainty	
	Weak and strong procedural uncertainty				
Campos et al. (2007)	Type B uncertainty			Type A uncertainty	
Stirling (2010), Oehmen and Kwakkel (2020)	Risk	Uncertainty		Ambiguity	Ignorance
Dequech (2011)	Weak substantive uncertainty			Strong substantive uncertainty	
	Weak and strong procedural uncertainty				
	Risk	Ambiguity		Fundamental uncertainty	
Packard et al. (2017)	Risk/Ambiguity		Creative uncertainty	Environmental uncertainty	Absolute uncertainty
Townsend et al. (2018)	Uncertainty		Complexity	Ambiguity	Equivocality
Angus et al. (2023)	Subjective uncertainty		External unpredictability		

Source: Adapted from Packard et al. (2017) and extended by author

2. Reframing types of uncertainty as levels of contingency

To promote construct clarity and avoid terminological confusion, the umbrella term uncertainty in the broader sense (i.b.s) is renamed *contingency*. According to Spinoza (2003), refers contingency to a specific openness of possibilities and options. Contingent situations are characterized by chance, which means that something may or may not happen, that something may or may not be true. Levels of contingency encompass different degrees of what is known and what can be known about specific decision situations. Situations of (almost) perfect information characterize lower levels of contingency, while higher levels are characterized by decreasing information quality (in terms of amount and clarity). Contingency may replace the umbrella term uncertainty (i.b.s.) to allow for the coverage of different types of uncertainty and beyond.

The levels of contingency are outlined in the following chapter. They depend on specific epistemological configurations represented by the availability of specific knowledge dimensions. These include i) knowledge about WHAT are possible future states/outcomes of action and the related relevant variables, ii) knowledge about HOW LIKELY possible future states/outcomes of action and the influence of relevant variables are, iii) knowledge about WHY future states/outcomes of action will occur as a result of the causal relationship and distinctiveness of outcome-related variables, and finally, based on this, vi) knowledge about WHEN future states/outcomes of action will occur because of knowledge about sequence of outcome-related variables. The levels of contingency discussed increase with the lack of information. The identified and concluded levels are certainty, risk, uncertainty (i.n.s.), complexity, ambiguity/ equivocality, and isotropy/radical uncertainty.

Certainty

Certainty represents the lowest level of contingency and marks the starting point of the epistemological contingency framework. Certainty is ascribed to situations that are characterized as trivial because they have only one (reasonable) condition or state. In trivial situations, a given, specific input always produces a specific, predictable output (just like an equation with one variable). Triviality assumes a clear causal relationship between input and output (Foerster, 1985). In contrast, non-trivial situations can have at least two conditions or states, e.g. , these situations can produce one or another output for the same input, or they can produce different outputs for a given input (Foerster & Pörksen, 2023). **Figure 1** illustrates this distinction.

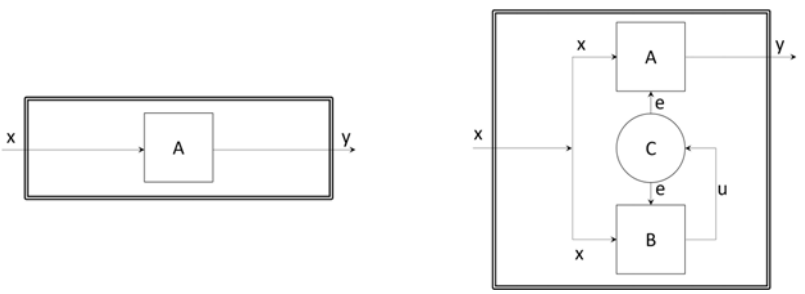

Figure 1 Situations of certainty (left) and situations of higher levels of contingency (right) exemplified by trivial and non-trivial machines
Source: Depiction based on Foerster, 2011, pp. 357–359

In situations of certainty, agents have knowledge of possible outcomes of actions/future states and their probabilities (Laux, Gillenkirch & Schenk-Mathes, 2014). In the case of sequences of events (variables), agents are familiar with consequences (sequence of outcome-related variables) and eventual outcomes/future states. For example, a traffic light for car traffic will turn green in a fixed and known time after it turns red. The pedestrian light will turn red after a certain number of seconds, which may indicate to the agent that it is time to shift into first gear of the car. Knowledge of the regularities of processes, sequences, causalities, and the differentiability of their intermediate events (variables) enables agents to be certain about the eventual outcomes of activities and actions. The same applies to situations in which a traffic light is turned off. Agents who are experienced drivers will most likely not wait for the light to turn green. They can

clearly determine what alternative courses of action are available in known situations, and what eventual outcomes of actions follow from the states of the situation and their choices. The expected value of all future events is one, and all alternatives to a choice are "certain" alternatives. Situations of triviality are situations of low contingency and thus situations of certainty.

Risk

Formal sciences, engineering, and the insurance industry define risk as a stochastic and calculable quantity that is aggregated in the form of an expectation value. Insurance industry concludes expectation values of possible outcomes and future states as results from the product of the expected amount of damage/loss (or benefit/gain) and the probability that a future state will occur (Krohn & Krücken, 1993). Such a definition presupposes the quantifiability of the variables and intermediate states involved, which is typically achieved by stochastic or empirical methods based on large numbers of cases or iterations. Insurance companies can quantify risks and contract costs if they know the number of potential policyholders, the frequency of insured events, and the amount of damage. This can also include individual risks for specific contracts (e.g., insured damage by martens in addition to partial coverage), where the risk becomes the target variable of a mathematical calculation (Laux et al., 2014).

In contrast to the formal sciences, social sciences such as business administration are faced with the challenge that variables for risk calculation are often not or only incompletely quantifiable. In many cases, they are even unknown. Against the backdrop of bounded rationality, social science prefers to deal with the (non-)existence of information in the context of risk. This does not necessarily exclude proximate calculations ("[...] risk is most commonly conceived as reflecting variations in the distribution of eventual outcomes" (March & Shapira, 1987, p. 1404)), but makes the application of the term less dependent on quantitative dimensions ("[and] is embedded, of course, in the larger idea of choice as affected by the expected return on an alternative" (March & Shapira, 1987, p. 1404)). Thus, the concept of risk operationalized in social sciences is not strictly formal allowing to include the option of experience-based probabilities (educated guesses) and hence incomplete (because partially impossible) calculations.

For the development of an epistemological, contingency-based decision-making framework, the question arises as to the extent to which the concept of risk should be held in multiple (formal and/or social science) perspectives. In terms of distinctiveness, it seems less appropriate to build on two perspectives. In addition, the social science perspective of risk includes epistemological configurations of knowledge that are equally (or even more) applicable to uncertainty (i.n.s.) (see chapter on uncertainty). This suggests an operationalization of risk more along the lines of a formal concept, according to Savage (1972). According to that, a situation is said to be risky if all possible outcomes of actions/future states and relevant variables as well as their probabilities of occurrence are known. However, risk may involve incomplete knowledge of the causal relationships between all outcome-related variables and thus limited knowledge of when future states will occur. Put differently, although agents may a) know what can happen (possible outcomes/future states) and b) be able to state the probability of each possible outcome, they c) do not know with certainty when a future state will occur because d) they lack information about the causal relationship of all outcome-related variables. A typical example for that is flipping a coin. Outcomes are known (heads, tails), probability is known (50/50), the sequence of outcome-related variables (flipping, dropping, bouncing around) is known, but the outcome is not specifically determinable (physics behind the outcome) because of the inability to control the underlying causalities/relationship of outcome-related variables that lead to the outcome (heads or tails). Moreover, risky situations are also characterized by the prerequisite of being repeatable. Only the repetition of a situation (e.g., flipping a coin over and over again) with stable inputs, a limited number of variables, and subsequent output states allows the calculation of probabilities for the outcome (e.g. , ~ 50/50 out of 1000 attempts). This is an empirical challenge, especially for more complex situations, because the estimates of the probabilities often depend on the number of repetitions, which is determined by the number of variables involved. The larger the number of variables and output states, the larger the number of iterations required.

Uncertainty

"Uncertainty must be taken in a sense radically distinct from the familiar notion of risk, from which it has never been properly separated", notes

Knight (1964, p. 19). The distinction is drawn along the availability of quantifiable information. Decisions whose consequences (outcomes of actions/future states) are based on objectively known probabilities of occurrence and that can be calculated with the help of repetition or cumulative data collections are ascribed to be risky. On the other hand, *uncertainty (i.b.s)* in situations means that probabilities are not fully measurable or calculable in an empirical, formal sense. While risk can be reduced by a priori calculation or probabilistic estimation, uncertainty can only be managed by judgment and experience. Consequently, unlike risk, uncertainty is not insurable (Knight, 1964).

Knightian uncertainty serves as a result of this distinction and marks an expedient recourse to the construct of uncertainty in entrepreneurship and management literature. Because "[...] uncertainty is prevalent in business and other social situations, it is pervasive in entrepreneurial settings[...]" (Sorenson & Stuart, 2008, p. 530) and thus forms the starting point for the application of decision-making strategies such as effectuation in managerial decision-making (Sarasvathy & Kotha, 2001). Nevertheless, management research operationalizes the construct of uncertainty inconsistently, not generally as Knight understands it, and sometimes imprecisely. Essentially, the definitional scope of uncertainty (i.b.s.) ranges from ignorance of information, to lack of specific information, to the impossibility of having information and data (Packard et al., 2017; Ramoglou, 2021). Such variance in understanding the structure points to authors who equate uncertainty with *isotropy*. For them, there is perfect formal calculability on the one hand, and perfectly incalculable, unpredictable situations on the other. Definitions cover aspects such as that "environmental issues are, by their nature uncertain; the future is unknowable, and the framing of environmental issues occurs in a future context" (York & Venkataraman, 2010, 252f.). Or uncertainty defined as "[...] situation in which the missing information is yet to be created [...]" (Kuechle, Boulu-Reshef, & Carr, 2016, p. 46), which refers to the impossibility of recognizing future outcomes and much less being able to take them into account. The present paper adopts such a perspective and, at the appropriate point introduces a more distinct and precise construct of isotropy (see the chapter on Isotropy) by detaching the state from uncertainty (i.b.s).

Knight (1964, p. 265) also understands uncertainty in a similar way to isotropy, but less radically, implicitly stating that uncertainty is an objective problem that can only be addressed by society as a whole: "We must notice also the development of science and of the technique of social organization. Greater ability to forecast the future and greater power to control the course of events manifestly reduce uncertainty, and of still greater importance is the status of the various devices noted in the last chapter for reducing uncertainty by consolidation." While such a definition includes isotropic states in the sense of not knowing or not being able to foresee (akin to e.g. *unknowability* according to Ramoglou, 2021), it also points to a partial possibility of controlling, treating, or managing uncertainty through the collection of data and information. The problem with the Knightian understanding of uncertainty remains that it leaves a very broad epistemological spectrum open next to the formalist concept of risk. On the one hand, there are decision situations and outcomes that can be calculated, and on the other, there are decision situations and outcomes/future states that cannot even be predicted. Presumably, there must be something in between, because neither are all everyday decisions based on probabilistic calculations, nor are they made at random.

In the face of such challenges, later authors only partially adhere to Knight's strictly probabilistic distinction. They understand uncertainty not as linked to the general availability of information and data, but as determined by the possibilities of generating them. Uncertainty is seen not so much as objectively radical in the sense of the inability to know, but rather as a consequence of the inability or impossibility to accurately determine the outcomes of future decision states, e.g. because of a poor understanding of causal relationships between outcome-related variables (Downey & Slocum, 1975). Such a moderate understanding of uncertainty is primarily based on the assumption that some relationships between variables and outcomes are not yet or cannot be formally explored or manifested probabilistically.

Thus, March (1994) proposes a more nuanced understanding of uncertainty. He distinguishes between uncertainty, radical uncertainty, and Knightian uncertainty, which are often used synonymously. His distinction is based on a moderate definition of uncertainty and is different from the ones named above. Knightian uncertainty is more likely to represent the contingency level of

ambiguity according to Oehmen and Kwakkel (2020), Townsend et al. (2018) and Stirling (2010). Although ambiguity is to some extent related to uncertainty in the moderate sense, it is also different in that ambiguity is based on a general lack of information. Uncertainty, however, is based on a temporarily limited understanding of what's known. Hence, *uncertainty in the narrow sense (i.n.s.)* may here be based on the assumption "[...] there is a real world that is imperfectly understood" (March, 1994, p. 178).

Questions about the objects of inquiry in the context of uncertainty can reflect the distinction between the moderate concept of uncertainty, ambiguity (Knightian uncertainty), and isotropy (radical uncertainty). Is there uncertainty in the environment? Are agents uncertain? Or are both of them uncertain? Isotropy/radical uncertainty and, to some extent, ambiguity (Knightian uncertainty) assume that uncertainty originates outside of the agent. This type of uncertainty, also known as Type A uncertainty, is characterized by stochastic variability of the environment (Campos et al., 2007), probabilities, outcomes, and relationships that cannot be identified or predicted in advance (Miller, 2012). Future states and outcomes of actions are incompletely known or not known at all, the probabilities of their occurrence are not calculable or calculable only to a limited extent, and the relationship between outcome-related variables is not yet fully understood. As a result, it remains highly uncertain what will come next (sequence of outcome-related variables) (Hoffman & Hammonds, 1994). Thus, in a planned way, e.g., through deliberate experimentation, perfect Type A uncertainty is considered irreducible. But there are also decision situations with partially available information, except for what is not yet known, that can be used to initiate processes of uncertainty reduction.

In addition, there is Type B uncertainty. It is caused by the agent's subjective inability to process available information. Type B uncertainty is similar to epistemic uncertainty and arises from a lack of knowledge, from scientific ignorance, or simply from non-observability (Campos et al., 2007).[2] Type B uncertainty is typically residual uncertainties that occur in educated guesses that are based on the opinions of experts or on logical-deductive methods of cognition. They are therefore not necessarily intractable. They are (theoretically) reducible through the expansion of systemic processing capacities (larger numbers of cases, more sensitive measurement methods, deliberate learning, improvement of indicators, investment of time and resources in experiments), since an approximation to complete information in a situation (even if not quantifiable) prevails or is attainable. In practice, however, clear causal relationships or sequences of outcome-related variables can only be probabilistically validated to a limited extent.

Distinguishing between Type A and Type B uncertainty then allows for different ways of relating the two types to each other. When Type A uncertainty is present, Type B uncertainty is also present. This is because agents cannot subjectively incorporate more information than is objectively available. The presence and perception of Type B uncertainty means that information about variables, regularities, and causalities is available but not (yet) reducible to certainty or risk. The hierarchy of uncertainty (i.b.s.) represented by the major uncertainty types A and B is shown in **Figure 2**. The contingency level of risk, as described earlier, is also subsumed under certainty.

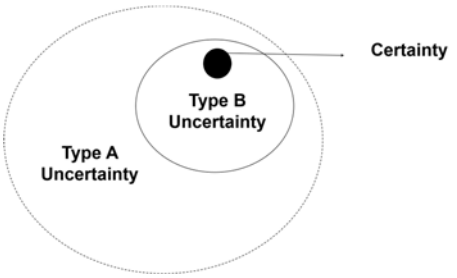

Figure 2 Relationships between types of uncertainty (i.b.s.)
Source: the author's own depiction

[2] Other authors distinguish between *primary uncertainty* and *secondary uncertainty* (Sutcliffe and Zaheer (1998), *aleatory uncertainty and epistemic uncertainty* (Packard, Bylund & Clark, 2021); Packard and Clark (2020)) or *weak* and *strong substantive uncertainty* (Dequech (2011); Dosi and Egidi (1991)), which are equivalent to Type A and Type B uncertainty.

Figure 3 shows the assumptions developed so far for different levels of contingency between uncertainty (i.b.s.). In addition to isotropy/radical uncertainty, which is assigned to Type A, and the subdivision of Type B uncertainty into uncertainty (i.n.s.) and complexity (see next chapter), ambiguity/equivocality (Knightian uncertainty) can be understood as an intersection of the two types. Type A uncertainty describes an objective lack of information. Type B uncertainty describes a subjective lack of ability or capacity to deal with the available information. Uncertainty (i.n.s.) differs from the formalistic concept of risk in its probabilistic limitations, since predictions about future states cannot (yet) be calculated. Nevertheless, experience-based and experience-supported predictions of future outcomes are possible in decision situations of uncertainty (i.n.s.). The chosen understanding of uncertainty (i.n.s.) thus fills a part of the space between radical uncertainty and calculable risk.

Uncertainty (i.n.s.) is similar to the concept of risk used in the social sciences. It allows for recourse to experience in estimating future outcomes. Theoretically, if agents can identify and manage all relevant variables, interrelationships, probabilities of occurrence, and sequences of outcome-related variables, such decision situations can be reduced from uncertainty (i.n.s.) to risk (formally) or even certainty. In practice, however, such endeavors are limited by the lack of time, the scarcity of resources, and the multiplicity of variables, including their interrelationships.

However, under uncertainty (i.n.s.), well-informed agents can make relatively reliable predictions. Either by applying experience-based, subjectively collected *a posteriori* probabilities, which serve as *a priori* probabilities for estimating future outcomes, or by applying and abstracting historical data to similar decision-making situations. Thus, the management of uncertainty (i.n.s.) largely depends on the ability of agents to make reliable, though not fully probabilistic, predictions by activating, applying, and linking existing information. This way, the concept is similar to what Arend (2022) calls *subjective uncertainty* and to what Spender (1989) refers as incompleteness to. Uncertainty (i.n.s.) is present when possible outcomes of actions and variables, including their characteristics, are known, but the causal relationships, sequence and probabilities of the outcomes are not yet fully probabilistically derived, or cannot be fully probabilistically derived.

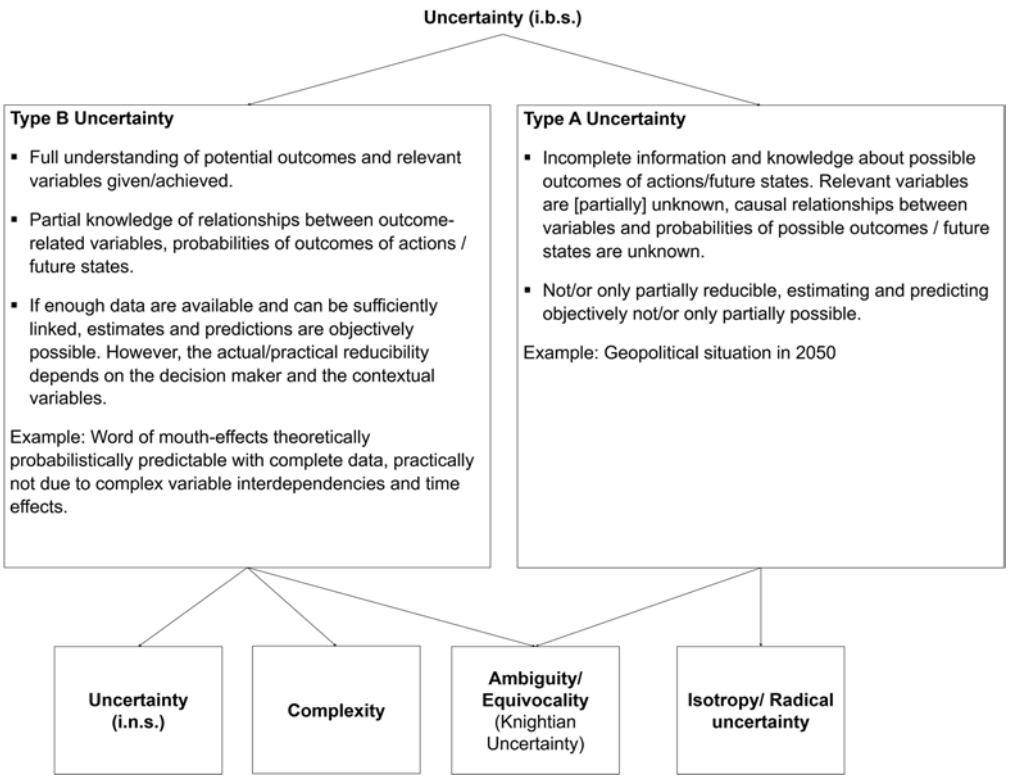

Figure 3 Ontology of major uncertainty types and contingency level differentiation
Source: the author's own depiction

Complexity

The *complexity* of knowledge structures in systems and organizations has a long tradition in cybernetic research. This, of course, has implications for management research if the management of complexity in dynamic environments becomes a special capability (Teece, 2007, 2012). Individual perceptions of complexity, among other things, significantly influence the application of decision strategies such as causation or effectuation to execute decisions (Mathiaszyk, 2017). Complexity has two main origins: *detail* and *dynamic complexity* (Townsend et al., 2018). Detail complexity represents a formal understanding and refers to the number of considered variables. Dynamic complexity arises from the possible interactions and interdependencies of the variables that are involved. The more variables and the more dependencies, the higher the degree of complexity.

A concept closely related to complexity is *emergence*. Emergence is a social, psychological, or physical phenomenon and ordering concept referring to a change in condition with new properties (for example, the whole is more than the sum of its parts). Complex systems do not behave linearly, but have the property of being able to form new structures based on how their elements interact.

Thus, a specific property of emergence is that it is not possible to infer an observed phenomenon directly from the properties of the underlying variables. The non-linearity of complex systems has come into particular focus as the success factors of organizations do not seem to follow a linear distribution, but rather an exponential one (success multiplies according to the Matthew effect)
Crawford, Aguinis, Lichtenstein, Davidsson, P., & McKelvey, 2015). Attribution difficulties arise when agents face complexity. They are challenged to compete in a complex environment because, on the one hand, they must identify relevant factors and variables that may influence their actions and, on the other hand, know and estimate the interactions and outcomes of these variables. Complexity is therefore generally considered as the "[...] heterogeneity and range of factors that have to be taken into account [...]" (Clarysse, Brunee, & Wright, 2011, p. 140) as well as "[...] the number of opportunity contingencies that must (be) addressed successfully" (Davis, Eisenhardt & Bingham, 2009, p. 420).

Complexity means that possible outcomes of actions/future states and variables are or can be known to agents (WHAT), in accordance with the introduced epistemological dimensions for classifying levels of contingency. Ambiguity would exist if outcomes of actions/future states or variables were beyond knowledge. Complexity arises from the number of variables involved, how they interact, and emergent dependencies. Sequences (WHEN) and causal relationships (WHY) between variables are partially but not completely clear to agents. Different interactions may have similar outcomes. As a result, formal probabilities for outcomes can hardly be inferred, not least because of the often small number of empirically measurable and comparable cases (HOW LIKELY). Complexity, however, remains a problem of emergence, not of fulfillment (according to Lorenz, 1975). It can be solved by identifying, selecting, and understanding relationships between relevant variables. To cope with external complexity (Crawford et al., 2015), agents need to increase internal complexity. Put differently, complexity can only be solved by complexity (Ashby, 1956; Beer, 1994).

Ambiguity/equivocality

In addition to complexity, *ambiguity* plays an important role in management research as well as for studying decision-making in business and organizational theory (Townsend et al., 2018, p. 671). Some authors understand ambiguity as a decision-making environment in which agents know the possible outcomes of their actions/future states, but it is not possible for them to specify the corresponding probabilities (Holm, Opper & Nee, 2013). Others explain ambiguity as a "[...] problem of interpretation because it results from a lack of understanding and/or consensus regarding the applicability of available knowledge" Rindova, V., Ferrier, W. J., & Wiltbank, 2010, p. 1477). Both of these perspectives limit ambiguity to a subjective problem of knowledge. On the other hand, ambiguity is understood as synonymous with isotropy/radical uncertainty (Fox & Tversky, 1995), which would mark ambiguity as an objective knowledge problem.

In the following, ambiguity is going to be treated as a bipartite concept, similar to the concept of *external unpredictability* by Arend (2022). It contains both objective and subjective limits of knowledge. That is, ambiguity is characterized by epistemological elements that are subjectively not yet known and epistemological elements that are objectively unknown (yet) and thus subjectively

cannot be known.

Difficulties in predicting outcomes of repeated identical behavioral experiments led Ellsberg (1961) to conclude that ambiguity, along with uncertainty and risk, must be a distinct problematic category within decision theory. Ambiguity depends on the amount, type, reliability, and clarity of available information as well as agents' confidence in inferring outcome probabilities. Ambiguity thus takes into account what is also known in scientific discourse as the impossibility of making sense. In certain scenarios, agents are not able to distinguish signals from the noise in their environment (Weick, 1995) and are unable to translate an observed process or variable into a rational system (Townsend et al., 2018). Ambiguity then encompasses a decision environment "[...] in which alternative states are hazily defined or in which they have multiple meanings" as well as where "a 'real' world may itself be [...] a product of social construction" (March, 1994, p. 179). This is a reflection of the fact that in an ambiguous situation, although some information is available, there is always also an as yet unmarked space of no information.

Ambiguity is also considered to be similar to *equivocality*. By definition, equivocality arises from the existence of multiple meanings or interpretations of an object (Daft & Macintosh, 1981). Consequently, equivocality cannot be solved by more information because "the key problem in an equivocal situation is not that the real world is imperfectly understood and that additional information will render it understandable; instead, the problem is that additional information may not actually resolve misunderstandings" (Frishammar , Florén & Wincent, 2 011, p. 553). Ambiguous/equivocal situations do not have objectively clear answers (Townsend et al., 2018) and can only be resolved "through shared observations and discussion until a common grammar and course of action can be agreed upon" (Daft & Weick, 1984, p. 291). Or as Arend (2022, p. 5858) puts it: "Such problems are not only complex – because they involve interdependencies and unknowns – but are also non-optimizable."

The boundary between ambiguity/equivocality, complexity and isotropy/radical uncertainty is drawn along the lines of objectively available knowledge. Decision situations characterized by ambiguity/equivocality are to be placed between the major uncertainty types A and B defined by Campos et al. (2007). Ambiguity/equivocality exists when possible outcomes of actions/future states and outcome-related variables are not fully known because they cannot yet be fully known. Next to not knowing relevant variables, this is due to indifference to the relevance of known variables, their probabilities of appearing, sequences and causal relations (Davis et al., 2009; Ellsberg, 1961). Ambiguity differs from uncertainty (i.n.s.) in that the former is based not only on incomplete knowledge of causal relationships between means and ends, but primarily on the impossibility of predicting possible outcomes/future states. This is because relevant variables are not fully known. Their properties/roles are not yet distinguishable. (Garud & van de Ven, 1992).

Isotropy/radical uncertainty

Finally, the contingency level of *isotropy/radical uncertainty* will also be described, although it has already been referred to in the decomposition of the uncertainty (i.b.s.) construct earlier in this paper. Isotropy/radical uncertainty applies to decision situations in which outcome-related variables and their interrelationships are still completely unknown or undetermined in society (objectively). Similar to situations of incommensurability (Spender, 1989) and absolute uncertainty (Packard et al., 2017), isotropy/radical uncertainty applies to epistemological entities that are neither present nor can be predicted (Schneider, 1997). Outcomes of actions/future states in situations of isotropy/radical uncertainty are random and cannot be predicted based on current knowledge. The same is true for the probabilities of their occurrence. This is because outcome-related variables, causal relations and sequence of relevant variables are not yet perceived and processed by society. Outcomes of actions/future states in situations of isotropy/radical uncertainty are usually single events, from which knowledge about interrelationships etc. can only become generated retrospectively (sensemaking). Thus, the present paper supports Ramoglou's (2021) distinction between Knightian uncertainty and unknowability, understanding the former as similar to ambiguity/equivocality and the latter as similar to isotropy/radical uncertainty.

Isotropy cannot be resolved by intentional system-immanent emergence. This would require knowledge of a certain number of variables, dependencies, and correlations as a starting point for a goal definition (e.g., through research). Instead, isotropy/radical uncertainty is based on the fact that "[...] that in decisions and actions

involving uncertain future consequences it is not always clear ex ante which pieces of information are worth paying attention to and which not" (Sarasvathy, 2008, p. 69). The resolution of isotropy/radical uncertainty is only possible through evolutionary leaps (fulgurations). In practice, the handling of isotropy/radical uncertainty[3] can be observed in terms of partnership heuristics in effectuation. *Crazy quilt* relies on flexible, arbitrary partnerships to achieve indeterminate sensemaking. Agents interact with partners who are close to them, known to them, willing to collaborate, and technically available. The purpose of engaging in partnerships is open-ended, not predefined, and emerges as participants interact. These kinds of activities are used to deliberately encourage contingency, to give unexpected outcomes and serendipity a chance. Rather than being overwhelmed by or resigned to a priori incomplete information, the challenge then becomes one of managing (and investigating) contingent situations quite effectively (Griffin & Grote, 2020). Similar to complexity, isotropy/radical uncertainty can only be countered by isotropy/radical uncertainty (Townsend et al., 2018). Random solutions must be generated for random decision situations. Indeterminate outcomes may then be the starting point for structured knowledge generation/experimentation.

3. Aggregated epistemological contingency framework

Error! Reference source not found. summarizes the discussed levels of contingency. The identified levels differ according to the epistemological configuration whether there is knowledge of possible outcomes of actions/future states and relevant variables (WHAT), knowledge of their probabilities (HOW LIKELY), knowledge of the sequence of outcome-relevant variables (WHEN), and knowledge of the causal relationship of outcome-relevant variables/the distinctiveness of all variables (WHY). The spectrum of the epistemological contingency framework is bounded on the left by the contingency levels of certainty and risk. Situations of certainty are represented by given knowledge about possible outcomes of actions/future states and relevant variables, including the probabilities of their sequences and how the variables are related to each other. Causal relationships are unambiguous. Outcomes are predictable and insurable. Risk is different from certainty because knowledge of causal relationships is incomplete and therefore immediate outcomes of actions/future states cannot be fully predicted.

Uncertainty (i.n.s.) and complexity both imply that certain predictions based on experience are possible, but that these are not yet fully revealed in the context of the variations of the variables involved. Possible outcomes of actions/future states and outcome-related variables are largely known. However, it is not yet empirically possible to fully trace causal relationships and effects of all variables beyond doubt or to prove them in a probabilistic sense. Complexity is further exacerbated by the need to account for too many variables with unknown causal relationships. Situations in which identical inputs generate different outputs, or different inputs generate identical outputs can be described as complex.

Ambiguity/equivocality represents a level of contingency in which there is more or less a lack of information. Compared to uncertainty (i.n.s.) and complexity, where there is imperfect knowledge about causal relationships between variables and outcomes, ambiguity occurs when agents do not fully know which outcomes of actions/future states can occur or what relevance which variables have within causal relationships. The fact that parts of the outcome-related knowledge have not yet been encountered is a major challenge in reducing this level of contingency. Agents can only work with incomplete causal relationships because they do not know what is missing. Consequently "[...] no certain answers exist and perhaps the right questions have yet to be formulated" Daft, Lengel & Trevino, 1987, p. 359).

The far-right pole of the epistemological contingency framework is isotropy/radical uncertainty. It is characterized not only by incomplete knowledge about possible outcomes of actions/future states and relevant variables, but also by incomplete knowledge about of their existence. Outcomes have no dominant probability, everything is equally possible (or not) (chaos), and beyond an existing "lack of clarity" for agents, "it is difficult to interpret or distinguish between possibilities" (Davis et al., 2009, p. 424).

[3] Some would say hoping for serendipity.

Table 2 Epistemological contingency framework: Increasing levels of contingency (from left to right) depending on available knowledge qualities

Level of (un)certainty/contingency → Criterion ↓	**Certainty**	**Risk**	**Uncertainty (i.n.s)**	**Complexity**	**Ambiguity/Equivocality**	**Isotropy/Radical Uncertainty**
WHAT? Complete knowledge of all outcomes of actions/future states and relevant variables	Given	Given	Given	Given	Incomplete	Missing
HOW LIKELY? Complete knowledge of probabilities of all outcomes of actions/future states and relevant variables	Given	Given	Incomplete	Incomplete	Missing	Missing
WHY? Complete knowledge of distinctiveness and causal relationships (of/between relevant variables)	Given	Incomplete	Incomplete	Incomplete	Missing	Missing
WHEN? Complete knowledge of sequence of relevant variables causing distinct outcomes	Given	Incomplete	Incomplete	Missing	Missing	Missing
Objective/subjective insurability	Given	Given	Potentially yes (, but depending on the possibility of empirical validation, a sufficient N of repetitions or based on educated guesses)	Potentially yes (, but depending on the possibility of empirical validation, a sufficient N of repetitions or based on educated guesses)	Missing	Missing
Example	e.g. "Death and taxes"	e.g. flipping a coin	e.g. competing in a pitch with an unknown N of competitors	e.g. development of United States Declaration of Independence in 1787	e.g. consequences of artificial intelligence	e.g. fortuity, development and rise of Facebook, discovery of ultraviolet light, Higgs-Boson
Major types of certainty and uncertainty (i.b.s.)	Certainty		Type B		Type A (depending on level of isotropy)	Type A

Source: own compilation

Discussion and conclusion

In order to enable the selection of appropriate strategies for specific decision-making situations, this paper aims to delineate types of uncertainty along their epistemological configurations in relation to specific knowledge contexts. In order to provide a framework that includes differences within uncertainty (i.b.s.), the terms certainty and uncertainty are first discussed. They are decomposed into distinguishable configurations of epistemological elements (knowledge). The distinction is conceptually related to Townsend et al. (2018) but extends their approach by including all conceivable levels of contingency and differing between them according a tailored set of knowledge entities. The paper is also related to Packard et al. (2017), who postulate open and closed sets of options and outcomes. These are signified by the presence (closed)/absence (open) of knowledge about all possible future states (outcomes) and the presence (closed)/absence (open) of knowledge about courses of action to achieve the corresponding outcomes/future states (options). Although the presented paper adopts the basic idea of existence/absence of knowledge regarding outcomes and options, it carves out the need for extending and clarifying the discussion about uncertainty.

The paper introduces contingency as an alternative umbrella term to avoid multiple meanings of uncertainty and to achieve construct clarity. Based on a literature review reflecting the main conceptualizations of uncertainty, it is concluded that knowledge and different epistemological configurations determine the levels of contingency. Some configurations of contingency require going beyond Packard et al. 's (2017) concept by also including aspects such as formal probabilities, clarity in terms of cause-effect relationships and finally the differentiation between subjective and objective knowledge. Therefore, the paper includes and refers to further concepts developed by Angus et al. (2023) (subjective uncertainty, external unpredictability), Townsend et al. (2018) (uncertainty, complexity, ambiguity, equivocality), Oehmen and Kwakkel (2020) (risk, uncertainty, ambiguity, ignorance), Campos et al. (2007) (type B and type A uncertainty), Spender (1989) (incompleteness, indeterminacy, irrelevance, incommensurability), Thompson (2017) (incompleteness, contingency), Ellsberg (1961) (ambiguity), Savage (1972) (risk, uncertainty), and, of course, Knight (1964) (risk, uncertainty) to conclude a framework that covers the varying presence and absence of different knowledge. It is assumed that agents may have complete or incomplete knowledge about all possible outcomes of actions/future states and relevant variables (WHAT), their probability of occurrence (HOW LIKELY), the causal relationships among relevant variables (WHY), and their sequence (WHEN). Levels of contingency vary depending on the extent to which each variable is present. The identified levels of contingency are developed and discussed, and summarized in form of an epistemological contingency framework. It covers states ranging from complete information to unknowability. These states are named as certainty, risk, uncertainty in the narrow sense (i.n.s.), complexity, ambiguity/equivocality, and isotropy/radical uncertainty.

The framework can serve as a prerequisite (e.g., configuration, presence, and availability of knowledge) for effective decision-making by enabling the selection of an appropriate decision strategy. Decision theory has developed several strategic approaches to deal with contingency in order to enable and ground decision-making (Chandler, DeTienne, McKelvie & Mumford, 2011; Dew, Read, Sarasvathy & Wiltbank, 2009; Sarasvathy, 2001). That is, causation focuses “on the predictable aspects of an uncertain future” while effectuation focuses “on the controllable aspects of an unpredictable future” (Sarasvathy, 2001, p. 251). These approaches have been the subject of intense debate due to the seemingly arbitrary and overlapping assumptions about their configuration (Arend, Sarooghi & Burkemper, 2015; Grégoire & Cherchem, 2020; Read, Sarasvathy, Dew & Wiltbank, 2016). This paper contributes to construct-clarity of uncertainty by complementing the discussion on the configuration of Knightian uncertainty, unknowability (Ramoglou, 2021) as well as (objective) unpredictability and (subjective) uncertainty (Angus et al., 2023) or, how Packard and Clark (2020) call it, epistemic uncertainty and aleatory uncertainty.

The developed epistemological contingency framework suggests the assignment of decision situations to specific levels of contingency. In order to reduce contingency in decision-making, organizations can control for subjectively given and objectively available knowledge to evaluate decision-making strategies. Further research

should aim to explore more about the types of knowledge within levels of contingency (e.g., declarative/accumulated knowledge, procedural/structural knowledge, conceptual knowledge) and match them with decision-making strategies (including the most commonly used ones: effectuation, causation, bricolage, but also beyond). This will lead to a better understanding of situation-specific decision-making strategies. It will also help organizations to choose strategies to consciously and effectively reduce contingency in decision-making situations. Harms, Alfert, Cheng & Kraus (2021) have recently undertaken an initiative in this direction. The authors find that the successful innovation of business models depends on the successful adaptation of appropriate decision strategies to the decision situations.

Contribution to decision-making theory

In order to outline effective decision-making, differentiations within the original concept of uncertainty are necessary. This paper shows that in order to avoid synonymous use and lack of differentiation, different levels of contingency can replace the generic term uncertainty (i.b.s.). An understanding of uncertainty (i.b.s.) can still be meaningfully applied, as it exists in the form of two major types (Type A and Type B uncertainty). Their classification generally results from the relationship between completeness and incompleteness of information or data. Type A uncertainty represents an objective problem, while Type B uncertainty relates only to the agent. The distinction between objective and subjective uncertainty has implications for choosing effective decision-making strategies as well as for measuring decision-making.

The measurement of contingency perception in empirical studies as a predictive element for decision-making has to take into account that measurement results depend on the units of investigation (respondents) as well as on the objects of investigation (see e.g. Angus et al., 2023). Depending on individual expertise, agents update more or less limited amounts of information from their environment. On this basis, they coordinate their behavior. This is normal in cases of (perceived) imperfect information, which agents often encounter when decision-making[4], without recognizing or collecting the maximum possible amount and quality of information before acting (Busenitz & Barney, 1997; McMullen & Kier, 2016). From a subjective perspective, although information about outcomes, relevant variables, probabilities, and causal relationships may be (objectively) available, decision-making situations may be individually assigned to higher/more complex levels of contingency. This way, the context of decision-making (in terms of available knowledge) may be misinterpreted, leading to ineffective decision strategies (Packard & Clark, 2020) (e.g. applying adaptive, flexible approaches in situations of low contingency instead of predictive, planning approaches).

By deliberately generating knowledge and filling information gaps, a better understanding of objective contingency in specific decision situations enables agents to select more appropriate strategies for effective decision-making. The proposed conceptualization of an epistemological contingency framework helps to address the question of whether strategists should adapt or shape markets on the basis of specific constituent elements such as intentions, epistemologies, and enactment strategies (Rindova & Courtney, 2020). In addition to individual dispositions, such as being risk-averse or risk-seeking, and operational capabilities, the outlined levels of contingency clarify the role of epistemologies in understanding the incompleteness of information and concluding coping or mitigating strategies in contingency situations. To conclude, the following steps are suggested for identifying levels of contingency and concluding effective strategies for reducing them.

1. The exclusivity of the decision problem must be questioned in order to objectively classify a decision situation: Is the problem objectively and/or subjectively given? Are objective information/solutions available (e.g., expert knowledge, market research approaches)?
2. If subjective information gaps or deficiencies are identified, but objective information is available, how can the gap be filled by updating subjectivity (e.g., deliberate own research, factor market expertise, trial & error, effectuation)? This reflects the effectiveness of the decision-making process, as all decision-making strategies require resources.

[4] E.g. Applying trial & error according to Hauser, Eggers & Güldenberg, (2020).

3. If objective information gaps are identified, how can contingency be reduced (e.g. by developing reduction strategies such as deliberate experimentation)?

Given the framework and corresponding recommendations, the paper sharpens the microfoundations of decision-making in general and in dynamic environments in particular. The provided understanding of contingency and its configurations allows agents to infer strategies for acquiring information and making successful decisions. Studies such as the one by Magruk (2021) can be supported by this when it comes to discussing foresight methodologies in situations of emerging technologies.

Implications and further research

In order to make decision strategies more applicable to epistemologically diverse decision situations, widely discussed decision-making paradigms (effectuation, causation, bricolage etc.) need to be revisited and more clearly differentiated. For example, some paradigms are constructed in an overlapping manner, which leads to incomplete recognition of all existing decision strategies within empirical studies. For example, anything apart from causation is often labeled effectuation, although it is not distinguished from trial and error (or other paradigms.) After the revision and differentiation of the paradigms, their effect on the reduction of contingency must be investigated. To what extent specific decision strategies contribute to the reduction of contingency in order to effectively enable reliable decisions would be an appropriate avenue of research. The answer to this question requires an alignment between the variations of decision-making paradigms (including their inherent types of knowledge, their transition, and their transferability) and their assignment to different levels of contingency. The study of knowledge generation among scientists in the context of the SARS-CoV-2 pandemic would be an interesting, if not primarily managerial, research case. At the beginning of 2020, German scientists knew very little about the virus in terms of transmission (aerosol vs. smear infection, etc.), resistance to temperature and ultraviolet light, or the effects of preventive tools. By 2022, researchers were able to predict infections and incidences over 6 months in advance with almost no deviation. This included variations in instrumental scenarios. The case illustrates an archetypal development of knowledge and how to transform this into a simulated, prediction-based model. A publication by Gričar and Bojnec (2022) provides another example of the development and application of such a model.

The application of *fuzzy logic* or even *supervaluationism* to the presented epistemological contingency framework would be another highly interesting avenue of further research. Fuzzy logic is based on fuzzy sets, in contrast to conventional *Boolean* logic. In both models, a property of an object is defined as membership of a set, but in fuzzy logic membership is progressively less sharply defined by a 0/1 (yes/no) distinction. Attribution is made formally by assigning a numerical value from an interval to each element as a degree of membership, or linguistically by accepting fuzziness in transition states (Klir, G. J., Zadeh, L. A [Lotfi A.], & Zadeh, L. A [Lotfi Asker, 1996)[5]. However, in linguistic semantics today, fuzzy logic is generally considered unsuitable for modeling vagueness and similar phenomena in natural language (Kamp & Partee, 1995; Sauerland, 2012). Instead of the assignment of an indeterminate statement, the method of supervaluation is preferred. Here, the assignment of a classical truth value (0;1) is postponed because its classification is not yet clear, or it depends on a parameter that must be substantiated by information from the context (Kamp & Partee, 1995). Such cases are well characterized by contingency levels of complexity and above. They involve indeterminable variables and cannot yet be unambiguously classified as true or false (Rinard, 2014). The application of supervaluation to the levels of contingency described above can help to identify the intersections between certain levels, according to the given qualities of the knowledge. On this basis, gaps in knowledge can be identified, filled by a deliberate accumulation of knowledge, and finally, transitions and strategies that allow for the transition between the levels of contingency can become visible.

Authorship

Conceptualization, methodology, visualization, writing original draft, writing-review-editing: Sebastian L. Grüner

[5] E.g. “Back up the car a little bit more, please!” instead of “Back up the car 12,5cm more, please!”.

References

Angus, R. W., Packard, M. D., & Clark, B. B. (2023). Distinguishing unpredictability from uncertainty in entrepreneurial action theory. *Small Business Economics*, *60*(3), 1147–1169. https://doi.org/10.1007/s11187-022-00651-4

Arend, R. J. (2022). Strategic decision-making under ambiguity: insights from exploring a simple linked two-game model. *Operational Research*, *22*(5), 5845–5861. https://doi.org/10.1007/s12351-022-00728-8

Arend, R. J., Sarooghi, H., & Burkemper, A. (2015). Effectuation as ineffectual? Applying the 3E theory-assessment framework to a proposed new theory of entrepreneurship. *The Academy of Management Review*, *40*(4), 630–651. https://doi.org/10.5465/amr.2014.0455

Ariely, D. (2010). *Predictably irrational: The hidden forces that shape our decisions*. Harper Collins https://doi.org/10.1037/e653632011-003

Aristotle, & Sachs, J. (2002). *Aristotle's metaphysics*. Green Lion Press.

Ashby, W. R. (1956). *An Introduction to Cybernetics*. Chapman & Hall. https://doi.org/10.5962/bhl.title.5851

Audretsch, D. B., & Belitski, M. (2021). Frank Knight, uncertainty and knowledge spillover entrepreneurship. *Journal of Institutional Economics*, *17*(6), 1005–1031. https://doi.org/10.1017/S1744137421000527

Barr, C., Doyle, M., Clifford, J., Leo, T. de, & Dubeau, C. (2003). *There's more to math: A framework for learning and instruction.* Waterloo Catholic District School Board.

Beer, S. (1994). *Decision and Control: The meaning of Operational Research and Management Cybernetics*. Wiley & Sons.

Berge, T. ten, & Hezewijk, R. van (1999). Procedural and declarative knowledge. *Theory & Psychology*, *9*(5), 605–624. https://doi.org/10.1177/0959354399095002

Berglund, H., Bousfiha, M., & Mansoori, Y. (2020). Opportunities as artifacts and entrepreneurship as design. *Academy of Management Review*, *45*(4), 825–846. https://doi.org/10.5465/amr.2018.0285

Busenitz, L. W., & Barney, J. B. (1997). Differences between entrepreneurs and managers in large organizations: biases and heuristics in strategic decision-making. *Journal of Business Venturing*, *12*(1), 9–30. https://doi.org/10.1016/S0883-9026(96)00003-1

Camerer, C., & Weber, M. (1992). Recent developments in modeling preferences: uncertainty and ambiguity. *Journal of Risk and Uncertainty*, *5*(4), 325–370. https://doi.org/10.1007/BF00122575

Campos, F., Neves, A., & Campello de Souza, F. M. (2007). Decision-making under subjective uncertainty. In *2007 IEEE Symposium on Computational Intelligence in Multi-Criteria Decision-Making*. https://doi.org/10.1109/MCDM.2007.369421

Chandler, G. N., DeTienne, D. R., McKelvie, A., & Mumford, T. V. (2011). Causation and effectuation processes: a validation study. *Journal of Business Venturing*, *26*(3), 375–390. https://doi.org/10.1016/j.jbusvent.2009.10.006

Clarysse, B., Bruneel, J., & Wright, M. (2011). Explaining growth paths of young technology-based firms: structuring resource portfolios in different competitive environments. *Strategic Entrepreneurship Journal*, *5*(2), 137–157. https://doi.org/10.1002/sej.111

Crawford, G. C., Aguinis, H., Lichtenstein, B., Davidsson, P., & McKelvey, B. (2015). Power law distributions in entrepreneurship: implications for theory and research. *Journal of Business Venturing*, *30*(5), 696–713. https://doi.org/10.1016/j.jbusvent.2015.01.001

Daft, R. L., Lengel, R. H., & Trevino, L. K. (1987). Message equivocality, media selection, and manager performance: implications for information systems. *MIS Quarterly*, *11*(3), 355–366. https://doi.org/10.2307/248682

Daft, R. L., & Macintosh, N. B. (1981). A Tentative exploration into the amount and equivocality of Information processing in organizational work units. *Administrative Science Quarterly*, *26*(2), 207–224 https://doi.org/10.2307/2392469

Daft, R. L., & Weick, K. E. (1984). Toward a model of organizations as interpretation systems. *The Academy of Management Review*, *9*(2), 284–295. https://doi.org/10.2307/258441

Davis, J. P., Eisenhardt, K. M., & Bingham, C. B. (2009). optimal structure, market dynamism, and the strategy of simple rules. *Administrative Science Quarterly*, *54*(3), 413–452. https://doi.org/10.2189/asqu.2009.54.3.413

Dequech, D. (2011). Uncertainty: a typology and refinements of existing concepts. *Journal of Economic Issues*, *45*(3), 621–640. https://doi.org/10.2753/JEI0021-3624450306

Descartes, R. (Ed.). (1996). *Cambridge texts in the history of philosophy*. *Meditations on first philosophy: With selections from the Objections and Replies* (Rev. ed.). Cambridge Univ. Press https://doi.org/10.1017/CBO9780511805028.019

Dew, N., Read, S., Sarasvathy, S. D., & Wiltbank, R. (2009). Effectual versus predictive logics in entrepreneurial decision-making: differences between experts and novices. *Journal of Business Venturing*, *24*(4), 287–309. https://doi.org/10.1016/j.jbusvent.2008.02.002

Dosi, G., & Egidi, M. (1991). Substantive and procedural uncertainty. *Journal of Evolutionary Economics*, *1*(2), 145–168. https://doi.org/10.1007/BF01224917

Downey, H. K., & Slocum, J. W. (1975). Measures, research, and sources of variation. *The Academy of Management Journal*, *18*(3), 562–578. https://doi.org/10.2307/255685

Ellsberg, D. (1961). Risk, ambiguity, and the savage axioms. *The Quarterly Journal of Economics*, *75*(4), 643–669. https://doi.org/10.2307/1884324

Foerster, H. von. (1985). *Sicht und Einsicht: Versuche zu einer operativen Erkenntnistheorie*. Springer https://doi.org/10.1007/978-3-663-13942-3

Foerster, H. von. (2011). *Wissen und Gewissen: Versuch einer Brücke* (1. Aufl. [Nachdr.]. *Suhrkamp-Taschenbuch Wissenschaft: Vol. 876*. Suhrkamp.

Foerster, H. von, & Pörksen, B. (2023). *Wahrheit ist die Erfindung eines Lügners: Gespräche für Skeptiker* (13th ed.). *Systemische Horizonte*. Carl Auer Verlag.

Fox, C. R., & Tversky, A. (1995). Ambiguity aversion and comparative ignorance. *The Quarterly Journal of Economics*, *110*(3), 585–603. https://doi.org/10.2307/2946693

Freiling, J. (2008). RBV and the road to the control of external erganizations. *Management Revue*, *19*(1/2), 33–52. http://www.jstor.org/stable/41783570

Frishammar, J., Florén, H., & Wincent, J. (2011). Beyond managing uncertainty: insights from studying equivocality in the fuzzy front end of product and process innovation projects. *IEEE Transactions on Engineering Management*, *58*(3), 551–563. https://doi.org/10.1109/TEM.2010.2095017

Garud, R., & van de Ven, A. H. (1992). An empirical evaluation of the internal corporate venturing process. *Strategic Management Journal*, *13*(S1), 93–109. https://www.jstor.org/stable/2486354

Grégoire, D. A., & Cherchem, N. (2020). A structured literature review and suggestions for future effectuation research. *Small Business Economics*, *54*(3), 621–639. https://doi.org/10.1007/s11187-019-00158-5

Gričar, S., & Bojnec, Š. (2022). Did human microbes affect tourist arrivals before the COVID-19 shock? Pre-effect forecasting model for Slovenia. *International Journal of Environmental Research and Public Health*, *19*(20). https://doi.org/10.3390/ijerph192013482

Griffin, M. A., & Grote, G. (2020). When is more uncertainty better? A model of uncertainty regulation and effectiveness. *Academy of Management Review*, *45*(4), 745–765. https://doi.org/10.5465/amr.2018.0271

Harms, R., Alfert, C., Cheng, C.-F., & Kraus, S. (2021). Effectuation and causation configurations for business model innovation: Addressing COVID-19 in the gastronomy industry. *International Journal of Hospitality Management*, *95*, 102896. https://doi.org/10.1016/j.ijhm.2021.102896

Hauser, A., Eggers, F., & Güldenberg, S. (2020). Strategic decision-making in SMEs: effectuation, causation, and the absence of strategy. *Small Business Economics*, *54*(1), 775-790. https://doi.org/10.1007/s11187-019-00152-x

Hmieleski, K. M., & Corbett, A. C. (2006). Proclivity for improvisation as a predictor of entrepreneurial intentions. *Journal of Small Business Management*, *44*(1), 45–63. https://doi.org/10.1111/j.1540-627X.2006.00153.x

Hoffman, F. O., & Hammonds, J. S. (1994). Propagation of uncertainty in risk assessments: the need to distinguish between uncertainty due to lack of knowledge and uncertainty due to variability. *Risk Analysis*, *14*(5), 707–712. https://doi.org/10.1111/j.1539-6924.1994.tb00281.x

Holm, H. J., Opper, S., & Nee, V. (2013). Entrepreneurs under uncertainty: an economic experiment in China. *Management Science*, *59*(7), 1671–1687. https://www.jstor.org/stable/23443876

Hume, D. (2021). *A treatise of human nature*. Lokis Publishing; [manufacturer not identified].

Kahneman, D., & Tversky, A. (1979). Prospect theory. An analysis of decision under risk. *Econometrica*, *47*(2), 263–291. https://doi.org/10.2307/1914185

Kamp, H., & Partee, B. (1995). Prototype theory and compositionality. *Cognition*, *57*(2), 129–191. https://doi.org/10.1016/0010-0277(94)00659-9

Klir, G. J., Zadeh, L. A [Lotfi A.], & Zadeh, L. A [Lotfi Asker] (Eds.). (1996). *Advances in fuzzy systems - applications and theory: Vol. 6. Fuzzy sets, fuzzy logic, and fuzzy systems: Selected papers*. World Scientific.

Knight, F. H. (1964). *Risk, Uncertainty and Profit*. Hougthon Mifflin Company.

Krohn, W., & Krücken, G. (1993). Risiko als Konstruktion und Wirklichkeit. Eine Einführung in die sozialwissenschaftliche Risikoforschung. In W. Krohn & G. Krücken (Eds.), *Riskante Technologien: Reflexion und Regulation. Einführung in die sozialwissenschaftliche Risikoforschung* (pp. 9–44). Suhrkamp.

Kuechle, G., Boulu-Reshef, B., & Carr, S. D. (2016). Prediction- and control-based strategies in entrepreneurship: the role of information. *Strategic Entrepreneurship Journal*, *10*(1), 43–64. https://doi.org/10.1002/sej.1211

Laux, H., Gillenkirch, R. M., & Schenk-Mathes, H. Y. (2014). *Entscheidungstheorie* (9th ed.). Springer.

Lorenz, K. A. (1975). *Die Rückseite des Spiegels. Versuch einer Naturgeschichte menschlichen Erkennens*. Piper.

Magruk, A. (2021). Analysis of uncertainties and levels of foreknowledge in relation to major features of emerging technologies: the context of foresight research for the fourth industrial revolution. *Sustainability*, *13*(17), 9890. https://doi.org/10.3390/su13179890

March, J. G. (1994). *Primer on Decision-making: How Decisions Happen*. Free Press.

March, J. G., & Shapira, Z. (1987). Managerial perspectives on risk and risk taking. *Management Science*, *33*(11), 1404–1418. https://www.jstor.org/stable/2631920

Mathiaszyk, L. P. (2017). *Corporate effectuation: Effectual strategy for corporate management* [, University of Wuppertal – Bergische Universität Wuppertal]. BibTeX.

McMullen, J. S., & Kier, A. S. (2016). Trapped by the entrepreneurial mindset: opportunity seeking and escalation of commitment in the mount everest disaster. *Journal of Business Venturing*, *31*(6), 663–686. https://doi.org/10.1016/j.jbusvent.2016.09.003

Miller, J. I. (2012). The mortality problem of learning and mimetic practice in emerging industries: dying to be legitimate. *Strategic Entrepreneurship Journal*, *6*(1), 59–88. https://doi.org/10.1002/sej.1128

Milliken, F. J. (1987). Three types of perceived uncertainty about the environment: state, effect, and response uncertainty. *The Academy of Management Review*, *12*(1), 133–143. https://doi.org/10.2307/257999

Mitchell, R. K., Busenitz, L., Lant, T., McDougall, P. P., Morse, E. A., & Smith, J. B. (2002). Toward a theory of entrepreneurial cognition: rethinking the people side of entrepreneurship research. *Entrepreneurship Theory and Practice*, *27*(2), 93–104. https://doi.org/10.1111/1540-8520.00001

Nonaka, I., & Takeuchi, H. (1995). *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*. Oxford University Press. https://doi.org/10.1093/oso/9780195092691.001.0001

Nonaka, I., & Toyama, R. (2007). Strategic management as distributed practical wisdom (Phronesis). *Industrial and Corporate Change*, *16*, 371–394. https://doi.org/10.1093/icc/dtm014

Oehmen, J., & Kwakkel, J. (2020). Risk, uncertainty, and ignorance in engineering systems design. In A. Maier, J. Oehmen, & P. E. Vermaas (Eds.), *Handbook of engineering systems design* (pp. 1–32). Springer International Publishing. https://doi.org/10.1007/978-3-030-46054-9_10-2

Ogden, C. (n.d.). *Killed by Google*. Retrieved January 3, 2024, from https://killedbygoogle.com/

Otto, F. E. (2023). Attribution of extreme events to climate change. *Annual Review of Environment and Resources*, *48*(1), 813–828. https://doi.org/10.1146/annurev-environ-112621-083538

Packard, M. D., Bylund, P. L., & Clark, B. B. (2021). Keynes and Knight on uncertainty: peas in a pod or chalk and cheese? *Cambridge Journal of Economics*, *45*(5), 1099–1125. https://doi.org/10.1093/cje/beab025

Packard, M. D., & Clark, B. B. (2020). On the mitigability of uncertainty and the choice between predictive and nonpredictive strategy. *Academy of Management Review*, *45*(4), 766–786. https://doi.org/10.5465/amr.2018.0198

Packard, M. D., Clark, B. B., & Klein, P. G. (2017). Uncertainty types and transitions in the entrepreneurial process. *Organization Science*, *28*(5), 840–856. https://doi.org/10.1287/orsc.2017.1143

Polanyi, M. (1966). *The tacit dimension*. Doubleday & Company.

Ramoglou, S. (2021). Knowable opportunities in an unknowable future? On the epistemological paradoxes of entrepreneurship theory. *Journal of Business Venturing*, *36*(2), 106090. https://doi.org/10.1016/j.jbusvent.2020.106090

Read, S., Sarasvathy, S. D., Dew, N., & Wiltbank, R. (2016). Response to Arend, Sarooghi, and Burkemper (2015): Cocreating effectual entrepreneurship research. *The Academy of Management Review*, *41*(3), 528–536. https://doi.org/10.5465/amr.2015.0180

Rinard, S. (2014). The principle of indifference and imprecise probability. *Thought: A Journal of Philosophy*, *3*(2), 110–114. https://doi.org/10.1002/tht3.118

Rindova, V., & Courtney, H. (2020). To shape or adapt: Knowledge problems, epistemologies, and strategic postures under Knightian uncertainty. *Academy of Management Review*, *45*(4), 787–807. https://doi.org/10.5465/amr.2018.0291

Rindova, V., Ferrier, W. J., & Wiltbank, R. (2010). Value from Gestalt: How sequences of competitive actions create advantage for Firms in nascent markets. *Strategic Management Journal*, *31*(13), 1474–1497. https://doi.org/10.1002/smj.892

Sanchez, R. (2005). 'Tacit knowledge' versus 'explicit knowledge' Approaches to knowledge management practice. In D. Rooney, G. Hearn, & A. Ninan (Eds.), *on the Knowledge Economy* (pp. 191–203). Edward Elgar. https://doi.org/10.4337/9781845426842.00025

Sarasvathy, S. D. (2001). Causation and effectuation: Toward a theoretical shift from economic inevitability to entrepreneurial contingency. *The Academy of Management Review*, *26*(2), 243–263. https://doi.org/10.2307/259121

Sarasvathy, S. D. (2008). *Effectuation: Elements of entrepreneurial expertise*. Edward Elgar. https://doi.org/10.4337/9781848440197

Sarasvathy, S. D., & Kotha, S. (2001). Managing Knightian uncertainty in the new economy: the RealNetworks case. In J. Butler (Ed.), *E-Commerce and Entrepreneurship (Hc) (Research in Entrepreneurship and Management)* (pp. 31–62). Information Age Publishing.

Sauerland, U. (2012). Vagueness in language: The case against fuzzy logic revisited. In P. Cintula, C. G. Fermueller, & L. Godo (Eds.), *Studies in logic: Vol. 36. Understanding vagueness: Logical, philosophical, and linguistic perspectives* (pp. 185–198). College Publ.

Savage, L. J. (1972). *The Foundations of Statistics* (2nd ed.). Dover Publications.

Schneider, D. (1997). *Theorie der Unternehmung*. de Gruyter.

Seghers, A., Manigart, S., & Vanacker, T. (2012). The impact of human and social capital on entrepreneurs' knowledge of finance alternatives. *Journal of Small Business Management*, *50*(1), 63–86. https://doi.org/10.1111/j.1540-627X.2011.00344.x

Shackle, G. L. S. (2010). *Uncertainty in Economics and Other Reflections*. Cambridge Univ. Press.

Sharot, T., & Sunstein, C. R. (2020). How people decide what they want to know. *Nature Human Behaviour*, *4*(1), 14–19. https://doi.org/10.1038/s41562-019-0793-1

Shepherd, D. A., & Patzelt, H. (2018). *Entrepreneurial cognition: Exploring the mindset of entrepreneurs*. Palgrave Macmillan. https://doi.org/10.1177/0149206314541153

Shepherd, D. A., Williams, T. A., & Patzelt, H. (2015). Thinking about entrepreneurial decision-making: Review and research agenda. *Journal of Management*, *41*(1), 11–46. https://doi.org/10.1177/0149206314541153

Shubik, M. (1954). Information, risk, ignorance, and indeterminacy. *The Quarterly Journal of Economics*, *68*(4), 629. https://doi.org/10.2307/1881881

Sniazhko, S. (2019). Uncertainty in decision-making: a review of the international business literature. *Cogent Business & Management*, *6*(1), Article 1650692. https://doi.org/10.1080/23311975.2019.1650692

Sorenson, O., & Stuart, T. E. (2008). Entrepreneurship: a field of dreams? *Academy of Management Annals*, *2*(1), 517–543. https://doi.org/10.5465/19416520802211669

Spender, J.-C. (1989). *Industry recipes: An enquiry into the nature and sources of managerial judgement*. Teilw. Zugl.: Manchester, Univ., Diss., 1980. Blackwell.

Spinoza, B. de. (2003). *The Ethics: Ethica Ordine Geometrico Demonstrata*. Retrieved December 21, 2023, from https://www.gutenberg.org/files/3800/3800-h/3800-h.htm

Stirling, A. (2010). Keep it complex. *Nature*, *468*(7327), 1029–1031. https://doi.org/10.1038/4681029a

Sutcliffe, K. M., & Zaheer, A. (1998). Uncertainty in the transaction environment: an empirical test. *Strategic Management Journal*, *19*(1), 1–23. Retrieved November 8, 2023, from https://www.jstor.org/stable/30941771

Teece, D. J. (2007). Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, *28*(13), 1319–1350. https://doi.org/10.1002/smj.640

Teece, D. J. (2012). Dynamic capabilities: routines versus entrepreneurial action. *Journal of Management Studies*, *49*(8), 1395–1401. https://doi.org/10.1111/j.1467-6486.2012.01080.x

Thompson, J. D. (2017). *Organizations in action*. Routledge. https://doi.org/10.4324/9781315125930

Townsend, D. M., Hunt, R. A., McMullen, J. S., & Sarasvathy, S. D. (2018). Uncertainty, knowledge problems, and entrepreneurial action. *Academy of Management Annals*, *12*(2), 659–687. https://doi.org/10.5465/annals.2016.0109

Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, *211*(30), 453–458. https://doi.org/10.1126/science.7455683

Tversky, A., & Kahneman, D. (1992). Advances in prospect theory: cumulative representation of uncertainty. *Journal of Risk and Uncertainty*, *5*(4), 297–323. https://doi.org/10.1007/BF00122574

✉ Correspondence

Sebastian L. Grüner

RheinMain University of Applied Sciences
Kurt-Schumacher-Ring 18, 65197 Wiesbaden, Germany

E-mail: sebastian.gruener@hs-rm.de

U.S. Bureau of Labor Statistics. (2023). *Survival of private sector establishments by opening year*. Retrieved January 12, 2024, from https://www.bls.gov/bdm/us_age_naics_00_table7.txt

Weick, K. E. (1995). *Sensemaking in organizations*. SAGE.

Wiklund, J., & Shepherd, D. (2003). Knowledge-based resources, entrepreneurial orientation, and the performance of small and medium-sized businesses. *Strategic Management Journal*, *24*(13), 1307–1314. https://doi.org/10.1002/smj.360

York, J. G., & Venkataraman, S. (2010). The entrepreneur-environment nexus: uncertainty, innovation, and allocation. *Journal of Business Venturing*, *25*(5), 449–463. https://doi.org/10.1016/j.jbusvent.2009.07.007

STRATEGIC MANAGEMENT, Vol. 29 (2024), No. 3, pp. 028-042

DOI: 10.5937/StraMan2200029P

Received: August 08, 2022
Revised: October 04, 2022
Accepted: October 07, 2022
Published online: November 22, 2022

Determining the investors' strategy during the COVID-19 crisis based on the S&P 500 stock index[1]

Juraj Pekár

University of Economics in Bratislava, Bratislava, Slovakia
https://orcid.org/0000-0002-3614-2962

Ivan Brezina

University of Economics in Bratislava, Bratislava, Slovakia
https://orcid.org/0000-0002-6227-3616

Marian Reiff

University of Economics in Bratislava, Bratislava, Slovakia
https://orcid.org/0000-0002-4064-704X

Abstract

Background: The most significant changes caused by the COVID-19 crisis were the sharp increase in working from home and the growing importance of e-commerce, which affected the development of some industries. This change also affects the investors' investment operations, which are based on analysis to ensure an unquestionable certainty of the invested financial amount and a satisfactory return. It is, therefore, interesting to analyze the possible return of the chosen investment strategy based on the optimization model of portfolio selection based on the CVaR risk measure.

Purpose: The paper aims to present the possible use of the analysis of returns of effective portfolios constructed based on the optimization model of portfolio selection based on the CVaR risk measure during the crisis (COVID-19) and the pre-crisis period.

Study design/methodology/approach: Paper presents the impact of the COVID-19 crisis on investor decision-making through the CVaR risk measure, which was implemented on the historical data of the components of the Standard and Poor's 500 stock index (S&P 500) in the crisis period as well as in the pre-crisis period.

Findings/conclusions: The presented approach based on the CVaR risk rate measure and the relevant portfolio selection model provides the investor with an effective tool for allocating funds to the financial market in particular segments in both monitored periods.

Limitations/future research: Time series data are divided into two periods based on visible factors such as the number of COVID-19 cases. In future research, we aim to divide monitored periods based on unobservable factors influencing investors' decisions, such as bull or bear mood on the market.

Keywords

optimization model, return, portfolio selection CVaR, COVID-19 crisis, S&P 500

Introduction

The global economy had already been affected by the climate crisis before the crisis caused by the COVID-19 virus. The COVID-19 virus caused a global crisis (Sukharev, 2020), (Figus, 2021), which directly affected the economies of individual countries and the stock markets (precious metals, commodities, and cryptocurrencies also experienced a significant drop), and the resulting losses were very significant for all investors sometimes with catastrophic consequences. The

[1] Extended version of the paper presented at Strategic Management and Decision Support Systems in Strategic Management SM 2022 scientific conference

closure of individual economies had an impact on entire industrial sectors and thus also on the financial sector. There are signs that a return to the normal functioning of financial markets is out of the question in the foreseeable future. It is possible that the world has entered an age of accelerating significant crises.

After the global crisis caused by the COVID-19 virus subsided, the invasion of Ukraine changed global geopolitics, which also caused a dramatic increase in energy and food prices, significantly impacting the global economy. This price increase had a significant knock-on effect across national and transnationally sectors.

In general, it can be assumed that even though particular crises may end at some point in time, it is likely that other crises will emerge, whether in the form of disease, conflict, or natural disasters. All these facts cannot be assumed, and if so, then only with a certain probability.

Therefore, in times of accelerating crises, any company's decision-making and management are complex and based on uncertain information and knowledge, accumulated experience, and, to a large extent, intuition. Therefore, it is necessary to transform existing decision-making models and proven management practices into models and practices that can at least partially capture new realities, contributing to managing current and future crises and perhaps even mitigating their impacts (Zinecker, Doubravský, Balcerzak, Pietrzak, & Dohnal, 2021). Above all, decision-making models that can respond to current crises must be applied. The aspect of volatility and uncertainty must be incorporated into these models.

It is evident that every crisis is not only temporary, but in the end, it is always an excellent investment opportunity. Therefore, every investor should decide which assets to invest in the next one. An investor cannot predict the future, but they should know how it might develop. The development in 2020 turned out to be unpredictable and proved the truth of the claims that it is impossible to forecast the development of markets with greater accuracy.

The effects of the COVID-19 crisis caused a significant drop in the value of investments, which can be observed in the stock markets by a temporary drop in share prices. A good prerequisite for successfully overcoming the crisis is the effective distribution of the investor's assets and the creation of a portfolio that reduces the risk of losses in unexpected and unpredictable situations. One of the approaches to creating an efficient stock portfolio is using an optimization model based on the Conditional Value at Risk (CVaR) risk measure. At the same time, decision-making assumptions can include a current phenomenon, the assumption of a crisis's emergence, e.g., the crisis caused by the COVID-19 virus.

The contribution aims to present the possible use of the analysis of returns of efficient portfolios constructed based on the optimization model of portfolio selection based on the CVaR risk measure. The analysis was carried out on the historical data of the Standard and Poor's 500 stock index (S&P 500) components during the crisis and pre-crisis period. The S&P 500 stock index, one of the world's best-known stock indexes, is composed of the stocks of the 500 most prominent and most widely traded US companies in the United States. Analyses of the impact of the COVID-19 pandemic on the investment strategy were carried out based on historical prices (weekly data) of selected shares included in the S&P 500 stock index (491 shares). Because the authors wanted to analyse investment strategies based on a portfolio selection model using data before the COVID-19 crisis and data affected by the COVID-19 crisis, two cases were analysed:

1. Input data for Period 1 from 1. Jan 2018 to 31. Dec 2019 - before COVID-19.
2. Input data for Period 2 from 1. Jan 2020 to 31. Dec 2021 – occurrence of COVID-19.

1. Investing under uncertainty

Decision-making is an integral part of every investor's work. Investors use accumulated experience, necessary information, knowledge about the given problem, and intuition. When dealing with various investment situations, it is assumed that the investor knows the possible variants of the decision and their consequences. Variants of the decision and their consequences depend on the state of the investment environment. In contrast, in conditions of risk, which is part of every investment, the investor knows the probability of occurrence of individual states of the investment environment. In conditions of uncertainty, the investor only knows the types of states of the investment environment without knowing the probability of their occurrence (Kaplan & Barish, 1967). An economic crisis can be predicted with some probability, but the occurrence of other types of crises (e.g., a crisis caused by COVID-19) is highly uncertain.

In general, every crisis impacts the global and national economies and causes upheavals in the financial market. For example, in the 2008 crisis, oil lost more than 70% of its value (oil price fell from more than $147 per barrel to around $36 per barrel). The crisis also caused shocks in the financial market, which is confirmed by the fact that in the same period, the stock market was 20% below its historical highs already for 12 months before the collapse. The current crisis started a few days after the historically highest levels of stock markets.

During the crisis caused by the COVID-19 virus, the price of oil fell twice as fast as it did during the crisis in 2008. The COVID-19 virus caused a global crisis that affected individual countries' economies and the stock markets (Kotlebova, Arendas, & Chovancova, 2020). This crisis caused a significant drop in the value of investments in the stock markets. It was possible to observe a temporary drop in share prices (Pekár, Berezina, & Reiff, 2022).

Economic theory expects repeated economic crises that lead to depression and, consequently, recession. In the 20th century, approximately twenty economic crises and many other crises associated with geopolitical events such as wars, and terrorist attacks, were identified. The economic crisis itself is part of a natural economic cycle. It can be characterized by a sharp and immediate deterioration of most economic indicators (e.g., short-term interest rate, individual companies' insolvency, financial institutions' collapse, and asset prices). In the past, economic crises were mostly a rare phenomenon. Nowadays, the frequency of their outbreaks is higher. A study by Davis (2014) analyzed 28 worst political or economic crises in the last hundred years, which result primarily from the increasing liberalization of globally connected financial markets, resulting in crisis transmission from one country to another. (Kirman, 2010).

It can be assumed with certainty that the COVID-19 crisis is not the last global crisis that will affect the global economy and, therefore, the world financial and stock markets. According to Deutsche Bank, at least four possible crisis scenarios will probably threaten the world economy in the next decade. It can be a major flu pandemic, a global war, the global consequences of a volcano eruption, or a solar flare (Reid, Templeman, & Allen, 2020). Deutsche Bank considers a power outage caused by a solar flare or a world military conflict the most likely scenario. Of course, this would affect not only traditional financial and stock markets. The aforementioned Deutsche Bank analysis does not claim that any of the mentioned scenarios will actually occur. It is based only on available statistical data and the impact of the crisis on the capital markets.

The crisis caused by the COVID-19 pandemic significantly accelerated global changes and trends, essentially forcing consumers to change their behavior (Youssef, Redzepagic, & Zeqiri, 2022), which also led to a change in companies' production processes. There was a sharp change in dependence on new technologies, e-commerce, social networks, etc. It is possible to assume that after the end of the COVID-19 crisis, investment funds will continue to be directed to sectors preferred during the crisis, such as technology and related digitization, healthcare, environmental protection, and mitigating the effects of climate change (Małkowska, Urbaniec, & Kosała, 2021).

In addition to global changes, the crisis caused by COVID-19 also changed the mindset of many people who, after many years of economic growth, did not think about securing their own financial reserves. In the past period, many realized that they could lose not only their income but also their savings could depreciate, and therefore began to lose the possibility of investing their financial resources.

The most significant changes caused by the COVID-19 crisis were the sharp increase in working from home and the growing importance of e-commerce, which affected the development of some industries:

1. Information technology - the importance of software and hardware companies grew.
3. Communication services - telecommunications companies can be described as relatively stable businesses, but in times of recession, they usually appear to be a good investment choice.
4. Entertainment industry - some entertainment companies have grown because staying at home has made people play more video games or subscribe to streaming services (like Netflix or Disney+).
5. Food industry - due to the unpredictability of further developments, food industry companies, especially food delivery companies, have also grown.

An appropriately chosen investment strategy is an essential factor in every investment in the

financial markets. In contrast, investments should be diversified into assets such as shares, bonds, funds, or gold. In addition to financial knowledge, skills, and the ability to make the most of available funds, an investor's effective decision-making on the stock market also requires an overview and understanding of mutual relationships (Chandra, 2008). The investor's decision-making about financial investments is determined by the optimal use of the invested resources. The goal is to create an "optimal" portfolio with the highest possible returns. The profitability of the created portfolio can be calculated as a weighted average of the returns of the individual financial assets that make up the portfolio. At the same time, the weights are formed by the shares of individual types of financial assets (Pekár et al., 2022).

It is evident that historically all crises affected the stock markets, and losses during the crisis amounted to several tens of percent. However, any dip in the stock markets was only temporary, and in the long run, the crisis factor was negligible because historically, markets always rise. That is why investing during a crisis is also very important, even if it has its peculiarities. Investing during a crisis is primarily affected by uncertainty, is riskier, and the timeline and extent of economic recovery are highly uncertain. Because nothing is certain during a crisis (companies may cease operations, and the value of their shares may fall), it is essential to diversify the portfolio (Paunov, 2012).

Different financial portfolios can be created by combining different financial assets. Financial assets generally represent cash accounts in a bank or the value of accounts of securities, bonds, and other intangible assets of an individual or institution. Every investor can invest in any financial asset, but they should respect the fundamental intertwined factors: the yield, risk, and liquidity of the given asset. The decision on the method of distribution of financial assets fundamentally impacts the overall performance of the created portfolio.

When deciding on the created portfolio, the investor must emphasize a certain level of risk because, from the point of view of the future, the cash flows of individual assets are uncertain. The investor is only interested in the expected returns and risk, with the help of which the investor can express the perceived attractiveness of the created portfolio. In general, the investor tries to build a type of portfolio of securities that bring high profit while simultaneously differing to minimize possible loss from risk. The problem is that these two goals are often at odds, so investors must consider the trade-off they are willing to accept.

2. Risk measures

In order to achieve the highest return, the investor must accept a certain level of risk. Risk represents the possibility that the actual return differs from the expected return. Thus, risk essentially represents the uncertainty of future income. Certain risks, but not all, can be reduced by diversifying investment funds. An investor can decide to place his investment funds instead of in one security in many securities and thus create a diversified portfolio. Thus, the basis of diversification is the allocation of investments in different variations of assets in order to minimize the risk associated with the expected returns of individual securities.

The cornerstone of portfolio management (modern portfolio theory) is the portfolio theory created by Markowitz (1952). Markowitz was the first to contribute to the theory of financial markets with the theory of decision-making on portfolio selection under conditions of uncertainty. This theory showed how the multidimensional problem of investing in a large number of assets, each with different characteristics, can be solved under conditions of uncertainty. He reduced this problem to a relationship between only two elements: the expected return and the variance of portfolio returns. An investor should diversify his portfolio and, at the same time, maximize the expected return. Markowitz pointed to a solution to the problem of practical calculation of an optimal portfolio using a quadratic programming problem. In his theory, he was criticized for using the concept of risk using the variance of investments and the covariance between investments, given that the variance measures the dispersion of an asset's returns around the expected return and considers returns below and above the expected return to be equal (Markowitz, 1952).

In a later study Markowitz (1959) recognized these limitations and proposed a new measure of lower partial risk that measures risk below expected return. He called it semi-dispersion (semi-variance). In the subsequent periods, investors' interest revolved around measures of lower partial risk, among which we include the already mentioned lower semi-variance (lower semi-standard deviation), lower semi-absolute deviation, and Value at Risk (VaR) and Conditional value at risk (CVaR). The advantage of lower partial risk measures is that they are

appropriate when the distribution of returns is asymmetric (Krokhmal, Palmquist, & Uryasev, 2002). Currently, many authors are engaged in the search for suitable measures of risk (Roman & Mitra, 2009), (Liu & Chen, 2018).

Drawdown risk rate

Investors tend to compare the risk's current value with the past's best value. In (Cheklov, Uryasev, & Zabarankin, 2003), the drawdown function is defined as the difference between the maximum return of the portfolio until time T and the value of the portfolio at time T. Examples of drawdown risk measures are Absolute Drawdown (AD), Maximum Drawdown (MDD), Average Drawdown (AVDD), Drawdown at Risk (DAR) and Conditional Drawdown at Risk (CDaR). Despite their computational simplicity, drawdown measures do not describe the actual market situation and should be used in combination with other measures.

Quantile risk measure

Quantile risk measures include Value at Risk (VaR) or Conditional Value at Risk (CVaR). The risk rate VaR determines what the minimum level of loss with a given probability, confidence level is. On the other hand, the CVaR risk rate expresses the average value of the loss below a specified level of confidence. These measures will be analyzed in more detail below.

The first regulatory VaR measurements were initiated in 1980 when the Securities and Exchange Commission tied firms' capital requirements to losses that would occur with 95 percent certainty over a 30-day interval in various security classes. Historical returns were used to calculate these potential losses in order to create sufficient capital to cover the potential losses. Garbade and Kenneth (1986) introduced the VaR risk measure based on covariances in bond yields of different maturities.

The breakthrough associated with the expansion and subsequent development of VaR is attributed to J.P. Morgan, which developed the market standard for measuring risk using VaR, the so-called Risk Metrics system. Currently, VaR is used not only by large but also by smaller financial companies and investors.

VaR is actually a risk assessment method that uses classical statistical methods. It can be included among the measures of lower partial risk. VaR essentially measures the largest expected loss in a certain period at a given confidence interval (Yamai & Yoshiba, 2005). It is therefore defined as a one-sided confidence interval of possible value losses that arose as a result of changes in the prices of commodities, securities, interest rates, and exchange rates. At the same time, every investor asks himself how much value he can lose with a certain probability in a certain period. VaR is an accepted tool for answering this question (Wang, Huang, Wu, & Zhang, 2019).

VaR has become a standard tool for risk management in the financial sphere, mainly due to its conceptual and computational simplicity. Conceptual problems of VaR are also presented in the literature (Artzner, Delbaen, Eber, & Heath, 1999), (Basak & Shapiro, 2001), (Guo, Chan, Wong, & Zhu, 2019) and (Arreola Hernandez & Al Janabi, 2020). For example, in (Artzner et al., 1999), the following shortcomings are mentioned:

2. VaR measures only the percentile of profits and losses, so it does not take into account losses above the VaR level ("tail risk")
3. VaR is not a coherent measure of risk because it is not subadditive.

It is precisely to mitigate the problems that VaR brings that the alternative risk measure CVaR was proposed. CVaR is already a coherent measure of risk. Another advantage in solving portfolio selection tasks is the possible transformation into a mathematical programming task. CVaR is defined as the expected loss exceeding the VaR value. Based on this definition, CVaR only considers loss values that are higher than the VaR value. The CVaR value is defined:

$$CVaR_{\alpha}(X) = E\left(L(X) \middle| L(X) \geq VaR_{\alpha}\right) \qquad (1)$$

alternatively

$$CVaR_{\alpha}(X) = E\left(-X \middle| -X \geq VaR_{\alpha}\right) \qquad (2)$$

where X denotes the random variable representing the return, $L(X) = -X$ denotes the loss function of the random variable X and VaR_{α} is the value at risk at the significance level α.

In the case of defining the CVaR value using the return function represented by the random variable X, we can express the CVaR based on equation (2):

$$CVaR_{\alpha}(X) = -E\left(X \middle| X \leq -VaR_{\alpha}\right) \qquad (3)$$

Let $f(x), x \in X$ be the probability density function of a continuous random variable X. Then CVaR can be expressed:

$$CVaR_\alpha(X) = -\frac{1}{\alpha}\int_{-\infty}^{-VaR_\alpha} xf(x)dx \tag{4}$$

Assuming the existence of a discrete random variable X, represented by the vector $r = (r_1, r_2, ... r_T)$, where T is the number of components, the above risk measure can be defined:

$$\begin{aligned} CVaR_\alpha(X) &= VaR_\alpha - \frac{1}{\alpha}E\left[\left|\mathbf{r} + VaR_\alpha\right|_-\right] \\ CVaR_\alpha(X) &= VaR_\alpha + \frac{1}{\alpha}\sum_{t=1}^{T} p_t \max(-(r_t + VaR_\alpha), 0) \end{aligned} \tag{5}$$

VaR and CVaR values can also be interpreted graphically. Figure 1 shows at the significance level α and assuming a normal distribution.

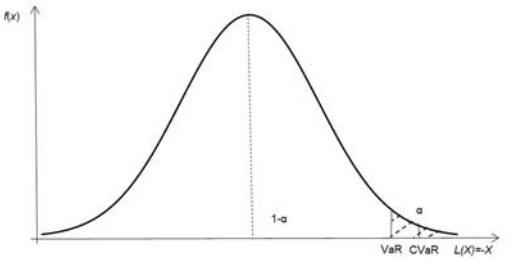

Figure 1 VaR and CVaR in case of normal distribution
Source: the authors' own calculation

In the general distribution of returns, CVaR has more suitable properties than VaR. Numerical experiments indicate that CVaR minimization usually also leads to near-optimal solutions in terms of VaR since VaR never exceeds CVaR. Therefore, portfolios with a low CVaR value must also have a low VaR value. Moreover, when the distribution of losses and returns is normal, these two measures of risk are equivalent (Rockafellar & Uryasev, 2002), i.e., and provide the same optimal portfolio. However, for other types of distributions, the optimal CVaR and VaR risk portfolios may be completely different. In addition, VaR minimization can extend the tail in excess of VaR because VaR does not control for losses in excess of VaR. (Gaivoronski & Pflug, 2005) confirmed that in some cases, VaR and CVaR optimization could lead to quite different portfolios.

Rockafellar and Uryasev (2002) demonstrated that linear programming tools could be used to optimize the Conditional Value-at-Risk (CVaR). A simple description of the CVaR minimization approach and CVaR constrained optimization problems can be found in (Uryasev, 2000). Several case studies have shown that risk optimization using the CVaR risk measure can be implemented for large portfolios and a large number of scenarios with relatively small computational resources (Uryasev, 2000), (Rockafellar & Uryasev, 2002), (Pekár, Brezina, & Brezina, 2018)and (Sun, Aw, Li, Teo, & Sun, 2020).

3. CVaR-based portfolio selection model

Consider the construction of a portfolio that consists of n assets with yield vectors $\mathbf{r}_1$, $\mathbf{r}_2$, ..., $\mathbf{r}_n$, representing discrete random variables. When searching for an optimal portfolio, we chose CVaR as the risk measure. In this part, a model is constructed that deals with the optimization of the composition of the portfolio, i.e., how to diversify the assets in the portfolio so that the risk is minimal for a given return.

Let $E(\mathbf{r}_j)$ represent the expected return on the j-th asset. It will be also used the term E_j as the expected return on the portfolio and r_{jt} is the t-th component (t = 1, 2, ..., T) of the discrete random variable X_j represented by the returns vector $\mathbf{r}_j$ for j = 1,2, ..., n. Let us assume that an investor invests in individual assets with a particular share represented by weights $\mathbf{w} = (w_1, w_2, ...w_n)^T$. Then the expected portfolio return is determined as $\sum_{j=1}^{n} w_j E(\mathbf{r}_j)$. Assume that the expected value of the random variable X_j can be expressed as the geometric mean calculated from these data. The CVaR function for a discrete random variable at the significance level α has the form:

$$\begin{aligned} CVaR_\alpha(\mathbf{w}) &= VaR_\alpha - \frac{1}{\alpha}E\left[\left(\mathbf{r}^T\mathbf{w} + VaR_\alpha\right)_-\right] \\ CVaR_\alpha(\mathbf{w}) &= VaR_\alpha + \frac{1}{\alpha}\sum_{t=1}^{T} p_t \max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt}w_j, 0) \end{aligned} \tag{6}$$

where $\left(\mathbf{r}^T\mathbf{w} + VaR_\alpha\right)_-$ the expression is the negative part of the sum $\mathbf{r}^T\mathbf{w} + VaR_\alpha$, and thus the given relationship can be written as follows:

$$\left(\sum_{j=1}^{n} r_{jt}w_j + VaR_\alpha\right)_- = -\max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt}w_j, 0) \tag{7}$$

Since we are using the VaR value in the definition of CVaR, which is unknown, it must be a variable in the model, and we must include it in the objective function. An objective function can then be written for the portfolio selection problem based on the CVaR risk measure:

$$\min\left\{VaR_\alpha - \frac{1}{\alpha}E\left[\left(\mathbf{r}^T\mathbf{w} + VaR_\alpha\right)_-\right]\right\} \tag{8}$$

alternatively

$$\min\left\{VaR_\alpha + \frac{1}{\alpha}\sum_{t=1}^{T} p_t \max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt} w_j, 0)\right\} \quad (9)$$

The optimization aims to minimize the risk in the area of CVaR and the portfolio's expected return. Therefore, the minimization task for CVaR has the form:

$$\begin{aligned} &\min\left\{VaR_\alpha + \frac{1}{\alpha}\sum_{t=1}^{T} p_t \max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt} w_j, 0)\right\} \\ &\sum_{j=1}^{n} E_j w_j \geq E_P \\ &\sum_{j=1}^{n} w_j = 1 \\ &w_1, w_2, \ldots w_n \geq 0 \end{aligned} \quad (10)$$

where E_P is the required minimum portfolio return.

The first structural constraint ensures the admissible portfolio achieves a minimum return at the E_P level. The second structural limitation corresponds to the assumption of investing all available funds, i.e., the sum of the weights equals 1.

To transform the objective function into a linear form, a non-linear relation $\max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt} w_j, 0)$ must be replaced. For this transformation, the variables z_t can be used, where $z_t \geq 0$ (t = 1, 2, ..., T), and will take the value of the difference between VaR and the return of the portfolio in state t, if the return is lower than or equal to VaR, otherwise will be equal zero. Then the final linear programming problem with the new variable $z_j \geq \max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt} w_j, 0)$ can be expressed as:

$$\begin{aligned} &\min\left\{VaR_\alpha + \frac{1}{\alpha}\sum_{t=1}^{T} p_t z_t\right\} \\ &z_t + \sum_{j=1}^{n} r_{jt} w_j + VaR_\alpha \geq 0, t = 1, 2, \ldots T \\ &\sum_{j=1}^{n} E_j w_j \geq E_P \\ &\sum_{j=1}^{n} w_j = 1 \\ &w_1, w_2, \ldots w_n \geq 0, z_1, z_2, \ldots z_T \geq 0 \end{aligned} \quad (11)$$

When determining the effective portfolios in the following text, we used model (11). At the same time, in the fourth section of the paper, the investment weights in individual shares were calculated for different values of E_P (required minimum return). By solving this task, we will determine the optimal weights of assets in the portfolio at the specified minimum value of the expected return while minimizing the CVaR risk function. The interested reader can find more about CVaR in Hamdi, Karimi, Mehrdoust, & Belhaouari, (2022), Bodnar, Lindholm, Niklasson, & Thorsen, (2022), Arici, Campi, Care, Dalai, & Ramponi, (2021), Wang & Zhu, (2021) and Kang, Li, & Li, (2020).

4. Preference of financial assets for the creation of a portfolio and the analysis of COVID-19 impact on the investment strategy

Different financial portfolios can be created by combining different financial assets. Financial assets generally represent cash accounts in a bank or the value of accounts of securities, bonds, and other intangible assets of an individual or institution. Every investor can invest in any financial asset, but he should respect the fundamental intertwined factors: the yield, risk, and liquidity of the given asset. The decision on the method of distribution of financial assets fundamentally impacts the overall performance of the created portfolio.

The investor's decision-making about financial investments goes through the process of searching, finding, and realizing the optimal use of invested resources. At the same time, the investment operations should be based on analysis to ensure particular security of the invested financial amount and a corresponding satisfactory return. Its goal is, therefore, to create a suitable portfolio. The profitability of the created portfolio can be calculated as a weighted average of the returns of the individual financial assets that make up the portfolio. In contrast, the weights comprise the shares of individual types of financial assets.

Therefore, in order not have to follow many different types of stocks, the investor can focus on existing stock indexes. Stock indices generally represent an essential indicator of the development of the world economy, as they provide information on the development of a specific part of the stock market or the entire market. They are also used to measure the average profitability of a specific market (benchmark). A stock index is a dimensionless stock market indicator that concentrates the movement of individual stock prices into one aggregate number and therefore has an indicative value about the tendency of the entire

market. Most stock exchanges have their own index.

Standard and Poor's 500 stock index (S&P 500) components were analysed to compare the impact of the COVID-19 disease. The S&P 500 stock index, one of the world's best-known stock indexes, is composed of the stocks of the 500 most prominent and most widely traded US companies in the United States. Based on the historical prices of stocks included in the S&P 500 index, analyses of the impact of the COVID-19 pandemic on the investment strategy were conducted exactly on weekly data from 491 stocks with available data for the analysed periods. Because the authors aim to analyse investment strategies based on a portfolio selection model using pre- COVID-19 and during-COVID-19 data, two cases were analysed:

1. Input data for Period 1 from 1. Jan 2018 to 31. Dec 2019 - before COVID-19.
2. Input data for Period 2 from 1. Jan 2020 to 31. Dec 2021 – occurrence of COVID-19.

The time series data are divided into periods based on the COVID-19 pandemic information illustrated in Figure 2 with the number of daily new cases in US (Finch & Hernández Finch, 2020). In order to describe the analysed periods, Tables 1A and 1B summarize the calculated average weekly returns of the S&P 500 stocks that are preferred in the investment strategy in Period 1 (2018-2019) and the stocks that are preferred in the investment strategy in Period 2 (2020-2021). The stock symbols used in the tables are the following: AES Corporation (AES), Amcor plc (AMCR), Advanced Micro Devices (AMD), Broadcom Inc. (AVGO), Chipotle Mexican Grill, Inc. (CMG), Copart (CPRT), DexCom, Inc. (DXCM), Enphase Energy (ENPH), Essex Property Trust (ESS), Entergy Corporation (ETR), Garmin International Ltd. (GRMN), HCA Healthcare (HCA), Hartford Financial Services Group, Inc. (HIG), Hershey Company (HSY), Dr Pepper (KDP), Eli Lilly & Co (LLY), Lamb Weston Holdings, Inc. (LW), Mettler-Toledo International Inc. (MTD), Newmont (NEM), Nike, Inc. (NKE), O'Reilly Auto Parts (ORLY), Healthpeak Properties, Inc. (PEAK), PulteGroup, Inc. (PHM), Pinnacle West Capital (PNW), Pool Corporation (POOL), Public Storage (PSA), Qualcomm (QCOM), Qorvo (QRVO), Everest Re (RE), Ralph Lauren Corporation (RL), Tesla, Inc. (TSLA), Tyler Technologies, Inc. (TYL).

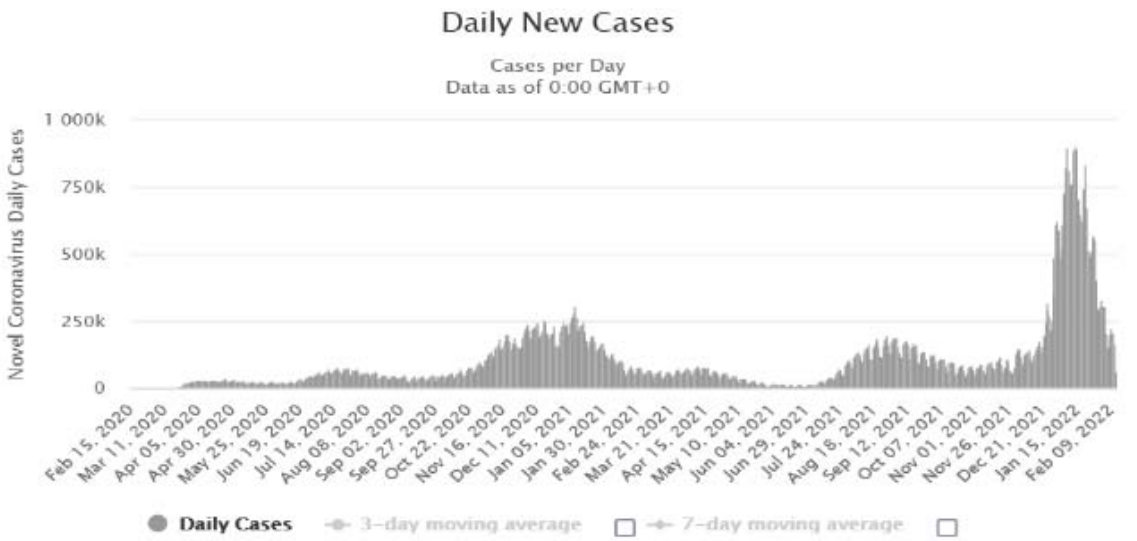

Figure 2 Number of new cases reported in the USA
Source: Worldometers, 2022

Table 1A Period 1 average weekly return and period 2 average weekly return of S&P 500 index stocks preferred in investment strategy during Period 1 Units of data are in %.

Mean	AES	AMCR	AMD	AVGO	CMG	CPRT	DXCM	ENPH	ESS	ETR	GRMN	HCA
Period 1	0.66	0.01	1.30	0.22	0.95	0.71	1.36	2.27	0.27	0.46	0.53	0.53
Period 2	0.23	0.22	1.06	0.80	0.68	0.46	0.82	1.77	0.22	0.01	0.37	0.55
Difference	-0.43	0.21	-0.24	0.58	-0.26	-0.25	-0.54	-0.49	-0.04	-0.46	-0.17	0.01

Mean	HIG	HSY	KDP	LLY	LW	MTD	NEM	NKE	ORLY	PEAK	PHM	PNW
Period 1	0.13	0.30	0.64	0.45	0.40	0.21	0.18	0.46	0.50	0.40	0.14	0.14
Period 2	0.19	0.31	0.29	0.75	-0.33	0.73	0.39	0.50	0.47	0.13	0.37	-0.14
Difference	0.05	0.01	-0.35	0.30	-0.73	0.52	0.21	0.04	-0.03	-0.27	0.23	-0.28

Mean	POOL	PSA	QCOM	QRVO	RE	RL	TSLA	TYL
Period 1	0.49	0.11	0.35	0.52	0.25	0.15	0.26	0.46
Period 2	0.95	0.60	0.74	0.33	0.05	0.01	2.37	0.53
Difference	0.46	0.49	0.39	-0.19	-0.20	-0.14	2.11	0.06

Source: the authors' own calculations

Table 1B Period 1 average weekly return and period 2 average weekly return of S&P 500 index stocks preferred in investment strategy during Period 2 Units of data are in %.

Mean	ABBV	CLX	CTRA	DLR	ETSY	FTNT	HRL	IDXX	KEYS	KR	MSCI
Period 1	-0.04	0.10	-0.47	0.11	0.76	0.86	0.24	0.43	0.82	0.10	0.66
Period 2	0.51	0.17	0.18	0.45	1.53	1.13	0.12	0.88	0.69	0.48	0.83
Difference	0.54	0.07	0.65	0.33	0.77	0.27	-0.12	0.44	-0.12	0.38	0.17

	NFLX	NVDA	ORCL	REGN	SEDG	TSLA	WST
Period 1	0.42	0.08	0.11	-0.03	0.88	0.26	0.40
Period 2	0.59	1.55	0.50	0.52	0.99	2.37	1.10
Difference	0,18	1.47	0.39	0.55	0.11	2.11	0.70

Source: the authors' own calculations

The highest value was achieved by the difference (2.11%) in the average earnings of Tesla, Inc. (TSLA) because the average return in Period 1 was 0.26%, and in Period 2, the return was 2.37%. The lowest value was achieved by difference (-0.73%) and was acquired by the company Lamb Weston Holdings, Inc. (LW), whose average return in Period 1 was 0.4%, but in Period 2 only -0.33%. From the above, it follows that the average weekly return of S&P 500 shares for period 1 and period 2, which are preferred in the investment strategy in period 2, COVID-19 had a substantial impact on the financial markets because the average return of most of the selected S&P 500 shares was significantly higher than in the first period.

As mentioned earlier, CVaR (also Average Excess Loss) is a risk indicator used to quantify the extent of potentially large losses. The metric is calculated as the average α% of the worst-case scenarios over a certain time horizon.

From Table 2a and 2b, it is clear that the highest risk (the lowest value) CVaR of the S&P 500 stocks that occur in the investment strategy in Period 1 (2018-2019) and the stocks that occur in the investment strategy in Period 2 (2020-2021), was calculated for Dr Pepper (KDP), which corresponds to a value of -63.76%. In the second period (Period 2), the lowest CVaR risk rate of the S&P 500 stocks that appear in the investment strategy in Period 1 (2018-2019) and the stocks that appear in the investment strategy in Period 2 (2020-2021) was calculated for the company PulteGroup, Inc. (PHM), which represents a value of -34.77%. Also, the most notable difference between the calculated values of CVaR in Period 1

and Period 2 was calculated for the company Dr Pepper (KDP). The value of 52.06% means that the investment risk has decreased for this company. Conversely, the highest negative value of -26.63% in the "difference" row in Table 2a for company PulteGroup, Inc. (PHM) means that in Period 2, compared to Period 1, the investment risk increased the most among all companies considered.

Table 2A Period 1 CVaR values and period 2 CVaR values of S&P 500 index stocks preferred in investment strategy during Period 1 Units of data are in %.

CVaR	AES	AMCR	AMD	AVGO	CMG	CPRT	DXCM	ENPH	ESS	ETR
Period 1	-6.43	-6.30	-15.71	-11.97	-5.42	-13.65	-8.51	-16.36	-4.99	-3.52
Period 2	-16.75	-24.76	-9.25	-18.36	-10.70	-4.91	-17.34	-21.82	-12.98	-12.32
Difference	-10.32	-18.47	6.46	-6.39	-5.29	8.74	-8.82	-5.46	-8.00	-8.80

CVaR	GRMN	HCA	HIG	HSY	KDP	LLY	LW	MTD	NEM	NKE	ORLY
Period 1	-3.29	-8.81	-5.71	-5.63	-63.76	-6.24	-6.81	-7.89	-8.10	-5.72	-3.54
Period 2	-8.31	-29.78	-22.50	-8.63	-11.70	-8.37	-19.55	-6.29	-8.31	-11.99	-13.12
Difference	-5.02	-20.97	-16.79	-3.00	52.06	-2.13	-12.74	1.60	-0.20	-6.26	-9.58

CVaR	PEAK	PHM	PNW	POOL	PSA	QCOM	QRVO	RE	RL	TSLA	TYL
Period 1	-5.46	-8.14	-4.59	-4.80	-4.93	-12.28	-5.31	-5.29	-7.67	-12.31	-5.66
Period 2	-21.24	-34.77	-15.97	-9.71	-10.64	-5.43	-10.58	-11.37	-15.92	-11.29	-9.21
Difference	-15.78	-26.63	-11.37	-4.91	-5.71	6.84	-5.27	-6.08	-8.25	1.02	-3.55

Source: the authors' own calculations

Table 2B Period 1 CVaR values and period 2 CVaR values of S&P 500 index stocks preferred in investment strategy during Period 2 Units of data are in %.

CVaR	ABBV	CLX	CTRA	DLR	ETSY	FTNT	HRL	IDXX	KEYS	KR	MSCI
Period 1	-8.17	-6.35	-9.81	-6.32	-12.33	-7.93	-5.13	-7.64	-6.87	-10.97	-7.26
Period 2	-9.25	-9.97	-11.48	-9.16	-16.14	-5.91	-4.88	-9.51	-7.01	-7.41	-8.59
Difference	-1.08	-3.62	-1.66	-2.84	-3.81	2.01	0.26	-1.87	-0.14	3.56	-1.33

CVaR	NFLX	NVDA	ORCL	REGN	SEDG	TSLA	WST
Period 1	-9.00	-13.56	-9.60	-10.49	-16.60	-12.31	-6.82
Period 2	-8.99	-11.74	-6.28	-8.04	-19.39	-11.29	-6.08
Difference	0.02	1.81	3.32	2.45	-2.78	1.02	0.74

Source: the authors' own calculations

4. Investment recommendation based on the portfolio selection model

We use a mathematical programming model (11) to construct a portfolio based on the historical data (historical weekly returns in Period 1 and Period 2) for 491 S&P 500 stocks. By solving the model, we obtain efficient portfolios at different values of the expected weekly returns listed in tables 3 and 4 in the column marked E_P (set required minimum expected return of the portfolio). The stated E_P values are obtained as the smallest and largest values of the portfolio's expected returns, while the other values are determined by dividing the interval into equal parts.

Table 3 for period 1 and table 4 for period 2 show the calculated solutions. The value of the objective function representing the minimum value of CVaR is given in the column labelled CVaR. In other columns, the shares invested in individual stocks are listed for different expected return values.

Table 3 Distribution of investment in effective S&P 500 portfolios for Period 1. Unlisted stocks have weights equal to 0, thus they are not invested in any analyzed period. Units of data are in %.

	CVaR	Ep	AES	AMCR	AMD	AVGO	CMG	CPRT	DXCM	ENPH	ESS	ETR	GRMN	HCA	HIG	HSY	KDP
EP1	1.54	0.28	0.0	2.5	0.0	4.7	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	8.6
EP2	1.76	0.57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	3.5	16.7	0.0	7.3	1.6	2.7	17.0
EP3	2.57	0.85	0.0	0.0	0.0	0.0	7.1	0.0	0.8	12.1	0.0	29.1	2.4	2.2	0.0	0.0	18.8
EP4	3.91	1.14	5.9	0.0	0.2	0.0	17.5	0.0	0.0	19.9	0.0	0.0	4.6	0.0	0.0	0.0	19.7
EP5	5.53	1.43	13.1	0.0	4.0	0.0	16.8	0.0	4.3	28.4	0.0	0.0	0.0	0.0	0.0	0.0	13.8
EP6	7.35	1.71	7.0	0.0	4.4	0.0	0.0	3.3	18.7	38.9	0.0	0.0	0.0	13.6	0.0	0.0	0.0
EP7	9.31	2.00	0.0	0.0	11.1	0.0	0.0	5.4	28.6	44.5	0.0	0.0	0.0	4.9	0.0	0.0	0.0
EP8	11.42	2.29	0.0	0.0	11.0	0.0	1.0	0.0	32.1	55.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EP9	14.45	2.57	0.0	0.0	11.3	0.0	0.0	0.0	10.9	77.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EP10	18.36	2.86	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	CVaR	Ep	LLY	LW	MTD	NEM	NKE	ORLY	PEAK	PHM	PNW	POOL	PSA	QCOM	QRVO	RE	RL	TSLA	TYL
EP1	1.54	0.28	0.0	0.0	1.2	7.0	3.6	0.0	0.0	5.1	22.9	0.0	23.9	0.0	0.0	13.0	6.3	0.0	0.8
EP2	1.76	0.57	0.0	0.0	0.0	11.1	1.5	3.0	0.0	14.4	2.4	2.0	0.5	0.0	0.0	10.4	0.0	0.0	0.0
EP3	2.57	0.85	1.6	0.0	0.0	0.0	3.7	0.0	8.0	5.8	0.0	0.0	0.0	8.5	0.0	0.0	0.0	0.0	0.0
EP4	3.91	1.14	0.0	5.2	0.0	0.0	21.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0	0.0	0.0	0.0
EP5	5.53	1.43	0.0	0.0	0.0	0.0	7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	0.0	0.0	3.8	0.0
EP6	7.35	1.71	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	0.0	0.0	6.6	0.0
EP7	9.31	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0
EP8	11.42	2.29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
EP9	14.45	2.57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EP10	18.36	2.86	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: the authors' own calculations

Table 4 Distribution of investment in effective S&P 500 portfolios for Period 2. Unlisted stocks have weights equal to 0, thus they are not invested in any analyzed period. Units of data are in %.

	CVaR	Ep	ABBV	CLX	CTRA	DLR	ETSY	FTNT	HRL	IDXX	KEYS	KR	MSCI	NFLX
EP1	2.53	0.42	6.7	37.6	5.8	0.6	0.0	0.0	16.7	1.2	5.6	0.0	10.1	0.0
EP2	3.43	0.71	0.0	23.4	0.0	0.0	0.0	0.0	0.0	0.0	6.0	10.7	1.9	19.5
EP3	4.92	0.99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.3	0.0	22.6
EP4	6.53	1.27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	21.7
EP5	8.28	1.55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
EP6	10.23	1.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EP7	12.22	2.12	0.0	0.0	0.0	0.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EP8	14.30	2.40	0.0	0.0	0.0	0.0	20.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0
EP9	16.51	2.68	0.0	0.0	0.0	0.0	25.4	2.9	0.0	0.0	0.0	0.0	0.0	0.0
EP10	19.50	2.96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	CVaR	Ep	NVDA	ORCL	REGN	SEDG	TSLA	WST
EP1	2.53	0.42	0.0	0.0	15.8	0.0	0.0	0.0
EP2	3.43	0.71	9.9	0.0	15.6	7.3	0.0	5.8
EP3	4.92	0.99	25.5	0.0	18.4	5.3	0.3	9.6
EP4	6.53	1.27	21.5	0.0	24.4	0.0	12.0	17.9
EP5	8.28	1.55	54.6	0.0	19.9	0.0	9.6	15.0
EP6	10.23	1.83	42.1	0.0	21.6	0.0	29.7	6.6
EP7	12.22	2.12	21.8	0.1	22.7	0.0	49.6	0.0
EP8	14.30	2.40	0.0	3.6	11.2	0.0	63.1	0.0
EP9	16.51	2.68	0.0	0.0	0.0	0.0	71.7	0.0
EP10	19.50	2.96	0.0	0.0	0.0	0.0	100.0	0.0

Source: the authors' own calculations

We can read from Table 3 that the recommendation based on the portfolio selection model using input data for Period 1 (years 2018-2019 before COVID-19) is to invest in the shares: AES, AMCR, AMD, AVGO, CMG, CPRT, DXCM, ENPH , ESS, ETR, GRMN, HCA, HIG, HSY, KDP, LLY, LW, MTD, NEM, NKE, ORLY, PEAK, PHM, PNW, POOL, PSA, QCOM, QRVO, RE, RL, TSLA, TYL.

When applying the model for input data for Period 2 (years 2020-2021, COVID-19 crisis), the investment portfolio consists of shares: ABBV, CLX, CTRA, DLR, ETSY, FTNT, HRL, IDXX, KEYS, KR, MSCI, NFLX, NVDA, ORCL, REGN, SEDG, TSLA, WST (Table 4). Comparing the values in Table 3 and Table 4, results obtained from the model approach (11), it is clear that in both periods, the recommended investments are the same only for the TSLA (Tesla, Inc.) stock, which appears in both investment portfolios.

Conclusion

Investors should have tools available to decide which assets it is possible and crucial to invest in, considering scenarios with the idea of the highest profit with minimal risk, based on the assumption that a global or regional crisis may arise in a specific time horizon for any reasons. Therefore, every investor should be interested in alternative or diverse investment models. Investment companies offer different investment forms, for example, a stock index or a portfolio of shares created by an investment company. The subject of the presented analysis was the proposal of a viable approach and tool for such a decision.

On the Standard and Poor's 500 stock index (S&P 500), the authors compare the impact of the COVID-19 crisis on return and risk indicators, which are fundamental investment indicators, using established methods of calculating returns and risk. A portfolio selection model was proposed to determine a suitable investment strategy, with criteria of return maximization and risk minimization through the CVaR risk measure.

Accomplished analyzes of the impact of the COVID-19 pandemic on the investment strategy was carried out on the historical data of the S&P 500 companies' stock prices. First, average weekly returns for all S&P 500 companies were calculated for Period 1 (pre- COVID-19) and Period 2 (during COVID-19). Tables 1a and 1b show the average weekly returns of selected S&P 500 companies' stocks. At the same time, the investment risk measure was calculated using the CVaR risk for all S&P 500 stocks. Tables 2a and 2b show the CVaR risk indicator for selected S&P 500 stocks, while this table also contains the calculated difference between the CVaR values in Period 1 and Period 2. The lowest value represents the highest risk increase, and the highest positive value represents the most significant reduction in investment risk of all considered index companies S&P 500.

In order to create a portfolio based on information from the historical data of S&P 500 companies, a mathematical programming task (11) was used. The solution provides efficient portfolios at different values of expected weekly returns. The results are shown in Tables 3 and 4, representing the proportion of shares invested in individual companies' stocks.

The article presents an analysis of the impact of the COVID-19 crisis on the stock market, while the main goal is to analyze the impact of the crisis on market changes, which was reflected in demand for

individual stocks in various industrial segments. Based on the obtained solutions, a significant impact of the COVID-19 crisis can be noted because the investment strategy in particular periods is diametrically different. It is possible to assume that a different type of global crisis would direct investments to other industry segments. The restructuring of the market manifested itself in investing in such a way that companies that increased the expected returns during this period while maintaining appropriate portfolio diversification came to the forefront of investing.

Similar analyses were published by the authors in a paper (Pekár et al., 2022), in which authors carried out similar analyses for the stock index Dow Jones Industrial Average (DJIA), which is one of the world's most famous stock indices. The DJIA is a stock index of thirty US companies comprising the largest and most widely traded stocks in the United States. The analysis carried out showed that the most significant increase in the share of relevant shares in the total investment corresponds to companies from the field of information technology Apple, Inc. (AAPL) and Microsoft (MSFT)). Another typical company with a significantly increased share of investments is Walmart (WMT), an American multinational retail corporation that operates a chain of hypermarkets, discount department stores, and grocery stores. A segment in which increased demand for products and services was recorded during the COVID-19 pandemic.

The authors reached similar conclusions when analyzing the S&P 500 stock index. Table 3 shows the diversity of the distribution of investments in effective S&P 500 portfolios for Period 1 (32 companies from different industries), which corresponds to the classical recommendations for investors from the point of view of risk diversification. On the contrary, Table 4 shows the distribution of investments in the effective portfolios of the S&P500 for Period 2 in only 18 companies, corresponding to the segments that experienced the most significant growth during the COVID-19 crisis. We can mention above all the IT segment (FTNT, KEYS, NVDA, ORCL), then the pharmaceutical industry (ABBV, IDXX, REGN, WST), online streaming services (NFLX), the energy-saving industry (CTRA, SEDG), and food segment (HRL, KR).

The presented analysis was based on the S&P 500 stock index, while the results are comparable to the authors' previous published results on the DJIA stock index data. Because the S&P 500 stock index contains a more significant number of stocks, the portfolio was made up of stocks of several companies. However, the direction of investments in comparable segments resulted from analyses carried out on both stock indices.

The mentioned analysis procedure does not have to be implemented on the selected stock index. In addition to the listed, e.g., Wilshire, Russell 2000, Nasdaq Composite, FT-SE 100, Morgan Stanley Capital International World, Dow Jones Eurostoxx, RTSI, DAX, ATX, CAC 40, Hang Seng, Nikkei Stock Average, PX 50, SAX, etc., but also on any own set of selected assets.

It can be concluded that the model approach based on the CVaR risk rate and the relevant portfolio selection model provides the investor with an effective tool for deciding on the allocation of available funds in the financial market.

Acknowledgements

This work was supported by the Grant Agency of Slovak Republic – VEGA grant no. 1/0339/20 „Hidden Markov Model Utilization in Financial Modelling “

References

Arici, G., Campi, M. C., Care, A., Dalai, M., & Ramponi, F. A. (2021). A theory of the risk for empirical CVaR with application to portfolio selection. *Journal of & Systems Science & Complexity*, 34(5), 1879-1894. https://doi.org/10.1007/s11424-021-1229-3

Arreola Hernandez, J., & Al Janabi, M. A. (2020). Forecasting of dependence, market, and investment risks of a global index portfolio. *Journal of Forecasting, 39*(3), 512-532. https://doi.org/10.1002/for.2641

Artzner, P., Delbaen, F., Eber, J. M., & Heath, D. (1999). Coherent measures of risk. *Mathematical finance, 9*(3), 203-228. https://doi.org/10.1111/1467-9965.00068

Basak, S., & Shapiro, A. (2001). Value-at-risk-based risk management: optimal policies and asset prices. *The review of financial studies, 14*(2), 371-405. https://doi.org/10.1093/rfs/14.2.371

Bodnar, T., Lindholm, M., Niklasson, V., & Thorsen, E. (2022). Bayesian portfolio selection using VaR and CVaR. *Applied Mathematics and Computation*, 427, 127120. https://doi.org/10.1016/j.amc.2022.127120

Davis, N. (2014). *Being Right or Making Money*. New Jersey: John Wiley & Sons.

Figus, A. (2021). Social evolution in times of COVID-19 between politics, economics, and health. *Strategic Management, 26*(1), 66-72. https://doi.org/10.5937/StraMan2101066F

Finch, W. H., & Hernández Finch, M. E. (2020). Poverty and COVID-19: rates of incidence and deaths in the United States during the first 10 weeks of the pandemic. *Frontiers in Sociology, 5*, 47. https://doi.org/10.3389/fsoc.2020.00047

Gaivoronski, A. A., & Pflug, G. (2005). Value-at-risk in portfolio optimization: properties and computational approach. *Journal of risk, 7*(2), 1-31. https://www.doi.org/10.21314/JOR.2005.106

Garbade, K. & Kenneth D. (1986). Assessing risk and capital adequacy for Treasury securities. *Topics in money and Securities Markets, 22,* New York: Bankers Trust.

Guo, X., Chan, R. H., Wong, W.-K., & Zhu, L. (2019). Mean–variance, mean–VaR, and mean–CVaR models for portfolio selection with background risk. *Risk Management, 21*(2), 73-98. https://doi.org/10.1057/s41283-018-0043-2

Hamdi, A., Karimi, A., Mehrdoust, F., & Belhaouari, S. B. (2022). Portfolio selection problem using CVaR risk measures equipped with DEA, PSO, and ICA Algorithms. *Mathematics*, 10(15), 2808. https://doi.org/10.3390/math10152808

Cheklov, A., Uryasev, S., & Zabarankin, M. (2003). *Portfolio optimization with drawdown constraint. Asset and Liability Management Tools, Risk Books*. London.

Kang, Z. L., Li, X. Y., & Li, Z. F. (2020). Mean-CVaR portfolio selection model with ambiguity in distribution and attitude. *Journal of Industrial and Management Optimization*, 16(6), 3065-3081. https://doi.org/10.3934/jimo.2019094

Kaplan, S., & Barish, N. N. (1967). Decision-making allowing for uncertainty of future investment opportunities. *Management Science, 13*(10), B-569-B-577. https://doi.org/10.1287/mnsc.13.10.B569

Kirman, A. (2010). The economic crisis is a crisis for economic theory. *CESifo Economic Studies, 56*(4), 498-535. https://doi.org/10.1093/cesifo/ifq017

Kotlebova, J., Arendas, P., & Chovancova, B. (2020). Government expenditures in the support of technological innovations and impact on stock market and real economy: the empirical evidence from the US and Germany. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 15(4), 717-734. https://doi.org/10.24136/eq.2020.031

Krokhmal, P., Palmquist, J., & Uryasev, S. (2002). Portfolio optimization with conditional value-at-risk objective and constraints. *Journal of risk, 4*, 43-68. doi:https://doi.org/10.21314/JOR.2002.057

Liu, J., & Chen, Z. (2018). Time consistent multi-period robust risk measures and portfolio selection models with regime-switching. *European Journal of Operational Research, 268*(1), 373-385. https://doi.org/10.1016/j.ejor.2018.01.009

Małkowska, A., Urbaniec, M., & Kosała, M. (2021). The impact of digital transformation on European countries: Insights from a comparative analysis. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, *16*(2), 325-355. https://doi.org/10.24136/eq.2021.012

Markowits, H. M. (1952). Portfolio selection. *Journal of Finance, 7*(1), 71-91.

Markowitz, H. M. (1959). *Portfolio Selection Efficient Diversification of Investments*. Yale: Yale University Press.

Paunov, C. (2012). The global crisis and firms' investments in innovation. *Research policy, 41*(1), 24-35. https://doi.org/10.1016/j.respol.2011.07.007

Pekár, J., Berezina, I., & Reiff, M. (2022). Determining the investor's strategy during the COVID-19 crisis based on CVaR risk measure. *Proceedings of the 27th International Scientific Conference Strategic Management and Decision Support Systems in Strategic Management* (pp. 7-13), Subotica: Faculty of Economics in Subotica.

Pekár, J., Brezina, I., & Brezina, I. J. (2018). Portfolio Selection Model Based on CVAR Performance Measure. *Proceedings of the 19th International Scientific Conference on Quantitative Methods in Economics - Multiple Criteria Decision Making* (pp. 266-271), Bratislava: Letra Edu s.r.o.

Reid, J., Templeman, L., & Allen, H. (2020). After COVID: The next massive tail risk. *Thematic Research*. Retrieved April 18, 2022 from: https://www.dbresearch.com/servlet/reweb2.ReWEB?rwsite=RPS_EN-PROD&rwobj=ReDisplay.Start.class&document=PROD0000000000509478

Rockafellar, R. T., & Uryasev, S. (2002). Conditional value-at-risk for general loss distributions. *Journal of Banking & Finance, 26*(7), 1443-1471. https://doi.org/10.1016/S0378-4266(02)00271-6

Roman, D., & Mitra, G. (2009). Portfolio selection models: a review and new directions. *Wilmott Journal: The International Journal of Innovative Quantitative Finance Research, 1*(2), 69-85. https://doi.org/10.1002/wilj.4

Sukharev, O. S. (2020). Economic crisis as a consequence COVID-19 virus attack: risk and damage assessment. *Quantitative Finance and Economics, 4*(2), 274-293. https://doi.org/10.3934/QFE.2020013

Sun, Y., Aw, E. L. G., Li, B., Teo, K. L., & Sun, J. (2020). CVaR-based robust models for portfolio selection. *Journal of Industrial & Management Optimization, 16*(4), 1861-1871. https://doi.org/10.3934/jimo.2019032

Uryasev, S. (2000). *Conditional value-at-risk: Optimization algorithms and applications*. Retrieved April 18, 2022 from: https://uryasev.ams.stonybrook.edu/wp-content/uploads/2011/11/FinNews.pdf

Wang, G. J., & Zhu, C. L. (2021). BP-CVaR: A novel model of estimating CVaR with back propagation algorithm. *Economics Letters*, 209, 110125. https://doi.org/10.1016/j.econlet.2021.110125

Wang, Q., Huang, W., Wu, X., & Zhang, C. (2019). How effective is the tail mean-variance model in the fund of fund selection? An empirical study using various risk measures. *Finance Research Letters*, 29, 239-244. https://doi.org/10.1016/j.frl.2018.08.012

Worldometers. (2022). Daily New Cases. https://www.worldometers.info/coronavirus/country/us/

Yamai, Y., & Yoshiba, T. (2005). Value-at-risk versus expected shortfall: a practical perspective. *Journal of Banking & Finance, 29*(4), 997-1015. https://doi.org/10.1016/j.jbankfin.2004.08.010

Youssef, A. B., Redzepagic, S., & Zeqiri, A. (2022). The key changes to the hospitality business model under COVID-19. *Strategic Management*. https://doi.org/10.5937/StraMan2200015Y

Zinecker, M., Doubravský, K., Balcerzak, A. P., Pietrzak, M. B., & Dohnal, M. (2021). The COVID-19 disease and policy response to mitigate the economic impact in the EU. *Technological and Economic Development of Economy, 27*(3), 742-762. https://doi.org/10.3846/tede.2021.14585

✉ **Correspondence**

Marian Reiff

Operations Research and Econometrics, Faculty of Economic Informatics, University of Economics,
Dolnozemská 1, 852 35 Bratislava, Slovakia

E-mail: marian.reiff@euba.sk

STRATEGIC MANAGEMENT, Vol.29 (2024), No. 3, pp. 043-053

DOI: 10.5937/StraMan2300039S

Received: September 28, 2022
Revised: November 15, 2022
December 21, 2022
Accepted: December 23, 2022
Published online: March 20, 2023

Assessing sustainable economic development efficiency: a DEA approach

Kosta Sotiroski

Sv. Kliment Ohridski University, Bitola, Faculty of Economics, Prilep, North Macedonia
https://orcid.org/0000-0002-4005-0526

Kovács Péter

University of Szeged, Szeged, Hungary
https://orcid.org/ 0000-0002-7376-8673

Aleksandra Marcikić Horvat

University of Novi Sad, Faculty of Economics Subotica, Subotica, Serbia
https://orcid.org/0000-0002-4199-4238

Otilija Sedlak

University of Novi Sad, Faculty of Economics Subotica, Subotica, Serbia
https://orcid.org/0000-0002-7430-7027

Vuk Lakić

Student of the University of Novi Sad, Faculty of Economics Subotica, Subotica, Serbia
https://orcid.org/0000-0002-5803-4874

Boris Radovanov

University of Novi Sad, Faculty of Economics Subotica, Subotica, Serbia
https://orcid.org/0000-0002-4728-7286

Abstract

Background: Widely used in efficiency analysis, data envelopment analysis (DEA) found its use in country efficiency measurement concerning the achievement of desired values of macroeconomic indicators, most often the goals from the category of economic growth.

Purpose: The objective of the paper is to examine the possibility of DEA application in sustainable development research.

Methodology: The analysis was conducted using a non-oriented DEA model with variable return-to-scale in a group of 26 EU countries and Serbia, as a membership candidate. Four variables were used as input variables: inflation rate, unemployment rate, poverty rate and ecological footprint per capita. Three variables were used on the outputs side: inequality-adjusted human development index, GDP per capita and ecological deficit or reserve per capita. The annual data was collected for the time period of eight years, form 2010 until 2017.

Findings: Results show that Finland is the only country efficient throughout the entire period. Average efficiency close to maximum was achieved by the Netherlands. Significant efficiency was achieved by Luxembourg, Germany and Sweden among countries that were EU members before 1995. Among other EU countries, Slovenia and Hungary achieved efficiency on a nearly maximum level. Also, efficient in more than half of the observed years were Cyprus and Romania. The most inefficient countries were the three Baltic countries: Lithuania, Latvia, and Estonia. Among the EU member countries before 1995, Italy and Portugal were the most inefficient. Concerning EU candidate Serbia, the efficiency achieved was generally close to average.

Limitations: The performed analysis can answer the question of which country is the most efficient on the way to sustainability. However, the DEA method cannot show whether a country is developing absolutely sustainably or unsustainably, because DEA is a relative method and can only measure efficiency compared to the other units.

Keywords: data envelopment analysis; efficiency; sustainable development; European Union

Introduction

Technical efficiency was first defined by Koopmans (1951), as a state in which producers can produce more of a certain output if and only if they lower the production of another output or uses more of certain input. The decades-long search for adequate measurements of technical efficiency resulted in the conception of *data envelopment analysis (DEA)* in the second half of the 20th century, with foundations in the work of Michael James Farrell (1957). Development of this method made efficiency measurement on the 0-1 scale possible by putting into ratio summed weights of multiple outputs and inputs, even if presented in different and non-comparable units of measurement. The creators of the first CCR DEA model (Charnes, Cooper & Rhodes, 1978) presupposed diverse applications in efficiency testing, regarding both profit and non-profit institutions.

Parallel with the ongoing pursuit of adequate technical efficiency measurements, *sustainable development* caught more attention from theoreticians and policymakers. Significant attention to this universal goal for humanity was drawn by members of the Club of Rome by the publication of *'Limits to Growth'* (Meadows et al., 1972). At the dawn of the new millennium, the United Nations (UN) published *Millennium Declaration* (2000) with set *Millennium Development Goals*, while later in the 21st century the knowledge on the subject was systematized and *Millennium Development Goals* transformed into 17 *Sustainable Development Goals*. Although there are no generally accepted definitions and indicators concerning sustainable development, most often it is perceived from (1) economic, (2) social, and (3) environmental aspects (Bojović, 2011).

The objective of this paper is to test the possibility of DEA application in sustainable development assessment, aiming to create a single efficiency indicator that includes all three aspects of sustainable development at the same time. For the purpose of the paper, an adequate DEA model and input and output variables had to be selected. First and second sections present theoretical analysis of both DEA method and sustainable development phenomenon in comparison to economic growth and development respectively, based on existing literature. The third section is dedicated to model and variables to be included selection, and also to the selection of *decision-making units (DMU)* to be observed. For purposes of model simplicity, the impact of excluded variables is abstracted. The fourth section is dedicated to the presentation and quantitative and qualitative interpretation of analysis results.

Hypotheses *H1: Data envelopment analysis is applicable in sustainable development assessment* and *H2: Data envelopment analysis relativity limits application in sustainable development assessment* present a starting standpoint for this paper. Both hypotheses are a result of an examination of literature from relevant fields. Methods of theoretical analysis and quantitative and qualitative analysis of DEA results calculated from panel data (2010-2017) involving 27 countries were used in the paper. The data was collected from relevant and credible sources (UN, The World Bank, and Global Footprint Network) and additionally adjusted due to certain specificities of mathematical method.

1. Literature review

While testing the efficiency of states of the United States in agriculture in his work *The Measurement of Productive Efficiency* Farrell (1957) was the first to develop methods of productive efficiency measurement as a ratio between different inputs and a certain output or different outputs and a certain input. Such approach presented a step further from using average labour productivity as referent value in efficiency measurement because it included diverse inputs while focusing on technical competency and objective output instead of minimal production costs. Further development of methods for efficiency assessment was needed. The most significant contribution was made by Charnes, Cooper, and Rhodes (1978) through the development of data envelopment analysis (DEA), specifically the CCR model. What DEA enabled was the inclusion of multiple different input and output variables at the same time.

1.1. Data envelopment analysis

Data envelopment analysis can be defined as a non-parametric decision making method with a set objective of maximum efficiency (Charnes, Cooper & Rhodes, 1978). DEA was derived from the classical microeconomic theory of production. The focus of analysis is on decision making units (DMU), subjects that use multiple inputs to generate multiple outputs (Škare & Rabar, 2016). DEA has been accepted as a useful tool for performance assessment and ranking of DMUs

(Rahmani et al. 2020). An important step to successful DEA application is choosing organisations or subjects of the same kind as DMUs. Also, it is necessary to use the same variables as inputs and outputs for every particular DMU, and make sure that quantitative data on variables used as inputs and outputs is already existent. Like Farrell's (1957) method, DEA remains sensitive to input and output variable selection.

It has already been stated that DEA was derived from the classical theory of production. The aforementioned theory uses Pareto-optimality as an ultimate indicator of efficiency (Charnes, Cooper, Golany, Seiford & Stutz, 1985). Conditions (1) and (2) from the previous paragraph that have to be met to achieve efficiency substantiate the essence of Pareto-optimum – the inability of any position improvement without any other position worsening. DEA-calculated efficiency presents an extension of the Pareto-Koopmans efficiency concept (Krivonozhko, Utkin, Volodin, Sablin & Patrin, 2004).

DEA calculates efficiency as a ratio between a weighted sum of outputs and the weighted sum of inputs. Diverse inputs and outputs have to be aggregated to form one virtual output and one virtual input (weighted sums), that would thereafter be put into ratio. Due to such approach, it is necessary to ponder inputs and outputs, to multiply them by technical coefficients according to their respective relative relevance (Cook & Seiford, 2009). Technical coefficients are treated as variables in DEA linear programming model formulation and are not mutually comparable. Solving a specific linear programming problem results in calculating technical coefficients, which is a solution recommended by the creators of the first DEA model (Charnes et al., 1978), lacking clearly defined multiplicators.

Such formulation allows the inclusion of inputs and outputs expressed in diverse and mutually incomparable units of measure, which is one of DEA's biggest advantages (Škare & Rabar, 2016). Some other advantages have already been mentioned, first and foremost the possibility of multiple inputs and outputs inclusion at the same time. Formulating a production function explicitly is unnecessary to conduct a DEA calculation. Additionally, after determining efficiency lower than maximum, DEA can point out sources of inefficiency through dual prices, calculated by solving a linear programming problem.

The main disadvantages of DEA are sensitivity to the choice of input and output variables and the inability to predict. DEA presents an ex-post analysis based on already known data (Škare & Rabar, 2016). 'Rule of thumb' states that, to apply DEA successfully, the number of selected DMUs has to be at least two to three times higher than the number of variables used as inputs and outputs combined, so that efficiency results would be adequately dispersed (Sarkis, 2007).

1.2. Economic growth, development and sustainability

The problem of *economic growth* presents one of the most important problems that concern economists and politicians. Economic growth is an increase in the production of goods and services in a national economy and is measured as the growth of a macroeconomic aggregate gross domestic product (GDP) over an observed period, most often annually. On the other hand, additionally to quantitative growth, *economic development* presupposes structural changes in production and distribution, and as such has a qualitative aspect as well. Economic growth is a necessary condition of economic development (Acemoglu, 2012).

The standpoint of abandonment of exclusive usage of GDP in welfare measurement is increasingly gaining its foothold. Many authors, including van den Bergh (2009; 2022) and Kubiszewski et al. (2013), point out the problems of extensive GDP usage and signify the necessity of developing and using alternative indicators (Beyond GDP). Still, GDP remains the most used macroeconomic indicator due to its simplicity and clarity, while economic policy founded upon neoclassical economics places its focus on high economic growth as its only goal (Bojović, 2011).

In their book *Limits to Growth*, a group of authors (Meadows et al., 1972) comprehensively examined the problem of sustaining the trends of growth of population, production, and pollution at the time, in circumstances of resource scarcity, most importantly in the production of food and energy. The research objective was to point out that the unsustainability problem was a global one and to formulate the world model that shows the co-dependency of variables connected to studied phenomena. In the following decades, growing attention was dedicated to the problem of *sustainable development*. According to Wang et al. (2022), economic development and energy consumption have increased ecological issues of sustainable economics. Nevertheless, with labour

and capital, energy is an essential input for the economic growth (Mardani et al. 2017). Therefore, its careful inclusion in the model as an input is of great importance. In support of this, Halkos et al. (2015) reported that high production efficiency level of a country does not ensure a high eco-efficiency performance.

The lack of consensus on the definition of sustainable development presents a big obstacle in the research of sustainable development. Dominantly, sustainability is observed from three aspects: (1) aspect of economic progress, (2) aspect of environment preservation, and (3) aspect of social development. Simultaneous achievement of goals related to all three aspects is a necessity, while goals achievement must be maintained in the long run also. The cohesion of policies aimed at achieving such goals is not simple and presents another problem of sustainable development (Petrov, Trivić & Ćelić, 2018). In terms of applying all three aspects, Matsumoto et al. (2020) examines labour, capital and energy as common inputs with gross domestic product, carbon dioxide and particulate matter emissions and waste as outputs.

Made by the United Nations (UN), the *'Millennium Declaration'* (2000) obliged signing sovereign countries to cooperate in achieving *Millennium Development Goals* by 2015 (Sachs & McArthur, 2005). In 2012, *Millennium Development Goals* were redefined into 17 *Sustainable Development Goals* in the process during which the knowledge concerning the field of sustainable development was systematized (Sachs, 2012).

Considering the lack of a universally accepted definition of sustainable development, many contexts in which sustainable development is mentioned, and terminology, data, and measurement methods not being systematized, formulation of a universally accepted set of indicators of sustainable development was not achieved. Different initiatives through time defined different indicators, but none of those succeeded in gaining a stable foothold as theoretically supported and politically relevant (Petrov et al., 2018). According to Labaj et al. (2014), it is of urgent need to develop new approaches for assessing the economic performance while taking into account economic as well as social and environmental goals.

2. Research methodology

DEA tends to present DMU efficiency in outputs maximisation while using minimum inputs or inputs minimization while attaining maximum outputs. Additionally, DEA is conducted based on existent and known data on inputs and outputs. Taking specified DEA characteristics and general availability of macroeconomic data into consideration, hypothesis *H1: Data envelopment analysis is applicable in sustainable development assessment* can be defined.

After the analysis has been conducted, the production possibility frontier, as an analysis result of the most efficient observed DMU, is reached empirically. Thereby, DMU can be either below or on the production possibility frontier. It is deducted that the production possibility frontier is determined by the efficiency of the most efficient observed DMU, which in return can be regarded as maximally efficient.

The DMUs on the production possibility frontier are marked as having the efficiency of 1, while those DMUs that are below the frontier are marked as having the efficiency somewhere in the range from 0 to 1, depending on the distance to the frontier (Škare & Rabar, 2016). The analysis results are therefore dependent on the selection of DMUs to be included as well. It can further be said that DEA presumes maximum efficiency achievable as efficiency manifested by the most efficient included DMU.

Every particular DMU can be characterised as either relatively efficient or relatively inefficient. To characterise certain DMU as efficient, the following conditions must be met: (1) it is impossible to increase any output without decreasing other output or increasing any input and (2) it is impossible to decrease any input without increasing other input or decreasing any output (Charnes, Cooper & Rhodes, 1981).

The fact that DEA is a relative method allows comparing DMUs and benchmarking, but does not state enough on whether the most efficient DMU, despite being characterised as efficient, achieves satisfactory absolute levels of input and output values (whether absolute levels of inputs and outputs are in cohesion with targeted referent values, if there are such). Therefrom stems the hypothesis *H2: Data envelopment analysis relativity limits application in sustainable development assessment*.

CCR and BCC models are two basic DEA models. CCR model was first developed by the creators of the method itself (Charnes et al., 1978) and it is named after their initials. The objective function of the non-linear CCR model contains maximum efficiency h_0 of the observed DMU as a

weighted sum of its outputs y_{r0} multiplied by technical coefficients u_r, where

$$(1.1.)\ r = 1, \ldots, s$$

with s being the number of different outputs; divided by the weighted sum of its inputs x_{i0} multiplied by technical coefficients v_i, where

$$(1.2.)\ i = 1, \ldots, m$$

with m being the number of different inputs. Constraints contain efficiencies of all the other DMUs as ratios between weighted sums of outputs y_{rj} and inputs x_{ij}, where

$$(1.3.)\ j = 1, \ldots, n$$

with n being the number of DMUs observed, and the condition of technical coefficients being higher than a small positive value ε (Cook & Seiford, 2009). The efficiency of other DMUs can be lower than or equal to 1, and inserted values of inputs and outputs always have to be equal to or higher than 0. In the further development of the model (Charnes et al., 1981), condition of non-negativity was replaced with the condition of positivity, to avoid neglection of the impact of certain input or output by multiplying them with a technical coefficient of 0. Objective function and constraints are formulated as ratios, which makes the model non-linear and non-convex. It is possible to rearrange the model to become a linear programming problem.

The primal DEA linear programming model is called the weight problem, while the dual model is called the envelopment problem. Reduced to linear programming, with regards to usage of above-designated marks, the weighted problem is formulated (Martić, Novaković & Baggia, 2009):

o.f.

$$(1.4.)\ \mathrm{Max} h_0 = \sum_{r=1}^{s} u_r y_{r0}$$

s.t.

$$(1.5.)\ \sum_{i=1}^{m} v_i x_{i0} = 1$$

$$(1.6.)\ \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0$$

$$(1.7.)\ u_r \geq \varepsilon,\ \ r = 1, \ldots, s$$

$$(1.8.)\ v_i \geq \varepsilon, i = 1, \ldots, m.$$

Formulating dual problem results in dual variable λ_j, a weighted sum of j-th DMU, and s_i^+ and s_i^-, which represent output increasements or input decreasements respectively, necessary for DMU to become efficient.

With regards to orientation, the DEA model can be input-oriented if the ratio shown is output/input, output-oriented if the ratio shown is input/output, and non-oriented (Cook & Seiford, 2009). In every stage of the development of the CCR model, constant return-to-scale was presumed. The first extension of the CCR model was made by Banker, Charnes, and Cooper (1984) and it was named BCC model after their initials. Efficiency measurement calculated using the BCC model represents efficiency measurement when differences in the scale of production are ignored. Another constraint was added to the model for variable return-to-scale to be tolerated (Škare & Rabar, 2017). Every DMU in the BCC model is compared only to DMUs that have a similar scale of production. Therefore, presuming multiple DMU groups with different scales, the BCC model shows more efficient single DMUs in the same sample than the CCR model, with the efficiency of every single DMU being higher than the one calculated by the CCR model (Martić, Novaković & Baggia, 2009).

2.1. Applying DEA in sustainable development assessment

There are four main phases in conducting an efficiency study using the DEA method:

1. Defining and selecting decision-making units whose relative efficiency should be determined
2. Determining input and output variables that are relevant and suitable for assessing the relative efficiency of selected decision-making units
3. Selection of an adequate DEA model
4. Solving DEA models, analysis and interpretation of results.

In the first phase, it is actually decided what will be the subject of the analysis. Furthermore, it is important to determine the primary goal of decision-making units and, based on it, determine whether they strive to minimize input or maximize output variables. The previous phases create preconditions for solving the model and analysis of the solution, which should lead to certain conclusions regarding the level of efficiency and ways of improvement. It is also necessary to choose which input and output variables will be used in the analysis. Nowadays, various variants of DEA model are developed in different areas of application. Therefore, selection of the adequate DEA model is also an important step in the analysis.

Numerous authors (Golany & Thore, 1997; Afonso & St. Aubyn, 2013; Škare & Rabar, 2017; Koisova, Grmanova, Skrovankova & Kostrova, 2019; Marcikić Horvat et al., 2021) examined the phenomena of economic growth and development, while applying various DEA models and selecting different combinations of input and output variables. Taking a high level of GDP per capita or high GDP growth rate as an objective desired to be achieved by policy, without a maximum limit, those variables are qualified to be selected for the model as output variables, while factors decreasing

the level of GDP or slowing its growth could be included as input variables, just like factors that present the additional effort in achieving growth.

Can DEA be further applied to analyse sustainable development, its characteristics taken into consideration? There is a possibility of achieving high GDP or high GDP growth rate, but in such a manner that is devastating for the environment. That is why Mardani et al. (2018) introduced possible applications of inputs and outputs of DEA in the fields of environmental and energy economics. Simultaneously, it is necessary to consider social development, dimensions such as equity and the quality of an individual's life. While examining sustainable development, it is not only necessary to have economic growth analysed from the quantitative aspects, but from the qualitative aspect too.

To examine the applicability of DEA in sustainable development research, the model to be applied to inspect the data has to be defined. Such a model should include countries as DMUs and a certain number of variables as inputs and outputs. The final version of the analysis includes countries of the European Union excluding Malta, and Serbia as a candidate for membership. This sample was taken from a variety of possible combinations based on data availability for countries in a time period and the geopolitical importance of the European Union.

The analysis time frame is a period from the year 2010 to the year 2017. Selection of time period in the 21st century was needed to present the state after the adoption of *The Millennium Declaration* (United Nations, 2000), the first instance of global policy direction toward sustainable development. For the start year, 2010 was taken in order to eliminate the effects of the global economic crisis of 2008 as much as possible, while 2017 was taken for the end year because it is the last year for which the data on all the variables included has been published. With sustainable development being a long-run category, every country is observed every year as an independent DMU. That way, a country is not only compared with other countries in a given year but also with the results of previous or following years.

The variables had to be selected so that they illustrate all three aspects of sustainable development. The input variables are:

1. inflation rate (GDP deflator) – the indicator of price (in)stability and monetary stability
2. unemployment rate – indicator in which percentage labour force does not participate in the production process
3. poverty rate, measured as a percentage of the population of a country living below a poverty threshold of 3.2 United States dollars per capita daily, purchase-power-parity adjusted
4. ecological footprint per capita – the measure of the negative influence of human activity on the environment. It indicates whether nature is capable of renewing itself at the rate at which the society exploits it, where natural capacity is characterised as biocapacity and the negative effects of human activity on the environment as the ecological footprint (Sarkodie, 2021).

Variables used as outputs are:

(1) inequality-adjusted human development index (IHDI) – Human development index (HDI) is a composite indicator that measures life quality by taking into consideration life expectancy, education, and purchasing power of a resident. Adjusted for inequality, it shows such quality in an environment where a certain degree of inequality is present, taking HDI as a potential that can be achieved, while IHDI represents the actual situation (Alkire & Foster, 2010).
(2) GDP per capita – national output relative to the population size
(3) ecological deficit or reserve per capita – the difference between biocapacity and ecological footprint relative to the size of the population. It indicates whether or not the effects of economic activity on the environment overcome the effects that the environment could withstand while maintaining the current resource renewal rate, and how big is the positive (reserve) or negative (deficit) gap (Lin et al., 2015).

Inflation rate and ecological deficit or reserve per capita are such indicators that they can be negative. As DEA was not perceived to include negative variable values, those values have to be adjusted (Portela, Thanassoulis & Simpson, 2004). The absolute of the most negative value concerning every of the stated variables was added to the value of those variables for every DMU. That way the inflation of the DMU with the most intensive deflation was considered 0 for the purposes of the

analysis, while every DMU maintained the same difference. The identical procedure was undertaken for the ecological deficit or reserve per capita.

The data regarding IHDI and poverty rate was retrieved from United Nations Development Programme, Human Development Data Centre. Regarding GDP per capita, unemployment rate and inflation rate the source used was World Bank Open Data, while the data regarding biocapacity and ecological footprint, based on which ecological deficit or reserve was calculated, was retrieved from Global Footprint Network, Open Data Platform. Table 3.1 contains correlation coefficients between variables.

The analysis included 27 countries across 8 years, which makes for 216 DMUs, compared by efficiency computed based on data for 7 variables, with biocapacity also being included as it is used to calculate ecological deficit or reserve. DEA model selected to be used is a non-oriented model presuming variable return-to-scale. Constant return-to-scale would require that every DMU operates at an optimum scale, which is not always the case (Marcikić Horvat et al., 2021).

Table 1 Variable correlation coefficients

	IHDI	Poverty rate	GDP per capita	Inflation rate	Unemployment rate	Ecological footprint per	Biocapacity per capita	Ecological deficit
IHDI	1.00							
Poverty rate	-0.62	1.00						
GDP per capita	0.73	-0.44	1.00					
Inflation rate	-0.20	0.23	-0.07	1.00				
Unemployment rate	-0.57	0.36	-0.51	-0.08	1.00			
Ecological footprint per capita	0.36	-0.27	0.50	0.11	-0.23	1.00		
Biocapacity per capita	0.33	-0.12	0.15	0.10	-0.22	0.28	1.00	
Ecological deficit or reserve per capita	0.13	0.03	-0.12	0.04	-0.09	-0.28	0.85	1.00

Source: the authors' calculation

Descriptive statistics concerning variables is shown in Table 2 Taking into consideration characteristics of DEA, usage of variables measured in mutually incomparable units should present no problem for the analysis (Škare & Rabar, 2016).

Table 2 Descriptive statistics for variables

	n	Min	Max	Mean	Std. Deviation
IHDI	216	0.676	0.882	0.797	0.053
Poverty rate	216	0	12.63	1.30	2.03
GDP per capita	216	5589	123514	32003	23011
Inflation rate	216	-2.98	8.91	1.55	1.62
Unemployment rate	216	2.89	27.47	10.44	5.14
Ecological footprint per capita	216	2.70	15.82	5.21	2.04
Biocapacity per capita	216	0.21	13.03	3.52	3.11
Ecological deficit or reserve per capita	216	-14.31	7.10	-1.69	3.51

Source: the authors' calculation

3. Results and Discussion

The results of the conducted analysis are shown in Tables 3 and 4. Finland is the only country efficient throughout the entire period. Average efficiency close to maximum was achieved by the Netherlands, inefficient in 2012, 2013, and 2015, but being close to maximum efficiency. Significant efficiency was achieved by Luxembourg, which was only inefficient in 2015 and 2017, Germany, inefficient only in 2010 and 2016, and Sweden, inefficient in the time period 2010-2012, among countries that were EU members before 1995. Among other EU countries, Slovenia achieved efficiency on a nearly maximum level, being inefficient in the time period 2011-2013, while Hungary was on average close to efficiency, being inefficient in 2011, 2013, and 2014. Also, Cyprus and Romania were efficient in more than half of the observed years.

The most inefficient countries were the three Baltic countries: Lithuania, Latvia, and Estonia, in that order. Throughout the entire period, either Lithuania or Latvia was the most inefficient country. The most significant drop in efficiency occurred in Latvia, which went from the maximum efficiency in the first observed year to the efficiency of 0.77 in the last observed year. Estonia was slightly more efficient in 2015 and 2017 than in the rest of the observed period. Among the EU member countries before 1995, the most inefficient were Italy and Portugal.

The most significant improvement was that achieved by Cyprus, going from efficiency of 0.81 in the first year to being efficient during the period 2013-2017. Other improving countries include France, achieving an efficiency of 0.86 in the first year and being efficient in 2014 and 2017, Poland, going from 0.80 in the first year to 0.99 in the last

year, while being efficient in 2016, Slovakia, and Serbia. Greece improved during the first half of the observed period but deteriorated during the second half.

EU member countries before 1995 were on average more efficient than other EU countries. Concerning EU candidate Serbia, the efficiency achieved was generally close to average, falling behind only slightly. Serbia was efficient in 2015 and more efficient than an average country in 2017. The countries were most efficient on average in 2014 and 2015 with an efficiency score of 0.95 and least efficient in 2011 with a score of 0.91 and in 2010 with a score of 0.92, with the difference being small.

Also, similar to the findings of Matsumoto et al. (2020), the EU countries experienced the sustainable efficiency improvement during the observed period, although fluctuations were observed in most cases.

Table 3 DEA efficiency scores by country and year (part 1)

Country	Efficiency				
	2010	2011	2012	2013	2014
EU members in 1995*					
Austria	0.93	0.94	0.95	0.93	0.94
Belgium	0.89	0.92	0.91	0.91	0.92
Denmark	0.96	1.00	1.00	0.99	0.99
Finland	1.00	1.00	1.00	1.00	1.00
France	0.86	0.93	0.90	0.92	1.00
Germany	0.96	1.00	1.00	1.00	1.00
Greece	0.86	0.82	0.89	1.00	0.96
Ireland	1.00	0.96	0.96	0.97	1.00
Italy	0.82	0.83	0.86	0.88	0.89
Luxembourg	1.00	1.00	1.00	1.00	1.00
Netherlands	1.00	1.00	0.99	0.99	1.00
Portugal	0.82	0.90	0.92	0.90	0.93
Spain	0.91	0.95	0.98	0.95	0.98
Sweden	0.94	0.99	0.97	1.00	1.00
Other EU countries**					
Bulgaria	0.93	0.85	0.92	1.00	0.96
Croatia	1.00	0.80	0.82	0.90	0.98
Cyprus	0.81	0.92	1.00	1.00	1.00
Czech Republic	1.00	0.94	0.90	0.91	0.92
Estonia	0.79	0.82	0.78	0.82	0.82
Hungary	1.00	0.97	1.00	0.99	0.98
Latvia	1.00	0.81	0.82	0.80	0.77
Lithuania	0.77	0.79	0.78	0.81	0.80
Poland	0.80	0.82	0.84	0.90	0.91
Romania	0.96	0.91	1.00	1.00	1.00
Slovakia	0.87	0.87	0.93	0.92	0.94
Slovenia	1.00	0.96	0.98	0.99	1.00
EU candidate country					
Serbia	0.88	0.84	0.91	0.90	0.93
Yearly average	0.92	0.91	0.93	0.94	0.95

Notes:*Although a member country in 1995, United Kingdom is excluded from the analysis as it is no longer a member of the EU, **Due to unavailability of data for every variable, Malta is excluded from the analysis

Source: the authors' calculation

Table 4 DEA efficiency scores by country and year (part 2)

Country	Year			
	2015	2016	2017	Average
EU members in 1995				
Austria	0.91	0.94	0.94	0.94
Belgium	0.92	0.92	0.93	0.92
Denmark	0.99	0.99	1.00	0.99
Finland	1.00	1.00	1.00	1.00
France	0.92	0.94	1.00	0.93
Germany	1.00	0.99	1.00	0.99
Greece	0.90	0.90	0.89	0.90
Ireland	0.99	0.99	1.00	0.98
Italy	0.89	0.87	0.88	0.87
Luxembourg	0.98	1.00	0.98	0.99
Netherlands	0.99	1.00	1.00	1.00
Portugal	0.89	0.84	0.82	0.88
Spain	0.97	0.89	0.89	0.94
Sweden	1.00	1.00	1.00	0.99
Other EU countries				
Bulgaria	0.89	0.88	0.90	0.92
Croatia	0.96	0.95	0.94	0.92
Cyprus	1.00	1.00	1.00	0.97
Czech Republic	1.00	0.98	1.00	0.96
Estonia	0.94	0.83	0.92	0.84
Hungary	1.00	1.00	1.00	0.99
Latvia	0.82	0.77	0.77	0.82
Lithuania	0.82	0.80	0.77	0.79
Poland	0.97	1.00	0.99	0.90
Romania	0.97	1.00	1.00	0.98
Slovakia	0.96	1.00	0.92	0.93
Slovenia	1.00	1.00	1.00	0.99
EU candidate country				
Serbia	1.00	0.91	0.97	0.92
Yearly average	0.95	0.94	0.94	0.93

Source: the authors' calculation

Comparative analysis of countries regarding measured relative efficiency is enabled by performed calculation using retrieved data. The best results were calculated for countries having high values of output variables and having low values of input variables, all while maintaining an adequate cohesion of values concerning economic development, social development, and

environment preservation. The efficiency of every country aiming to achieve various diverse sustainable development goals at the same time was examined through a calculation using the DEA model, which allows confirmation of the hypothesis *H1: Data envelopment analysis is applicable in sustainable development research.*

By such an approach the comparison of countries based on efficiency was enabled, taking into consideration that the maximum efficiency is the efficiency exhibited by the most efficient country in its most efficient year. Still, it is very important to conclude whether the country is sustainable or not when examining sustainable development. Although it shows how efficient a country is in achieving and coordinating activities towards the achievement of goals, while being compared with other countries, this analysis cannot answer the question of whether a country is sustainable or not. Being the most efficient of the group does not necessarily mean it is absolutely sustainable, just that it is relatively more or less efficient than the other.

Taking into consideration that in addition to comparison and ranking of the countries one against the other, the sustainable development analysis needs to include a mark on whether a country can be considered sustainable or not, the DEA method could be used in sustainable development analysis while being complemented by another method or indicator that overcomes this disadvantage. Therefore, hypothesis *H2: Data envelopment analysis relativity limits application in sustainable development research* is confirmed. Additionally, DEA cannot be used to predict future values and changes of the indicators, but only to analyse already acquired data, and conduct *ex-post* analysis, where other additional problems exist concerning the scope of the analysis if the data is largely unavailable.

One of the possible solutions to overcome these disadvantages is to measure precisely the potentials and sustainability limits for countries and to measure (in)efficiency through the gaps to the potential values. Generally, DEA can be used to comparatively measure and analyse the efficiency of countries on their way to sustainability, but it is impossible to give the final verdict on whether some countries can be considered sustainable or not. Also, the results of the relative DEA method depend largely on both variable and DMU selection, so it is necessary to try out different input-output combinations of the variables and different scopes of analysis regarding the time frame and countries observed.

Conclusion

Widely used in efficiency analysis, the DEA method found its use in country efficiency measurement concerning the achievement of desired values of macroeconomic indicators, most often the goals from the category of economic growth. Based on the objective of the paper, it contains the examination of DEA applicability in sustainable development measurement. The ultimate sustainable development goal is reaching economic sustainability in the frame dictated by the environment while achieving both intragenerational and intergenerational justice and equality (Bojović, 2011).

Using acquired data, the analysis was conducted using a non-oriented DEA model with variable return-to-scale in a group of 27 countries: 26 current EU countries and 1 membership candidate. The inflation rate, unemployment rate, poverty rate, and ecological footprint per capita were used as input variables, while output variables used were GDP per capita, IHDI, and ecological deficit or reserve per capita. Successful conduct of the analysis resulted in confirmation of the hypothesis *H1: Data envelopment analysis is applicable in sustainable development research*. In other words, both economic and environmental variables significantly affect overall efficiency of observed countries (Matsumoto et al., 2020). Therefore, He at al. (2016) recommended improving the level of agricultural modernization, increasing the proportion non-fossil energy, developing renewable energy and reducing pollutant emission in order to promote sustainable economic growth.

Bearing in mind the problem examined in this paper, DEA should be used carefully by linking technology innovation in science with political and managerial efforts and so reducing the problem related to climate change and environmental pollution (Sueyoshi et al., 2017). Mostly, technical progress is the most powerful contributor to economic growth, while political and management efficiency are the two main obstacles preventing further improvement (Wang & Feng, 2015). For this reason, measuring the efficiency of economic growth plays an important role in the decision-making process and reducing managerial inefficiency.

Analysis can answer the question of which country is the most efficient on the way to sustainability, or what are all the countries that are efficient in achieving high output variable and low input variable values, or in coordinating the achieving of different goals related to sustainable development at the same time. However, the DEA method cannot show whether a country is developing absolutely sustainably or unsustainably, because DEA is a relative method and can only measure efficiency compared to other units, without stating whether that efficiency is enough to achieve the ultimate goal. These statements are a confirmation of the hypothesis *H2: Data envelopment analysis relativity limits application in sustainable development research*.

Limitations of this study are mainly linked with the applied methodology, since the results of DEA models highly depend on the selection of sample and variables. DEA is a relative method and can only measure efficiency compared to other units. Therefore, modification of the selection of countries in the analysis or choice of different input or output variables would definitely change the results of DEA analysis which is the interesting topic for further research. Further steps that could be taken to improve the possibility to apply the DEA method in sustainable development analysis could be finding better ways to measure country potentials regarding variables and gaps of actual to potential values, and improving the databases in order to provide for further measurements through changing variable combinations and inclusion of different DMUs.

References

Acemoglu, D. (2012). Introduction to economic growth. *Journal of economic theory*, *147*(2), 545-550. https://doi.org/10.1016/j.jet.2012.01.023

Afonso, A. & St. Aubyn, M. (2013). Public and private inputs in aggregate production and growth – a cross-country efficiency approach, *Applied Economics*, 45(32), 4487-4502. https://doi.org/10.1080/00036846.2013.791018

Alkire, S., & Foster, J. E. (2010). Designing the inequality-adjusted human development index, OPHI working paper no. 37, University of Oxford. https://doi.org/10.2139/ssrn.1815248

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis*. Management Science, 30(9), 1078–1092.* https://doi.org/10.1287/mnsc.30.9.1078

Bojović, V. (2011). Sustainable development – multiple meanings yet unambiguous necessity. *Economic Themes*, *2*, 175-192.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research 2*(6), 429-444. https://doi.org/1016/0377-2217(78)90138-8

Charnes, A., Cooper, W. W., & Rhodes, E. (1981). Evaluating program and managerial efficiency: an application of data envelopment analysis to program follow through. *Management science 27*(6), 668-697. https://doi.org/10.2307/2631155

Charnes, A., Cooper, W. W., Golany, B., Seiford, L., & Stutz, J. (1985). Foundations of data envelopment analysis for Pareto-Koopmans efficient empirical production functions. *Journal of econometrics*, *30*(1-2), 91-107. https://doi.org/10.1016/0304-4076(85)90133-2

Cook, W. D., & Seiford, L. M. (2009). Data envelopment analysis (DEA) – thirty years on*. European Journal of Operational Research 192(1), 1–17.* https://doi.org/10.1016/j.ejor.2008.01.032

Farrell, M.J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*. 3, 253–290. DOI: 10.2307/2343100

Global Footprint Network*. Open Data Platform,* Retrieved January 24, 2022 from https://data.footprintnetwork.org/

Golany, B., & Thore, S. (1997). The economic and social performance of nations: efficiency and returns to scale. *Socio-Economic Planning Sciences*, *31*(3), 191-204. https://doi.org/10.1016/S0038-0121(96)00032-8

Halkos, G., Tzeremes N., & Kourtzidis, S. (2015). Measuring sustainable efficiency using a two-stage data envelopment analysis approach. *Journal of Industrial Ecology*, 20(5), 1159-1175. https://doi.org/10.1111/jiec.12335

He, J., Wan, Y., Feng, L., Ai, J., & Wang, Y. (2016). An integrated data envelopment analysis and energy-based ecological footprint methodology in evaluating sustainable development, a case study of Jiangsu Province, China. *Ecological Indicators*, 70, 23-34. https://doi.org/10.1016/j.ecolind.2016.05.042

Koišová, E., Grmanova, E., Škrovánková, K., & Kostrova, J. (2019). Competitiveness of regions in the Visegrád group countries. *Engineering Economics*, *30*(2), 203-210. https://doi.org/10.5755/j01.ee.30.2.21746

Koopmans, T. C. (1951). Efficient allocation of resources. *Econometrica: Journal of the Econometric Society*, 455-465. https://doi.org/10.2307/1907467

Krivonozhko, V. E., Utkin, O. B., Volodin, A. V., Sablin, I. A., & Patrin, M. (2004). Constructions of economic functions and calculations of marginal rates in DEA using parametric optimization methods. *Journal of the Operational Research Society*, *55*(10), 1049-1058. https://doi.org/10.1057/palgrave.jors.2601759

Kubiszewski, I., Costanza, R., Franco, C., Lawn, P., Talberth, J., Jackson, T., & Aylmer, C. (2013). Beyond GDP: Measuring and achieving global genuine progress. *Ecological economics*, *93*, 57-68. https://doi.org/10.1016/j.ecolecon.2013.04.019

Labaj, M., Luptacik, M., & Nezinsky, E. (2014). Data envelopment analysis for measuring economic growth in terms of welfare beyond GDP. *Empirica*, 41, 407-424. https://doi.org/https://doi.org/10.1007/s10663-014-9262-2

Lin, D., Wackernagel, M., Galli, A., & Kelly, R. (2015). Ecological footprint: informative and evolving – a response to van den Bergh and Grazi (2014). *Ecological indicators*, *58*, 464-468. https://doi.org/10.1016/j.ecolind.2015.05.001

Marcikić Horvat, A., Radovanov, B., & Sedlak, O. (2021). Comparative efficiency analysis of economic growth using a nonparametric approach . *Proceedings of The 2nd World Conference on Management, Business, and Economics, 2021*, 15-17 October 2021, Budapest (Hungary), Diamond Scientific Publishing. ISBN: 978-609-485-232-9.

Mardani, A., Zavadskas, E., Streimikiene, D., Jusoh, A., & Khoshnoudi, M. (2017). A comprehensive review of data envelopment analysis (DEA) approach in energy efficiency. *Renewable and Sustainable Energy Reviews*, 70(1), 1298-1322. https://doi.org/10.1016/j.rser.2016.12.030

Mardani, A., Streimikiene, D., Balezentis, T., Saman, M., Nor, K., & Khoshnava, S. (2018). Data envelopment analysis in energy and environmental economics: an overview of the state-of-the-art and recent development trends. *Energies*, 11(8), 2002. https://doi.org/10.3390/en11082002

Martić, M., Novaković, M., & Baggia, A. (2009). Data envelopment analysis-basic models and their utilization. *Organizacija*, *42*(2), 37-43.

Matsumoto, K., Makridou, G., & Doumpos, M. (2020). Evaluating environmental performance using data envelopment analysis: the case of European countries. *Journal of cleaner production*, 272, 122637. https://doi.org/10.1016/j.jclepro.2020.122637

Meadows, D. H., Meadows, D. H., Randers, J., & Behrens III, W. W. (1972). The limits to growth: a report to the club of Rome (1972).

Petrov, V., Trivić, N., & Ćelić, Đ. (2018). Assessing sustainability of the Southeast European economies. *Economics of Agriculture*, *65*(2), 519-529. https://doi.org/10.5937/ekoPolj1802519P

Portela, M. S., Thanassoulis, E., & Simpson, G. (2004). Negative data in DEA: a directional distance approach applied to bank branches. *Journal of the Operational Research Society*, *55*(10), 1111-1121. https://doi.org/10.1057/palgrave.jors.2601768

Rahmani S., Matin R.K., Khunsiavash M., & Moghadas Z. (2020). Cross-efficiency evaluation in data envelopment analysis with stochastic data: a chance-constrained programming approach, *Economic Computation and Economic Cybernetics Studies and Research*, 54(2), 129-149. https://doi.org/10.24818/18423264/54.2.20.08

Sachs, J. D., & McArthur, J. W. (2005). The millennium project: a plan for meeting the millennium development goals. *The Lancet*, *365*(9456), 347-353. https://doi.org/10.1016/S0140-6736(05)17791-5

Sachs, J. D. (2012). From millennium development goals to sustainable development goals. *The Lancet, 379*(9832), 2206–2211. https://doi.org/10.1016/S0140-6736(12)60685-0

Sarkis, J. (2007). Preparing your data for DEA. In *Modeling data irregularities and structural complexities in data envelopment analysis* (pp. 305-320). Springer, Boston, MA. https://doi.org/10.1007/978-0-387-71607-7_17

Sarkodie, S. A. (2021). Environmental performance, biocapacity, carbon & ecological footprint of nations: drivers, trends and mitigation options. *Science of the Total Environment*, *751*, 141912. https://doi.org/10.1016/j.scitotenv.2020.141912

Škare, M., & Rabar, D. (2016). Measuring economic growth using data envelopment analysis. *Amfiteatru Economic Journal*, *18*(42), 386-406. Available at: http://hdl.handle.net/10419/169008

Škare, M., & Rabar, D. (2017). Measuring sources of economic growth in OECD countries. *Engineering Economics*, *28*(4), 386-400. https://doi.org/10.5755/j01.ee.28.4.18502

Sueyoshi, T., Yuan, Y., & Goto, M. (2017). A literate study for DEA applied to energy and environment. *Energy Economics*, 62(1), 104-124. https://doi.org/10.1016/j.eneco.2016.11.006

United Nations Development Programme. *Human Development Data Centre,* Retrieved January 24, 2022 from http://hdr.undp.org/en/data

United Nations Millennium Summit, & United Nations. (2000). *United Nations Millennium Declaration*. New York: United Nations, Dept. of Public Information.

Van den Bergh, J. C. (2009). The GDP paradox. *Journal of Economic Psychology*, *30*(2), 117-135. https://doi.org/10.1016/j.joep.2008.12.001

Van den Bergh, J. C. (2022). A procedure for globally institutionalizing a 'beyond-GDP'metric. *Ecological Economics*, *192*, 107257. https://doi.org/10.1016/j.ecolecon.2021.107257

Wang, Z., & Feng, C. (2015). A performance evaluation of the energy, environmental, and economic efficiency and productivity in China: an application of global data envelopment analysis. *Applied Energy*, 147, 617-626. https://doi.org/https://doi.org/10.1016/j.apenergy.2015.01.108

Wang, S., Ren, H., Liang, L., Li, J., & Wang, Z. (2022). The effect of economic development on carbon intensity of human well-being: evidence from spatial econometric analyses. *Journal of Cleaner Production*, 364, 132632. https://doi.org/10.1016/j.jclepro.2022.132632

The World Bank. *World Bank Open Data,* Retrieved January 24, 2022 from https://data.worldbank.org/

✉Correspondence

Aleksandra Marcikić Horvat

University of Novi Sad, Faculty of Economics Subotica
Segedinski put 9-11, 24000, Subotica, Serbia

E-mail: aleksandra.marcikic.horvat@ef.uns.ac.rs

STRATEGIC MANAGEMENT, Vol. 29 (2024), No. 3, pp. 054-072

DOI: 10.5937/StraMan2300055D

Received: April 13, 2023
Revised: June 20, 2023
July 10, 2023
August 31, 2023
September 07, 2023
Accepted: September 11, 2023
Published online: November 01, 2023

The impact of motivation to decision on digital transformation of social entrepreneurship

Irena Đalić

University of East Sarajevo, Faculty of Transport and Traffic Engineering, Doboj, Bosnia and Herzegovina
https://orcid.org/0000-0001-9583-5403

Živko Erceg

University of East Sarajevo, Faculty of Transport and Traffic Engineering, Doboj, Bosnia and Herzegovina
https://orcid.org/0000-0002-3295-9211

Abstract

Background: Today, the digital transformation of business is one of the conditions for survival on the market. The development of digital technology is progressing rapidly, and only the business entities that keep pace with this development can expect good business results. Social entrepreneurship is an excellent way to solve the problems of social inequality and poverty and thus leads to economic growth and development.

Purpose: The main goal of this research is to create a theoretical model of digital transformation of social entrepreneurship. This model can be a useful tool for deciding on the digital transformation of business. We investigated motivation of managers and employees as an influencing factor for the digital transformation of business. We declared other influencing factors as constants.

Study design: We measured motivation by personal and professional use of the Internet, the acquisition of digital skills, the cost of labour of those who are involved in the digitisation process, and the application of data protection software. Ninety-seven social entrepreneurship entities from Bosnia and Herzegovina (B&H) participated in the research. The research was carried out using questionnaires, and we analysed the obtained data using correlation and regression methods.

Findings: The results showed that motivation is a significant factor in the digital transformation of social entrepreneurship. Based on the results of the research, we have created a model of digital transformation of social entrepreneurship entities that can lead to economic and social development through steps applicable in practice.

Limitations/future research: The most significant limitation of the research is the lack of an official register of social entrepreneurship entities from which we can collect data about the number of these entities. To future researchers, we leave open questions of other influencing factors for the development of social entrepreneurship, such as knowledge, sources of funding for initial business activities, etc.

Keywords

social entrepreneurship, motivation, managerial decision-making, digital transformation, social and economic development

Introduction

As Schumpeter's theory (1942) says, the quality of community life depends on the number of entrepreneurs (Bazhal, 2016). If everything worked as in theory, there would be neither hungry nor poor people today, and we are aware that these are big problems nowadays. However, the fact is that people who have some physical disability or other health problems cannot live normally due to the lack of understanding of the community and poor employment opportunities. It is very important to find some alternative ways of reducing social inequality and increasing the inclusion of marginalised groups of society in all economic and social streams of the community. One of the possibilities, which perhaps offers the best and highest quality solution, is the

development of social entrepreneurship. Social entrepreneurship refers to activities that seek to solve numerous social problems, that is, to transform society for the better (Gigauri, Panait, Apostu & Raimi, 2022). According to Ramadani, Agarwal, Caputo, Agrawal and Dixit (2022), a social entrepreneur (SE) is a person who uses revolutionary ideas and solutions to solve social problems. These entrepreneurs are delighted to bring about beneficial improvements through their courageous efforts and deeds. SEs accept that this approach connects them with their life's purpose and that their actions impact the world (p. 3437). Social entrepreneurship does not mean only the acquisition of profit as the basic goal of business but also the investment of that profit in solving social problems. Social entrepreneurship and social innovation is receiving increasing attention in tackling social issues (Manjon, Merino & Cairns, 2022). This research is focused on analysing the connection and relationship between the digital transformation process and the development of social entrepreneurship. Looking at social problems and becoming aware of them, a social entrepreneur must continuously offer innovative solutions for current social problems. The crisis caused by the pandemic of the COVID-19 virus is the best indicator of the importance of digitisation, ideas, innovations and knowledge.

Petković (2021) lists six technological mega trends that will shape the future of societies: "people and the Internet, computing, communications and storage everywhere, the 'Internet of things', artificial intelligence (AI) and Big data, sharing economy and distributed trust, digitisation of matter" (pp. 195-196). The positive effects of digital transformation on the development of the economy and society are immeasurable compared to the time before digitalisation. Fossen and Sorgner (2018) proved that digitisation has a positive effect on the growth and development of entrepreneurship in the United States of America (USA). Ratten (2018) and Altınay and Altınay (2018) also proved, in their research, what and how much impact digitisation has on the development of social entrepreneurship in different business spheres.

The research problem is presented by the following question: How to improve the digital transformation of social entrepreneurship entities?

This research measures the influence of motivation on the digital transformation of social entrepreneurship. Other factors are not measured. Digital transformation offers opportunities for the development of social entrepreneurship.

The research subject was determined based on the defined problem. The research subject is a theoretical-empirical analysis of motivation and its influence on the digital transformation of social entrepreneurship with special reference to Bosnia and Herzegovina (B&H). The research subject is in the field of entrepreneurial and theoretical economics. Hagberg, Sundstrom and Egels-Zandén (2016) describe digitisation as the most important transformational process in business (p. 694). Pernebrink and El Azab (2019) also talk about the importance of the speed of digitisation in business. The geographical area of research in this paper is the territory of B&H.

The theoretical part of the analysis refers to the review of relevant literature in the field of digitalisation and social entrepreneurship, as well as the impact of the digitalisation process on the development and innovation of social entrepreneurship. The empirical analysis is based on examining business entities from B&H. The research was conducted in the form of a survey with a structured questionnaire.

The development of social entrepreneurship increases employment and reduces social benefits, develops innovation and competitiveness, and has multiple positive impacts on the development of the economy and society. This research will be useful to the small and medium-sized enterprises (SMEs) sector and entrepreneurship in order to introduce advanced technologies in their business and complete the digitisation process in the fastest and easiest way. Also, this research should awaken the awareness of existing small and medium-sized enterprises and entrepreneurs about the importance of solving some social problems and that in this way both economic and social goals can be achieved. Large companies can also benefit from this research in terms of understanding the importance of digitization, the transition from traditional to modern business, and the importance and possibility of solving social problems. The public is not sufficiently familiar with both the digitalisation process and the concept and significance of social entrepreneurship, and that is why this research could raise awareness and encourage anyone who has a business idea and is thinking about starting a business to focus on this kind of business.

This paper consists of seven parts: an introduction, a literature review, a development of the hypothesis, a description of empirical research

methods, a presentation of research results, discussion and a conclusion.

1. Literature review

The concept of social entrepreneurship. Three main reasons people decide to become entrepreneurs and start their own business: "to be their own boss, to follow their ideas and achieve financial rewards" (Barringer & Ireland, 2016, p. 7). When we add the fulfilment of a social mission, i.e. solving a social problem to these reasons, we come to the concept of a social entrepreneur. The basic principles of the social economy are: democratic association and action, solidarity and cooperation (McVeigh & Wolfer, 2004, pp. 2-10). According to Martin and Osberg (2007), the term social entrepreneurship refers to those "business ventures that, in addition to generating profit for the owners, also have some (higher) social or ecological purpose" (p. 34). These companies are different from other classic for-profit companies on the market because they measure their success not only by the profit they have achieved but also by the degree of positive social or ecological changes they have produced – by the degree of created social capital (Santos, 2012, p. 344). Gawell (2014) states that social entrepreneurship implies social engagement and entrepreneurial activity. Social entrepreneurship involves recognising and solving social problems such as exclusion, poverty, unemployment, etc., applying of innovative methods and strategies. Social entrepreneurship plays a significant role in solving social problems, as confirmed by the latest research (Tan Luc, Xuan Lan, Nhat Hanh Le & Thanh Trang, 2022); Crupi, Liu & Liu, 2022; Adro & Fernandes, 2022). The Schwab Foundation for Social Entrepreneurship states that "social entrepreneurship is about the application of practical, innovative, sustainable approaches with the aim of developing society, with an emphasis on those who are marginalised and poor" (Schwabfound, n.d.). According to Dickel and Eckardt (2021), a distinction should be made between a social entrepreneur and a social enterprise. Namely, social enterprises primarily (therefore not exclusively) operate in the private non-profit sector, while social entrepreneurs, as leaders in social change, operate in the private for-profit, public and private non-profit sectors (Petković, 2021). Sengupta, Sahay and Croce (2018) formulated a new social entrepreneurship framework that includes five key dimensions of social entrepreneurship:

- social protection,
- social capital,
- social entrepreneur,
- creation of economic value, and
- collective endurance (p. 773).

Digital transformation. In the broadest sense, digitalization represents translating an analogue signal into a digital form (Brennen & Kreiss, 2016). In modern society, it represents one of the most important transformational processes both in the business world and beyond (Hagberg et al., 2016). It changes organisational structures, management strategies and relationships with customers and other companies (De Groen, Lenaerts, Bosc & Paquier 2017). Digitisation enables, improves and transforms business operations, functions, models, processes and activities through digital technologies and digitised data (Legner et al., 2017). Transformation is described as a general process that begins with a situation that moves towards a changed and, it is assumed, better situation (Gray & Rumpe, 2017, p. 307). Digital transformation is a cultural, organisational and operational change of an organisation, industry or system through smartly integrating digital technologies, processes and competencies at all levels and functions (Vial, 2019). Digital transformation uses modern and advanced technologies to create value and new services, create innovation and gain the ability to quickly adapt to the changing circumstances that characterise today's modern markets and economies (Schwertner, 2017). Digital transformation refers to a process that begins in the moment when organisation starts thinking about the introduction of digital technologies in all areas of business and lasts until the moment of their complete integration (Ebert & Duarte, 2018). However, "digital transformation also includes individuals: it is not enough to introduce digital technology into business, it is also important to train employees" (Ragulina, Suglobov & Melnik, 2018, p. 171). Digitalisation of social entrepreneurship is an inevitable process that cannot be avoided in modern society (Chandna, 2022). The latest research in this area shows how important the role of digital transformation is in achieving business results (Kraus et al., 2022; Konopik, Jahn, Schuster, Hoßbach & Pflaum, 2022; Peng & Tao, 2022; Rupeika-Apoga, Petrovska & Bule., 2022; Li, 2022).

Motivation. Robbins and Judge (2015) define motivation as a person's persistence to achieve

goals. There are three basic elements of motivation: strength, direction and persistence. The motivation of employees, which is necessary to accept digitalisation, can be achieved with the help of adequate education, in which employees gain new knowledge and thereby strengthen their self-confidence (Jha, Bilalovic, Jha, Patel & Zhang 2017). In addition to the advantages of digitisation, there are also certain disadvantages that are mainly related to employees' fear of losing their jobs. According to Roos and Shroff (2017), employees have a great fear of digitisation. According to them, the problem is rapid technological development, which can overtake human learning abilities. In other words, while workers acquire new knowledge and learn new skills, they may already become obsolete due to the exponential growth of technologies. According to Pernebrink and El Azab (2019), the reasons for workers' fear and resistance to digitisation are related to the perception of workplace threats as well as the perception of benefits from advanced technologies. In order to overcome this problem, according to Degryse (2016), it is crucial to identify the human role in work and what it is that should not be left to machines. Cejthamr (2020) believes that technological changes occurring on the market are very fast and will not stop, and that they do not leave managers who must prepare for adequate responses. The motivation of managers and employees is the key factor of digital transformation, which is a condition for survival in given changes. Motivation has a significant impact on employee results (Santoso & Riyanto, 2020; Chien, Mao, Nergui & Chang 2020; Hajiali, Kessi, Budiandriani, Prihatin & Sufri, 2022; Widarko & Anwarodin, 2022; Megawaty, Hamda & Aida, 2022; Loor-Zambrano, Santos-Roldán & Palacios-Florencio, 2022; Sugiarti, 2023). Lindawati and Parwoto (2021) proved that motivation has a significant impact on the job satisfaction of workers and management during digital transformation. Everyone in the organisation must be motivated to accept new working conditions in the digital era, especially managers who must also influence the motivation of workers in order to accept digital transformation as necessary to achieve the organization's goals.

2. Development of the research hypothesis

We will measure the motivation of managers and employees for involvement in the digitalization process by personal and professional use of the Internet, the acquisition of basic and advanced digital skills, the level of labour costs of workers who are directly or indirectly involved in the digitalisation process, and by the application of data protection and security software such as: authentication, authorisation, cryptography, digital signature, digital certificate, antivirus and firewall (Bastari, Eliyana, Syabarrudin, Arief & Emur, 2020; Chik & Abdullah, 2018). When we talk about youth unemployment, the key problems are the mismatch of competencies with the needs of employers and the lack of work experience (Prodanov, 2018). The main prerequisite for developing countries to catch up with the currents of the fourth industrial revolution is the education of managers in companies to recognise global digitisation trends, investment in the education of young people and the training of personnel for new occupations, as well as encouraging users to use online services with more confidence (Stošić-Mihajlović & Nikolić, 2017). The development of advanced digital technology has led to major changes in the market and the loss of jobs. The social entrepreneurship is a way to develop successful strategies based on feelings of solidarity, morality and social responsibility that will enable overcoming this problem (Prodanov, 2018).

Based on these studies, we define the research hypothesis (H:) *Increasing the motivation of employees and managers to participate in the digital transformation process will improve the development of social entrepreneurship entities*.

3. Methods

Empirical research conducted for the purposes of testing the research hypothesis is a combined – theoretical and quantitative research. In order to be able to form a theoretical model that will contribute to the development of social entrepreneurship, secondary and primary data were collected, processed, analysed and interpreted. As part of the theoretical research, a review of domestic and foreign literature was carried out. This part of the research gave us an insight into the current state of the research problem and enabled us to analyse the results of recent research in this area and to discuss and compare them with the results of empirical research conducted for the purposes of testing the research hypothesis and seeking answers to the research problem.

For data processing, we used automatic data processing using the Google Drive application, which displays the data from the completed

questionnaire tabularly and graphically in MS Excel.

There are quantitative methods to analyse and test hypotheses:

- Binomial distribution - probability distribution model (Sylla, 2014),

$$P(x) = \binom{n}{x} p^x q^{n-x}$$

$$x = 0,1,2,\ldots,n \quad (1)$$

$P(x) = 0$ for all other x.

- Chi square test or χ^2 test - testing the significance between the frequency of distribution and the mutual connection of different characteristics (Lovrić, Komić & Stević, 2006),

$$\chi^2 = \sum_{i=1}^{r} \frac{(f_i - f_i^*)^2}{f_i^*} \quad (2)$$

- Duncan test of variance analysis – analysis of the impact of one phenomenon to another (Duncan, 1955; Čobanović, Nikolić-Đorić & Mutavdžić, 2003),

$$R_{(p,v,\alpha)} = \sigma_m \cdot r_{(p,v,\alpha)} \quad (3)$$

Signum test – since the collected results had non-parametric characteristics that deviate from the expected binomial distributions, the Signum test was also used, and it was also used for hypothesis testing (Stević et al., 2021; Stević et al., 2019).

The population in this paper consists of business entities and non-profit organisations on the territory of B&H that are engaged in social entrepreneurship, solving a certain social problem by investing part of their profits. The sample is formed by random selection, by surveying a certain number of subjects of social entrepreneurship. The methods that were used in this research for data processing and analysis, allowed the determination of the motivation impact on making a decision about digital transformation. The influence of motivation on the digital transformation of social entrepreneurship was measured. Motivation is observed as an independent variable, and the digital transformation of social entrepreneurship as a dependent one. For the purposes of research, questionnaires were used. The first part of questionnaire refers to the general information about the subjects of social entrepreneurship. The second part of the questionnaire refers to the motivation of managers and other employees. In order to be able to compare the results of the analysis, the methods of comparison and classification, then the methods of analysis and synthesis were used. Based on the application of these methods and the results obtained, a new theoretical model is proposed in this research. This model, if applied, should contribute to improving the development of social entrepreneurship as a factor in the development of the economy and society. In the end, we compared the results obtained with the results of similar research and considered the possibilities of their application in B&H and other small open economies in development.

4. Research results, hypothesis testing and development of model

In order to verify the hypothesis, we will analyse the motivation of employees and management for digitalisation of business in social entrepreneurship entities in B&H through the questionnaire and use the results of our empirical research.

4.1. General information

Our research covered the whole territory of B&H (Table 1).

Table 1 Headquarters of subjects of social entrepreneurship that participated in the research

Number of entities	Headquarters
12	Sarajevo
11	Mostar
10	Banja Luka
4	Tuzla, Vareš
3	Prijedor, Bijeljina, Zenica, Foča, Jablanica, Brčko
2	Bratunac, Ustikolina, Konjic, East Ilidža, Doboj, Šamac, East Sarajevo.
1	Zavidovići, Teslić, Sanski Most, Olovo, Breza, Laktaši, Goražde, Gacko, Grahovo, Sapna, Sekovići, Prnjavor, Žepče, Ljubinje, Gradačac, Modriča, Kladanj, Lopare, Srebrenica, Trebinje, Domaljevac, Rogatica, Brod, Prozor-Rama.

Source: the authors

Most of the social entrepreneurship entities that participated in the research were registered as citizens' associations (28.9%), followed by limited liability companies (23.7%), then independent entrepreneurs (18.6%). 12.4% of organisations are registered as non-governmental organisations, 8.2% of organisations are registered as

cooperatives and 4.1% of organisations are registered as foundations.

The research results show that social entrepreneurship entities in B&H are engaged in various activities. 25.8% of respondents are engaged in agriculture, which is the most represented activity in the sample. In second place is trade with 22.7% participation in the total sample. In third place is the provision of psychological and health services with 9.3% participation. This is followed by tourism, education and the food industry with a 7.2% share each. There are also ecology with 5.2%, hospitality with 3.1% and finance with 2.1% participation.

The number of employees per organisation is approximately exponentially distributed, determined by the large unevenness of the number of employees. The largest, dominant group consists of companies with up to 10 employees (81), and the average number of employees is 10.092. Therefore, the research mostly covered micro-enterprises (Figure 1).

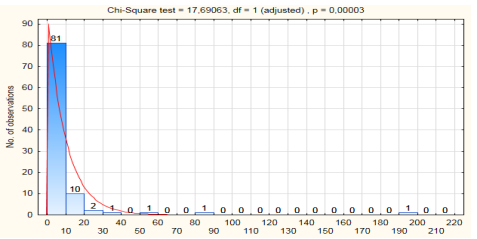

Figure 1 Histogram of the distribution of the number of employees by organization
Source: the authors

The average life expectancy of employees is normally distributed, with a mean age of 40.104 years, with a standard deviation of 6.49 years (χ^2=11.36219, df=7, p=0.12358). This distribution is shown in Figure 2.

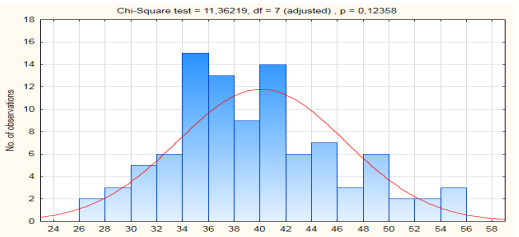

Figure 2 Histogram of the distribution of the life expectancy of employees
Source: the authors

Table 2 shows the answers to the question "What social problems does your organization deal with?". It was possible to give several answers to this question at the same time. From the analysed answers, we can conclude that the most frequent problem which organisations deal with is the inclusion of marginalised groups of society in economic flows. Next, there is the education of marginalised groups of society through various seminars and trainings, as well as health care and other problems that the respondents try to solve through their activities.

Table 2 Social problems

Solving social problems	Number of responses
Inclusion of marginalised groups of society in economic flows	83
Education of marginalised groups of society	36
Health Care	23
Ecological problems	11
Other	5

Source: the authors

To the question "We are satisfied with the level of development of social entrepreneurship in our economic environment" (with answers: (0) strongly disagree, (1) disagree, (2) agree, (3) strongly agree), the answers are reflected in general dissatisfaction. More precisely, 95 out of 97 respondents (95/97=0.9793 – absolutely insignificant binomial distribution) gave answers (eccentrically negative) from the negative domain, and only 2 answers from the positive domain, where not a single respondent had an absolute agreement with the question. The mathematical expectation of 0.4532 and the standard deviation of 0.5404 (group of 56 respondents) were realised (Figure 3).

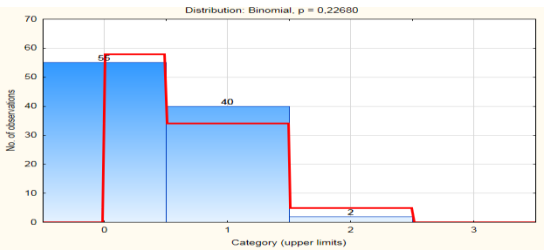

Figure 3 Histogram of significant binomial distribution of satisfaction
Source: the authors

According to the answers to this question, we see that the respondents are dissatisfied with the level of development of social entrepreneurship.

4.2. Digitalisation

The distribution of answers to the question: "Current digital skills of employees" with the following answers ((0) none, (1) weak, (2) good, (3) very good) was not verified as significant (χ^2=9.58069, df=2, p=0.0031) by binomial

distribution with parameter p=0.4398. The responses realised a mathematical expectation of 1.3196 and a standard deviation of 0.7295 with mode 1 (group of 54 respondents) (Figure 4).

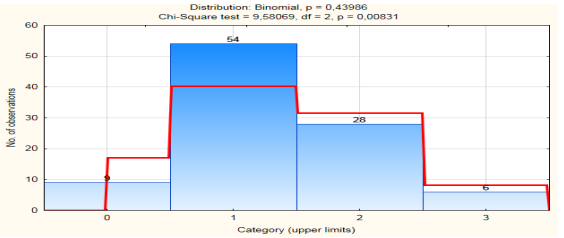

Figure 4 Histogram of the insignificantly binomial distribution of current digital skills of employees
Source: the authors

The distribution of answers to the question "The current structure of employees is a big problem in the process of digitalisation of business" with the following answers: ((0) strongly disagree, (1) disagree, (2) agree, (3) strongly agree) was verified by significant (χ^2=1.21230, df=2, p=0.5454) binomial distribution with parameter p=0.5773. Mathematical expectation of 1.7319 and standard deviation of 0.8840 with mode 2 (group of 36 respondents) were realised. A total of 57 answers are in the positive domain. This binomial distribution is centred with a slight slope to the positive response domain (Figure 5).

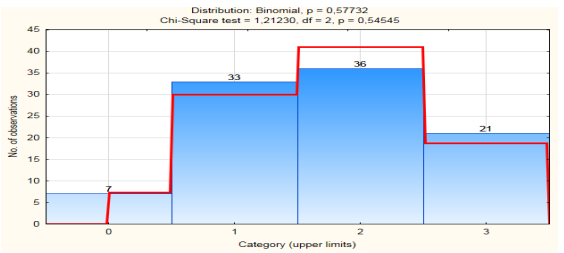

Figure 5 Histogram of significant binomial distribution of employee structure problems in the digitisation process
Source: the authors

If the question of the current digital skills of employees is considered as a factor – grouping variable, and the question "Average life expectancy of employees" from the general information section as a dependent variable, the following results of Duncan's analysis of variance test are obtained (Table 3):

Table 3 The current digital skills of employees in relation to average life expectancy

	(0)	(1)	(2)	(3)
Average:	41.111	42.849	38.036	36.833
(0) none		0.6391	0.4073	0.2796
(1) weak	0.6391		0.2235	0.1417
(2) good	0.4073	0.2235		0.7456
(3) very good	0.2796	0.1417	0.7456	

Source: the authors

The distribution of answers to the question: "How often do you use the Internet for personal reasons?" with the following answers: ((0) strongly disagree, (1) sometimes use, (2) often use, (3) constantly use) was not verified by significant (p<0.0001) binomial distribution with parameter p=0.9037. The answers to this question realised a mathematical expectation of 2.7113 and a standard deviation of 0.4554 with mode 3 (group of 69 respondents) (Figure 6).

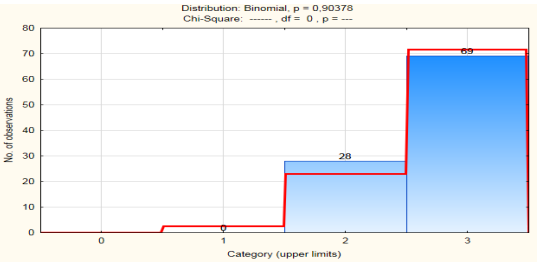

Figure 6 Histogram of non-significant binomial distribution of personal reasons for using the Internet
Source: the authors

The distribution of answers to the question: "How often do you use the Internet for professional reasons?" with the following answers: ((0) do not use at all, (1) sometimes use, (2) often use, (3) constantly use) was verified by significant (p=0.9999) binomial distribution with parameter p=0.9106. The answers to this question realised a mathematical expectation of 2.6082 and a standard deviation of 0.5506 with mode 3 (group of 73 respondents) (Figure 7).

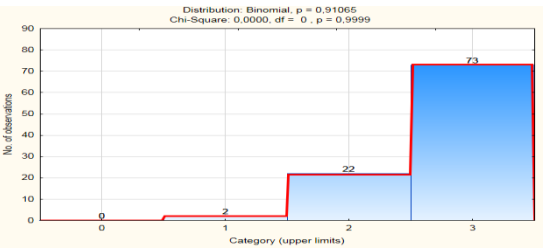

Figure 7 Histogram of significant binomial distribution of professional reasons for using the Internet
Source: the authors

The distribution of answers to the question: "The big problem of insufficient digitisation is the lack of young educated staff" with the following answers: ((0) strongly disagree, (1) disagree, (2) agree, (3) strongly agree) was verified by significant (χ^2=0.03762, df=1, p=0.8462) binomial distribution with parameter p=0.8462. The answers realised the mathematical expectation of 2.3711 and the standard deviation of 0.6819 with mode 3 (group of 47 respondents) (Figure 8).

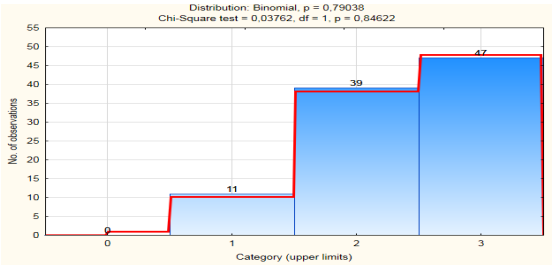

Figure 8 Histogram of the significant binomial distribution of the lack of young educated staff as a problem of insufficient digitisation
Source: the authors

The distribution of responses to the statement: "We protect data with advanced data protection software" with the following responses: ((0) strongly disagree, (1) disagree, (2) agree, (3) strongly agree) was not verified by significance (χ^2=20.03368, df=1, p<0.0001) by binomial distribution with parameter p=0.3058. The responses realised the mathematical expectation of 0.9175 and the standard deviation of 1.0172 with mode 1 (group of 46 respondents) (Figure 9).

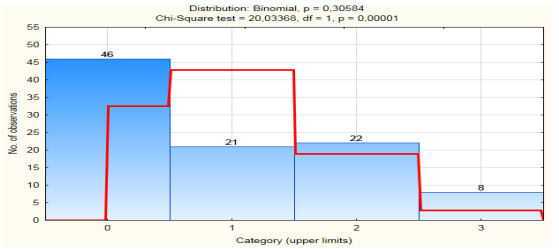

Figure 9 Histogram of non-significant binomial distribution of data protection with advanced software
Source: the authors

4.3. Motivation

Distribution of responses to the statement: "Employees are motivated to acquire skills and knowledge necessary for the application of digital technologies" with the following answers: ((0) strongly disagree, (1) disagree, (2) agree, (3) strongly agree) was not verified by a significant (χ^2=17.94343, df=2, p=0.0001) binomial distribution with parameter p=0.6118. The responses realized a mathematical expectation of 1.8351 and a standard deviation of 0.6069 with mode 2 (group of 59 respondents) (Figure 10).

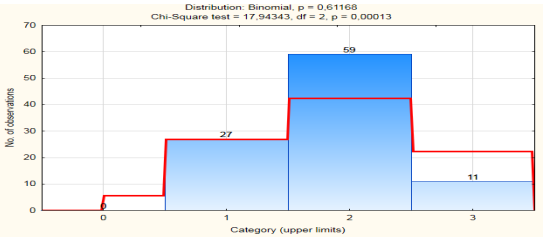

Figure 10 Histogram of non-significant binomial distribution of motivation for acquiring skills and knowledge necessary for the application of digital technologies
Source: the authors

The distribution of answers to the question: "Employees are motivated to acquire skills and knowledge necessary for the application of digital technologies" was not verified by a significant binomial distribution (p=0.0001) and had the following answers respectively:

(0) strongly disagree	0
(1) disagree	27
(2) agree	59
(3) strongly agree	11

Mathematical expectation of 1.8351 with mode 2 (group of 59 respondents) is in agreement with the answer "I agree" in relation to the motivation of employees to acquire the skills and knowledge necessary for the application of digital technologies. If we take the answer to the question "Employees are motivated to acquire skills and knowledge necessary for the application of digital technologies" as a factor, and the question: "Current digital skills of employees" as a dependent variable, we get the following results of Duncan's analysis of variance test (Table 4):

Table 4 Employee motivation in relation to current digital skills

	(0)	(1)	(2)	(3)
Average:	/	0.7407	1.3898	2.3636
strongly disagree	/	/	/	/
disagree	/	0.0005		0.0001
agree	/	0.0001	0.0001	
strongly agree	/		0.0005	0.0001

Source: the authors

The distribution of responses to the statements "Employees are motivated to acquire skills and knowledge necessary for the application of digital technologies" and "Current digital skills of employees" was not verified by binomial distributions, so we conclude that part of the answers was subjective. Let us remind: the average value of employees' digital skills was 1.3196. Regardless of the subjectivity of the answer, we unreservedly conclude that the perceived motivation of employees is a key factor in the

current digital skills of employees! All the values in Table 4 (there was no answer "strongly disagree") highlight significant differences!

If the statement "The current structure of employees is a big problem in the process of digitalisation of business" is considered as a factor - grouping variable, and the statement "Employees are motivated to acquire the skills and knowledge necessary for the application of digital technologies" as a dependent variable, the following results of Duncan's analysis of variance test are obtained (Table 5):

Table 5. The influence of the current structure of employees on the motivation to acquire skills and knowledge necessary for the application of digital technologies

	(0)	(1)	(2)	(3)
Average:	2.5714	2.2121	1.5278	1.5223
none		0.0365	0.0001	0.0000
weak	0.0365		0.0002	0.0002
good	0.0001	0.0002		0.9814
very good	0.0000	0.0002	0.9814	

Source: the authors

The distribution of responses to the statement "Employees are motivated to acquire skills and knowledge necessary for the application of digital technologies,, was not verified by binomial distribution, so we conclude that part of the answers was subjective. However, we still conclude that the structure of employees has a significant influence on the motivation of employees to acquire skills and knowledge necessary for the application of digital technologies.

Distribution of responses to the statement: "Trainer expertise affects employees' motivation for digital skills training" with the following responses ((0) strongly disagree, (1) disagree, (2) agree, (3) strongly agree) was not verified by a significant ($p<0.0001$) binomial distribution with parameter $p=0.8694$. The responses realised a mathematical expectation of 2.7319 and a standard deviation of 0.4898 with mode 3 (group of 61 respondents) (Figure 11).

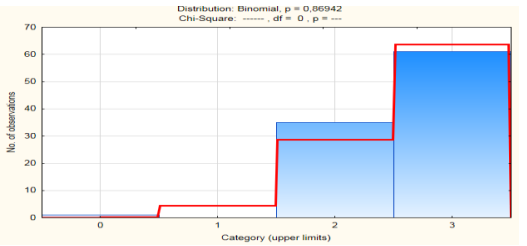

Figure 11 Histogram of the non-significant binomial distribution of the influence of the trainer's expertise on the motivation of workers
Source: the authors

Distribution of responses to the statement: "Acquiring digital skills through training and learning increases the motivation of employees to apply digital technologies" with the following answers: ((0) strongly disagree, (1) disagree, (2) agree, (3) strongly agree) was not verified by a significant ($p<0.0001$) binomial distribution with parameter $p=0.8625$. The responses realized a mathematical expectation of 2.5876 and a standard deviation of 0.5543 with mode 3 (group of 59 respondents) (Figure 12).

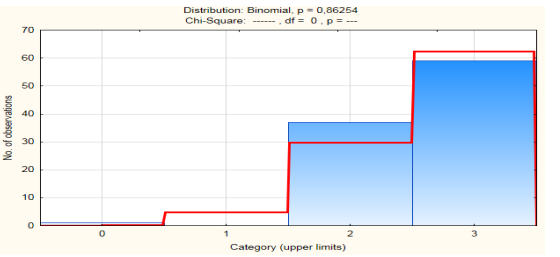

Figure 12 Histogram of the non-significant binomial distribution of the impact of acquiring digital skills through training and learning on increasing the motivation of workers to apply digital technologies
Source: the authors

For the question: "Earnings of employees who are directly or indirectly involved in the digitisation process in the next 3 to 5 years" with the following answers: ((1) will decrease, (2) remain the same, (3) will increase), the answers realised mathematical expectation of 1.2371 and standard deviation of 0.4512 with mode 2 (group of 72 respondents), i.e. the majority of respondents believe that the earnings of employees will stagnate (Figure 13).

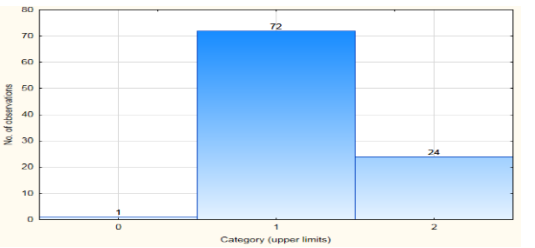

Figure 13 Histogram of the distribution of changes in the earnings of workers in the next 3 to 5 years
Source: the authors

Distribution of responses to the statement: "Older employees are less motivated to get involved in the digitization process" with the following answers ((0) strongly disagree, (1) disagree, (2) agree, (3) strongly agree) was verified by a significant ($\chi^2=0.27756$, df=1, $p=0.5983$) binomial distribution with parameter $p=0.7972$. The answers realized the mathematical expectation

of 2.3917 and the standard deviation of 0.7438 with mode 3 (group of 51 respondents) (Figure 14).

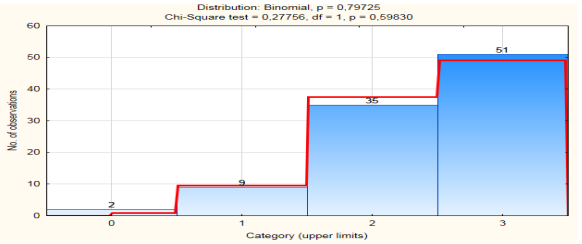

Figure 14 Histogram of the significant binomial distribution of the motivation of older workers for inclusion in the digitisation process
Source: the authors

The distribution of responses to the statement: "For data protection we use (you can choose several responses at the same time)" gave the following results:

- Authentication 12
- Authorisation 27
- Cryptography 1
- Digital signature 2
- Digital certificate 0
- Antiviruses 86
- Firewall 25
- Password 1
- None 1

Responses: Cryptography (1), Digital signature (2), Digital certificate (0), Password (1) and None (1) were not considered as a factor due to the small number of respondents who highlighted them. Also, the answer Antiviruses (86) was not considered as a factor due to the large number of respondents who highlighted them.

The impact of data protection by *authentication* as a factor:

- on the distribution of answers to the question: "How often do you use the Internet for personal reasons?" showed a significant impact (p=0.0036). Respondents who use authentication had an average value of 3.000, and among respondents who do not use authentication, this value was 2.650. *Respondents who use the Internet more often for personal reasons significantly apply authentication as a protection system*;
- on the distribution of answers to the question: "How often do you use the Internet for professional reasons?" showed a significant impact (p=0.0123). Respondents who use authentication had a significantly higher average value of 3.000, and for respondents who do not use authentication, this value was 2.675. *Respondents who use the Internet more often for professional reasons significantly apply authentication as a protection system*;
- on the distribution of responses to the statement: "The expertise of the trainer affects the motivation of employees to acquire digital skills" showed a significant impact (p=0.0231). Respondents who use authentication had a significantly higher average value of 2.882, and among respondents who do not use authentication, this value was 2.550. *Respondents who apply authentication as a protection system significantly emphasise the importance of the trainer's expertise on the motivation to acquire digital skills*;
- on the distribution of responses to the statement: "Acquiring digital skills through training and learning increases the motivation of employees to apply digital technologies" showed a significant impact (p=0.0151). Respondents who use authentication had a significantly higher average value of 2.882, and among respondents who do not use authentication, this value was 2.525. *Respondents who apply authentication as a protection system significantly emphasise the importance of training and learning on the motivation to acquire digital skills*;
- on the distribution of responses to the statement: "Earnings of employees who are directly or indirectly involved in the digitisation process in the next 3 to 5 years" showed a significant impact (p=0.0001). Respondents who use authentication had a significantly higher average value of 1.7059, and among respondents who do not use authentication, this value was 1.1375. *Respondents who use authentication have a significantly higher belief in the growth of earnings in the next 3 to 5 years*;
- on the distribution of responses to the statement: "We protect data with advanced data protection software" showed a significant impact (p=0.0001). Respondents who use authentication had a

significantly higher average value of 2.4118, and among respondents who do not use authentication, this value was 0.6000. *Respondents who use authentication are fully aware of the potential of protection, while respondents who do not use it are aware of the fact that their data is not protected (there is an extremely large difference in ratings)*;

- the distribution of responses to the statement: "Older employees are less motivated to get involved in the digitisation process" did not show a significant impact (p=0.0945). Respondents who use authentication had an average value of 2.1176, and among respondents who do not use authentication, this value was 2.4500. This means that *the approach to the application of authentication does not create differences in the motivation of older employees for involvement in the digitisation process*;
- on the distribution of responses to the statement: "The big problem of insufficient digitization is the lack of young educated staff" did not show a significant impact (p=0.1965). Respondents who use authentication had an average value of 2.1765, and among respondents who do not use authentication, this value was 2.4125. This means that *the approach to the application of authentication is not related to the lack of young educated staff.*

The impact of data protection by *authorization* as a factor:

- on the distribution of answers to the question: "How often do you use the Internet for personal reasons?" showed a significant impact (p=0.0006). Respondents who use authorization had an average value of 2.9630, and among respondents who do not use authorization, this value was 2.6143. *Respondents who use the Internet more often for personal reasons significantly use authorization as a protection system*;
- on the distribution of answers to the question: "How often do you use the Internet for professional reasons?" showed a significant impact (p=0.0035). Respondents who use authorisation had a significantly higher average value of 2.9630, and among respondents who do not use authorization, this value was 2.6420. *Respondents who use the Internet more often for professional reasons significantly use authorization as a protection system*;
- on the distribution of responses to the statement: "The expertise of the trainer affects the motivation of employees to acquire digital skills" showed a significant impact (p=0.0004). Respondents who use authorisation had a significantly higher average value of 2.9259, and among respondents who do not use authorization, this value was 2.4857. *Respondents who apply authorisation as a protection system significantly emphasise the importance of the trainer's expertise on motivation to acquire digital skills*;
- on the distribution of responses to the statement: "Acquiring digital skills through training and learning increases the motivation of employees to apply digital technologies" showed a significant impact (p=0.0032). Respondents who use authorisation had a significantly higher average value of 2.8519, and among respondents who do not use authorisation, this value was 2.4857. *Respondents who apply authorisation as a protection system significantly emphasise the importance of training and learning on the motivation to acquire digital skills*;
- on the distribution of responses to the statement: "Earnings of employees who are directly or indirectly involved in the digitization process in the next 3 to 5 years" showed a significant impact (p=0.0001). Respondents who use authorization had a significantly higher average value of 1.5926, and among respondents who do not use authorization, this value was 1.1000. *Respondents who use authorization have a significantly higher belief in the growth of earnings in the next 3 to 5 years*;
- on the distribution of responses to the statement: "We protect data with advanced data protection software" showed a significant impact (p=0.0001). Respondents who use authorisation had a significantly higher average value of 1.8889, and among respondents who do not use authorisation, this value was

0.5428. *Respondents who use authorisation are fully aware of the potential of protection, while respondents who do not use it are aware of the fact that their data is not protected (there is an extremely large difference in ratings)*;

- on the distribution of responses to the statement: "Older employees are less motivated to get involved in the digitisation process" did not show a significant impact (p=0.1794). Respondents who use authorisation had an average value of 2.5556, and among respondents who do not use authorisation, this value was 2.3286. This means *that the approach to the application of authorisation does not create differences in the motivation of older employees for involvement in the digitisation process*;
- on the distribution of responses to the statement: "The big problem of insufficient digitisation is the lack of young educated staff" did not show a significant impact (p=0.5050). Respondents who use authorisation had an average value of 2.2963, and among respondents who do not use authorisation, this value was 2.4000. This means that *the approach to the application of authorisation is not related to the lack of young educated staff.*

The impact of data protection by firewall as a factor is:

- on the distribution of answers to the question: "How often do you use the Internet for personal reasons?" showed a significant impact (p=0.0072). Respondents who use a firewall had an average value of 2.9200, and among respondents who do not use a firewall, this value was 2.6389. *Respondents who use the Internet more often for personal reasons significantly use a firewall as a protection system*;
- on the distribution of answers to the question: "How often do you use the Internet for professional reasons?" showed a significant impact (p=0.0063). Respondents who use a firewall had a significantly higher average value of 2.9600, and among respondents who do not use a firewall, this value was 2.6528. *Respondents who use the Internet more often for professional reasons significantly use a firewall as a protection system*;
- on the distribution of responses to the statement: "The expertise of the trainer affects the motivation of employees to acquire digital skills" showed a significant impact (p=0.0427). Respondents who use a firewall had a significantly higher average value of 2.8000, and among respondents who do not use a firewall, this value was 2.5417. *Respondents who use a firewall as a protection system significantly emphasise the importance of the trainers' expertise on motivation to acquire digital skills*;
- on the distribution of responses to the statement: "Acquiring digital skills through training and learning increases the motivation of employees to apply digital technologies" showed a significant impact (p=0.0255). Respondents who use a firewall had a significantly higher average value of 2.8000, and among respondents who do not use a firewall, this value was 2.5139. *Respondents who apply a firewall as a protection system significantly emphasise the importance of training and learning on the motivation to acquire digital skills*;
- on the distribution of responses to the statement: "Earnings of employees who are directly or indirectly involved in the digitisation process in the next 3 to 5 years" showed a significant impact (p=0.0001). Respondents who use a firewall had a significantly higher average value of 1.5600, and among respondents who do not use a firewall, this value was 1.1250. *Respondents who use a firewall have a significantly higher belief in the growth of earnings in the next 3 to 5 years*;
- on the distribution of responses to the statement: "We protect data with advanced data protection software" showed a significant impact (p=0.0001). Respondents who use a firewall had a significantly higher average value of 2.0000, and among respondents who do not use a firewall, this value was 0.5416. *Respondents who use a firewall are fully aware of the potential of protection, while respondents who do not use it are aware of the fact that their data is not protected*

(there is an extremely large difference in ratings);

- on the distribution of responses to the statement: "Older employees are less motivated to get involved in the digitisation process" did not show a significant impact (p=0.8059). Respondents who use a firewall had an average value of 2.3600, and among respondents who do not use a firewall, this value was 2.4028. This means *that the approach to the application of firewall does not create differences in the motivation of older employees for involvement in the digitisation process*;
- on the distribution of responses to the statement: "The big problem of insufficient digitisation is the lack of young educated staff" did not show a significant impact (p=0.80705). Respondents who use a firewall had an average value of 2.4000, and among respondents who do not use a firewall, this value was 2.3611. This means that *the approach to the application of firewall is not related to the lack of young educated staff.*

Relations of distributions of the answers to the questions from "How often do you use the Internet for personal reasons?" to "Acquiring digital skills through training and learning increases the motivation of employees to apply digital technologies" (Q1, Q2, Q3, Q4), "Older employees are less motivated to get involved in the digitisation process" (Q5) and "The big problem of insufficient digitisation is the lack of young educated staff" (Q6) were compared by Signum tests. The results are given in Table 6:

Table 6 Signum tests the agreement of the distribution

Signum distribution tests	Questions from the Questionnaire					
	Q1	Q2	Q3	Q4	Q5	Q6
	(2.7113)	(2.7319)	(2.6082)	(2.5876)	(2.3917)	(2.3711)
(2.7113)		0.7518	0.0665	0.0291	0.0051	0.0017
(2.7319)	0.7518		0.0550	0.0247	0.0011	0.0002
(2.6082)	0.0665	0.0550		0.6171	0.0736	0.0223
(2.5876)	0.0291	0.0247	0.6171		0.1124	0.0162
(2.3917)	0.0051	0.0011	0.0736	0.1124		0.8445
(2.3711)	0.0017	0.0002	0.0223	0.0162	0.8445	

Source: the authors

Respondents who, for personal and professional reasons, often or constantly use the Internet believe that the expertise of trainers has a significant impact on the motivation of employees to acquire digital skills through training and learning, but generally do not believe that acquiring digital skills through training and learning increases the motivation of employees to apply digital technologies. This means that the training was evaluated by respondents who use the Internet intensively only in the case when it was conducted by an expert trainer!

Also, respondents who often or constantly use the Internet for personal and professional reasons do not think that older employees are less motivated to get involved in the digitisation process and do not think that the big problem of insufficient digitisation is the lack of young educated staff. This means that respondents who use the Internet intensively believe that even older workers can use the Internet with the same intensity!

Respondents who especially evaluate the expertise of the trainers believe that older employees are less motivated to get involved in the digitalisation process and do not believe that the major problem of insufficient digitalisation is the lack of young, educated staff. This means that respondents who emphasise the expertise of trainers believe that the professional trainers do not pay enough attention to older employees, that older employees can achieve the necessary level for inclusion in digitisation processes and that the lack of young staff is not crucial for favourable digitisation.

Respondents who value training believe that older employees are less motivated to get involved in the digitalisation process and do not believe that the major problem of insufficient digitalisation is the lack of young, educated staff. This means that respondents who emphasise the value of training and learning believe that older employees are not given the chance to train and learn, that older employees can achieve the necessary level for inclusion in digitisation processes and that the lack

of young staff is not crucial for favourable digitisation.

All those who believe that older employees are less motivated to participate in the digitalisation process also believe that a major problem of insufficient digitalisation is the lack of young, educated staff. The answer to these questions brings us back to the importance of the trainer's expertise, training and learning! The motivation of employees, which is necessary to accept digitalisation, can be achieved with the help of adequate education, in which employees gain new knowledge and thereby strengthen their self-confidence (Jha et al., 2017). The main prerequisite for developing countries to catch up the fourth industrial revolution is the education of managers to recognise global digitisation trends, investment in the education of young people and the training of personnel for new occupations, as well as encouraging employees to use online services with more confidence (Stošić-Mihajlović & Nikolić, 2017). Motivation positively and significantly affects the use of websites and other digitisation applications (Bastari, Eliyana, Syabarrudin, Arief, & Emur, 2020, p. 6). Motivation is a factor that has a significant impact which is associated with certain forms of technology use (Henry & Lamb, 2019, p. 614). Motivation plays an important role in the development of digital competences and the ability to use digital technologies (Beardsley, Albó, Aragón & Hernández-Leo, 2021, p. 1458).

According to the results of the research, we conclude that improving the motivation of employees and managers to participate in the digital transformation process will contribute to the development of social entrepreneurship entities, and we *confirm the hypothesis*.

4.4. Model of development of social entrepreneurship

In this part of the paper, we will propose certain steps that could create the conditions for the digitisation of social entrepreneurship entities and thereby enable the development of social entrepreneurship and the improvement of the economic and social image of B&H measured through the increase in the inclusion of marginalised groups in economic and social flows, the increase in the number of employees, the reduction of social support and poverty rates, reducing the number of ecological problems and increasing the rate of economic growth in B&H. We will present these steps with the model shown in Figure 15.

It is necessary to speed up the process of digital transformation of social entrepreneurship entities by providing sufficient motivation, removing the fear of job loss due to digitalisation, through training and increasing managers' understanding of the importance of digitalisation in the struggle to achieve competitive advantages in modern business conditions. In order to encourage the digital transformation of social entrepreneurship, it is necessary to increase the motivation of employees and managers to participate in the digitalisation process through the engagement of quality and expert consultants for the application of digitalisation, the creation and implementation of an incentive system of human resource management (increase in earnings, monetary rewards, advancement in work, incentive working hours, etc.), adaptation of the education and training program to older employees and finally through the provision of data protection and security using various softwares (antiviruses, cryptography, firewall, authentication, etc.). All the mentioned would improve the process of digitisation of social entrepreneurship entities. This would lead to the inclusion of marginalised social groups in economic flows, better social and health protection of these groups, reduction of social helps from the state budget, reduction of poverty and unemployment rates and finally to the increase of economic growth. All this would have a positive impact on the economy of B&H.

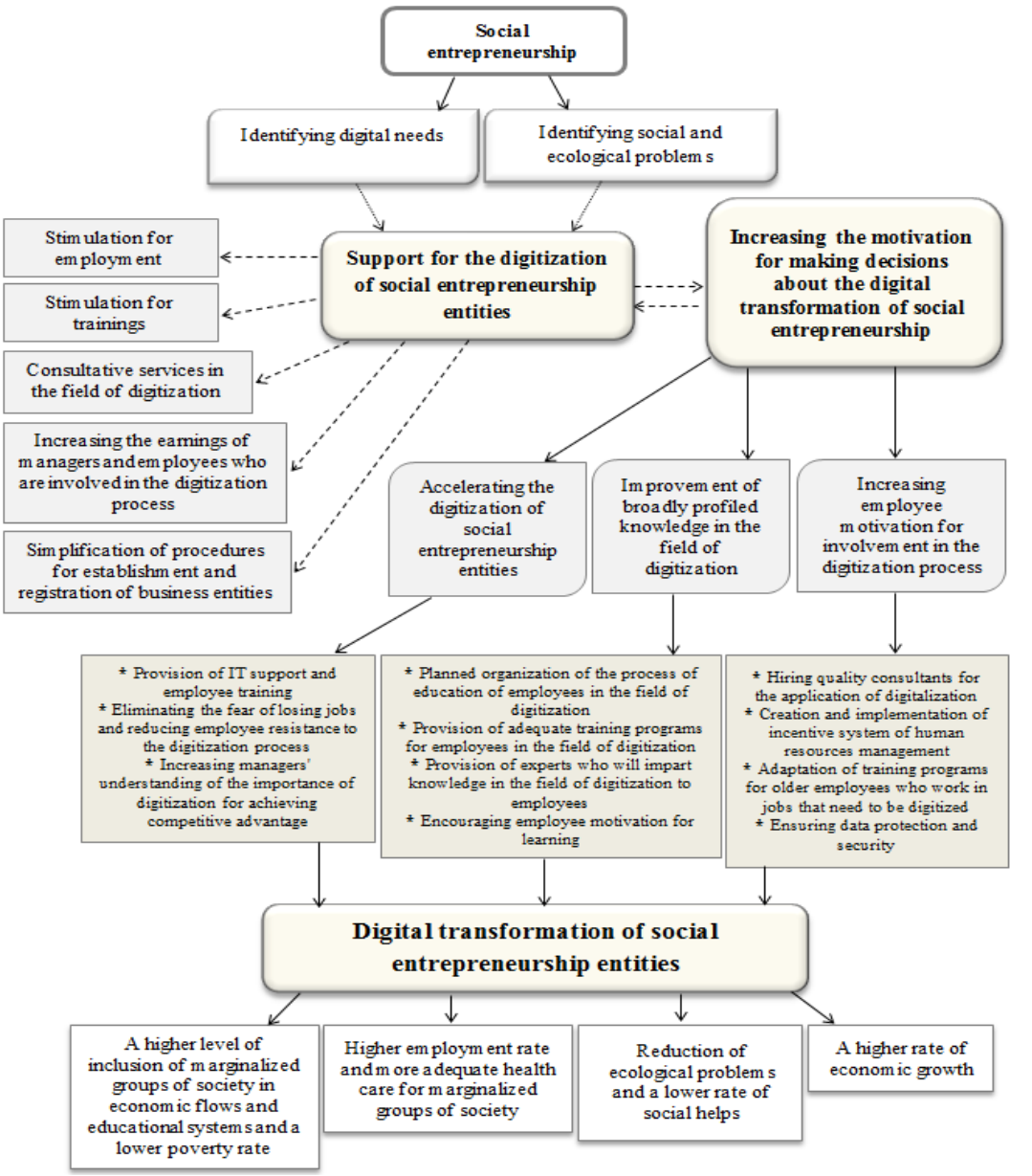

Figure 15 A model of digital transformation of social entrepreneurship entities
Source: the authors

5. Discussion

Gabryelczyk, Sipior and Biernikowicz (2022) investigate the importance of motivation in making decisions about the digital transformation of business. These authors define motivation as "the goals that an institution pursues and the vigor with which it pursues those goals" (p. 1). The motivations on which the organizational change of business processes is based are an indispensable element of decision-making. Their research shows that motivation is the main factor used in the decision to implement digital transformation. These authors also developed a model by which a motivational framework can help researchers and practitioners think broadly about the potential benefits of digitization at a time when digital transformation is accelerating. Carell, Lauenroth and Platz (2018) also showed the importance of managers' motivation for making decisions about the digital transformation of business. The research was carried out on two real business examples where their design thinking model was applied. Here, it was also shown that the digital

transformation of business has numerous advantages compared to the traditional way of business.

Demir (2021) investigates the effects of digitalisation on social entrepreneurship and social value. The geographical area of the research refers to European countries. This author states that the limiting circumstance of the research is the lack of studies dealing with this topic. He came to the conclusion that there is a strong connection between the increase in the digitisation process and the development of social entrepreneurship, especially after the COVID-19 crisis. Torres and Augusto (Torres & Augusto, 2020) made a quantitative comparative analysis of the impact of digitalisation and social entrepreneurship on national well-being. The results of this research show that digitisation has an important impact on national well-being. However, the absence of social entrepreneurship can contribute to a low level of national well-being in countries that show a low level of digitisation, poor education systems and inadequate management. Thus, the results support the idea that social entrepreneurship is more important in countries where governments fail to meet social needs.

Conclusion

Twenty-seven subjects of social entrepreneurship from all over B&H participated in this research. It was impossible to find the exact number of subjects of social entrepreneurship on the territory of B&H. Not a single competent institution has information about it. The sample of respondents was formed in various ways, through social entrepreneurship forums and associations and by respondents sharing the questionnaires among themselves. So, the exact population of social entrepreneurship subjects in B&H remains unknown. The research showed that social entrepreneurship is at a low level of development. The conclusion is that there is not enough understanding of the importance of this area of economic activity. Through research, it is shown how important motivation is for making decisions about digital transformation and how important digital transformation is for the development of social entrepreneurship. This can be seen from the reviewed literature, as well as from the results of empirical research. The conclusion is that motivation would contribute to the digital transformation of social entrepreneurship. As a result, a model of several steps was developed in order to provide digital transformation of social entrepreneurship. This would contribute to the development of social entrepreneurship. As the developed model shows, the improved development of social entrepreneurship would lead to a reduction in unemployment, a reduction in social support, a reduction in ecological problems, better health care, that is, to the development of society and the economy.

The scientific and pragmatic contribution of the research. The scientific contribution is reflected in the analytical, theoretical and empirical significance of this research. The *analytical* significance of the research represents the possibility of determining the development direction of B&H, as well as the proposed new model of steps that will enable the digital transformation. In that way, this model will enable the development of social entrepreneurship, which will increase the competitiveness of this sector and thus ensure the strengthening of the economy and society. This research contributes to the existing *theories* in this field of research. Researching the literature, we came to the conclusion that this is still an under-researched area in domestic and foreign literature. There is a small number of papers that deal with the connection between motivation and digital transformation. Results of *empirical* research proved that motivation affects the digital transformation and that social entrepreneurship contribute to the development of economy and society.

The pragmatic contribution is reflected in enabling the application of the obtained results in practice, and that will be useful for *decision-makers* in social entrepreneurship entities, because it shows the advantages of digital transformation of social entrepreneurship development. This research will contribute to *investors* to getting know about the advantages of social entrepreneurship. The obtained results will also be useful to the *academic community*, which will be able to learn more about the role and significance of the motivation in making a decision about the digital transformation and about the development of social entrepreneurship. Considering that the research in this area is relatively recent, this paper will arouse greater interest in the academic community for research in this field. The research can be interesting to the *general public* because it shows the significance of the development of social entrepreneurship, which should be the driving force for solving economic and social problems in developing countries.

Limitation of the research. The biggest problem relates to the collection of data about the number of subjects of social entrepreneurship in B&H. Not a single institution that deals with business entities and entrepreneurship has any data about the number of subjects of social entrepreneurship, nor which of the registered business entities are engaged in social entrepreneurship.

Future research. We leave open the questions about the number of subjects of social entrepreneurship to future researchers, questions of other influencing factors on the development of social entrepreneurship such as knowledge, sources of funding for initial business activities, etc. Future researchers can deal with obstacles to the development of social entrepreneurship in underdeveloped countries, as well as their elimination. Future researches could be focused on innovating business models and the importance of innovation in social entrepreneurship.

References

Adro, F. D., & Fernandes, C. (2022). Social entrepreneurship and social innovation: Looking inside the box and moving out of it. *Innovation: The European Journal of Social Science Research*, *35*(4), 704-730. https://doi.org/10.1080/13511610.2020.1870441

Altınay, F., & Altınay, Z. (2018). Women as social entrepreneurship and use of technology. *European Journal of Sustainable Development*, *7*(3), 183-183. http://dx.doi.org/10.14207/ejsd.2018.v7n3p183

Barringer, B. R., & Ireland, R. D. (2016). *Entrepreneurship: Successfully launching new ventures*. Upper Saddle River: Prentice Hall.

Bastari, A., Eliyana, A., Syabarrudin, A., Arief, Z., & Emur, A. P. (2020). Digitalization in banking sector: the role of intrinsic motivation. *Heliyon*, *6*(12), e05801. http://dx.doi.org/10.1016/j.heliyon.2020.e05801

Bazhal, I. (2016). The theory of economic development of JA Schumpeter: key features. https://mpra.ub.uni-muenchen.de/69883/

Beardsley, M., Albó, L., Aragón, P., & Hernández-Leo, D. (2021). Emergency education effects on teacher abilities and motivation to use digital technologies. *British Journal of Educational Technology*, *52*(4), 1455-1477. https://doi.org/10.1111/bjet.13101

Brennen, J. S., & Kreiss, D. (2016). Digitalization. *The international encyclopedia of communication theory and philosophy*, 1-11. https://doi.org/10.1002/9781118766804.wbiect111

Carell, A., Lauenroth, K., & Platz, D. (2018). Using design thinking for requirements engineering in the context of digitalization and digital transformation: a motivation and an experience report. *The Essence of Software Engineering*, 107-120. http://dx.doi.org/10.1007/978-3-319-73897-0_7

Cejthamr, V. (2020). Redefining motivation in digital transformation: employee motivation in a flat organization. In *Examining Cultural Perspectives in a Globalized World* (pp. 141-173). IGI Global. http://dx.doi.org/10.4018/978-1-7998-0214-3.ch007

Chandna, V. (2022). Social entrepreneurship and digital platforms: Crowdfunding in the sharing-economy era. *Business Horizons*, *65*(1), 21-31. https://doi.org/10.1016/j.bushor.2021.09.005

Chien, G. C., Mao, I., Nergui, E., & Chang, W. (2020). The effect of work motivation on employee performance: Empirical evidence from 4-star hotels in Mongolia. *Journal of Human Resources in Hospitality & Tourism*, *19*(4), 473-495. http://dx.doi.org/10.1080/15332845.2020.1763766

Chik, Z., & Abdullah, A. H. (2018). Developing and validating instruments for measurement of motivation, learning styles and learning disciplines for academic achievement. *International Journal of Academic Research in Business and Social Sciences*, *8*(4), 594-605. http://dx.doi.org/10.6007/IJARBSS/v8-i4/4035

Crupi, A., Liu, S., & Liu, W. (2022). The top-down pattern of social innovation and social entrepreneurship. Bricolage and agility in response to COVID-19: cases from China. *R&D Management*, *52*(2), 313-330. https://doi.org/10.1111/radm.12499

Čobanović, K. J., Nikolić-Đorić, E. B., & Mutavdžić, B. C. (2003). Multiple comparison tests. *Letopis naučnih radova Poljoprivrednog fakulteta*, *27*(1), 66-73. https://scindeks.ceon.rs/article.aspx?artid=0546-82640301066C

De Groen, W. P., Lenaerts, K., Bosc, R., & Paquier, F. (2017). Impact of digitalization and the on-demand economy on labor markets and the consequences for employment and industrial relations. Final Study. CEPS Special Report, August 2017. https://www.eesc.europa.eu/sites/default/files/resources/docs/qe-02-17-763-en-n.pdf

Degryse, C. (2016). Digitalization of the economy and its impact on labor markets. *ETUI research paper-working paper*. http://dx.doi.org/10.2139/ssrn.2730550

Demir, H. C. (2021). The effects of digitalization on social entrepreneurship and social value. In *Creating Social Value through Social Entrepreneurship* (pp. 102-119). IGI Global. http://dx.doi.org/10.4018/978-1-7998-4727-4.ch006

Dickel, P., & Eckardt, G. (2021). Who wants to be a social entrepreneur? The role of gender and sustainability orientation. *Journal of Small Business Management*, *59*(1), 196-218. http://dx.doi.org/10.1080/00472778.2019.1704489

Duncan, D. B. (1955). Multiple range and multiple F tests. *Biometrics*, *11*(1), 1-42. https://doi.org/10.2307/3001478

Ebert, C., & Duarte, C. H. C. (2018). Digital transformation. *IEEE Softw.*, *35*(4), 16-21. http://dx.doi.org/10.1109/MS.2018.2801537

Fossen, F. M., & Sorgner, A. (2018). The effects of digitalization on employment and entrepreneurship. In *conference proceeding paper, IZA–Institute of Labour Economics*. https://conference.iza.org/conference_files/MacroEcon_2018/sorgner_a21493.pdf

Gabryelczyk, R., Sipior, J. C., & Biernikowicz, A. (2022). Motivations to adopt BPM in view of digital transformation. *Information Systems Management*, 1-17. http://dx.doi.org/10.1080/10580530.2022.2163324

Gawell, M. (2014). Soci(et)al entrepreneurship and different forms of social enterprise. *Social entrepreneurship: Leveraging economic, political, and cultural dimensions*, 23-41. http://dx.doi.org/10.1007/978-3-319-01396-1_2

Gigauri, I., Panait, M., Apostu, S. A., & Raimi, L. (2022). The essence of social entrepreneurship through a Georgian lens: social entrepreneurs' perspectives. *Administrative Sciences*, *12*(3), 75. https://doi.org/10.3390/admsci12030075

Gray, J., & Rumpe, B. (2017). Models for the digital transformation. *Software & Systems Modeling*, *16*, 307-308. http://dx.doi.org/10.1007/s10270-017-0596-7

Hagberg, J., Sundstrom, M., & Egels-Zandén, N. (2016). The digitalization of retailing: an exploratory framework. *International Journal of Retail & Distribution Management*, *44*(7), 694-712. http://dx.doi.org/10.1108/IJRDM-09-2015-014001

Henry, A., & Lamb, M. (2019). L2 motivation and digital technologies. *The Palgrave handbook of motivation for language learning*, 599-619. https://doi.org/10.1007/978-3-030-28380-3_29

Hajiali, I., Kessi, A. M. F., Budiandriani, B., Prihatin, E., & Sufri, M. M. (2022). Determination of work motivation, leadership style, employee competence on job satisfaction and employee performance. *Golden Ratio of Human Resource Management*, *2*(1), 57-69. https://doi.org/10.52970/grhrm.v2i1.160

Jha, S. K., Bilalovic, J., Jha, A., Patel, N., & Zhang, H. (2017). Renewable energy: Present research and future scope of Artificial Intelligence. *Renewable and Sustainable Energy Reviews*, *77*, 297-317. http://dx.doi.org/10.1016/j.rser.2017.04.018

Kraus, S., Durst, S., Ferreira, J. J., Veiga, P., Kailer, N., & Weinmann, A. (2022). Digital transformation in business and management research: an overview of the current status quo. *International Journal of Information Management*, *63*, 102466. https://doi.org/10.1016/j.ijinfomgt.2021.102466

Konopik, J., Jahn, C., Schuster, T., Hoßbach, N., & Pflaum, A. (2022). Mastering the digital transformation through organizational capabilities: A conceptual framework. *Digital Business*, *2*(2), 100019. https://doi.org/10.1016/j.digbus.2021.100019

Legner, C., Eymann, T., Hess, T., Matt, C., Böhmann, T., Drews, P., ... & Ahlemann, F. (2017). Digitalization: opportunity and challenge for the business and information systems engineering community. *Business & information systems engineering*, *59*, 301-308. https://doi.org/10.1007/s12599-017-0484-2

Li, L. (2022). Digital transformation and sustainable performance: the moderating role of market turbulence. *Industrial Marketing Management*, *104*, 28-37. https://doi.org/10.1016/j.indmarman.2022.04.007

Lindawati, M., & Parwoto, P. (2021). The impact of transformational leadership and motivation on employee performance with job satisfaction as intervening variable in Indonesian banking industry during digital transformation. *Journal of Industrial Engineering & Management Research*, *2*(4), 51-66. https://doi.org/10.7777/jiemar.v2i4.162

Loor-Zambrano, H. Y., Santos-Roldán, L., & Palacios-Florencio, B. (2022). Relationship CSR and employee commitment: mediating effects of internal motivation and trust. *European research on management and business economics*, *28*(2), 100185. https://doi.org/10.1016/j.iedeen.2021.100185

Lovrić, M., Komić, J., & Stević, S. (2006). Statistička analiza metodi i primjena, *Univerzitet u Banjoj Luci, Ekonomski fakultet, Banja Luka*.

Manjon, M. J., Merino, A., & Cairns, I. (2022). Business as not usual: a systematic literature review of social entrepreneurship, social innovation, and energy poverty to accelerate the just energy transition. *Energy Research & Social Science*, *90*, 102624. https://doi.org/10.1016/j.erss.2022.102624

Martin, R. L., & Osberg, S. (2007). Social entrepreneurship: the case for definition. *Stanford Social Innovation Review*, *5*(2), 29–39. https://doi.org/10.48558/TSAV-FG11

McVeigh, F. J., & Wolfer, L. T. (2004). *Brief history of social problems: A critical thinking approach*. University Press of America.

Megawaty, M., Hamdat, A., & Aida, N. (2022). Examining linkage leadership style, employee commitment, work motivation, work climate on satisfaction and performance. *Golden Ratio of Human Resource Management*, *2*(1), 01-14. https://doi.org/10.52970/grhrm.v2i1.86

Peng, Y., & Tao, C. (2022). Can digital transformation promote enterprise performance? — From the perspective of public policy and innovation. *Journal of Innovation & Knowledge*, *7*(3), 100198. https://doi.org/10.1016/j.jik.2022.100198

Pernebrink, L., & El Azab, A. (2019). Retailing in the digital age: a cross-sectional survey of employees' attitudes toward digitalization. https://www.diva-portal.org/smash/get/diva2:1287454/FULLTEXT01.pdf

Petković, S. (2021). Preduzetništvo i inovacije u digitalnoj eri. *Univerzitet u Banjoj Luci, Ekonomski fakultet, Banja Luka*.

Prodanov, H. (2018). Social entrepreneurship and digital technologies. *Economic Alternatives*, *1*(1), 123-138. https://econpapers.repec.org/scripts/redir.pf?u=http%3A%2F%2Fwww.unwe.bg%2Fuploads%2FAlternatives%2F9_Prodanov_EAlternativi_en_1_2018.pdf;h=repec:nwe:eajour:y:2018:i:1:p:123-138

Ragulina, J. V., Suglobov, A. E., & Melnik, M. V. (2018). Transformation of the role of a man in the system of entrepreneurship in the process of digitalization of the Russian economy. *Quality-Access to Success*, *19*. https://www.researchgate.net/publication/326982205_Transformation_of_the_role_of_a_man_in_the_system_of_entrepreneurship_in_the_process_of_digitalization_of_the_Russian_economy

Ramadani, V., Agarwal, S., Caputo, A., Agrawal, V., & Dixit, J. K. (2022). Sustainable competencies of social entrepreneurship for sustainable development: exploratory analysis from a developing economy. *Business Strategy and the Environment*, *31*(7), 3437-3453. https://doi.org/10.1002/bse.3093

Ratten, V. (2018). *Sport entrepreneurship: Developing and sustaining an entrepreneurial sports culture*. Springer.

Rupeika-Apoga, R., Petrovska, K., & Bule, L. (2022). The effect of digital orientation and digital capability on digital transformation of SMEs during the COVID-19 pandemic. *Journal of Theoretical and Applied Electronic Commerce Research*, *17*(2), 669-685. https://doi.org/10.3390/jtaer17020035

Robbins, S. P., & Judge, T. A. (2015). Organizational Behavior. New Jersey: Person Education. In: Inc.

Roos, G., & Shroff, Z. (2017). What will happen to the jobs? Technology-enabled productivity improvement–good for some, bad for others. *Labour & Industry: a journal of the social and economic relations of work*, *27*(3), 165-192. http://dx.doi.org/10.1080/10301763.2017.1359817

Santos, F. M. (2012). A positive theory of social entrepreneurship. *Journal of business ethics*, *111*(3), 335-351. https://doi.org/10.1007/s10551-012-1413-4

Santoso, N. B. A., & Riyanto, S. (2020). The effect of work motivation, organizational commitment, and job satisfaction on the contract employee's performance of Pt Bank Rakyat Indonesia branch office of Jakarta Daan Mogot. *International Journal of Innovative Science and Research Technology, 5*(1), 561-568. https://www.researchgate.net/publication/343390506_The_Effect_of_Work_Motivation_Organizational_Commitment_and_Job_Satisfaction_on_the_Contract_Employees_Performance_of_Pt_Bank_Rakyat_Indonesia_Branch_Office_of_Jakarta_Daan_Mogot

Schwabfound (n.d.). Schwab Foundation. https://www.schwabfound.org/about

Schwertner, K. (2017). Digital transformation of business. *Trakia Journal of Sciences*, *15*(1), 388-393. http://dx.doi.org/10.15547/tjs.2017.s.01.065

Sengupta, S., Sahay, A., & Croce, F. (2018). Conceptualizing social entrepreneurship in the context of emerging economies: an integrative review of past research from BRIICS. *International Entrepreneurship and Management Journal*, *14*, 771-803. https://doi.org/10.1007/s11365-017-0483-2

Stević, Ž., Đalić, I., Pamučar, D., Nunić, Z., Vesković, S., Vasiljević, M., & Tanackov, I. (2019). A new hybrid model for quality assessment of scientific conferences based on Rough BWM and SERVQUAL. *Scientometrics*, *119*(1), 1-30. http://dx.doi.org/10.1007/s11192-019-03032-z

Stević, Ž., Tanackov, I., Puška, A., Jovanov, G., Vasiljević, J., & Lojaničić, D. (2021). Development of modified SERVQUAL–MCDM model for quality determination in reverse logistics. *Sustainability*, *13*(10), 5734. https://doi.org/10.3390/su13105734

Stošić-Mihajlović, L., & Nikolić, M. (2017). Social entrepreneurship supported by creative economy. *Ekonomika*, *63*(4), 75-88. http://dx.doi.org/10.5937/ekonomika1704075S

Sugiarti, E. (2023). The Influence of training, work environment and career development on work motivation that has an impact on employee performance at PT. Suryamas Elsindo Primatama In West Jakarta. *International Journal of Artificial Intelligence Research*, *6*(1.2). https://doi.org/10.29099/ijair.v6i1.304

Sylla, E. D. (2014). Tercentenary of Ars Conjectandi (1713): Jacob Bernoulli and the founding of mathematical probability. *International Statistical Review*, *82*(1), 27-45. http://dx.doi.org/10.1111/insr.12050

Tan Luc, P., Xuan Lan, P., Nhat Hanh Le, A., & Thanh Trang, B. (2022). A co-citation and co-word analysis of social entrepreneurship research. *Journal of Social Entrepreneurship*, *13*(3), 324-339. https://doi.org/10.1080/19420676.2020.1782971

Torres, P., & Augusto, M. (2020). Digitalisation, social entrepreneurship and national well-being. *Technological Forecasting and Social Change*, *161*, 120279. http://dx.doi.org/10.1016/j.techfore.2020.120279

Unicef.org, (2020). Strategija socijalnog uključivanja Federacije Bosne i Hercegovine za period 2021-2027.https://www.unicef.org/bih/media/6491/file/Strategija%20socijalnog%20uklju%C4%8Divanja%20Federacije%20Bosne%20i%20Hercegovine%20za%20period%202021-2027..pdf

Vial, G. (2019). Understanding digital transformation: a review and a research agenda. *The journal of strategic information systems*, *28*(2), 118-144. http://dx.doi.org/10.1016/j.jsis.2019.01.003

Widarko, A., & Anwarodin, M. K. (2022). Work motivation and organizational culture on work performance: organizational citizenship behaviour (OCB) as mediating variable. *Golden Ratio of Human Resource Management, 2*(2), 123-138. https://doi.org/10.52970/grhrm.v2i2.207

✉ **Correspondence**

Irena Đalić

University of East Sarajevo, Faculty of Transport and Traffic Engineering
Vojvode Mišića 52, Doboj, Bosnia and Herzegovina

E-mail: irena.djalic@sf.ues.rs.ba

STRATEGIC MANAGEMENT, Vol. 29 (2024), No. 3, pp. 073-083

DOI: 10.5937/StraMan2300047P

Received: February 24, 2023
Revised: May 08, 2023
Accepted: May 10, 2023
Published online: June 02, 2023

Determinants of learning outcomes with online teaching based on students' perception

Viktorija Petrov

University of Novi Sad, The Faculty of Economics in Subotica, Novi Sad, Serbia
https://orcid.org/0000-0001-6216-9715

Zoran Drašković

University Business Academy in Novi Sad, Faculty of Economics and Engineering Management, Novi Sad, Serbia
https://orcid.org/0000-0002-8647-7680

Đorđe Ćelić

University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
https://orcid.org/0000-0003-2200-1357

Matej Rus

University of Maribor, Faculty of Economics and Business, Maribor, Slovenia
https://orcid.org/0009-0007-8766-9370

Abstract

Background: Research on the topic of determining success of online learning is on the rise. Defining the key success factors, i.e. determinants of online learning success, is extremely important, especially at present as all higher education institutions have been forced to try their hand at teaching with the help of technology.

Purpose: Thus a research examining factors of learning outcomes of online learning was conducted. Learning outcomes were modelled as dependent variable, while the set of independent model variables included: course design, student motivation, student self-regulation and dialogue (instructor-student, student-student).

Study design/methodology/approach: Five research hypotheses were tested by analysing data collected from the students of the University of Novi Sad. A structured questionnaire was employed to collect data on the attitudes of users (students) to online learning. Respondents expressed their views (perception) about statements and valued them on a 5 point Likert scale. The instrument was applied to a sample of 360 responses using PLS structural equation modelling.

Findings/conclusions: All five hypothesis were supported with the analysis, confirming the importance of research from the aspect of contribution to the literature dedicated to identifying the key success factors of online learning. Additional contribution refers to the research conducted in Serbia, i.e. at the University of Novi Sad.

Limitations/future research: A more detailed analysis of the model itself and the possibility of finding the interdependence of constructs that affect perceived learning outcomes and user satisfaction remains as an area for further research.

Keywords: online learning, success factors, learning outcomes, PLS modelling

Introduction

Organizing online learning at higher education institutions became the focus of research in a large number of scientific disciplines with the outbreak of the pandemic. Although the use of online platforms for collaboration and knowledge exchange had existed before, with the onset of COVID-19 pandemic all higher education institutions were forced to adapt to the new situation (Mo, Hsieh, Lin, Jin & Su, 2021, Elneel et al, 2023). The teaching staff, technical support, as well as the students themselves in most cases had had no previous experience with online learning (Ventura-León, Caycho-Rodríguez,

Mamani-Poma, Rodriguez-Dominguez, & Cabrera-Toledo, 2022), but during the two years of the pandemic, all were bound to use technology as both a mediator and assistant in sharing knowledge.

Technological advances and digitalization are causing huge changes in teaching practices, forcing the academic world to evolve from the traditional style of one-way teaching and learning, to acquisition or even consumption (Belanche, Casaló, Orús & Pérez-Rueda, 2020).

Distance learning could be defined as an interaction of human and non-human elements that engage in it through platforms in order to acquire knowledge and/or skills (Eom & Ashill, 2016, p. 186). More precisely, distance learning should be understood as education that uses one or more technologies to deliver instruction to students who are separated from the instructor, and to support regular and substantive interaction between the students and instructor synchronously or asynchronously (Vidergor, H., 2023, p. 2). It is necessary to monitor the quality of distance learning, and the two most often emphasized learning goals listed in research papers are: distance learning outcomes (Fandos-Herrera, Jiménez-Martínez, Orús, Pérez-Rueda & Miguel Pina, 2023; Verstege, Pijeira-Díaz, Noroozi, Biemans, & Diederen, 2019; Kauffman, 2015), and user satisfaction (Bacci, Fabbricatore, & Iannario, 2022; Dai, Teo, Rappa & Huang, 2020; Gopal, Singh & Aggarwal, 2021; Eom, Wen & Ashill, 2006).

All tools that are digitized and provide learning opportunities using learning materials such as: texts, images and video clips, enabling personal pace of learning are characterized with terms *e-learning*, *m-learning* or *distance learning* in the literature (Basak, Wotto & Bélanger, 2018). The main difference between e-learning and distance learning is the isolation that is the main characteristics of distance learning, while e-learning could be lectured in classroom or internet lab.

By defining the basic characteristic of e-learning as constructing knowledge, we clearly opt for the constructivist model, which implies that knowledge is created, as opposed to the objectivist, or behaviourist model (Piaget, 1977; Wang Hu, Li & Yu, 2021). Models that rely on or derive from the constructivist model are: collaboration, socioculturalism, cognitive information processing model, discovery learning, and facilitated learning (Eom & Ashill, 2016). A common feature of all these models is that knowledge is created through e-learning, but they don't agree on how the knowledge is best constructed (from the ultimate individualism of the student, to collectivism).

The paper is based on a constructivist assumption, and a systematic overview of the basic assumptions and implications (Eom & Ashill, 2018). According to this point of view, e-learning is an open system with three entities (students, instructor, and learning management system (LMS)) that are in constant interaction with each other and with the surroundings, with the goal to optimize output in the form of learning outcomes and satisfaction. The system is derived from the Virtual learning environment (VLE) effectiveness model of Piccoli, Ahmad and Ives, 2001. Linking the described system with the framework of technology-based learning (TBL) (Loderer, Pekrun & Lester, 2020) an instrument was created that was applied to the student perception (Alavi, & Leidner, 2001). That research was conducted in the Midwestern United States (Eom & Ashill, 2016), which inspired the research presented in this paper.

Research has shown numerous contributors to successful online learning. Motivation as one of the main antecedents of participation aside, perceived learning support, such as structured course design and effective interactions with instructors and peer learners, was proven to contribute to successful online learning (Albelbisi, Yusop & Selleh, 2018). Previous studies have identified that motivation, perceived learning support, learning engagement, and self-regulated learning strategies are vital factors for successful distant learning (Littlejohn, Hood, Milligan & Mustain, 2016)

The aim of this exploratory research study is to examine the interplay between motivation, student self-regulation, dialogue, course design, and perceived learning outcomes. We propose a research model that involves all variables measured in order to explain individual perceived learning outcomes in distance learning in Serbia (see Figure 1).

1. Factors that contribute to online learning success

Within this paper we examine the attitudes of students of the Faculty of Technical Sciences and the Faculty of Economics, University of Novi Sad, regarding the achieved learning outcomes during distance learning. Respondents gave their opinion (perception) about the independent variables of the model, which included: student motivation, student self-regulation, dialogue (instructor-student,

student-student) and course design; as well as about the dependent variable - learning outcome. We tested our research hypotheses through the analysis of data collected from a sample of 360 students from the University of Novi Sad.

The main goal of this paper is to examine the attitudes of students of the University of Novi Sad towards online classes, and to determine the existence of statistically significant relationships with the dependent variable - learning outcome.

1.1. Course design

Course Design is part of the formal role of the instructor, which represents the rigidity or flexibility of the goal of education, teaching strategy, and assessment methods (Kim et al., 2021). It also describes the range in which the program can cover and respond to all student requests. The basic categories that describe and can improve course design are: course overview and introduction, learning objectives, assessment and measurement, and instructional materials.

It has been shown that course design has a substantial influence on students' satisfaction (Eom & Ashill, 2016), student's participation (Kornpitack & Sawmong, 2022), and that course design significantly influences learning, both in traditional and online settings (Lee, 2014). Furthermore, it has been found that course design significantly affects perceived usefulness, perceived ease of use and quality of e-learning, and perceived usefulness and quality of e-learning are the main drivers of student satisfaction (Nedeljković & Rejman - Petrović, 2022).

Therefore, in this study we hypothesize:
H1: Couse design is positively associated with Learning Outcomes.

1.2. Student Motivation

Change of the learning environment from face-to-face to distance teaching puts more responsibility on students to organize their time better and to self-motivate (Stevens, Bienz, Wali, Condie & Schismenos, 2021), as they transition from the role of passive to active learners. Self-motivation is a psychological construct and can be defined as the summoning of willpower that directs behaviour towards a specific goal (Zimmerman & Martinez-Pons, 1992). It has been shown that numerous student characteristics have a significant effect on satisfaction and learning outcomes (Bitzer & Janson, 2014). Some of those are: previous experience with distance learning, experience with using computers, self-efficacy, learning style, motivation, metacognition, and learning engagement (Prins, Veenman & Elshout, 2006). In this paper we focus on: motivation, self-regulated learning including metacognition, and learning engagement. Self-motivation could be defined as intrinsic, a psychological characteristic that causes an individual to carry out activities that will lead to personal satisfaction. On the other hand, extrinsic motivation represents a psychological characteristic which causes an individual to undertake activities that will enable him to achieve a separable outcome such as a reward, or recognition. These two types of motivation are also two measuring instruments that are suitable for explaining self-motivation (Schoor & Bannert, 2011). Following the controlled-to-autonomous continuum, three motivational profiles emerged: impersonal - amotivation, controlled - introjected and external regulation, and autonomous motivation - intrinsic, integrated, and identified regulation (Wei, Saab & Admiraal, 2023).

Based on the above review of potential students' motivation in online learning setting, the following hypothesis was formulated:
H2: Student Motivation is positively associated with Learning Outcomes.

1.3. Student self-regulation

The basic premise of the constructivist school of learning is that the most efficient learning happens when things are discovered at a time and pace that suits each individual. It is clear that students who are self-regulated and independent will achieve better success in an online learning environment. Students who are self-regulated are said to be "metacognitively, motivationally, and behaviorally active participants in their own learning process" (Zimmerman, 2008). This type of students take the initiative for the start and pace of their studies, coordinate their involvement and do not wait for lecturers, parents, or any other agents to initiate and guide them.

Self-regulated learning (SLR) implies planning, monitoring and adapting one's thoughts, feelings and actions in a cyclical process to attain a personal goal (Zimmerman, 2000) and it is one of crucial presumptions for the success in an online learning environment (Pelikan et al., 2021). Metacognitive processes involve learners' ability to plan, schedule, and evaluate their learning progress. Motivational processes indicate that the learners are self-motivated and willing to take responsibility for their successes or failures (Kuo, Walker, Belland & Schroder, 2013).

Information processing approach (Winne & Hadwin, 1998) portrays self-regulated learning as a model of three processes, namely: forethought, performance, and self-reflection according to Zimmerman (2000). Based on previous work on self-regulated learning, Green & Azevedo (2007) conclude that there is no typical cycle, most learning involves recycling through the cognitive architecture until a clear definition of the task has been created (Phase 1), followed by the production of learning goals and the best plan to meet them (Phase 2), which leads to the enacting of strategies to begin learning (Phase 3). According to other scholars, there are six sub-scale constructs: self-evaluation and mood-adjustment - preparation phase, task-strategies and environment-structuring - implementation phase, and help-seeking and time-management - reflection phase (Martinez-Lopez, Yot, Tuovila & Perera-Rodríguez, 2017).

Previous research has suggested that the learning design and the application of SRL strategies determine the learning effectiveness in learning activities during the COVID-19 pandemic (Panadero, Jonsson & Botella, 2017; Panigrahi, Srivastava & Panigrahi, 2021), that SRL strategies play a critical role in assessing student learning in online learning environments (Atmojo, Muhtarom & Lukitoaji, 2020), and that teachers can enhance their students' self-regulation in online learning and assist them in being more focused in online learning (Yu, Hu & Chen, 2022). Thus e-learning stakeholders should introduce effective strategies to overcome the lack of students' self-regulated learning because students with low SRL level would experience difficulties in autonomous learning settings, they would become dissatisfied, view the e-learning system as not useful, and resist using it (Al-Adwan, Albelbisi, Hujran, Al-Rahmi & Alkhalifah, 2021).

Some studies have identified essential factors exerting a great influence on online learning outcomes as motivation and self-efficacy (Yang, Tsai, Kim, Cho & Laffey 2006; Chen & Hu, 2020; Vrieling-Teunter, Stijnen & Bastiaens, 2021). After elaborate analysis of the importance of self-regulation in learning, the following hypothesis was formulated:

H3: Student self-regulation is positively associated with learning outcomes.

1.4. Dialogue (instructor - student and student – student)

In the online student-centered learning, a teacher could provide individualized instruction based on teacher-student interactions and communication, where teacher feedback could improve students' learning outcomes and enhance their engagement. Remote feedback, together with a contextualized and situated approach, is considered essential in online learning (Yu, 2021).

Unlike face-to-face classes, which rely on lectures as the basic learning method, collaboration assumes that knowledge is constructed socially via shared understanding groups through different knowledge discovery models such as: social collaborative learning, interactive, and discovery learning. The term dialogue is used to describe substantive, constructive, and meaningful interaction valued by each group participant. Dialogue promotes learning through active participation and enables deep cognitive engagement with the goal of developing higher level knowledge (Saghafian & O'Neill, 2018).

Education is characterized by interaction between instructor, student and content, and many studies have emphasized its importance in enhancing effectiveness in online education (Burnett, Bonnici, Miksa & Kim 2007; Yunusa & Umar, 2021). However, Kornpitack and Sawmong (2022) observed that many courses were being conducted online without the aid and assistance of a learning management system that would enable interaction of learners with their classmates, teachers, and assignments.

Three different types of interaction could be classified as: learner-content interaction, learner-instructor interaction, and learner-learner interaction (Bernard et al., 2009). Learner-content interaction refers to students' access to the materials that they are supposed to study (textbooks, course readings, lecture notes, audio-video materials). It is identical in traditional and online education, but instructor-student interaction and student-student interaction (dialogue) differ significantly. Kuo et al. (2013) found that student-content interaction was the strongest predictor of student satisfaction, and instructor-student interaction followed as the second strongest predictor that significantly contributed to student satisfaction.

Two hypotheses were formulated in regards to dialogue:

H4: Instructor-student dialogue is positively associated with learning outcomes, and

H5: Student-student dialogue is positively associated with learning outcomes.

The research hypotheses are graphically represented by the model shown in Figure 1.

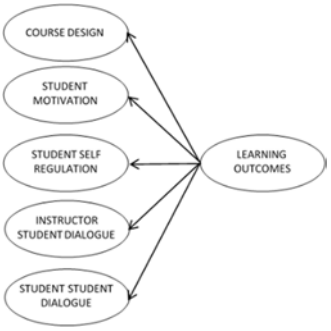

Figure 1 The research model
Source: the authors' research

2. Research methodology

For this research, we used a survey instrument that was developed and applied in (Eom & Ashill 2016). The instrument is based on the commonly administered IDEA (Individual Development and Educational Assessment) student rating system from Kansas State University, and the Motivated Strategies for Learning Questionnaire (MSLQ) authored by Pintrich, Smith, Garcia and McKeachie in 1993. The instrument itself was tested for suitability in Serbia (Petrov, Drašković, Uzelac & Ćelić, 2022) and proved adequate.

The instrument consists of seven parts. The first includes general information about the respondents, such as: age, gender, faculty, types of study, level of study, and experience in distance learning. The following blocks of questions (statements) are devoted to constructs: Course Design; Student Motivation; Self-Regulation; Student-Student Dialogue; Instructor-Student Dialogue; and Learning Outcomes.

Respondents rated their degree of (dis)agreement with the statements on a five-point Likert scale. To analyse the data collected via the questionnaires, we used IBM SPSS Statistics 25.0 statistical software for descriptive statistics on the data from the first part of the questionnaire (demographic characteristics of the respondents). SmartPLS 4.0 software was used for graphical approach to modelling structural equations using the least squares technique on the basis of variance (PLS-SEM), and for the analysis of the respondents' answers from the second part of the questionnaire, dedicated to examining the importance of factors influencing learning outcomes.

2.1. Demographics of the sample

Data was collected during the regime of online teaching in Serbia. Multiple methods of communication with students were used. Majority of students were contacted via previously formed teams on the MS Teams learning platform, but also via a database of student contacts on the Moodle platform.

Table 1 Demographics of the sample

		N of participants	% of participants
Gender			
	Male	131	36.4
	Female	229	63.6
Age			
	18-22	306	85.0
	23-26	32	8.9
	27-34	16	4.4
	35-44	6	1.7
Faculty			
	Faculty of Technical Sciences	213	59.2
	Faculty of Economics	147	40.8
Type of education			
	Vocational	35	9.7
	Academic	325	90.3
Academic programme			
	Bachelor	330	91.7
	Master	30	8.3
Experience in attending online classes			
	None	4	1.1
	Insufficient	75	20.8
	Sufficient	281	78.1
Total sample size (n) = 360			

Source: the authors

In total, over 2,500 students of the University of Novi Sad who were enrolled at the Faculty of Technical Sciences in Novi Sad and the Faculty of Economics in Subotica were contacted.
A total of 360 valid and complete questionnaires were collected during the one-month student survey. Response rate was around 14%, which is acceptable for this type of survey. Table 1 portrays demographic profile of the students.

Of the total number of respondents, 306 (85%) were between 18 and 22 years of age, 32 (8.9%) were between 23 and 26 years of age, 16 (4.4%) respondents were between 27 and 34 years of age, and 6 of them (1.7%) were between 35 and 44 years of age. When it comes to the gender of the respondents, 131 (36.4%) of them were male, and 229 (63.6%) were female.

In regard to academic program, the predominant number of respondents, 330 of them (91.7%), were from undergraduate/bachelor programs, while 30 of them (8.3%) were from master programs.

In terms of the faculty at which they studied, 213 (59.2%) of them were from the Faculty of Technical Sciences, while 147 (40.8%) were from the Faculty of Economics. Additionally, 35 (9.7%) of them were enrolled in vocational studies, while 325 (90.3%) were enrolled in academic studies.

The last demographic characteristic concerns the experience in attending online classes; 4 (1.1%) of the respondents said that they had no experience in attending online classes, 75 (20.89%) had insufficient, and 281 (78.1%) respondents said that they had enough experience in attending online classes.

2.2. Applied methods

All theoretical concepts used in this research have been taken from previous studies published in the scientific literature and they provide a theoretical, rational framework for this research.

The instrument was applied to a sample of 360 respondents using the structural equation model-based PLS methodology for two reasons. The first is that PLS is suitable for application in the early stages of theory development and testing. The more significant reason is that it is particularly suitable for analysing respondents' attitudes.

Latent variables, such as: attitudes, emotions, personality, motivation and the like, represent phenomena whose existence is concluded on the basis of observed behaviour. In this research, the respondents' attitudes were evaluated with a five-point Likert scale, and viewed as latent variables. Numerous authors have evaluated latent variables, i.e. examined complex interdependencies of latent constructs, with the aid of the statistical-econometric technique of structural equation modelling (SEM). SEM enables the modelling of the influence paths of latent constructs, i.e. variables that cannot be observed or directly measured.

Since latent constructs lack direct observations, they are operationalized, i.e. approximately measured using indicators that are called measurable, or manifest variables. For research conducted using questionnaires, each question in the questionnaire represents a measurable, manifest indicator. The parts of the structural equation model are: the structural model (in which the relations of latent constructs are defined) and the measurement model (which connects the latent constructs with their measurement indicators). Two types of techniques (methods) can be applied when modelling structural equations: covariance-based techniques (CB-SEM), and partial least squares techniques based on variance (PLS-SEM).

Although both techniques have the same roots, Hair, Sarstedt, Ringle and Mena (2012) state that the covariance structural equation modelling (CB-SEM) approach is considered particularly useful when conducting theory testing. On the other hand, variance-based structural equation modelling (PLS-SEM) approach is considered a 'soft' modelling approach to be applied in predictive studies when proven theory does not exist, or when theoretical assumptions and methods of measurement are insufficiently developed. PLS-SEM technique maximizes the explained variance of the endogenous latent variables by estimating the partial relationships of the model in an iterative series of Ordinary Least Squares (OLS) regression. To summarize, PLS-SEM emphasizes prediction while relaxing data requirements and specifying relationships.

3. Results and discussion

Structural equation modelling using variance-based least squares technique (PLS-SEM) can be used to estimate parameters in hierarchical latent variable models. Testing of the reflective-reflective hierarchical latent model used in the study was conducted according to the recommendations of Hair et al. (2012) along with requirements regarding data and model characteristics.

In accordance with the criteria for evaluating the results of reflective models, and in accordance with the fact that the research used a reflective-reflective hierarchical latent model and within it the approach of repeating indicators, the constructs of all three hierarchical levels were tested by measuring: indicator reliability, internal consistency, convergent validity, and discriminant validity of latent constructs.

The composite reliability of the group of indicators which measure the construct is based on the Composite Reliability (CR) and Average Variance Extracted (AVE). Internal consistency was confirmed in all constructs measured by both indicators. If we take into account the Composite Reliability indicator, which represents the internal consistency of the test, i.e. the degree to which all test subjects covary with each other, with a limit of 0.7 as acceptable in Table 2, it is noticeable that for each construct the value of this indicator is in the range of 0.81 to 0.96.

The application of this indicator is more frequent for Confirmatory Factor Analysis (CFA), unlike the indicator Crombach's Alpha, which is

more suitable for Exploratory Factor Analysis (EFA). Average Variance Extracted is in the interval from 0.631 to 0.864, which is considered acceptable, that is, more variance is covered by the construct than by measurement error.

Table 2 Reliability validation of the model

Construct	Factor Loading	α	CR	AVE	VIF
Course Design	0.816***	0.864	0.880	0.647	2.566
	0.857***				2.769
	0.825***				1.881
	0.773***				1.706
	0.747***				1.713
Instructor Student Dialogue	0.893***	0.901	0.935	0.769	0.891
	0.913***				0.91
	0.908***				0.901
	0.789***				0.807
Student Student Dialogue	0.705***	0.814	0.947	0.612	2.044
	0.788***				2.591
	0.843***				1.439
	0.835***				2.081
Student Self-Regulation	0.807***	0.813	0.868	0.631	1.778
	0.760***				1.792
	0.774***				1.767
	0.833***				1.485
Student Motivation	0.704***	0.719	0.748	0.526	1.846
	0.853***				1.480
	0.702***				1.162
Learning Outcomes	0.743***	0.921	0.927	0.864	2.024
	0.933***				3.394
	0.941***				3.912
	0.914***				3.127

Source: the authors

During the analysis, the indicator of multicollinearity embodied in the variance inflation factor (VIF) was also taken into account. As the VIF values are below 5, it can be considered that the observed independent variable is not highly correlated with another independent variable. The results are shown in Table 2.

After testing the internal consistency and convergent validity of the constructs, an examination of the uniqueness of each latent construct in relation to other latent constructs in the structural, hierarchical model follows, by testing the discriminant validity of the latent constructs. Discriminant validity was tested with the use of the Fornell-Larcker criterion (Hair et al., 2012). Table 3 presents results of the examination of the discriminant validity of the mentioned constructs in this way.

Table 3 Discriminant validity Heterotrait Monotrait Ratio HTMT

	CD	ISD	SM	SSR	SSD
CD					
ISD	0.747				
SM	0.704	0.575			
SSR	0.704	0.517	0.791		
SSD	0.713	0.816	0.505	0.473	
LO	0.584	0.534	0.309	0.196	0.670

Source: the authors

Since the square root of the average value of the extracted variance (AVE) of each construct is greater than all the correlations of each construct with other constructs in the model, the discriminant validity of them can be confirmed. In other words, all constructs in the model can be viewed as separate entities, i.e. they should not be regrouped and/or merged with each other.

The causal relationship of the hypotheses was tested examining the structural model using Smart PLS software.

Table 4 Hypotheses confirmation for dependent variable Learning Outcomes

Path	Path coefficient	Hypothesis
H1: Course Design	0.525***	supported
H2: Student Motivation	0.286***	supported
H3: Student Self - Regulation	0.172***	supported
H4: Instructor Student Dialogue	0.496***	supported
H5: Student Student Dialogue	0.721***	Supported

Note: *** significant at $p \leq 0.001$

Source: the authors

The statistical significance of the hypothesized relationships was examined by bootstrapping procedure. The t-test for the standardized path coefficients and for calculated p values were verified based on a two-tailed test with significance levels of 0.01 and 0.05.

Our results suggest the presence of a significant positive relationship between chosen constructs and dependent variable Learning Outcomes.

To test our hypothesis we utilized partial least square-based structural equation modelling using SmartPLS software. A hierarchical latent variable model using reflective-formative type was used, as suggested by Becker, Klein and Wetzels (2012).

Based on the analysis, the evidence was obtained suggesting that Learning Outcomes among students at University of Novi Sad could be explained by a second-order hierarchical model which is reflected by Course Design, Student Self-

Regulation and Student-Student Dialogue, as is presented in Figure 2.

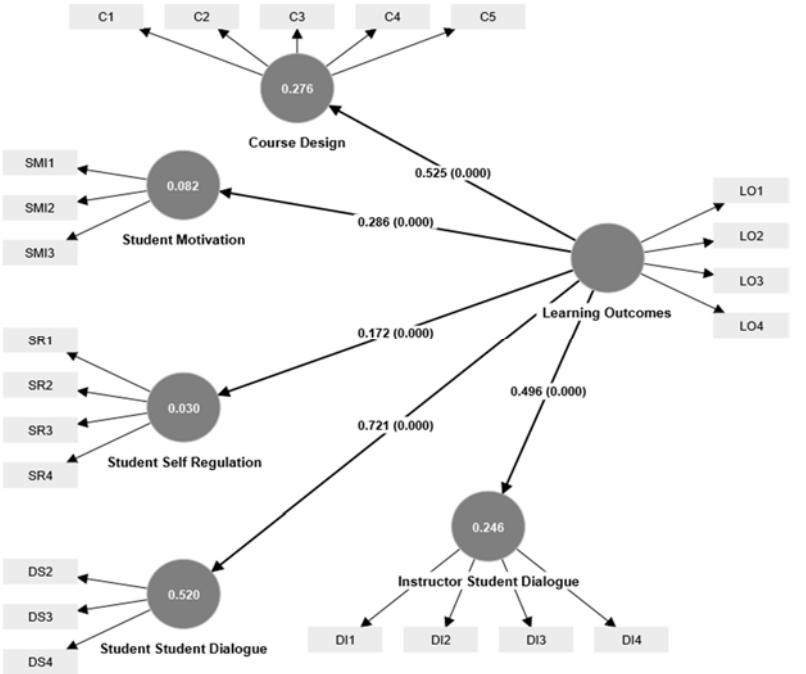

Figure 2 The research model - results
Source: the authors

Conclusion

The results of the presented research are important from the aspect of contributing to the literature dedicated to identifying the key success factors of online learning. Additional contribution refers to the research conducted in Republic of Serbia, i.e. at the University of Novi Sad. The statistical analysis led to the revised measurement model, whose results provided support for the reliability and convergent and discriminant validities of the measures used in the study.

The results of this study have significant implications for lecturers. It is clear that the role of the lecturer through course design is the cornerstone of the university online education. Improving the skills and knowledge of lecturers in the areas of: course structure preparation, discussions and interactions, technological solutions for collaboration during lectures or other types of student engagement, as well as motivation methods; would significantly affect the target variable learning outcomes.

One area for further research remains a more detailed analysis of the model itself and the possibility of finding the interdependence of constructs that affect perceived learning outcomes and user satisfaction.

References

Al-Adwan, A. S., Albelbisi, N. A., Hujran, O., Al-Rahmi, W. M. & Alkhalifah, A. (2021). Developing a holistic success model for sustainable e-learning: a structural equation modeling approach. *Sustainability, 13*(16), 9453. https://doi.org/10.3390/su13169453

Albelbisi, N., Yusop, F.D. & Selleh, U.K.M. (2018). Salleh Mapping the factors influencing success of massive open online courses (MOOC) in higher education. *Eurasia Journal of Mathematics, Science and Technology Education, 14* (7), 2995-3012. https://doi.org/10.29333/ejmste/91486

Alavi, M. & Leidner, D. E. (2001). Research commentary: Technology-mediated learning – A call for greater depth and breadth of research. *Information Systems Research, 12*(1), 1-10. https://doi.org/10.1287/isre.12.1.1.9720

Atmojo, S. E., Muhtarom, T. & Lukitoaji, B. D. (2020). The level of self-regulated learning and self-awareness in science learning in the COVID-19 pandemic era. *Indonesian Journal of Science Education, 9*(4), 512-520. https://doi.org/10.15294/jpii.v9i4.25544

Bacci, S., Fabbricatore, R. & Iannario, M. (2022). Multilevel IRT models for the analysis of satisfaction for distance learning during the COVID-19 pandemic, *Socio-Economic Planning Sciences*, 101467. https://doi.org/10.1016/j.seps.2022.101467

Basak, S. K., Wotto, M. & Bélanger, P. (2018). E-learning, M-learning and D-learning: conceptual definition and comparative analysis. *E-Learning and Digital Media, 15*(4), 191-2016. https://doi.org/10.1177/2042753018785180

Becker, J. M., Klein, K., & Wetzels, M. (2012). Hierarchical Latent Variable Models in PLS-SEM: Guidelines for using reflective-formative type models. *Long Range Planning, 45*(5-6), 359-394. https://doi.org/10.1016/j.lrp.2012.10.001

Belanche, D., Casaló, L.V., Orús, C. & Pérez-Rueda, A. (2020). Developing a Learning Network on YouTube: Analysis of Student Satisfaction with a learner-generated content activity. In: Peña-Ayala, A. (eds) *Educational Networking. Lecture Notes in Social Networks*. Springer, Cham. https://doi.org/10.1007/978-3-030-29973-6_6

Bernard, R. M., Abrami, P. C., Borokhovski, E., Wade, C. A., Tamim, R. M., Surkes, M. A., & Bethel, E. C. (2009). A meta-analysis of three types of interaction treatments in distance education. *Review of Educational Research, 79*(3), 1243–1289. http://www.jstor.org/stable/40469094

Bitzer, P. & Janson, A. (2014): Towards a holistic understanding of technology-mediated learning services - a state-of-the-art analysis. In: *European Conference on Information Systems (ECIS)*, Tel Aviv, Israel Retrieved January 15, 2023 from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2470946

Burnett, K., Bonnici, L. J., Miksa, S. D., & Kim, J. (2007). Frequency, intensity and topicality in online learning: an exploration of the interaction dimensions that contribute to student satisfaction in online learning. *Journal of Education for Library and Information Science, 48*(1), 21–35. http://www.jstor.org/stable/40324318

Chen, X., & Hu, J. (2020). ICT-related behavioral factors mediate the relationship between adolescents' ICT interest and their ICT self-efficacy: evidence from 30 countries. *Computers & Education, 159*, 104004. https://doi.org/10.1016/j.compedu.2020.104004

Dai, H. M., Teo, T., Rappa, N. A. & Huang, F. (2020). Explaining Chinese university students' continuance learning intention in the MOOC setting: a modified expectation confirmation model perspective, *Computers & Education, 150*, 103850. https://doi.org/10.1016/j.compedu.2020.103850

Elneel, D. A. H., Kahtan, H., Fakharudin, A. S., Abdulhak, M., Al-Ahmad, A. S., & Alzoubi, Y. I. (2023). The Factors Influenced by Stakeholder Identification in E-learning Systems: A Survey. *Journal of King Saud University-Science*, 102566.

Eom, B.; Wen, H. J. & Ashill, N. (2006). The Determinants of students' perceived learning outcomes and satisfaction in university online education: an empirical investigation. *Decision Sciences Journal of Innovative Education, 4*(2), 215-235. https://doi.org/10.1111/j.1540-4609.2006.00114.x

Eom, B. & Ashill, N. (2016). The determinants of students' perceived learning outcomes and satisfaction in university online education: an update. *Journal of Innovative Education, 14*(2), 185-215. https://doi.org/10.1111/dsji.12097

Eom, B. & Ashill, N. (2018). A System's view of e-learning success model. *Journal of Innovative Education, 16*(1), 42-76. https://doi.org/10.1111/dsji.12144

Fandos-Herrera, C., Jiménez-Martínez, J., Orús, C., Pérez-Rueda, A. & Miguel Pina, J. (2023). The influence of personality on learning outcomes and attitudes: the case of discussants in the classroom, *The International Journal of Management Education,21*(1). 100754. https://doi.org/10.1016/j.ijme.2022.100754

Hair, J. F., Sarstedt, M., Ringle, C. M., & Mena, J. A. (2012). An assessment of the use of partial least squares structural equation modeling in marketing research. *Journal of the Academy of Marketing Science, 40*(3), 414–433. https://doi.org/10.1007/s11747-011-0261-6

Gopal, R., Singh, V. & Aggarwal, A. (2021). Impact of online classes on the satisfaction and performance of students during the pandemic period of COVID 19. *Education and Information Technologies, 26*, 6923–6947. https://doi.org/10.1007/s10639-021-10523-1

Green, J. A. & Azevedo, R. (2007). A Theoretical review of winne and hadwin's model of self-regulated learning: new perspectives and directions. *Review of Educational Research*, *77*(3), 334-372. https://doi.org/10.3102/003465430303953

Kauffman, H. (2015). A review of predictive factors of student success in and satisfaction with online learning. *Research in Learning Technology*, *23*. https://doi.org/10.3402/rlt.v23.26507

Kornpitack, P. & Sawmong, S. (2022). Empirical analysis of factors influencing student satisfaction with online learning systems during the COVID-19 pandemic in Thailand. *Heliyon*, *8*(3):e09183. https://doi.org/10.1016/j.heliyon.2022.e09183

Kim, D., Jung, E., Yoon, M., Chang, Y., Park, S., Kim, D. & Demir, F. (2021). Exploring the structural relationships between course design factors, learner commitment, self-directed learning, and intentions. *Computers and Education, 166,* 104171. https://doi.org/10.1016/j.compedu.2021.104171

Kuo, Y-C., Walker, A. E., Belland, B. R. & Schroder, K. E. E. (2013). A predictive study of student satisfaction in online education programs, *International Review of Research in Open and Distributed Learning, 14*(1), 16–39. https://doi.org/10.19173/irrodl.v14i1.1338

Lee Joohi (2014). An Exploratory study of effective online learning: assessing satisfaction levels of graduate students of mathematics education associated with human and design factors of an online course. *International Review of Research in Open and Distributed Learning*, *15*(1), 111–132. https://doi.org/10.19173/irrodl.v15i1.1638

Littlejohn, A, Hood, N., Milligan, C & Mustain P. (2016) Learning in MOOCs: Motivations and self-regulated learning in MOOCs, *The Internet and Higher Education*, *29*, 40-48. https://doi.org/10.1016/j.iheduc.2015.12.003

Loderer, K., Pekrun, R. & Lester, J. (2020). Beyond cold technology: a systematic review and meta-analysis on emotions in technology-based learning environments. *Learning and Instruction, 70,* 101162. https://doi.org/10.1016/j.learninstruc.2018.08.002

Martinez-Lopez, R., Yot, C., Tuovila, I. & Perera-Rodríguez, V-H. (2017). Online self-regulated learning questionnaire in a Russian MOOC, *Computers in Human Behavior, 75*, 966-974. https://doi.org/10.1016/j.chb.2017.06.015

Mo, C. Y., Hsieh, T. H., Lin, C. L., Jin, Y. Q. & Su, Y.S. (2021). Exploring the critical factors, the online learning continuance usage during COVID-19 Pandemic. *Sustainability*, *13*, 5471. https://doi.org/10.3390/su13105471

Nedeljković, I., & Rejman-Petrović, D. (2022). Investigating critical factors influencing the acceptance of e-learning during COVID-19. *Strategic Management*, *27*(4), 30-40. https://doi.org/10.5937/StraMan2200019N

Panadero, E., Jonsson, A. & Botella, J. (2017). Effects of self-assessment on self-regulated learning and self-efficacy: Four meta-analyses, *Educational Research Review, 22*, 74-98. https://doi.org/10.1016/j.edurev.2017.08.004

Panigrahi, R., Srivastava, P. R. & Panigrahi, P. K. (2021). Effectiveness of e-learning: the mediating role of student engagement on perceived learning effectiveness. *Information Technology and People, 34*(7), 1840-1862. https://doi.org/10.1108/ITP-07-2019-0380

Pelikan, E.R., Lüftenegger, M., Holzer, J., Korlat, S., Spiel, C. & Schober, B. (2021). Learning during COVID-19: the role of self-regulated learning, motivation, and procrastination for perceived competence. *Zeitschrift für Erziehungswissenschaft* 24, 393–418. https://doi.org/10.1007/s11618-021-01002-x

Petrov, V., Drašković, Z., Uzelac, Z., & Ćelić, Đ. (2022). Determinants of learning outcomes and satisfaction with online teaching based on students' perception - suitability of applying the instrument. *Proceedings of 27th International Scientific Conference Strategic Management and Decision Support Systems in Strategic Management*, 184-189. https://doi.org/10.46541/978-86-7233-406-7_205

Piaget, J. (1977). *The development of thought: Equilibration of cognitive structures.(Trans A. Rosin)*. Viking.

Piccoli, G., Ahmad, R., & Ives, B. (2001). Web-based virtual learning environments: a research framework and a preliminary assessment of effectiveness in basic IT skills training. *MIS Quarterly, 25*(4) 401-426. https://doi.org/10.2307/3250989

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the motivated strategies for learning questionnaire (mlsq). *Educational and Psychological Measurements, 53*, 801-813. https://doi.org/10.1177/0013164493053003024

Prins, F. J., Veenman, M. V. J. & Elshout J. J. (2006). The impact of intellectual ability and metacognition on learning: new support for the threshold of problematicity theory. *Learning and Instruction, 16*, 374-387. http://dx.doi.org/10.1016/j.learninstruc.2006.07.008

Saghafian, M. & O'Neill, D. K. (2018). A phenomenological study of teamwork in online and face-to-face student teams. *Higher Education, 75*(3), 57-73. https://doi.org/10.1007/s10734-017-0122-4

Schoor, C. & Bannert, M. (2011). Motivation in a computer-supported collaborative learning scenario and its impact on learning activities and knowledge acquisition. *Learning and Instruction, 4*, 560-573. https://doi.org/10.1016/j.learninstruc.2010.11.002

Stevens, G. J., Bienz, T., Wali, N., Condie, J & Schismenos, S. (2021). Online university education is the new normal: but is face-to-face better? *Interactive Technology and Smart Education 18*(3), 278-297. https://doi.org/10.1108/ITSE-08-2020-0181

Ventura-León, J., Caycho-Rodríguez, T., Mamani-Poma, J., Rodriguez-Dominguez, L. & Cabrera-Toledo, L. (2022). Satisfaction towards virtual courses: Development and validation of a short measure in COVID-19 times, *Heliyon*,8, (8). e10311. https://doi.org/10.1016/j.heliyon.2022.e10311

Verstege, S., Pijeira-Díaz, H. J., Noroozi, O., Biemans, H. & Diederen, J. (2019). Relations between students' perceived levels of self-regulation and their corresponding learning behavior and outcomes in a virtual experiment environment, *Computers in Human Behavior, 100*, 325-334. https://doi.org/10.1016/j.chb.2019.02.020

Vidergor, Hava (2023). The effect of teachers' self-innovativeness on accountability, distance learning self-efficacy, and teaching practices. *Computers & Education*, *199*, 104777. https://doi.org/10.1016/j.compedu.2023.104777

Vrieling-Teunter, E., Stijnen, S. & Bastiaens, T. (2021). Promoting student teachers' self-regulated learning in the workplace. *Vocations and Learning, 14*, 223–242. https://doi.org/10.1007/s12186-021-09264-6

Wang, B., Hu, X., Li, P. & Yu, P. (2021). Cognitive structure learning model for hierarchical multi-label text classification. *Knowledge-Based System, 218*(C). https://doi.org/10.1016/j.knosys.2021.106876

Wei, X., Saab, N. & Admiraal, W. (2023). Do learners share the same perceived learning outcomes in MOOCs? Identifying the role of motivation, perceived learning support, learning engagement, and self-regulated learning strategies. *The Internet and Higher Education, 56.* https://doi.org/10.1016/j.iheduc.2022.100880

Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker, J. Dunlosky, & A. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Hillsdale, NJ: Lawrence Erlbaum

Yang, C. C., Tsai, I. C., Kim, B., Cho, M. H., & Laffey, J. M. (2006). Exploring the relationships between students' academic motivation and social ability in online learning environments. *Internet and Higher Education*, *9*, 277–286. https://doi.org/10.1016/j.iheduc.2006.08.002

Yu, H.-H., Hu, R.-P. & Chen, M.-L. (2022). Global pandemic prevention continual learning—taking online learning as an example: the relevance of self-regulation, mind-unwandered, and online learning ineffectiveness, *Sustainability*, *14*(11), 6571. https://doi.org/10.3390/su14116571

Yu Z, (2021). A meta-analysis and bibliographic review of the effect of nine factors on online learning outcomes across the world, *Education and Information Technologies*, *27*, 2457–2482. https://doi.org/10.1007/s10639-021-10720-y

Yunusa, A. A., & Umar, I. N. (2021). A scoping review of critical predictive factors (CPFs) of satisfaction and perceived learning outcomes in E-learning environments. *Education and Information Technologies, 26*(1), 1223–1270. https://doi.org/10.1007/s10639-020-10286-1

Zimmerman, B. J. (2008). Investigating self-regulation and motivation: historical background, methodological developments, and future prospects. *American Educational Research Journal, 45*(1). https://doi.org/10.3102/0002831207312909

Zimmerman, B. J. & Martinez-Pons, M. (1992). Perceptions of efficacy and strategy use in the self-regulation of learning. In Schunk, D. H. & Meece, J. L. *Student Perceptions in the Classroom*, Routledge 185-209.

Zimmerman, B. J. (2000). Self-efficacy: an essential motive to learn. *Contemporary Educational Psychology, 25*(1), 82-91. https://doi.org/10.1006/ceps.1999.1016

✉ **Correspondence**

Viktorija Petrov

University of Novi Sad, The Faculty of Economics in Subotica, 9-11 Segedinski put, Subotica 24000, Serbia

E-mail: viktorija.petrov@ef.uns.ac.rs

Manuscript requirements

The paper must be written in the template which can be found on the Submission of Papers page of the Strategic Management journal web site (https://www.smjournal.rs/index.php/home/about/submissions) and to be sent, together with the Copyright and Use Agreement.

Headings must be short, clearly defined, and numbered, except for Introduction and Conclusions. Apply at most three levels of headings.

All tables, graphs and diagrams are expected to back your research findings. They should be clearly referred to and numbered consecutively in Arabic numerals. They should be placed in the text at the appropriate paragraph (just after its reference).

Tables should be centered. All tables must have captions. The title of your table should follow the table number. Tables should not be wider than the margins of the paper.

Figures should be centered. All figures must have captions. The title of figures should appear immediately below the figure. The title of the figure should follow the figure number. Figures should not be wider than the margins of the paper. Figures will not be redrawn by the publisher. Figures should be high-quality grayscale graphics (please, do not use colors): vector drawings (with text converted to curves) or 300 dpi bitmaps.

Please do not supply any graphics copied from a website, as the resolution will be too low. In all figures taken or adapted from other sources, a brief note to that effect is obligatory, below the figure. One sentence at least referring to the illustration is obligatory.

Mathematical expressions should be numbered on the right side, while all variables and parameters must be defined.

Proof

Authors are responsible for ensuring that all manuscripts (whether original or revised) are accurately typed before final submission. One set of proof will be sent to authors, if requested, before the final publication, which must be returned promptly.

Strategic Management

International Journal of Strategic Management and
Decision Support Systems in Strategic Management

www.smjournal.rs

ISSN: 1821-3448
ISSN 2334-6191 (Online)

The references should specify the source (such as book, journal article or a web page) in sufficient detail to enable the readers to identify and consult it. The references are placed at the end of the work, with sources listed alphabetically (a) by authors' surnames or (b) by the titles of the sources (if the author is unknown). Multiple entries by the same author(s) must be sequenced chronologically, starting from the earliest, e.g.:

> Ljubojević, T.K. (1998). Ljubojević, T.K. (2000a). Ljubojević, T.K. (2000b). Ljubojević, T.K., & Dimitrijević, N.N. (1994).

The DOI number or URL of a full text version should be added if it exists.
Here is a list of the most common reference types:

A PERIODICALS

Authors must be listed by their last names, followed by initials. Publication year must be written in parentheses, followed by a full stop. Title of the article must be in sentences case: only the first word and proper nouns in the title are capitalized. The periodical title must be in title case, followed by the volume number, which is also italicized:

> Author, A. A., Author, B. B., & Author, C. C. (Year). Title of article. *Title of Periodical, volume number* (issue number), pages.

➲ **Journal article, one author, paginated by issue.**

Journals paginated by issue begin with page 1 in every issue, so that the issue number is indicated in parentheses after the
volume. The parentheses and issue numbers are not italicized, e.g.

> Seliverstova, Y. (2021). Workforce diversity management: A systematic literature review. *Strategic Management*, *26*(2), 3–11. https://doi.org/10.5937/StraMan2102003S

➲ **Journal article, one author, paginated by volume.**

Journals paginated by volume begin with page 1 in issue 1, and continue page numbering in issue 2 where issue 1 ended, e.g.

> Perić, O. (2006). Bridging the gap: Complex adaptive knowledge management. *Strategic Management, 14*, 654–668.

➲ **Journal article, two authors, paginated by issue.**

Dakić, S., & Mijić, K. (2020). Regression analysis of the impact of internal factors on return on assets: A case of meat processing enterprises in Serbia. *Strategic Management*, *25*(1), 29–34. https://doi.org/10.5937/StraMan2001029D

➲ **Journal article, two authors, paginated by volume.**

Ljubojević, K., & Dimitrijević, M. (2007). Choosing your CRM strategy. *Strategic Management, 15*, 333-349.

➲ **Journal article, three to six authors, paginated by issue.**

Marić, S., Uzelac, O., & Strugar-Jelača, M. (2019). Ownership structure as a measure of corporate performance. *Strategic Management*, *24*(4), 28–37. https://doi.org/10.5937/StraMan1904028M

➲ **Journal article, three to six authors, paginated by volume.**

Boškov, T., Ljubojević, K., & Tanasijević, V. (2005). A new approach to CRM. *Strategic Management, 13*, 300-310.

➲ **Journal article, more than six authors, paginated by issue.**

Ljubojević, K., Dimitrijević, M., Mirković, D., Tanasijević, V., Perić, O., Jovanov, N., et al. (2005). Putting the user at the center of software testing activity. *Management Information Systems, 3*(1), 99-106.

➲ **Journal article, more than six authors, paginated by volume.**

Strakić, F., Mirković, D., Boškov, T., Ljubojević, K., Tanasijević, V., Dimitrijević, M., et al. (2003). Metadata in data warehouse. *Strategic Management, 11*, 122-132.

➲ **Magazine article.**

Strakić, F. (2005, October 15). Remembering users with cookies. *IT Review*, *130*, 20-21.

➲ **Newsletter article with author.**

Dimitrijević, M. (2009, September). MySql server, writing library files. *Computing News, 57,* 10-12.

➲ **Newsletter article without author.**

VBScript with active server pages. (2009, September). *Computing News,57,* 21-22.

B. BOOKS, BROCHURES, BOOK CHAPTERS, ENCYCLOPEDIA ENTRIES, AND BOOK REVIEWS

Basic format for books

Author, A. A. (Year of publication). *Title of work: Capital letter also for subtitle*. Publisher.

➲ **Book, one author.**

Ljubojević, K. (2005). *Prototyping the interface design*. Faculty of Economics in Subotica.

➲ **Book, one author, new edition**

Dimitrijević, M. (2007). *Customer relationship management* (6th ed.). Faculty of Economics in Subotica.

➲ **Book, two authors.**

Ljubojević, K., Dimitrijević, M. (2007). *The enterprise knowledge portal and its architecture*. Faculty of Economics in Subotica.

➲ **Book, three to six authors.**

Ljubojević, K., Dimitrijević, M., Mirković, D., Tanasijević, V., & Perić, O. (2006). *Importance of software testing*. Faculty of Economics in Subotica.

➲ **Book, more than six authors.**

Mirković, D., Tanasijević, V., Perić, O., Jovanov, N., Boškov, T., Strakić, F., et al. (2007). *Supply chain management*. Faculty of Economics in Subotica.

➲ **Book, no author or editor.**

Web user interface (10th ed.). (2003). Faculty of Economics.

➲ **Group, corporate, or government author.**

Statistical office of the Republic of Serbia. (1978). *Statistical abstract of the Republic of Serbia.* Ministry of community and social services.

➲ **Edited book.**

Dimitrijević, M., & Tanasijević, V. (Eds.). (2004). *Data warehouse architecture*. Faculty of Economics.

➲ **Chapter in an edited book.**

Repa, V. (2019). Deriving Key Performance Indicators from Business Process Model. In M. Pańkowska & K. Sandkuhl (Eds.), *Perspectives in Business Informatics Research. BIR 2019. Lecture Notes in Business Information Processing, vol 365.* (pp. 148–162). Springer. https://doi.org/10.1007/978-3-030-31143-8_11

➲ **Encyclopedia entry.**

Mirković, D. (2006). History and the world of mathematicians. In *The new mathematics encyclopedia* (Vol. 56, pp. 23-45). Faculty of Economics.

C. UNPUBLISHED WORKS

➲ **Paper presented at a meeting or a conference.**

Ljubojević, K., Tanasijević, V., Dimitrijević, M. (2003). *Designing a web form without tables*. Paper presented at the annual meeting of the Serbian computer alliance, Beograd.

➲ **Paper or manuscript.**

Boškov, T., Strakić, F., Ljubojević, K., Dimitrijević, M., & Perić, O. (2007. May). *First steps in visual basic for applications*. Unpublished paper, Faculty of Economics Subotica, Subotica.

➲ **Doctoral dissertation.**

Strakić, F. (2000). *Managing network services: Managing DNS servers*. Unpublished doctoral dissertation, Faculty of Economics Subotica.

➲ **Master's thesis.**

Dimitrijević, M. (2003). *Structural modeling: Class and object diagrams*. Unpublished master's thesis, Faculty of Economics Subotica.

D. ELECTRONIC MEDIA

The same guidelines apply for online articles as for printed articles. All the information that the online host makes available must be listed, including an issue number in parentheses:

Author, A. A., & Author, B. B. (Publication date). Title of article. *Title of Online Periodical, volume number* (issue number if available). https://www.anyaddress.com/full/url/

➲ **Article in an internet-only journal**

Tanasijević, V. (2003, March). Putting the user at the center of software testing activity. *Strategic Management*, *8* (4). https://www.ef.uns.ac.rs/sm2024

➲ **Document from an organization**

Faculty of Economics. (2008, March 5). *A new approach to CRM*. https://www.ef.uns.ac.rs/papers/acrm.html

➲ **Article from an online periodical with DOI assigned.**

Jovanov, N., & Boškov, T. A PHP project test-driven end to end. *Management Information Systems*, 2 (2), 45-54. https://doi.org/10.5937/StraMan213302003S

➲ **Article from an online periodical without DOI assigned.**

Online journal articles without a DOI require a URL.

Author, A. A., & Author, B. B. (Publication date). Title of article. *Title of Journal, volume number*. https://www.anyaddress.com/full/url/

Jovanov, N., & Boškov, T. A PHP project test-driven end to end. *Management Information Systems*, 2 (2), 45-54. https://www.ef.uns.ac.rs/mis/TestDriven.html

REFERENCE QUOTATIONS IN THE TEXT

➲ **Quotations**

If a work is directly quoted from, then the author, year of publication and the page reference (preceded by “p.”) must be included. The quotation is introduced with an introductory phrase including the author’s last name followed by publication date in parentheses.

According to Mirković (2001, p. 201), “The use of data warehouses may be limited, especially if they contain confidential data”.

Mirković (2001, p. 201), found that “the use of data warehouses may be limited”. What unexpected impact does this have on the range of availability?

If the author is not named in the introductory phrase, the author's last name, publication year, and the page number in parentheses must be placed at the end of the quotation, e.g.

He stated, “The use of data warehouses may be limited,” but he did not fully explain the possible impact (Mirković, 2001, p. 201).

➲ **Summary or paraphrase**

According to Mirković (1991, p. 201), limitations on the use of databases can be external and software-based, or temporary and even discretion-based.

Limitations on the use of databases can be external and software-based, or temporary and even discretion-based (Mirković, 1991, p. 201).

➲ **One author**

Boškov (2005) compared the access range…

In an early study of access range (Boškov, 2005), it was found...

➲ When there are **two authors**, both names are always cited:

Another study (Mirković & Boškov, 2006) concluded that…

➲ If there are **three or more authors** the abbreviation "et al." (Latin for "and others") is employed in APA in-text citations when referencing works with three or more authors. The format is to include only the first author's last name, followed by "et al.," a comma, and the year of publication. For instance, (Dakic et al., 2024) would be used as an example.

➲ **Unknown author**

If the work does not have an author, the source is cited by its title in the introductory phrase, or the first 1-2 words are placed in the parentheses. Book and report titles must be italicized or underlined, while titles of articles and chapters are placed in quotation marks:

A similar survey was conducted on a number of organizations employing database managers (Limiting database access, 2005).

If work (such as a newspaper editorial) has no author, the first few words of the title are cited, followed by the year: (The Objectives of Access Delegation, 2007)

Note: In the rare cases when the word "Anonymous" is used for the author, it is treated as the author's name (Anonymous, 2008). The name Anonymous must then be used as the author in the reference list.

➲ **Organization as an Author**

If the author is an organization or a government agency, the organization must be mentioned in the introductory phrase or in the parenthetical citation the first time the source is cited:

According to the Statistical Office of the Republic of Serbia (1978), …

Also, the full name of corporate authors must be listed in the first reference, with an abbreviation in brackets. The abbreviated name will then be used for subsequent references:
The overview is limited to towns with 10,000 inhabitants and up (Statistical Office of the Republic of Serbia [SORS], 1978).

The list does not include schools that were listed as closed down in the previous statistical overview (SORS, 1978).

➲ When citing **more than one reference from the same author**: (Bezjak, 1999, 2002)

➲ When several **used works by the same author were published in the same year**, they must be cited adding a, b, c, and so on, to the publication date:

(Griffith, 2002a, 2002b, 2004)

➲ **Two or more works in the same parentheses**

When two or more manuscripts are cited parenthetically, they must be cited in the same order as they appear in the reference list, separated by a semicolon.

(Bezjak, 1999; Griffith, 2004)

➲ **Two or more works by the same author in the same year**

If two or more sources used in the submission were published by the same author in the same year, the entries in the reference list must be ordered using lower-case letters (a, b, c…) with the year. Lower-case letters will also be used with the year in the in-text citation as well:

Survey results published in Theissen (2004a) show that…

➲ To **credit an author for discovering a work** when you have not read the original:

Bergson's research (as cited in Mirković & Boškov, 2006)…

Here, Mirković & Boškov (2006) will appear in the reference list, while Bergson will not.

➲ When **citing more than one author**, the authors must be listed alphabetically:

(Britten, 2001; Sturlasson, 2002; Wasserwandt, 1997)

➲ When there is **no publication date**: (Hessenberg, n.d.)

➲ **Page numbers must always be given for quotations**:

(Mirković & Boškov, 2006, p.12)

Mirković & Boškov (2006, p. 12) propose the approach by which "the initial viewpoint…

➲ **Referring to a specific part of a work**:

(Theissen, 2004a, chap. 3) (Keaton, 1997, pp. 85-94)

➲ **Personal communications, including interviews, letters, memos, e-mails, and telephone conversations**, are cited as below. (These are *not* included in the reference list.)

(K. Ljubojević, personal communication, May 5, 2008).

FOOTNOTES AND ENDNOTES

A few footnotes may be necessary when elaborating on an issue raised in the text, adding something that is in indirect connection, or providing supplementary technical information. Footnotes and endnotes are numbered with superscript Arabic numerals at the end of the sentence, like this.1 Endnotes begin on a separate page, after the end of the text. However, *Strategic Management* **does not recommend the use of footnotes or endnotes.**

ЦИП – Каталогизација у публикацији
Библиотека Матице српске, Нови Сад

005.21

STRATEGIC managament : international journal of strategic managament and decision support systems in strategic managament / editor-in-chief Lazar Raković. - Vol. 14, no. 1 (2009) - . - Subotica: University of Novi Sad, Faculty of Economics, 2009-. - 30 cm

Tromesečno. - Nastavak publikacije: Strategijski menadžment = ISSN 0354-8414
ISSN 1821-3448

COBISS.SR-ID 244849927

Rešenjem Ministarstva za informisanje Republike Srbije, časopis "Strategijski menadžment" upisan je u registar javnog informisanja pod brojem 2213, od 7. avgusta 1996. Rešenjem Ministarstva za nauku i tehnologiju Republike Srbije br. 413-00-435/1/96-01 časopis je oslobođen opšteg poreza na promet proizvoda kao publikacija od posebnog interesa za nauku.

ISSN 1821-3448