Information theory of firm

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Abstract – The article formulates the information theory of firm, introduces the concept of firm as an operating system, which controls the firm’s operation by the means of the information resources processing, in an analogy with the operating system at a microprocessor in the computing devices, represents the director as an information processing element, describes the board of directors as the electronically-scanned electronically-steered phased array radar, considers the scientific problem of strategy creation by the interlocking interconnecting overlapping directors in the boards of directors in the firms in the economic system with the induced nonlinearities. We highlight a fact that the director makes the information sensing, filtering, processing, resonant absorption, analysis, decision making, strategy creation, hence it can be empirically represented as a processing element with the Harvard or von Neumann director’s mindset architectures in line with the digital signal processing science. We think that the board of directors in corporate governance system can be theoretically represented as the electronically-scanned electronically-steered phased array radar with a certain number of electronic devices (directors can be modeled as electronic devices with the active antenna elements, filters banks, digital signal processors, memory chipsets in agreement with the microwave and digital signal processing sciences). We developed the MicroITF operating system and software programs, 1) to control the firm operation by the means of the information resources processing; 2) to accurately characterize the director’s performance by means of a) the filtering of the generated/transmitted/received information by the director into the separate virtual channels, depending on the information content, and b) the measurement of the levels of signals in every virtual channel with the generated/transmitted/received information by the director, in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms during the Quality of Service (QofS) measurements process, and 3) to create the winning virtuous business strategies by the interlocking interconnecting directors in the boards of directors in the firms, using the patented recursive artificial intelligence algorithm.

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Keywords: information theory of firm, firm business strategy creation, optimal corporate governance structures, board of directors composition, interlocking directors networks, boards seats accumulation number, information flows measurements, operating systems in computing devices, digital signal processing, information absorption, econophysics, microeconomics.
Introduction

In this empirical condensed research essay, the authors would like to do the following things: 1) to create the information theory of the firm, 2) to review the interconnecting interlocking directors networks configurations in the boards of directors of publicly traded and non-traded firms, and 3) to research the strategy creation problem by the interlocking interconnecting directors in the boards of directors in the firms during the strategic governance of firms in the challenging time, when the innovation breakthrough processes originate the creative innovative disruptions appearances during the capitalism evolution in Schumpeter (1911, 1939, 1947), Christensen (Christensen (June 16, 1977; Fall, 1992a, b; 1997; 1998; December, 1998; April, 1999a, b, c; 1999a, b; Summer, 2001; June, 2002; 2003; March, April, 2003; January, 2006), Bower, Christensen (January, February, 1995; 1997; 1999), Christensen, Armstrong (Spring, 1998), Christensen, Cape (December, 1998), Christensen, Dann (June, 1999), Christensen, Tedlow (January, February, 2000), Christensen, Donovan (March, 2000; May, 2010), Christensen, Overdorf (March, April, 2000), Christensen, Bohmer, Kenagy (September, October, 2000), Christensen, Craig, Hart (March, April, 2001), Christensen, Milunovich (March, 2002), Bass, Christensen (April, 2002), Anthony, Roth, Christensen (April, 2002), Kenagy, Christensen (May, 2002; 2002), Christensen, Johnson, Rigby (Spring, 2002), Hart, Christensen (Fall, 2002), Christensen, Verlinden, Westerman (November, 2002), Shah, Brennan, Christensen (April, 2003), Christensen, Raynor (2003), Burgelman, Christensen, Wheelwright (2003), Christensen, Anthony (January, February, 2004), Christensen, Anthony, Roth (2004), Christensen, Baumann, Ruggles, Sadtler (December, 2006), Christensen, Horn, Johnson (2008), Christensen, Grossman, Hwang (2009), Dyer, Gregersen, Christensen (December, 2009; 2011), Christensen, Talukdar, Alton, Horn (Spring, 2011), Christensen, Wang, van Bever (October, 2013)). The authors will apply the sophisticated econometrical econophysical techniques with the purpose to accurately characterize the firm within the information theory of the firm, achieving the strategic research goals in Schumpeter (1906, 1933), Bowley (1924), Fogel (1964), Box, Jenkins (1970), Grangel, Newbold (1977), Van Horne (1984), Taylor S (1986), Tong (1986, 1990), Judge, Hill, Griffiths, Lee, Lukepol (1988), Hardle (1990), Grangel, Teräsvirta (1993), Pesaran, Potter (1993), Banerjee, Dolado, Galbraith, Hendry (1993), Hamilton (1994), Karatzas, Shreve (1995), Campbell, Lo, MacKinlay (1997), Rogers, Talay (1997), Hayashi (2000), Durbin, Koopman (2000, 2002, 2012), Ilinski (2001), Greene (2003), Koop (2003), Davidson, MacKinnon (2004), Cameron, Trivedi (2005), Vialar, Goergen (2009).
Let us make a chronological literature review to accurately characterize both the directors and the interconnecting interlocking overlapping directors’ networks in the boards of directors in the theory of firm, aiming to create a coherent picture on a range of the researched problems, the obtained research results and the progress made in the field of our research interest. The authors would like to highlight the fact that the research on the firm (the business enterprise) was in the scope of responsibilities by the National Bureau of Economic Research in the USA for a long time in Mitchell (February 7 1921). We would like to begin with the important fundamental research in the economics in Brandeis (1915, 1933). The corporate managers’ functions, modern corporation structures and private property meaning have been considered in Berle (1932), Berle, Means (1932). The problems on the business administration have been uncovered in Selznick (1949, 1957). The nature of business elite’s power has been described in Mills (1956). The issues such as the critical evaluation of corporate director, the boards of directors possible structures and the corporate strategy creation have been considered in Vance (1964, 1968, 1983). A series of research articles by Williamson (1964, 1975, 1984, December 1985, 1988, 1996, 2002, 2007) has been focused on the corporate governances problems in the theory of firm. The topics on the board of directors and effective management in the firm have been discussed in Koontz (1967). Travers (1968), Dooley (1969) researched the interlocks in the corporate management. The research on the state in the capitalist society has been presented in Miliband (1969). The power and functions of the boards of directors from the theoretical synthesis point of view have been studied in Zald (1969). The higher circles have been described in Domhoff (1970). Bunting, Barbour (Autumn 1971), Bunting (1976) presented a study on the interlocking directorates in large American corporations, 1896 - 1964. The directors, board of directors and president have been precisely characterized in Mace (1971, 1986), Mace (March-April 1972). Child (1972) focused his research on the organizational structure, environment and performance. The formation of the sphere of influence has been discussed in Levine (1972). The theory of organization has been formulated in Pfeffer (1972, 1973, 1981, 1982, 1983, 1987, 1991), Pfeffer, Salancik (1978, 2003). Bacon (1973, 1993) discussed the corporate directorship practices, the corporate boards problems and the corporate governance issues. Blumberg (1973) presented his reflections on the proposals for the corporate reform through change in the composition of the board of directors. Granovetter (1973) highlighted the strength of weak ties.

Let us move forward with the author’s original proposals consideration on the information theory of the firm, making the innovative modeling of the firm, director, board of directors, and researching the business strategy creation problem in details.

Modeling of firm as operating system to control, manage and process information resources in information theory of firm

Let us begin the research by formulating the purpose of the firm as in Ledenyov D O, Ledenyov VO (2013b): “Mano (1970) defines the purpose of the firm as: “Therefore, the activity of the firm should be thought of as the process of producing the organizational utilities by combining the various cooperative activities and converting them into inducements and deriving the next contributions from the member mentioned above. In this case all the members want to sustain such cooperative activities to get more satisfaction (or inducements) and less sacrifice (or their cooperative activities). The actual purpose of leading principle of the firm can be abstractly said to be the maintenance and development of the firm itself. In other words, it can be said to be the maintenance of the balance of the organizational utilities and their increase. Unless the differential between the produced organizational utilities and the inducement derived from its utilities is equilibrium or positive, the firm will become bankrupt at some future time.”

Kantarelis (2007) presents an interesting summary of his research findings on the purpose of the firm:

1. “The firm identifies a consumer need and develops/invents a recipe on how to satisfy that need;
2. The firm makes the right decisions with respect to making or buying inputs so that it delivers its recipe at the lowest possible cost;
3. The firm provides the best incentives to its stakeholders;
4. The firm constantly and deliberately evolves through the relentless pursuit of competitive, organization and strategic advantage.”
Let us describe the **organizational structure of the firm** as in *Ledenyov D O, Ledenyov VO (2013b)*: “Barnard (1938, 1948, 1949, 1958) introduced the two types of organizations such as the lateral organization and scalar (or hierarchical) organization. According to Mano (1970): “The firm consists of not only stockholders, employees, and managers, but also creditors, government authorities, consumers and material suppliers:

1. **Stockholders** contribute a cooperative action to supply long-term capital in order to pursue the dividends, stock dividends, and the rise of stock value.
2. **Creditors** contribute a cooperative action to supply short-term capital mainly to earn interest.
3. **Consumers** contribute a cooperative action to supply cash in order to purchase goods or services.
4. **Government** authorities contribute a cooperative action to supply many conveniences in order to receive various taxes or donations, and material suppliers contribute a cooperative action to supply materials and facilities to get returns.
5. **Employees** and managers contribute the cooperative actions which combine the actions contributed by other members to produce organizational utilities in Barnard (1938) as large as possible and divide the utilities into various inducements or incentives as mentioned above in order to get contributions from members. They contribute such actions in order to get wages, utilizing right of employee benefit plans, social positions, honors and authority.”


1) **Barriers to entry creation**,  
2) **Strategic boundaries definition**,  
3) **Limits to growth evaluation**.

The **existing modern theories of the firm** have been created by many prominent thinkers and described in *Ledenyov D O, Ledenyov VO (2013b)*:

1. “The **neo-classical theory of the firm** describes the various market structures, regulation issues, strategic pricing, barriers to entry, economies of scale and scope and even optimum portfolio selection of risky assets, and establishes the principle of profit maximisation, according to which profit is maximised, when marginal revenue is equal to marginal cost in the conditions of complete information. The theory does not allow for firm evolution in Kantarelis (2007).
2. The **transaction cost theory of the firm** states that the people begin to organise their production in the firms, when the transaction cost of coordinating production through the market exchange in the conditions of the imperfect information, is greater than within the firm in *Coase (1937)*. It does not take into consideration agency costs or firm evolution, neither does it explain how vertical integration should take place in the face of investments in human assets, with unobservable value, that cannot be transferred in *Kantarelis (2007)*.

3. The **managerial theory of the firm** suggests that the managers would seek to maximise their own utility and consider the implications of this for firm behaviour in contrast to the profit-maximising case in *Baumol (1959, 1962), Marris (1964)* and *Williamson (1966)*.

4. The **principal–agent theory of the firm** extends the **neo-classical theory of the firm** and **managerial theory of the firm** by adding agents to the firm, and it considers the friction due to asymmetric information between owners of firms and their stakeholders or managers and employees; the friction between agent and principal requires precise measurement of agent performance and the engineering of incentive mechanisms. The weaknesses of the theory are many: it is difficult to engineer incentive mechanisms, it relies on complicated incomplete contracts (borderline unenforceable), it ignores transaction costs (both external and internal), and it does not allow for firm evolution in *Spence and Zeckhauser (1971), Ross (1973), Kantarelis (2007)*.

5. The **behavioural theory of the firm** assumes that the groups of people participate in setting goals and making decisions on the production; inventory; market share; sales and profits in the firm, potentially creating conflicts. The theory proposes that the real firms aim to satisfy rather than maximize their results in agreement with the bounded rationality concept in *Cyert, March (1963)*.

6. The **evolutionary theory of the firm** states that the firm possesses unique resources: financial, physical, human and organizational. It sees the firm as a reactor to change and a creator of change for competitive advantage. The firm, as a creator of change, may cause creative destruction, which in turn may give birth to new industries and enable sectors of, or entire, economies to grow. The theory does not take to the account that the creative innovation process cannot be easily programmed within a firm or a nation in *Kantarelis (2007)*."
Let us highlight the most significant research works on the **theory of the firm**:


Going to the description of our new research proposals, the authors think that the firm receives/transmits the constant information data streams, processes the big information files and mainly deals with the various kinds of information in the information century, hence it makes sense to describe the firm in the frames of the information theory, which is formulated by the authors for the first time.

**The Ledenyov information theory of the firm proposes that the firm controls and manages the information resources, hence it is possible to theoretically model the firm as the operating system (OS), which controls, manages and processes the firm’s information resources.**

The authors think that a certain analogy can be drawn between the firm’s operating system in the information theory of the firm and the operating system in a microprocessor (quantum processor) in a computing device in the computer science.
In accordance with the *Ledenyov information theory of the firm, the firm’s deterministic operating system controls and manages the firm’s information resources with the application of a computing kernel*, which has a number of functions

1) Making the computational operations with the information data streams,

2) Activation and deactivation of the business tasks in the time domain,

3) Setting the business task priorities in the time domain,

4) Making the sequential preemptive or time-sliced scheduling of business task execution in the time domain,

5) Supporting the communications between the business tasks over the time period,

6) Managing the allocation of and access to the memory by the business tasks at certain time moments.

7) Tracking the business tasks in the time domain,

8) Supporting the multitasking execution in the time domain.

We developed the *MicroITF operating system* with the following purpose to control, manage and process the firm’s operations by the means of the information resources processing.

Going from a conducted comparative analysis of the source codes of the different operating systems, the authors came to a conclusion that the *MicroITF operating system* is based on the new innovative computing technologies, which are much more advanced than the known technologies, used in the near real time VxWorks operating system by WindRiver; Windows operating system by Microsoft; MacOS and iOS operating system by Apple, Android operating system by Google and Linux / Unix open source operating systems.

The authors would like to explain that the *MicroITF operating system* can be emulated at the computing devices with the Linux, Unix, Windows, MacOS, iOS, Android, Amoeba operating systems with the purposes:

1) to control the firm operation by the means of the information resources processing;

2) to accurately characterize the director’s performance by means of a) the filtering of the generated/transmitted/received information by the director into the separate virtual channels, depending on the information content, and b) the measurement of the levels of signals in every virtual channel with the generated/transmitted/received information by the director, in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms during the Quality of Service (QoS) measurements process, and

3) to create the winning virtuous business strategies by the interlocking interconnecting directors in the boards of directors in the firms, using the patented recursive artificial intelligence algorithm.
Representation of director as processing element in analogy with digital signal processor in information theory of firm, and modeling of board of directors as electronically-scanned electronically-steered phased array radar in information theory of firm

It is a well known fact that the information can be transmitted in the analogue and digital formats over the wireless, wireline and optical communication channels in agreement with the research findings in the information theory and the information communication theory in Shannon (1948), Yaglom A M, Yaglom I M (1983), Ledenyov D O, Ledenyov V O (2015d).

The authors would like to formulate the Ledenyov theory of the board of directors as well as the interlocking interconnecting directors’ networks in the boards of directors in the firms, going from the information theory and information communication theory perspectives in Shannon (1948), Yaglom A M, Yaglom I M (1983), Ledenyov D O, Ledenyov V O (2015d).

The authors make a logical assumption that the director works with the information in the board of directors in the firm, performing various kinds of manipulations with the information to form his opinions and make his decisions on the business related issues in the firm. Therefore, let us focus our attention on a possible representation of the director in terms of the information communication theory. The authors come up with a research idea that the director works to make the decisions on the a number of different business related tasks in the firm by doing the following things:

1. The information sensing/detection, we can conditionally imagine that the director is a sensing and detecting device with the embedded optical, sound, chemical sensors and detectors, which can gather the information data streams in the information fields.

2. The information filtering, it would be interesting to say that every director has the accumulated knowledge base, subject oriented skills developed during his education at university, professional experiences obtained in the process of work, can allow the director to tune into the selected information data streams at certain frequencies and to filter out the undesired information streams, working at the board of directors in the firm. The filtered information by every director is different, but some correlations may occur. Moreover, the filtered information can be distorted during the information filtering process, because of various factors such as the existing imperfections in the director’s professional education, professional experiences, and problems with the data communication channels.

3. The information processing, we would like to make a theoretical proposition that the director can be represented as an information processing element with the Harvard
director’s mindset architecture or the von Neumann director’s mindset architecture or some other possible director’s mindset architectures in agreement with the digital signal processing and business administration sciences. Let us suppose that the classical von Neumann director’s mindset architecture has a single memory to store the data and program instructions; and the Harvard director’s mindset architecture has the two separate memories to keep the data and program instructions, achieving a high degree of concurrency in Hwang, Briggs (1984), Anceau (1986), Fountain (1987), Chen (editor) (1988), Van de Goor (1989), Prisch (1998), Wanhammar (1999). Thus, we firmly believe that the director’s mindset architecture may have the multiple distinctive impacts on the information processing volume, quality and time, resulting in an appearance of the different professional director’s characteristics. In other words, the nature of the director’s mindset architecture can partly explain an observation of variations in the functional performance of the board of directors, resulting in the different paths of enterprises evolution.

4. The information resonant absorption, the authors want to note that the director’s resonant absorptive capacity in respect to the information, that is an ability to obtain and memorize the knowledge and information from the external environment, is defined by the director’s professional education, professional experiences, etc. The absorption phenomena with an emphasis on the knowledge creation and accumulation in the organization in the economics has been researched in Cohen, Levinthal (1989, 1990), Nonaka (1994), Kumar, Nti (1998), Lane, Lubatkin (1998), Farina (2008). The director’s resonant absorptive capacity in respect to the information is to some degree analogous to the resonant absorption phenomena in the condensed matter and soft condensed matter in the physics and chemistry, which has been researched by the authors early:


b) The absorption of the electromagnetic signals in the condensed matter (the high pure metals and superconductors) at the ultrasonic frequencies has been investigated in the solid state physics at the in Ledenyov O P (2012a, b, c), Ledenyov V O, Ledenyov D O, Ledenyov O P,


6. the decision making, let us highlight the fact that the decision making must be conducted with the consideration of the obtained analytic results in the certain time period, using the reasoning techniques with an application of the theoretical and practical knowledge base, which is accumulated by the director.

Therefore, it is logical to assume that in view of the fact that the director makes the information sensing, filtering, processing, resonant absorption, analysis, decision making, strategy creation, hence the director can be empirically represented as a processing element with the Harvard or von Neumann director’s mindset architectures in line with the digital signal processing science as in Ledenyov D O, Ledenyov V O (January 22 2015).

The authors proposed a concise definition of the board of directors in Ledenyov D O, Ledenyov V O (January 22 2015): “a group of elected appointed directors (institutional
agents), who control all the business activities by the management team (corporate agents) toward the firm’s business development, constitute a board of directors.”

We have already emphasized that the standard board of directors in the firm can be represented as a matrix in Ledenyov D O, Ledenyov V O (January 22 2015).

\[
\text{Board of Directors} = \begin{bmatrix}
d_{1,1} & d_{1,2} & d_{1,j} \\
d_{2,1} & d_{2,2} & d_{2,j} \\
d_{i,1} & d_{i,2} & d_{i,j}
\end{bmatrix},
\]

where \( d_{i,j} \) is the position of a director’s seat in the matrix, which describes the standard board of directors in the firm.

We also highlighted a fact that the board of directors composition dynamics over the time can be described by the generalized formula as in Santella, Drago, Polo (November 11 2007), Ledenyov D O, Ledenyov V O (January 22 2015)

\[
\text{board}_{c,t} = \text{board}_{c,t-1} + \int_{t}^{t+1} (en - ex) dt,
\]

where

\[
en(t) = \frac{d}{dt} en \cdot t = en,
\]
\[
ex(t) = \frac{d}{dt} ex \cdot t = ex,
\]

\( en(t) \) is the number of directors entrants at time \( t \),
\( ex(t) \) is the number of directors exits at time \( t \),
\( \text{board}_{c,t} \) is the board of directors size at time \( t \),
\( c \) is the company,
\( i \) is the director.

Heimbrandt (2007) writes: “As the modern firm has continued to grow and its owner base has widened, the owners’ opportunities to exert influence has diminished. While the board of directors is a strategic resource available to management it is also the owners’ primary tool for exercising control. To a large extent research on the role of the board of directors has focused on the relationship between various characteristics of the board and the firm’s financial result. Research literature within the field of corporate governance has established three primary roles for the board of directors: setting strategy, controlling management and being a resource available to management. The vast majority of research within the field is primarily based on investor owned firms.”
Going to the topics of the **information analysis and subsequent decision making by the director in the board of directors in the firm**, let us focus on a possible representation of the **board of directors** in terms of the **information communication theory**. In the predefined set of coordinates, the **board of directors** with a certain number of elected appointed directors can be theoretically represented as

1. **An electronically scanned electronically steered phased array radar** with a certain number of active elements (directors), which can sense the information and tune into the selected **information carrier frequencies bands in the information fields**;

2. **A filters bank** with a certain number of **information filters**, which tunes into the certain data streams frequencies and reject the unnecessary information streams in the adjacent channels over all the frequencies range;

3. **An array of digital signal processors** with the **Harvard / von Neumann architectures**, which process the digitized data streams, using the predefined **information processing algorithms**, which can be implemented in the **hardware** or the **software**;

4. **A memory chipset** with the ultra fast short and long term memories, which store the **absorbed information** and provides a fast access to the absorbed information.

In other words, we think that the **board of directors in the corporate governance system** can be theoretically represented as the electronically-scanned electronically-steered phased array radar with a certain number of the electronic elements/devices (directors, who can be modeled as electronic devices with the active antenna elements, filters banks, digital signal processors, memory chipsets in agreement with the microwave and digital signal processing sciences).

Let us take a general look on the **board of directors position and characteristics within the firm**. Fig. 1 shows the relationship between ownership structure, composition of the board and firm performance in Desender (2009).

![Diagram](image)

**Fig. 1. Relationship between ownership structure, composition of the board and firm performance (after Desender (2009)).**
Fig. 2 demonstrates a relationship between the ownership structure, board composition and external audit services in Desender, García-Cestona, Crespi, Aguilera (November 23, 2009).

Tab. 1 presents the independent variables description in Ştefănescu (March 2013).

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Variables description</th>
<th>Predicted sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board independence</td>
<td>B_Indep number of non-executive directors / total number of members</td>
<td>+</td>
</tr>
<tr>
<td>Board size</td>
<td>B_Size total number of members on the board</td>
<td>-</td>
</tr>
<tr>
<td>Board education</td>
<td>B_Edu number of members with high level of education / total number of members</td>
<td>+</td>
</tr>
<tr>
<td>Board experience</td>
<td>B_Exp number of members with cross-directorship / total number of members</td>
<td>+</td>
</tr>
<tr>
<td>Board gender</td>
<td>B_Gen male members / total number of members</td>
<td>+</td>
</tr>
<tr>
<td>Board meetings</td>
<td>B_Met number of board meetings / year</td>
<td>+</td>
</tr>
</tbody>
</table>

Tab. 1 Independent variable description (Ştefănescu (March 2013)).
There is a big number of variables to characterize the board of directors (see below). Tab. 2 shows the corporate governance variables definitions in Horváth, Spirollari (2012).

<table>
<thead>
<tr>
<th>Name of Variable</th>
<th>Acronym</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent Variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tobin’s Q</td>
<td>TQ</td>
<td>The market value of equity plus total debt divided by the book value of total assets of the company.</td>
</tr>
<tr>
<td><strong>Independent Variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Board composition</td>
<td>BODCOM</td>
<td>The proportion of non-executive directors to total number of directors on the board.</td>
</tr>
<tr>
<td>CEO duality</td>
<td>DUAL</td>
<td>Dummy variable, taking a value of 1 for firms with the CEO as Chair, and 0 otherwise.</td>
</tr>
<tr>
<td>Board size</td>
<td>BSIZE</td>
<td>Total number of directors on the board.</td>
</tr>
<tr>
<td>Audit committee independence</td>
<td>ACIND</td>
<td>The proportion of independent directors on the audit committee.</td>
</tr>
<tr>
<td>Audit committee activity</td>
<td>ACMEET</td>
<td>The number of audit committee meetings held in a year 2010.</td>
</tr>
<tr>
<td>Audit committee size</td>
<td>ACSIZE</td>
<td>Total number of directors on the audit committee.</td>
</tr>
<tr>
<td><strong>Control Variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm Size</td>
<td>FSIZE</td>
<td>The book value of the total assets of the company.</td>
</tr>
<tr>
<td>Leverage / Debt proportion</td>
<td>DEBT</td>
<td>The percentage of total liabilities to total assets.</td>
</tr>
</tbody>
</table>

Tab. 3. Firm performance variables definitions
Tab. 4 shows the main interpretations (definitions) of *board involvement* in the *strategic process* in Ghaya (October 2011).

<table>
<thead>
<tr>
<th>Author</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andrews (1980)</td>
<td>Andrews (1980) argues that board of directors is in a great position to contribute on the strategic planning and formulation. He associates an effective ‘board strategic contribution’ to Board involvement in the critical strategic issues as generating alternatives and search for new opportunities [...] also, in supporting management imagination, overseeing innovative processes and reviewing CEO propositions*.</td>
</tr>
<tr>
<td>Rindova (1999)</td>
<td>Rindova (1999), board involvement in strategy is associated to directors’ participation in the thinking through of strategy making: environmental scanning and interpretation and strategic formulation.</td>
</tr>
<tr>
<td>McNulley and Pettigrew (1999)</td>
<td>McNulley and Pettigrew (1999) have proposed a detailed set of strategic activities that board of directors can insure during the strategic decision making process. They identify choice, change and control as key aspects of corporate strategy and illustrate three level of board involvement in strategy: ‘taking decision’, ‘shaping decisions’ and ‘shaping the content, context and conduct of strategy’.</td>
</tr>
<tr>
<td>Forbes and Milliken (1999)</td>
<td>Forbes and Milliken (1999) defined ‘board task performance’ as the board’s ability to perform its control and service tasks effectively [...] control tasks include decisions regarding hiring and compensation management. The service tasks include providing experts during major events and generating and analysis strategic alternatives during board meeting. (p. 492)</td>
</tr>
<tr>
<td>Demb and Neubauer (1992)</td>
<td>Demb and Neubauer (1992) consider establishing the strategic direction of the corporation as the most important task of board of directors (P.50). In consequence, a meaningful board involvement, for them, is characterized by the manner in which directors help to define company strategy (p.55) [...] it depends on the strategy process (p. 73).</td>
</tr>
<tr>
<td>Stiles and Taylor (2001)</td>
<td>Stiles and Taylor (2001) associate board involvement in strategic decision making in large organizations to “setting the context of strategy” through several activities: reviewing the corporate definition, actively assessing and reviewing strategic proposals and often changing proposals through comment and advice [...] encouraging management with good track records in their strategic aims and through the selection of directors” (p. 31)</td>
</tr>
<tr>
<td>Huse (2007)</td>
<td>Huse (2007) argued that board strategic involvement is widely related to the content of strategy. He define strategy as “the development, maintenance and monitoring of the firms’ core competencies with the purpose of achieving long-term results and survival. Strategic decision-making involves resolving uncertainty, complexity and conflict” (P.239). So, board strategic involvement covers “corporate mission development, strategy conception and formulation, and strategy implementation [...] the board can be involved to various degrees in each of these areas.” (p. 240)</td>
</tr>
<tr>
<td>Karoni (2009)</td>
<td>For Karoni (2009), board involvement represents the effective measurement of the intensity with which board undertakes its strategic activities (P.153). It is related to different forms of board activation. The author defines board activation as “the decision to make a portfolio of activities. This decision can be individual or collective, deliberated or emergent, voluntary or forced. Board activation leads to the expression of a set of expectations and generates either strong or weak level of commitment on boards’ activities.” (p. 153)</td>
</tr>
<tr>
<td>Minichilli, Zattoni and Zona (2009)</td>
<td>Minichilli, Zattoni and Zona (2009) defined board task performance as “the ability of the board to perform six tasks related both to service (advice, networking and strategic participation) and control (behavioral, output and strategic control) (p. 56).” This empirical definition was inspired from the theoretical framework of Huse (2005) about board involvement and the model of Zona and Zattoni (2006) of board task effectiveness.</td>
</tr>
<tr>
<td>Zhang (2010)</td>
<td>Zhang (2010) have studied empirically the impact of possessing and using diverse information of board members on the quality of board task performance. They define board task performance as “a source of competitiveness, which can protect the firm’s long-term health against managerial short-term plans.” It covers set of activities such as, the development of the firm’s mission and vision, the formulation of business concepts, the evaluation and control of strategic proposals and the implementation of approved strategies.(p. 474)</td>
</tr>
</tbody>
</table>

*Tab. 4. Main interpretations (definitions) of board involvement in strategic process (after Ghaya (October 2011)).*
Tab. 5 describes a set of board activities in the steps of the strategic decision making process in Ghaya (October 2011).

<table>
<thead>
<tr>
<th>Steps of the strategic process</th>
<th>Board activities (Board involvement in...)</th>
<th>Board roles</th>
<th>Main references</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Major objectives and analysis of the company and its environment</strong></td>
<td>1. Setting (initiating and discussing) major objectives of the company policy</td>
<td>Strategy + service</td>
<td>Rindova (1999), McNulty and Pettigrew (1999)</td>
</tr>
<tr>
<td></td>
<td>5. Identification of opportunities and problems that the company could avail (depending on its human and financial resources)</td>
<td>Strategy + service</td>
<td>Huse (2007), Rindova (1999)</td>
</tr>
<tr>
<td></td>
<td>7. Analysis of the competitive position of the company vis-à-vis the retained problem/opportunity</td>
<td>Strategy</td>
<td>McNulty and Pettigrew, 1999</td>
</tr>
<tr>
<td></td>
<td>8. Evaluation of management’s proposals and/or propositions of alternative options (advantages and disadvantages, etc.)</td>
<td>Strategy</td>
<td>McNulty and Pettigrew, 1999</td>
</tr>
<tr>
<td><strong>Strategic implementation</strong></td>
<td>11. Review and approve corporate plan of implementation and actions (main steps and setting objectives and indicators to monitor the implementation progress)</td>
<td>Strategy + control</td>
<td>Lorsch and Maclver (1989)</td>
</tr>
<tr>
<td></td>
<td>12. Tracking of the decision implementation</td>
<td>Strategy + control</td>
<td>Huse (2007)</td>
</tr>
<tr>
<td></td>
<td>13. intermediation with important external actors to facilitate the implementation</td>
<td>Service</td>
<td>Pfeffer (1972, 1973)</td>
</tr>
<tr>
<td></td>
<td>15. Identification of solutions for the emergent problems of management</td>
<td>Service</td>
<td>Pettigrew (1992)</td>
</tr>
<tr>
<td></td>
<td>16. Facilitate (intermediation in) acquiring resources (financial, cognitive or technological resources)</td>
<td>Service</td>
<td>Pfeffer and Salancik (1978)</td>
</tr>
<tr>
<td><strong>Control and evaluation</strong></td>
<td>17. Monitoring the achievement of strategic goals</td>
<td>Strategy + control</td>
<td>Huse (2007), Rindova (1999)</td>
</tr>
<tr>
<td></td>
<td>18. Financial monitoring (control by results, accounts, budget, etc.)</td>
<td>Control</td>
<td>Zahra and Pearce (1989)</td>
</tr>
<tr>
<td></td>
<td>19. Monitoring the performance of the company via financial and strategic measures</td>
<td>Control</td>
<td>Fama and Jensen (1983)</td>
</tr>
<tr>
<td></td>
<td>21. The process of appointment or revocation of the CBO and controlling compensation</td>
<td>Control</td>
<td>Lorsch and Maclver (1989)</td>
</tr>
</tbody>
</table>

Tab. 5. Set of board activities in the steps of the strategic decision making process (after Ghaya (October 2011)).
Tab. 6 provides information on the synthesis of board of directors’ contributions in the corporate governance theories in Ghaya (October 2011)).

<table>
<thead>
<tr>
<th>Theory / Discipline</th>
<th>Board contribution</th>
<th>Theory / Discipline</th>
<th>Board contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONTRACTUAL THEORIES</strong></td>
<td></td>
<td><strong>STRATEGIC AND COGNITIVE THEORIES</strong></td>
<td></td>
</tr>
<tr>
<td><strong>MAIN IDEAS</strong>: - the firm is a nexus of contracts based on an agency relationship between top managers and shareholders/stakeholders. -Board of directors has a little contribution in the firm life, monitoring role without participation in initiating strategy.</td>
<td><strong>MAIN IDEAS</strong>: - the firm is a directory of key skills. Knowledge has a capital role in the creating value. -Board has an important role in establishing the corporate strategy.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>T</strong>: Legalistic approach</td>
<td>Nominating CEO and monitoring his performance; evaluating company performance and representing shareholders’ interest</td>
<td><strong>T</strong>: Resource dependence theory (and social networks theory)</td>
<td>Board reduces environmental uncertainty and participates to insure critical resources, legitimacy and reputation of the company.</td>
</tr>
<tr>
<td><strong>D</strong>: Corporate Law (Chaganti et al., 1985, etc.)</td>
<td></td>
<td><strong>D</strong>: Organizational theory &amp; Sociology (Pfeffer, 1972, 1973; Pfeffer and Salansik, 1978)</td>
<td></td>
</tr>
<tr>
<td><strong>T</strong>: Agency theory (and transaction-cost theory)</td>
<td>Board ensures intermediation between managers and owners. It contributes on strategic control and monitoring managers’ effectiveness.</td>
<td><strong>T</strong>: Stewardship theory</td>
<td>Managers are not only opportunistic agents. They are also good stewards of company assets. Board should assure the stewardship of firm assets. It participates in the discussion of strategic options.</td>
</tr>
<tr>
<td><strong>D</strong>: Economics &amp; Finance (Fama and Jensen, 1983, etc.)</td>
<td></td>
<td><strong>D</strong>: Theories of organizations (Donaldson and Davis, 1991; Davis and al., 1997)</td>
<td></td>
</tr>
<tr>
<td><strong>T</strong>: Stakeholder theory</td>
<td>Board provides the link between managers and other stakeholders (managers, employees, etc.), and insure arbitration of value creation.</td>
<td><strong>T</strong>: Class Hegemony</td>
<td>Board represents capitalist elites over social and economic institutions. This theory has not explained board process but only his composition.</td>
</tr>
<tr>
<td><strong>D</strong>: theory of organizations (Charreaux and Debricer, 1998, etc.)</td>
<td></td>
<td><strong>D</strong>: Sociology (Mills, 1965, in Zahra et Pearce, 1989)</td>
<td></td>
</tr>
<tr>
<td><strong>T</strong>: Managerial hegemony</td>
<td>Board members don’t participate to establish the corporate strategy because of their low availability and low commitment. The real running of the organization is assumed by corporate management.</td>
<td><strong>T</strong>: Cognitive perspective (and strategic choice)</td>
<td>Board of directors is a capital actor in the strategy setting. It participate actively in all steps of the strategic decision making process. The knowledge and experience of directors are crucial for board efficiency.</td>
</tr>
<tr>
<td><strong>D</strong>: theories of organizations (Mace, 1971; Lorsch and McIver, 1989)</td>
<td></td>
<td><strong>D</strong>: cognitive psychology (Child, 1972; Rindova, 1999, etc.)</td>
<td></td>
</tr>
</tbody>
</table>
Tab. 7. Shows the characteristics of the board of directors in Ghaya (October 2011).

<table>
<thead>
<tr>
<th>Board characteristics</th>
<th>Details</th>
<th>Main references</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Relational characteristics</strong></td>
<td>Having developed networks (with external actors), being directors in other companies, organizational reputation, negotiation competences with management and external actors</td>
<td>Huse (2007), Charreux (2003), McNulty and Pettigrew (1999), Rouby (2008), etc.</td>
</tr>
<tr>
<td><strong>Functioning characteristics</strong></td>
<td>Meeting preparation, number and length of formal meetings, assiduity, informal meetings, training and procedure of directors’ evaluation, consulting external consultants, committees (meetings, members, etc.)</td>
<td>Lorsch and Maelver (1989), Huse (2007), Godard (2006), Gomez and Moore (2009), etc.</td>
</tr>
</tbody>
</table>

**Fig. 3** proposes an operational model of board involvement in strategic decision making process in Ghaya (October 2011).

**Fig. 3.** Operational model of board involvement in strategic decision making process (after Ghaya (October 2011)).
Let us now discuss the board of director’s performance evaluation problem in details. Evaluating the board of directors competences, professional capabilities and work performance, Carretta, Farina, Schwizer (2006) suggest: “The degree of effectiveness of a board should be appreciated taking into account the business structure, ownership and institutional model of the firm, on the one hand, and the characteristics of its board, in terms of its composition, structure and skills, on the other hand.”

Fig. 4 shows the perspectives and tools for the evaluation of the board of directors in Carretta, Farina, Schwizer (2006).

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Individual directors</th>
<th>Whole board</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observation of specific individual requirements</td>
<td>Observation of specific institutional and organizational characteristics</td>
</tr>
<tr>
<td></td>
<td>Questionnaires (self-evaluation, peer evaluation)</td>
<td>Group self-evaluation</td>
</tr>
<tr>
<td></td>
<td>One-to-one interviews</td>
<td>Qualitative</td>
</tr>
</tbody>
</table>

**Fig. 4. Perspectives and tools for evaluating board of directors (after Carretta, Farina, Schwizer (2006)).**

Fig. 5 provides some information on the procedure for calculating the performance of board of directors in Carretta, Farina, Schwizer (2006).

**Fig. 5. Procedure for calculating the performance of board of directors (after Carretta, Farina, Schwizer (2006)).**
Fig. 6 compiles a checklist for surveying the institutional and organizational characteristics in *Carretta, Farina, Schwizer (2006)*.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Institutional</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is the size of the board adequate vis-à-vis the activities to be carried out?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are the roles of chairman of the board and chief executive separate?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is the degree of representativeness of the shareholders adequate?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is the number of independent directors higher than or equal to that of the executive directors?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do some directors also hold directorships in other companies?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are there any female directors?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Organizational</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have board committees been created?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are the tasks and powers apportioned and delegated (between the BoD, Executive Committee, senior management)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are meetings held frequently (at least 7 times a year)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are the board meetings attended by other stakeholders (managers, etc.)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there a policy for communicating price-sensitive information to the outside?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are remunerations commensurate to the commitment required from the directors’ (attendance, time, special tasks, required output and contribution)?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 6.** Checklist for surveying the institutional and organizational characteristics *(after Carretta, Farina, Schwizer (2006)).*

Fig. 7 depicts a procedure for the measurements of the board professional skills in *Carretta, Farina, Schwizer (2006)*.

**Fig. 7.** Procedure for measuring the professional skills of the board *(after Carretta, Farina, Schwizer (2006)).*
Let us explain that the following original research proposals on an *accurate characterization of the overlapping interconnecting interlocking directors’ networks in the boards of directors in the firms* have been formulated in the *corporate governance research* in Ledenyov D O, Ledenyov V O (2015a), namely the authors suggested that:

1) Transmitted/Received information data-stream measurements,
2) Transmitted/Received information bit error rate measurements,

have to be used to accurately characterize the interlocking interlinking interconnecting directors networks in addition to the well known parameters such as:

a) Director’s boards seats accumulation number,
b) Overlapping interconnecting interlocking directors networks configuration
c) Centrality,
d) Freeman degree,
e) Betweenness.

In other words, the authors suggested that: “the information, which is generated, transmitted and received by the director in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms can accurately characterize the overlapping interconnecting interlocking directors networks performance, and tell the true story about the director’s competence and effectiveness, impacting the involved firms’ valuations,” in Ledenyov D O, Ledenyov V O (2015a). It was also explained that: “The director can have a big director’s boards seats accumulation number, an advanced overlapping interconnecting interlocking director’s professional networks configuration, a high degree of centrality, however, at the same time, the director can generate, transmit, receive the low information data streams (the information data flows) in the advanced overlapping interconnecting interlocking director’s professional networks, behaving as a passive observer and making the little or no useful contributions to the boards of directors work in the considered firms,” in Ledenyov D O, Ledenyov V O (2015a). The authors came to a logical conclusion that: “the information, which is generated, transmitted and received by the director in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms is the only important parameter, which can accurately characterize the director’s competence, efficiency and effectiveness during his/her work assignments in the boards of directors in the firms. In any firm, the work performance, shown by every director, will ultimately impact the work performance, demonstrated by the board of directors, which will certainly be reflected in the firm’s valuation in Carretta, Farina, Schwizer (2006), Black, Kim (2011),” in Ledenyov D O, Ledenyov V O (2015a). The attention was drawn to the fact that: “We
do believe that the generated, transmitted, and received information data streams in the interlocking interlinking interconnecting directors’ networks have a highly asymmetric nature, because of some reasons. In our opinion, every director has the different education, professional experience, accumulated knowledge base and can allocate the different amounts of time to work at the boards of directors in the firms, hence the director will generate, transmit, receive the various information data streams (the information data flows), resulting in the asymmetric information data streams appearance in the interlocking interlinking interconnecting directors’ networks in the boards of directors in the firms”, in Ledenyov D O, Ledenyov V O (2015a). It makes sense to note that the above propositions in Ledenyov D O, Ledenyov V O (2015a) have been made, considering the present research achievements in the wireline information communication networks (ADSL), wireless information communication networks (GSM, WCDMA, UMTS), the optical information communication networks (SONET, ATM, all optical CDMA), which can be accurately characterized by both

1) the transmitted/received data stream measurements, and

2) the existing bit error rate measurements (BER), using the eye diagram and the special measurement equipment, in accordance with the US Federal Communication Commission (FCC) technical requirements.

Let us add that a research assumption that the positive and negative feedback loops can quite possibly lead to the destructive coordination among the directors by eliminating the randomness element and by introducing the greater uniformity in the pursuing business strategies has been proposed in Ledenyov D O, Ledenyov V O (2015a). It was stated that: “We would like to emphasis that the conducted empirical research reveals another interesting fact that the positive and negative feedback loops, which can be created by the interlocking directors networks in the boards of directors in the firms, can quite possibly lead to the destructive coordination among the directors in the boards of directors in the firms by eliminating the randomness element and introducing the greater uniformity in the pursuing business strategies (the destructive coordination term is well described in Whitehead (2011, 2014))”, in Ledenyov D O, Ledenyov V O (2015a). We would like to clarify that the total risk calculation, using the similar risk management techniques in the financial institutions, can result in an increase of systemic risk and a possible systemic collapse of financial institutions due to the destructive coordination presence.

Let us highlight the fact that the problem of stability in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms has been considered from the econophysics point of view in Ledenyov D O, Ledenyov V O (2015a). The authors wrote:
“We think that the stability of interlocking interconnecting directors’ network depends on the nature of stochastic dynamic processes in the interlocking interconnecting directors’ network, hence it can be impacted by the election / appointment / introduction of a new directors into the overlapping interconnecting interlocking directors networks in the boards of directors in the firms in the time domain in Anishenko, Vadivasova, Astakhov (1999), Kuznetsov (2001). The stability is an important parameter in all types of modern networks in the economics, finances, electronics, energy sector, and information communication industry in Page, Wooders, Kamat (2005). For example, it is a well known fact that a fast random addition of the energy consumers to the energy distribution networks may result in a shift of the energy distribution networks out of a stable state, because of the origination of the stochastic dynamic resonance. The same processes can have place in the case of the electronic circuits with the interconnected networks of electronic components, hence the stability of electronic circuits is considered as an important parameter. The stability of wireless, wireline and optical communications networks with the millions of active users is assumed to be quite important parameter as well,” in Ledenyov D O, Ledenyov V O (2015a).

The special MicroID software program to compute the real-world director’s election / appointment numbers in the boards of directors in the firms, was developed in Ledenyov D O, Ledenyov V O (2015a): “Using the knowledge base in the probability theory in De Laplace (1812), Bunyakovsky (1846), Chebyshev (1846, 1867, 1891), Markov (1890, 1899, 1900, 1906, 1907, 1908, 1910, 1911, 1912, 1913), Kolmogorov (1938, 1985, 1986), Wiener (1949), Brush (1968, 1977), Shiryaev (1974, 1988, 1995), Pugachev (1979), the authors derived the appropriate universal formula to compute the probability number of the additional directorship mandates issues, depending on a set of already existing directorship mandates in the case of the interconnecting interlocking directors’ networks in the boards of directors in the firms, \[ P(b + 1|b) \], in Milakovíc, Raddant, Birg (2009), Alfarano, Milakovíc (2009); and developed the MicroID software program, which makes the actual probabilistic prediction toward the director’s election / appointment in the boards of directors in the firms, taking to the consideration both the director’s technical characteristics and the interconnecting interlocking director’s network parameters. We tested the MicroID software program, improved the computing recursive algorithm, and evaluated the accuracy of developed prediction models, comparing the obtained computing results with the real-world director’s election / appointment numbers in the boards of directors in the firms in the considered cases of research interest.”

In this research paper, let us focus our research attention on our most interesting research proposal to introduce the Quality of Service (QoS) measurements to accurately
characterize the director’s performance in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms in Ledenyov D O, Ledenyov V O (2015a). The authors made the following research proposal: “We propose to introduce the Quality of Service measurements scale for the directors’ competence and effectiveness measurements during their work performance evaluation in the boards of directors in the firms, going from the accurate characterization of the generated, transmitted and received information streams by the director in the boards of directors in the firms over a certain period of time,” in Ledenyov D O, Ledenyov V O (2015a).

Therefore, in the present research article, we would like to take a few steps forward and describe the innovative advanced technology to accurately characterize the director’s performance in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms during the Quality of Service (QoS) measurements process, which has been developed by the authors during the research in the last fifteen years. We make the Ledenyov Quality of Service evaluation method proposition to filter the generated/transmitted/received information by the director into the separate virtual information channels, depending on the information content, and to measure the level of signal in every virtual channel with the purpose to accurately characterize the director’s performance in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms during the Quality of Service (QoS) measurements process. For example, using the MicroITF software program, we can investigate a certain number of directors in the boards of directors in the firms at the same time and analyse the following director’s virtual information communication channels, which are generated/transmitted/received by the directors in the boards of directors in the firms, in our measurements:

1) The strategic generated/transmitted/received information virtual channel,
2) The tactical generated/transmitted/received information virtual channel,
3) The numerical generated/transmitted/received information virtual channel,
4) The text generated/transmitted/received information virtual channel,
5) The audio generated/transmitted/received information virtual channel,
6) The video generated/transmitted/received information virtual channel,
7) The graphic generated/transmitted/received information virtual channel,
8) The decisions density generated/transmitted/received information virtual channel.
The above *Ledenyov Quality of Service evaluation method* is based on the innovative advanced technology developed for the spread spectrum wireless communication networks, the spread spectrum optical communication networks and computer networks, where the different virtual information communication channels can be practically created with the application of

1) the **various signal spreading codes** *(WCDMA wireless/optical communication networks)*, and/or

2) the **different signal coding schemes in the multilayered protocols stacks** *(the computer networks)*

over the same physical channel with the certain frequencies bandwidth, in the time domain. The levels of signals in the different virtual channels can be measured precisely, providing the necessary data on the director’s Quality of Service in the boards of directors in the firms in an analogy with the QoS measurements in the spread spectrum wireless communication networks and the spread spectrum optical communication networks.

In this research publication, we would like to discuss shortly the **important obtained research results** by saying that the special software program *MicroITF* has been created by the authors to accurately characterize the director’s performance by means of

1) the filtering of the generated/transmitted/received information by the director into the separate virtual channels, depending on the information content, and

2) the measurement of the levels of signals in every virtual channel with the generated/transmitted/received information by the director, in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms during the Quality of Service (QoS) measurements process.

Presently, we can only report the **preliminary research results** by saying that *MicroITF* software program has been developed, tested and applied successfully to make the QoS measurements as far as the selected directors in the firms, corporations in Europe, North America, Asia and Australia is concerned.


**Winning virtuous strategy creation by interlocking interconnecting interlinking directors in board of directors in firm in accordance with information theory of firm**

Exploring the research problem on the winning virtuous strategy creation by the interlocking interconnecting interlinking directors in the board of directors in the firm in the frames of the information theory of firm, the authors prefer to use the research approach by the Ledenyov’s school of scientific thinking, which complements the empirical philosophical intuitive logical opinions on the strategy creation issues, which have been nurtured and expressed by the Porter’s strategy institute, with the most innovative econophysical econometrical information-technology-driven thoughts on the origins of winning successful
strategies, proposed by the Ledenyov’s school of scientific thinking. One of the interesting problems to understand is: How can the board of directors create the winning successful business strategies for the company (organization) in the information theory of the firm? Answering the above question, let the authors formulate the Ledenyov theory on the winning virtuous business strategies creation by the directors in the boards of directors in the firms at the resonant absorption of discrete information in the diffusion - type financial economic systems with the induced nonlinearities.


Making the concluding comments on the strategy creation issue, the authors think that the different levels of the information sensing, information filtering, information processing, information absorption, information analysis and decision making with the obtained information by the director may have the certain positive or negative impacts on the director’s winning virtuous strategy creation ability in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms.

Of course, the most complicated task for every wise director is to adjust to the optimal levels of the information sensing, information filtering, information processing, information absorption, information analysis, decision making, which can allow the winning virtuous strategy creation in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms. We would like to mention that the excessive or insufficient levels of the information sensing, information filtering, information processing, information absorption, information analysis by the director may result in the bifurcations and chaos appearances in the frames of a decision making process on the winning virtuous strategy creation in the case of presence of the considered overlapping interconnecting interlocking directors networks in the boards of directors in the firms.

Conclusion

The article formulates the information theory of firm, introduces the concept of firm as an operating system, which controls the firm’s operation by the means of the information resources processing, in an analogy with the operating system at a microprocessor in the computing devices, represents the director as an information processing element, describes the board of directors as the electronically-scanned electronically-steered phased array radar, considers the scientific problem of strategy creation by the interlocking interconnecting overlapping directors in the boards of directors in the firms in the economic system with the induced nonlinearities.

We highlight a fact that the director makes the information sensing, filtering, processing, resonant absorption, analysis, decision making, strategy creation, hence it can be empirically represented as a processing element in a digital signal processor with the Harvard or von Neumann director’s mindset architectures in line with the digital signal processing science.

We think that the board of directors in corporate governance system can be theoretically represented as the electronically-scanned electronically-steered phased array radar with a certain number of electronic devices (directors, who can be modeled as electronic devices with the active antenna elements, filters banks, digital signal processors, memory chipsets in agreement with the microwave and digital signal processing sciences).

Using all the proposed theoretical assumptions, we propose the Ledenyov theory on the winning virtuous strategies creation by the interlocking interconnecting directors in the boards of directors in the modern firms in a harmony with the management science.

We developed the MicroITF operation system and software programs:
1) the operation system to control the firm operation by means of the information resources near-real-time processing in the modern firms in the case of the diffusion-type financial economic system with the induced nonlinearities. The operating system is based on the accumulated knowledge of source code architecture for the near real time VxWorks operating system by WindRiver.

2) the software program to accurately characterize the director’s performance by means of a) the filtering of the generated/transmitted/received information by the director into the separate virtual channels, depending on the information content, and b) the measurement of the levels of signals in every virtual channel with the generated/transmitted/received information by the director, in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms during the Quality of Service (QoS) measurements process; and

3) the software program to create the winning virtuous business strategies by the interlocking interconnecting directors in the boards of directors in the modern firms in the case of the diffusion-type financial economic system with the induced nonlinearities, using the patented recursive artificial intelligence.

The MicroITF operating system and software programs can be emulated/installed at the computing devices with the Linux, Unix, Windows, MacOS, iOS, Android, Amoeba operating systems.

The authors think that the information theory of firm will improve our understanding on the modern information society economics functioning.

Acknowledgement

The directors in the boards of directors in the firms face a number of business challenges as a result of appearing disruptions in the economics in an information age. In this introductory condensed research article, the authors use an original research approach in an attempt to create the information theory of the firm and to find a possible solution for the strategy creation problem, which has to be solved by the directors in the boards of directors during the strategic governance of the firms.

The international students prepared the brief abstracts of our invited lectures at the leading universities around the World over the last two decade, and then the authors combined our lecture notes with the brief abstracts of our invited lectures, aiming to write a research article. We also decided to include some our thoughts, expressed during the Q&A sessions after
the presented lectures and kindly recorded by our students. In addition, the authors included the most interesting comments, professional advises, private opinions on the research subject by the directors of firms, recorded during a few thousands of business meetings in Europe, North America and Asia. In our opinion, the presented research findings may be in the scope of interest by the MBA students, professors in the business administration, management, finances, economics sciences, directors in the boards of directors, chairmen of the boards of directors, subject experts, and business leaders, who would like to stay up to the date on the recent developments in the business administration science.

The first author's knowledge on the origins of the nonlinearities in the complex systems in the electrical, electronic, computer and financial engineering has been obtained during the intensive innovative scientific collaboration with Prof. Janina E. Mazierska, Personal Chair, Electrical and Computer Engineering Department, James Cook University, Townsville, Australia and former Dean, Electrical and Computer Engineering Department, James Cook University, Townsville, Australia, and former IEEE Director Region 10 in Australia, and IEEE Fellow. The first author would like to acknowledge Prof. Janina E. Mazierska by expressing his sincere gratitude for the kind scientific advices on how to develop the logical mathematical analysis skills, the scientific problems analytic solving ability and the abstract scientific thinking to tackle the complex scientific problems on the nonlinearities in the microwave superconductivity as well as on the nonlinearities in the economics, applying the interdisciplinary scientific knowledge together with the advanced computer modeling techniques in the course of the cutting-edge highly innovative research projects at James Cook University in Townsville in Queensland in Australia in 2000 – 2015 after the graduation from V. N. Karazyn Kharkov National University in Kharkov in Ukraine in 1994 – 1999.

There would be appropriate to say that, in an information age, the first author’s special efforts have been primarily directed towards the scientific information gathering, systematization and detailed analysis in the frames of this research project on the business strategy creation by the directors in the boards of directors in the firms; hence, the first author would like to thank the professional stuff at the central library at James Cook University in Townsville, Queensland, Australia for providing the first author with all the necessary technical support in relation to the literature search on the subjects of his multidisciplinary research interest in the electronic research databases at Australian universities, replying to the numerous chaotic research requests timely, and making everything possible to assist with the completion of the highly innovative advanced research on the business strategy creation by the directors in the boards of directors in
the firms, which has been conducted at the James Cook University in Townsville, Queensland in Australia in 2000 – 2015.

The first author would like to comment that the informative scientific discussions on the business strategy creation by the directors in the boards of directors in the firms, which have been conducted by the first author with the M.Sc. students, Ph.D. candidates, professors, visiting scientists and other faculty members during the numerous scientific seminars and brain storm research meetings at James Cook University in Townsville in Queensland in Australia, are generously appreciated, because these valuable scientific opinions exchanges encouraged the first author to generate the new original scientific ideas and make the creative imperative integrative intelligent conceptual co-lateral adaptive logarithmic thinking with the application of the inductive, deductive and abductive logics analysis as far as the business strategy creation by the directors in the boards of directors in the firms, is concerned.

A certain part of an introductory condensed research article has been written during the first author’s yachting with the Australian friends in Melbourne, Victoria, Australia and in Brisbane, Queensland, Australia, when a number of the creative research ideas and important research findings on the business strategy creation by the directors in the boards of directors in the firms, came to his mind. Most of the ideas have been discussed with the Australian friends, when on the yachts. Sometimes, the thoughtful discussions have been further conducted during the “numerous meetings without the ties” with the great Australian philosophers, professors, scientists, businessmen, lawyers, governmental officials and political leaders in the relaxing trusted mutual-respect atmosphere, characterized by the pluralism of research opinions on the topics of interest, during the Yarra valley, Mornington-Peninsula, and Hunter valley limo wine tours (www.yarravalleylimowinetours.com.au, www.huntervalleylimotours.com.au). All these exchanges by the scientific opinions fascinated the first author’s mind, stimulated the abstract thinking on the presented assumptions, and inspired to work consistently to complete the writing of this highly innovative condensed research article on the business strategy creation by the directors in the boards of directors in the firms, at James Cook University in Townsville, Brisbane, and Gold Coast in Queensland in Australia as well as in Melbourne and Sydney in Australia in 2015.

The first author would like to thank cordially all the European universities rectors, universities deans, distinguished professors, world renowned financiers, reputable economists and well respected businessmen for many tens of highly creative and productive business meetings during the first author’s global intellectual journey over the European capitals, including: Warsaw, Poland; Berlin, Germany; Amsterdam, The Netherlands; Brussels, Belgium;
Luxemburg, Luxemburg; Paris, France; Barcelona, Madrid, Spain; and Coimbra, Lisbon, Porto, Portugal in October, 2014. It was nice to meet and discuss all the problems of mutual research interest with the old European Friends, coming from Brisbane, Australia.

It is not possible to underestimate an influence by the classic music on the development of strategic thinking skills, hence a visit by the first author to the City of Vienna in Austria in Europe during the Christmas and New Year festivities in December 2014- January 2015 had a quite positive overall impact on the completion of research article writing.

The intensive research work on the information theory of the firm in combination with the sport training exercises has been conducted by the first author during his visits to the skiing tourism destinations in Bukovel and in Dragobrat in Western Ukraine in March 2015. The fresh air, pine trees wood, delicious meals and high level service at Radisson hotel contributed to the research article writing completion and software development. In addition, during the first author’s visit to Ukraine in March 2015, it was nice to see the beautiful architecture of old buildings at University of Czernowitz, where Prof. Joseph Alois Schumpeter had been worked on the theory of economic development in 1909 – 1911.

After the graduation from V. N. Karazyn Kharkov National University in Kharkov in Ukraine in 1988-1993, the second author worked on the research programs in a number of universities and institutions around the World. Considering this research paper, the second author would like to kindly acknowledge the numerous private communications with the participants of the V. Ya. Bunyakovsky international conference with the special focus on the V. Ya. Bunyakovsky’s research contributions to the mathematical theory of probability and its modern applications in the econophysics and econometrics, which had place during a tour to the Town of Bar, Vinnytsya Region, State of Ukraine in the time of the conference, organized by the Institute of Mathematics of National Academy of Sciences of Ukraine (NASU), Kyiv, Ukraine on August 20 – 21, 2004. Absorbing the brilliant research ideas during a fruitful exchange by the scientific opinions among the conference attendees, the second author came up with a remarkable conclusion that the foundations of the mathematical theory of probability by V. Ya. Bunyakovsky enable us to perform a more accurate scientific analysis and characterization of the complex research problems on the business strategy creation by the directors in the boards of directors in the firms. The first author has been worked on the research article, discussing the points of mutual research interest with the second author, during his regular visits to the Town of Bar, Vinnytsya Region, State of Ukraine over the recent years.

It is a real tremendous pleasure to comment that some fundamental issues on the business strategy creation by the directors in the boards of directors in the firms have been researched by
the second author during his intensive research assignments at the Rotman School of Management, University of Toronto, Canada in 1998 – 1999 and 2005 – 2006. The second author met with many hundreds of North American Corporations Presidents, Board of Directors Chairman, Chief Executive Officers (CEOs), Chief Information Officers (CIOs), Chief Operating Officers (COOs) and visited the Research Triangle Park high-tech cluster near Durham in North Carolina in the USA as well as the Kanata high-tech cluster near Ottawa in Ontario; the Calgary high-tech cluster in Calgary in Alberta; the Richmond high-tech cluster near Vancouver in British Columbia, the Montreal high-tech cluster in Montreal in Quebec in the North America in 1998 – 2006, making his innovative research on the business strategy creation by the directors in the boards of directors in the firms. The obtained information has been researched and analyzed by the second author at the Rotman School of Management, University of Toronto, Canada, which was a global hub of innovative scientific thinking in the economics and finances mainly due to the high level organizational and personal efforts by Prof. Roger L. Martin, former Dean, Rotman School of Management, University of Toronto, Canada, who strongly supported and facilitated the initiation of innovative research and the creation of intensive business education courses in Canada on that time. It is important to underline the fact that the Prof. Roger L. Martin, former Dean, Rotman School of Management, University of Toronto, Canada took a right decision to support our innovative research by all the available resources at Rotman School of Management, University of Toronto, Canada, including the library, computer laboratory and professional management consulting. Indeed, the Rotman School of Management, University of Toronto, Canada was a global financial and economic center of gravity on that time, where the highly innovative research work has been conducted by the second author from the early morning hours until the deep night, being occasionally interrupted by the thoughtful long hours scientific discussions on a variety of research problems in the finances with Profs. John C. Hull and Roger L. Martin, Rotman School of Management, University of Toronto, Canada in 1998 – 1999 and in 2005 - 2006. It makes sense to note that, in some cases, the intensive research discussions and numerous consultations have been continued during our frequent meetings at the Economic Club of Toronto, Empire Club of Canada and Canadian Club in Toronto, Canada outside the U of T in 2005 – 2006. Using every free minute in our busy research schedules, we discussed all the scientific problems of mutual research interest, aiming to find the possible solutions for the challenging research problems in the economics, finances, econophysics and econometrics in the time of globalization.

Moreover, the second author would like to thank Prof. Roger L. Martin, former Dean at the Rotman School of Management for a kind invitation to attend a day-long seminar, which has
been organized by the Rotman School of Management, University of Toronto, Toronto, Canada at the Canadian room at the Fairmont Royal York Hotel in Toronto, Canada on June 3, 2005. The second author has been particularly interested in an announced presentation of research on the complex interlocking directors networks in the boards of directors within the Canadian corporations by Tim Rowley, Professor, Rotman School of Management, Toronto, Canada; visiting Professor, INSEAD, France.

The second author would like to thank Prof. Roger L. Martin, former Dean at the Rotman School of Management for a cordial personal invitation to attend a day-long seminar: “Creativity: 21st Century Capital,” which has been organized by the Rotman School of Management, Toronto, Canada at the Fairmont Royal York Hotel on June 2, 2006. It was a nice opportunity to discuss an increasing role of creativity in the business opportunities widening in the XXI century with Mr. Thomas Stewart, former Editor-in-Chief, Harvard Business Review, Boston, USA; Prof. Jonathan Feinstein, Yale University, USA; and Prof. Richard Florida, Rotman School of Management, Canada. It is necessary to especially highlight a long polemics on the numerous examples of creativity in the field of econophysics, which has been conducted with Prof. Jonathan Feinstein, Yale University, USA. It makes sense to mention an interesting thoughtful conversation on the strategic governance in North America, which has been conducted with Prof. Roger L. Martin and cheered by a friendly toast with the two glasses of young white wine from the Niagara Fall region in Ontario, Canada.

It is wonderful to see that Prof. Michael E. Porter, Founding Director, Strategy Institute, Harvard Business School, Harvard University finds the enough time to write the numerous research articles and books despite of his heavy administrative work load at the Strategy Institute, Harvard Business School, Harvard University. As always, we are very grateful to Prof. Michael E. Porter, Bishop William Lawrence University Professor and former Dean of Harvard Business School, Harvard University, who is considered by the authors as a father of the modern business strategy, for his valuable personal efforts and time to write a number of interesting informative research articles and books as well as to create the lecture notes, providing us with his professional expertise, exceptional quality professional advices and wise opinions in the field of competitive strategy in the 21st century. In fact, Prof. Michael E. Porter is regarded by the authors as a “guiding star” in the science of strategy.

Of course, the important groundbreaking research results on the creative disruption and evolutionary economics, obtained by Prof. Joseph Alois Schumpeter at the University of Vienna in Austria in 1905 – 1908, University of Czernowitz in Ukraine in 1909 – 1911, University of Graz in Austria in 1912 – 1914, University of Bonn in Germany in 1925 – 1932, Harvard
University in the USA in 1932 – 1950, had a considerable enigmatic influence on the presented research opinions by the authors. The first author’s visit to University of Czernowitz in Ukraine in March 2015 is just a clear confirmation of the above statements. As we all know, the ideas on the creative destruction have been further researched by Prof. Clayton M. Christensen, Kim B. Clark University Professor of Business Administration, Harvard Business School, Harvard University and other notable scientists, hence we studied and absorbed the modern research approaches and findings on the creative destruction by Clayton M. Christensen as well. Let us say that Prof. Clayton M. Christensen presents the Scandinavian approach to the understanding of the research problem on the creative disruption and evolutionary economics.

The authors would like to highlight a fact that Prof. Michael C. Jensen’s research papers made a considerable influence on the formation of the author’s research approaches and opinions on the theory of firm. Therefore, it is nice to see that Prof. Michael C. Jensen’s, Chairman, Social Sciences Research Networks, NY, USA continues his active research work and plays an important role in the global economics research by chairing the Social Sciences Research Networks, which is a truly global organization in our time.

Developing the understanding on a number of complex research problems in the theory of the firm, the organizational forms, the agency problems, the investment decisions, the authors tried to read and understand the brilliant research ideas by Prof. Eugene Fama, Chicago University, USA. Presently, the authors would like to say that it is possible to understand the most innovative ideas on the theory of firm by Prof. Eugene Fama, because of his simple language and clear logics used to describe complex research problems in the research papers.

Recently, the second author had a wonderful opportunity to discuss some research problems on the interconnecting interlocking directors networks in the boards of directors in the publicly traded and non-traded firms in New York in the USA with Charles K. Whitehead, Professor of Business Law, Cornell University Law School, New York, USA at V. N. Karazin Kharkiv National University in Kharkiv, Ukraine in December, 2014. Therefore, the second author expresses his personal thanks to Charles K. Whitehead for the six informative invited lectures on the M&A corporate deals, dynamics of the boards of directors, and legal aspects of corporate governance in New York in the USA.

It is not conceivable to write this research article without the multiple useful research inputs from and encouragements by our Friends. Indeed, playing the tennis at the tennis courts or the golf at the golf playgrounds with our research collaborators, business partners, friends in various developing and developed countries around the World frequently, we have already conducted many thousands of thoughtful discussions on various research topics, hence we would
like to thank all our global Friends for their brilliant ideas, interesting opinions, wise suggestions and shared experiences on the subject of our research interest in the economics and finances.

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