ISSN 2543-6597

Bialystok University of Technology
Faculty of Management

DE GRUYTER
OPEN

ISMSME
International Society for Manufacturing, Service and Management Engineering

Engineering Management in Production and Services

Volume 9 • Issue 3 • 2017

Frequency

ECONOMICS AND MANAGEMENT
is published quarterly since 1998

As of the beginning of 2017 the journal
is published under a new name:
ENGINEERING MANAGEMENT
IN PRODUCTION AND SERVICES

Copyrights ©

Publisher

Bialystok University of Technology
Wiejska 45A, 15-351 Bialystok, Poland

The International Society
for Manufacturing Service
and Management Engeneering (ISMSME)

Submission

Papers for submission should be prepared according to the *Authors Instructions* available at www.empas.pb.edu.pl

All papers should be submitted through the electronic submission system

Editor-in-Chief

Joanna Ejdys
Bialystok University of Technology
Faculty of Management
Wiejska 45A, 15-351 Bialystok, Poland
Phone: (+4885) 746 9825
Fax: (+4885) 746 9835
e-mail: j.ejdys@pb.edu.pl

Indexation

Journal is indexed in EBSCO Business Source Ultimate (Complete), Index Copernicus, ERIH PLUS, Google Scholar, Central European Journal of Social Sciences and Humanities, Research Papers in Economics (RePEc), BazTech and BazEkon databases

Deputy Editors-in-Chief

Łukasz Nazarko
e-mail: l.nazarko@pb.edu.pl

Katarzyna A. Kuźmicz
e-mail: k.kuzmicz@pb.edu.pl

Editorial Office Secretary

Danuta Szpilko
Bialystok University of Technology
Faculty of Management
Wiejska 45A, 15-351 Bialystok, Poland
Phone: (+4885) 746 9880
Fax: (+4885) 663 1988
e-mail: d.szpilko@pb.edu.pl

Editorial Office

Bialystok University of Technology
Wiejska 45A, 15-351 Bialystok, Poland
Phone: (+4885) 746 9825
Fax: (+4885) 663 1988
e-mail: empas@pb.edu.pl
www.empas.pb.edu.pl

Technical Editors

Krzysztof Stepaniuk
e-mail: k.stepaniuk@pb.edu.pl

Kira Chiżniak
e-mail: k.chizniak@pb.edu.pl

Ministry of Science and Higher Education
Republic of Poland

1. Increasing the share of foreign reviewers and the improvement of the evaluation process of papers submitted to "Ekonomia i Zarządzanie" journal ("Economics and Management") (currently "Engineering Management in Production and Sevices");
2. Increasing the share of foreign scholars in the Scientific Board of the "Ekonomia i Zarządzanie" journal ("Economics and Management") (currently "Engineering Management in Production and Services");
3. Amelioration of the English language version of "Ekonomia i Zarządzanie" journal ("Economics and Management") (currently "Engineering Management in Production and Services");
4. Improving the mechanism of securing the originality of texts published in "Ekonomia i Zarządzanie" journal ("Economics and Management") (currently "Engineering Management in Production and Services")

– tasks financed in the framework of the contract no. 819/P-DUN/2017 by the Ministry of Science and Higher Education from the funds earmarked for the public understanding of science initiatives.

Table of contents

DE GRUYTER OPEN

ISMSME International Society for Manufacturing, Service and Management Engineering

received: 30 December 2016
accepted: 20 June 2017

pages: 7-9

Success factors of project and process management — lessons learned from EPPM 2016

Hesham S. Ahmad, Subhi M. Bazlamit, Arkadiusz Jurczuk, Cezary Orłowski

Corresponding author:

Hesham S. Ahmad

Al-Zaytoonah University of Jordan,
Faculty of Engineering and Technology,
Department of Civil
and Infrastructure Engineering, Jordan
e-mail: h.ahmad@zuj.edu.jo

Subhi M. Bazlamit

Al-Zaytoonah University of Jordan,
Faculty of Engineering and Technology,
Department of Civil
and Infrastructure Engineering, Jordan
e-mail: hajjee@live.com

Arkadiusz Jurczuk

Bialystok University of Technology,
Faculty of Management, Poland
e-mail: a.jurczuk@pb.edu.pl

Cezary Orłowski

WSB University in Gdańsk,
Department of Information
Technology Management, Poland
e-mail: corlowski@wsb.gda.pl

DOI: 10.1515/emj-2017-0021

Introduction

The aim of this post-conference report is to present key-issues delivered by participants of the Project and Process Management sessions (PPM) at the 7th International Conference on Engineering, Project, and Production Management (EPPM 2016). EPPM 2016 was held in Bialystok, Poland in 21-23 September. The conference was organised by Bialystok University of Technology (BUT), the Association of Engineering, Project, and Production Management (EPPM), the International Society for Manufacturing, Service and Management Engineering (ISMSME), the Committee of Production Engineering of the Polish Academy of Sciences, and the Agency for Restructuring and Modernisation of Agriculture. The format of the EPPM 2016 Conference involved

a mixture of keynote speeches, individual presentations on topical issues, and extensive panel discussions. It featured 89 papers in five thematic sessions across the two conference days. Over 115 delegates attended EPPM 2016 from more than 20 countries across Europe, Asia, and the rest of the world. Further information is available at eppm2016.pb.edu.pl. This international event explored key business and scientific problems, including findings, and enabled the introduction of new achievements in the field of engineering management, project and production management.

Project and Process Management aspects on the EPPM 2016

One of the key sessions of EPPM 2016 was devoted to a key-aspect of modern organisations, i.e. project and process management. This session focused on several major and emerging issues including risk and knowledge management, project portfolio management (Dumrak et al., 2017, pp. 157-164; Pimachangthong & Boonjing, 2017, pp. 579-586; Hadjinicolaou et al., 2017, pp. 274-281) as well as agile approach and process modelling in business practice (Orlowski et al., 2017, pp. 524-531; Gabryelczyk & Jurczuk, 2017, pp. 198-205). Further points that emerged from the discussion during PPM sessions included: project scheduling, budgeting and IT systems (Gurcanli et al., 2017, pp. 265-273; Peng et al., 2017, pp. 563-570; Niazi & Painting, 2017, pp. 510-517; Ayessaki & Smallwood, 2017, pp. 42-49; Al-Hazim et al., 2017, pp. 18-24; Ahmad et al., 2017, pp. 3-9; Bazlamit at al., 2017, pp. 83-90; Snyman & Smallwood, 2017, pp. 651-657). During four PPM sessions, a total of 19 presentations were offered by more than 50 authors.

The main points that came out of the discussion during PPM sessions support the suggestion that aiming for successful management of projects, more intense effort should be exerted on a planning preparation, scheduling and cost evaluation. These aspects determine the project risk as well as its cost overrun (Al-Hazim et al., 2017, pp. 18-24). Moreover, implementation of effective IT systems can simplify and help organise the handling of the various work-related information and processes within the cycle of project management (Ahmad et al., 2017, pp. 3-9; Bazlamit et al., 2017, pp. 83-90). It was also suggested that controlled and predicted transformation processes in organisations are crucial for project success (Orłowski et al., 2017, pp. 524-531). Considering the role of information technology in project and process management, it is worthwhile considering the problem with demanded competency, distribution and comprehension of new knowledge by project participants. Furthermore, employee competency should be improved to the level required by the project aim and scope (Ahmad et al., 2017, pp. 3-9; Bazlamit et al., 2017, pp. 83-90; Gabryelczyk & Jurczuk, 2017, pp. 198-205). However, one of the biggest challenges, which was highlighted by most participants, was communication by project stakeholders.

Conclusions

Challenges presented during PPM sessions suggested some implications for further research and possible ways for the engagement of businesses and researchers in the development of good practice for project and process management. Discussions and presentations covered different business and science perspectives on project and process management, helping EPPM delegates to discern some key-aspects. It is suggested that discussions of the EPPM 2017 conference could consider:

- project and process maturity,
- the financial and social contingency of a project,
- project team building and communication,
- the methodology for the project and process monitoring.

Most EPPM 2016 participants believed that the quality of speakers and the scope of the content was unparalleled. The PPM sessions allowed participants and EPPM delegates to enhance their research perspective and build relationships for scientific opportunities in the area of project and process management.

Literature

Ahmad, H. S., Bazlamit, I. M., & Ayoush, M. D. (2017). Investigation of Document Management Systems in Small Size Construction Companies in Jordan. *Procedia Engineering*, *182*, 3-9. doi:10.1016/j.proeng.2017.03.101

Al-Hazim, N., Salem, Z. A., & Ahmad, H. (2017). Delay and Cost Overrun in Infrastructure Projects in Jordan. *Procedia Engineering*, *182*, 18-24. doi:10.1016/j.proeng.2017.03.105

Ayessaki, W. Y., & Smallwood, J. (2017). Influencing Workers' Performance through Health and Safety Interventions. *Procedia Engineering*, *182*, 42-49. doi:10.1016/j.proeng.2017.03.111

Bazlamit, S. M., Ahmad, H. S., & Al-Suleiman (Obaidat), T. I. (2017). Pavement Maintenance Applications Using Geographic Information Systems. *Procedia Engineering*, *182*, 83-90. doi:10.1016/j.proeng.2017.03.123

Dumrak, J., Baroudi, B., & Hadjinicolaou, N. (2017). Exploring the Association between Project Management Knowledge Areas and Sustainable Outcomes. *Procedia Engineering*, *182*, 157-164. doi:10.1016/j.proeng.2017.03.152

Gabryelczyk, R., & Jurczuk, A. (2017). Does Experience Matter? Factors Affecting the Understandability of the Business Process Modelling Notation. *Procedia Engineering*, *182*, 198-205. doi:10.1016/j.proeng.2017.03.164

Gurcanli, G. E., Turkoglu, H., & Bilir, S. (2017). Heavy Equipment Scheduling for Horizontal Construction Projects. *Procedia Engineering*, *182*, 265-273. doi:10.1016/j.proeng.2017.03.189

Hadjinicolaou, N., & Dumrak, J. (2017). Investigating Association of Benefits and Barriers in Project Portfolio Management to Project Success. *Procedia Engineering*, *182*, 274-281. doi:10.1016/j.proeng.2017.03.191

Niazi, G. A., & Painting, N. (2017). Significant Factors Causing Cost Overruns in the Construction Industry in Afghanistan. *Procedia Engineering*, *182*, 510-517. doi:10.1016/j.proeng.2017.03.145

Orłowski, C., Ziółkowski, A., & Paciorkiewicz, G. (2017). Quantitative Assessment of the IT Agile Transformation. Procedia Engineering, *182*, *524-531*. doi: 10.1016/j.proeng.2017.03.147

Peng, L., & Chua, D. K. H. (2017). Decision Support for Mobile Crane Lifting Plan with Building Information Modelling (BIM). *Procedia Engineering*, *182*, 563-570. doi:10.1016/j.proeng.2017.03.154

Pimchangthong, D., & Boonjing, V. (2017). Effects of Risk Management Practice on the Success of IT Project. *Procedia Engineering*, *182*, 579-586. doi.org/10.1016/j.proeng.2017.03.158

Snyman, T., & Smallwood, J. (2017). Improving Productivity in the Business of Construction. *Procedia Engineering*, *182*, 651-657. doi:10.1016/j.proeng.2017.03.175

DE GRUYTER OPEN

ISMSME International Society for Manufacturing, Service and Management Engineering

received: 10 January 2017
accepted: 8 June 2017

pages: 37-50

New social cooperation model in service oriented economy: the case of employee financial participation in the Baltic states

Remigijus Civinskas, Jaroslav Dvorak

ABSTRACT
The article discusses the issues of employee financial participation in Baltic states which differs and depends on political, legal and economic preconditions. The aim of the research is to analyse employee financial participation as an instrument for collaboration in companies and a new social cooperation model in the Baltic states. The qualitative research was conducted by telephone and e-mail in 2016. The interviews were carried out with the experts (academics, civil servants, lawyers and human resource consultants working in a relevant field) as well some trade union and company representatives. In general, the new policy for supporting employee financial participation has been renewed in Latvia and Lithuania. It started recently with the revision of the legislative framework that was initially established during the privatisation period. The revision of the Law of Companies was driven by the business interest (to have a new effective human resource management tool or to transfer employee share plans from parent companies in Western countries to subsidiaries in the Baltic states) to introduce (or revise, in the case of Lithuania) new employee share ownership (ESO) plans. The research has also proven that there are common similarities in the use of employee financial participation plans despite the existing differences which are based on national features, such as tax and legal regimes, historical development patterns, or economic and structural factors.

KEY WORDS
Baltic states, company management, employee financial participation, employee ownership, profit sharing

DOI: 10.1515/emj-2017-0024

Corresponding author:

Remigijus Civinskas

Vytautas Magnus University,
Faculty of Political Sciences and Diplomacy, Lithuania
e-mail: r.civinskas@pmdf.vdu.lt

Jaroslav Dvorak

Klaipėda University,
Faculty of Social Sciences, Lithuania
e-mail: jaroslav.dvorak@ku.lt

Introduction

Societies and economies of the Baltic states have been influenced by a rapid change during the transition time from a planned economy and closely controlled society to the market economy and free society. These radical changes have had different effects on the development of socio-economic institutes. Low-level employee participation in decision making at a company level is explained by a special pattern of the privatisation process, corporate and organisational cultures, liberal market environment (Sippola, 2009; Sippola, 2013; Mygind, 2012; Woolfson et al., 2011). These problems and a special development pattern provide a unique opportunity to discuss employee financial participation in terms of the best approaches and models. In the Baltic

countries, all the stakeholders (labour unions, employer organisations and policy makers) are searching for the best form of employee empowerment and involvement in the decision-making process. Research and good practice examples show that some schemes of employee ownership and financial participation are directly linked to the renewal of industrial relations in terms of management–union relations, industrial conflict management and managerial authority relations (Poole & Jenkins, 2013; Lowitzsch, 2009b). Ongoing control in decision-making and entrepreneurial co-determination are strong arguments for taking one of employee financial participation schemes. They could be reinforced by other economic arguments, such as enhancement of motivation and productivity (O'Boyle, 2016; Lowitzsch, 2009a).

In the Baltic states, the academic discussion about employee financial participation started some years ago. The current topics in financial employee participation research are related to the studies of organisational effects and institutional settings (Jaakson & Kallaste, 2014; Eamets et al., 2008; Rimas, 2009), the historical tradition based on negative effects of post-Soviet privatisation (Eamets et al., 2008), influence of employee motivation on productivity improvement (Berķe-Berga, 2014) or search for the "best fit" model of employee ownership (Berķe-Berga, 2013). Lawyers and consultants have published some informative articles about financial employee participation schemes with the focus on possible motivational effects that can be achieved. It must be emphasised that the Baltic states have a very low occurrence of employee financial participation as well as little support (Eamets, 2008; Mygind, 2012; Jaakson, 2014; Berke-Berga, 2013). Up to now, employee financial participation has been regulated to a very low extent in the Baltic states (Lowitzsch, 2009a). Recently, new regulations have been introduced for the promotion of financial initiatives as well as new tax incentives (Estonian, 2011; Latvian, 2013; Lithuanian, 2016).

The research has three main tasks. First, the overview of concepts, instruments and schemes of financial participation is provided. Second, the research outlines public financial policies for the promotion of financial participation in the Baltic states and discusses the links between employee financial participation schemes and direct or indirect participation in a company's decision-making process. Third, the article reveals the employee participation practices and potential in the Baltic states.

The findings reported in this paper are based on the data collected through qualitative research. Some stakeholders (legal organisations, NGOs and some academics) are keen on promoting employee ownership ideas in the Baltic states. Despite this interest, the literature on this issue remains scarce. The existing literature is limited to brief articles on the internet news portals, some academic studies or a comparative report.

Tab. 1. Functions and coding of interviewees

No.	Code	Interviewee
Lithuania		
1.	LT1	civil servant, ministerial advisor
2.	LT2	civil servant, ministerial advisor
3.	LT3	advocate, researcher working on a relevant topic
4.	LT4	advocate
5.	LT5	human resources adviser
6.	LT6	researcher, economist
7.	LT7	trade union representative
8.	LT8	representative of a company with functioning ESO and FP plans
9.	LT9	advocate
10.	LT10	lithuanian Bank employee
11.	LT11	expert from an employer organisation
Latvia		
1.	LV1	civil servant, ministerial advisor
2.	LV2	researcher, economist
3.	LV3	trade union representative
Estonia		
1.	EE1	researcher, economist
2.	EE2	researcher, economist
3.	EE3	trade union representative

1. Literature review

1.1. Concept of employee financial participation and core issues

Employee financial participation has a century-long history, but it has been intensively and extensively used in the last 30 years (McCarthy, 2016). In some cases, employee financial

ownership benefits the company's growth. Financial participation is referred to differently, and the use of concepts depends on the context or form of employee ownership. In the following definition, an aspect of shared meaning is the idea of employee involvement. The main forms of employee financial participation are defined as any arrangement that allows employees to become involved in the financial results of their companies (McCarthy, 2016).

Such arrangements can be broadly categorised into three main groups of forms/schemes linked to each other:

- profit sharing (PS) (in cash or shares, paid immediately or deferred),
- individual ESO (employee shares or stock options),
- employee stock ownership plans (ESOP, collective ESO, with shares acquired through an intermediary entity, financed by a share of profits allocated to employees in addition to their remuneration) (Lowitzsch & Hashi, 2014).

These forms attribute to the common European model of employee financial participation as it was discovered by comparative studies (Lowitzsch, 2008; Lowitzsch & Hashi, 2014). These schemes can be selected and implemented depending on one's interest, needs and context. Preference for some schemes depends on country-level factors. Some schemes are more related to possibility improved labour productivity and performance (Blasi et al., 2010a; O'Boyle et al., 2016; Bryson & Freeman, 2010). Among various schemes, share ownership has the clearest positive association with productivity, but its impact is the largest when firms combine it with other forms of participation (Bryson & Freeman, 2010; Poutsma & Braam, 2012). It is important to note that employee ownership has a substantial number of sources on the analysis of impact employee ownership has on company's performance.

Another group of authors focuses on human resource management, industrial relation and the issues posed by financial participation (Landau et al., 2007). Financial participation is used as a complementary or substitute instrument in the perspective of human resource management practice. It is claimed that employees who participate in the ownership and financial results of a firm become more dedicated to the company and focus on performance goals. However, economic studies have shown that companies often either switch between schemes or use several of them (Bryson & Freeman, 2010; Poutsma & Braam, 2012). ESO is understood by scholars and some practitioners as a means of enhancing labour-management 'partnerships' and, this way, extending industrial democracy (Poole & Jenkins, 2013; Pendleton, 2001). It is important to note that there are conflicting explanations of employee financial participation forms in terms of function.

Several definition and terms are used in this research to describe employee financial participation. The literature regarding this socio-economic phenomenon covers a range of disciplines (human resource management, economics, corporate finance and industrial relations). Therefore, employee ownership is often described using different definitions and concepts:

- *employee participation in decision-making*. Participation is often understood as a participatory process that involves employees and employers. This process is related to formal institutions such as work councils. It also described as a day-to-day relational process (an employee and his/her supervisors) that allows employees to influence company decisions by so-called "informal participation." Finally, participation is linked to results. It is possible to define it as a process that allows employees to exert some influence over their work, over the conditions under which they work and over the results of their work (Poutsma, 2001);
- the main principles of employee financial participation. *Voluntariness* and *openness* to all employees (Lowitzsch, 2014) are frequently used principles;
- *plans*/*forms* and *schemes*. Financial participation has a broad spectrum of systems and is a complex phenomenon. Therefore, various research uses different categories and typologies for description and analysis. The main categories of plans are pillars for an explanation. It is reasonable to use them for an explanation; however, this raises many difficulties, as the explanation could be too complicated. Schemes are a descriptive term. In practice, some schemes may have some supportive legislation. The schemes could be understood as broad-based plans on a company level. The concept financial participation refers to all schemes (Lowitzsch & Hashi, 2014);
- *models*. The term models is used to describe the existing or feasible employee financial participation schemes that it includes;
- *employee ownership*, *employee-owned businesses*. It could be explained as companies fully or mainly owned by their employees, including

management (either directly and/or indirectly). The extent of employee ownership varies from workers having complete ownership of the firm to owning the majority stake or non-negligible minority stake, usually through a trust or another legal entity that votes the shares as a group (Blasi et al., 2010b);
- *co-owned companies* (*co-ownership*). This term is wider. It describes companies where employees, including management, have a large or significant but minority stake in the company;
- *employee share ownership*. It takes any form of shareholding, large and small, by employees in the company;
- *worker cooperatives.* A form of employee ownership. Cooperatives tend to adopt a specific form of legal entity (the Industrial and Provident Society), conform to the seven principles of cooperation and insist on equal shares and voting rights;
- *trust-owned businesses*. This term encompasses businesses in which company's shares are entirely owned by either or both an employee trust and a charitable trust to provide permanence to an ownership structure;
- *ownership culture*. The use of some employee ownership plans (mostly ESOPs) and orientation to performance create an ownership culture. It is a type of organisational culture (Thomson, Stanley & McWilliams, 2013).

Finally, the terms such as *democratic capitalism*, *mutual companies*, and *shared entrepreneurship/collaboration* are used to refer to the companies that practice employee financial participation (Shipper et al., 2014).

1.2. Forms and models of employee financial participation

The key issue in some academic and supportive policy discussions is related to the coverage of share ownership, i.e. the following questions are addressed:
- What part of the employees are eligible to participate in financial participation forms?
- To which groups are the forms applied?
- What economic sectors are preferable?

As research has shown, the selectivity of plans is related to the company's interest, business models and other motives. The researchers make a distinction between narrow-based (selective, frequently used to executives or managers) and broad-based (all employee) forms/schemes (Poutsma et al., 2013; Lowitzsch, 2009b; McCarthy, 2016).

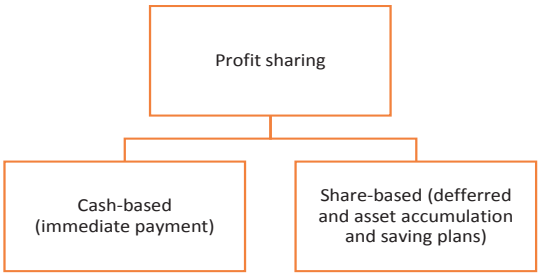

Fig. 1. Forms of profit sharing

1.2.1. Profit sharing

PS functions refer to the situation when an employer pays her/his employees for some performance measures (sales, profits, etc.). In practice, PS can take different forms. These payments can be made in cash bonuses. As the research has revealed, bonuses are often paid in company stock (or other schemes are used). Thus, what is received as a profit share becomes employee ownership (Blasi et al., 2010a; Ugarković, 2008). Researchers and policy makers distinguish cash-based payments and share-based PS forms (Fig. 1).

PS is based on the formula that links profits with employee bonuses after thresholds targets are met. In other cases, these are not formally prescribed, and employers have more discretion to pay bonuses (Reynolds, 2015; Blasi et al., 2010a).

There are special forms of share-based PS. One of them is the so-called "deferred PS." This term covers the distribution of bonus payments on a deferred basis, i.e. it could be granted as several shares, and employees can sell them after some period. The bonuses are also invested in special funds or frozen in accounts for a projected time. This scheme is used the most often, as research suggests (Lowitzsch, 2009b). Asset accumulation and savings plans provide the employees with a possibility to set aside bonuses in an account. They can be invested in stocks, bonds or other financial instruments for a period before being made available to the employee. These are long-term instruments that have different names, such as savings plans, incentive or investment plans (Poutsma, 2001).

1.2.2. Employee share ownership

Employee ownership is another important form of financial participation in the perspective

of employee involvement in the decision-making process. The extent of employee ownership varies from workers having complete ownership of the company to owning a majority stake or a non-negligible minority stake (Blasi et al., 2010a). It can be started by a company (funds can be raised) or by employee initiatives. Poutsma et al. (2010) pointed out that "ESO provides for participation in ownership. As a result of share ownership employees may benefit from the receipt of dividends, the capital gains that accrue to company equity, or a combination of the two." The ESO can be collective (some forms of trust are often used) and individual.

ESO is not directly related to the company's performance in comparison to PS, i.e. it is not financed from the company's profits. However, the link to the company's profitability exists. The participants gain indirectly from the growth of the company's market value in shares.

ESO has a non-automatic connection with employee shareholder involvement in the company's decision-making process. They can be given either non-voting stock or voting share. They can have limited control or no control over the company's management decisions when shares are held in trusts. In this case, trustees may be appointed by management rather than elected by employees (Lowitzsch, 2009b).

There is a broad range of ESO arrangements. They can be grouped into three main forms according to the share acquisition: direct purchase sold at market prices and non-discounted or sold on privileged conditions giving a discount, cooperatives), transfers financed by the company profits (distributed free) and options to buy shares in the future (Lowitzsch, 2009a; Reynolds, 2015; Blasi et al., 2010a). When the employer does contribute an (equal) amount in cash or shares, the plan is called a "share savings plan".

Employee share ownership plans are distinguished according to the criteria of employee's own shares. They are referred to as direct where employees as individuals own shares in the company, or indirect where a block of shares is held in employee trusts (Tab. 2). These trusts exercise control of the company on behalf of employees or through a combination of the two (Olagues & Summa, 2010; Postlethwaite et al., 2005).

Tab. 2. Plans of ESO

Forms	Plans
Direct purchase and share saving	• distributed free, • sold at market prices, • cooperatives (all company shares are owned by members and employee buyouts)
Transfers financed by company profits	• broad-based stock options (the so-called ESO) are given to a group of employees (not on individual performance conditions). The company grants employee options over shares which entitle them to acquire shares in the company at a later date, but at a price fixed when the option was granted. They cannot be traded. The rewards come from the gains arising in stock prices. The employers are often using ESO contracts as compensation (they are named as "compensation contracts"). These contracts amount to a "short" position in the employer's equity, • employee stock ownership plans (the so-called ESOP) contain a loan to an employee benefit trust. It obtains company stock and allocates it through periodic contributions to each employee's ESOP account. The loan may be repaired by payments from the profits, from dividends paid on the stock held by the ESOP

To provide a proper understanding, it is necessary to explain essential ESOP plans by presenting concepts and terminology. ESOP are most popular in the US and Western Europe. These plans enable collective ownership by using special funds raised from employees (McCarthy, 2016).

ESOP are often promoted by government policies by creating special legislation and taxation regimes. The significance of the new forms of ownership is that the new philosophy of equality (holding equal shares), a new process of management (the role relation between workers and managers) was formed (Pendleton, 2001; Blasi et al., 2016). ESOP are related to participation in decision-making, information sharing, high-trust and with a variety of positive perceptions of the company culture (Blasi et al., 2016). An economic argument in favour of ESOP is based on the expectation that employee ownership improves enterprise performance (Kim, 2016). Some empirical research suggests that ESOP impact on a company's performance seems to be small but significant (Kim & Ouimet, 2016; Blasi et al., 2010b; Blasi et al., 2013). Other meta-analytical studies explain that the results are mixed (O'Boyle, Patel & Gonzalez-Mule, 2016).

2. Employee financial participation in the Baltic States: an overview of similarities, differences and trends

Most research and policy studies conclude that privatisation was the main driving force behind the initial spread of employee financial participation in Central and Eastern Europe (Mygind, 2012; Kranz et al., 2016; Lowitzsch, 2009b). As a transition process, privatisation also developed specific conditions that influenced this advance, i.e. privatisation allowed receiving shares at a reduced price. As an effect of this transition, various schemes were introduced. The understanding of employee financial participation differs among countries. However, there is a very specific common characteristic: many companies were owned by a wide group of employees. Some special privatisation plans were used, including those similar to ESOP, voucher schemes, shares to insiders, mass privatisation, leasing methods and employee-management buyouts (Lowitzsch & Hashi, 2006). Based on case studies, companies with employee ownership plans performed rather well in some countries. In other countries, schemes of the employee ownership type were mostly unsuccessful (Mygind, 2012; Berķe-Berga, 2013a). On the other hand, the current knowledge about employee financial participation is limited by a lack of coherent empirical data.

Recent studies (based on surveys and data analyses, i.e. the survey conducted in 2008) have revealed that employee financial participation in Central and Eastern European countries is mostly (except some countries) declining (Mygind, 2012; Lowitzsch, 2009a; Lowitzsch, 2012). This decline is explained by different economic and supportive policies as well as cultural factors (Mygind, 2012; Lowitzsch, 2009b):

- difficult legal framework,
- complex accounting regulations,
- lack of promotion policy and supportive institutional setting (in some countries),
- lack of participative culture (in some countries),
- lack of capital investment and capital intensity,
- long productive crisis,
- negative conditions on a company level (i.e. in some countries, the financial system improved conditions for both managers and external owners in relation to employees, etc.).

The academic research demonstrates very different trends in the use of employee financial participation schemes and supportive policies in Central and Eastern Europe. The Baltic states often stand out among other countries. This distinction is based on the following several arguments:

- incidence of employee financial participation is low in the Baltic states,
- lack of supportive policies (tax and legal regulation) and backing from society and stakeholders,
- difficult legal framework (Eamets et al., 2008; Mygind, 2012; Berķe-Berga, 2013b; Darskuviene & Vazniokas, 2006; Rimas, 2009; Lowitzsch & Hashi, 2014; Lowitzsch, 2009a).

A comparative study has analysed the scale, features and effects of employee financial participation in the Baltic states (Gaponenko, 2008). The main conclusions are as follow:

- large companies and some middle-sized companies are prepared to offer employee financial participation plans,
- the lack of knowledge and understanding of employee financial participation instruments and benefits,
- Lithuanian employers have a better understanding and willingness to offer employee ownership and PS plans in comparison to Latvian and Estonian. The third period could be viewed as especially conditional because only some research discusses the effects of the economic/financial crisis for initiatives of PS and employee ownership plans (Berķe-Berga, 2013; Jaakson & Kallaste, 2014).

3. Scope of employee financial participation

Accessibility to information on the scope of employee financial participation is a complex issue. There are no special registers for companies using PS or employee ownership plans. However, some surveys have been done in Estonia and Latvia by academic researchers (Berķe-Berga, 2013; Jaakson & Kallaste, 2014).

Some empirical data are presented in a recent study on employee financial participation named "The Promotion of Employee Ownership and Participation" (Lowitzsch & Hashi, 2014). For the analysis, the research group used the data of the European Company Survey (ESC) (the largest company survey data), CRANET Survey on Human Resource Manag-

ers (research conducted by a network of universities in 2010) and the European Working Conditions Survey (EWSC, 2010).

3.1. Employee ownership

The research has demonstrated that 5.2 percent of European companies used ESO plans in 2013 (ESC. CRANET — 19.9%; EWSC — 13.5%). In this context, the proportion of Baltic companies (ESC — 7.9%) offering similar plans is much greater (Tab. 3). Lithuanian and Estonian companies offer a relatively higher number of stock option plans. In this case, it is necessary to interpret the data critically.

Tab. 3. Proportion of companies offering employee ownership plans [%]

Estonia	Latvia	Lithuania
2013 ESC: 8.40 2010 Cranet: 10.50 2010 EWCS: 1.17	2013 ESC: 1.40 2010 EWCS: 1.00	2013 ESC: 13.90 2010 Cranet: 7.30 2010 EWCS: 0.56

*ESC covers companies with 10 and more employees

Academic and policy studies explain that similar data from the European surveys indicate stock option plans which were left from the privatisation period, i.e. narrow-based employee ownership plans (Berķe-Berga, 2013a; Jaakson & Kallaste, 2014; Darskuviene & Vazniokas, 2006). This implication supports the data from EWSC survey (Tab. 3). Employee ownership plans are known only relatively by a very low number of employees.

This assumption is supported by the qualitative research. According to the respondent, employee ownership is associated with a recent practice of offering stock options to employees. The respondents who participated in the qualitative research also argued that broad-based employee ownership plans have little popularity in the Baltic countries (interviews with EE3, LV1, LV2, LT1, LT3, LT5, LT6, LT7). This proves earlier findings that previously active share ownership schemes were closed later in the Baltic countries (Jaakson & Kallaste, 2014).

A survey by scholars demonstrates that PS with employees is more common than employee ownership. Based on survey data (2011) that had a sample of 1000 private organisations, Estonian researchers Krista Jaakson and Epp Kallaste found that employee ownership exists only in seven percent (this corresponds to EWSC, Tab. 3) of organisations. According to the findings, PS plans were offered by 21.3% of Estonian companies in 2011 (Jaakson & Kallaste, 2014; Kollektiivsed töösuhted, 2011). Latvian scholars have done several motivational studies, analysing employee attitudes towards some PS and stock options plans. The survey (2012) results provide a full motivational picture. The researchers concluded that:

- analysing the factors noted as important by respondents holding shares in the context of share ownership, financial benefits of the shares or dividends and value appreciation were underlined,
- the analysis of respondent answers regarding the purchase options of company shares have demonstrated that the total of 75% of respondents would buy shares at a 50% discount with a "freeze" term of three years. Conversely, 78% of respondents gave a positive answer to the question about the acquisition of shares (without a discount) in the case shareholders were willing to sell,
- based on the overall results of the survey data, researcher Berķe-Berga concluded that the distribution of ESO might contribute to higher levels of employee motivation and productivity (Berķe-Berga, 2013b).

The proportion of companies, offering PS, is significantly higher than employee ownership. More than a half of companies offer PS schemes (mostly bonuses paid annually for employees) according to the ESC survey in Lithuania and slightly less in Estonia (Tab. 4). Such proportions are in line with some earlier studies done in Estonia (Jaakson & Kallaste, 2014; Kollektiivsed töösuhted, 2011).

Tab. 4. Proportion of companies offering PS [%]

Estonia	Latvia	Lithuania
2013 ESC: 42.20 2010 Cranet: 5.30 2010 EWCS: 12.23	2013 ESC: 22.50 2010 EWCS: 9.40	2013 ESC: 55.40 2010 EWCS: 12.52

It must be emphasised that there is some divergence in the survey data. The surveys are often explained by the formulation of questions and survey samples (e.g. the Cranet sample excluded companies with fewer than 200 employees). Another argument is that the Baltic economies were growing after the harsh economic crisis when employers revised their remuneration policies. Certainly, directing profits together with employees could be much more motivating in this environment.

4. National legal frameworks on employee financial participation

Considering legal regulation, the Baltic states do not provide detailed rules on employee financial participation except for some supported schemes. National regulations on employee financial participation schemes have little density in the Baltic states. In other words, there are few laws related mostly to employee ownership plans and no special legislation on PS (Tab. 5) (Berķe-Berga, 2013a; Rimas, 2009; Lowitzsch, 2014; Jaakson, 2014; Orlova, 2013; Jakabsone, 2016).

The Baltic states use the same type of employee ownership plans. In practice, several employee ownership plans are offered to employees or can be purchased from Lithuanian stock exchange markets as action shares (in public limited liability company), stock options and non-vested shares.

The main legal problems related to the use of employee ownership plans according to the qualitative research information are listed further in the text.

Lithuania:

- the regulation is outdated; it remained since the same since the privatisation period. Thus, it does not respond to the business needs. For instance, some norms of the Law on Companies have been applicable for a long time (interview with LT3, LT4, LT9, LT10);
- unspecified eligibility criteria for shares;
- existing taxes (social security tax) imposed on the given shares (interview with LT3);
- owners of private a limited liability company are careful about offering shares to employees for the reason of unclear management, the handover of shares in the case the employee leaves the firm (unclear priority rights; fixing the market value of the share and other problems) (interview with LT9, LT4).

Latvia:

- the regulation is outdated and does not correspond to business needs (interview with LV1);
- unspecified eligibility criteria for shares (inappropriate regulations for an employer giving shares to an employee) (interview with LV3);
- according to the Latvian Commercial Law, Latvian companies cannot initiate the comparison of shares to non-resident companies. The com-

Tab. 5. Legal and fiscal framework on employee ownership in the Baltic states

Estonia	Latvia	Lithuania
The legal framework neither creates nor prevents incentives for the development of employee ownership schemes. Private Companies – Estonian Commercial Law contains no special rules on ESO concerning the acquisition, limitations on the number of shares or issuance of employee stock for any specific undertaking; general rules therefore apply. Some employees still hold shares purchased during privatisation and thus have the rights attached to these securities according to the Commercial Code and Securities Market Law. If securities issued by a company are offered solely to its employees or managers, the prospectus need not be made public and registered. Consequently, employees and management are not entitled to compensation pursuant to Article 25 of the Securities Market Law on losses resulting from the volatility of acquired securities	In Latvia, employee shares (referred to as employee stock in the Latvian law) are currently an object of taxation at the same tax level as salary plus additional taxes related to capital gains. Complete guidelines for implementation of ESO models are not developed. Laws which constitute any of ESO types apply only to personnel shares. Accordingly, the allocation of shares for the employees in accordance with local legislation is only possible in joint-stock companies. The Law on Personal Income Tax of 2000 clearly marked the moment of gaining income by holders of employee shares: it was the moment of redemption when a resigning holder of employee shares exchanged them for ordinary voting shares or sold shares to the issuer against certain consideration. The given norm stipulating that employee shares be taxable upon their transfer remained in effect until 2010	In Lithuania, no complete guidelines for implementation of ESO models are currently developed. The Law on Companies contains some special rules on ESO. During capital increase, companies can issue employee shares after all shares subscribed at the time of incorporation have been paid for (Art. 43, Law on Companies). The Law on Companies sets no maximum percentage on new employee shares. They are not to be distributed among all employees wishing to purchase them, except for management. A restriction period of no longer than three years must be determined, within which employee shares can be sold only to other employees. During this period, employee shares are not only of limited tradability but also non-voting, although employee shares are ordinary shares. The Law of Companies stipulates that an employee must pay for subscribed employee shares before the restriction period for the transfer of shares expires

mercial law does not restrict foreign enterprises to redeem shares in the market or to issue new shares and award them to their employees (interview with LV1).

Estonia:

- lack of special rules on PS or ESO plans (interview with EE1).

According to respondents, the main problems are related to eligibility of stock options offered to employees. Another issue is related to the lack of special legal schemes in the Estonian case (regulations for employee stock options or other plans), legal loopholes (outdated regulation, restriction for initiations of stock option plans) or unspecified eligibility criteria for shares.

The respondents reflected problems related to the regulation of employee financial participation. A Lithuanian lawyer (having provided roughly 100 consultations) pointed out several problems:

"The main problem is related to eligibility criteria. For instance, remuneration of shares has to be done in cash according to the Law on Companies. Thus, an employee who gets a reward in cash has to pay 25 percent in cash. This is the gap in the realisation of this scheme (interview with LT3)."

The following respondent discussed the eligibility criteria as a Latvian civil servant, emphasising legal restrictions for some companies. The respondent pointed out:

"The main restriction to the introduction of employee financial participation in Latvia is due to inappropriate regulations of The Commercial Law of the Republic of Latvia which prohibits Latvia's enterprises to obtain their own shares. With the insufficiently regulated commercial law, Latvia's companies are discriminated when compared to non-residents, allowing them to gain privileges in the market and promote competitiveness since Latvia's legislation allows foreign enterprises (registered outside of Latvia) to introduce EPF. The commercial law does not restrict foreign enterprises to redeem shares in the market or to issue new shares and award them to their employees. For example, employees of Swedbank branches in Latvia can purchase shares of the parent Swedbank Company located in its home country Sweden (interview with LV1)."

The qualitative research data indicates that taxation in Latvia and Lithuania inhibits the spread of employee stock options plans (interviews with LT4, LT5, LV1).

The academic research and studies indicate the absence of special legal regulation for PS in the Baltic states. On the other hand, there are no direct restrictions on employers using PS schemes (Tab. 6).

Base on the qualitative interview data, Lithuanian companies mix a stock option plan with employee PS in the form of paying bonuses. One respondent, chief advocate of a law firm, reflected as follows:

"We have a client, a company. The client decides to share the profit after running performance objectives are reached if employees reach strategic aims they are offered to buy the company's share. Others take another option, they have performance objectives interlinked with the motivational system. The employees can choose the money, i.e. "here and now" or they can get the companies share and invest […]. It depends on the type of motivational systems."

In the Baltic states, employers are using material bonuses (intangible benefit guarantees, the ability to use a company car for private purposes, health insurance, compensation of telephone expenses, additional

Tab. 6. Legal and fiscal framework on PS in the Baltic states

Estonia	Latvia	Lithuania
No special legislation on PS regarding employees exists; therefore, there are neither direct incentives nor direct restrictions. The resident company pays income tax at the rate of 21% (20% starting from 2015) on distributed profits	There are no legal limitations or regulations pertaining to PS. Salaries may be made dependent upon company profit and benefits may be provided in the form of premiums or other forms directly linked to the profits of a particular company. However, all benefits are subject to a personal income tax. This reduces the incentive to provide additional benefits. Dividends are not subject to tax	There is no specific regulation on sharing profits. Since companies pay income tax on dividends, this is viewed as an expensive method of profit distribution; therefore, priority is given to share buyback schemes. Employee monetary incentive schemes used in companies include payments of premiums and bonuses

holidays, etc. and a bonus (interview with EE1, EE2, LV1, LV3, LT).

5. New supportive policy initiatives

In the Baltic states, the new supportive regulation for employee ownership was initiated in 2011 (Estonia) and 2015–2016 (Latvia and Lithuania). These initiatives indicate new favourable attitudes conditioned by economic interest of some employer groups.

The qualitative research specifies that new legislative initiatives have been caused by active involvement of lobbying organisations (i.e. Latvian Confederation of Employers, lobbyist acting for Scandinavian banks in Lithuania, representatives of so-called start-ups companies). The policy problems raised by a stakeholder got a late support from government institutions (Ministries of Finance in Lithuania and Latvia and Central Bank of the Republic of Lithuania) (interviews with LV1, LV2, LT1, LT2, LT3, LT5, LT6).

Problems related to the policy supporting employee financial participation:

- the lack of special rules on PS or ESO plans,
- in the Baltic states, tax legislation and ESO models (in this case, the only plans of personnel shares) have no tax benefits (i.e. tax advantages for ESO),
- the lack of support for awareness raising initiatives which could be possibly initiated by the employee or/and employer organisations) (interviews with LV1, LV2, LT1, LT2, LT3, LT5, LT6, EE1).

In the Baltics, ESO supportive policy was directed on issues related to taxation and social security contributions. Firstly, it is necessary to point out that the Baltic states do not have a lengthy tradition of tax initiatives for the promotion of ESO compared to Western countries. The analyses of fiscal initiatives indicate that in the Baltic states, there were several such initiatives (Tab. 7).

In Latvia and Lithuania, new supportive policy initiatives started on the development of employee ownership schemes in 2014 and 2016.

5.1. Latvia

In Latvia, the Ministry of Finance with social partners (the Confederation of Latvian Employers) and several trade unions established a group responsible for the introduction of employee financial participation in Latvia. The proposed solutions did not precondition the EPF implementation. The institutional group did not finish its work due to the economic and financial crisis in 2008. The policy agenda was changed due to the volatile economic environ-

Tab. 7. Policy measures supporting employee financial participation in the Baltic states

Estonia	Latvia	Lithuania
Taxing of stock options changed in 2011 and the Tax and Customs Board has specified the terms in 2013. In general, selling employer shares at a lower than market price to employees is considered a fringe benefit subject to social and income tax. ESO is not explicitly incentivised, and if the transaction takes place below the market price, it is considered as a part of compensation and is taxed as such	In 2010, the Latvian Personal Income Tax Law was supplemented with the rule on taxation of capital income, while the reference to employee shares was omitted. Therefore, the time when employee shares should be considered as income liable to tax became unclear. The current version of the Law provides a clear and unequivocal answer that shares received on the privileged basis constitute the labour income of an employee and are therefore taxable the same way as a salary. New labour taxation rules (as well as rules on tax exemption) enforced in Latvia in 2013 allow employees acquire shares of their enterprise free of charge or at a discount. Currently, the amendments in the Law on Income Tax are attributed to foreign enterprises	Taxing stock options was changed in 2015 (Rules of the State Social Insurance Fund Budget Formation and Implementation, the government resolution). According to regulations in effect since 2015, employee stock options are tax-exempt for employers if the granting period is at least three years (i.e. the right to shares is granted after the three years period)

ment. The circumstances changed after six years when the question of employee financial participation reappeared in policy discussions (interview with LT3).

The Cabinet of Ministers started a debate about employee participation while discussing the Business Environment Action Plan for 2014-2015 (Rīkojums..., 2014). This issue had not disappeared from the policy agenda. A new working group was created in the Ministry of Justice and involved advocates, members of an employer association and a government representative). The working group discussed the loopholes in the current legal framework on employee ownership and is decided that it is necessary to develop current stock options and work on new plans. The working group discussed the amendments to the Latvian Commercial Law prepared by the Ministry of Justice. The members of the working group stressed the importance of employee stock options as an effective instrument of human resource management. According to the qualitative research data, Latvian labour unions took a neutral stand in the discussion. The respondent took such a position on the argument that planned amendments were not related to employee participation in decision-making (in control) at a company level (interview with LV3).

5.2. Lithuania

In Lithuania, the government initiated a working group on the revision of the Law on Companies. According to the respondent from the Ministry of Economy, a new revision of employee shares was initiated as one of agenda questions (interview with LT2). Others pointed out that this legislative initiative was influenced by business lobbying groups (interview with LT4). The working group was initiated by the Ministry of Economy, the Ministry of Finance and the Central Bank of the Republic of Lithuania. According to the report on the analysis of the regulatory impact, the importance of employee stock options may be viewed as an effective human resource management instrument for increasing motivation and forming loyalty towards the company (Seimas of Republic of Lithuania, 2015). It is worth mentioning that the working group does not have a related new legislative initiative with ideas of employee involvement in control or the decision-making process at a company level. Employee motivation and loyalty were the main arguments in the discussions (interview with LT1, LT2, LT10).

New amendments or, more precisely, two schemes have been introduced (for limited liability companies):

- an individual employee stock ownership plan (employee action option plan. In comparison to the current regulation, employers will be able to hand over shares gratuitously);
- PS scheme or, more precisely, share-based PS (company profit can be transferred to employee shares) (Seimas of Republic of Lithuania, 2015).

In general, the new policy for supporting employee financial participation has been renewed in Latvia and Lithuania. It started recently with the revision of the legislative framework that remained unchanged since the privatisation period. The revision of the Law on Companies was driven by the business interest (to have a new effective human resource management tool or to transfer employee share plans from parent companies in Western countries to subsidiaries in the Baltic states) to introduce (or revise in the case of Lithuania) new ESO plans. In the two Baltic countries, special working groups (with delegated members from ministries and experts) started working on new initiatives. The working groups (most of the members) generally supported the idea of a special framework for ESO and financial participation. This is indicated in documents (minutes), interview data and the new draft law. Generally, the process started successfully, but fiscal frameworks must be balanced.

Conclusions

According to the qualitative research data, the ESO concept has limited awareness in the Baltic states. The respondents pointed out several general reasons (except for a legal framework and promotive tax initiatives), limiting the use of ESO:

- the lack of information about benefits,
- conservative business cultures and non-innovative human resource managing practices,
- indifference of trade unions and, partly, employee organisations,
- the domination of Scandinavian investment, organisational cultures and human resource practices. This reason was reflected differently. A part of respondents saw Scandinavian corporations as a driving force. For others, Scandinavian human resource management models and practices seemed to be limited. The lack of informa-

tion was indicated by the respondents as the main factor limiting awareness about employee financial participation.

According to the results, the Baltic states do not provide detailed rules on employee financial participation except for some supported schemes. However, comparisons across the national regulations on employee financial participation schemes showed little density. In other words, there were few laws related mostly to employee ownership plans and no special legislation on PS. The Baltic states use the same type of employee ownership plans. In practice, several employee ownership plans are offered to employees or can be purchased from Lithuanian stock exchange markets, including action shares (in a public limited liability company), stock options and non-vested shares. As reflected by respondents, the main problems are related to eligibility of stock options by employees. Another problem is related to the lack (Estonian case) of special legal schemes (the regulation for employee stock options or another plan), legal loopholes (outdated regulation, restriction for initiations of stock option plans) or unspecified eligibility criteria for shares.

In the Baltic states, the new supportive regulation for employee ownership was initiated in 2011 (Estonia) and 2015-2016 (Latvia and Lithuania). These initiatives indicate new favourable attitudes conditioned by economic interest of some employer groups. The qualitative research specifies that new legislative initiatives have been caused by active involvement of lobbying organisations (i.e. the Latvian Confederation of Employers, a lobbyist acting for Scandinavian banks in Lithuania, representatives of so-called start-up companies). The policy problems raised by stakeholders received late support from government institutions. Problems related to the policy supporting employee financial participation:

- the lack of special rules on PS or ESO plans,
- in the Baltic states, tax legislation and ESO models (in this case, the only plans of personnel shares) have no tax benefits (i.e. tax advantages for ESO),
- the lack of support for awareness raising initiatives, which could be possibly initiated by the employee or/and employer organisations.

Literature

Berķe-Berga, A. (2013a). *Development of Employee Share Ownership in Latvia* [Doctoral dissertation]. Riga, Latvia: Riga Technical University.

Berke-Berga, A. (2013b). Employee ownership model for Latvia. Scientific *Journal of Riga Technical University*: *Economics and Business*, *23*, 6-12.

Berķe-Berga, A. (2014). Development of Employee Share Ownership in Latvia. *International Journal of Business and Management Studies*, *3*(1), 167-178.

Blasi, J., Freeman, R., & Kruse, D. (2016). Do Broad-based Employee Ownership, Profit Sharing and Stock Options Help the Best Firms Do Even Better? *British Journal of Industrial Relations*, *54*(1), 55-82.

Blasi, J. R., Kruse, D. L., & Freeman, R. B. (2010a). Epilogue (and Prologue). In D. L. Kruse, R. B. Freeman, J. R. Blasi (Eds.), *Shared Capitalism at Work*: *Employee Ownership*, *Profit and Gain Sharing*, *and Broad-based Stock Options* (pp. 377-386). Chicago, USA: University of Chicago Press.

Blasi, J. R., Kruse, D. L., & Freeman, R. B. (2010b). Introduction. In D. L. Kruse, R. B. Freeman, J. R. Blasi (Eds.), *Shared Capitalism at Work: Employee Ownership*, *Profit and Gain Sharing*, *and Broad-based Stock Options* (pp. 1-41). Chicago, USA: University of Chicago Press.

Blasi, J., Kruse, D., & Weltmann, D. (2013). Firm Survival and Performance in Privately Held ESOP Companies. In D. Kruse (Ed.), *Sharing Ownership*, *Profits*, *and Decision-Making in the 21st Century* (pp. 109-124). Bingley, England: Emerald Group Publishing Limited.

Bryson, A., & Freeman, R. B. (2010). How Does Shared Capitalism Affect Economic Performance in the United Kingdom? In D. L. Kruse, R. B. Freeman, J. R. Blasi (Eds.), *Shared Capitalism at Work: Employee Ownership*, *Profit and Gain Sharing*, *and Broad-based Stock Options* (pp. 201-224). Chicago, USA: University of Chicago Press.

Darskuviene, V., & Vazniokas, P. (2006). Stock Ownership as a Form of Employee and Management Financial Participation: Factors of Development in Lithuania. *Organizacijų Vadyba: Sisteminiai Tyrimai*, *38*, 33-51.

Eamets, R., Mygind, N., & Spitsa, N. (2008). The Development of Employee Financial Participation in Estonia. *Baltic Journal of Management*, *3*(2), 218-231.

Gapoņenko, I. et al. (2008). *Eiropas pieredze darbinieku finansiālai līdzdalībai uzņēmuma darbības rezultātos un tās izmantošana Baltijas valstīs* [*European experience of employee financial participation in company performance and its use in the Baltic States*]. Riga, Latvia: Eiropas Pētījuma Institūts.

Jaakson, K., & Kallaste, E. (2014). Who Uses Employee Financial Participation in an Adverse Environment? The Case of Estonia. *Economic and Industrial Democracy*, *37*(3), 449-467.

Kollektiivsed töösuhted [Collective Employment Relationships]. (2011). *Kvantitatiivuuringu raport* [*Quantitative Study Report*]. Tallinn, Estonia: Keskus CentAR.

Kranz, O., Steger, T., & Hartz, R. (2016). The Employee as the Unknown Actor? A Discourse Analysis of the Employee Share Ownership Debate with Special Emphasis on Central and Eastern Europe. *Organizacija*, *49*(2), 77-92.

Landau, I., Mitchell, R., O'Connell, A., & Ramsay, I. (2007). *Employee Share Ownership*: *A Review of the Literature*. Melbourne, Australia: Melbourne Law School, & The University of Melbourne.

Lowitzsch, J. (Ed.). (2009a). *Financial Participation of Employees in the EU-27*. London, England: Palgrave Macmillan.

Lowitzsch, J. (Ed.). (2009b). *The PEPPER IV Report*: *Benchmarking of Employee Participation in Profits and Enterprise Results in the Member and Candidate Countries of the European Union*. Berlin, Germany: Free University of Berlin, Institute for Eastern European Studies, & Inter-University Centre Split-Berlin.

Lowitzsch, J. (2012). *Employee Financial Participation in Public Services in the European Union*. Retrieved from http://www.ceep.eu/images/stories/pdf/events/efp/reportEFP.pdf

Lowitzsch, J., & Hashi, I. (2006). *The PEPPER III Report: Promotion of Employee Participation in Profits and Enterprise Results in the New Member and Candidate Countries of the European Union*. Berlin, Germany: Free University of Berlin, Institute for Eastern European Studies, & Inter-University Centre Split-Berlin.

Lowitzsch, J., & Hashi, I. (2014). *The Promotion of Employee Ownership and Participation*. Brussels, Belgium: European Union.

McCarthy, D. (2016). Employees Financial Participation. In J. Holsher, H. Tomann (Eds.), *Palgrave Dictionary of Emerging Markets and Transition Economics*, (pp. 508-521). London, England: Palgrave Macmillan.

Mygind, N. (2012). Trends in Employee Ownership in Eastern Europe. *The International Journal of Human Resource Management*, *23*(8), 1611-1642.

O'Boyle, E. H., Patel, P. C., & Gonzalez-Mulé, E. (2016). Employee Ownership and Firm Performance: A *Meta-analysis*. *Human Resource Management Journal*, *26*(4), 425-488.

Olagues, J., & Summa, J. F. (2010). *Getting Started in Employee Stock Options*. New Jersey, USA: John Wiley & Sons.

Orlova, J. (2013). Nepieciešamība iekļaut akciju opciju regulējumu komerclikumā [The need to incorporate stock options into commercial law]. *Jurista vārds*, *27*(28), 778-779.

Pendleton, A. (2001). *Employee Ownership, Participation and Governance*: *A Study of ESOPs in the UK*. London, England, & New York, USA: Routledge.

Pendleton, A. (2011). Employee Ownership in Britain: Diverse Forms, Diverse Antecedents. In E. J. Carberry (Ed.), *Employee Ownership and Shared Capitalism: New Directions in Research*, pp. 311-339. Baltimore, USA: Labor and Employment Relations Association.

Poole, M., & Jenkins, G. (2013). *The Impact of Economic Democracy*: *Profit-sharing and Employee-shareholding Schemes*. New York, USA: Routledge.

Postlethwaite, R., Michie, J., Burns, P., & Nuttall, G. (2005). *Shared Company*: *How Employee Ownership Works*. Melton, England: Job Ownership Limited.

Poutsma, E. (2001). *Recent Trends in Employee Financial Participation in the European Union*. Dublin, Ireland: European Foundation for the Improvement of Living and Working Conditions.

Poutsma, E., & Braam, G. (2012). Financial Participation Plans and Firm Financial Performance: Evidence from a Dutch Longitudinal Panel. In A. Bryson (Ed.), *Advances in the Economic Analysis of Participatory and Labor-managed Firms*, (pp.139-183). Bingley, England: Emerald Group Publishing Limited.

Poutsma, E., Ligthart, P., Pendleton, A., & Brewster, C. (2013). The Development of Employee Financial Participation in Europe. In E. Parry, E. Stavrou, M. Lazarova (Eds.), *Global Trends in Human Resource Management* pp. 179-213. London, England: Palgrave Macmillan.

Reynolds, J. N. (2015). *Sharing Profits*. London, England: Palgrave Macmillan.

Richter, A., & Schrader, S. (2016). Financial Participation and Recruitment and Retention: Causes and Consequences. *The International Journal of Human Resource Management* (In Press).

Rīkojums Nr. 694 Par Uzņēmējdarbības vides uzlabošanas pasākumu plānu 2014-2015 gadam [*Directive Nr. 694 of the Cabinet of Ministers of Latvia on the Action Plan for Improvement of the Business Environment for 2014-2015*] *2014* (LV).

Rimas, J. (2009). Akcijų opcionai kaip privataus kapitalo investuotojo ir bendrovės vadovų interesų derinimo priemonė [Stock options as a means to align the interests of the private equity investor and target managers]. *Teisė*, *73*, 124-136.

Seimas of Republic of Lithuania [Parliament of Lithuania]. (2015). *Explanatory Letter on Law of Joint Stock Company of Republic of Lithuania*. Retrieved from https://e-seimas.lrs.lt/rs/lasupplement/TAP/360917d0aed911e59010bea026bdb259/cc237458aed911e59010bea026bdb259/format/ISO_PDF/

Sippola, M. (2009). The Two Faces of Nordic Management? Nordic Firms and Their Employee Relations in the Baltic States. *The International Journal of Human Resource Management*, *20*(9), 1929-1944.

Sippola, M. (2013). The Awkward Choices Facing the Baltic Worker: Exit or Loyalty. *Journal of Baltic Studies*, *44*(4), 451-473.

Shipper, F., Manz, C. C., Manz, K. P., & Nobles, B. (2014). Shared entrepreneurship: Toward an ethical, dynamic, empowering, freedom-based process of collaborative innovation. In F. Shipper (Ed.), *Shared Entrepreneurship* pp. 7-26. New York, USA: Palgrave Macmillan.

Thompson, P. B., Shanley, M., & McWilliams, A. (2013). Ownership culture and strategic Adaptabilit. *Journal of Business Strategies*, *30*(2), 145-179.

Ugarković, M. (2008). Profit Sharing: Supplement or Substitute? In M. Ugarković (Ed.), *Profit Sharing and Company Performance* (pp. 71-78). Wiesbaden, Germany: Gabler Verlag, & Springer Fachmedien.

Woolfson, C., Kallaste, E., & Berzins, J. (2011). Industrial Relations and Social Dialogue in the Baltic States-Crisis, Conflict and Compromise. In S. Contrepois, V. Delteil, P. Dieuaide, S. Jeffrys (Eds.), *Globalizing Employment Relations* (pp. 179-197). London, England: Palgrave Macmillan.

DE GRUYTER OPEN

ISMSME International Society for Manufacturing, Service and Management Engineering

received: 30 November 2016
accepted: 15 April 2017

pages: 51-62

Learning orientation in nursing homes in Poland

Joanna Ejdys, Dainora Gedvilaite

ABSTRACT
As a major challenge of a social, economic, and institutional nature, the phenomenon of population ageing is the basis for concern in terms of the direction of further socio-economic development. By the year 2050, the number of older people around the world will amount to more than 2 billion, constituting 22% of the total population. Over 75, people are faced with increased risk of disability (physical and mental), which can deprive of independent existence. The welfare system will not only have to meet the growing demand for nursing homes, but also the increasing requirements for the safety and quality of services. The innovation of nursing homes will be conditional on the learning of the units of this sector. The scientific goal of the pursued study was to evaluate the influence of learning orientation on the innovation of nursing homes in Poland. Learning orientation has been the subject of the Author's interest in the context of four constructs: (i) commitment to learning, (ii) shared vision, (iii) open-mindedness, and (iv) intra-organisational knowledge sharing. The article presents the results of a quantitative research conducted on a sample of 169 nursing homes in Poland. The study aimed to examine relationships between the four constructs of learning orientation and organisational innovativeness of nursing homes in Poland. The regression model confirmed the existing statistically significant positive relationship between open-mindedness and organisational innovativeness.

KEY WORDS
nursing homes, learning orientation, innovativeness

DOI: 10.1515/emj-2017-0025

Corresponding author:

Joanna Ejdys

Faculty of Management,
Bialystok University of Technology,
Poland
e-mail: j.ejdys@pb.edu.pl

Dainora Gedvilaite

Faculty of Business Management,
Vilnius Gediminas Technical University,
Lithuania
e-mail: dainora.gedvilaite@vgtu.lt

Introduction

The processes related to ageing (greying) population are among of the most important short to mid-term challenges all over the world. The share of older people (+65) in Poland increased from 10.2 per cent in 1990 to 16.0 per cent in 2015 (Central Statistical Office (CSO), 2016). Globally, the number of older people (over 60) is expected to more than double, from 841 million people in 2013 to more than 2 billion in 2050, representing 22% of the population (United Nations, 2017; Bloom, Canning & Fink, 2011). The projected population in three main age groups in 2050 in Poland (Tab. 1) shows that the number of people above the age 65 will increase from 6 071 in 2015 to 11 097 thousand in 2050, representing an increase of over 83%. In the population

Tab. 1. Population projection by biological age groups (in thousands)

Year	Population by age group				Total
	0-14 years	15-64	>65 years	>85 years	
2015	5 728	26 620	6 071	1 560	38 419
2050	4 120	18 733	11 097	3 537	33 951

Source: elaborated by the author based on (CSO, 2017).

structure, the share of people over 65 will increase from 16.0% in 2015 to 33.0% in 2050.

In the population age structure, the population older than 85 plays a special role. At this age, the deteriorating physical condition reduces the ability to independently function in the society. As ageing progresses, older people find it increasingly more difficult to independently meet their basic needs. The global phenomenon of population ageing results in greater numbers of older people in need of care, while possibilities of family care are simultaneously decreasing. Europe has about 60% of people aged 75 and older with limitations in their daily activities (Organisation for Economic Co-operation and Development (OECD), 2013).

The processes associated with the ageing population will result in a steady increase in the interest for long-term care services, such as nursing home. Residential care refers to the services of care and social support, provided in supported living arrangements (OECD, 2008, p. 1). On the one hand, the growing interest in the care provided by nursing homes (residential care) results from lengthening duration of life and is also accompanied by the extended presence in the labour market, which often prevents children from taking care of their parents. On the other hand, the increasing demand for residential care services will arise because globally, as little as 40 per cent of older people live independently, i.e. alone or with their spouse only (United Nations, 2013). Lonely existence of older people is a common occurrence and constitutes a serious social problem. It requires the development of a variety of care measures in the form of institutionalised social welfare.

Considering the projected dynamics of changes in the population structure, the availability of places in nursing homes indicates a significant gap in this area. The availability of vacancies in nursing homes is much lower than the existing demand. Only Lithuania stands out in terms of the availability of vacancies in nursing homes with are as many as 66 vacancies per every 100 people over 65 years of age. The countries with the lowest coefficient of vacancies in residential care facilities include Bulgaria (0.32 per 100 people over 65 years of age) and Romania (0.79). In Poland, the analysed ratio amounts to 1.66 (Eurostat database, 2014).

In Poland, for more than 78 thousand available vacancies in nursing homes, around 10 thousand new pensioners are accepted every year. A queue amounts to an average of 7 thousand pensioners annually. Considering the functions performed by the social welfare homes in Poland and their types, 30% of the total number of vacancies available in social assistance institutions is allotted for the elderly aged over 65.

The growing demand for nursing homes will led to growing expectations connected with the quality of such services and increasing requirements for long-term care services from the perspective of a family paying for such services (Ejdys, 2017). The need to ensure high-quality care for the older people (high-quality, long-term care) is associated with several irregularities in this regard, reported widely in the media. Many national reports, individual research and survey results confirm the poor quality of services (Capitman et al., 2005; OECD, 2013; Kautsch et al., 2017).

The requirements of today's generation of "baby boomers" are much higher than those of their parents. Particular attention is given to such qualities of the care system for the older people as ensuring independence, autonomy, and privacy. In addition, a modern system of care for the older people should be characterised by the ability to create a culture focused on improving the quality of services, market orientation manifested in the customisation of services according to customer expectations, the involvement of older people in the process of service improvement, providing security to pensioners. The processes of service improvement should be focused on three areas: workforce, living environment, and assistive technologies (OECD, 2013; Halicka, 2016). Establishing such a system requires the adoption at the unit level of learning orientation

conditioning the development of innovative processes.

The next part of the study presents the theoretical assumptions of learning orientation as the primary determinant of improving the innovativeness of processes and services. At the same time, the results of previous studies were pointed out, proving a significant correlation between innovation and learning orientation.

1. Literature review

The term "learning orientation" is often identified in the literature with the terms "learning organisation", and "organisational learning". According to the author, despite the very frequent synonymous treatment of these terms, each of them should be considered in a different context (Fig. 1).

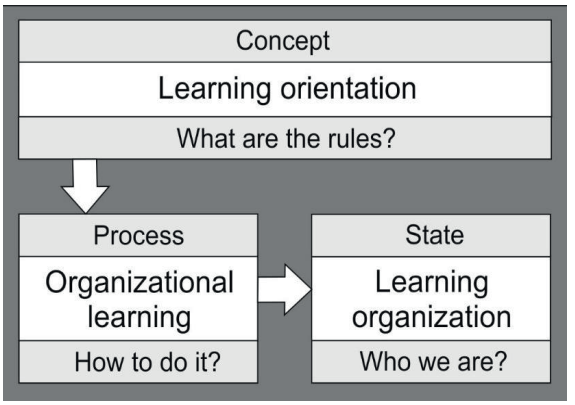

Fig. 1. Differences between "learning orientation", "learning organisation", and "organisational learning"

The most general term that reflects the conceptual level is the notion of "learning orientation". According to the Sinkula et al., learning orientation is a set of organisational values which influence an organisation's disposition to create and utilize knowledge and the degree to which proactive learning appears (Sinkula, Baker & Noordewier, 1997). The system of values adopted in the organisation also reflects the organisational culture, representing a system of values, norms and behaviours relating to the sphere of interpersonal contacts within the company itself or its surroundings. In the broad terms, learning orientation is the way an organisation "learns", together with learning members of the organisation and the entire environment. In the era of a turbulent and unpredictable environment, it is difficult to imagine that the learning orientation would solely address the interior of the organisation. A prerequisite of this orientation is being open to the surroundings to acquire, disseminate and share knowledge.

"Organisational learning" is the second term presented in Fig. 3. It refers to the process approach, ensuring the transition from the conceptual to the organisational level. Individual members of the organisation must answer the question of how to implement the principles of learning orientation in their organisation. One way is to use the process approach. In such context, organisational learning is an important and basic organisational process, through which information and knowledge can be processed and the attributes, behaviours, capabilities, and performance of an organisation can be changed (Cohen & Levinthal, 1990). Organisational learning consists of a series of subprocesses, such as knowledge acquisition, knowledge sharing, and knowledge utilisation (Nevis, Dibella & Gould, 1995). These processes may also be considered from the perspective of a member of an organisation in a network of connections (Hu, 2014).

Formation of a learning organisation is a tangible result of the use of the process approach encompassing organisational learning. At this level, a measurement should be performed allowing to answer the following questions: What is the level of maturity of our learning organisation? To what extent have the principles of learning orientation and organisational learning processes been adopted and in what has the organisation succeeded? Greater interest in the concept of the learning organisation was stimulated by the book *The Fifth Discipline*: *The Art And Practice of the Learning Organisation* authored by the Peter Senge and published in 1990 (Senge, 2006).

Despite the seemingly easy distinction between the three analysed concepts, the differences between them often become blurred and are even used interchangeably. Many authors see the same relationships between the terms "learning organisation" and "organisational learning" as opposites. For some, organisational learning is seen as an element and aspect of a learning organisation (Ortenblad, 2002), and for others, a learning organisation is seen as a special case, the result of the implementation of organisational learning (Easterby-Smith, 1997; Ortenblad, 2001). According to Ortenblad, organisational learning is one of the four components

Tab. 2. Different understating of the constructs of "learning orientation", "organisational learning" and "learning organisation" from the perspective of value, process and act

Learning orientation	Organisational learning	Learning organisation
a set of organisational values which influence an organisation's propensity to create and use knowledge, and the degree to which proactive learning occurs (Sinkula et al., 1997)	organisational learning occurs when members of the organisation **act as learning agents** for the organisation, responding to internal and external changes (Argyris & Schön, 1978)	has a meaning that emphasises an individual, individual **development and active learning**, and aims to use the results of this process to have an advantage over its rivals (Somunoglu et al., 2012)
learning-oriented **values** are manifested in a firm's behaviour and processes of knowledge acquisition, creation, and transfer (Gavin, 1993)	**the process** through which information and knowledge can be processed and the attributes, behaviours, capabilities, and performance of an organisation can be changed (Cohen & Leventhal, 1990)	the idea which consists of four categories: **learning at work, organisational learning, climate for learning, learning structure** (Ortenblad, 2013)
the organisation-wide activity of creating and using knowledge to enhance competitive advantage (Calantone, Cavusgil & Zhao, 2002)	can be considered as a **process of change** in thought and action both shared and individually, which is affected by the organisation of the institution (Vera & Crossan, 2004)	is an institution in which information is **created, transferred, and the behaviours of the workers are shaped** based on the knowledge obtained (Öneren, 2008)
a set of values that stimulate organisational members to engage in knowledge creation and sharing activities (Liu, Luo & Shi, 2002)	is an attempt **to develop structures and systems** that make large organisations more adaptable and responsive to change (Alas, Zernand-Vilson & Vadi, 2012)	represents a **process** having a set of stages; it is stated that the structure of the learning organisation emerges only once these stages are passed (Somunoglu et al., 2012)
as a **cultural aspect** that emphasises the **process** of improving insights, knowledge, and understanding to improve organisational performance and customer value (Nasution, Mavondo, Matanda & Ndubisi, 2011)	embraces the concept of knowledge **creation** (Begona Lloria & Moreno-Luzon, 2014)	

of a learning organisation. Among the other components, the author included learning at work, the climate for learning, and the learning structure.

Despite a considerably easy distinction between the three analysed concepts in theoretical and terminological fields, it appears they are often treated interchangeably, and the differences between them are blurred (Tab. 2). Unless there is a rather clear distinction between the terms "learning orientation" and "organisational learning", then at the most operational level, "learning organisation" often includes elements of both organisational culture, processes and concrete actions. For this reason, measuring the level of maturity of a "learning organisation" is very difficult and only seemingly easy, and it turns out that it is easier to indirectly measure the learning orientation.

Comparing the concepts "learning orientation" and "learning organisation" at the level of constructs, one can observe many common elements (Tab. 3).

However, a closer analysis of the two concepts shows a different level of operationalisation, particularly when it comes to the moment of measuring their level of implementation or application. The concept of "learning orientation" is more general and emphasises a set of principles and values favourable to the creation of a general climate oriented to learning. In contrast, the concept of "learning organisation" refers more to particular solutions and best

Tab. 3. Comparison of the two concepts at the construct level

Learning orientation (Calantone et al., 2002)	Learning organisation (Ortenblad, 2013)
commitment to learning	climate for learning
shared vision	learning at work
open-mindedness	organisational learning
Intra-organisational knowledge sharing	learning structure

Tab. 4. Methodological approach in the two concepts

Characteristics	Learning orientation	Learning organisation
Level of generalisation	generic	detailed
Application level	branch/sector	organisation
Research methods	quantitative	qualitative
Research tools	survey (CATI, CAWI)	case study, interview

Tab. 5. Learning orientation and innovation as a research object

Author(s)	Examined relationships	Country	Branch	Sample	Findings
(Calantone et al., 2002)	Learning orientation-innovativeness Learning orientation-performance	US	manufacturing and service industries	187	Learning orientation influences firm innovativeness Positive relationship between learning orientation and firm performance
(Nasution et al., 2011)	Learning orientation-innovativeness Learning orientation-customer value	Indonesia	Hotels	231	Positive relation between learning orientation and innovation Positive relation between learning orientation and customer value
(Li et al., 2010)	Learning orientation-product innovation	China	Cross-sectional samples	351	Learning orientation has a positive impact product innovation
(Kaya & Patton, 2011)	Learning orientation-innovation performance	Turkey	Cross-sectional samples	135	Learning orientation has an important effect on innovation performance
(Pesamaa, Shoham, Wincent & Ruvio, 2013)	Learning-orientation-organisational innovativeness	Israel	Healthcare industry	395	Learning orientation should be considered for understanding effective innovativeness work for competitive service delivery
(Salge & Vera, 2012)	Learning orientation-innovative Learning orientation-service quality	UK	Public hospital services	153	Moderating the role of learning orientation to innovative activity and public service quality
(Laukkanen, Nagy, Hirvonen, Reijonen & Pasanen, 2013)	Learning orientation-brand performance Learning orientation-market performance	Hungary, Finland	Cross-sectional samples	1120	Learning orientation can be seen to offer tools to enhance performance both in transitional and in mature markets
(Ejdys, 2015)	Learning orientation – organizational innovativeness	Poland	Residential care units	115	Statistically significant positive relationships between learning orientation and innovativeness were not confirmed
(Tajeddini, 2016)	Learning orientation-firm performance	Iran	Public organisation	127	Learning orientation and innovativeness leads to better public organisation performance
(Sheng & Chien, 2016)	Learning orientation -incremental innovation Learning orientation -radical innovation	Taiwan	High-tech industry	200	Learning orientation has a stronger effect on incremental innovation than on radical innovation

Source: elaborated by the author based on (Ejdys, 2014).

practices used at the level of the organisation. Therefore, an attempt to measure both concepts requires a different methodological approach (Tab. 4).

Considering the author's matter of interest, associated with the exploration of relationships between the term "learning orientation" and innovation of a chosen sector, understanding of the term "learning orientation" and the scope of previous studies in this area were subjected to detailed analysis.

According to Calantone, Cavusgil and Zhao, the construct of learning orientation has been conceptualised into (i) commitment to learning, (ii) shared vision, (iii) open-mindedness, and (iv) intra-organisational knowledge sharing (Calantone et al., 2002; Kaya & Patton, 2011; Li, Guo, Yi & Liu, 2010; Narver & Slater, 1990; Nasution et al., 2011; Wang, 2008). Commitment to learning means the extent to which the organisation promotes and assigns a value to the learning process, and the created climate for learning. Commitment to learning is a part of a long-term strategy rather than a single action. Shared vision means the focus of the entire organisation on learning, and not only its selected members. Open-mindedness is a tendency for evaluation and assessment of routine activities/behaviours and rewarding new ideas while accepting and learning from mistakes. Intra-organisational knowledge sharing is the ability to develop mechanisms, policies, behaviours enabling the spreading of learning principles between all units of the organisation.

One of the most important features of learning-oriented firms is that they can anticipate environmental and market changes and undertake the necessary changes if required (Calantone et al., 2002). A learning orientation may also be define as a process of information accumulation, information dissemination and shared interpretation that increases both individual and organisational effectiveness due to the direct impact on the results (Kaya & Patton, 2011).

A systematic study of the relationship between learning orientation and firm innovation has not been carried out for two reasons (Calantone et al., 2002). According to Calantone et al., first, there is no consensus on how to define and operationalise the learning orientation construct. Second, the role of learning orientation in firm innovativeness remains unclear. Learning orientation in relation to the innovation was the object of research in the context: innovativeness, product innovation, firms performance, service quality and customer value (Ejdys, 2014). The results of the literature review on the relationship between learning orientation and innovation are presented in Tab. 5.

The conducted literature review confirmed that learning orientation is crucial factor for innovation and performance. The existing positive relationship between learning orientation and the innovation of the companies were proved.

Research on the relationship between learning orientation and innovation concern many sectors of both the productive and services sectors. As claimed by Ortenblad, all types of organisation can and should become learning organisations (Ortenblad, 2013), which means that they should be learning-oriented organisations.

Considering the need for the required changes of both the quantitative and qualitative nature in the care sector for the older people, the research on learning orientation seems to be justified.

2. Methodology of the research

2.1. Data

The data used to test the hypothesis was gathered from 169 nursing homes in Poland. The questionnaire was sent to a total number of 804 nursing homes in Poland. The rate of return was at the level of 21%. The surveyed nursing homes with a total number of 16958 beds, represent 21.1% of all available beds in nursing homes in Poland (78793).

All nursing homes offer living and nursing services to their residents. Among all 169 surveyed units, 1.2 per cent were micro companies (1–9 employees), 38.5 per cent — small sized companies (10–49 workers), and 58.0 per cent — medium firms (50–249 workers) and 2.4 per cent were big enterprises (more than 250 workers) (Tab. 6).

According to the type of geographic market, surveyed residential care was represented in 13.6 per

Tab. 6. Profile of the nursing homes by the number of workers

Company size	Frequency	Percentage
1–9 workers	2	1.2
10–49 workers	65	38.5
50–249 workers	98	58.0
>250 workers	4	2.4
Total	169	100.0

cent of municipal units, 54.4 per cent of district units and 32.0 per cent of regional units (Tab. 7).

Tab. 7. Profile of the nursing homes by geographic market

Territorial extent	Frequency	Percentage
Local (municipal)	23	13.6
District (poviat)	92	54.4
Province	54	32.0
Total	169	100.0

2.2. Measures

In this study, the survey method was used to collect data. The questionnaire, conducted based on confidentiality, was distributed between January 2015 and May 2015. All constructs were measured using a seven-point Likert scale to access the degree, to which the respondents agreed or disagreed with each of the items (1=totally disagree to 7=totally agree) (Ejdys, 2014; Ejdys, 2017).

Due to the fact, that the examined constructs ("learning orientation" and "innovativeness") are

Tab. 8. Constructs and measurement items

Item description	
Commitment to learning	
C1	The basic values of this organisation include learning as a key to improvement
C2	The sense around here is that residential care employee learning is an investment, not an expense
C3	Learning in my organisation is seen as a key commodity necessary to guarantee organisational survival
Shared vision	
V1	There is a commonality of goals in our organisation
V2	All employees of residential care are committed to the goals of this organisation
V3	Employees view themselves as partners in charting the direction of the organisation
Open-mindedness	
O1	We are not afraid to reflect critically on the shared assumptions we have made about our customers
O2	Cooperation with the R&D sector and the higher education are the basic source of knowledge about new solutions, methods and technologies
O3	Personnel in this enterprise realises that the very way they perceive the marketplace must be continually questioned
O4	The organisation interprets information received from residents without any negative attitude
O5	We continually judge the quality of our decisions and activities taken over time
O6	Management appreciates and rewards new ideas offered by employees
Intra-organisational knowledge sharing	
IKS1	There is a good deal of organisational conversation that keeps alive the lessons learned from history
IKS2	We always analyse unsuccessful organisational endeavours from the past and communicate them widely
IKS3	We have specific mechanisms for sharing lessons learned from organisational activities among departments (units, teams)
IKS4	Top management repeatedly emphasises the importance of knowledge sharing in our company
IKS5	We put little effort in sharing lessons and experiences
Organisational innovativeness	
I1	Organisation is characterised by a higher level of innovation than other residential care
I2	Organisation is characterised by a higher level of quality delivered services than other foreign residential care
I3	Organisation is characterised by the rapid process of innovation implementation
I4	Members of the organisation are encouraged to think and behave in an original and innovative
I5	New technologies determine the competitive advantage of our organisation
I6	External environment is the main source of technological innovation
I7	The organisation cooperates very closely with other stakeholders (medical sector, research institutions) in research and development of new solutions
I8	The development of new technology in the residential care unit is relatively faster than in other units

Source: elaborated by the author based on (Calantone et al., 2002; Kaya & Patton, 2011; Li et al., 2010; Narver & Slater, 1990; Nasution et al., 2011; Wang, 2008).

Tab. 9. Cronbach's alpha, means and standard deviations

Constructs	Alpha	Mean	Standard deviation
Commitment to learning (C)	0.825	5.63	1.06
Shared vision (V)	0.858	5.71	0.97
Open-mindedness (O)	0.806	5.47	0.88
Intra-organisational knowledge sharing (IKS)	0.868	5.49	0.96
Organisational innovativeness (I)	0.914	4.25	1.11

latent variables, the need emerged to adopt direct measures. Based on the literature review (Calantone et al., 2002; Kaya & Patton, 2011; Li et al., 2010; Narver & Slater, 1990; Nasution et al., 2011; Wang, 2008), the author adopted 17 items measuring learning orientation and 8 items measuring innovativeness (Tab. 8).

The Cronbach's alpha coefficients of the constructs (ranging from 0.806 to 0.14) were used (Tab. 9). The author used the average score of measures of each construct for further analysis.

3. Analysis and results

Among the analysed characteristics (constructs) concerning the measurement of learning orientation, the ones that were rated most highly were the elements connected with shared vision (5.71) and commitment to learning (5.63). The relatively low-rating was given to open-mindedness (5.47) and intra-organisational knowledge sharing (5.49) (Fig. 2).

The obtained results indicate that in the examined sector for the care of the older people, elements indicating the commitment to learning were evaluated relatively highly. This is due to the specific nature of the sector, in which a significant part of the workforce are people with medical training (nurses) or persons who formerly worked in the medical sector (orderlies, midwives and nurses). The older people get gradually educated by participating in various training courses, specialised courses or postgraduate programs. The research has shown that such organisations shape their organisational culture, which is favourable to learning of individual members. Similarly, the element of a shared vision has been assessed at a high level, pointing to the fact that in the surveyed organisations, the employee participation in the shaping of the future development direction is important and employees are actively involved in the setting of strategic objectives of the organisation.

Significantly lower scores of opened mindedness confirm the need to improve openness to change and rewarding of new ideas and solutions. At the same time, more attention must be given to communication with residents who are a source of knowledge about possible improvements, weaknesses or corrections. Residents are usually mentally fit but have physical disabilities. They are keen observers and the "reviewers" of the conditions at the facility. The feature of openness is also frequently associated with the culture of tolerance for mistakes and learning from mistakes. However, the sector of care for

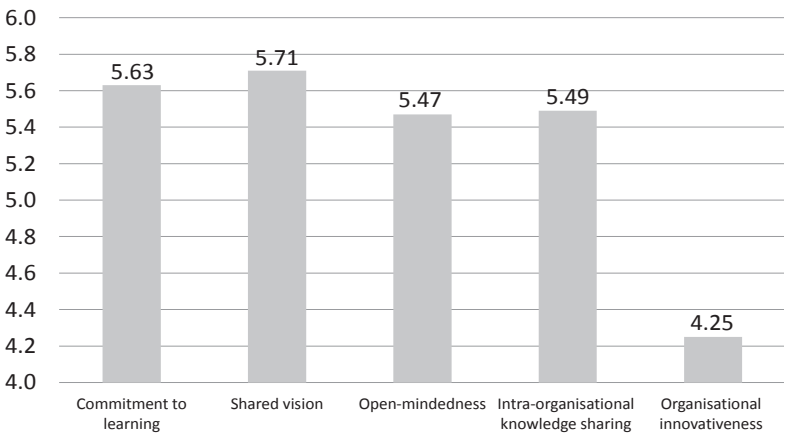

Fig. 2. Average rating of learning orientation and innovativeness

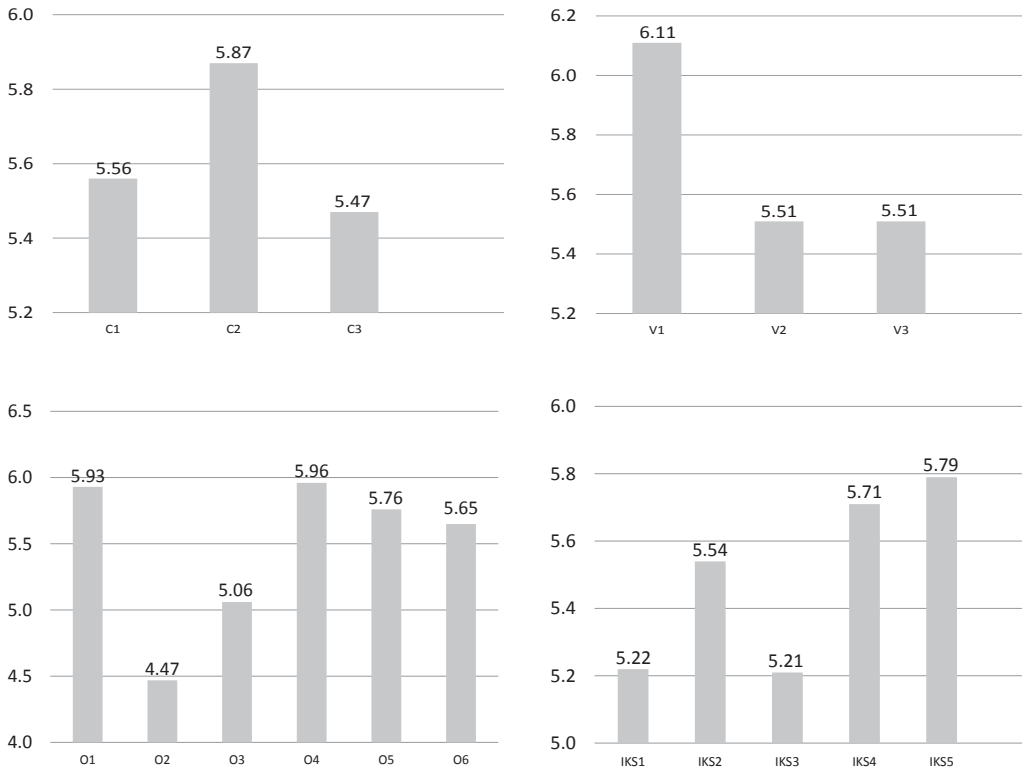

Fig. 3. Average rating of learning orientation items

the elderly must be careful with this type of policy, especially when it comes to taking care of people as even a small mistake can result in irreversible consequences.

The relatively low score obtained for intra-organisational knowledge sharing, indicates the need to develop mechanisms related to sharing knowledge and experience within the organisation. It is advisable to build interdisciplinary teams which would jointly solve the emerging problems, often of socio-psychological nature.

Fig. 3 presents the obtained mean scores of evaluations for individual characteristics (items) within the constructs of learning orientation.

The commitment to learning had relatively the lowest evaluation result, indicating the fact that the learning processes guarantee the survival of an organisation (C3). This result can be explained by the surplus of demand over supply of care services for the older people. Still, the annual number of people waiting for placement in a nursing home is twice as high as the number of vacancies. However, in a longer term, it should be expected that this factor will become even more important together with the increasing expectations and requirements of customers.

The analysis of the shared vision (V) construct shows that while common organisation goals are highly valued in the surveyed organisations, the involvement of employees in the development of common goals (V2) and the setting of strategic development directions (V3) have a distinctly lower score.

Within the construct of open-mindedness, the surveyed units gave a relatively low score to the cooperation with the R&D sector and universities as a source of new approaches, methods and technologies (O2). Unfortunately, the conducted study does not indicate the cause of the result as it remains unknown whether the surveyed units did not cooperate with the R&D sector at all or the cooperation with unsatisfactory.

Within the construct of intra-organisational knowledge sharing, the surveyed units gave the lowest score to the practice allowing for learning from the past (IKS1) and having specific mechanisms for knowledge sharing between the cells or units (IKS3).

Tab. 10 shows a significant correlation between the learning orientation constructs. Analysing the existing correlations between the constructs of learning orientation and organisational innovativeness, we

Tab. 10. Correlation matrix

	Commitment to learning (C)	Shared vision (V)	Open-mindedness (O)	Intra-organisational knowledge sharing (IKS)	Organisational innovativeness (I)
Commitment to learning (C)	1.000				
Shared vision (V)	0.596**	1.000			
Open-mindedness (O)	0.695**	0.698**	1.000		
Intra-organisational knowledge sharing (IKS)	0.644**	0.652**	0.768**	1.000	
Organisational innovativeness (I)	0.363**	0.420**	0.568**	0.442**	1.000

** Correlation is significant at the level of 0.01 (bilaterally).

Tab. 11. Results of Multiple Regression Analysis

	Unstandardised coefficient		Standardised coefficient	t-value	p-value
	B	Standard error	Beta		
Fixed	0.315	0.481		0.656	0.513
Commitment to learning (C)	-0.082	0.097	-0.078	-0.838	0.403
Shared vision (V)	0.066	0.107	0.057	0.611	0.542
Open-mindedness (O)	0.712	0.146	0.567	4.896	0.000
Intra-organisational knowledge sharing (IKS)	0.022	0.122	0.019	0.184	0.854
F	19.898				
p	0.000				

Dependent variable: organisational innovativeness (I)
Predictors: SE – staff engagement

can see that the strongest influence is exerted by the open-mindedness construct (0.568).

Tab. 11 reports the results of the follow-up regression analysis, in particular, the beta coefficients for the parameters. In the regression model, which analyses the simultaneous effect of four constructs of learning orientation on variable organisational innovativeness, only the relation between opened mindedness (O) and organisational innovativeness (I) is statistically significant ($p<0.05$).

Conclusions

The study aimed to examine relationships between four construct of learning orientation: commitment to learning, shared vision, open-mindedness, intra-organisational knowledge sharing and organisational innovativeness of nursing homes in Poland. Regression model confirmed the existing statistically significant positive relationship between open-mindedness and organisational innovativeness.

Understanding the term open-mindedness within the context of old age residential care, services cannot be limited to the features assigned to employees. Residents must also be the source of this openness (open-mindedness). It is inextricably linked to the principle of customer orientation as being aware of their needs and expectations, residents should be able to articulate them, while social care home managers should strive to satisfy them. In the context of improving the innovation of the services provided by nursing houses for older people, it is necessary to develop the cooperation with R&D centres and universities as a source of innovative solutions of procedural, marketing, and productive (service) nature.

The specificity of the analysed care sector for the older people requires a different approach to

organisational learning processes. Certain solutions, such as those related to creating a culture of learning from mistakes, are not acceptable as even a small mistake can lead to serious consequences.

In addition, the complex issue of care for the older people enforces a broadly defined interdisciplinarity regarding methods, tools and innovative solutions, competencies and qualifications of personnel and learning processes.

In the context of future research on the care sector for the older people, further detailed analyses could be made on methods, tools, and assessment of the involvement of residents in the process of organisational learning to improve the quality and innovation of services. Identification of good practice in this field and its further popularisation could become an important element in the dissemination of knowledge about the processes of organisational learning.

Literature

Alas, R., Zernand-Vilson, M., & Vadi, M. (2012). Management techniques in Estonian organizations: learning organization and business process reengineering. *World Conference on Business, Economics and Management*, *62*, 494-498. doi:10.1016/j.sbspro.2012.09.080

Argyris, C., & Schön, D. A. (1978). *Organisational Learning: A Theory of Action Perspective*. New York, USA: Addison-Wesley.

Begona Lloria, M., & Moreno-Luzon, M. D. (2014). Organizational learning: Proposal of an integrative scale and research instrument. *Journal of Business Research*, *67*(5), 692-697. doi:10.1016/j.jbusres.2013.11.029

Bloom, D. E., Canning, D., & Fink, G. (2011). Implications of Population Aging for Economic Growth. *NBER Working Paper Series*. Retrieved from http://www.nber.org/papers/w16705.pdf

Calantone, R. J., Cavusgil, S. T., & Zhao, Y. S. (2002). Learning orientation, firm innovation capability, and firm performance. *Industrial Marketing Management*, *31*(6), 515-524. doi:10.1016/S0019-8501(01)00203-6

Capitman, J., & Bishop, C. (2005). *Long-term Care Quality: Historical Overview and Current Initiatives*. Retrieved from http://www.newschool.edu/ltcc/pdf/txBackground03-10-05FINAL.pdf

Central Statistical Office. (2016). *Demographic yearbook of Poland*. Retrieved from http://stat.gov.pl/en/topics/statistical-yearbooks/statistical-yearbooks/demographic-yearbook-of-poland-2016,3,10.html

Central Statistical Office. (2017). *Population projection by biological age groups* (*in thousands*). Retrieved from http://demografia.stat.gov.pl/bazademografia/Prognoza.aspx

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive-Capacity - A New Perspective on Learning And Innovation. *Administrative Science Quarterly*, *35*(1), 128-152. doi: 10.2307/2393553

Easterby-Smith, M. (1997). Disciplines of organizational learning: contributions and critiques. *Human Relations*, *50*(9), 1085-1113. doi: 10.1177/001872679705000903

Ejdys, J. (2014). Strategic orientation of small and medium size enterprises. *Economics and Management*, *19*(4), 346-358. doi: 10.5755/j01.em.19.4.8098

Ejdys, J. (2015). Innovativeness of residential care services in Poland in the context of strategic orientation. *Procedia - Social and Behavioral Sciences*, *213*, 746-752. doi: 10.1016/j.sbspro.2015.11.461

Ejdys, J. (2017). The Role of Internal Stakeholders in the Process of Creation Social Responsible Long-Term Care System in Poland. In M. H. Bilgin, H. Danis, E. Demir, U. Can (Eds.), *Country Experiences in Economic Development*, *Management and Entrepreneurship* (pp. 733-744). Cham, Switzerland: Springer.

European Union. (2013). *Europe's Societal Challenges An analysis of global societal trends to 2030 and their impact on the EU*. Retrieved from www.rand.org

Garvin, D. A. (1993). Building a Learning Organization. *Harvard Business Review*, *71*(4), 78-91. Retrieved from http://www.hbs.edu/faculty/Pages/item.aspx?num=3583

Halicka, K. (2016). *Prospektywna analiza technologii. Metodologia i procedury badawcze* [*Prospective technology analysis. Methodology and research methods*]. Białystok. Poland: Oficyna Wydawnicza Politechniki Białostockiej.

Hu, B. (2014). Linking business models with technological innovation performance through organizational learning. *European Management Journal*, *32*(4), 587-595. doi:10.1016/j.emj.2013.10.009

Kautsch, M., Lichoń, M., Matuszak, N., Erskine, J., & Whitfield, M. (2017). Are there just barriers? Institutional perspective on the development of e-health in Poland. *Engineering Management in Production and Services*, *9*(2), 64-72.

Kaya, N., & Patton, J. (2011). The effects of knowledge-based resources, market orientation and learning orientation on innovation performance: an empirical study of Turkish firms. *Journal of International Development*, *23*(2), 204-219. doi: 10.1002/jid.1662

Laukkanen, T., Nagy, G., Hirvonen, S., Reijonen, H., & Pasanen, M. (2013). The effect of strategic orientations on business performance in SMEs A multigroup analysis comparing Hungary and Finland. *International Marketing Review*, *30*(6), 510-535. doi: 10.1108/IMR-09-2011-0230

Li, Y., Guo, H., Yi, Y., & Liu, Y. (2010). Ownership Concentration and Product Innovation in Chinese Firms: The Mediating Role of Learning Orientation. *Management and Organization Review*, *6*(1), 77-100. doi: 10.1111/j.1740-8784.2009.00162.x

Liu, S. S., Luo, X. M., & Shi, Y. Z. (2002). Integrating customer orientation, corporate entrepreneurship, and learning orientation in organizations-in-transition: an empirical study. *International Journal of Research in Marketing*, *19*(4), 367-382. doi:10.1016/S0167-8116(02)00098-8

Narver, J. C., & Slater, S. F. (1990). The Effect of a Market Ortentatton on Business Profrtabitity. *Journal of Marketing*, *54*, 20-35. Retrieved from http://bear.warrington.ufl.edu/weitz/mar7786/Articles/narver%20and%20slatter.pdf

Nasution, H. N., Mavondo, F. T., Matanda, M. J., & Ndubisi, N. O. (2011). Entrepreneurship: Its relationship with market orientation and learning orientation and as antecedents to innovation and customer value. *Industrial Marketing Management*, *40*(3), 336-345. doi:10.1016/j.indmarman.2010.08.002

Nazarko, J., & Kononiuk, A. (2013). The critical analysis of scenario construction in the Polish foresight initiatives. *Technological and Economic Development of Economy*, *19*(3), 510-532.

Nazarko, J. (2011). Kształtowanie polityki proinnowacyjnej regionu np. Forsightu technologicznego NT FOR Podlaskie 2020. *Optimum – Studia Ekonomiczne*, *2*, 241-251.

Nevis, E. C., Dibella, A. J., & Gould, J. M. (1995). Understanding Organizations as Learning-Systems. *Sloan Management Review*, *36*(2), 73-85. Retrieved from http://sloanreview.mit.edu/article/understanding-organizations-as-learning-systems

Öneren, M. (2008). The approach of learning organisation in companies. *Zonguldak Karaelmas University Journal of Social Sciences*, *7*(4), 163-178.

Organisation for Economic Co-operation and Development. (2008). *Conceptual framework and definition of long-term care expenditure. Revision of the System of Health Accounts*. Paris, France: OECD Publishing. Retrieved from http://www.oecd.org/els/health-systems/Conceptual%20Framework%20and%20Methods%20for%20Analysis%20of%20Data%20Sources%20for%20Long-Term%20Care%20Expenditure.pdf

Organisation for Economic Co-operation and Development. (2013). *A good Life in Old Age? Monitoring and Improving Quality in Long-Term Care*. Paris, France: OECD Publishing. doi:10.1787/9789264194564-en

Ortenblad, A. (2001). On differences between organizational learning and learning organization. *The Learning Organization*, *8*(3), 125-133. doi: 10.1108/09696470110391211

Ortenblad, A. (2002). A typology of the idea of learning organization. *Management Learning*, *33*(2), 213-230. doi: 10.1177/1350507602332004

Ortenblad, A. (Ed.). (2013). *Handbook of Research on the Learning Organization. Adaptation and Context*. Cheltenham, England, & Northampton, USA: Edward Elgar.

Senge, P. M. (2006). *The fifth discipline: the art and practice of the learning organization*. New York, USA: Currency Doubleday.

Sinkula, J. M., Baker, W. E., & Noordewier, T. (1997). A framework for market-based organizational learning: Linking values, knowledge, and behavior. *Journal of the Academy of Marketing Science*, *25*(4), 305-318. doi: 10.1177/0092070397254003

Somunoglu, S., Erdem, E., & Erdem, U. (2012). A Study on Determining the Perception of Learning Organisation Applications by Health Sector Workers. *Journal of Medical Systems*, *36*(6), 3925-3931. doi: 10.1007/s10916-012-9864-9

Sheng, M. L., & Chien, I. (2016). Rethinking organizational learning orientation on radical and incremental innovation in high-tech firms. *Journal of Business Research*, *69*, 2302-2308.

Tajeddini, K. (2016). Analyzing the influence of learning orientation and innovativeness on performance of public organizations: The case of Iran. *Journal of Management Development*, *35*(2), 134-153.

United Nations. (2017). *World Population Prospects. The 2017 Revision. Key Findings and Advance Tables*. New York, USA: United Nations. Retrieved from http://esa.un.org/unpd/wpp

Vera, D., & Crossan, M. (2004). Strategic leadership and organizational learning. *Academy of Management Review*, *29*(2), 222-240. Retrieved from http://www.jstor.org/stable/20159030

Wang, C. L. (2008). Entrepreneurial orientation, learning orientation, and firm performance. *Entrepreneurship Theory and Practice*, *32*(4), 635-657. doi.org/10.1111/j.1540-6520.2008.00246.x

Volume 9 • Issue 3 • 2017

DE GRUYTER OPEN

ISMSME International Society for Manufacturing, Service and Management Engineering

received: 5 January 2017
accepted: 30 June 2017

pages: 28-36

Prerequisites for the modelling of empty container supply chains

Katarzyna Anna Kuźmicz, Erwin Pesch

ABSTRACT

Containerisation of freight transport significantly facilitates the flow of traded goods between remote destinations. The most important container transport routes link Asia with North America and Europe. The seasonality and imbalance of trade are the main factors giving rise to problems related to empty container repositioning. The aim of this paper is to develop a concept of empty container supply chains and formulate prerequisites for its modelling in the search for the optimal solution with the help of linear programming and mixed integer programming methods. This paper indicates causes of the empty container relocation problem based on the literature analysis with a special focus on the Eurasian transportation route. Also, it provides a concept of empty container supply chain, prerequisites for its modelling and examples of container supply chains modelling presented in the literature. The main results of the paper include conceptualisation of an empty container supply chain and suggested modelling prerequisites. The paper contributes to research in the field of supply chain management and optimisation of transportation.

KEY WORDS

container transportation, supply chains, modelling, optimisation methods

DOI: 10.1515/emj-2017-0023

Corresponding author:

Katarzyna Anna Kuźmicz

Bialystok University of Technology,
Faculty of Management,
International China and Central-Eastern Europe Institute of Logistics and Service Science, Poland
e-mail: k.kuzmicz@pb.edu.pl

Erwin Pesch

University of Siegen, Faculty III: School of Economic Disciplines, Management Information Science, Centre for Advanced Studies in Management, HHL Leipzig Graduate School of Management, Germany
e-mail: erwin.pesch@uni.siegen.de

Introduction

Containerisation was a breakthrough solution in cargo transportation and had an undisputable influence on global supply chains. However, it is not that freight is moving faster along the respective modes servicing supply chains, but that the cargo handling efficiency at container terminals, where usually the transport mode is changed, has significantly increased the velocity of transhipments and, consequently, of supply chains (Notteboom & Rodrigue, 2008). Containerisation enabled the expansion to global markets by improving the reliability and flexibility as well as reducing costs of freight distribution.

According to Boysen et al. (2013), a container is a cargo-containing box that can be separated from

Tab. 1. Top trade routes (TEU shipped) in 2013

Route	West Bound	East Bound	North Bound	South Bound	Total
Asia – North America	7 739 000	15 386 000			23 125 00
Asia – North Europe	9 187 000	4 519 000			13 706 000
Asia – Mediterranean	4 678 000	2 061 000			6 739 000
Asia – Middle East	3 700 000	1 314 000			5 014 000
North Europe – North America	2 636 000	2 074 000			4 710 000
Australia – Far East*			1 072 016	1 851 263	2 923 279
Asia – East Coast South America			621 000	1 510 000	2 131 000
North Europe/Mediterranean – East Coast South America			795 000	885 000	1 680 000
North America – East Coast South America			656 000	650 000	1 306 000

* Data from 2012

Source: (Drewry Container Forecaster, 2013; World Shipping Council, 2017).

a wagon and to continue transportation by another means, i.e. using a different mode (such as ship or truck). Standardised containers facilitate transportation and higher flows of cargo (Rodrigue, 2013). Among twelve standard containers, Twenty-foot Equivalent Unit (TEU) and Forty-foot Equivalent Unit (FEU) are the two basic standard sizes. 40-foot containers dominate international, especially on long-haul routes, such as from China to Europe.

Container transportation comprises most of the global transportation. According to Drewry Maritime Research, the global container fleet accounted for about 32.9 million TEU in 2012 (World Shipping Council, 2017). Most of this fleet comprises dry containers (standard and special) making up about 89% of the fleet. Insulated reefer containers and tanks together add up to 7% of the fleet. Reefers require specific temperature for transportation of goods and amount to approximately 6.25% of the global fleet. Tank containers used for transport of liquids comprise about 0.75% of the global fleet. According to the data of Drewry Maritime Research, in 2012, the dry container fleet was approximately 29.3 million TEU, reefer containers — 2.1 million TEU, and tank containers — about a quarter million TEU of the total fleet. It is estimated that an average annual growth of containers amounts to 1.6 million TEU.

A trade route refers to a trade between an origin group of countries and a destination group of countries (World Shipping Council, 2017). The top global trade routes described in TEU shipped are presented in Tab. 1.

The substantial differences in TEUs shipped in one direction in comparison to the other direction indicate the scale of the empty container relocation problem.

According to the ranking of the ten biggest container exporters in the World (World Trade Service, 2017), China is the leader of containerised cargo export as in the years 2010, 2013, and 2014 it exported 31.3 — 36 million TEU, respectively). Considering import, China takes the second place after the USA. Therefore, studies of container transportation have to be made through the prism of the trade routes and transport corridors China – USA and China – Europe.

Container transportation became a vibrant field for scientific research of the strategic, tactical and operational problems of management. It embraces management of maritime transportation (Lee & Song, 2017) as well as intermodal transportation (Meers et al., 2017). Most of the studies focus on shipping routing and network analysis (Song & Dong, 2013), shipping competition, alliances and resource sharing agreements (Xie, 2017) as well as management with environmental issues (Obrecht & Knez, 2017; Tao et al., 2017). One of the significant research fields is empty container repositioning which is analysed together with routing problems, inventory control, location problems, network planning container leasing prices, etc. (Braekers et al., 2011; Zheng et al., 2017). On the basis of the literature analysis it can be stated that approaching the empty container problem with the assumption that they have their own supply chain which can be modelled in search for optimality is an interesting research problem.

1. The cause of the empty-container problem

Substantial offshoring of manufacturing activities to Asia and China significantly increased the global container transportation during the latest years (Fransoo at al., 2013). The high imbalance of trade exchange between the countries results in the surplus of empty containers that need to be returned to the owner or moved for further demand. Since China exports much more than imports, its trade imbalance reached almost EUR 200 billion in 2015 (European Commission, 2017). A substantial container surplus is stocked in ports of USA and Europe waiting to be filled and sent further. Notteboom and Rodrigue (2007) indicate that the reason for the empty-container problem is not only trade imbalance but also repositioning costs, container manufacturing, and leasing costs as well as customer preferences for use. All these reasons make empty container repositioning a very complex and topical problem.

The rising demand for container transportation triggers the search for new possibilities and new corridors. Taking trade routes between Asia and Europe as an example, a dynamic growth of infrastructure development can be observed in the route China – Europe. It is a part of a Chinese policy embodied in One Belt One Road (OBOR) concept comprising maritime (one Road) and rail or intermodal (One Belt) transportation. In Europe, this concept is most often referred to as the New Silk Road (NSR). There are three main alternative corridors along the NSR (Sahbah, 2014; Nazarko & Kuzmicz, 2017; Ejdys, 2017) but the Northern Corridor starting with the Russian Trans-Siberian Railway line, then going through Russia, Belarus and Poland. The latter is often referred to by the Chinese as a gate to Europe seems to be most viable. The initiative is financially supported by the Asian Infrastructure Investment Bank and the Silk Road Fund (since 2014). The development of the OBOR concept mostly concentrates on the land part based on railway transport. The advantage of the route is less time needed for transportation in comparison to that using a maritime route, but it is still significantly more expensive than shipping. It is perceived as a middle option between fast and expensive air transportation and cheap but time-consuming shipping.

Rail connections between China and Europe are rapidly developing and they are strongly supported by the central and local authorities of China. The intensity of efforts made by China and countries aspiring to take part in OBOR initiative allows predicting a substantial growth in intermodal transportation which will significantly affect full and empty container supply chains.

2. The concept of the empty-container supply chain

Supply chain management includes decision making about facility location, production, transportation and inventory control (Pirim, Al-Turki & Yilbas, 2014). Rodrigue et al. (2013) refer to supply chains as commodity chains that functionally integrate a network of production, trade and service activities from the transformation of raw materials through manufacturing stages to delivering of a finished good to the market. It is conceptualised as a series of nodes linked by different transactions including sales and intra-company transfers aiming for added value. Transportation is no longer treated separately from supply chains. Its development significantly influences global supply chains by expanding the territorial range of supply chains. Significant technical development and especially that of intermodal transportation influences the continuity of transportation and supply chains (Rodrigue, 2013).

Containers hold cargo to be shipped and can be treated as a subject of supply chains (Fransoo, 2013; Willis & Ortiz, 2004). Fig. 1 presents the supply chain concept showing the dual role of containers. It can be assumed that empty containers have their own supply chain which covers containers, container terminals and means of transport, such as trucks, trains or ships (Zain et al., 2014).

Song and Dong (2015) describe container transportation chains (Fig. 2). They consider exporters who require empty containers and shipping companies who provide them to customers. Cargoes are packed into containers at a depot or port and are then transported to another depot or port to wait for vessels. Later, laden containers are transported through sea corridors or by rail corridors to finally arrive at the port or depot of their destination. Subsequently, they are transported to the importers or to a depot to be unpacked. Empty containers can either be stored in an inland depot or moved to a port depot to wait for future use or repositioning to other ports.

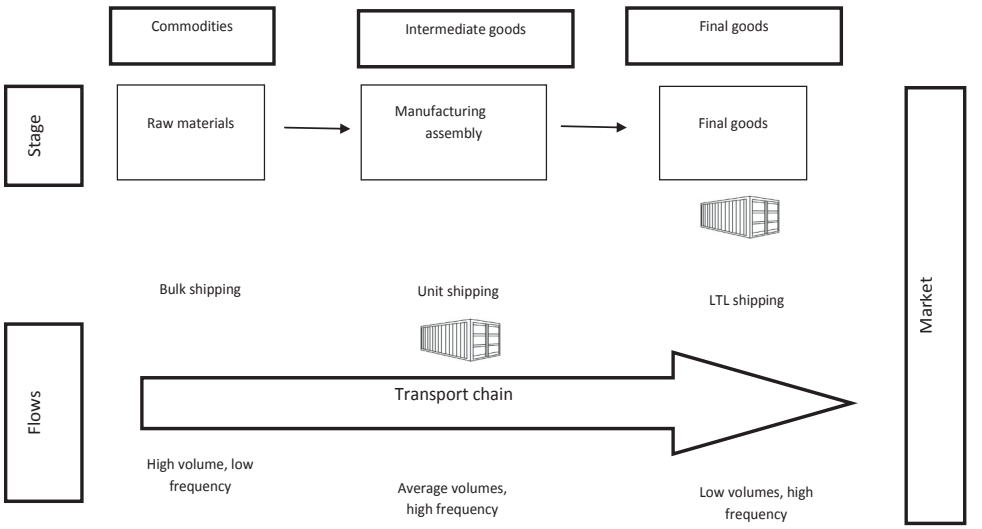

Fig. 1. Containers in the supply chain concept

Source: elaborated by the authors based on (Rodrigue, 2013; Asa, 2017).

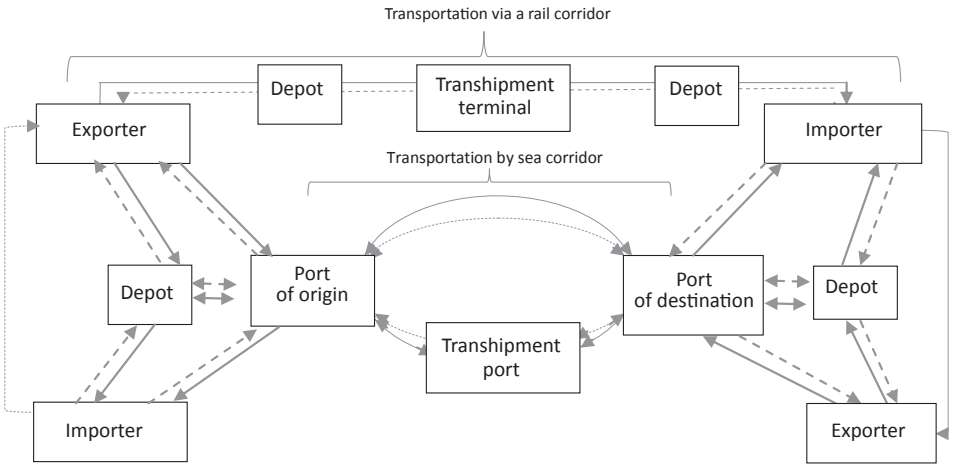

Fig. 2. Container transportation chain

Source: elaborated by the authors based on (Song & Dong, 2015).

Song and Dong make (2015) underline that this transportation chain actually involves two chains, i.e. the one of laden containers and the other of empty ones. These chains are interconnected and use the same infrastructure. Solid lines in the Fig. 2 designate flows of laden containers and dashed-lines represent flows of empty containers.

3. Prerequisites for modelling

Ivanow and Sokolov (2010) indicate three main approaches to supply chain modelling: optimisation, simulation and heuristics. However, a hybrid of these approaches is often applied, joining, for example, simulation and optimisation methods. An extensive survey of these approaches applied in the supply

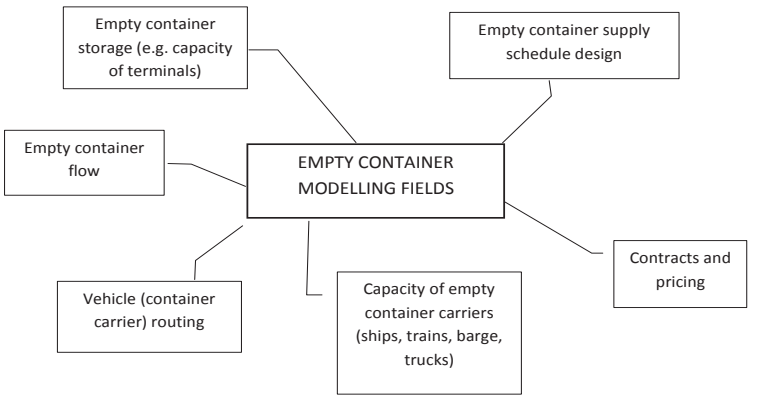

Fig. 3. Empty container modelling fields

Source: elaborated by the authors on the basis of (Breakers et al., 2011; Braekers et al., 2013; Song & Dong 2015; Mittal et al., 2013; Zheng et al., 2016; Chen et al., 2016).

chain domain is presented in Chandra and Grabis (2007). The difficulty in applying optimisation to supply chains lies in the development of a model that would represent the complexity and uncertainty of the supply chain with satisfying accuracy and would still be relatively simple to solve (Harrison, 2005).

Empty-container repositioning is modelled in the literature as a location problem (Mittal et al., 2013), routing problem (Braekers et al., 2013a), routing and assignment problem (Nossack & Pesch, 2013), inventory control problems (Dang et al., 2012) or cargo flow optimisation problem (Song & Dong, 2012). The focus of location problems is the inland depot localisation. Fig. 3 indicates different fields of empty-container modelling. They cover empty container supply schedule design, contracts and pricing, the capacity of empty container carriers such as ships, trains, barge and trucks, vehicle routing as a means of container transportation, empty container flow and storage of empty containers including the capacity of terminals.

Supply chains can be modelled as a network design. It can also be referred to as network modelling because it involves the development of a mathematical model of the supply chain (Watson et al., 2014). This model is then solved with optimisation methods. Watson et al. (2014) divide supply chain modelling into modelling to determine the optimal location of facilities (warehouses, plants or suppliers) and the best flow of products through the network structure of this facility.

To formulate a supply chain network model, the following elements are required: an objective function, constraints, decision variables and data. The methodology includes the formulation of the mathematical model and verification of a model by solving a representative set of instances with linear or integer programming methods, or mixed integer programming methods (Fig. 4).

The objective is the goal of the optimisation and the criteria that are used to compare different solutions. It must be quantifiable. In the case of empty-container repositioning, the key criterion is cost minimisation. It can minimise costs related to transportation, container rental, delays in delivery of empty containers, etc.

The constraints define the rules for feasible solutions. These are a set of constraints that narrow down the solution space. In empty-containers supply chains, they can restrict the capacity of container depots, define time windows for delivery or restrict the means of empty-container transportation distances in case of transportation or location problems.

In the model of the empty-containers supply chain, the main decision variables can include, for

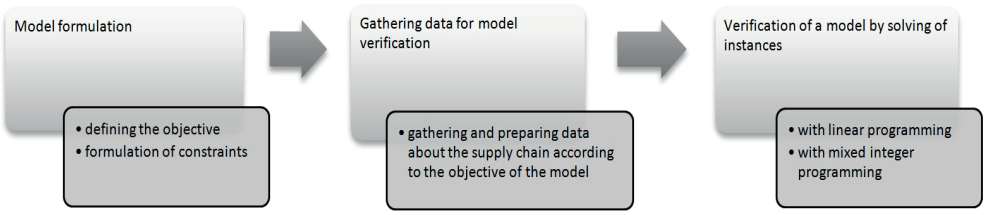

Fig. 4. Methodology of the supply chain modelling with optimisation methods

instance, the number of containers that should be transported from an importer to an exporter, or from a depot to an exporter; or the number or the location of container depots that should be used. These decision variables must meet the restrictions formulated as constraints.

The model should be then tested using real data, see Kendall et al. (2016). The availability of data is often problematic and, therefore, the model can be tested by running multiple scenarios, considering approximate data, or adjusting the available data (Watson et al., 2014).

Extensive literature is available on the topic of empty-container repositioning. For review, consider Braekers et al. (2011). To illustrate approaches to supply chain modelling, a few examples are given.

A study by Almeder et al. (2009) is an example of applying a mixed integer programming in the context of a discrete-event simulation for a supply chain. The study considers a supply chain network model with different facilities and modes of transport connecting these facilities with a central planner. The objective is to reduce costs by optimising the production/transportation schedule and reducing inventory levels by considering the stochastic environment. They aim at optimal operation plans for supply chain networks using a combination of optimisation with simulation in an iterative form. The study also investigated the influence of contingency time for delays on the quality of the solution.

Sanei et al. (2016) developed a two-stage supply chain network model for a single product system under uncertainty conditions. In the objective function, the total transportation cost of the supply chain network is minimised. Constraints comprise capacities, demand, satisfaction and product flow conservation. Variable cost, fixed charge, supply and demand parameters are in interval forms. Solutions of the instances of the problem are obtained by CPLEX.

A location-inventory problem in modelling supply chains is extensively addressed by Farahani et al. (2015). They provide an in-depth review investigation of the location-inventory models. Four primary types of these models are presented, i.e. is the basic location-inventory problem, dynamic-location-inventory problem, location-inventory-routing problem and inventory-transportation. Most of the mathematical formulations of the models involve binary or integer variables and are simplified by an infinite time horizon, and a continuous review as the predominant inventory policy with a rarely applied periodic review. They indicate that papers published after 2011 usually reflect real-life conditions in the models such as finite storage and transportation capacity, routing and transportation costs, finite time horizons and secondary objectives including service level and stochastic demand data.

Alharbi et al. (2015) studied schedule design for sustainable container supply chain networks with port time windows. Time windows refer to the time in a week when berths in the ports provide services to the ships. This consideration is an added value of this paper. Schedule decisions are made by liner companies every three to six months. The aim of the study is to minimise the sum of costs (ship costs and fuel costs) ensuring that ports can service the ships on the planned days. Considering port berth services makes this model easily applicable in real-life conditions. In the objective function ship costs, bunker costs and penalty costs are minimised. The sets of constraints include the elimination of asymmetric solutions, ship speed, sailing time, different time components on a round-trip journey, time restrictions on arrivals at ports, and those referring to the availability of berths. The model is a mixed integer nonlinear non-convex model reformulated as an integer linear optimisation model with an iterative approach.

Conclusions

The study indicates the expected rise in container transportation resulting from the intense development of transportation corridors within the New Silk Road initiative. In this context, the significance of empty-container relocation connected with great trade imbalance between China and Europe is stressed and denoted as a field of interest for scientific research. An empty-container supply chain is conceptualised, and introductory premises of its modelling are presented. Different fields of modelling in the domain of empty containers are indicated showing how many aspects of this problem need optimisation. Later, some hints for modelling are suggested together with several examples of the modelling application in supply chains.

A further study will include an investigation of empty-container supply chains and a more detailed elaboration of its concept. Applying game theory to find solutions that satisfy different actors of the empty-container supply chain seems to be

an interesting topic for future research, cf. Kovalyov, & Pesch (2014). The service provider, i.e. the container transporting company, might be interested in selling their transport places best possible and additionally to satisfy their clients (producers of goods that are supposed to be shipped). As soon as a client's products are ready to be shipped the shipping company is interested to reach the most promising positions in a waiting queue of containers competing for the rare transport positions. The client has an incentive to pay a limited amount for reaching an earlier shipping position in the queue as a compensation to those clients that consequently would suffer from a delayed transport. However as long as the compensation of clients whose transport is postponed covers their additional costs resulting from the delay, they might accept that competitors reach better service positions earlier in the queue. Reaching an earlier service position might lure a client to promise a payment that is higher than the savings gained for the better position. On the other hand, a client whose service is delayed might claim a compensation that is much higher than the shipping company's real cost of the delay. The service provider has an incentive to avoid these resulting instabilities and could try to come up with a mechanism where all clients report the true values. The client receiving a better position would report the true value of her monetary benefit as well as the client moving back in the waiting queue reports the real cost incurred to the service provider. A good mechanism sets incentives to report correct values because lying is risky and would not lead to any competitive advantage for this this mechanism (set of rules). The revenue of the service of the service provider might be independent of the design of the mechanism and is simply a fixed payment, independent of the time interval for shipping. Alternatively the shipping service could be a part of the game. An equilibrium that satisfies all participants of the game so that none of them has an incentive to change their position need not always exit. And even if it exists it might be difficult to find.

In a cooperative game clients might be interested in forming coalitions in order to reduce the shipping costs. Combinatorial auctions would pick the optimal coalitions of jointly bidding clients. A challenging research field could also be dynamic pricing of transportation routes or transportation positions on the vessel or train. Dynamic prices for shipping need not only depend on the attributes linked to the clients and their cargo, as there are the weight, the number of containers, the frequency of shipping, the type of container (foldable if empty, or reefers), the accuracy in delivery (within a specified time interval, etc.) but further heavily depends on the demand within a certain period as well as the demand for specific service (e.g. train, truck, vessel, fast or slow).

Similar questions arise when tucks deliver or pickup containers at the terminal. The service provider and their clients need to agree on time intervals of service to avoid congestions and unnecessary waiting times. Different time intervals may be priced differently in order to equally spread the truck arrivals over the planning horizon.

As storage space at terminals is rare and costly and the number of empty containers that need to be stored might accumulate to a substantial amount, decisions are necessary, where to locate empty container inventory nearby the terminal, in such a way that the delivery costs and access time will be minimal. This additional requires high quality forecasting methods in order to foresee the amount of inbound and outbound empty containers.

One of the major challenges at each sea port is loading and unloading of vessels such the number of reshuffling container moves by berth cranes are small. Reshuffling happens whenever a lower container in a stack is blocked for unloading by containers that need to be removed first to make the lower container in the stack accessible. Reshuffling is a result of poor planning of incoming and outgoing freight between the different ports and also heavily depends on the amount of freight to be unloaded in a port. Closely related is the question of how to stack containers in a vessel and in which order to unload them. If all containers to be unloaded in the next port are stacked on one side of the vessel it is very likely that the vessel will tilt during the loading or unloading procedure. Therefore loading and unloading procedures are required that equally balance the total weight but achieve a fast access to those containers that need to be unloaded next. A high number of empty containers might provide some loading flexibility if the particular container to be accessed is less relevant, but it increases the risk of an unbalanced freight and requires that heavy containers are stored deep down in the vessel.

Acknowledgements

Studies have been carried out within the framework of the grant MB/WZ/2/2016 and funded by the Polish Ministry of Science and Higher Education.

Literature

Alharbi, A., Wang, S., & Davy, P. (2015). Schedule design for sustainable container supply chain networks with time windows. *Advanced Engineering Informatics*, *29*(3), 322-331.

Almeder, Ch., Preusser, M., & Hartl, R. F. (2009). Simulation and optimization of supply chains: alternative or complementary approaches? *OR Spectrum*, *31*(1), 95-119.

Asa, Z. (2017). Shipping container. *Creative Commons*. Retrieved from https://thenounproject.com/term/shipping-container/116963/

Boysen, N., Fliedner, M., Jaehn, F., & Pesch, E. (2013). A survey on container processing in railway yards. *Transportation Science*, *47*(3), 312-329.

Braekers, K., Janssens, G. K., & Caris, A. (2011). Challenges in managing empty container movements at multiple planning levels. *Transport Reviews*, *31*(6), 681-708.

Braekers, K., Janssens G. K., & Caris, A. (2013a). Integrated planning of loaded and empty container movements. *OR Spectrum*, *35*(2), 457-478.

Braekers, K., Janssens G. K., & Caris, A. (2013b). Optimal shipping routes and vessel size for intermodal barge transport with empty container repositioning. *Computers in Industry*, *64*(2), 155-164.

Chandra, C., & Grabis, J. (2007). *Supply chain configuration*. New York, USA: Springer.

Chen, R., Dong, J. X., & Lee, Ch-Y. (2016). Pricing and competition in a shipping market with waste shipments and empty container repositioning. *Transportation Research Part E: Methodological*, *85*, 32-55.

Dang, Q-V., Yun, W-Y., & Kopfer, H. (2012). Positioning empty containers under dependent demand process. *Computers and Industrial Engineering*, *62*(3), 708-715.

Ejdys, J. (2017). New Silk Road – A Weak or a Strong Signal? *Procedia Engineering*, *182*, 182-188.

European Commission. (2017). Countries and Regions. China. *Trade*. Retrieved from http://ec.europa.eu/trade/policy/countries-and-regions/countries/china

Farahani, R. Z., Bajgan, H. R., & Kaviani, M. (2015). Location-inventory problem in supply chains: a modelling review. *International Journal of Production and Research*, *53*(12), 3769-3788.

Fransoo, J. C., & Lee, Ch-Y. (2013). The critical role of ocean container transport in global supply chain performance. *Production and Operations Management*, *22*(2), 253-268.

Harrison, T. P. (2005). Principles for the strategic design of supply chains. In T. P. Harrison, H. L. Lee, J. J. Neale (Eds.), *The practice of supply chain management* (pp. 3-12). New York, USA: Springer.

Ivanow, D., & Sokolov, B. (2010). *Adaptive supply chain management*. London, England: Springer-Verlag.

Kendall, G., Blazewicz, J., Bai, R., de Causemaecker, P., Gendreau, M., John, R., Li, J., McCollum, B., Pesch, E., Qu, R., Sabar, N., Vanden Berghe, G., & Yee, A. (2016). Good laboratory practice for optimization research. *Journal of the Operational Research Society*, *67*(4), 676-689.

Kovalyov, M. Y., & Pesch, E. (2014). A game mechanism for single machine sequencing with zero risk. *Omega – The International Journal of Management Science*, *44*, 104-110.

Lee, Ch-Y., & Song, D-P. (2017). Ocean container transport in global supply chains: Overview and research opportunities. *Transportation Research Part B: Methodological*, *95*, 442-472.

Meers, D., Macharis, C., Vermeiren, T., & van Lier, T. (2017). Modal choice preferences in short-distance hinterland container transport. *Research in Transportation Business & Management*, *23*, 46-53.

Mittal, N., Boile, M., Baveja, A., & Theofanis, S. (2013). Determining optimal inland-empty-container depot locations under stochastic demand. *Research in Transportation Economics*, *42*(1), 50-60.

Nazarko, J., & Kuźmicz, K. A. (2017). Introduction to the STEEPVL analysis of the New Silk Road Initiative. *Proceedia Engineering*, *182*, 497-503.

Nossack, J., & Pesch, E. (2013). Truck scheduling problem in intermodal container transportation. *European Journal of Operational Research*, *230*(3), 666-680.

Notteboom, T., & Rodrigue, J. P. (2007). Re-Assessing Port-Hinterland Relationships in the Context of Global Commodity Chains. In J. Wang, D. Olivier, T. Notteboom, B. Slack (Eds.), *Port, Cities and Global Supply Chains* (pp. 51-68). London, England: Ashgate.

Notteboom, T., & Rodrigue J. P. (2008). Containerisation, box logistics and global supply chains: The integration of ports and liner shipping networks. *Maritime Economics & Logistics*, *10*, 152-174.

Obrecht, M., & Knez, M. (2017). Carbon and resource savings of different cargo container designs. *Journal of Cleaner Production*, *155*(1), 151-156.

Pirim, H., Al-Turki, U., & Yilbas, B. S. (2014). *Supply Chain Management and Optimization in Manufacturing*. Cham, Switzerland: Springer.

Rodrigue, J. P., Comtois, C., & Slack, B. (2013). *The Geography of Transport Systems*. London, England, & New York, USA: Routledge.

Sahbaz, U. (2014). *The Modern Silk Road: One Way or Another?* Bucharest, Romania: The Black Sea Trust for Regional Cooperation.

Sanei, M., Moahmoodirad, A., & Niroomand, S. (2016). Two-stage supply chain network design problem with interval data. *International Journal of e-Navigation and Maritime Economy*, *5*, 74-84.

Song, D. P., & Dong, J. X. (2012). Cargo routing and empty container repositioning in multiple shipping service routes. *Transportation Research Part B: Methodological*, *46*(10), 1556-1575.

Song, D. P., & Dong, J. X. (2013). Long-haul liner service route design with ship deployment and empty container repositioning. *Transportation Research Part B: Methodological*, *55*, 188–211.

Song, D. P., & Dong, J. X. (2015). *Empty container repositioning. Handbook of Ocean Container Transport Logistics*. Cham, Switzerland: Springer.

Watson, M., Lewis, S., Cacioppi, P., & Jayaramann, J. (2014). *Supply chain network design. Applying optimization and analytics to the global supply chain*. New Jersey, USA: Pearson Education.

Willis, H. H., & Ortiz, D. S. (2004). *Evaluating the security of the global containerized supply chain*. Santa Monica, USA: RAND Corporation.

World Shipping Council. (2017). *Global container fleet*. Retrieved from http://www.worldshipping.org/about-the-industry/containers/global-container-fleet

Tao, X., Wu, Q., & Zhu, L. (2017). Mitigation potential of CO2 emissions from modal shift induced by subsidy in hinterland container transport. *Energy Policy*, *101*, 265-273.

Xie, Y., Liang, X., Ma, L., & Yan, H. (2017). Empty container management and coordination in intermodal transport. *European Journal of Operational Research*, *257*(1), 223-232.

Zain, R. M., Rahman, M. N., Nopiah, Z. M., & Saibani, N. (2014). Statistics and Operational Research International Conference (SORIC 2013). *AIP Conference Proceedings*, *1613*, 403-419.

Zheng, J., Sun, Z., & Zhang, F. (2016). Measuring the perceived container leasing prices in liner shipping network design with empty container repositioning. *Transportation Research Part E: Logistics and Transportation Review*, *94*, 123-140.

DE GRUYTER OPEN

ISMSME International Society for Manufacturing, Service and Management Engineering

received: 5 December 2016
accepted: 20 May 2017

pages: 63-75

Role of stakeholders leading to development of higher education services

Rimvydas Labanauskis, Romualdas Ginevičius

ABSTRACT

In this article, a higher education institution (HEI) is analysed as an organisation performing under change conditions. In this context, needs and expectations of a wide range of university stakeholders are analysed. The aim of this article is to indicate the roles of stakeholders leading to the development of an HEI. Although Ishikawa's cause-and-effect diagram is used when identifying possible causes of a problem, it can also be seen as a method that allows splitting the subject into separate parts, which are causally interrelated. During the research of the activity fields of the HEI and the boundaries related to its surrounding groups, the connections between different groups, their interests and expectations towards the activities of the HEI were determined. The article is prepared using the theoretical-analytical approach. It contains the analysis of the literature on HEI stakeholders, quality management systems and issues concerning the organisational development. The conclusions include insights and suggestions for further research on the ways an HEI can correspond to the needs of stakeholders.

KEY WORDS

higher education institution (HEI), stakeholders, cause and effect, organisational development

DOI: 10.1515/emj-2017-0026

Corresponding author:

Rimvydas Labanauskis

Vilnius Gediminas Technical University,
Faculty of Business Management,
Lithuania
e-mail: rimvydas.labanauskis@vgtu.lt

Rimvydas Labanauskis

Vilnius Gediminas Technical University,
Faculty of Business Management,
Lithuania
e-mail: romualdas.ginevicius@vgtu.lt

Introduction

At the end of the XX century, the mission of HEIs was to transfer their knowledge to the young generation (studies) and create new knowledge (science). Another important field of activity is a search for innovative solutions by frequently combining knowledge from different research fields. This way, new ideas were generated, new knowledge was created as well as new spheres of economic activities were developed.

By eliminating borders between states and cultures such globalisation processes, as permeability and speed of information, inevitably transferred the monopoly of higher education from the level of domestic policy to a global dimension. Constantly changing conditions, rapid technological progress,

development of internationalisation and vanishing walls between diverse regional cultures pose new challenges for higher education. Having involuntarily switched to market conditions yet striving to remain competitive in the higher education market, HEIs must search for adequate solutions. They manoeuvre between their fundamental values, societal commitments and changes as well as tendencies in the global labour market. HEIs face a difficult task to satisfy expectations of different stakeholders at the same time keeping away from becoming diploma mills. These issues are considered relevant for this type of research.

The remaining research gap may be defined as HEI relations with stakeholders to achieve the overall development of the HEI. Therefore, the research aims to find out how HEI relations with stakeholders can determine the development of the HEI. An assumption is made that the coherent development of instruments within the HEI quality management system focusing on consideration and coordination of various needs of different stakeholders could be an essential element behind the development of the HEI.

The research object of this article is HEI relationships with stakeholders. The article analyses an HEI as an organisation performing under changing conditions. It strives for exceptional attributes that comprise a competitive edge of an HEI among its competitors and helps attract more students (customers), which allows for a coherent development of future activities and the reduction of negative external impact.

Taking a quality management system as an instrument or driver for a progressive HEI strategy, it is obvious that the essence is hidden within the approach of the HEI towards the stakeholders. This validates the adoption of the stakeholder theory. At the same time, economically measured development is important as a pre-condition for the long-term competitive advantage of an HEI. It follows, therefore, that the aim of the research is to determine the factors influencing the development of an HEI with reference to interests and expectations of its diverse stakeholders. The durability of the processes of an HEI (i.e. study programmes, research and development, the third mission) is considered.

The contribution of this article is two-fold. It contributes to the stakeholder theory by supplementing the peculiarities of its adoption to HEIs. In this respect, theoretical constraints of the stakeholder theory are broadened by introducing its relations to quality management methods. The approach of quality management systems adds HEIs as an additional research object. The analysis of solutions for the development of the HEI sustainability is determined by its performance efficiency, growth and stability.

The article is grounded on the theoretical-analytical approach. The analysed literature includes issues on social partners of HEIs as well as the organisational development. These questions are analysed in the general context of higher education focusing on the question how HEI relations with diverse groups of stakeholders could create conditions for the long-term development of the HEI.

The cause-and-effect diagram is used in this article as a novel approach for the already known quality management method to reflect the interaction of expectations held by various social partners in pursuance of the HEI development.

1. Changing conditions and challenges of HEIs in Lithuania

First, this section will reveal the generic changing conditions to illustrate the dynamic setting in which HEIs operate today. Second, it will explain the conditions and challenges faced by HEIs in Lithuania.

Analysts and experts from around the world make predictions on the status of higher education in the future. Firstly, it is maintained that the use of education technologies (distance learning, modelling equipment, game-type programme equipment) will open up new ways for interactive and problem-based learning. Secondly, HEIs face the challenge to prepare young people for jobs that currently do not exist or are only in the naissance stage (Salmi, 2013). Referring to the traditional approach towards studies, when a lecturer conveys knowledge for students sitting in an auditorium, the previously mentioned aims are most probably unachievable. Namely, technologies have a fundamental role transforming higher education. The main tendencies that will accelerate the application of technologies in higher education are the following (Johnson et al., 2014):

- the growth and influence of the social media,
- the integration of the internet, hybrid and cooperation-based learning methods,
- the increase of data-based learning and evaluation,

- the shift in the attitude towards the student as a customer to the student as a co-producer,
- the development of an agile approach towards change,
- the evolution of learning on the internet.

Conditions influencing the activities of HEIs had rapidly changed especially during the last decade. They determined the increase in the competition among the HEIs as well as their difficulties in becoming exceptional by discovering or pursuing a unique direction. Under such conditions, it is challenging to resist responding to a struggle posed by the present conditions (short-term focus) but rather maintain the basic direction leading to sustainable organisational development (long-term focus).

The recent decade saw the rise of a new additional area of HEI activity referred to as the "third mission of universities". This new area includes knowledge management, cooperation between different sectors of the economy and society, and the pursuit of a new (additional) role for knowledge and higher education in the changing world. This way, HEI mission expanded across the frontiers of studies and research incorporating the service for society, which requires cooperation and partnership (Maric, 2013). A contemporary university perceives the third mission as an opportunity to concentrate and strengthen the capabilities of studies and research without indicating the ways this mission should be reached. The acceptance of the third mission does not self-sustain institutional development but renders a new potential (Nelles & Vorley, 2010).

Searching for the ways to become exceptional and attract more students, HEIs most frequently create and provide new study programmes, network with businesses and employees, and track careers of their graduates. Besides, HEIs use marketing techniques and participate in trendy national and international higher education rankings. Some authors highlight the rankings as a policy and management tool (Agasisti & Johnes, 2015), while others note that despite active participation in different rankings, the relationship between reputation and quality of HEI is still unclear (Ramirez & Berger, 2014). Participation of an HEI in rankings is firstly considered as an instrument for marketing and communication, facilitating the positioning and image of the HEI. Despite the place the HEI takes in a certain ranking, the result of such endeavour will depends on the adequately formulated and suitably interpreted message. The choice of indicators and their measurement weights used for the evaluation of HEIs reflect only priorities and values of the ranking agencies. At the same time, immense differences among the traditions of institutions, their mission as well as the types of benchmarked institutions are ignored (Marginson, 2007). International rankings often benchmark the reputation and appeal relying on opinions and refusing the concept of higher education quality (Hazelkorn, 2011). Since objective benchmarking is impossible, the ranking results are only relevant to a certain methodology (Palfreyman, 2012). It is uncommon for a university's stakeholder, be it a business or a student, to have an ability to assess achievements of a certain HEI in a ranking which gives, for example, the 429 or the 492 position. HEIs with profound changes in their activities could remain in the same or even lower position, if, suppose, the number of participating institutions in the ranking had increased in that year. In any case, the flourishing industry of HEI rankings only confirms the growing competition among HEIs and the search for the ways to stand out among other institutions as well as be attractive to more students (customers) and stakeholders. The fashion to participate in rankings can be thus considered as misdirecting the attention of HEIs from the established objectives that should be reached by undertaking their core activities. In other words, HEIs should use strategic planning instruments and quality management systems for the established, integral analysis and operational planning.

Next, we will analyse how the environment in which HEIs perform in Lithuania had changed recently and what influence these changes had on the HEIs.

In Lithuania, higher education has grown into mass figures, which is no exception. Similar tendencies can also be observed in Latvia and Estonia. In 2007, the total number of higher education students in the Baltic countries had reached 400 thousand. During that time, some HEIs and numbers of students gradually grew (Paliulis & Labanauskis, 2015). According to Statistics of Lithuania, the number of students in Lithuanian HEIs has grown from 197 thousand in 2005 to 210 thousand in 2008 while the number of institutions stayed the same, i.e. 45.

Although a variety of national (grants and loans) and international (mobility programmes) instruments have been used to increase the accessibility of higher education, the national statistical yearbooks of Lithuania suggest that the number of students in Lithuania continues to decrease since 2010 (Fig. 1).

A lower number of students enrolling HEIs means lower income from tuition fees whether paid

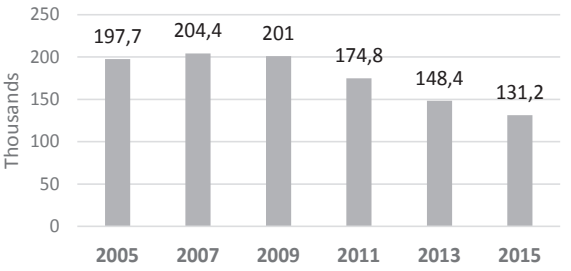

Fig. 1. Number of students in Lithuanian HEIs in 2005-2015

Source: elaborated by the author based on (Statistics Lithuania, 2015).

by the state or students, weaker scientific and creative potential, unpopular personnel management decisions (cuts in wages and tenure positions), infrastructure management struggles, and issues related to investments into research and studies.

Negative demographic trends or, more precisely, decreasing fertility rates mean fewer students (customers) in the future. Another important aspect is the choice of an HEI and a study programme. Authors claim that current consumers have plenty of alternative service providers (Munteanu et al., 2010). They can easily replace a service provider as their satisfaction primarily depends on the quality of the provided service. This also applies to higher education students. The quality of service is the key factor that determines the decision to choose and finish studies as well as continue seeking for a higher degree at the same HEI (Munteanu et al., 2010). Students choose an HEI, a study programme, and even the country for their studies. The numbers of students choosing post-secondary studies abroad increase every year. According to UNESCO (UNESCO Institute of Statistics, 2017), about 12 thousand of Lithuanian citizens chose a full-time study programme in a foreign country in 2013.

It should be noted that Lithuanian network of HEIs is very large, especially considering the number of inhabitants. During 2012–2015, Lithuania had 45 HEIs. Therefore, the current conditions, i.e. the reduction in the overall number of students as well as those choosing studies abroad, pose a true challenge for HEIs in Lithuania. Even though the country tries to attract students from abroad, the reduction of local students cannot be counterbalanced by full-time students as well as part-time students (within the frames of exchange programmes) coming to Europe from other world regions.

Coming back to the sustainable development aspect, two approaches arise: the national or even regional, based on institutional consolidation of HEIs. The institutional collaboration can operate in at least three ways, i.e. cooperation, coordination or merger (Harman & Harman, 2003). The implications of demographic changes and financial aspects serve as necessary evidence for the top managers of HEIs and policy makers to consolidate the network of these institutions. This is necessary to increase the efficiency of operations, achieve greater teaching value, and enhance research. Also, such decisions mean an immense responsibility as the consolidation process itself does not suppose the higher quality of performance or more sustainable development. An institutional approach analyses the institution as a unit focusing on internal processes and its linkages with external processes and the environment. Subsequently, this paper focuses on the sustainable development from the institutional point of view.

In Lithuania, a recent analysis revealed a significant difference in the preparedness to study in an HEI among students who are financed by the state and students paying their tuition fees. The competition scores of students enrolling to state financed study places are significantly higher when compared to the scores of self-paying students (Research and Higher Education Monitoring and Analysis Centre MOSTA, 2015). Therefore, the preparedness of students within a study programme is uneven. Consequently, such heterogeneity of the students burdens the work of lecturers and complicates the study process. Since 2015, HEIs in Lithuania agreed to establish a minimum competitive score for students admitted to state funded places.

Some authors indicate that with the Bologna Process, the use of quality reached a sort of technical level. As it refers to quality assurance techniques (Saarinen, 2010), it may be emphasised that legal regulation of national higher education and the mechanism of study quality assurance initiated by the Bologna process committed HEIs in Lithuania to create and apply inner study quality assurance systems. External study programme evaluation and institutional HEI assessment refer to Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG). HEIs in Lithuania introduced quality management systems certified to ISO 9001 standard. In some cases, systems integrated several quality management standards, such as ISO 9001, ISO 14001, and OHAS 18001. HEIs with their main activities in the field of management and business integrated quality management systems which received international quality accreditations such as CEEMAN International Quality Accredita-

tion (IQA) or EFMD EPAS. However, a gap remains in the analysis of the ways the integrated quality management systems influence the activities and development of the HEIs.

Summarising the changing conditions and challenges of HEIs in Lithuania, we can distinguish demographic downturn, increasing competition and tension between HEIs. This means the reduction in the number of students (customers) as well as the state funding of HEIs. A wide network of HEIs determines the defragmentation of the higher education system. A minimally controlled wide accessibility to studies hampers the assurance of the quality of studies and influences the results of HEI activities.

Performing under the changing conditions, HEIs must strive for real uniqueness to remain in the higher education market as well as comprehensively develop its activities in the future. HEIs should rapidly progress the implementation of their studies, research and operations (performance) in general.

It is notable that HEIs are not working alone while performing their tasks and activities. In this context, we take a closer look at a wide range of stakeholders and social partners of HEIs with the diversity of their needs and expectations.

2. Stakeholders and their interlinkages with HEIs

In the business world, stakeholders are usually categorised into primary and secondary. The primary stakeholders are those who are directly affected by organisational performance and have an interest in solving potential problems. As such, the primary stakeholders are beneficiaries of activities performed by the organisation; besides, they directly affect the success of the organisation. Secondary stakeholders have an indirect influence by playing an intermediary role and can also have a high impact on potential outcomes (Stankevičienė & Vaiciukevičiūtė, 2014).

The main reason to use the stakeholder theory in this article is determined by the complexity of higher education. Surrounded by a variety of stakeholders with different expectations and requirements, HEIs need to find a balance between these groups. Secondly, we assume that an HEI should start from the analysis of needs and expectations of the stakeholders when choosing or developing their quality management system.

The review of the literature on the stakeholder theory can be started from Freeman and his book "Strategic Management: A stakeholder approach" (1984). The core idea of this theory states that an organisation, which manages stakeholder relationships effectively will survive longer and perform better than an organisation that does not (Freeman, 1984). The scientific literature on the stakeholder theory provides numerous definition of a stakeholder. In some studies, the term "stakeholders" is replaced by the term "customers" (Iacovidou, Gibbs & Zopiatis, 2009). However, the latter term is more controversial in the context of higher education; therefore, we use "stakeholders". Stakeholders can be "all agents (representatives), who can influence or become influenced when implementing organisation's objectives" and" any individual or a group, which can influence or can be influenced when implementing organisation's objectives" (Pesqueux & Damak-Ayadi, 2012; Bourne & Walker, 2005; Mainardes, Alves & Raposo, 2012). Stakeholders acting in field of higher education are interested in the activities of HEIs and are most frequently divided into internal and external (Melewar & Akel, 2005), primary and secondary (Maric, 2013) or overt and latent (Jongbloed, Enders & Salerno, 2008; Garvare & Johansson, 2010; Mainardes, Alves & Raposo, 2013). Higher education stakeholders could also be categorised as commercial and non-commercial (Melewar & Akel, 2005).

The role of stakeholders in higher education is also analysed in the context of ESG. The findings from cases of seven European countries "reveal that the importance of stakeholders varies across the countries and across the types of stakeholders" (Leisyte & Westerheijden, 2014).

One of the current research papers provides a stakeholder map in higher education. According to the map, stakeholders belong to one of two subgroups, i.e. partners or customers. The idea is that such maps help HEIs to identify most important stakeholders, collect feedback and improve processes (Kettunen, 2015).

Stakeholders approach universities from different angles, for example, employers and business groups – from the economic perspective, families of present and future students and social organisations – from the social perspective, academicians and other providers of educational services – from the perspective of education. Often, external stakeholders approach activities of a university referring to the local context in the first place; meanwhile, others draw upon the national or international contexts

(Houston, 2008). The variety shows the importance of this element in the life of an HEI.

An HEI is an integrated organisation surrounded by a larger number of various stakeholders. Thus, their internal connections and expectations are of immense importance. An HEI is an essential part of a stakeholder's "ecosystem" and, therefore, one of its primary activities should be to create the maximum value for its partners. This task is unfortunately encumbered by diverse and often discrepant expectations of these partners.

In a democratic society, interests are negotiated to find compromises. In negotiating these compromises, higher education stakeholders must negotiate all definitions of quality, not just preferred ones (Pitman, 2014).

In 2013, John Borwick prepared a map of scientific partners of higher education in the United States, emphasising external partners and their relations with HEIs as well as internal connections. The adapted and complemented map, representing relations between an HEI and its stakeholder groups in Lithuania (as well as most of the European countries) is provided in Fig. 2.

While exploring these relations, it is noticeable that government is responsible for legal regulation (legislative acts), financing of HEIs, financial support to students (grants, compensation of loan interest, etc.), and job creation for graduates and students. Accreditation institutions evaluate and accredit HEIs and study programmes, provide relevant and useful information to support government decisions, guide prospective students (e.g., choosing the studies), inform students and their parents. Media and ranking agencies perform analyses and provide information that may be useful for the prospective students, their parents and HEIs. HEIs provide the alumni with an identity, organise various events and offers for qualification improvement. The alumni provide HEIs with feedback and support. They are invited to give lectures for students and share practical experience during events. Aiming to recruit new students, HEIs provide them with information on study options. Parents pay tuition fees and provide additional finan-

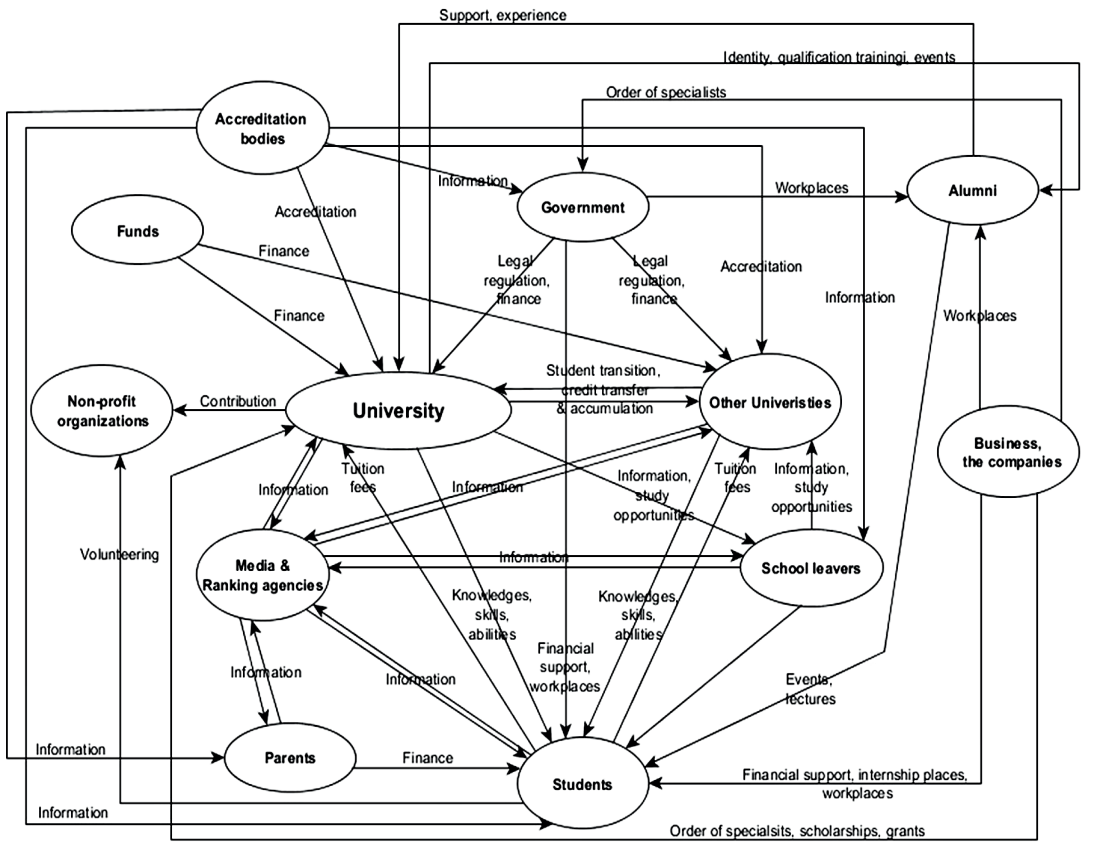

Fig. 2. Map and linkages of stakeholder groups in HEIs

Source: elaborated by the author based on (Borwick, 2013).

cial support. Various foundations provide financial support to HEIs in the form of grants, etc. Non-governmental (non-profit) organisations expect support from HEIs and student volunteers. HEIs compete for students and collaborate in thematic networks at the same time. Students have possibilities to switch an HEI and continue their studies elsewhere; consequently, credit transfer and accumulation procedures are implemented. Business and private companies are among the most important stakeholders of HEIs. The government orders services, gets specialists trained, funds the higher education. Employers also take part in the management of HEIs and their study programmes, establish grants and placements for students. In general, all HEI activities and results are provided to the society, i.e. not only economically active (working) individuals but also persons of a wide outlook, who are capable of perceiving and analysing world realities, read into and understand the surroundings, signs and information in diverse forms. It all comprises the educational level of the society and the potential of culture and creativity (self-expression). In this scheme of linkages, an HEI and a student are the subjects that face the major part of expectations and interests of the stakeholders (Fig. 2).

Subsequent to the analysis of a substantial number of external partners and their expectations, we can evaluate the importance of the labour market and its interest in processes and results that take place in higher education. Some stakeholders are driven by economic reasons, and others have social interests (Eagle & Brennan, 2007). At the same time, it should be noted that this map does not reveal stakeholder groups that function inside the HEI, such as several levels of administration (university, faculty, and departmental), lecturers, PhD students and young researchers, service personnel and their networks.

When trying to define the influence of the environment, it is meaningful to divide HEIs according to their founders. HEIs founded by the state have the state government as the main source of funding (state funded student places, targeted financing); subsequently, the government is their most important stakeholder. Non-state (private) HEIs do not receive state funding for their activities; however, they perform under the same conditions (legal regulation of higher education, institutional and study programme assessment and accreditation) as the state HEIs. This way, the competitive environment for non-state HEIs is disadvantageous.

This scheme clearly demonstrates the variety of HEIs extending their activities from studies or knowledge transfer and research to community (society) services as well as new types of partnerships within the surrounding environment (Jongbloed, Enders & Salerno, 2008). The stakeholders act as partners, supporters, content makers and change agents. The presented figure allows indicating stakeholders interested in the activities of an HEI and evaluating of their possible influence and impact.

The analysis of the HEI stakeholder network demonstrates that different groups of stakeholders have different needs and expectations towards an HEI, which must find a compromise. It is important to note that the value for HEIs is not created by separately functioning stakeholders. Only joint actions of HEIs and stakeholders result in activities that satisfy both sides and are worthwhile. Fig. 2 provides the map of HEIs and their external links; however, the reflected stakeholder network does not show the level of influence of each player or their position within the HEI.

3. HEI ACTIVITIES AND INTERACTIONS WITH STAKEHOLDERS IN CONNECTION WITH CAUSE AND EFFECT

According to Fadeeva et al. (2014), quality assessment as a transformative process underlines the need to involve the multiple internal and external stakeholders concerned with moving HEIs to become more change focused (Fadeeva at al., 2014). The cause-and-effect diagram created by the Kaoru Ishikawa was used to indicate the essential cause of the problem. Causes are usually grouped into five main categories (personnel, methods, machines, measurements and environment), specifying the sources of deviations (Ishikawa, 1986). Using the logics of this method, we will indicate the most important areas of HEI activities, in which the interaction with different groups of stakeholders is possible. This allows aiming for the maximum economic benefit for the HEI.

Firstly, we group internal and external stakeholders of an HEI and various factors, the presence or use of which could influence on the HEI development. The first group named the "Environment" is mostly composed of external stakeholders of the HEI. It is

suggested to start the analysis from the appeal of the region, i.e. – the choice of location for studies (the geographical region, state, and climate), and conditions to study and social guarantees (support). Next, we should consider the legal framework for higher education and HEIs. It is important to remember the role of international documentation and agreements, such as the Bologna process communiques, ESG guidelines on the quality of higher education. The national level can be described by laws, legal acts and internal documents of an HEI. Locally-focused HEIs with the underdeveloped international dimension (none or few international students/lecturers, few internationally implemented study programmes) heavily depend on demographic fluctuations.

The network of HEIs is the determining factor that could influence the national context. However, HEI networks should be analysed considering the specificity of their country (e.g. Lithuania). Agencies that implement higher education policies and undertake assessments are most frequently national but can also be international.

Other participants, e.g. employers, businesses, professional associations, non-governmental and non-profit organisations, state and private foundations, and ranking agencies can be regarded as national or international players depending on their activities.

The next group is "Infrastructure and buildings", which falls outside the scope of stakeholders. This group of factors refers to the land and buildings owned or rightfully used by an HEI. Buildings can be grouped depending on their purpose, i.e. those designated for studies and science processes, i.e. auditoriums, laboratories for research and teaching, administrative premises of the university and faculty (other units), library, bookstore, sports and practice facilities, archive, catering and other utility rooms. Separate attention is devoted to student dormitories as an important campus element.

"Management" group includes all internal HEI management bodies (the university senate, council, rectorate) as well as external social partners, such as a local and international network of partners. This area also covers financial management. It should also be noted that social partners are usually a part of management bodies as well as strategic partnerships.

The group named "Organisation and sale of studies" includes the portfolio of study programmes, studies according to forms and types, qualification improvement courses, distance learning and MOOCs. Specialized secondary schools and other forms of collaboration with the secondary level of education are also included. Artistic and scientific activities are also attributed to this group as a complementary part of studies. This part of HEI performance is a top priority for all internal (students, teachers, management bodies) and external stakeholder (e.g. employers).

"Science and its commercialisation" group covers scientific publications, their citation indices, scientific conferences organised and attended, orders and contracts with the state and businesses. Patents, new businesses and spin-offs/start-ups are also included.

"Internationalisation and communication strategy" involves marketing campaigns, organised and attended study exhibitions and career days, visits to schools and companies, HEI representation in various working groups, a network of international partners, participation in rankings, use of the feedback, and collection of information from students, lecturers, and social partners.

Fig. 3 fits all the above-mentioned parts in the cause-and-effect diagram. The analysis of HEI activities according to six conditional parts represented in the diagram reveals the complexity of an HEI as an organisation. Subsequently, the abundance and diversity of partners and stakeholders are also represented. At the same time, we can notice that none of the mentioned parts includes the independent role of an HEI. These activities are regulated or determined by the needs of external players (partners, stakeholders). Fig. 2 includes interconnections and expectations of different stakeholders. Fig. 3 reveals the involvement of the HEI resource management and its performance. Ishikawa's cause-and-effect diagram represented in Fig. 3 does not cover a certain part of personnel or human resources on purpose. The logics for this is that certain cause-and-effect domains and subdomains correspond to certain interests and expectations of different stakeholders. Management of all activities requires a good system, and, more importantly, fluent internal communication between executives and administration as well as the units. In practical terms, it should be noted that challenges and disruptions of the internal communication do not depend upon the size of an organisation. They can slow down a successful higher education performance aiming for strategic objectives as well as good economic activity results. Simultaneously, inconsistent, discrepant or delayed communication results in a higher probability of mistakes and a longer period for reaction to the needs of internal and external stakeholders.

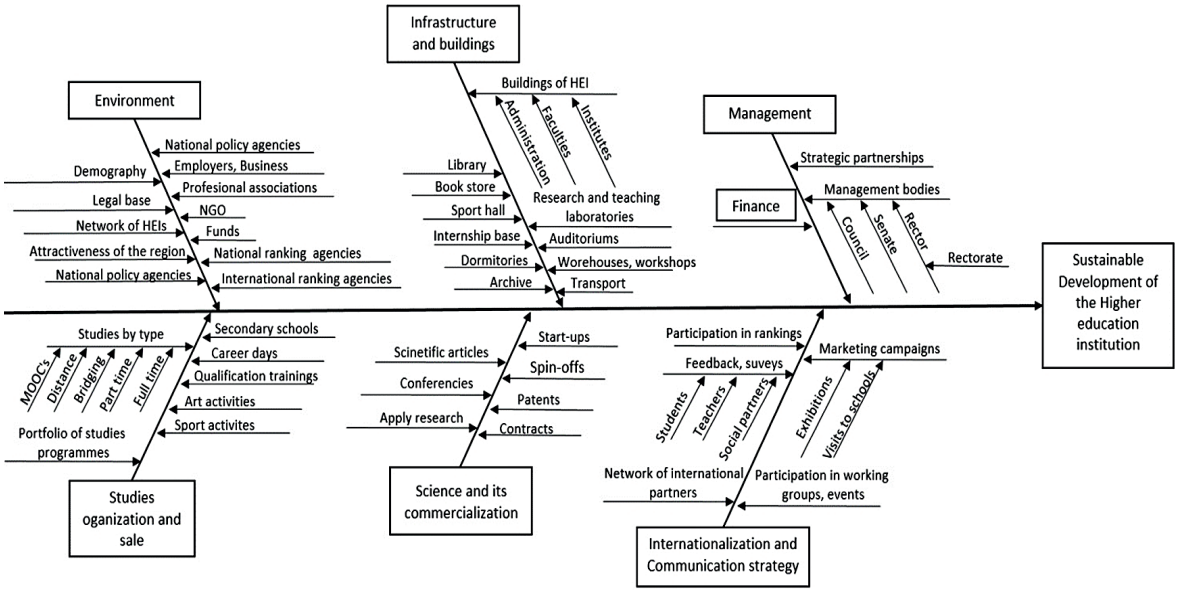

Fig. 3. Causes affecting the overall activity of an HEI leading to its development

Source: elaborated by the author based on Ishikawa's Cause-and-Effect Diagram.

4. Role of stakeholders leading to the development of an HEI

Many different authors have been writing about stakeholders in the private sector, but the public sector still lags behind with some proper implications and in-depth analyses (Ipsos MORI, 2009). In this chapter, we describe the role of stakeholders in the development of an HEI through HEI performance activities devoted to the measurement of stakeholder needs, expectations and experiences. The measurement is based on indicators to determine the stakeholder role in the HEI development.

As pointed out by Ramos and Pires (2013) "indicators can improve the dialogue with stakeholders, engaging them in sustainability matters and providing key relevant information for their decisions and aspirations" (Ramos & Pires, 2013). The problem is that the indicators tend to become an instrument of the activity, rather than the instrument for measuring the quality of the provided service (Munteanu et al., 2010). Indicators of an organisation are assessed not only by the organisation but also by stakeholders. Thus, the importance of the indicators can be different for different groups of stakeholders.

It is crucially important to evaluate the expectations of stakeholders that are relevant to certain indicators. Most frequently, expectations are unfeasible. Moreover, even with the desirable indicator reached, the expectations tend to rise. In leveraging the satisfaction of the stakeholders, the alternative for the improvement of indicators is the lowering of the stakeholder expectations.

Usually, HEIs measures their activities according to their strategic management plans or main operations, such as studies, research and international activities (or achievements). The variety of indicators varies from the result to effectiveness and efficiency.

In this context, stakeholders can be a significant source of information to determine whether an HEI is state of the art. Tab. 1 provides the linkage between expectations and experience of main stakeholder groups with the improvement of an HEI.

The basic elements of the classical organisational activities are performance costs, time and quality management. The context of higher education is considered as very complex because HEIs have a unique selection of external drivers for change (O'Mahony & Garavan, 2012). Success in the implementation of the HEI development depends on self-positioning, assessment and relevance to the needs of customers with an indication that the resources are limited. Firstly, the needs of customers are indicated using the formal methods such as surveys and focus groups (Kleijnen et al., 2014). The literature also stresses the importance of inclusion of the mid-managers into the integration process. They have the main

Tab. 1. Improvement of HEI activities using expectations and experience of stakeholders

Stakeholder group	Location	Expectations (needs)	Experience	Improvements of targeted HEI activities
Employers	external	• fulfilment of labour market demand, • highly skilled professional employees	• participation in HEI governance bodies, • experience from employed graduates, • ability to provide suggestions for studies and R&D activities based on gained experience	• management, • infrastructure & buildings
Managers of HEI	internal	• achievement of strategic goals, • implementation of the HEI strategies, • appropriate indicators to make decisions, • timely statistical data	• quality culture and quality management system, • continuous improvement, • accountability, • measurement tools for stakeholders, • set of study programmes, • improvements after external evaluations (institutional, study programmes, R&D performance)	• all HEI performance activities
Academics	internal/ external	• appropriate working environment, • achievement of the learning outcomes of a study programme, • development of studies curriculum based on scientific achievements, • participation in international programs and projects	• development of study, programmes, • workload of studies, • monitoring of studies and R&D processes, • job satisfaction	• studies, • R&D activities, • internationalisation, • communication
Students	internal	• motivation, • development of personal abilities, • career opportunities, • social status	• flexible learning methods, • workload of studies, • ability to complete selected studies, • opportunities for further education and career, • international mobility experience, • procedures for appeals, • opportunities for reflection, • participation in student-life activities	• studies, • R&D activities, • internationalization, • communication

Source: elaborated by the author based on the Map and linkages of stakeholder groups in HEIs and the overall activity of HEIs.

role in understanding the change process and explaining it to other employers (O'Mahony & Garavan, 2012).

Tab. 1 has provided possible improvements of targeted HEI activities based on different stakeholder group expectations, needs and experience.

Despite the fact what employers are seen as one of the most powerful external stakeholder groups, their ability to suggest HEI studies and R&D activities is very limited.

Owning the right to make decisions regarding the overall HEI performance and activities, HEI managers are the most powerful internal group of stakeholders. However, they should strive for external opinions to not miss relevant issues.

The academicians are seen as a strong group of stakeholders who have an opinion about the processes taking place in the HEI. At the same time, they implement the HEI policy in studies and R&D activities. They do have expectations but also experience, so

information gained from this group is extremely valuable.

Due to limited experience and understanding of HEI activities, students are not clearly assumed as contributors to the integration of the HEI quality management system. The scientific literature often criticises the approach to a student as a consumer (Houston, 2008). Moreover, a student plays different roles as a customer and an active participant in the processes they experience. Recent graduates and employers may evaluate the academic quality as customers and, for non-academic departments, students may assess the quality of services they receive as customers (Tari & Dick, 2016).

Recent graduates or alumni are seen as the most valuable source of information about all HEI activities. They are not only familiar with the processes they experienced but also can be good advocates for the HEI among youngsters and in the society.

Once the needs and expectations of stakeholders are identified, and they are placed within the activities of the HEI, it is easy to plan resources and capabilities as well as establish the priorities. Therefore, the system that indicates the priorities and defines the weights of elements (sub-criteria) is necessary. However, the effectiveness of this model needs to be empirically tested in further studies.

Conclusions

The organisational development is seen as consistent and permanent efforts of an HEI. Social and economic changes of the recent decade determined the changes of the conditions for HEIs. The statement is illustrated by the example of the situation of the higher education in Lithuania. Having in mind the general negative demographic context, HEIs have to be clear about their exceptionality and increase their attractiveness to stay in the higher education market.

Higher education stakeholders can be grouped and analysed in various ways. A detailed analysis provides their linkages with HEIs, also their needs and expectations. Different groups of stakeholders have different needs; thus, their objectives are diverse. Consequently, HEIs have to find a compromise, harmonise and establish priorities leveraging the needs of the stakeholders.

The analysis based on the cause-and-effect diagram revealed the complexity and diversity of HEI performance. This also contributes to the streams of scientific literature on the strategic management of HEIs.

Stakeholders are seen as a powerful information source that can be used for the HEI development. The article presents possible ways for improvement of HEI performance using expectations, needs and experience of different stakeholder groups. Stakeholder inclusion in HEI activities could be a powerful element in finding the right ways to the development and improvement of an HEI.

Literature

Agasisti, T., & Johnes, G. (2015). Efficiency, costs, rankings and heterogeneity: the case of US higher education. *Studies in Higher Education*, *40*(1), 60-82. doi: 10.1080/03075079.2013.818644

Borwick, J. (2013). Mapping the system of US higher education. *HEIT Management*. Retrieved from http://www.heitmanagement.com/blog/2013/09/mapping-the-system-of-us-higher-education/

Bourne, L., & Walker, D. H. T. (2005). Visualising and mapping stakeholder influence. *Management Decision*, *43*(5), 649-660. doi: 10.1108/00251740510597680

Central Statistical Bureau of Latvia. (2015). *Statistical yearbook of Latvia 2014*. Riga, Latvia: Central Statistical Bureau of Latvia.

Čiegis, R., & Zeleniūtė, R. (2008). Ekonomikos plėtra darnaus vystymosi aspektu [Economic development in the aspect of sustainable development]. *Taikomoji Ekonomika: Sisteminiai Tyrimai*, *2*(1), 37-54.

Freeman, R. E. (1984). *Strategic Management*: *A stakeholder approach*. Boston, USA: Pitman.

Garvare, R., & Johansson, P. (2010). Management for sustainability – A stakeholder theory. *Total Quality Management & Business Excellence*, *21*(7), 737-744. doi: 10.1080/14783363.2010.483095

Harman, G., & Harman, K. (2003). Institutional mergers in Higher Education: Lessons from International Experience. *Tertiary Education and Management*, *9*(10), 29-44.

Hazelkorn, E. (2011). *Rankings and the Reshaping of Higher Education*: *The Battle for World-Class Excellence*. New York, USA: Palgrave McMillan.

Houston, D. (2008). Rethinking quality and improvement in higher education. *Quality Assurance in Education*, *16*(1), 61-79. doi: 10.1108/09684880810848413

Eagle, L., & Brennan, R. (2007). Are students customers? TQM and marketing perspectives. *Quality Assurance in Education*, *15*(1), 44-60.

Fadeeva, Z., Galkute, L., Mader, C., & Scott, G. (2014). *Sustainable development and quality assurance in higher education*. London, England: Palgrave-Macmillan.

Iacovidou, M., Gibbs, P., & Zopiatis, A. (2009). An Exploratory Use of the Stakeholder Approach to Defining and Measuring Quality: The Case of a Cypriot Higher Education Institution. *Quality in Higher Education*, *15*(2), 147-165. doi: 10.1080/13538320902995774

Ipsos MORI. (2009). *Understanding your stakeholders. A best practice guide for the public sector*. London, England: Ipsos MORI. Retrieved from https://www.ipsos-mori.com/Assets/Docs/Publications/sriunderstanding-stakeholders-november-2009.pdf

Ishikawa, K. (1986). *Guide to Quality Control*. Tokyo, Japan: Asian Productivity Organization.

Johnson, L., Becker, S., Estrada, V., & Freeman, A. (2014). *Horizon Report*: *2014*. *Higher Education*. Luxembourg: Publications Office of the European Union, & Austin, USA: The New Media Consortium. Retrieved from http://www.nmc.org/pdf/2014-nmc-horizon-report-he-EN.pdf

Jongbloed, B., Enders, J., & Salerno, C. (2008). Higher education and its communities: Interconnections, Interdependencies and Research Agenda. *Higher Education*, *56*, 303-324.

Kettunen, J. (2015). Stakeholder relationships in higher education. *Tertiary Education and Management*, *21*(1), 56-65. doi: 10.1080/13583883.2014.997277

Kleijnen, J., Dolmans, D., Willems, J., & van Hout, H. (2014). Effective quality management requires a systematic approach and a flexible organisational culture: a qualitative study among academic staff. *Quality in Higher Education*, *20*(1), 103-126. doi: 10.1080/13538322.2014.889514

Leisyte, L., & Westerheijden, D. F. (2014). Stakeholders and quality assurance in higher education. In H. Eggins (Ed.), *Drivers and Barriers to Achieving Quality in Higher Education* (pp. 83-97). Rotterdam, Netherlands: SensePublishers. doi: 10.1007/978-94-6209-494-9_7

Mainardes, E., Alves, H., & Raposo, M. (2012). A model for stakeholder classification and stakeholder relationships. *Management Decision*, *50*(10), 1861-1879. doi:10.1108/00251741211279648

Mainardes, E., Alves, H., & Raposo, M. (2013). Identifying stakeholders in a Portuguese university: a case study. *Revista de Educación*, *362*, 429-457. doi: 10.4438/1988-592X-RE-2012-362-167

Maric, I. (2013). Stakeholder analysis of higher education institutions. *Interdisciplinary Description of Complex Systems*, *11*(2), 217-226. doi: 10.7906/indecs.11.2.4

Marginson, S. (2007). Global university rankings: implications in general and for Australia. *Journal of Higher Education Policy and Management*, *29*(2), 131-142.

Melewar, T. C., & Akel, S. (2005). The role of corporate identity in the higher education sector. *Corporate Communications*: *An International Journal*, *10*(1), 41-57. doi: 10.1108/13563280510578196

Munteanu, C., Ceobanu, C., Boba, C., & Anton, O. (2010). An analysis of customer satisfaction in a higher education context. *International Journal of Public Sector Management*, *23*(2), 124-140. doi: 10.1108/09513551011022483

Nelles, J., & Vorley, T. (2010). From policy to practice: engaging and embedding the third mission in contemporary universities. *International Journal of Sociology and Social Policy*, *30*(7/8), 341-353. doi: 10.1108/01443331011060706

O'Mahony, K., & Garavan, T. N. (2012). Implementing a quality management framework in a higher education organisation: A case study. *Quality Assurance in Education*, *20*(2), 184-200. doi: 10.1108/09684881211219767

Palfreyman, D. (2012). Rankings and the Reshaping of Higher Education: The Battle for World-Class Education. *Perspectives*: *Policy and Practice in Higher Education*, *16*(2), 66-68. doi: 10.1080/13603108.2011.620996

Paliulis, N. K., & Labanauskis, R. (2015). Benchmarking as an Instrument for Improvement of Quality Management in Higher Education. Business. *Management and Education*, *13*(1), 140-157. doi:10.3846/bme.2015.220

Pesqueux, Y., & Damak-Ayadi, S. (2012). Stakeholder theory in perspective, Corporate Governance. *The International Journal of Business in Society*, *5*(2), 5-21. doi: 10.1108/14720700510562622

Pitman, T. (2014). Reinterpreting higher education quality in response to policies of mass education: the Australian experience. *Quality in Higher Education*, *20*(3), 348-363. doi: 10.1080/13538322.2014.957944

Ramirez, G. B., & Berger, J. B. (2014). Rankings, accreditation, and the international quest for quality. *Quality Assurance in Education*, *22*(1), 88-104.

Ramos, T., & Pires, S. M. (2013). Sustainability assessment: the role of indicators. In S. Caeiro, W. L. Filho, C. Jabbour, U. M. Azeiteiro (Eds.), *Sustainability Assessment Tools in Higher Education Institutions* (pp. 81-99). Cham, Switzerland: Springer.

Research and Higher Education Monitoring and Analysis Centre MOSTA. (2015). *Lietuvos studijų būklės apžvalga* [*Lithuanian Research Assessment Exercise*]. Vilnius, Lithuania: MOSTA.

Saarinen, T. (2010). What I Talk About When I Talk About Quality. *Quality in Higher Education*, *16*(1), 55-57. doi: 10.1080/13538321003679507

Salmi, J. (2013). *Global View on Tertiary Education. Welcome to the University of the Future*. Retrieved from http://tertiaryeducation.org/

Stankevičienė, J., & Vaiciukevičiūtė, A. (2014) Conceptual strategy map implementation for higher education institution. *The 8th international scientific conference Business and Management 2014*: *selected papers*, *Vilnius*: *Technika*, 709-716.

Statistics Estonia. (2015). *Statistical Yearbook of Estonia 2015*. Tallin, Estonia: Statistics Estonia.

Statistics Lithuania. (2015). *Education 2014*. Vilnius, Lithuania: Statistics Lithuania.

Tarí, J. J., & Dick, G. (2016) Trends in quality management research in higher education institutions. *Journal of Service Theory and Practice*, *26*(3), 273-296. doi: 10.1108/JSTP-10-2014-0230

UNESCO Institute of Statistics. (2017). *Education Pages: international student flow*. Retrieved from http://www.uis.unesco.org/Education/Pages/international-student-flow-viz.aspx

Watty, K. (2006). Want to Know About Quality in Higher Education? Ask an Academic. *Quality in Higher Education*, *12*(3), 291-301. doi: 10.1080/13538320601051101

Yarrow, D., Robson, A., & Owen, J. (2004). Organizational Excellence: Do your Stakeholders Agree? *Total Quality Management & Business Excellence*, *15*(5/6), 869-878. doi: 10.1080/14783360410001680305

Volume 9 • Issue 3 • 2017

DE GRUYTER OPEN

ISMSME International Society for Manufacturing, Service and Management Engineering

received: 15 February 2017
accepted: 25 June 2017

pages: 10-27

Oilfield development and operations planning under geophysical uncertainty

Yury Redutskiy

ABSTRACT

The oil and gas industry nowadays is challenged by dealing with nonconventional reserves and offshore environments. Decision-making associated with projects in the petroleum sector has to handle various technological issues, risks, and uncertainty. The Smart Fields approach was introduced to cope with complicated production conditions and make the production of hydrocarbons economically efficient. A significant part of this approach is proactive planning which implies taking into account the uncertainty, or lack of knowledge of the recoverable reserves, future hydrocarbon prices and various operational issues inherent in the projects. In this study, a multi-stage stochastic programming approach is employed to cover the relevant engineering issues of oilfield development and petroleum production while addressing the geophysical uncertainty related to the developed deposit. The proposed model covers such aspects as well drilling, gathering pipeline infrastructure planning, capacity selection for the infrastructure and the processing units, as well as planning the production operations with consideration of artificial lift efficiency. The model aims to optimise the entire field lifecycle, given the chosen planning criterion, that is an economic criterion of the project's net present value. The contribution of the developed model to the area of planning in the petroleum industry is the detailed consideration of the technology: the flows and pressures in the planned infrastructure, reservoir behaviour, and the artificial lift performance. The goal of including these technological details is to apprehend the economic trade-off between investments, operating costs and the prospective revenues, given the lack of knowledge of the geophysical properties of the developed deposit. The stochastic modelling implemented in this study is relevant to the development projects in nonconventional environments, where several deposits of various sizes are present; however, not each deposit's properties get to be studied in detail.

KEY WORDS

development and production planning, electrical submersible pump, multi-stage stochastic programming, oilfield infrastructure design, oilfield operations optimisation, strategic planning

DOI: 10.1515/emj-2017-0022

Corresponding author:

Yury Redutskiy

Molde University College,
Faculty of Logistics, Norway
e-mail: yury.redutskiy@himolde.no

Introduction

Various kinds of energy are vital for the global society to develop. Nowadays, companies producing the energy resources of oil and gas face many challenges. Many of these challenges are associated with the technological complexity of nonconventional and offshore reserves broadly put to use during the past few decades (Mathieson, 2007). To handle the difficulties posed by the nonconventional reserves, the Smart Field or Intelligent Field approach has been developed. The distinctive features of this approach are best described in comparison to the standard, time-tested petroleum production solutions that have been applied for large onshore reserves. The planning capabilities for operations given the standard approach are to a large extent limited to simplified

models and one-at-a-time decisions. The overall lifecycle of the developed reserves is merely monitored, rather than precisely controlled. All this is due to the lack of awareness as to how exactly a certain control decision affects the reservoir draining process, both in the short and the long run. On the contrary, Smart Field solutions employ certain advanced instrumentation and specialised software, all of which aim to improve the knowledge of operations and predict the outcome of each control action (Redutskiy, 2017a). The goal of advanced capabilities of smart solutions is to maintain the economic efficiency of hydrocarbon production in the risky nonconventional environments. An important feature of the smart approach is proactive planning and control which implies coordinating development and production operations while considering the uncertainty about the future, which may include the lack of knowledge of the recoverable reserves, future hydrocarbon prices and many operational issues at various points of a given project.

Making decisions with consideration of uncertainty requires accounting for the phases that the oil and gas industry projects undergo, as well as how the uncertainty manifests during these phases, and how it becomes resolved. Every project begins with the exploration of hydrocarbon occurrences by a geological survey, seismic studies, and drilling of exploratory wells. The next step is the deposit appraisal which mainly implies estimation of oil and gas reserves. Further, the field development activities begin. They include drilling wells, constructing a gathering pipeline and processing facilities. The production of hydrocarbons begins when the infrastructure is ready and ends with the field abandonment after the reserves are depleted. Given the description of the project phases, one may observe that there is a process of gradual uncertainty resolution over the timespan of the project. During earlier stages, there is very little knowledge of the volume of recoverable hydrocarbons in the explored or developed deposit. The quality and the composition of the flow from the reservoir, as well as its change with time, is not entirely apprehended. Also, decision-makers may only anticipate how profitable the whole project will turn out, given the possibilities of sudden changes in the hydrocarbon market price. With time, as the field becomes mature, all these unknowns become revealed, and by the end of the project lifecycle, the full relevant information becomes available to contribute to the knowledge and experience of petroleum engineers for future projects.

A peculiar aspect of uncertainty resolution is attributed to the nonconventional production environments, especially offshore locations. Offshore production sites usually consist of several reservoirs (formations where the petroleum is trapped geologically), some of which are considerably large, while others are small (often referred to as "marginal fields"). All these reservoirs become explored during the geological survey and the seismic studies. However, a more detailed examination of the porous media and the fluid properties through exploratory drilling is often performed only for larger fields for economic reasons. As a result, for these larger deposits, a considerable amount of knowledge is gathered during the appraisal phase. However, for the marginal reservoirs, significant uncertainty prevails, and in many cases, it may lead to these resources not being developed.

To comprehend the relevant uncertainty aspects inherent in the reservoir development and petroleum production processes, these issues, i.e. stochastic events, processes, and characteristics, are accounted below in the three broad categories:

- *functional uncertainty*. A lot of dangerous and expensive machinery guided by a complex automation system is employed in oil and gas projects. This direction addresses the issues of potential technological incidents, hardware failures, repairs and restorations, and systems maintenance in general;
- *geophysical uncertainty*. These issues include the knowledge of formation characteristics, fluid properties, and their behaviour during the deposit draining. More and more information is collected, as the reservoir is being developed and drained, thereby gradually annihilating the lack of knowledge. Among the initially uncertain parameters that might be considered in this group, there are initial flow rates from the production wells (or initial well productivities), initial oil cut (percentage of oil in the produced fluid), production decline rates, total recoverable volume of hydrocarbons, water breakthrough time (production ending time due to water-flooding);
- *economic uncertainty.* Parameters of this group are related to the changing market conditions influencing such parameters as oil price, prices for the machinery/equipment, and so on. Generally speaking, the discount rate may also be an indicator of certain market situations from the investment perspective.

From the very general perspective of uncertainty consideration, an important observation should be made at this point. The nature of petroleum industry projects is complex enough to include both exogenous and endogenous uncertainty types (Jonsbråten, 1998a). The former one may be addressed as an "external" from the decision-making viewpoint on the considered process, i.e. these parameters are revealed independently from the project-related decisions. The economic parameters fall under this category. Further, the functional and the geophysical uncertainty issues make the petroleum industry projects and problems stand out in the area of stochastic programming because these two groups of stochastic factors fall under the category of endogenous, or decision-dependent uncertainty. It means that the decisions made during the earlier stages of the project when only a little information is available, considerably affect the process itself, its efficiency, outcome, profits, etc.

In this paper, the issues of oilfield development and scheduling the production operations under uncertainty will be addressed. In this context, the uncertainty of the functional type appears not quite as relevant as, for instance, for the problems of automation and control system design. See, for example, (Redutskiy, 2017b) that this uncertainty type prompts to focus on choosing the hardware components, making decisions on redundancy (backing-up) the necessary tools, etc. Additionally, incorporating uncertainty of the economic type for the oilfield planning purposes will not be addressed in this study, that is the price of oil will not be regarded as stochastic. This assumption is made due to the primary focus of this research on the technological details. A proper representation of uncertainty in the future market value of hydrocarbons requires a deep analysis and a rather sophisticated representation in the model. Therefore, a stable demand for hydrocarbons from various industries (chemical, textile, pharmaceutical, construction etc.) will be considered further, and thereby, conditions of the hydrocarbons market are presumed as rather favourable.

The main angle of this research is the long-term planning of oilfield development and production operations, that is planning the lifecycle of a given field which is prompted by the state-of-the-art Smart Field approach. From the viewpoint of engineering projects of field development in modern-day conditions, this research addresses a number of strategic decisions like well-drilling and laying out the infrastructure with consideration of the future operations, that is choosing reasonable production rates, artificial lift running mode, as well as the throughput of the gathering system during the project's planning horizon. An economic indicator of net present value (NPV) is employed for the decision-making model presented further. This indicator allows finding a trade-off between the capital expenditures (CAPEX), i.e. drilling and infrastructure investments, and operational expenditures (OPEX) associated with fluid processing and artificial lift performance.

Thus, the geophysical uncertainty issues are the main stochastic factors taken into consideration in the multi-stage stochastic programming problem presented further. The model covers strategic planning issues relevant to the development of a given oilfield, namely, well drilling, gathering pipeline design, and processing facility choice. All the development activities are planned and hydrocarbon production is scheduled over the given time horizon, corresponding to the deposit lifecycle. The model considers in detail the reservoir description and artificial lift performance. The proposed decision-making framework is especially relevant for the cases of exploring the possibilities including the marginal reservoirs into the development projects, given that the significant level of geophysical uncertainty remains for these marginal deposits by the time the engineering project of the main production site development is commenced. The proposed model is applied to a study example of a marginal offshore field based on a real-life data from several engineering projects available to the author.

1. Overview of the research area

For almost seven decades, various optimisation models have been developed by many researchers to better comprehend the problems of planning and control over technological processes in the oil and gas industry. Early research in the area of petroleum resource development and production management comprised deterministic models, for example, in research (Aronofsky & Williams, 1962), (Devine & Lesso, 1972), (Frair & Devine, 1975). Later research, for instance (Iyer et al., 1998), (Van den Heever et al., 2001) or (Dawson & Fuller, 1999), included large-scale mixed integer linear and non-linear problem settings which require specialised algorithms to

facilitate their application to real-life problem instances.

Incorporating uncertainty into strategic decision-making appears to be one of the relatively recent directions in research of oil and gas project planning. One of the earlier papers focusing on endogenous resource uncertainties for planning problem sector projects is (Haugen, 1996). Later, another work (Jonsbråten, 1998b) encompassed an optimal field development planning problem under the exogenous uncertainty of the future price for hydrocarbon resources.

Several papers by Grossmann research group at Carnegie Mellon University explore the problems of petroleum field development and production, i.e. in the same research domain as this study. (Goel & Grossmann, 2004) attempt to optimise capital investments and operations of a gas field under uncertainty in reserves. (Tarhan et al., 2009) consider the development and operations planning for an oil and gas field under uncertainty in initial flow rates, recoverable reserves and water breakthrough time. (Gupta & Grossmann, 2014) address the fluid composition in addition to multiple scenarios of geophysical properties of the deposit, while planning the field infrastructure.

Generally, the class of problems addressed in the mentioned papers and also this research is called process network synthesis. A seminal work for this domain of stochastic models is (Tarhan & Grossmann, 2008). The paper incorporates a few theoretical developments concerning the issues of decision-dependent uncertainty.

Another notable direction in the stochastic optimisation of oil and gas field development involves the use of a reservoir simulation models. The paper (Cullick et al., 2004) describes planning the investments into a production system for several deposits with consideration of economic criteria and a certain tolerable level of risk, set up by a field operating company. The authors use finite-difference reservoir model to evaluate the properties of the deposit. Another research incorporating stochastic reservoir properties is presented in the article (Bellout et al., 2007), where the authors contemplate simultaneous decisions on well locations and the anticipated operating modes.

Application of deterministic modelling for planning field infrastructure and operations, for instance, suggested in (Frair & Devine, 1975) or (Iyer et al., 1998), leads to solutions when either all the wells in the plan must be drilled or certain wells or sections of a petroleum deposit are avoided because they are deemed unprofitable in the circumstances of the deterministic data provided for the models. Stochastic modelling solutions also help to choose a certain number of wells for draining of the deposit. However, such solutions set up a reasonable strategy for learning about the deposits with uncertain reserves. That is, there might be an initial or a pilot plan, and the possibilities of expansions if the process is deemed profitable. To sum up, while deterministic models are prone to exclude small deposits from the development plan, the stochastic models might demonstrate certain flexibility and reveal the potential of small deposits due to consideration of optimistic and pessimistic evaluations of various uncertain geophysical parameters.

The model presented in the following section adopts the ideas of incorporating uncertainty in field development and operations planning (Tarhan et al., 2009). However, the necessary adaptations are made to fit the process descriptions into an engineering perspective through incorporating such details as pressure and flow profiles in the gathering system, artificial lift performance, and well interactions in the reservoir.

2. Field development and production scheduling model

Further, the problem of oilfield development and production planning is formulated for an offshore field, as demonstrated in Fig. 1. The wellheads located on the seabed are grouped into clusters around manifolds which play the role of gathering stations. The connections between the wells and the manifolds are made with short rigid pipelines called 'jumpers'. The gathered petroleum is delivered from these clusters, first, to a system of risers, and then to a processing facility, a platform called a 'floating production, storage and offloading' (FPSO) unit, where the export-quality petroleum is prepared. Usually, the processed hydrocarbons are offloaded to a shuttle tanker, which delivers the product to an onshore storage base.

An important assumption regarding the nature of a planning problem presented in this research is that the focus is entirely on the structures of the surface facilities (located on the seabed) and the system's

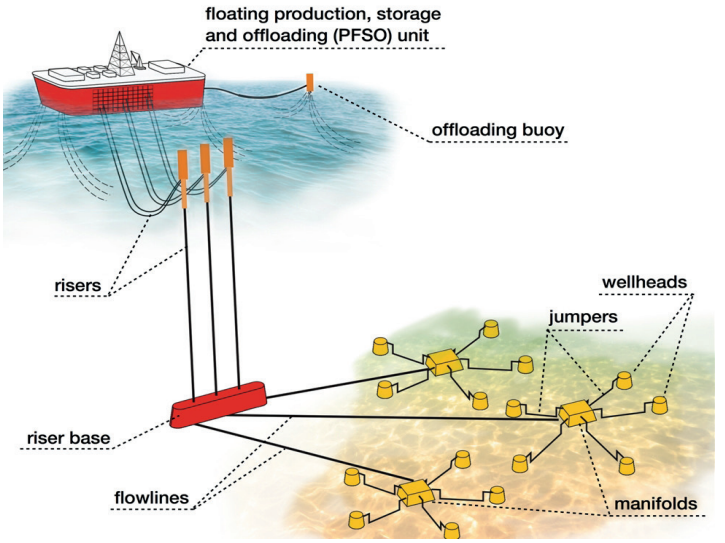

Fig. 1. Standalone offshore production system

Source: author's elaboration based on (Bai & Bai, 2012).

capacities. With this assumption, the layout of the underground structures is disregarded in the model (it is considered as simple as possible, perhaps, ordinary monobore wells).

In this research, the issue of operational efficiency of an artificial lift system is taken under a rather detailed consideration. In some works, e.g. (Tarhan et al., 2009), the operational costs are taken as a fixed amount of money per volume of produced fluid. However, there is a considerable amount of research like (Takács, 2009) or (Wang et al., 2002) pointing to the benefits of considering the operational efficiency of the chosen artificial lift. Given that one of the aims of this research is to capture the economic trade-off between all the capital investments, operational expenditures and profits from producing hydrocarbons, the operational efficiency is addressed here to some extent in details. For our setting, the production of hydrocarbons is assumed to be conducted with electrical submersible pumps (ESP). The decision-making model will drive the machinery's performance to work as closely to the best efficiency point as possible, so that the costs associated with operations can be suitably identified and balanced with other expenditures. The operating mode of the ESP equipment (and by extension its efficiency) is defined by the process values of hydrocarbon production flow rates from the wells and also, the frequency of the alternating current (AC) controlling the pump drive and allowing a certain flexibility in the pump operations.

The flows in the planned structures are considered homogeneous and consisting of oil and water. With this, it is assumed that there are no gas slugs in the flow. This is a reasonable assumption given that ESP technology allows separating the gas from the flow inside the well.

The model below considers in detail the flows and the pressures throughout the entire production system. With this, the pressures in the systems are balanced, and capacity limitations of the chosen gathering structures are considered. Ultimately, this allows avoiding the negative impact of the surface pipeline's backpressure on the wells' operations.

A simple linear model of the reservoir is considered here for long-term planning purposes. The model accounts for the reservoir productivity and interactions between the well during operations. The representation of the resource depletion with time is assumed to take an exponential form.

Given the assumptions above, the goal of the decision-making model is to make the following choices:

- the number of wells to drill and their locations,
- the number, location, and capacities of manifolds,
- the assignment of wells to manifolds (connecting with jumpers), capacities of the jumpers,
- capacities of the flowlines connecting the manifolds to the riser base,
- the processing capacity of the platform, and the need for expanding this capacity,
- the assignment of each development activity (drilling wells, installing manifolds, jumpers, flowlines, and capacity expansions) to periods,
- production operations (production rates, AC frequencies, and so on) during each period,
- the timeline for the end of the production operations after the water breakthrough.

These decisions are made with the consideration of geophysical uncertainty considered in the form of the following stochastic parameters in the provided mathematical formulation:

- *reservoir productivity and well interaction factors* which come in the form of a matrix (coefficients) of a linear model. Note that these parameters

directly correspond to the initial oil flow rates at the start of the production operations;
- *production decline rate*. Note that this parameter in combination with initial production rates leads to an eventual estimation of recoverable reserves of the deposit;
- *water breakthrough time*, the timeline when the hydrocarbon production becomes no longer possible due to the wells starting to produce only water that is being injected into the reservoir to maintain the necessary pressure.

A distinctive trait of the oil and gas industry projects is that knowledge, especially that of the deposit geophysics, is obtained gradually throughout the operations. It means that uncertainty represented by the listed stochastic parameters does not resolve completely at every planning period of the multi-stage problem. The uncertainty is mitigated gradually by discovering certain information based on the decisions made during some earlier periods. The assumptions regarding this learning process for the problem setting considered in this research are listed below. The representation of gradual uncertainty resolution in the mathematical model mostly adopts the ideas of (Tarhan et al., 2009), with necessary adaptations for this paper:

- there is an initial start-up development programme comprising drilling a rather small predefined number of wells N^{init}, install a certain number of manifolds, lay out the pipeline, and eventually start the production process. This initial programme collects the knowledge of the reservoir, i.e. values of the productivity coefficients and well interaction coefficients. By extension, this allows to figure out the initial production rates from the drilled wells, as well as the intensity of the well interaction through the porous medium;
- there is a possibility to continue the field development by drilling more wells (up to N^{ext} in total), and respectively expand the gathering infrastructure. Fulfilling this extended development programme allows gaining full knowledge of the production decline slopes for the producing wells, and by extension, the deposit's recoverable reserves;
- as an alternative to the expensive and troublesome extended development programme, the knowledge of the recoverable reserves may be unveiled by producing only from the N^{init} wells that were initially drilled. However, a certain time $T^{\dagger}$ of continuous production must elapse so that the values of production decline rates might be evaluated. This is another strategy that the model might suggest estimating the recoverable hydrocarbon reserves;
- the uncertainty in the water breakthrough time is assumed to be independent of the development/drilling decisions. This uncertainty gets resolved when the field becomes mature, i.e. the field must be producing for a certain number of years $T^{\ddagger}$, so that the water breakthrough time becomes known.

Below, the mathematical model is presented. The necessary notations are provided in Tab. 1-3.

The objective function (1) bears the meaning of maximising the expected net present value of the petroleum development and production project. The first term of the NPV for each single scenario represents the revenues from the sales of the produced petroleum. The second term describes the costs of well drilling. The next term corresponds to the manifold installations with the chosen capacities.

Tab. 1. Notations for the lifecycle planning model (sets and indices)

Notation	Description	Notation	Description
NW	total number of potential well drilling locations	i, j	wells, $i, j \in \{1...NW\}$
NM	maximum number of potential manifolds	m	manifolds, $m \in \{1...NM\}$
T	total number of time periods	t, τ	time periods, $t, \tau \in \{1...T\}$
NMC	number of manifold capacity options	k	manifold capacity, $k \in \{1...NMC\}$
NJC	number of jumper capacity options	l	jumper capacity, $l \in \{1...NJC\}$
NFC	number of flowline capacity options	r	flowline capacity, $r \in \{1...NFC\}$
NPC	number of platform processing capacity options	β	platform capacity, $\beta \in \{1...NPC\}$
NEC	number of potential processing capacity expansions	γ	expansion capacity, $\gamma \in \{1...NEC\}$
NS	total number of scenarios	s, s'	scenarios, $s, s' \in \{1...NS\}$

Tab. 2. Notations for the lifecycle planning model (parameters)

Notation	Description
x^{RB}, y^{RB}	location (horizontal coordinates) of the riser base, [m]
x_i^{WL}, y_i^{WL}	location (horizontal coordinates) of well *i*, [m]
x_m^{ML}, y_m^{ML}	location (horizontal coordinates) of manifold *m*, [m]
$L_{i,m}^{J}$	jumper length, corresponding to the distance between well *i* and manifold *m*, [m]
L_m^{MF}	length of the flowline, corresponding to the distance between manifold *m* and the riser base, [m]
H_i	depth of well *i*, [m]
H^{sea}	depth of the sea bed, [m]
TD_i	well *i* production tubing diameter, [m]
S_k	allowed number of connections manifold capacity option *k*
D_l^J	diameter of option *l* of the jumper capacity, [m]
D_r^{MF}	diameter of option *r* of the flowline capacity chosen for the manifold flowlines, [m]
Q_β^{FPSO}	processing capacity option β of initially installed FPSO, [m³/d]
Q_γ^{PCE}	capacity expansion option γ for the gathering system, [m³/d]
Δ_t	duration of time period *t*, [d]
N^{init}	number of wells to drill to complete the initial development plan
N^{ext}	number of wells to drill to complete the extended development plan, maximum allowed number of well-drilings
T^t	number of production years (or time periods) necessary to evaluate the recoverable hydrocarbon reserves
T^t	number of production years (or time periods) necessary to evaluate the water breakthrough time
T_s^{WB}	time interval before the water breakthrough occurs for the entire field and the production stops, scenario *s*
ε	minimal total field flow rate necessary for the whole system to be viewed as producing, small number, [m³/d]
DC_t	maximum number of wells to be drilled during time period *t*
MC_t	maximum number of manifolds to be installed during time period *t*
PC_t	maximum number of pipeline segments to be commissioned during time period *t*
C	pipeline grade factor for Hazen-Williams formula; assumes the value of 120 for new pipes, 94-100 for old pipes
p^{RBmin}	necessary pressure at the riser base during time period *t*, [Pa]
p^{BHmin}	the lowest allowed bottomhole pressure, [Pa]
p^R	reservoir pressure, [Pa]
ρ	the density of the produced fluid, [kg/m³]
g	standard acceleration due to gravity, [m/s²]
$\alpha_{i,j,s}$	reservoir model coefficients, whose values are related to the wells' productivity, as well as influence between each pair *i* and *j*, scenario *s*, [Pa·d/m³]
$\sigma_{i,s}$	production decline slope for well *i*, scenario *s*, [1/d]
f^{max}	the highest allowed alternating current frequency, [Hz]
B	large number
C_i^W	cost of drilling well *i*, [USD]
C_k^M	cost of manifold capacity option *k*, [USD]
C_l^J	cost of jumper capacity option *l* per unit of length, [USD/m]
C_r^F	cost of flowline capacity option *r* per unit of length, [USD/m]
C_β^{FPSO}	cost of the initially installed FPSO with the chosen processing capacity option β, [USD]
C_γ^{PCE}	cost of employing a processing capacity expansion option γ for the platform or the gathering system, [USD]
C_t^{proc}	cost of water handling during time period *t* per volume unit, [USD/m³]
P_t^{oil}	price of oil per volume unit in time period *t*, [USD/m³]
P_t^{el}	price of electricity during time period *t* per kWh, [USD/kWh]
δ_t	cash flow discounting coefficient for time period *t*, fraction
$P_s^{scenario}$	probability of scenario *s*, fraction $\in$ [0; 1]

Tab. 3. Notations for the lifecycle planning model (variables and functions)

Notation	Description
binary variables (decision variables)	
$z^{W}_{i,t,s}$	equals 1, if well i is drilled and completed at time period *t*, scenario *s*; 0, otherwise
$z^{M}_{m,k,t,s}$	equals 1, if manifold m is assigned a capacity option k and installed during time period *t*, scenario *s*; 0, otherwise
$z^{J}_{i,m,l,t,s}$	equals 1, if well *i* is tied back to manifold m via jumper with capacity option *l*, and the jumper is installed during time period *t*, scenario *s*; 0, otherwise
$z^{MF}_{m,r,t,s}$	equals 1, if a flowline from manifold *m* to the riser base capacity option *r* is installed during time period *t*, scenario *s*; 0, otherwise
$z^{FPSO}_{\theta,s}$	equals 1, if the platform is installed with the initial processing capacity option θ, scenario *s*; 0, otherwise
$z^{PCE}_{\gamma,t,s}$	equals 1, if the processing capacity expansion option γ is engaged starting period *t*, scenario *s*; 0, otherwise
binary variables (state variables)	
$z^{compl}_{i,t,s}$	equals 1, if well *i* is drilled and completed within the time up to period *t*, and the chain from the well to the platform is ready for production starting next time period, scenario *s*; 0, otherwise
$z^{prod}_{t,s}$	equals 1, there the reservoir is producing petroleum, i.e. water breakthrough has not yet happened in time period *t*, scenario *s*; 0, otherwise
$z^{flow}_{t,s}$	equals 1, if there is a flow from the drilled and operated wells during time period *t*, scenario *s*; 0, otherwise
$\zeta^{init.plan}_{t,s}$	equals 1, if only the initial development plan has been being implemented so far by the end time period *t*, scenario *s*; 0, otherwise
$\zeta^{ext.plan}_{t,s}$	equals 1, if an extended development plan is being implemented by the end time period *t*, scenario *s*; 0, otherwise
$\zeta^{maturity}_{t,s}$	equals 1, if by the end of time period *t*, the reservoir is mature enough to resolve the recoverable reserves uncertainty, scenario *s*; 0, otherwise
$\zeta^{wbt}_{t,s}$	equals 1, if by the end of time period *t*, the reservoir has been exploited long enough to determine the water breakthrough time, scenario *s*; 0, otherwise
$z_{s,s',t}$	equals 1, if at the beginning of period *t*, scenario *s* and *s'* are indistinguishable; 0, otherwise
continuous variables (process values and pipeline segment diameters)	
$q_{i,t,s}$	fluid production rate from well *i* during period *t*, scenario *s*, [m^3/d]
$oc_{i,t,s}$	oil cut for the flow from well *i* during time period *t*, scenario *s*, fraction
$q^{J}_{i,m,t,s}$	flow through the jumper between well *i* and manifold *m* during time period *t*, scenario *s*, [m^3/d]
$q^{MF}_{m,t,s}$	flow through manifold *m* during time period *t*, scenario *s*, [m^3/d]
$d^{J}_{i,m,s}$	diameter of the jumper between well *i* and manifold *m*, scenario *s*, [m]
$d^{MF}_{m,s}$	diameter of the flowline between manifold *m* and the riser base, scenario *s*, [m]
$p^{BH}_{i,t,s}$	bottomhole pressure at well *i* during time period *t*, scenario *s*, [Pa]
$p^{WH}_{i,t,s}$	wellhead pressure at well *i*, scenario *s*, [Pa]
$p^{M}_{m,t,s}$	pressure at manifold *m* during time period *t*, scenario *s*, [Pa]
$p^{RB}_{t,s}$	pressure at the riser base during time period *t*, scenario *s*, [Pa]
$p^{TD}_{i,t,s}$	total developed pressure of the ESP in well *i* during time period *t*, scenario *s*, [Pa]
$f^{ESP}_{i,t,s}$	AC frequency used in VSD controlling the ESP in well *i* during time period *t*, scenario *s*, [Hz]
$N^{HL}_{i,t,s}$	hydraulic lift power developed by the ESP installation in well *i* during time period *t*, scenario *s*, [kW]
$\eta^{ESP}_{i,t,s}$	total efficiency of the ESP installation in well *i* during time period *t*, scenario *s*, fraction
functions	
$F^{TDH}_{i}(q,f)$	total developed head of the pump installed in well *i*
$F^{eff}_{i}(q,f)$	motor efficiency characteristic for the pump drive installed in well *i*
$p^{fr}(q,d,L)$	friction losses in the pipeline segment
NPV_{s}	net present value of the project, scenario *s*

$$\max ENPV = \sum_{s=1}^{NS} P_s^{scenario} \cdot NPV_s$$

$$\begin{aligned} NPV_s = & \sum_{t=1}^{T} \delta_t \cdot P^{oil} \cdot \Delta_t \cdot \sum_{i=1}^{NW} oc_{i,t,s} \cdot q_{i,t,s} - \sum_{t=1}^{T} \delta_t \cdot \sum_{i=1}^{NW} C_i^W \cdot z_{i,t,s}^W - \sum_{t=1}^{T} \delta_t \cdot \sum_{m=1}^{NM} \sum_{k=1}^{NMC} C_k^M \cdot z_{m,k,t,s}^M \\ & - \sum_{t=1}^{T} \delta_t \cdot \sum_{i=1}^{NW} \sum_{m=1}^{NM} \sum_{l=1}^{NMC} C_l^J \cdot L_{i,m}^J \cdot z_{i,m,l,t,s}^J - \sum_{t=1}^{T} \delta_t \cdot \sum_{m=1}^{NM} \sum_{r=1}^{NFC} C_r^F \cdot L_m^{MF} \cdot z_{m,r,t,s}^{MF} \\ & - \sum_{\beta=1}^{NPC} C_\beta^{FPSO} \cdot z_{\beta,s}^{FPSO} - \sum_{t=1}^{T} \delta_t \cdot \sum_{\gamma=1}^{NEC} C_\gamma^{PCE} \cdot z_{\gamma,t,s}^{PCE} \\ & - \sum_{t=1}^{T} \delta_t \cdot C_t^{proc} \cdot \Delta_t \cdot \sum_{i=1}^{NW} \left(1 - oc_{i,t,s}\right) \cdot q_{i,t,s} - \sum_{t=1}^{T} \delta_t \cdot 24 \cdot P_t^{el} \cdot \Delta_t \cdot \sum_{i=1}^{NW} \frac{N_{i,t,s}^{HL}}{\eta_{i,t,s}^{ESP}} \end{aligned} \quad (1)$$

$$\delta_t = \left(1+i\right)^{-\left(\sum_{\tau=1}^{t} \Delta_t / 365 - 1\right)} \quad (2)$$

The fourth term corresponds to the costs of the jumpers, given their well-to-manifold allocations. The fifth term goes for the flowline costs. The sixth term is associated with the choice of the initial processing capacity of the platform, while the following term accounts for potential processing capacity expansions in the following years. The eighth term corresponds to the processing of the fluid flow, i.e. separating the petroleum from the water. The ninth term describes the electricity consumption for the chosen ESP operating modes. All the costs and revenues are considered for each period of the planning horizon and the discounting coefficients (2) for the uneven time periods are applied to adjust the cash flows to their present value.

The constraints for the model are provided below, and they are grouped into several broad categories.

2.1. Structure constraints

Constraints (3) state that at any potential well drilling location, no more than one well may be drilled. Constraints (4) state that at any potential manifold placing location, no more than one manifold may be installed, it may be installed only once, and only one capacity option may be chosen for it. Inequalities (5) and (6) say that each drilled well should be included in the gathering network by connecting it to a manifold via a jumper. Equality (7) declares that from any installed manifold, a flowline must be laid to the riser base, and a capacity choice should be made for the pipeline. Expression (8) ensures the installation of a processing platform with a certain chosen capacity.

$$\sum_{t=1}^{T} z_{i,t,s}^W \le 1, \quad \forall i \in \{1..NW\}, \forall s \in \{1..NS\} \quad (3)$$

$$\sum_{t=1}^{T} \sum_{k=1}^{NMC} z_{m,k,t,s}^M \le 1, \quad \forall m \in \{1..NM\}, \forall s \in \{1..NS\} \quad (4)$$

$$\sum_{t=1}^{T} \sum_{m=1}^{NM} \sum_{l=1}^{NJC} z_{i,m,l,t,s}^J \ge \sum_{t=1}^{T} z_{i,t,s}^W, \quad \forall i \in \{1..NW\}, \forall s \in \{1..NS\} \quad (5)$$

$$\sum_{t=1}^{T} \sum_{l=1}^{NJC} z_{i,m,l,t,s}^J \le 1, \quad \forall i \in \{1..NW\}, \forall m \in \{1..NM\}, \forall s \in \{1..NS\} \quad (6)$$

$$\sum_{t=1}^{T} \sum_{r=1}^{NFC} z_{m,r,t,s}^{MF} = \sum_{t=1}^{T} \sum_{k=1}^{NMC} z_{m,k,t,s}^M, \quad \forall m \in \{1..NM\}, \forall s \in \{1..NS\} \quad (7)$$

$$\sum_{\beta=1}^{NPC} z_{\beta,s}^{FPSO} = 1, \quad \forall s \in \{1..NS\} \quad (8)$$

2.2. Gathering system flows and capacities

A capacity choice for each manifold should be made according to the number of jumpers connected to it (9).

The capacity choice for the jumper and flowlines is provided in groups (10)–(12) and (13)–(16), respectively. To choose a suitable jumper diameter, a nonlinear function, also known as the Hazen-Wil-

liams formula (Centrilift, 1997), is used in (12) for determining the pressure drop in a pipeline. In this function, continuous decision variables for jumper lengths, flow rates (10) and diameters (11) are used. The latter two expressions are connected to the corresponding design binaries. The last term on the right-hand side of the expression (12) makes the pressure difference constraints enforced only for those 'well-manifold' pairs that are chosen by the model to be connected with jumpers. Similar logic applies to the description of the flows in the pipelines connecting the manifolds to the riser base (13)–(16).

The constraint (17) declares that the amount of fluid delivered to the processing unit should correspond to its processing capacity, whether it is merely initially chosen FPSO's capacity or some additional expansions have been employed.

2.3. Scheduling constraints

Logical constraints are applied to properly sequence the development activities in time. Specifically, they suggest that the pipeline segments must be installed only after the corresponding structural elements are completed. Expression (18) states that any jumper must be placed only after the corresponding well is drilled and the manifold is commissioned. Similarly, each flowline should be laid after the manifolds are installed (19). The following constraints (20)–(22) represent scheduling limitations, i.e. a maximum number of wells that can be drilled

$$\sum_{t=1}^{T}\sum_{i=1}^{NW}\sum_{l=1}^{NJC} z^{J}_{i,m,l,t,s} \le \sum_{t=1}^{T}\sum_{k=1}^{NMC} S_k \cdot z^{M}_{m,k,t,s}, \quad \forall m \in \{1..NM\}, \forall s \in \{1..NS\} \tag{9}$$

$$q^{J}_{i,m,t,s} = \sum_{\tau=1}^{t}\sum_{l=1}^{NJC} q_{i,t,s} \cdot z^{J}_{i,m,l,\tau,s}, \quad \forall i \in \{1..NW\}, \forall m \in \{1..NM\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{10}$$

$$d^{J}_{i,m,s} = \sum_{t=1}^{T}\sum_{l=1}^{NJC} D^{J}_{l} \cdot z^{J}_{i,m,l,\tau,s}, \quad \forall i \in \{1..NW\}, \forall m \in \{1..NM\}, \forall s \in \{1..NS\} \tag{11}$$

$$p^{WH}_{i,t,s} - p^{M}_{m,t,s} \ge p^{fr}\left(q^{J}_{i,m,t,s}, d^{J}_{i,m,s}, L^{J}_{i,m}\right) - B \cdot \left(1 - \sum_{\tau=1}^{t}\sum_{l=1}^{NJC} z^{J}_{i,m,l,\tau,s}\right), \forall i \in \{1..NW\}, \forall m \in \{1..NM\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\};$$
$$\text{where } p^{fr}(q,d,L) = 7.68 \cdot 10^{-9} \cdot \rho \cdot g \left(\frac{q}{C}\right)^{1.85} \cdot \frac{L}{D^{4.89}}, \text{and lengths } L^{J}_{i,m} = \sqrt{\left(x^{WL}_{i} - x^{ML}_{m}\right)^2 + \left(y^{WL}_{i} - y^{ML}_{m}\right)^2} \tag{12}$$

$$q^{MF}_{m,t,s} = \sum_{i=1}^{NW} q^{J}_{i,m,t,s}, \quad \forall m \in \{1..NM\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{13}$$

$$d^{MF}_{m,s} = \sum_{t=1}^{T}\sum_{r=1}^{NFC} D^{MF}_{r} \cdot z^{MF}_{m,r,t,s}, \quad \forall m \in \{1..NM\}, \forall s \in \{1..NS\} \tag{14}$$

$$p^{M}_{m,t,s} - p^{RB}_{t,s} \ge p^{fr}\left(q^{MF}_{m,t,s}, d^{MF}_{m,s}, L^{MF}_{m}\right) - B \cdot \left(1 - \sum_{\tau=1}^{t}\sum_{k=1}^{NMC} z^{M}_{m,k,\tau,s}\right), \forall m \in \{1..NM\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\};$$
$$\text{and lengths } L^{MF}_{m} = \sqrt{\left(x^{RB} - x^{ML}_{m}\right)^2 + \left(y^{RB} - y^{ML}_{m}\right)^2} \tag{15}$$

$$p^{RB}_{t,s} \ge p^{RB\min}, \quad \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{16}$$

$$\sum_{i=1}^{NW} q_{i,t,s} \le \sum_{\beta=1}^{NPC} Q^{FPSO}_{\beta} \cdot z^{FPSO}_{\beta,s} + \sum_{\gamma=1}^{NEC}\sum_{\tau=1}^{t} C^{PCE}_{\gamma} \cdot z^{PCE}_{\gamma,\tau,s}, \quad \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{17}$$

$$\sum_{\tau=1}^{t}\sum_{l=1}^{NJC} z^{J}_{i,m,l,t,s} \le \sum_{\tau=1}^{t} z^{W}_{i,\tau,s} \cdot \sum_{\tau=1}^{t}\sum_{k=1}^{NMC} z^{M}_{m,k,\tau,s}, \quad \forall i \in \{1..NW\}, \forall m \in \{1..NM\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{18}$$

$$\sum_{\tau=1}^{t}\sum_{r=1}^{NFC} z^{MF}_{m,r,t,s} \le \sum_{\tau=1}^{t}\sum_{k=1}^{NMC} z^{M}_{m,k,\tau,s}, \quad \forall m \in \{1..NM\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{19}$$

$$\sum_{i=1}^{NW} z^{W}_{i,t,s} \le DC_t, \quad \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{20}$$

$$\sum_{m=1}^{NM}\sum_{k=1}^{NMC} z^{M}_{m,k,t,s} \le MC_t, \quad \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{21}$$

$$\sum_{i=1}^{NW}\sum_{m=1}^{NM}\sum_{l=1}^{NMC} z^{J}_{i,m,l,t,s} + \sum_{m=1}^{NM}\sum_{r=1}^{NFC} z^{MF}_{m,r,t,s} \le PC_t, \quad \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{22}$$

and completed, and a maximum number of manifolds and pipeline segment that can be installed in each period.

2.4. Production scheduling

Logical constraints connecting the development and production phases require certain intricacy for proper decision-making in the setting that includes uncertainty considerations. Firstly, the intermediate (state) binary variable is introduced in (23) declaring that production from a well may only start no earlier than the entire path of infrastructure from the well to the riser base is finished. The processing platform is assumed to be installed and ready by the end of the very first period. Secondly, another intermediate variable is described in (24), ensuring the production from the reservoir is possible, i.e. that the water breakthrough has not happened. Finally, the logical constraints (25) allow the production to take place when the necessary conditions are met.

The constraint (26) describes yet another intermediate (state) binary, accounting for the periods when production is not only allowed but actually happens, i.e. if the production from the entire deposit is bigger than a pre-defined small value ε.

Technological constraints (27) represent the reservoir performance. The coefficients $\alpha_{i,j,s}$ correspond to the productivity indices for the wells and well interaction factors. The constraint (28) intends to provide an advisable range of the reservoir draining pressures. The next set of constraints (29) demonstrates how the operational conditions change from period to period, i.e. how the oil content in the produced fluid declines over time.

Constraints (30) through (32) characterise the performance of the artificial lift for every well in every period. Equation (30) describes the pressure developed by the ESP unit given the well inflow and the alternating current (AC) frequency controlling the motor. The function employs a polynomial approximation of a characteristic provided in the chosen pump documentation. The corrections are also applied to the curve given the variable AC frequency. The efficiency function (30) describes the total ESP system efficiency, a characteristic partly obtained from the curves from the equipment documentation and partly from the engineering reference sources like (Takács, 2009) and (Centrilift, 1997). Again, a polynomial approximation of the efficiency function is employed, with consideration of the variable AC frequency. Constraint (32) sets a technological limitation for the variable frequency drive used with the pumps. To estimate the energy used to lift the fluid from the formation to the processing unit, a formula of hydraulic lift power (33) adopted from (Takács, 2009) is used, and this concludes the evaluation of the artificial lift efficiency.

Finally, the pressure difference between the bottomhole and wellhead of each well is obtained in (34), given the chosen production operating mode for each period.

2.5. Uncertainty resolution

The following set of constraints (35)–(39) compute the values of the state binary variables that cor-

$$z_{i,t,s}^{compl} = \sum_{\tau=1}^{t} z_{i,\tau,s}^{W} \cdot \sum_{m=1}^{NM} \left[\sum_{\tau=1}^{t} \sum_{k=1}^{NMC} z_{m,k,\tau,s}^{M} \cdot \sum_{\tau=1}^{t} \sum_{l=1}^{NJC} z_{i,m,l,\tau,s}^{J} \cdot \sum_{\tau=1}^{t} \sum_{r=1}^{NFC} z_{m,r,\tau,s}^{MF} \right], \quad \forall i \in \{1..NW\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{23}$$

$$T_s^{WB} \cdot \left(1 - z_{t,s}^{flow}\right) \leq \sum_{\tau=1}^{t} \Delta_t \cdot z_{t,s}^{prod} \leq T_s^{WB} - 1 + B \cdot \left(1 - z_{t,s}^{flow}\right), \quad \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{24}$$

$$q_{i,t,s} \leq B \cdot z_{i,t-1,s}^{compl} \cdot z_{t,s}^{flow}, \quad \forall i \in \{1..NW\}, \forall t \in \{2..T\}, \forall s \in \{1..NS\} \tag{25}$$

$$\varepsilon \cdot z_{t,s}^{prod} \leq \sum_{i=1}^{NW} q_{i,t,s} \leq B \cdot z_{t,s}^{prod}, \quad \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{26}$$

$$p^{R} - p_{i,t,s}^{BH} = \sum_{j=1}^{NW} \alpha_{i,j,s} \cdot q_{j,t,s}, \quad \forall i \in \{1..NW\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{27}$$

$$p_{i,t,s}^{BH} \geq p^{BHmin}, \quad \forall i \in \{1..NW\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{28}$$

$$oc_{i,t,s} \cdot q_{i,t,s} \leq oc_{i,t-1,s} \cdot q_{i,t-1,s} - \sigma_{i,s} \cdot oc_{i,t-1,s} \cdot q_{i,t-1,s}, \quad \forall i \in \{1..NW\}, \forall t \in \{2..T\}, \forall s \in \{1..NS\} \tag{29}$$

$$\begin{gathered} p_{i,t,s}^{TD} = \rho \cdot g \cdot F_i^{TDH}\left(q_{i,t,s}, f_{i,t,s}^{ESP}\right), \quad \forall i \in \{1..NW\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\}; \\ F_i^{TDH}(q,f) = \left(a_2^{TDH} \cdot \left(q \cdot \frac{f_0}{f}\right)^2 + a_1^{TDH} \cdot q \cdot \frac{f_0}{f} + a_0^{TDH}\right) \cdot \left(\frac{f}{f_0}\right)^2 \end{gathered} \tag{30}$$

$$\begin{gathered} \eta_{i,t,s}^{ESP} = F_i^{eff}\left(q_{i,t,s}, f_{i,t,s}^{ESP}\right), \quad \forall i \in \{1..NW\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\}; \\ F_i^{eff}(q,f) = -\eta^{max}\left(\frac{2 \cdot f_0}{q^{max} \cdot f}\right)^2 \cdot q \cdot \left(q - q^{max} \cdot \frac{f}{f_0}\right) \end{gathered} \tag{31}$$

$$f_{i,t,s}^{ESP} \leq f^{max}, \quad \forall i \in \{1..NW\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{32}$$

$$N_{i,t,s}^{HL} = 10^{-3} \cdot \frac{q_{i,t,s}}{24 \cdot 60 \cdot 60} \cdot \left[\rho \cdot g \cdot \left(H_i + H^{sea}\right) - p_{i,t,s}^{BH}\right], \quad \forall i \in \{1..NW\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{33}$$

$$p_{i,t,s}^{BH} - p_{i,t,s}^{WH} \geq \rho \cdot g \cdot H_i + p^{fr}\left(q_{i,t,s}, TD_i, H_i\right) - p_{i,t,s}^{TD}, \quad \forall i \in \{1..NW\}, \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{34}$$

$$N_{t,s}^{wells} = \sum_{i=1}^{NW}\sum_{\tau=1}^{t} z_{i,\tau,s}^{compl}, \quad \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{35}$$

$$N^{init} \cdot \left(1 - \xi_{t,s}^{init.plan}\right) \le N_{t+1,s}^{wells} \le N^{init} - 1 + B \cdot \left(1 - \xi_{t,s}^{init.plan}\right), \quad \forall t \in \{1..(T-1)\}, \forall s \in \{1..NS\} \tag{36}$$

$$N^{ext} \cdot \left(1 - \xi_{t,s}^{ext.plan}\right) \le N_{t+1,s}^{wells} \le N^{ext} - 1 + B \cdot \left(1 - \xi_{t,s}^{ext.plan}\right), \quad \forall t \in \{1..(T-1)\}, \forall s \in \{1..NS\} \tag{37}$$

$$T^{\dagger} \cdot \left(1 - \xi_{t,s}^{maturity}\right) \le \sum_{\tau=1}^{t} \Delta_t \cdot z_{t,s}^{prod} \le T^{\dagger} - 1 + B \cdot \left(1 - \xi_{t,s}^{maturity}\right), \quad \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{38}$$

$$T^{\ddagger} \cdot \left(1 - \xi_{t,s}^{wbt}\right) \le \sum_{\tau=1}^{t} \Delta_t \cdot z_{t,s}^{prod} \le T^{\ddagger} - 1 + B \cdot \left(1 - \xi_{t,s}^{wbt}\right), \quad \forall t \in \{1..T\}, \forall s \in \{1..NS\} \tag{39}$$

respond to the learning process. These variables will further allow identifying the pairs of scenarios indistinguishable from the point of view of the accumulated knowledge by the end of each period, which in its turn influences the decisions that are to be made. The constraint (35) counts the number of wells drilled and completed up to the end of each period. The constraints (36) attains the proper value for the variable indicating whether the project is in the initial development phase or past it. The constraints (37) calculate a value for the variable indicating whether the project has moved to the phase of extended field development, i.e. more than N^{init} wells are being drilled. The constraints (38) account for the binary state variable indicating whether the field is mature enough to estimate its recoverable reserves. The constraints (39) account for the binary state variable indicating whether the field is mature enough to evaluate the end of production due to the water breakthrough.

Tab. 4 describes the scenario subsets *M1...M7* which differ only in the given uncertainty kinds specified with checkmarks in the table. Further, the constraints (40)–(46) reducing the decision space due to the scenario pairs (*s*, *s'*) being indistinguishable at certain time periods, are provided.

Decision "reduction". Conditional non-anticipativity constraints (40)–(46) reveal if any scenario pair is indistinguishable during the multi-stage decision-making process, based on the scenario subsets in Tab. 4.

Tab. 4. Scenario sets that differ only in the specified parameters

Parameter	M_1	M_2	M_3	M_4	M_5	M_6	M_7
Productivity and interactions	✓			✓	✓		✓
Decline slopes (recoverable reserves)		✓		✓		✓	✓
Water breakthrough time			✓		✓	✓	✓

$$\left(1 - \xi_{t,s}^{init.plan}\right) + z_{s,s',t} \ge 1, \ \xi_{t,s}^{init.plan} \ge z_{s,s',t}, \quad \forall t \in \{2..T\}, (s,s') \in M_1 \tag{40}$$

$$\left(1 - \xi_{t,s}^{init.plan}\right) + \left(1 - \xi_{t,s}^{maturity}\right) + z_{s,s',t} \ge 1, \xi_{t,s}^{init.plan} \ge z_{s,s',t}, \xi_{t,s}^{maturity} \ge z_{s,s',t}, \forall t \in \{2..T\}, (s,s') \in M_2 \tag{41}$$

$$\left(1-\xi_{t,s}^{wbt}\right)+z_{s,s',t}\geq 1,\ \xi_{t,s}^{wbt}\geq z_{s,s',t},\quad \forall t\in\{2..T\},(s,s')\in M_3 \tag{42}$$

$$\begin{gathered}\left(1-\xi_{t,s}^{init.plan}\right)+\left(1-\xi_{t,s}^{ext.plan}\right)+\left(1-\xi_{t,s}^{maturity}\right)+z_{s,s',t}\geq 1,\\ \xi_{t,s}^{init.plan}\geq z_{s,s',t},\ \xi_{t,s}^{ext.plan}\geq z_{s,s',t},\ \xi_{t,s}^{maturity}\geq z_{s,s',t},\ \forall t\in\{2..T\},(s,s')\in M_4\end{gathered} \tag{43}$$

$$\left(1-\xi_{t,s}^{init.plan}\right)+\left(1-\xi_{t,s}^{wbt}\right)+z_{s,s',t}\geq 1,\xi_{t,s}^{init.plan}\geq z_{s,s',t},\xi_{t,s}^{wbt}\geq z_{s,s',t},\forall t\in\{2..T\},(s,s')\in M_5 \tag{44}$$

$$\begin{gathered}\left(1-\xi_{t,s}^{ext.plan}\right)+\left(1-\xi_{t,s}^{maturity}\right)+\left(1-\xi_{t,s}^{wbt}\right)+z_{s,s',t}\geq 1,\\ \xi_{t,s}^{ext.plan}\geq z_{s,s',t},\ \xi_{t,s}^{maturity}\geq z_{s,s',t},\ \xi_{t,s}^{wbt}\geq z_{s,s',t},\ \forall t\in\{2..T\},(s,s')\in M_6\end{gathered} \tag{45}$$

$$\begin{gathered}\left(1-\xi_{t,s}^{init.plan}\right)+\left(1-\xi_{t,s}^{ext.plan}\right)+\left(1-\xi_{t,s}^{maturity}\right)+\left(1-\xi_{t,s}^{wbt}\right)+z_{s,s',t}\geq 1,\\ \xi_{t,s}^{init.plan}\geq z_{s,s',t},\ \xi_{t,s}^{ext.plan}\geq z_{s,s',t},\ \xi_{t,s}^{maturity}\geq z_{s,s',t},\ \xi_{t,s}^{wbt}\geq z_{s,s',t},\ \forall t\in\{2..T\},(s,s')\in M_7\end{gathered} \tag{46}$$

Now that the conditions for the decision space reduction (variable $z_{s,s',t}$ values) are provided, the similarities in the decisions across the indistinguishable scenario sets may be determined in (47).

Finally, the initial non-anticipativity constraints (48) are presented. They represent the lack of knowledge of the deposit's geophysics at the very beginning of the decision-making process. For small examples, these constraints are usually needed only for the period t=1. However, for larger examples, it might take more periods until the very first uncertainty kind gets resolved (for our model, it is the uncertainty in the reservoir productivity). That is why below, the constraints are written down for the general case, where *INAC* is a set of scenarios and periods for whom these initial non-anticipativity constraints are required.

$$\begin{aligned}
&z_{i,t,s'}^{W}-B\cdot(1-z_{s,s',t})\leq z_{i,t,s}^{W}\leq z_{i,t,s'}^{W}+B\cdot(1-z_{s,s',t}), && \forall i\in\{1..NW\},\forall t\in\{2..T\},(s,s')\in\{1..NS\}\\
&z_{m,k,t,s'}^{M}-B\cdot(1-z_{s,s',t})\leq z_{m,k,t,s}^{M}\leq z_{m,k,t,s'}^{M}+B\cdot(1-z_{s,s',t}), && \forall m\in\{1..NM\},\forall k\in\{1..NMC\},\forall t\in\{2..T\},(s,s')\in\{1..NS\}\\
&z_{i,m,l,t,s'}^{J}-B\cdot(1-z_{s,s',t})\leq z_{i,m,l,t,s}^{J}\leq z_{i,m,l,t,s'}^{J}+B\cdot(1-z_{s,s',t}), && \forall i\in\{1..NW\},\forall m\in\{1..NM\},\forall l\in\{1..NJC\},\forall t\in\{2..T\},(s,s')\in\{1..NS\}\\
&z_{m,r,t,s'}^{MF}-B\cdot(1-z_{s,s',t})\leq z_{m,r,t,s}^{MF}\leq z_{m,r,t,s'}^{MF}+B\cdot(1-z_{s,s',t}), && \forall m\in\{1..NM\},\forall r\in\{1..NFC\},\forall t\in\{2..T\},(s,s')\in\{1..NS\}\\
&z_{\gamma,t,s'}^{PCE}-B\cdot(1-z_{s,s',t})\leq z_{\gamma,t,s}^{PCE}\leq z_{\gamma,t,s'}^{PCE}+B\cdot(1-z_{s,s',t}), && \forall \gamma\in\{1..NEC\},\forall t\in\{2..T\},(s,s')\in\{1..NS\}
\end{aligned} \tag{47}$$

$$\begin{aligned}
&z_{i,t,s}^{W}=z_{i,t,s'}^{W} && \forall i\in\{1..NW\},(s,s',t)\in INAC\\
&z_{m,k,t,s}^{M}=z_{m,k,t,s'}^{M}, && \forall m\in\{1..NM\},\forall k\in\{1..NMC\},(s,s',t)\in INAC\\
&z_{i,m,l,t,s}^{J}=z_{i,m,l,t,s'}^{J}, && \forall i\in\{1..NW\},\forall m\in\{1..NM\},\forall l\in\{1..NJC\},(s,s',t)\in INAC\\
&z_{m,r,t,s}^{MF}=z_{m,r,t,s'}^{MF}, && \forall m\in\{1..NM\},\forall r\in\{1..NFC\},(s,s',t)\in INAC\\
&z_{\beta,s}^{FPSO}=z_{\beta,s'}^{FPSO}, && \forall \beta\in\{1..NPC\},(s,s',t)\in INAC\\
&z_{\gamma,t,s}^{PCE}=z_{\gamma,t,s'}^{PCE}, && \forall \gamma\in\{1..NEC\},(s,s',t)\in INAC
\end{aligned} \tag{48}$$

3. Computational experiment. Problem setting and optimisation algorithm

For the computational experiment, a marginal oilfield of five potential wells is considered. The planning horizon is ten years, divided into five problem stages (two years each). Eight scenarios representing geophysical uncertainty are provided in Tab. 5. All the scenarios are deemed equally probable. The matrix A_1 represents rather high reservoir productivity and at the same time high influence between the wells. These conditions allow flow rates from the five wells to be up to 500m^3/d. The matrix A_2 stands for a relatively low reservoir productivity and at the same time low influence between the wells. These conditions allow flow rates from the five wells to be up to 200m3/d. Vectors S_1 represents relatively fast production decline: the decline rates are ranging from $4{\cdot}10^{-4}$ to $9{\cdot}10^{-4}$1/d. Vectors S_2, on the contrary, represents slow decline: the rates are ranging from $2{\cdot}10^{-4}$ to $4.5{\cdot}10^{-4}$1/d. Water breakthrough time is estimated to be either T_1^{wbt}=8 years or T_2^{wbt}=6 years.

According to Tab. 4 and 5, the subsets *M1...M7* include the following scenario pairs:

- M1: (1,2); (3,4); (5,6); (7,8)
- M2: (1,3); (2,4); (5,7); (6,8)
- M3: (1,5); (2,6); (3,7); (4,8)
- M4: (1,4); (2,3); (5,8); (6,7)
- M5: (1,6); (2,5); (3,8); (4,7)
- M6: (1,7); (2,8); (3,5); (4,6)
- M7: (1,8); (2,7); (3,6); (4,5)

The initial development plan includes drilling two wells, while the extended plan implied drilling all five wells. The production decline slopes are considered to be revealed after two years from the start of the production. The same timeline applies to the revealing of water breakthrough time. Initial non-anticipativity constraints for such problem setting are required during the first period (years one and two) only. Conditional non-anticipativity constraints work during the second period (years three and four). From t=3 and further (years five to ten) all the relevant geophysical characteristics are considered known.

The model was run with the MIDACO solver in the Matlab environment. This solver implements a black-box optimisation algorithm for large-scale mixed-integer nonlinear problems (MINLP). The employed algorithm combines a meta-heuristic ant-colony optimisation with an Oracle penalty method of constraint handling. The model was run 30 times, and each time the result of the previous run was used as a starting point. The techniques suggested in the user manual of the solver were employed during the runs to avoid getting stuck in local optima and to refine the obtained solution. The results of the modelling computations are presented in Tab. 6.

4. Discussion of the modelling results

As seen in the results, the problem setting for the marginal field taken as an example is viewed as generally favourable by the algorithm both in the deterministic and the stochastic settings.

For the stochastic problem setting, the initial production plan (drilling two wells) is initiated for all the scenarios. Moreover, the algorithm finds it profitable to drill at least three wells in every single scenario, even for the cases of small production rates and fast production decline (s=2 and s=6).

For the processing platform, the algorithm chooses the largest available processing capacity (1000 m^3/d), which turns out suitable for the initial production plan as well as for the scenarios with low reservoir productivity (s∈{2,4,6,8}). For the scenarios with higher reservoir productivity (s∈{1,3,5,7}) and thereby higher production rates, the algorithm suggests a capacity expansion of 2000m^3/d to be installed during the second period, after the uncertainty in productivity has become resolved. Also, for the scenarios with high production rates, the algorithm suggests drilling a second cluster of wells: two more wells connected to a newly installed manifold.

Tab. 5. Scenarios for the computational example

Parameter	s=1	s=2	s=3	s=4	s=5	s=6	s=7	s=8
Productivity and interactions matrix	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2
Decline slopes vector	S_1	S_1	S_2	S_2	S_1	S_1	S_2	S_2
Water breakthrough time	T_1^{wbt}	T_1^{wbt}	T_1^{wbt}	T_1^{wbt}	T_2^{wbt}	T_2^{wbt}	T_2^{wbt}	T_2^{wbt}

Tab. 6. Modelling results

Scenario	Description	CAPEX	OPEX	NPV
s=1	During *t*=1, drill wells W1, W3, install manifold M1 with 4 connections, install corresponding jumpers J11, J31 with diameter 10'', and flowline MF1 with diameter 20''. Install FPSO with processing capacity 1000m^3/d. Begin production. During *t*=2, drill W2, install J21. During *t*=3, drill W4 and W5, install M2 with 2 connections, install J42, J52 (10''), and MF2 (20''). Expand processing capacity by 2000m^3/d	141.709	37.766	883.906
s=2	During *t*=1, drill W1, W3, install M1 (4 conn.), install J11 and J31 (10''), and MF1 (20''). Install FPSO with processing capacity 1000 m^3/d. Begin production. During *t*=2, drill W2, install J21 (4'')	90.209	0.75	154.491
s=3	During *t*=1, drill W1, W3, install M1 (4 conn.), install J11, J31 (10''), and MF1 (20''). Install FPSO with processing capacity 1000 m^3/d. Begin production. During *t*=2, drill W2, install J21 (10''). During *t*=3, drill W4, W5, install M2 (2 conn.), install J42 and J52 (10''), and MF2 (20''). Expand processing capacity by 2000m^3/d	139.151	41.237	889.131
s=4	During *t*=1, drill W1, W3, install M1 (4 conn.), install J11, J31 (10''), and MF1 (20''). Install FPSO with processing capacity 1000m^3/d. Begin production. During *t*=2, drill W2, install J21 (4''). During *t*=3, drill W4, W5, install M2 (2 conn.), install J42, J52 (4''), and MF2 (8'')	135.038	0.58	198.753
s=5	During *t*=1, drill W1, W3, install M1 (4 conn.), install J11, J31 (10''), and MF1 (20''). Install FPSO with processing capacity 1000m^3/d. Begin production. During *t*=2, drill W2, install J21 (10''). During *t*=3, drill W4, W5, install M2 (2 conn.), install J42, J52 (10''), and MF2 (20''). Expand processing capacity by 2000m^3/d. For *t*=5, no production; water breakthrough.	139.151	34.470	613.795
s=6	During *t*=1, drill W1, W3, install M1 (4 conn.), install J11 and J31 (10''), and MF1 (20''). Install FPSO with processing capacity 1000m^3/d. Begin production. During *t*=2 drill W2, install J21 (4''). For *t*=5, no production; water breakthrough.	90.209	0.48	113.985
s=7	During *t*=1, drill W1, W3, install M1 (4 conn.), install J11 and J31 (10''), and MF1 (20''). Install FPSO with processing capacity 1000m^3/d. Begin production. During *t*=2, drill W2, install J21 (10''). During *t*=3, drill W4, W5, install M2 (2 conn.), install J42, J52 (10''), and MF2 (20''). Expand processing capacity by 2000m^3/d. For *t*=5, no production; water breakthrough.	141.709	19.617	584.600
s=8	During t=1, drill W1, W3, install M1 (4 conn.), install J11 and J31 (10''), and MF1 (20''). Install FPSO with processing capacity 1000m^3/d. Begin production. During *t*=2, drill W2, install J21 (4''). During *t*=3, drill W4, W5, install M2 (2 conn.), install J42, J52 (4''), and MF2 (8''). For *t*=5, no production; water breakthrough.	135.038	0.31	143.049
				ENPV: 447.714
Average values solution	During *t*=1, drill W1, W3, install M1 (4 conn.), install J11 and J31 (4''), and MF1 (8''). Install FPSO with processing capacity 500m^3/d. Begin production. During *t*=2, drill W2, W4, W5, install M2 (2 conn.), install J21, J42, J52 (4''), and MF2 (8''). Expand processing capacity by 1000m^3/d	136.083	32.537	274.863

These things get done in the third period, after the uncertainty in production decline, and water breakthrough becomes resolved.

When it comes to the capacity choices for the pipeline segments, that is the corresponding diameters, the initial choice (for *t*=1) is larger diameters. This is attributed mainly to the non-anticipativity constraints. When the very first decisions are made, there is no information on the flow rates from the wells draining the reservoir. The set of constraints (11)–(16) monitors the pressure drops along the gathering system to ensure the necessary pressure at the riser base. Pipeline segment diameters influence these pressure drops dramatically: refer to constraint (12) where the value of the diameter in the pressure loss function is included with the power of −4.89. Thereby, the algorithm chooses the larger diameters to get the pressure drops to be rather small. When the productivity is revealed, the diameter choice is made with respect to the reservoir draining rates. This is how the choice is made for the jumper diameter from Well 2 to Manifold 1 in period *t*=2, and also for the second cluster of wells (Well 4, Well 5, Manifold 2, Flowline 2) in period *t*=3. For low production rates ($s \in \{2,4,6,8\}$), the lower pipeline diameters are chosen for both jumpers and flowlines,

and for the higher rates ($s \in \{1,3,5,7\}$), the higher capacity options are selected.

The last line in Tab. 6 describes the solution for the model, where instead of the stochastic parameters their average evaluations were assumed. One may observe that unlike the stochastic solution, this average values solution does not wait for the 3rd period to finish the field development. However, given that the values of the productivities and well influence factors are considered as the average values, the resulting production rates are rather low, only up to 270m^3/d. This explains the fact the NPV of average values solution is lower than the expected NPV (ENPV) of the stochastic one. In the stochastic solution, there four outcomes that are far better than the outcome of the deterministic solution, there are two outcomes that are a little worse than the deterministic one and only two that are far worse than in the average values case. Therefore, generally, the stochastic formulation of the development and production planning problem views the problem setting for this example as more favourable than the deterministic formulation.

Conclusions

The strategic planning problem of optimising oilfield development and production operations has been addressed in this research with consideration of geophysical uncertainty. It has been demonstrated that the approach to planning under uncertainty and the approach of planning based on deterministic modelling with average values of stochastic parameters reveal a different attitude to the project lifecycle. The results of the stochastic modelling approach prove to be more nuanced and considerate to learning about the uncertain behaviour of the planned process and applying the gained knowledge to achieve good results. These characteristic attributes of the stochastic modelling make it beneficial for engineering departments working with planning the oilfield development activities in nonconventional environments. It is especially relevant for development projects where marginal fields and reservoirs are present. These small deposits are usually not studied in detail; however, the decision whether to develop them or not needs to be made.

With regards to the model composed in this study and the example, this research demonstrates certain limitations and drawbacks regarding the stochastic parameter representation. First of all, the 2-point distributions for the values of the stochastic parameters given in the example may not be good enough for some cases. Second, the stochastic representation of the reservoir may prove to benefit from the use of the specialised reservoir-simulating software that may work in conjunction with the black-box optimisation algorithm.

Generally speaking, in the modern context of energy resources and the pursuit of renewable energy, it may be of interest for planning projects in the petroleum sector to consider the energy market situation by introducing the hydrocarbon market price as a stochastic parameter. It may prove to have some bearing on whether to develop certain reserves or not, or whether it is best to produce the petroleum with rather low rates despite the possibility of producing faster.

From the modelling perspective, any of the mentioned ideas for further research in this domain will definitely increase the complexity of the model. The model as presented in this study is already a large nonlinear non-convex combinatorial problem, and even for a small example, it has thousands of variables and constraints. Thus, adding more complexity to the model would require a specialised and highly efficient heuristic algorithm that should perhaps include some decomposition procedures.

Literature

Aronofsky, J. S., & Williams, A. C. (1962). The use of linear programming and mathematical models in underground oil production. *Management Science*, *8*(4), 394-407. doi: 10.1287/mnsc.8.4.394

Bai, Y., & Bai, Q. (2012). *Subsea engineering handbook*. Waltham, USA: Gulf Professional Publishing.

Bellout, M. C., Ciaurri, D. E., Durlofsky, L. J., Foss, B., & Kleppe, J. (2012). Joint optimization of oil well placement and controls. *Computational Geosciences*, *16*(4), 1061-1079. doi: 10.1007/s10596-012-9303-5

Centrilift. (1997). *Submersible pump handbook*. Claremore, USA: Baker-Hughes Inc.

Cullick, S., Heath, D., Narayanan, K., April, J., & Kelly, J. (2004). Optimizing multiple-field scheduling and production strategy with reduced risk. *Journal of petroleum technology*, *56*(11), 77-83. doi: 10.2118/88991-JPT

Dawson, R. G., & Fuller, J. D. (1999). A mixed integer nonlinear program for oilfield production planning. *INFOR: Information Systems and Operational Research*, *37*(2), 121-140. doi: 10.1080/03155986.1999.11732375

Devine, M. D., & Lesso, W. G. (1972). Models for the minimum cost development of offshore oil fields. *Management Science*, *18*(8), 378-387. doi: 10.1287/mnsc.18.8.B378

Frair, L., & Devine, M. (1975). Economic optimization of offshore petroleum development. *Management Science*, *21*(12), 1370-1379. doi: 10.1287/mnsc.21.12.1370

Goel, V., & Grossmann, I. E. (2004). A stochastic programming approach to planning of offshore gas field developments under uncertainty in reserves. *Computers & chemical engineering*, *28*(8), 1409-1429. doi: 10.1016/j.compchemeng.2003.10.005

Gupta, V., & Grossmann, I. E. (2014). Multistage stochastic programming approach for offshore oilfield infrastructure planning under production sharing agreements and endogenous uncertainties. *Journal of Petroleum Science and Engineering*, *124*, 180-97. doi: 10.1016/j.petrol.2014.10.006

Haugen, K. K. (1996). A stochastic dynamic programming model for scheduling of offshore petroleum fields with resource uncertainty. *European Journal of Operational Research*, *88*(1), 88-100. doi: 10.1016/0377-2217(94)00192-8

Iyer, R. R., Grossmann, I. E., Vasantharajan, S., & Cullick, A. S. (1998). Optimal planning and scheduling of offshore oil field infrastructure investment and operations. *Industrial & Engineering Chemistry Research*, *37*(4), 1380-1397. doi: 10.1021/ie970532x

Jonsbråten, T. W. (1998a). *Optimization models for petroleum field exploitation* [PhD thesis]. Bergen, Norway: Norwegian School of Economics and Business Administration.

Jonsbråten, T. W. (1998b). Oil field optimization under price uncertainty. *Journal of the operational research society*, *49*(8), 811-818. doi: 10.1057/palgrave.jors.2600562

Mathieson, D. (2007). Forces That Will Shape Intelligent-Wells Development. *Journal of Petroleum Technology*, *1*(8), 14-16. doi: 10.2118/0807-0014-JPT

Redutskiy, Y. (2017a). Conceptualization of smart solutions in oil and gas industry. *Procedia Computer Science*, *109*, 745-753. doi: 10.1016/j.procs.2017.05.435

Redutskiy, Y. (2017b). Optimization of Safety Instrumented System Design and Maintenance Frequency for Oil and Gas Industry Processes. *Management and Production Engineering Review*, *8*(1), 46-59. doi: 10.1515/mper-2017-0006

Takács, G. (2009). *Electrical submersible pumps manual: design, operations, and maintenance*. Burlington, USA: Gulf professional publishing.

Tarhan, B., & Grossmann, I. E. (2008). A multistage stochastic programming approach with strategies for uncertainty reduction in the synthesis of process networks with uncertain yields. *Computers & Chemical Engineering*, *32*(4), 766-788. doi: 10.1016/j.compchemeng.2007.03.003

Tarhan, B., Grossmann, I. E., & Goel, V. (2009). Stochastic programming approach for the planning of offshore oil or gas field infrastructure under decision-dependent uncertainty. *Industrial & Engineering Chemistry Research*, *48*(6), 3078-3097. doi: 10.1021/ie8013549

Van den Heever, S. A., Grossmann, I. E., Vasantharajan, S., & Edwards, K. (2001). A Lagrangean decomposition heuristic for the design and planning of offshore hydrocarbon field infrastructures with complex economic objectives. *Industrial & Engineering Chemistry Research*. *40*(13), 2857-2875. doi: 10.1016/j.compchemeng.2011.03.026

Wang, P., Litvak, M., & Aziz, K. (2002). Optimization of Production Operations in Petroleum Fields. *Society of Petroleum Engineers*, *77658*, 1-12. doi: 10.2118/77658-MS