MAPPING OF NATURAL GAS SUPPLY CHAINS: LITERATURE REVIEW

Davor Dujak
Faculty of Economics in Osijek,
University of Josip Juraj Strossmayer in Osijek, Croatia
E-mail: ddujak@efos.hr

Abstract

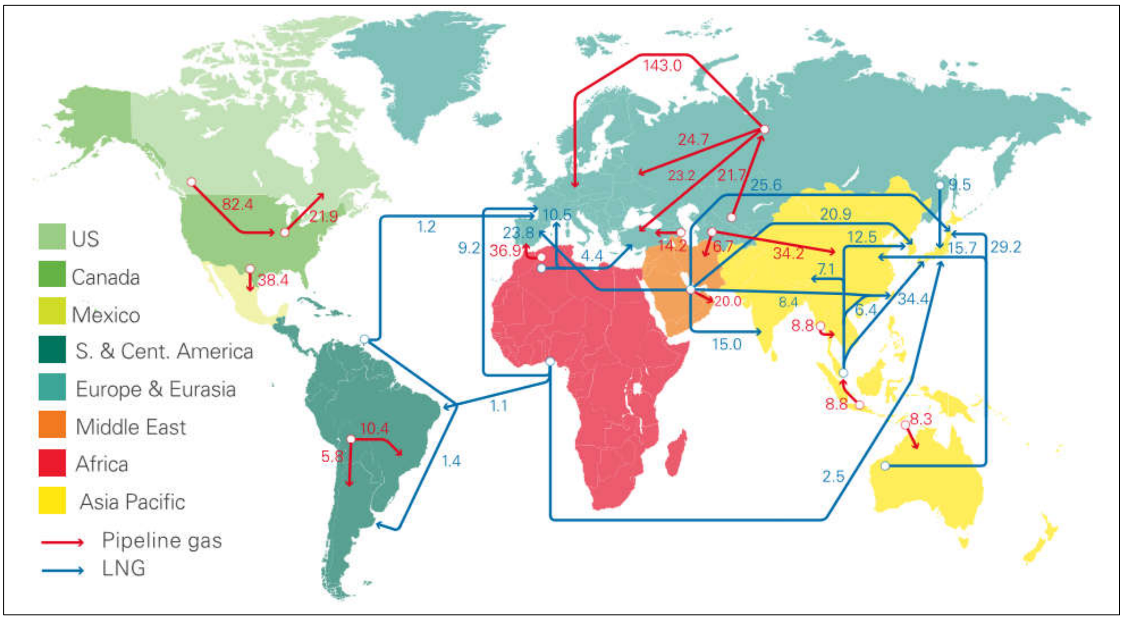
Natural gas is third most important fuel in the world with extremely complex supply chain that effects around one third of natural gas price. To mitigate complexity, to clarify position and processes, and to ensure maximum possible optimization of natural gas supply chain, practitioners and scientist use mapping method in creating a "picture" of natural gas supply chain. Aim of this research is to provide guidelines for effective use of mapping method in natural gas supply chain researches. Indicative preliminary research has be done by analysis analyzing and comparing most relevant scientific papers dealing with natural gas supply chain and their use of natural gas supply chain maps. Articles were analyzed according to following criteria: use of supply chain maps, type of used supply chain maps and selected supply chain map's attributes: coverage of map, spatial character of maps, number of supply chain tiers presented in maps, is there a focal point in maps and do maps highlight cycle view of supply chains. Results indicate that supply chain maps are essential tool for natural gas supply chain mapping where researcher mostly choose relationship based maps of evenly whole or part of supply chain, most often with 5 supply chain tiers, with no explicit spatial aspect, and no focal point and cycle view. Main study limitations are use of only one (although biggest) databases and limited number of papers taken into consideration. In further researches other relevant databases should be taken into consideration, and more specific maps' types could be analyzed.

Key words: supply chain, supply chain maps, natural gas, mapping

1. INTRODUCTION

Natural gas is fossil fuel that is third most important fuel today after coal and oil (Statista, 2017), and the fastest growing component of world primary energy consumption (Demirbas, 2006). It is also more environmentally friendly fuel than coal and oil (Liang et al, 2012). Specific of natural gas lies in a fact that areas of consumption and areas of production have significantly different spatial distribution, respectively some countries have significant gas surpluses, and other countries needs to import gas. Figure 1 shows natural gas trade movements worldwide.

Figure 1. Natural gas trade movements 2016 - trade flows worldwide (billion cubic metres)



Source: BP (2017). Natural gas trade movements according to CISStat, FGE MENAgas service, HIS [available at: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/natural-gas/natural-gas-trade-movements.html access August 1, 2017]

Trade agreements are almost always followed by supply chains for delivering subject of trade – physical flows of natural gas. Flows through natural gas supply chain are using either pipelines or LNG (Liquefied Natural Gas) transport form of transportation and warehousing. There are numerous definitions of supply chain, but for this paper we cite Chopra & Meindl (2016): *supply chain consist of all parties involved directly or indirectly, in fulfilling a customer request...includes all functions involved in receiving and filling a customer request*. Supply chain of natural gas is complex and important part of natural gas sector. Just transmission and distribution of natural gas to final consumers, accounts for more than 30 percent of natural gas price (Hamedi et al, 2009). Huge distances, many supply chain members, different technological, logistical and economical processes, complex law and professional regulations in different countries on the way to final consumer contribute to complexity and potential risks in natural gas supply chains. To mitigate complexity, to clarify position and processes, and to ensure maximum possible optimization of natural gas supply chain, practitioners and scientist use mapping method in creating a "picture" of natural gas supply chain.

Mapping is pervasive and supportive activity that is recommended for use in all areas of supply chain management and to all members of the supply chain. Gardner & Cooper (2003) state numerous reasons for use of maps (especially strategic supply chain maps) in supply chain management, and some of most important are arising from an ability of supply chain map to increase the understanding of a supply chain (both during its developing and its dissemination), to link the corporate and supply chain strategy, to display current channel dynamics and offer possibilities for chain redesign, and to ease integration processes in supply chain – both their implementation as well as their controlling. Even most simple supply chain map, collaboratively developed, will lead to clearer understanding of each member's position and processes in supply chain which in turn can result in avoiding of work duplication in supply chain, higher motivation, better coordination, forecasting and replenishment efficacy, and increased chances for other supply chain process improvement. This visual representation becomes a starting point (Lambert et al, 2014) for potential improvements in supply chain. Therefore, mapping (in line with use of metrics, ICT and different lean methods) has become essential tool for most supply chain practitioners and method of mapping has been widely used in scientific papers as well.

The aim of this paper is to give answer to following research questions: How often is method of mapping used in papers dealing with natural gas supply chains? Which type of supply chain maps are used in papers dealing with natural gas supply chains and what are maps' main attributes characteristics? By answering research question, paper will try to deliver its purpose – to provide overview and guidelines for more effective use of mapping method in natural gas supply chain researches. Paper starts with previous research review of supply chain mapping and continues with methodology clarification. Results of preliminary research are presented in next chapter, following by discussion and conclusion.

2. SUPPLY CHAIN MAPPING

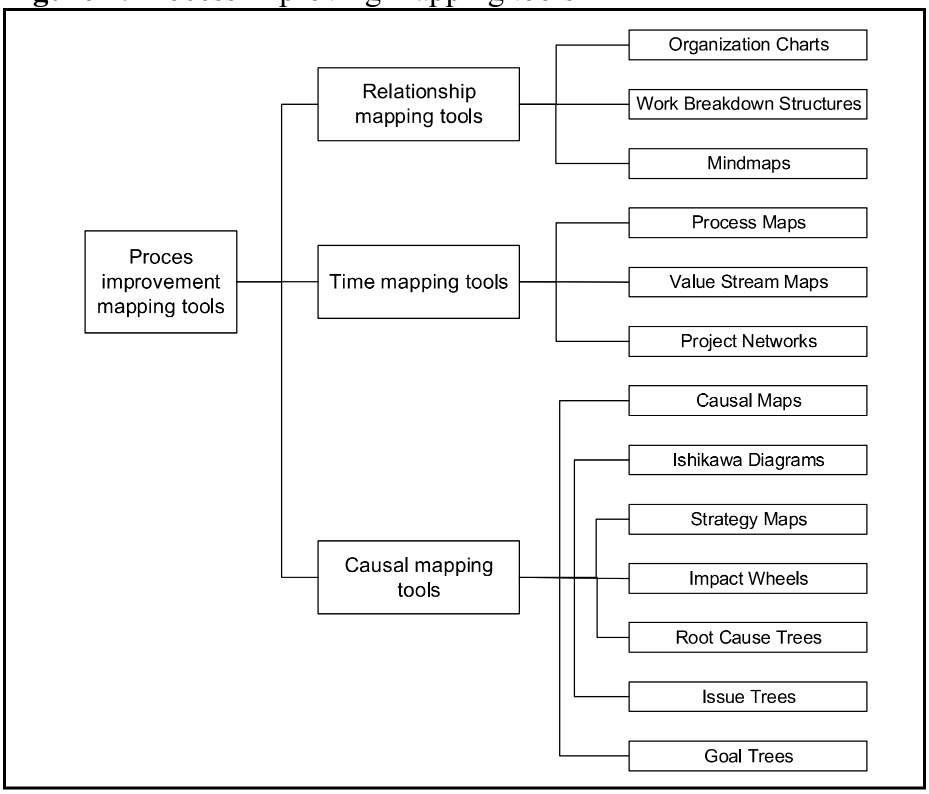
Gardner & Cooper (2003) define supply chain map as a *representation of the linkages and members of supply chain along with some information about the overall nature of the entire map*. Miyake et al (2010) highlights how supply chain map result from the collection of different kinds of data and results in a holistic view that "no one person has ever caught in its entirety". There are two essential elements that every supply chain map has to indicate: supply chain entity (member) and supply chain flow. Additionally, every map describes different features of entities, supply echelons, flow directions and flow characteristics, and characteristics of other activities in this supply chain. Supply chain maps can be developed either for whole supply chain, or just for its smaller parts (relationships between two or more entities).

Different approaches to supply chain mapping exist, resulting into different supply chain mapping classifications. According to Lambert's approach to the supply chain management based on the management of relations and cooperation, maps can be divided into relationship–based maps and activity-based maps (Lambert et al, 2014). Relationships-based maps are starting point for identifying the key members of the supply chain and are used for the allocation of resources within the network organization. They are usually drawn from the perspective of a company that is in focus (focal company), and usually map is done for the needs of this company (Lambert et al, 2014). Relationship-based maps are used to create broad picture with flows and other relationships among major groups of supply chain members, and they don't focus on specific activities. Relationships and/or flows are usually represented with different types of arrows (Handfield & Nichols, 2002), and most represented are material and information flows – as an example see supply chain map in (Kolinski & Sliwczynski, 2015).

On the basis of relationship-based maps, it is more easily to found possibilities for using activity-based map approach. Activity-based maps are used for more detailed analysis of processes that occur within a single economic entity, or among the business supply chain and are mostly occurring as a part of material, information or money flow. Lambert et al. (2014) especially highlight these types of activity-based maps: time-based process maps, pipeline inventory process maps and extended value stream maps. Time-based process maps represent events and activities in certain time frame with a goal of finding possibilities for decreasing (compressing) required time for fulfilling those activities. Pipeline inventory process maps present lead times and inventory at different stages of supply chain in one map, ensuring starting point for decreasing lead times in supply chain, and consequently lowering of safety inventory. While value stream maps are used for analyzing of production processes for identifying and elimination of no-value adding activities, extended value stream maps are crossing boundaries of enterprise to other entities on other levels of supply chain. They usually include information about value creation time, first time quality, waiting time, lead-time, and transport time for each part of analyzed process. Variation of extended value stream maps are called value chain maps and they are aligning sectors and participants through shared image of "as is" supply chain processes and how they could be improved – even more success is done if they are developed collaboratively between supply chain partners (Economic Development Board, 2015).

Hill (2009) talks about classification of map used to understand and improve processes into three categories: relationship mapping tools, time mapping tools and causal mapping tools (Figure 2).

Figure 2. Process improving mapping tools



Source: Hill (2009).

As processes are in the core of any supply chain, they can be evenly used for supply chain mapping. Compared to Lambert et al (2014), Hill introduces additional group of maps that are of huge significance for supply chain – causal maps. Causal mapping tools are diagrams that are mostly used for identifying the root causes of a problem (Hill, 2012) by presenting cause end effect relationship.

As additional supply chain mapping approaches, Miyake (2010) mentions Finne's dynamic clockspeed analysis, Towill's et al. quick scan methodology, and unavoidable SCOR (Supply Chain Operations Reference) model.

Although all of these maps could be used for supply chain mapping, Gardner & Cooper (2003) differentiate between main characteristics of strategic supply chain mapping and process mapping according to its orientation, details level and main purpose. Based on their findings Barosso et al (2011) has elaborated it in Table 1.

Table 1. Difference between supply chain and process mapping approaches

	Supply Chain Mapping	Process Mapping
Orientation	• Focuses on how material, information, and money flow: i) in both the upstream and downstream directions, and ii) through an organisation.	• Can be defined as the focus of the mapping procedure. • Generally directs its attention to a single operation or system within an organisation.
Det ail	• Emphasizes high-level measures such as volume, cost, or lead time.	• Tends to break down a process into activities and steps.
Purpose	• Is strategic. • Is used i) to help create a supply chain that conforms to a strategy, or ii) as a check to make sure the current chain is set up properly to fulfil that strategy.	• Is typically tactical. • The origin of that map comes from the recognition of a problem area and an attempt to improve operating efficiency. The goal is to make changes to the current operations of the organisation.

Source: Barosso et al (2011); Gardner & Cooper (2003)

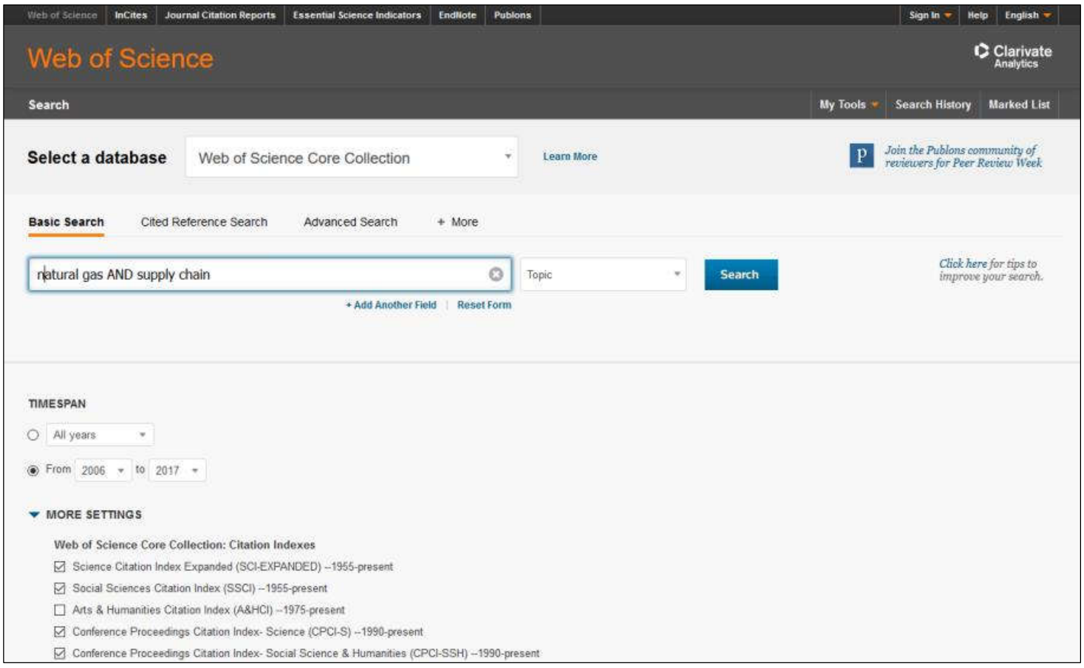
In last few decades, supply chain mapping is becoming more and more used tool for predicting and in advance avoiding of supply chain disturbances that can cause different material, information or finance flow disruptions (Barosso et al, 2011, Carvalho et al., 2012, Norrman & Jansson, 2004, Handfield & McCormack, 2007, Sheffi & Rice, 2005, Nishat Faisal et al., 2006). Barosso et al. (2011) are suggesting mapping approach for increasing supply chain resilience to a disturbance. Through six phases they start from current state of supply chain, and test different mitigation policies under disturbed conditions, providing methodology for making decisions about most appropriate mitigation activity.

According to Gardner and Cooper (2003), supply chain can be considered through three groups of supply chain map attributes: geometry, perspective and implementation issues. Geometry encompasses number and directions of supply chain tiers (representing supply chain length), aggregation (representing width of supply chain or competition in a tier), and spatial aspect – is a map geographically explicit representative or they are extremely simplified in spatial aspect. Perspective group of map attributes considers focal point approach (company or industry centric analysis approach), and scope level regarding product breadth, supply chain perspective, process view depth or cycle view. Implementation issues attributes are information density, live link to database and delivery mode.

3. METHODOLOGY

For the purpose of preliminary literature review analysis of using supply chain maps in articles dealing with natural gas supply chain, a basic search of Web of Science Core Collection (WoS CC) database was conducted. WoS CC was chosen as it is one of most relevant and worldwide used scientific databases of academic publications. Keywords used for searching were: „natural gas“ and „supply chain“. They were searched within the topic of publications indexed in Science Citation Index Expanded (SCI-Expanded), Social Science Citation Index (SCI), Conference Proceedings Citation Index (CPCI) and Emerging Sources Citation Index (ESCI). The oldest paper was published in 1993, but as 95 % of papers were published from 2006, the time span used for analysis was from 2006 to 2017 (Figure 3). According to above criteria, search resulted in 347 papers (286 articles and 69 proceedings papers).

Figure 3. Search of papers in WoS CC database used for analysis



Source: author's search in Web of Science Core Collection database (2017)

Natural gas supply chain as a topic was partly or fully covered in many research areas, and in Table 2 are presented research areas (according to Web of science categories) with 10 or more papers that met set criteria.

Table 2. Frequency of papers across research areas

Web of science categories	Number of papers within search results	% of 347
Energy fuels	138	40%
Environmental sciences	94	27%
Engineering chemical	92	27%
Green sustainable science technology	47	14%
Engineering environmental	43	12%
Environmental studies	39	11%
Operations research management science	27	8%
Thermodynamics	19	5%
Chemistry multidisciplinary	15	4%
Biotechnology applied microbiology	14	4%
Computer science interdisciplinary applications	13	4%
Engineering industrial	12	3%
Engineering electrical electronic	12	3%
Economics	12	3%
Transportation science technology	11	3%
Engineering mechanical	11	3%
Management	10	3%
Transportation	10	3%

Source: author's search in WoS Core Collection database (2017)

50 most relevant papers according to WOS CC list were chosen for preliminary analysis with intention of giving an overview of supply chain maps used in articles concerning natural gas supply chain.

4. RESEARCH RESULTS

After initial reviewing the title, abstracts and keywords of all found articles, 6 articles (Johnson & Covington, 2014; Hui & Xiao-Ping, 2009; Kamarudin et al., 2008; Camporeale et al, 2011; De Laporte et al, 2016; Lasher et al., 2008) that are not related to any aspect of natural gas supply chain were eliminated. There were 44 articles remaining that met the criteria set. Articles were analyzed according to following criteria: use of supply chain maps, type of used supply chain maps (according to classification by Hill, 2009 and Gardner and Cooper, 2003) and selected supply chain map's attributes (according to Gardner and Cooper, 2003): coverage of map, is there spatial character in maps, number of supply chain tiers presented in maps, is there a focal point in maps and do maps highlight cycle view of supply chains (Table 3).

Table 3. Overview of supply chain (SC) maps and their attributes from selected articles

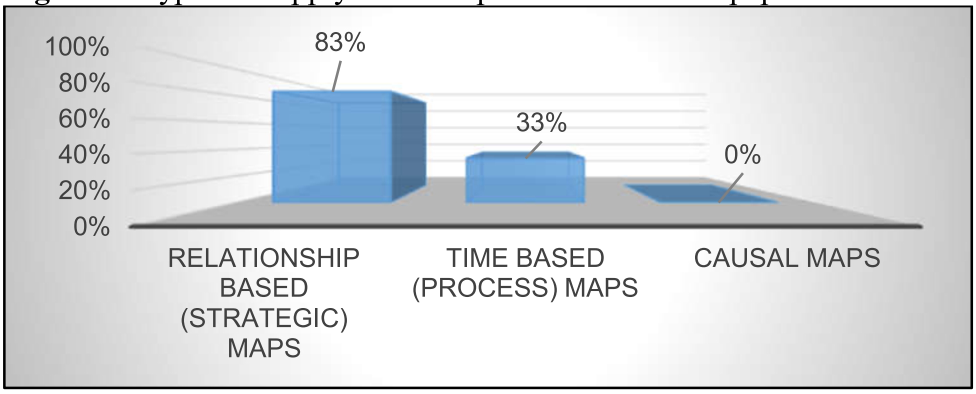
	Article	SC map		Type of SC map			Coverage of a map		Spatial		Number of SC tiers	Focal point		Cycle view	
		Yes	No	Relation-ship based (strategic)	Time based (process)	Causal maps	Whole SC	Part of SC	Yes	No		Yes	No	Yes	No
1	Yeli et al. 2006	√		√			√			√	3		√	√	
2	Schulz et al., 2005	√		√	√		√			√	4		√		√
3	Barton & Selot, 2007		√												
4	Hart & Hörmandinger, 2008	√		√				√		√	3		√		√
5	Grønhaug & Christiansen, 2009	√		√			√	√	√	√	5	√	√		√
6	Bittante et al., 2015	√		√				√	√		2		√		√
7	Kim et al., 2016	√		√	√		√	√		√	3		√	√	
8	Papapostolou et al., 2014	√		√			√			√	4		√		√
9	Chebeir et al., 2017	√		√			√			√	5		√		√
10	De La Cruz-Soto & Gutiérrez-Alcaraz, 2010		√												
11	Azadeh et al, 2015	√		√			√			√	5		√		√
12	Özelkan et al., 2008	√		√			√			√	7		√		√
13	Hamedi et al., 2009	√			√		√			√	7		√		√
14	Jokinen et al., 2015	√		√				√	√		2		√		√
15	Kang et al., 2016	√			√			√		√	3	√			√
16	Sanches-Pereira et al., 2015	√			√			√		√	8		√		√
17	Mahendra et al., 2014	√		√			√			√	3		√		√
18	Rosetta & Martens, 2008		√												
19	Balcombe et al., 2016	√		√			√			√	9		√		√
20	Khot & dnyanu Yadav, 2017	√		√			√			√	8		√		√
21	Zavala-Araiza et al., 2015	√		√				√		√	2		√		√
22	Kaufmann et al., 2009		√												
23	Berle et al., 2011	√			√			√		√	5		√		√
24	Azadeh et al., 2016		√												
25	Wlodek, 2016		√												

26	Vance et al., 2014		√												
27	Lechtenböhmer & Dienst, 2010	√		√				√	√		2		√		√
28	Bekkering et al., 2013	√		√				√		√	6		√		√
29	Salcedo & Maja, 2008	√		√				√		√	3		√		√
30	Elia et al., 2012		√												
31	Lee et al., 2016	√			√		√			√	7		√		√
32	Wang & Rutherford, 2015		√												
33	Littlefield et al., 2017	√		√	√		√			√	5		√		√
34	Mladenovska et al., 2017		√												
35	Kalashnikov et al., 2010		√												
36	Grossmann et al, 2014	√		√	√			√		√	3	√			√
37	Somoza et al., 2016		√												
38	Khalilpour & Karimi, 2012	√		√	√		√	√	√	√	5		√		√
39	Mikhailov, 2016		√												
40	Sakaguchi, 2010	√		√			√			√	7		√		√
41	Elia et al., 2013	√		√				√		√	3		√		√
42	Elia et al., 2015	√		√				√		√	2		√		√
43	Hall, 2012		√												
44	Miedema et al., 2016	√		√				√		√	3		√		√

Source: author

Research has shown that supply chain maps (at least one) are used in 30 (68 %) of selected most relevant 44 papers, while only in 14 (32 %) papers authors decided not to use supply chain map to enrich their papers. For further analysis, we took into consideration only those 30 papers containing maps that are representing natural gas supply chain. Figure 4 displays results of supply chain map types used in selected 30 papers.

Figure 4. Types of supply chain maps used in selected papers



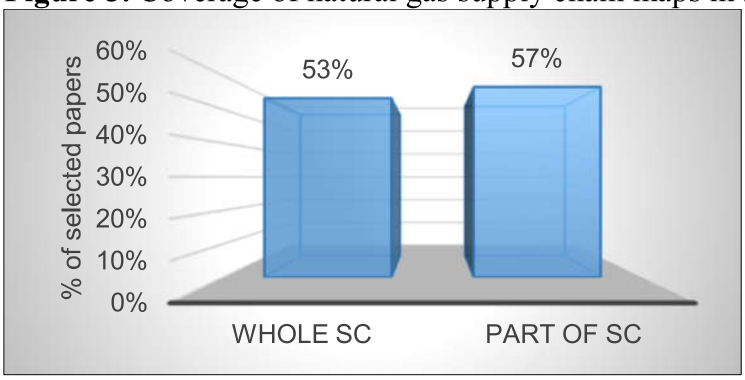
Source: authors' calculation

It can be concluded that most widely used supply chain map type for presenting natural gas supply chain is group of relationship based maps that have strategic character (in 25 papers, or 83%). Time based supply chain maps with their process orientation represent second choice for natural gas supply chain presentation (used in 10 papers, 33 %). As expected, no paper uses causal maps in natural gas supply chain presentation. In certain papers (5 of them), both relationship based and time based maps (or one map with both characteristics) can be found.

As seen on Figure 5 supply chain maps in selected papers evenly present the whole natural gas supply chain (in 16 papers), as well as only part of natural gas supply chain (in 17 papers). 2 of selected papers use maps for presenting both whole and part of natural gas supply chain.

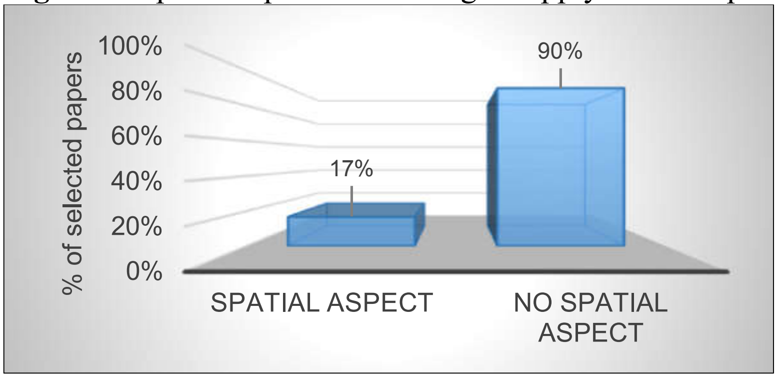
Geographically representative maps are not common in natural gas supply chain mapping – only 17 % of papers use maps with clear spatial aspect, while 90 % of selected papers don't use maps with explicit geographic representation (Figure 6).

Figure 5. Coverage of natural gas supply chain maps in selected papers



Source: authors' calculation

Figure 6. Spatial aspect of natural gas supply chain maps in selected papers



Source: authors' calculation

When it comes to number of natural gas supply chain tiers or echelons represented on maps in selected papers, number of tiers is very different and ranges from 2 tiers all the way to 9. For presenting whole natural gas supply chain, authors most often use 5 tiers maps, while for presenting only parts of supply chain 3 tiers maps are most often used. Additionally, time based or process maps usually have more tiers than relationship based maps.

Only 3 papers (or 10 %) use supply chain maps that are drawn from the perspective of a company or an echelon that is in focus (focal company/echelon), while 90 % of papers don't highlight one company or echelon in natural gas supply chain. And even less papers (2 or 7 %) indicate cycle view in their natural gas supply chain maps, while 28 papers (98 %) present only one way downstream flows – to the final consumer.

5. DISCUSSION AND CONCLUSION

The main goal of this paper was to present use of supply chain maps in scientific papers regarding natural gas supply chains. Paper intend to provide an overview of frequency of use, types and other attributes of supply chain maps used to present natural gas supply chains in existing scientific papers. Methodology of this research is based on search of WOS CC database, were 50 most relevant papers were extracted. After initial reviewing the title, abstracts and keywords 44 papers were identified as papers that deal with different aspect of natural gas supply chain. Further preliminary analysis was conducted on the basis of aforementioned criteria and attributes of supply chain maps. The results revealed that in more than two thirds of selected and analyzed papers authors decided to use natural gas supply chain maps for giving more clearer and understandable situation, relations or process flow in natural gas supply chain.

The most often used type of supply chain maps for mapping natural gas supply chain are relationship based maps (in 83 % of papers), based on strategically approach to primarily supply chain members and flows. This is very common in presenting supply chains as relationship based maps are suitable for presenting more static environment shown in general representation of all supply chain tiers (or few tiers as a part of supply chain), what is most often case in natural gas supply chain papers. Almost three time less are used time based supply chain maps that usually appear in form of process maps. According to this study, the whole natural gas supply chain is almost equally often represented on maps in selected papers as only parts of natural gas supply chain – this results from the main topic and accents of paper's research. Geographically representative maps are rear in papers dealing with natural gas supply chain, and great majority of papers use supply chain maps with no explicit spatial aspect. This could be explained with less importance of spatial aspect for optimization or other aspects of natural gas supply chain, and with difficulties of representing huge geographical areas on which natural gas supply chains stretch. Furtherly, natural gas supply chain maps mostly don't use focal approach and cycle view (as there are almost no return flows in natural gas supply chain). As a general conclusion, supply chain maps are essential tool for natural gas supply chain mapping where researcher mostly choose relationship based maps of evenly whole or part of supply chain, most often with 5 supply chain tiers, with no explicit spatial aspect, no focal point and cycle view.

As an indicative preliminary research, this study has certain limitations like use of only one (although biggest) databases and limited number of papers taken into consideration. In further researches other relevant databases should be taken into consideration, and more specific maps' types could be analyzed. Nevertheless, paper could serve as a good starting point for researchers who would like to use mapping method in their papers dealing with natural gas supply chains.

6. ACKNOWLEDGEMENT

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