ENSURING SUPPLY SECURITY IN CASE OF CATASTROPHIC SUPPLY CHAIN DISRUPTION

ZAPEWNIENIE BEZPIECZEŃSTWA DOSTAW W SYTUACJI WYSTĄPIENIA KATASTROFALNEGO ZABURZENIA ŁAŃCUCHA DOSTAW

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Abstract: *In article authors present literature analyses of the most important theoretical aspects concerning strategies of supplying, risk management in supply chain and disruptions occurring within supply chain. Nowadays, ignored by numerous companies, rare, catastrophic disruptions could lead to substantial loses when they occurred. After theoretical introduction authors present one of possible way of risk identification, evaluation and prioritization within supply chain, what could allow to develop appropriate plan of reaction to disruption before it occurs. Next article presents possible solutions, how to avoid or/and mitigate the risk and approach which could be applied by company when catastrophic disruption takes place.*

Streszczenie: *W artykule zaprezentowano przegląd literatury pod kątem najważniejszych aspektów teoretycznych dotyczących strategii zaopatrzenia, zarządzania ryzykiem w łańcuchu dostaw oraz zaburzeń występujących w łańcuchu dostaw. Obecne ignorowanie przez wiele firm rzadkich, katastrofalnych zaburzeń łańcucha dostaw może prowadzić do znacznych strat, kiedy takie zdarzenie wystąpi. Po wstępie*

teoretycznym autorzy przedstawiają jeden z możliwych sposobów identyfikacji, oceny i priorytetyzacji ryzyka w łańcuchu dostaw, co może pomóc opracować odpowiedni plan reagowania na zaburzenie zanim ono nastąpi. Następnie prezentowane jest rozwiązanie, jak unikać ryzyka oraz zmniejszać go oraz podejścia, jakie przedsiębiorstwo może zastosować, kiedy wystąpi katastrofalne zaburzenie łańcucha dostaw.
Keywords: *supply chain management, supply chain risk management, sourcing diversification, single sourcing, supply chain disruptions.*
Słowa kluczowe: *zarządzanie łańcuchem dostaw, zarządzanie ryzykiem w łańcuchu dostaw, dywersyfikacja źródeł zaopatrzenia, pozyskiwanie z jednego źródła, zaburzenia łańcucha dostaw.*

Introduction

In recent years, cost effectiveness became one of the major drivers in supply chain management (Chopra and Sodhi, 2014). It is strongly connected with lean and Just-in-Time (JIT) philosophies which underlines cost savings due to reducing all "wastes" (van Weele, 2010:260). JIT leads to close cooperation with single supplier (Chopra and Sodhi, 2014; Whitney, Jianxi Luo and Heller, 2014; Burke, Carillo and Vakharia, 2007) by using long term contracts (van Weele, 2010:264). It requires good supplier selection, based on proper criteria (e.g. financial stability, quality performance, costs etc.) chosen individually by a company (Freytag and Mikkelsen, 2007). This topic is basically connected with *sourcing* notion which can be defined as the process of finding, selecting, contracting and managing the proper source of supply, usually on a worldwide basis (van Weele, 2010:10).

1. Sourcing strategies

In the case of the number of used suppliers there are two basic sourcing strategies: *single sourcing* and *multiple sourcing* (Berger and Zeng, 2005; Burke, Carillo and Vakharia, 2007). *Sourcing strategy* also identifies kind of relationship between buyer and supplier, contract type and its duration (van Weele, 2010:11).

The multiple-sourcing strategy consists negotiations with several suppliers and is based on playing one supplier against another one (Berger and Zeng, 2006).

Single sourcing strategy is the concept which evolved together with increasing popularity of JIT. This approach is connected with need to develop a good cooperation with suppliers (Berger and Zheng, 2006; Burke, Carillo and Vakharia, 2007). Benefits of single sourcing strategy are (van Weele, 2010:266; Berger and Zeng, 2006; Burke, Carillo and Vakharia, 2007):

- Coordinated and cooperative relationship between buyer and supplier,
- Higher quality at lower costs for the buyer,
- Better information flows,
- Better planning of production and materials volume,
- Reduced inventory,
- Reduced order lead times,

- Administrative savings for supplier (electronically transaction of documents),
- Possibility to integrate planning systems between buyers and suppliers,
- Product and process innovations (as a result of improved communication).

Beside of these advantages, there are also disadvantages for suppliers which engage such a relationship – it causes big dependency of small suppliers on large manufactures and their demands. If any problems occur, smaller supplier can lose its entire business (van Weele, 2010:266). What is more, it also leads to big risk for supplier in case of catastrophic supply chain disruption (Bradley, 2014).

The decision which sourcing strategy should be used depends mostly on demand and supplier capacity – as Burke, Carillo and Vakharia (2007) presented in their research, the major factor which should decide on sourcing strategy is ratio between product demand and supplier capacity – relatively large supplier capacity (in comparison with product demand) allow firm source from one, the least cost supplier.

2. Catastrophic supply risk management

Globalization had led to significant and close integration of global economy (Cordon and Nie, 2011). It gives a lot of opportunities in field of purchasing all across the world (van Weele, 2010:202) but it also enhance risks of supply chain disruptions (Chopra and Sodhi, 2014).

Many companies understand their main tasks as producing the highest value for customers at the lowest costs (Cordon and Nie, 2011) and usually underestimate risks connected with rare disruptions (Whitney, Jianxi Luo and Heller, 2014; Chopra and Sodhi, 2014).

Basically we can divide risks connected with supply chains into two main categories (Whitney, Jianxi Luo and Heller, 2014, 2014; Chopra and Sodhi, 2014; Bradley, 2014):

- *Operational risk* – derives from supplier unreliability and demand uncertainty. It may concern coordination between supplies and demand, problems with quality or transport, etc.,
- *Disruptive risks* – this type of risk are much rarer and concern such events as terrorist attacks, fires, natural disasters, strikes, etc.

Disruptive risk have big impact on all supply chain – impact in one area causes a chain reaction effect and have influence on other areas (Chopra and Sodhi, 2014). To reduce risk impact company can use several methods (see Figure 1). However, in this paper we are going to focus on disruptive risk and not all of these methods can be applied in that field.
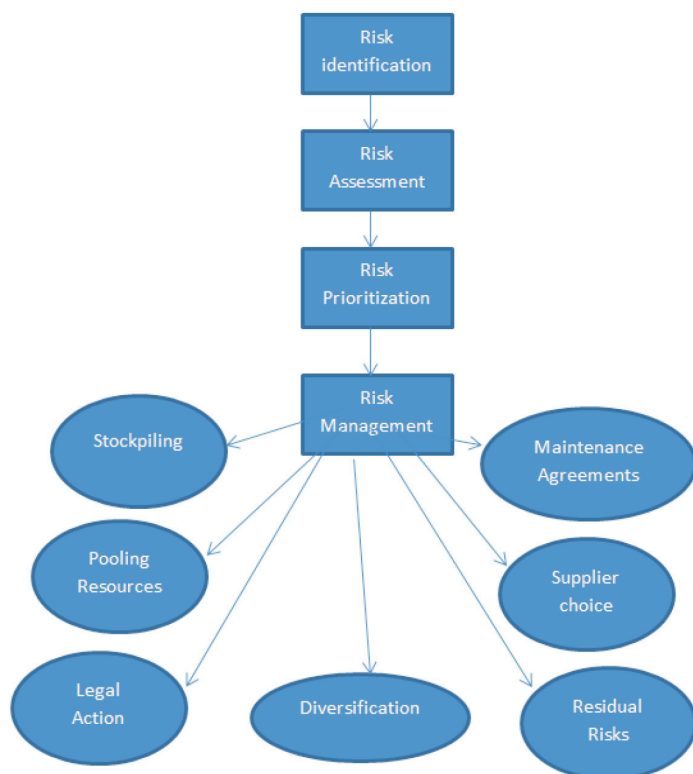
Fig. 1. A four-step supply chain risk management process
Based on: Berger and Zeng (2006)

Catastrophic supply chain disruptions are hard to predict and have big impact on supply chain (Chopra and Sodhi, 2014). Some examples are (Bradley, 2014; Nanto, Cooper and Donelly, 2011; Whitney, Jianxi Luo and Heller, 2014, Elahi; Sheikhzadeh and Lamba, 2014):

- terrorist attack on USA (9.11.2001 – USA tightened security controls on its border what caused closing of many auto assembly plants),
- Boeing's labor union strike (2008 – caused extra delay in Boeing Dreamliner program and big financial losses),
- Hurricane Katrina,
- Fukushima earthquake (2011 – caused supply chain disruptions in automotive industry all around the world and even delayed the introduction of Apple's iPad 2),
- Conflict on Ukraine (2013 – present – caused trade war between Russia and Western World – e.g. embargo established with Council Regulation (EU) No 833/2014).

As it was mentioned before, many managers ignore risks of such events because of the fact that they happen relatively rare (Chopra and Sodhi, 2014; Whitney, Jianxi Luo and Heller, 2014). However, this approach can lead to big loses in the case when such an event occurs (Cordon and Nie, 2011).

Disruption risk management can be divided into two categories (Whitney, Jianxi Luo and Heller, 2014):

- Risk mitigation – it is proactive preparedness before disruption occurs (e.g. carrying buffer inventories, diversification of suppliers and close collaboration between buyer and supplier),
- Responsiveness – action plans to apply when disruption occurs (e.g. using alternative suppliers).

3. Framework of evaluation of catastrophic supply chain disruptions

Preparing proper action plans, in case of catastrophic supply chain disruption, require understanding level of risk that some specific event will occur. Bradley (2014) presented a model of supply chain risk management which I am going to follow on the next pages.

This model contains:

- Identifying risk – methods which can be used are brainstorming, evaluating supply chain maps and interviews. First of all it is important to identify entities in which disruption can occur. These entities can be:
  - Location (e.g. Hamburg, Hong Kong),
  - Facilities (e.g. own factories, suppliers' factories),
  - Transportation (e.g. Carriers, Ports, Rail),
  - Suppliers,
  - Raw materials (e.g. wood, iron),
  - Parts.

Next thing that has to be done is to understand what kind of disruption can occur and have influence on supply chain entities. Examples of disruptions are presented in Table 1.

Table 1. Disruptive events

Disruption		
Earthquake	Bankruptcy	Labor strike
Hurricane	Takeover	Loss of key people
Civil Unrest	Terrorist attack	Shortage of workers
Shortage of raw materials	Work stoppage	Fire
Explosion	Hazardous waste spill	Structural collapse
War	Tornado	Embargo

Based on: Bradley (2014)

- Measuring risk – uses two metrics to evaluate risk – *probability* that such disruption will happen and its *impact* on supply chain. Additional metric can be likelihood of an event being *detected* before or after it occurs (Table 2).

Table 2. Example of detection measure scale

Detection score	Interpretation
1	A disruption can be easily recognized at least 1 week before it occurs,
2	A disruption can be recognized at least 1 day before it occurs,
3	A disruption can be recognized immediately,
4	A disruption detection would most likely take at least 1 day,
5	A disruption detection would most likely take at least 1 week.

Based on: Bradley (2014)

To estimate *possibility* metric (Table 3), company has to use proper data and experts opinions. Impact can be estimated by possible lost revenue, operating cost and duration of disruption (Table 4).

Table 3. Example of probability measure scale

Probability score	Interpretation
1	A disruptive event that is expected to occur on average every 50 years,
2	A disruptive event that is expected to occur on average every 10 years,
3	A disruptive event that is expected to occur on average every 5 years,
4	A disruptive event that is expected to occur on average once per year,
5	A disruptive event that is expected to occur on average few times per year.

Based on: Bradley (2014)

Table 4. Example of disruption impact measurement scale

Impact score	Meaning
1	Less than 0.05% of annual revenue
2	Approximately 1% of annual revenue
3	Approximately 5% of annual revenue
4	Significant impact: 10% to 40% of annual revenue
5	Possible bankruptcy of the company

Based on: Bradley (2014)

- Prioritizing risk – to estimate risk score company can use simple matrix, where axes represents utilizing probability and impact, but better option is to also include detection (Table 5).

In the context of methodology presented by Bradley (2014), important element of risk prioritization is selection of criteria which should reflect relevant aspects of choice and also allow arrange them considering their specific preferences. We could measure them using weighted factors, however it is worth to note that criteria could be treated as equal, that means have the same weights, or considered as not-equivalent, means, have different weighted factors.

Weighted factors have various interpretation depending on structure and context of situation in terms of risk evaluation. That is why their estimation could be processed in many different ways. The frequent approach bases on using of the opinion of expert(s) or/and decision maker(s), the second approach takes into account mathematical operations on data collection in terms of evaluation of their informational value. The first approach could be applied to quantitatively or qualitatively weighted criteria, since it takes into consideration preferences of the decision maker or/and expert, which are resultant of its informational value, experience, and perception of risk. The second approach to estimation of weights is processed mainly taking into consideration statistic and algebraic operations on data collection. It means that criteria shall be measurable and represented in form of real numbers.

Selection of concrete method amongst available variety of tools is extremely difficult, however development of recommendation which enable decision maker choice of appropriate procedure of weighted factors, tailored to structure of realised process of risk analysis could be performed. It is worth to note that choice of concrete method of selection of weighted factors is derivative of familiarity of respective procedure, quality of data collection and ability of applying. Good solution could be also selection of weighted factors using different methods and then compare them.

The way how company calculate total risk score should depend on specific company case and has to be carefully developed. As an example we present weighted factors selected arbitrarily by decision maker(s):

$$RS = 0,3 \times P + 0,6 \times I + 0,1 \times D$$

Where: *RS* – risk score, *P* – probability, *I* – Impact, *D* – Detection.

Table 5. Example of risk ranking

Failure mode	Entity	Disruption	Probability	Impact	Detection	Risk score
Location	Delhi	Flood	5	2	3	3,0
Location	Chicago	Tornado	2	3	3	2,7
Facility	Berlin	Strike	2	4	1	3,1
Transportation: Port	Sevastopol	War	1	4	4	3,1
Transportation: Port	Malaysia	Hurricane	4	2	2	2,6

Based on: Bradley (2014)

Example: Current war in Eastern Ukraine was highly unexpected just few years ago, but not impossible (scored 1 point in Probability). That event could cause big loses for company which source important part from partner located there (score 4 points in Impact). Because of quickly changing situation and problems with communication from this region, information about (for example) destruction of port could be deliver with some delay (score 4 points in detection).

Total risk score in such situation is:

$$RS = 0,3 \times 1 + 0,6 \times 4 + 0,1 \times 4 = 3,1$$

Important thing is that risk ranking should be a living document and has to be adjusted to continuously changing environment.

Disruptions with the highest risk score should be considered as the most dangerous and company should do something to avoid them (if it is possible) and decrease possible loses (Bradley, 2014). Company has basically 3 stages of response (Chopra and Sodhi, 2014):

- Detecting the disruption,
- Designing solution or selecting predesigned solution,
- Deploying the solution.

Evaluating risk score can give managers overview on which possible disruptions they should focus and predesign solutions. Better preparation can significantly improve time and quality of response (Whitney, Jianxi Luo and Heller, 2014). Some methods which can be used as temporary solutions for catastrophic disruptions are common with those which are used to deal with operational risk – hold an extra inventory and using alternative suppliers. However, these methods have limited possibilities to deal with big disruptions in long-term perspective (Whitney, Jianxi Luo and Heller, 2014). Nevertheless, allocating focus and resources to the most threatened areas can help in dealing with significant disruptions.

4.   Strategies of catastrophic supply disruption mitigation

4.1. Regionalize the supply chain

Model presented above can be helpful in finding entities which are the most exposed to risk in supply chain, but doesn't give us information how to avoid these risks. One of the methods how to decrease impact of catastrophic disruptions was proposed by Chopra and Sodhi (2014). These authors proposed regionalization of the supply chain. This approach provides important advantages for a company:

- Reduce risk in global supply chain,
- Gives opportunity to reduce distribution costs.

By using more than one supplier (even if second one provides only small amount of products) can significantly decrease impact of disruption (Chopra and Sodhi, 2014). However, it also involves higher costs – single sourcing strategy assumes that company choses the lowest supplier and also has benefits of economies of scale (Berger and Zeng, 2006). That is probably the reason why even some of companies which suffered because of catastrophic disruption and their single sourcing strategy didn't change their approach (Whitney, Jianxi Luo and Heller, 2014).

4.2. Temporary diversification

Even if company tries to avoid risk, some catastrophic disruption can happen and have influence on its supply chain. To deal with it, company can try to use temporary diversification – temporary using alternate supplier (Chopra and Sodhi, 2014; Whitney, Jianxi Luo and Heller, 2014). Of course it requires existence of additional supplier who also has sufficient volume flexibility. Important dependence in such situation is that the more specialized is the item or process, the harder is to find temporary provider (Whitney, Jianxi Luo and Heller, 2014).

Temporary diversification was used by Aisin Seiki in 1997. Aisin Seiki is a producer of P-valve used in automotive industry. After fire destroyed its plant, company (together with Toyota – its main customer) started to search for solution. Other suppliers, even those without big experience with P-valves, responded for calling for help and started production of P-valves according to engineering drawings and technical information from Aisin Seiki. Even if they never provided more than 30% of Aisin Seiki's needs, it allowed whole industry ''keep going'' till Aisin Seiki's recovered its production capacity. Involved companies (around 200 and 62 of them directly produced P-valves) were rewarded and their costs were reimbursed (Whitney, Jianxi Luo and Heller, 2014).

4.3. Close cooperation

Staying with single sourcing and close cooperation with supplier can be also considered as a way to improve response effectiveness (Cordon and Nie, 2011). This approach helped Riken Corporation (producer of piston rings – highly specialized engine part) in 2007, when earthquake damaged company's plant. Due to the fact that it was such specific part and there were no alternative suppliers with sufficient volume flexibility, diversification was not an option. Company's buyers were aware of dangerous for them if Riken would not start its production soon (e.g. Toyota lost production of more than 120.000 cars), so they provided wide range of help. It had consisted sending almost 650 people to help Riken to repair every damage. Thanks to that, company was able to start production again much faster than it would happen without external help (Whitney, Jianxi Luo and Heller, 2014).

Conclusions

Due to increasing globalization of production, sourcing and delivery as well as close integration of global economy, supply chains has became more vulnerable on catastrophic disruptions. They are also weakened by JIT philosophy which encourages for single sourcing and reduction of stock levels. Events like earthquake and tsunami in Japan in 2011 can cause tremendous loses for companies which lose their supply source (Nanto, Cooper and Donelly, 2011). Such situation is very hard to predict, nevertheless Japan is the region where earthquakes occurs relatively often –country is placed on the Ring of Fire – the area, where above 90% of all earthquakes happens (http://earthquake.usgs.gov). Because of that companies should apply proper approach to avoid loses. These solutions can take place before (like supply chain regionalization) or after disruption occurs (like help for supplier or temporary diversification). Both cases examined by Whitney, Jianxi Luo and Heller (2014) and used in this paper caused big loses but also were answered quickly. After these disruptions both companies prepared themselves better for such an events (buildings were improved or rebuild to be less vulnerable on fire and earthquakes).

Nevertheless, they didn't build any additional plants (what they planned to do just after disruption occurred).

Basically, diversification can be used when item is not highly-specialized and there are available other suppliers with sufficient production capacity. When item is unique and complex it can cause big troubles. In the case of Riken Corporation damages were big, but plant wasn't totally destroyed. If earthquake had been more powerful, it could cause much bigger loses (Whitney, Jianxi Luo and Heller, 2014).

Decreasing losses resulting from catastrophic supply chain disruptions can achieved by using all three approaches presented in this paper (Regionalization of supply chain, close cooperation and temporary diversification).

LITERATURE

[1] Berger P.D., Zeng A.Z. (2006), *Single versus multiple sourcing in the presence o risks*, Journal of the Operational Research Society, 57, 250-261.

[2] Bradley J.R. (2014), *An improved method for managing catastrophic supply chain disruptions*, Business Horizons, 57, 483-495.

[3] Burke G.J., Carillo J.E., Vakharia A.J. (2007), *Single versus multiple supplier sourcing strategies*, European Journal of Operational Research, 182, 95-112.

[4] Chopra S., Sodhi M.S. (2014), *Reducing the Risk of Supply Chain Disruptions*, MIT Sloan Management Review, 55 (3).

[5] Cordon C., Nie W. (2011), *Re-evaluating the supply chain post-Japanese earthquake*, IMD (https://www.imd.org/research/challenges/upload/TC025-11-RE-EVALUATING-THE-SUPPLY-CHAIN-POST-JAPANESE-EARTHQUAKE-2.pdf)

[6] Council regulation (EU) No 833/2014 concerning restrictive measures in view of Russia's actions destabilizing the situation in Ukraine (2014), Official Journal of the European Union.

[7] Elahi E., Sheikhzadeh M., Lamba N. (2014), *An Integrated Outsourcing Framework: Analyzing Boeing's Outsourcing Program for Dreamliner (B787)*, Knowledge and Process Management, Volume 21, Issue 1, 21, 13-28.

[8] Freytag V., Mikkelsen O.S. (2007), *Sourcing from outside – six managerial challenges*, Journal of Business & Industrial Marketing, Volume 22, Issue 3, 187-195.

[9] Gelderman J.C. and van Weele J.A. (2005), *Purchasing Portfolio Models: A Critique and Update*, *Journal of Supply Chain Management,* Volume 41, Issue 3, 19-28.

[10] Nanto D.K., Cooper W.H., Donelly J.M. (2011), *Japan's 2011 Earthquake and Tsunami: Economic Effects and Implications for the United States*, Congressional Research Service.

[11] van Weele A.J. (2010), *Purchasing and Supply Chain Management,* 5th ed., Cengage Learning.

[12] Whitney E.D., Jianxi Luo, Heller D.A. (2014), *The benefits and constraints of temporary sourcing diversification in supply chain disruption and recovery*, Journal of Purchasing & Supply Management, Volume 20, Issue 4, 238-250.