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Can IoT be Used to Mitigate Food Supply Chain Risk?

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Abstract

The Internet-of-Things are new, but extremely promising multiple technologies that will revolutionize food supply chain and the way we are selecting and buying food. Combination of ubiquitous cell-phone usage, ability to "communicate" with food packaging and transfer specific information regarding risks immediately at the any point on the globe is offering much higher standard of consumer safety.

Key words: *Internet of Things, food supply chain, risk mitigation*

1. INTRODUCTION

Concept of supply chain (SC) is developed with a main goal to lower the cost of final product where the increase throughput can be achieved while simultaneously reducing both inventory and operating expense and thus making that product more desirable by potential buyers/customers (Goldratt & Cox 2004). This can be illustrated with the definition of supply chain management (SCM) where SCM is the management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole (Christopher 1992). There is also another definition that the SCM is a set of approaches utilized to efficiently integrate suppliers, manufacturers, and stores, to that merchandise is produces and distributed at the right quantities, to the right location, and at the right time, in order to minimize system-wide costs while satisfying service level requirements (Simchi-Levi et al. 2000). Almost immediately after starting of implementation, organisations comprehended that time and information are crucial for taking the advantages of the SC. Further, process of globalisation physically extended SC, which, as a consequence, has longer time of transportation. Additionally, as all of this was not enough, political instability almost all over the world, raised the probability of disruption of SC. All of this added to the significance of efficient and reliable transportation and communication systems (Christopher & Peck 2004).

2. THEORETICAL BACKGROUND

In (Cooper et al. 1997), authors conducted analysis of the components of SC, which are following:

1. Planning and Control
2. Work structure
3. Organization structure
4. Product flow facility structure

5. Information flow facility structure
6. Product structure
7. Management methods
8. Power and leadership structure
9. Risk and rewards structure
10. Culture and attitude.

For this research, we will focus on components 2-work structure, 4-product flow facility structure, 5-information flow facility structure, 6-product structure and 9-risk and rewards structure.

Work structure is strongly influenced by technology used and Internet-of-Things – IoT is emerging technology that will have huge impact in shaping work structure and velocity of material and information flow in SC.

In recent years, we can find a lot of stories about calamitous events which directed development of society / civilization towards risk focused one. In the following paragraphs we will present some of those events.

It is well known event when in March 2000, a thunderstorm struck the Philips semiconductor plant at Albuquerque in New Mexico, which made silicon chips for products like cell-phones. Damage at first seemed minor, and fire fighters soon left the premises. At first, Philips informed major customers like Nokia and Ericsson that the delay to production would only be one week. But damage to some of the clean areas in the plant, created by smoke and water, was actually going to take months to remedy. Nokia has been prepared for such event and they quickly re-sourced missing chips, but Ericson was not, and they suffered loss of some 500 M$ and about 3% of market share (Harrison & Hoek 2008).

High-tech companies, particularly those involved in the telecommunications industry like Lucent Technologies (also known as Alcatel-Lucent and Alcatel), are especially susceptible to market fluctuations. Early in the 2000s, Lucent discovered rather belatedly that it had built way too many cell phones, a particularly acute problem since the shelf life of a new phone isn't much longer than that of a gallon of milk. Lucent, to put it succinctly, found itself in a supply chain crisis—over a 10-month period, the company wrote off a staggering $1 billion worth of inventory (Blanchard 2010).

Another interesting example of devastating consequences of unforeseen event is Mattel toys case. In 2007, Mattel was forced to recall 83 products, numbering more than 900,000 units. This occurred when it was discovered that the products contained toxic lead paint. Even Mattel's extensive audits did not uncover the problem in its China - based suppliers until after one - third of the tainted toys had been shipped to stores (Lynch 2009).

If we consider food supply chain (FSC) and how sensitive food could be, it can be easily concluded that right information in the right moment becomes much more important. For example, in the second half of 2008, when kidney-related illness skyrocketed amongst children in China, investigations quickly determined that the most likely cause was the addition of melamine, an industrial chemical, to milk supplies. When it was over 21 companies in the supply chain were implicated and found guilty of involvement in this tragic series of events. (Gurnani et al. 2012).

All of those are cases of possible devastating consequences of the events that organizations were not prepared for. But those consequences could be prevented or at least mitigated if organizations had sound risk management system in place. As we move rapidly into the era of not organizations but supply chain competition, we have to think about supply chain risk management systems (SCRM / SCRMS). Having in mind necessity for taking into account a risk, a number of principles emerge to guide the supply chain design, that can be summarised as the '4Rs': responsiveness, reliability, resilience and relationships (Christopher 1992). For the risk management perspective, most important principle is resilience. System resilience is the ability of a system to return to its original state or move to a new, more desirable state, after being disturbed (Christopher & Peck 2004).

There are lot of categorisation of risk. One could be by defining five categories / sources of risk as:

- Process
- Control
- Demand
- Supply and
- Environmental (Christopher & Peck 2004).

The other categorisation, more focused on FSC is the following (Dani 2015):

- Product contamination
- Loss of power
- Loss of IT
- Product recall other than contamination (packaging problems)
- Loss/disruption in logistics
- Unexpected economic challenges
- New food safety regulations
- Loss of water
- Increased labour costs
- Unavailability of raw material
- Loss of premises
- Strikes
- Pandemics
- Loss of supplier
- Natural disasters
- Rise in fuel price
- Loss of asset
- Terrorism.

Another important technology for this research is already mentioned IoT. In (Stankovski et al. 2015) three most common definitions of IoT are given:

- The interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data.

- IoT is a recent communication paradigm that envisions a near future, in which the objects of everyday life will be equipped with microcontrollers, transceivers for digital communication, and suitable protocol stacks that will make them able to communicate with one another and with the users, becoming an integral part of the Internet.
- IoT is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.

There is interesting observation in (Blanchard 2010), regarding adoption of Radio-frequency identification - RFID (so we can expect similar situation with IoT): first stage, of course, is denial ("RFID? You have got to be kidding!"), followed by anger ("How dare they try to force us to adopt this untested gimmick!"), then bargaining ("Okay, we'll do it, but we'll do the absolute least amount that we can get away with"), then depression ("We're going to go broke paying for all these tags"), and if things work out, to the final stage, acceptance ("Hey, we're actually a lot more productive now thanks to RFID"). We must do everything possible to reach final stage of this process in as short time as possible.

3. RESEARCH METHODOLOGY

We are now reaching a critical juncture, one that was high- lighted by the World Economic Forum's Global Risk Network in its "2008 Global Report on Risk." For the first time, supply chain risk was identified as one of the top global risks (Lynch 2009).
Risk in supply chains has assumed, however, added dimensions, providing, on the one hand, greater opportunities to manage these risks and, on the other, augmenting appreciably, and the risks that modern enterprises face. Since many of these risks are ill-understood and poorly evaluated, they are poorly managed. As a result they are also poorly measured, augmenting the risks that supply chains entities face (Kogan & Tapiero 2007).
International standard ISO 31000 Risk management – Principles and Guidelines (ISO 31000 2009) can be used by any public, private or community enterprise, association, group or individual. Therefore, ISO 31000:2009 is not specific to any industry or sector, but, because there is no risk management standard developed for food industry specifically, we will use it for this purpose.
When considering SC risk, one has to distinguish between:

- Operational risks (such as intra-firms operational risks, supply delay risks, synchronization risks, measurement risks, inventory risks, quality risks…)
- External risks (such as technology, financial markets, political, regulation and market structure risks, measurement risks…)
- Strategic risks (such as inter-firms risks, dependence, outsourcing, exchange, information asymmetry, moral hazard, adverse selection, non-transparency, measurement risks…)
- Risk externalities (environmental risks, non-detection risks, collective risks, ethic-social risks, regulation risks) (Kogan & Tapiero 2007).

Another, similar view at SC risks is something that is called as the Four Pillars of SCRM. These pillars include supply risk, process risk, demand risk, and environmental risk. Each pillar encompasses its own set of tools, techniques, tactics, metrics, people, processes, and program issues (Schlegel & Trent 2015)
Figure 1 presents relationships between the risk management principles, framework and process, as they are defined in standard ISO 31000.
First two activities of the RM process (Communication and consultation and Establishing the context) are specific for each SC, so we will skip it. Third activity (risk assessment) has been already done by (Dani 2015), but we will use only few identified risks – risks that could be mitigated by implementation of IoT:

- Product contamination
- Packaging problems
- New (and existing) food safety regulations
- Terrorism (intentionally contamination).

For the identified unacceptable risks, one should make decision what can be done with those risks. Best policy is to avoid risk, if it is possible and economically justified. If not, one should define mitigating procedure (either lowering the probability of occurrence or its consequences). Unfortunately, when food is in question, mitigation option is not enough (same is with transferring risk to insurance company). You cannot brag with the fact that last year hundreds of your consumers had stomach problems because of your product, and this year less than fifty. No consumer is willing to risk stomach problem, they will stop buying your product completely. So, we are at the beginning: it is mandatory to find a way to completely eliminate possibility that your alimentary product reaches at the table of the consumer.
After defining risk avoiding / mitigating procedures, it is advisable to conduct some tests of effectiveness of those procedures. Unfortunately in most cases it is impossible to conduct real life tests, so the only viable option is simulation, and there are a lot of work done about this, for example (Schätter et al. 2015). If tests are impossible to conduct, it is crucial to develop good Key Risk Indicators (KRI). There are two basic kinds of KRI: leading and trailing (lagging). Leading KRI are better, because they signal that situation is developing in the negative way, although the negative consequence are not yet evident nor developed. Trailing KRI indicates the degree of damage already happened. Obviously, leading KRI are much more useful than trailing KRI.

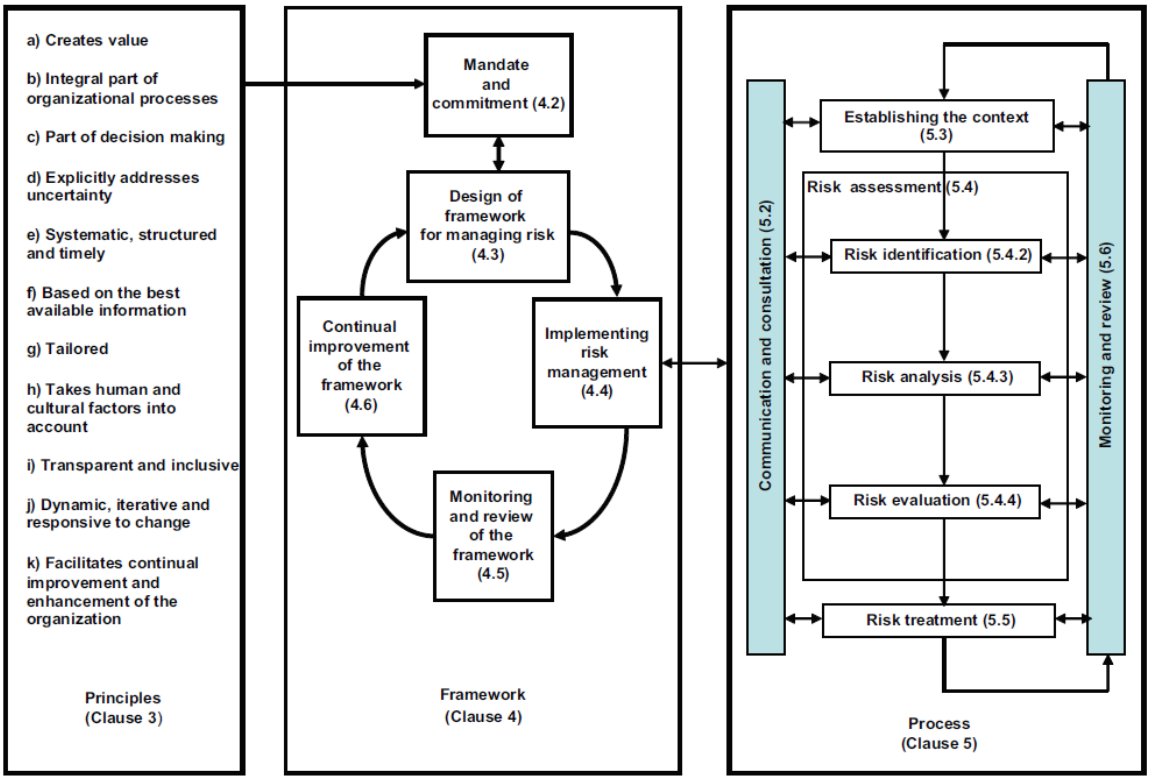

Figure 1. Relationships between the risk management principles, framework and process (ISO 31000 2009)

4. RESULTS

In the last decades of the 20th century, the European and world agribusiness and food industries are confronted with far-reaching changes. Customers are more self-assured and are making new demands on products and services and thus on suppliers. This requires a very radical change, i.e. the transformation of production-driven supply chains into market-driven supply chains (Folkerts & Koehorst 1997).
In (Bourlakis & Weightman 2004) one can find list of expert and public defined risks associated with food ranked in order of importance:

- Expert/Scientific: (1) Microbial contamination (2) Nutritional imbalance (3) Environmental concerns (4) Natural toxicants (5) Pesticide residues (6) Food additives
- Public: (1) Food additives (2) Pesticide residues (3) Environmental concerns (4) Nutritional imbalance (5) Microbial contamination (6) Natural toxicants

Gary Lynch in (Lynch 2009) presented general list of actors in the FSC: pesticide suppliers, feed suppliers, fertilizer suppliers, veterinary drug suppliers, agricultural production and harvesting, storage and transport of raw commodities, storage and transport of processed and manufactured goods, wholesale and retail distribution and food service sector.
We could add to this list only: packaging suppliers and IT services (and knowledge) suppliers.

Evidence suggests that the relationships between supply chain actors originate from the underlying market driven benefits, such as freshness, quality or lower costs (Folkerts & Koehorst 1997) and those benefits could be supported and improved by implementation of IoT.
Furthermore, Martin Christopher in (Christopher 1992) argues that building competitive platforms, that are grounded in idea of value-based growth, will require a much greater focus on managing the core processes that we referred to earlier. Whereas the competitive model of the past relied heavily on product innovation this will have to be increasingly supplemented by process innovation. The basis for competing in this new era will be:

Competitive advantage =
= Product excellence × Process excellence

And again we are coming to the conclusion that only with exact and timely information which involves implementation of IoT, we can create basis for process excellence.

5. FINDINGS AND DISCUSSION

Consumers' perceptions of risk stimulate information search and risk handling. When faced with a potentially risky purchasing decision, consumers may attempt to reduce the risk involved by developing strategies to reduce perceptions of risk and enable them to act with relative confidence in uncertain situations. Four generic

strategies to resolve or reduce perceived risk are the following (Bourlakis & Weightman 2004):

1. Reduce the perceived uncertainty about the product, or reduce the severity of real or imagined loss suffered if the product does fail.
2. Shift from one type of perceived loss towards one for which there is more tolerance.
3. Postpone the purchase.
4. Make the purchase and absorb the unresolved risk.

Every SC will like to help consumer to reduce perceived uncertainty (1) and make purchase with absorbing residual risk (4). So, SC will need to enable consumer to get accurate and complete data about product.

Risk of product contamination is one of the most present and most dangerous food risks. Contamination can originate externally - due to weak sanitation condition or internally – due to problems in food processing. Both problems can be prevented, and that is the best course of action. But, sometimes it is not enough. Consumers could be distrustful because they do not see all of the preventing procedures producer put in place. In that case, best solution is to enable consumer to "communicate" with product of with its "smart packaging". Smart packaging can monitor the food health and signal hazard situation the moment it detect results of degradation processes (specific gases, temperature, and raise in pressure…). That signal can be caught by receivers in warehouse, truck, and store shelves or even by consumer's mobile phone.

Packaging problems in most cases arise due to mishandling of heedless manipulation. Again, smart packaging can monitor pressure inside (vacuum or slightly raised pressure) and signal if there is change in pre-set pressure value.

New (and existing) food safety regulations usually demands that some parameters should be in specified interval or should be equal to zero. Smart packaging can be responsible for monitoring that parameter and signal if it receives values out of acceptable range.

Risk of intentionally contamination of the food can be mitigated by preventive measures (better solution) or detected by smart packaging, same as in the case of unintentional contamination.

6. CONCLUSION

Before starting implementation of IoT in FSC, one must have in mind problems regarding SC that are not easy to solve:

1. Technology implementations didn't work as promised.
2. Projects cost too much and never came close to meeting service targets.
3. Supply chain projects were inconsistent with a company's current business strategy
4. It was too difficult to manage change internally and externally (Blanchard 2010)

Strategic, external risk that supply chains encounter lies in the fact that firms within the chain have become major consumers of fast-changing technologies, in particular IT. At the same, they are increasingly losing control over these technologies. This in turn amplifies the technological risks that supply chains and enterprises face. IT outsourcing, a current fad, is a revealing signal of helplessness in managing a technology, imbedded in a strategic rationale; it has dire consequences for enterprises in the long run (Kogan & Tapiero 2007).

IoT implementation in FSC is something that is at its beginning and it is sure that there will be setbacks and problems of all kinds, but that does not mean that one should give up.

If one SC accepts to implement IoT and smart packaging they can have strategic advantage by enabling their customers/consumers to communicate with their product. It won't be a big problem to develop small application for mobile phone and enable consumer to read necessary information about product, from smart package. First, consumer will have to identify specific product / package (for example by reading QR (Quick Response) code from the package as suggested in (Tarjan et al. 2014)), and then to ask for and receive sent information. Consumer can get information about product ingredients which is very important for people suffering from allergies. That information can be fed in the application, and application could warn consumer that specific food is dangerous for him/her. Consumer could also get information about: nutrition values of product, calories, even about field where the some vegetable was grown or chemicals that were used to treat that field (if it was implemented Internet-of-Fields and FIWARE, as suggested in (Djukic et al. 2015)). Also, SC and consumer can have benefits by having exact information about how old product is and when is "best before" date. Retailer can also benefit by having the opportunity to compare predicted shelf-life of the product (as suggested in (Reljic et al. 2015)) and real shelf-life and according to that plan sales when best-before date comes close.

Final conclusion about IoT in FSC is that we are now at the denial phase ("IoT? You have got to be kidding!"). Developing smart package is at the beginning, but benefits are so huge, that it would not be wise not to go that way.

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Da li IoT može biti upotrebljen za ublažavanje rizika u prehrambenom lancu snabdevanja

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Rezime

Internet stvari predstavlja novi ali izuzetno obećavajući skup tehnologija, koji će uvesti revoluciju u prehrambeni lanac snabdevanja i način na koji biramo i kupujemo hranu. Kombinacija sveprisutne upotrebe mobilnih telefona, sposobnosti da se "komunicira" sa pakovanjem u kojem se nalazi hrana i da se prenose podaci koji su u vezi sa rizicima u kratkom vremenskom period i na bilo koju tačku na planeti, nudi mnogo viši nivo zaštite potrošača.

Ključne reči: *Internet stvari, prehrambeni lanac snabdevanja, ublažavanje rizika*