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Challenges of IoT Integration in Supply Chain Management: A Game-Theoretic Perspective on Motivating and Hindering Factors

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Abstract This paper presents a novel approach for evaluating the motivating and impeding factors influencing the implementation of the Internet of Things (IoT) in supply chain management, with a focus on developing an industry-wide trajectory using a game-theoretic model. Our research begins with an extensive review of academic literature to identify key factors that either facilitate or hinder IoT adoption in supply chains. We subsequently propose a systematic method designed for industry stakeholders to assess these relevant factors effectively. The applicability of our method is demonstrated through a case study in the Russian telecom industry, where we analyze both the benefits and challenges associated with IoT implementation using Partial Least Squares (PLS) analysis. The findings reveal critical insights into the dynamics of IoT integration and lead to the formulation of relevant assumptions for an evolutionary stable strategy, which are integrated into our game-theoretic model. This comprehensive approach not only enhances understanding of IoT adoption in supply chains but also provides actionable guidance for practitioners aiming to navigate the complexities of technological integration.

Keywords: Internet of Things, Supply Chain Management, Game Theoretical Approach, Evolutionary Stable Strategy.

1. Introduction

The fourth industrial revolution, Industry 4.0, Internet of Things (IoT), interconnection are one of the most hyped words both in the corporate and academic environment. First publications on the Internet of Things (IoT) have started as early as 1992, and the topic remained of interest in the past several years as well. A considerable amount of research has been done with regard to the application of IoT to such considerably sexy industries as banking and finance, manufacturing, healthcare, consumer electronics, and cars. The topic will remain of interest to business, as it is expected that by 2020 the Global IoT market will grow to USD 457 billion, attaining a Compound Annual Growth Rate (CAGR) of 28.5% (Forbes, 2018).

No matter the industry, supply chain management and operations, and logistics are a crucial component of a company's survival and success in the market. As strange as it may seem, the area of operational management is not considered as of primary importance for IoT application by some researchers and executives. Due to these reasons, a holistic literature review in this narrow topic is still lacking

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despite the potential benefits that IoT can bring to the operational effectiveness of a company through its integration in supply chain management.

As technology and economics develop, there will be required further research and development efforts to investigate the industrial development and applications of the Internet of Things, which makes the topic relevant for academics in various areas. There are several directions in which further research can go, including such topics at the direction of IoT infrastructure development for a chosen industry, assessment of business models for delivery of products and services, estimation of risks and core risk bearers, analysis of decision models to attain optimal profit, synchronized production and transportation topics as well as the research on impact of service sharing on enterprises. Indeed, the IoT in supply chain management provides a variety of interesting topics to academics and researchers.

Further speaking, Mishra et al. (2016) state that there is a limited number of studies that look into the relationship between the IoT adoption and supply chain performance. Additionally, Whitmore et al. (2015) noted that the topic of the IoT is poorly presented in the management literature and in general the topic of the IoT concentrated of technological research, which lacks managerial conclusion. Salam et al. (2023) proposes exploration of future trends and innovations in the IoT-driven supply chain landscape.

Based on the analysis of respective works of Mishra et al. (2016) and Whitmore et al. (2015) the following conclusions can be made. Firstly, there is an increasing interest in the topic of the Internet of Things in supply chain management on behalf of the research community. The number of papers on this topic peaked in 2018 with 94 academic works, and during 2019 31 paper has already been published. Secondly, compared to keywords of a broader scope, the necessity for further analysis of factors affecting the IoT implementation in supply chain management becomes evident.

Discussing factors that influence the IoT implementation, academic studies lack holistic, industry-specific cases, which could also use game theoretical approach for business purposes. So, industry-wide evaluation with a subsequent game theory model becomes the research problem of the current paper.

Research object of this study is the IoT implementation in supply chain management. The context of the research is the Russian telecom industry, which was chosen as the main provider and integrator of IoT solutions (iot.ru, 2018). Research subject is the analysis of factors influencing the implementation of the Internet of Things in supply chain management and their contribution to the evolutionary stable strategy.

The main goal of the current paper is to develop an approach for the evaluation of motivating and impeding factors for the IoT implementation in supply chain management and to estimate industry-wide course of development based on a game-theoretic model.

Structurally, the paper includes an introduction, three sections, conclusion, references list, and appendices.

The second chapter is dedicated to the overview of the existing research in the topic stated. The chapter covers the current state of the IoT and provides an overview of the current presence of the IoT in supply chain management. Additionally, the chapter concludes on the factors which affect the implementation of the IoT technology in supply chain activities.

The third chapter elaborates on the method of how to evaluate relevant factors and find the most important once. The chapter provides the research approach design and explains the rationale of all its structural elements, as well as discusses methods of ranking meta-inferences and lays out the selection of factors.

The fourth chapter demonstrates the results and discusses the application of the developed method to the Russian telecom industry. Additionally, the chapter adds flesh to the method of further data analysis using the evolutionary game theory, as well as interprets the empirical results of the study.

The current research paper uses both primary and secondary data sources. Primarily data was collected via a survey which attempts to provide an evaluation based on 24 relevant factors identified, assessed based on the Likert scale and later analyzed using XLSTAT software. Secondary data was obtained via the investigation of the existing scientific discussion. Relevant literature (journals, specialized books, internet articles, industry reports, and edited volumes) was identified by querying scholar databases for the terms “Internet of Things”, “IoT”, “supply chain”, “supply chain management”. The databases included: ProQuest, EBSCO, Emerald Insight, Science Direct, SCOPUS, Web of Science, Google Scholar. Moreover, in order to validate the overall work approach, a semi-structured expert interview was conducted with an incumbent Analyst from the National Technology Initiative (NTI) Center of Excellence in Wireless Technologies and Internet of Things from Skolkovo Institute of Science and Technology.

2. Existing Research on Factors Affecting the Internet of Things for an Adoption in Supply Chain Management

2.1. The current state of the Internet of Things

The very term the “Internet of Things” (IoT) was first coined by researchers in the Massachusetts Institute of Technology (MIT) in the late 90s. IoT is an integrated part of the Future Internet and could be defined as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual things have identities, physical attributes, virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network” (CERP-IoT, 2009). “Things” refer here to the idea that manufacturing products will be a part of the extended Internet since it will be possible to tag them during the production phase and track throughout the product’s whole lifecycle. In the ideal IoT system, each object has its unique digital identifier. The goal of IoT is to create a global network infrastructure to facilitate the easy exchange of commodities, services, and information (Liu and Sun, 2011).

The Internet of Things can be applied across various sectors. According to Mishra et al. (2016) basically, the application of the IoT can be categories into 4 major segments: industry, healthcare, smart environment, personal and social segment. Within the scope of the current paper, we will concentrate on one of the most well-known applications of the IoT - the Industrial Internet of Things (IIoT), which is applied in manufacturing and supply chain (Li et al., 2014). It is applied by some enterprises in order to promote operating efficiency and collect real-time information on site. IIoT enables greater control over the supply chain and related processes because it incorporates machine learning and big data technology, harnessing the sensor data, machine-to-machine (M2M) communication and automation technologies (Accenture, 2015).

Although the IoT is one of the hottest topics among enterprise leaders, IoT applications are still in its early stage. The depth of IoT integration into digital product models as well as new methods of manufacturing and networked cyber-physical systems can be seen as prerequisites for the success of the Industry 4.0 (Witkowski, 2017).

IoT market and drivers As stated in the introduction, the Global IoT market is expected to grow from USD 157 billion in 2016 to USD 457 billion by 2020 with a Compound Annual Growth Rate (CAGR) of 28.5% (Forbes, 2018). Since the numbers are impressive, 72% of the companies will increase their IoT spending in the next three years. At the same time, companies have higher expectations for scale, scope and return on investment (ROI) from their IoT initiatives.

According to Growth Enabler & Marketsand Markets analysis, the global IoT market share will be dominated by three sub-sectors: Smart Cities (26%), Industrial IoT (24%) and Connected Health (20%) with Discrete Manufacturing, Transportation and Logistics, and Utilities leading all industries in IoT spending by 2020, averaging EUR 40 billion each, with an average CAGR of 30% between 2015-2020 (BCG, 2017).

It is expected that in the nearest future research in IoT will concentrate on the following topics: Industrial Asset Management, Inventory and Warehouse Management, Smart Products and Supply Chain Management. The interest is risen by the IoT capability to improve accuracy, speed and scale of supply chains, which will redefine quality management, compliance, traceability and manufacturing intelligence. Furthermore, IoT will affect even currently non-technology-based industries (BCG, 2017). The main success factor here is tan IoT promote secure and scalable end-to-end integration solutions. Investments in Operational Sensing through IoT and situational awareness via analytics will deliver 30% improvement in Critical Process Cycle Times by 2018 (IDC, 2017). Additionally, the IoT adoption is expected to grow in logistics (especially in the segments of supply chain and warehousing), retail, manufacturing process, healthcare, utilities and energy, as well as education and insurance (Gregory, 2015, Kambies et al., 2016, Lee and Lee, 2015).

Although there seem to be certain benefits associated with the IoT technology, also, there are some limitations regarding why companies do not rush in the house-to-house IoT implementation. One of them – a lack of a global standard for the IoT (Gu and Liu, 2013). Lack of a universal standard is a barrier for private companies to consider the implementation of the technology not only in the supply chain but in other business functions. A lack of common standard impedes interoperability among business partners. Other 4 big problems associated with the technology, as identified by Ruan, Wu and Wu (2012) are technological concerns, cost concerns, business safety features of the IoT and also industry interoperability.

Features and characteristics IoT systems can be characterized by the following features: transparency, traceability, adaptability, scalability and flexibility (Chui et al., 2010). Due to these features, IoT has the potential to improve operational processes and reduce costs and risks. Nevertheless, as an open system and a new way of creating value, IoT imposes challenges on existing largely static information architectures used by a majority of supply-chains (Chui et al., 2010).

One of the main goals of the IoT is to link physical objects as a network so that they can be managed and interacted effectively. From this objective, the following characteristics of the IoT can be derived (Zhuming et al., 2014):

1. Pervasive sensing of objects.
2. Hardware and software integration.
3. A large number of nodes.

IoT is a technology that brings both operational effectiveness and revenue opportunities (Forbes, 2018) with its features and characteristics. The goal of operational effectiveness for enterprises in almost every industry is attained through the fact that the IoT enables assets tracking, monitors vendor relations helps with forecasting and inventory and improves the connection of carriers. Secondly, with increased transparency companies can not only build better relationships with customers through improved pricing strategies, but also create a reputation of socially responsible enterprises. By these means, revenue opportunities can be seized.

Necessary components of the IoT technology The core concepts underlying the IoT are not new. However, IoT information structures are complicated and require complex mathematical models, specialized algorithms as it has to deal with enormous amounts of real-time data collected and translate the output data into orders or tasks that can be readily used by operators or smart equipment (Zhang et al., 2011). A brief overview of core sub-technologies behind the IoT is listed below. Basically, IoT can be explained as a combination of web-based, things-based and semantic-based features (Chandrakanth et al., 2014). These features can be plainly translated into the respective terms: middle-ware, sensors and other technological hardware parts and knowledge.

In 1999 Massachusetts Institute of Technology (MIT) established the Auto-ID Center. At the same time, MIT proposed the electronic product code (EPC) encoding scheme and supporting relevant infrastructure. The EPCglobal Network was created to promote the interconnectedness of Radio Frequency Identification (RFID) in the supply chain (Thiesse et al., 2009). The incorporation of RFID technology into IoT infrastructure has been widely studied by Welbourne (2009). RFID has been so widely adopted in manufacturing, that nowadays it can be truly considered as one of the cornerstones of the IoT (Zhuming et al., 2014).

One of the pioneer works in the area was conducted by the International Telecommunication Union (ITU). ITU positioned IoT as a new dynamic network of networks, enabling anytime, anyplace connectivity for anything (ITU, 2005).

Other frequently used technologies in IoT are Service Oriented Architecture (SOA) (Guinard et al., 2010), Wireless Sensor Network (WSN) and machine-to-machine (M2M) communication. All these technologies are basic to the idea that within the Internet network clients, servers and routers are able to communicate with each other and therefore impact the enterprise systems.

Although, the majority of technologies used within the infrastructure are not new and already vastly implemented, what IoT changes are the number and kinds of devices as well as the interconnection of networks of devices across the Internet. The number of connected devices is expected to reach 50 billion by 2020 and it is no surprise that this number will grow even further as time passes. IoT is aimed at creating a global network with ubiquitous computing (Bandyopadhyay et al., 2011) and context-awareness among devices (Dong et al., 2010). With this technology, real-time visibility of the world will be possible. Information on temperature, humidity, localization, noise, orientation, vibration (Fleisch, 2010) will be sensed by objects with a sufficient level of intelligence. The data will be used to predict physical world events and make decisions autonomously with reduced human intervention.

The majority of problems in supply chain and logistics arise from the lack of real-time accurate information. In order to mitigate the problem IoT sounds as a perfect solution, as it provides information that is more detailed and up-to-date (Flugel and Gehrman, 2009) than currently available, alleviates the bullwhip effect (Yan and Huang, 2009), reduces counterfeiting (Yan and Huang, 2008), improves product traceability (Zhengxia and Laisheng, 2010), promotes differentiation and innovation (Deloitte, 2018). The realization of IoT involves many aspects including the holistic design of new business models (Dijkman et al., 2015) and the technology itself proposes much broader possibilities for implementation in real life.

IoT hype cycle. In order to evaluate the commercial viability of the new and emerging technologies Gartner – a global research and consulting company in the sphere of information technologies – has come up with such a methodology and Hype Cycle (Gartner, 2018). The Cycle is a graphic representation of the maturity and adoption of technologies, where 5 measurements of expectations change over time. 5 dimensions are (1) Innovation Trigger, (2) Peak of Inflated Expectation, (3) Trough of Disillusionment, (4) Slope of Enlightenment, (5) Plateau of Productivity (Figure 1). According to Gartner's research for Emerging Technologies (2018), the

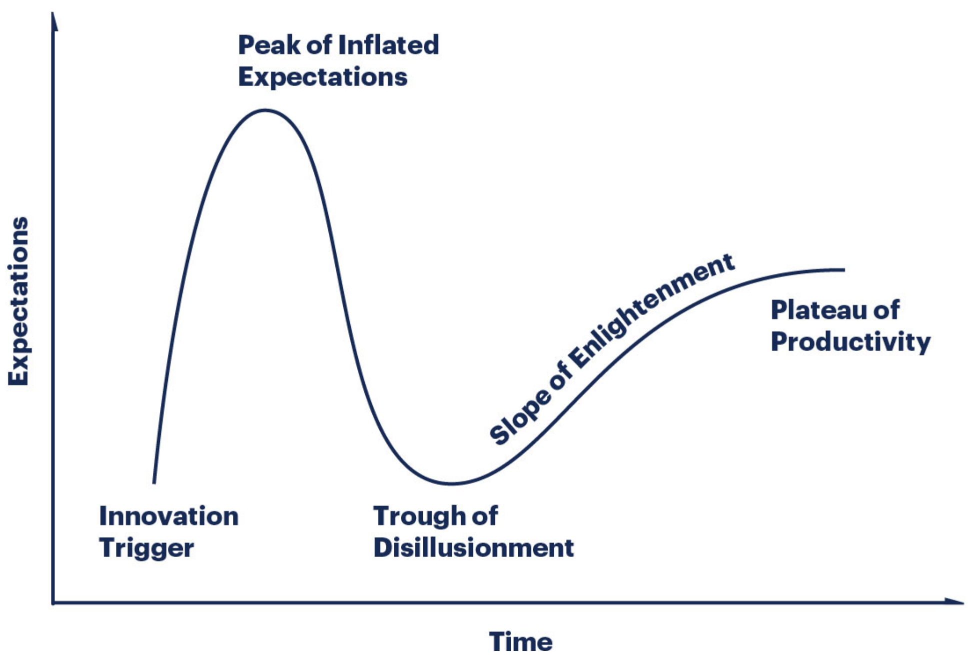

Fig. 1. Gartner hype cycle

development of IoT platforms has already passed the peak of inflated expectations but is still high on the curve. It is expected that the plateau for the technology will be reached within the next 5-10 years. Related to the IoT technology the following applications of it are at the peak: IoT Business Solutions, IoT Services, Automotive Real-Time Data Analytics (Gartner, 2018). However, in order for the plateau yet to come, many companies are to embark on the bumpy road of the IoT implementation in their business processes.

To conclude, in order to support IoT initiatives data-driven business models and decision-making mechanisms are required. Industrial application of IoT holds great potential for quality control, sustainable and green practices, supply chain traceability and overall supply chain efficiency. (Accenture, 2015). IoT brings remote tracking, assets tracking, control and optimization over processes, popper resources allocation and optimization, and context-aware automation and decision optimization (Chui et al., 2010; Fleisch, 2010). With these capabilities, companies can resolve complex problems which require sophisticated analysis, realize benefits, and enable real-time visibility at all steps of product creation and its lifecycle.

2.2. The current state of the Internet of Things integration in Supply Chain Management

Supply chain management is a foundational process that impacts nearly every enterprise. According to IBM, 65% of the value of a company's products or services is derived from suppliers. In this regard, operational lean is crucial to mitigate downward pressure on a company's margins. The value a company creates with its supply chain has traditionally been determined largely by how well it manages links within the supply chain pipeline: receive materials and components from upstream, create products, and distribute those products to customers downstream (Deloitte, 2018). Speed of production, quality and cost are considered as key factors, which help to estimate the functioning on the supply chain.

Supply chain management and logistics have many definitions which vary within researchers and academics. According to one of them, logistics can be defined as the task of managing 2 key flows: material flow (physical goods from supplier through the distribution centers to stores) and information flow of demand data from the end-consumer back to purchasing and to suppliers, and supply data from suppliers to the retailer, so that material flow can be accurately planes and controlled (Harrison, van Hoek, 2006).

At the same time, a supply chain is viewed as a group of partners who collectively convert a basic commodity (upstream) into finished product (downstream) that is valued by end-customers and who manage returns at each stage (Harrison, van Hoek, 2006) and promote efficient management of supply chains. Supply chain management (SCM) represents a new form of managing business and relationships with other members of the supply chain (Lambert, Cooper and Pagh, 1998).

Logistics and supply chain complement each other, as logistics support the competitiveness of the supply chain as a whole by meeting end-customer demand through supplying what is needed in the form it is needed, when it is needed, at a competitive cost (Harrison, van Hoek, 2006). There are four ways of competing through logistics: quality, speed, cost and better control of logistics processes. Harrison and van Hoek (2006) state that for supply chain and logistics continuous, synchronous flow is the key element. Continuous means that no interruptions are made through the data flow, synchronous means that everything runs smoothly. Improvement in supply chain performance can be achieved via several things. For example, through the reduction of costs, rise in the service level, and improvement of the overall system responsiveness (Yan et al., 2014). Information sharing, collaboration and agility are those factors which ensure supply chain system efficiency and integration.

Since information flow is one of the core components of supply chain management and logistics and since lack of information sharing hinders the effectiveness of logistics process, it can be concluded that IoT with its ability to optimize information allocation within different stakeholders can be vastly implemented in the area. For supply chain management objectives, this technology may allow machine-based decision making with minimum human intervention, provide accurate real-time information track of physical assets, automatic optimization of such operation activities as inventory management, warehousing management, delivery consolidation and transportation (Qiu et al., 2015).

IoT has initially been applied in Closed Loop Supply Chain with the aim of improving automation and efficiency. Using a closed loop based on bits, the IoT creates fundamentally new and non-linear ways to manage traditionally linear consequence of steps to create value for a company. Modern supply chain management can be not only about getting products faster, cheaper, and of better quality but also about getting managers the right information at the right time, so that they can better make informed supply chain decisions (Deloitte, 2018). IoT could also provide various advantages in SCM operations, such as improved inventory management, increased logistics transparency, business process optimization, and resource saving (Wagenaar, 2012). IoT has the power to increase the visibility for each individual item which will result in a highly visible supply chain. Geerts and O'Leary (2014) say that in the visible supply chain location and characteristics of an object can be ascertained at any point of time. The IoT implementation in SC increases profits and reduces lost value due to excess product manufacturing. Additionally, it allows faster response to clients' demands, increases the availability of suppliers and optimizes delivery process (Robinson, 2015).

Logistics 4.0 and Supply Chain Management 4.0. With the implementation of IoT in supply chain, we can talk about the next generation of supply chain management and Logistics 4.0 (Table 1). These topics, as well as smart supply chain management and digital supply chain concern various aspects of end-to-end logistics in the context of Industry 4.0. Close attention to data flows turned into actionable and intelligent decisions and actions are crucial to smart supply chain management in industrial transformation.

As it was stated in the first part of the literature review, core technologies underlying IoT solutions are not new and have been used for some time already. Comprehensive reviews of the RFID employment in supply chains can be referred to Collins and Parsa (2006) and Ngai et al. 2010. A consisted analysis of the value of RFID in item-level data visibility in manufacturing was conducted by Zhou et al. (2009). Decker et al. (2008) researched the benefits of attaching RFID and WSN to physical items in logistics processes with IoT usage. Rekik et al. (2008) analyzed the impact of RFID implementation in inventory inaccuracies.

First mentioned in 1982, supply chain implied a linear process. Virtualization brought by the IoT allows the development of informational aspects of operations out of touch with physical flows (Clarke, 1998; Verdouw et at., 2013). Virtual supply chain management does not require physical proximity (Pereira and Da Silva, 2015). From this standpoint, the route of physical products is no longer dependent on the location of forces performing coordination and control activities.

Traditionally it was believed that the supply chain ends when the final product is delivered to end-customer. However, with the introduction of IoT, the flow of data

Table 1. Industry 4.0 roadmap in logistics

Logistics					
Supply Chain logistics	Local operating structure	Global Operations Structure	Partial Global Resource planning / Controlling	Complete Global Resource Planning / Controlling	Open and Flexible Operations Footprint
Inbound Logistics	Push Delivery Process	Pull Delivery Process / JIS	Vendor Managed Inventory	Autonomous Inventory Management	Predictive Inbound Logistics Management (Big Data)
Warehouse Management	No Automation	Automatic Warehouse System	Automatic Warehouse Network	Supply Chain Warehouse Network	No Warehouse in Supply Chain
Intralogistics / Line Feeding	Manually steered rack, trolley	Manually steered train	Autonomous FTS on fixed routes	Autonomous FTS on open area	Autonomous FTS on open area steered by production machine
Outbound Logistics	Push Delivery Process	Order-Based Delivery Management	Active Delivery Management	Automatic Delivery Management	Predictive Delivery Management
Logistics Routing	Decentralized Vehicle / Equipment Fleet	Centralized Vehicle / Equipment Fleet	Pre-planned and Centralized Fleet	Real-time Routing and Connected Navigation	Autonomous Transportation Vehicle / Equipment

collected spreads beyond and continues to create value. Traditional value drivers of supply chain "better, faster, cheaper" are now substituted with their modern analogs of "magnitude, time, risk" (Deloitte, 2018). Data collected helps managers make more informed decisions and in its fullest expression IoT allows a company to transform supply chain activities from a cost center into a revenue generator.

Creating value from information in these ways can have potentially profound implications on supply chain management. For many years, the central objective of supply chain management has been to minimize variation in the supply chain. Variation was seen as the main enemy of efficiency as it contributed to the bullwhip effect. Bullwhip effect was usually created when the variation was revealed in upstream activities as due to traditional limitations of SCM the downstream activities were too slow to respond. With the IoT deployments, there is a possibility to mitigate the bullwhip effect, as timely and effective responses are possible. Variation, on the other hand, has been perceived as a foundation for new types of competitive advantage and innovation driver.

With a changed attitude towards variation and new capabilities deployed, the IoT is opening new ways to supply chain management, namely:

– Efficiency: IoT solutions increase transparency and reveal previously unseen information about supply chain flows which help increase the efficiency of a given unit.

– Differentiation: IoT solutions help improve customer experience and therefore drive greater differentiation. This objective can be attained through the inclusion of suppliers and distributors in the end-to-end supply chain and transform order system into a pull-driven one.
– Innovation: withthe integration of customers to end-to-end supply chain new innovative business models can emerge.

Although it is hard to predict what the future of the IoT in Logistics and Supply Chain Management might look like, researchers Ruan, Wu and Wu (2012) have completed the analysis of the past, present and the future of the IoT. The results of their work are summarized in Table 2.

Table 2. Prediction of stages of IoT in logistics

Stage	**Target**	**Characteristics**
Before 2000	The realization of the basic recognition capabilities	Warehousing, transportation, loading and unloading part of the link a small number of high-priced industry (alcohol and tobacco, medical care, luxury goods) application
2000 – 2010	Anti-collision (to improve stability), replication, and an external antenna identification	
2010 – 2020	Semi-automatic, automatic digital processing, and automated communications, power management (address energy issues)	Extended to the purchasing agent, terminal sales and circulation, more industries, as well as e-commerce, the emergence of new market segments and business models
2020 – 2025	Raise the degree of automation, automatic data processing to enhance the energy consumption problem solving, automatic positioning	Supplying in chain integration, and expand the "one-stop" solution services in the area of the whole industry chain
2025 – 2030 and after	Smart devices, automatic network connection, automatic positioning, the user interface processing	A modular, systematic, network and the virtual into the characteristics of the supply chain network management organization to achieve.

As we have mentioned earlier, there are definitely some business and economic benefits associated with the IoT implementation in supply chain management and logistics. Yet, there are also many difficulties like the cost, technology's maturity, security issues, standardization issues and many others. At the same time many scholars, researchers and business-insiders state that a far greater problem is the lack of a fully-formed profitable business model for the logistics industry which would have developed through inner driving processes (Pishdar et al., 2018). The "Garbage In Garbage Out" (GIGO) system will be working poor with the IoT, but if a company has a driver which would have allowed it to gain business drive for the cost of high-yield, a pricy and technologically complex hardware system will not be a problem.

To conclude, one may say that nowadays we can talk about next-generation development in logistics and supply chain management (Logistics 4.0, Supply Chain Management 4.0, Digital Supply Chain and etc.). It is expected that logistics will be a key factor determining a company's success or failure and expand in influence as technologies and management systems continue to evolve. The reason why the IoT topic in supply chain is taken so seriously can be seen in its ability to connect information about physical objects with the virtual world, increase the visibility of parts and processes, improve productivity, reduce costs and enhance the customer experience. Within its several years of hype and implementation, IoT has managed to show the transformation of supply chain management from linear to non-linear process and shifted the variation paradigm from trouble-maker in supply chain process to value-creator and innovation drive.

2.3. Factors affecting the Internet of Things for adoption in Supply Chain Management

When analyzing factors that affect supply chain management practices in general, one has to list such contextual factors as the industry a company operates in (Jharkharia & Shankar, 2006), its field of operation, size of a company, its position in the supply chain (Li et al., 2005, 2006, Halley & Beaulieu, 2010), operational capacities (Hsu et al., 2009) and competitive advantages related to production and manufacturing. In the academic literature, there are different views on what factors to assess when to implement IoT solutions into supply chain management. When introducing IoT into practice, such aspects as manufacturing (Bi et al., 2011), social networks (Atzori et al., 2012), and emergency responses (Yang et al., 2013) could be assessed. Concurrently, IoT-enabled solution can be introduced on the assessment of the following supporting pillars: physical asses service system (PASS), information infrastructure and decision support systems (Qiu et al., 2015). Within the context of this work, PASS can be viewed as a new business-model for IoT-enabled enterprises that binds physical assets with corresponding activities and services and provides a mechanism for information sharing. Yet, there is another pool of factors that can be analyzed when deciding on the deployment of IoT solution in the supply chain. Since the adoption of ultra-high frequency technology affects enterprise as a whole, it is necessary to evaluate cost, patents, existing infrastructure of the supply chain, return on investment (ROI), compatibility and technology transfer approach. Other important factors to be considered are perceived benefits, perceived cost, the trust of technology and external pressure (Tu, 2018). As we can see from the paragraph, there is a handful of factors to be considered which drive the research agenda across many industries and enterprises.

Although the Internet of Things is considered a relatively new topic in supply chain management, there are some technological standards that can be considered a de facto basis for successful further implementation of IoT. Among these basics, we can name the RFID item-tagging and EPCglobal network, which is the underlying IoT information infrastructure (Tu, 2018). However, despite the fact that overall cost of RFID tags and other infrastructure devices has dropped significantly, enterprises are still resistant and conservative to the application of IoT for supply chain management (Tu, 2018).

With the adaptation of IoT solutions comes a list of new requirements to enterprises, which can transform into potential challenges (Zhuming et al., 2014).

1. Complexity, as greater differentiation will promote a more complex and versatile product, which will result in the increasing complexity of manufacturing activities.
2. Increasing level of dynamics, as the share of real-time data over supply chain will boost.
3. Development of virtual entities, as physical and virtual resources will blend and have to be considered simultaneously to provide sufficient capabilities to the manufacturing process.
4. Increasing price of first-time mistakes, as fierce competition forces will push towards the avoidance of excessive inventory and minimization on non-value-added activities.

The majority of empirical research about IoT implementation has adopted either a qualitative or quantitative approach. Many researchers studied the adoption process of IoT through qualitative research in order to investigate the motivation behind the decision of IoT deployment in supply chain. Different enterprises in supply chain have different expectations regarding the benefits of IoT implementation. An example of qualitative research in the area would be Boeck and Wamba (2008) analysis of RFID implementation in the supply chain for the retail industry. The researchers used such qualitative methods as observation of participants, action research and Grounded Theory (GT). Since IoT is a disruptive technology, researchers are investigating the issue of organizational adaptation with the help of the diffusion of innovations (DOI) (Rogers Everett, 1995) and the technology-organization-environment (TOE) Framework (Tornatzky and Fleischer, 1990).

Data-driven qualitative research in the area shows that there are some concerns regarding the IoT implementation in business processes. These concerns are mainly related to cost, organizational level issues and to the face that the main factor influencing the IoT adoption is the external motivation force.

3. Method of evaluation of factors affecting the Internet of Things for an adoption in Supply Chain Management

This chapter is designed in order to describe the methodology used for the mixed research in current paper. This part of the work provides a rationale for all structural elements of the developed method. Moreover, the chapter also describes the survey and data collection. Methods were chosen in coherence with the goals of the investigated subject, their relevance and explanation justification. Firstly, the author will introduce the research design and explain the process of selection of the relevant methods. Secondly, the author will provide an overview of suitable methods and explain the specific method choice. Finally, there will be a process description for the creation of the relevant survey and data collection.

3.1. Research design

Based on the identified research gap in the field of IoT implementation in SCM the goal of the current research was stated as the development of an approach which will help evaluate both stop and go factors. The framework should serve the following purposes:

1. Give ad industry-wide overview of what perceived benefits promote the IoT implementation and what challenges impede the advance of IoT integration in SCM.
2. Take into account a company's perspective and be flexible to provide a company-specific recommendation with a check-list of what to improve in order to ensure smooth implementation of the IoT in SCM.
3. Take into account the profit generated from the IoT implementation for suppliers and core enterprises as well as the profit distribution (maximum survival in Evolutionary Game Theory terms).

Once the developed method is designed, it is applied to a chosen industry, which in the scope of the current paper in Russian telecom.

The paper at hand uses mixed method research. The mixed method offers a better insight into understanding the incentives behind firms' decisions to adopt IoT than just the use of either the qualitative or quantitative method alone (Tu, 2018). It is assumed that the mixed research method can successfully bridge the qualitative and quantitative research gap, as it helps to generalized the qualitative findings with the help of quantitative methods. It blends the merits of both research methods and, moreover, helps to cross-reference data in order to deepen the understanding of the topic researched. Since the goal of the paper is to provide a more in-depth understating of the IoT adoption in SCM, the mixed research will provide better insights than a single method. Detailed guidelines for mixed research methods in supply chain management can be referenced in Golic and Davis (2012).

The qualitative part of the research includes the choice of factors which might affect the implementation of the IoT in SCM via literature review and its justification based on the review of preliminary findings with an expert in the field. On the other hand, the quantitative part takes the findings of the qualitative phase and further develops the research approach applications: data will be collected via survey for the case industry and data analysis will be performed using the partial least squares (PLS) statistical method in XLSTAT. XLSTAT is a statistical software for data analysis in Excel. Each of the stages is further described in the paper in details and the practical implication of the approach on the specific company is discussed in details in Chapter 4.

As a result of the work done, the authors came up with the following visual representation of the developed research approach (Figure 2). As a result the research approach consists of several steps:

1. Gathering of factors which are relevant to the topic of thepaper.
2. Narrowing down based on the industry specifics and expert interview.
3. Design of a questionnaire which will help gather data for further interpretation.
4. Analysis of data collected and its subsequent inference.
5. Recalculation of the obtained evolutionary stable strategy point through some time period (Deming cycle rationale).

The steps and justification of the rationale behind them are described in consecutive stages later in this chapter.

3.2. Selection of the initial framework

In quantitative research, the theoretical foundation plays a major role in research development. The diffusion of innovations (later as DOI) (Rogers Everett, 1995)

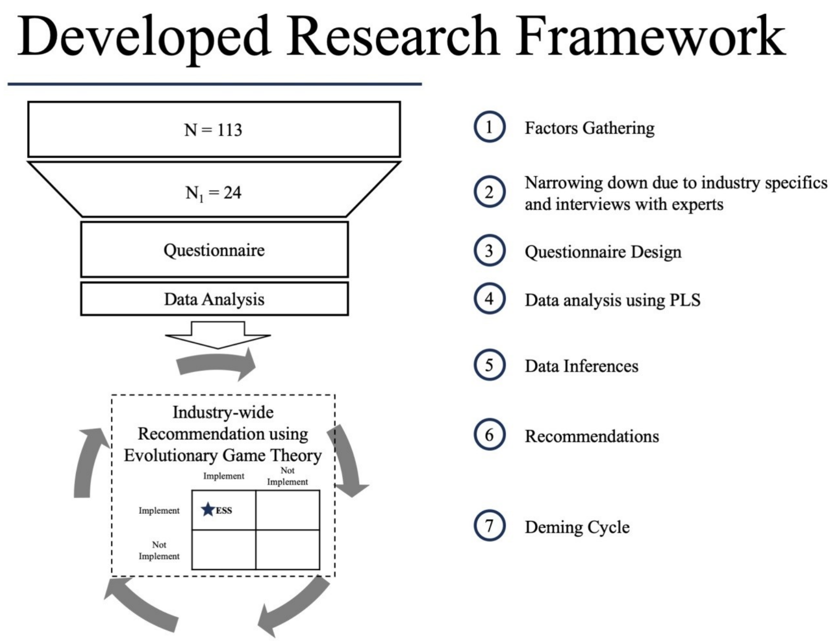

Fig. 2. Visualization of the research approach

and the technology-organization-environment (TOE) framework (Tornatzky and Fleischer, 1990) are two main theories used to investigate organizational adoption and intention to adopt IoT innovation from the organizational perspective.

DOI (Rogers Everett, 1995) is a widely used framework/theory to examine the innovation diffusion of technology adoption over time. According to DOI, there are 5 factors which affect technology adoption and explain variances in adoption rate: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability and (5) observability. However, the results of the qualitative investigation conducted by Agarwal and Prasad (1998), Tornatzky and Klein (1982) state that although the benefits of IoT implementation are clear, the decision about whether to adopt the new technology is not merely a technical issue or individual-level adoption behavior. The decision becomes an organization-level one. The same studies suggest that the external driving force should not be underestimated as well, because it affects a firm's adoption intention.

The TOE framework developed by Tornatzky and Fleischer (1990) relates of a high-level theoretical model, which helps to analyze the implementation/adoption decision on a firm level as well as identify factors which affect the innovation adoption. TOE promises a more holistic overview because it also provides ideas on the external environment a company operates in.

As a result, TOE framework was chosen as the basis of the quantitative research model. It is necessary to mention that TOE is an important part of the research design, but the created framework should incorporate more elements in order to fully reflect the main goal of the paper.

3.3. Selection of factors

Comprehensive analysis of several fundamental and many other supplementary works (Yan, 2018; Ruan, Wu, Wu, 2012; Haddud et al., 2017; Papert, Pflaum, 2016; Sowders, 2016, etc.) resulted in a list of 113 factors, which as respective authors have mentioned, can affect the implementation of the Internet of Things in Supply Chain Management. As a first step, factors were divided into 2 pools – benefits in challenges. At a later data clarification stage, all factors were critically analyzed and subdivided into several topics (Topic Level 1), namely, IoT Technology, Organization Issues, Process, Supply Chain, RFID, External factors, Product, Suppliers. Later, Level 1 topics were narrowed to an even more detailed level (Topic Level 2). Level 2 list of topics helps us estimate, what exact questions do company managers ask themselves when trying to figure out the pros and cons of implementing the Internet of Things in SCM. In order to visualize and have a clear understanding of the correlation of all 3 levels of topics, the author has gathered them in the Power Pivot using Microsoft Excel toolkit.

As the next step, the author divided topics in accordance with their belonging to the elements of the TOE framework, which resulted in a broad list of factors, which are represented in Table 3.

Table 3. Developed structure of factors affecting the implementation of the IoT in SCM based on TOE framework

	Technology	**Organization**	**External**
Benefits $\sum$ **56**	RFID – 4 factors *Total – 4 factors*	Process – 24 factors Supply Chain – 16 factors Product – 6 factors Suppliers – 2 factors Organization – 1 factor *Total – 49 factors*	External – 3 factors *Total – 3 factors*
Challenges $\sum$ **57**	IoT – 21 factors RFID – 2 factors *Total – 23 factors*	Organization – 13 factors Process – 9 factors Supply chain – 7 factors *Total – 29 factors*	External – 5 factors *Total – 5 factors*

It is clear that with the boundaries of the paper it is impossible to draft a comprehensive survey with detailed questions on each of the 113 factors which would have a high response rate. Due to this limitation, the author has decided to concentrate only on those factors and topics which are of the most importance to decision makers. The topics were chosen based on the results of the frequency analysis and framed in a company survey.

It is also crucial to mention that the structural overview of factors listed in Table 3 is neither exhaustive nor compulsory. Any decision maker is free to tailor, adjust and modify the factors based on the company's business model of specifics of supply chain management.

In order to benchmark the validity and reasoning of the chosen factors, an expert interview was conducted. Denis Dedov, an analyst with more than 12 years of industry experience in information technologies from Skolkovo Institute of Science and Technology agreed for a telephone interview after seeing the factors list and draft of the questionnaire. In Skolkovo Denis is working for the National Technology Initiative (NTI) Center of Excellence in Wireless Technologies and Internet of Things. As a manager, Denis is involved in various IoT-related projects on a daily basis. Regarding the feedback received from him on the factors chosen, he noted that the benefits listed and truly related to the industry needs of both Russian enterprises and suppliers. Regarding the costs and challenges side of the analysis he personally stated that to his mind the main challenges are related to the financial aspects, vague understanding of the economic effect of the implementation, lack of fast payback, management's ignorance of new technologies (IoT included) and the absence of a clear link to current KPIs of a particular employee. In general, the overall approach to the challenges was approved by Denis.

3.4. Methods of ranking for meta-inferences

The next section of the paper argues about the choice of the most appropriate method for the evaluation of factors and lays the way for their managerial applications. The researcher approached the choice of the method baring in mind that it should address the stated research gaps. Moreover, the method was also chosen on the basis of the idea that meta-inference analysis will be required to merge together both parts of the mixed method research.

Partial list squares (PLS) is a statistical technique of the structural equation model (from now on SEM) which as a component-based technique helps with exploratory or predictive research. As well as SEM, PLS provides parameter estimates for a system of liners equations (Hair et al., 2006). However, as Hair et al. (2006) state, it differs from the SEM method in several key aspects:

1. In PLS factors are regarded as individual composite scores, so the covariance between measured item scores is not re-created.
2. Degrees of freedom for PLS do not have such a meaningful role as for SEM.
3. PLS is more flexible with the optimization procedures and has fewer challenges with statistical identification and errors.
4. While SEM is reproducing the observed covariance between items observed, PLS find solutions on the group of minimizing the variance in endogenous constructs.
5. PLS does not require the characteristics of good measurement to produce results.
6. PLS is less sensitive to the considerations of sample size.

To elaborate, one can say that the advantages of the PLS method are that PLS can provide reliable estimates of the relationships measured. Even in conditions when the SEM method is useless due to some limitations, PLS can still come up with a solution. PLS can provide estimates even if the CFA was failed. Additionally, PLS focuses more on prediction as it statistically produces parameters which maximize explained variance. What is more is that PLS is a preferable method when measures of a particular data set are problematic. Under these conditions, PLS is a direct alternative to the SEM method.

Nevertheless, there are some disadvantages inherent in the PLS method. For example, the results produced by the PLS cannot be of significance if the measurement quality is violated and multi-item measures become available for latent constructs. In these regards the SEM method is more preferable for data analysis, as well as it is more preferable for the purposes of theory testing.

Since the nature of the analysis is more exploratory and not confirmatory and taking into account the limitations of the sample size and the qualitative estimation of the research based on the Likert scale, PLS method is the best option for the data processing (better than covariance-based SEM) taking into accounts such its benefits as (1) less strict requirements for sample size, (2) distribution-free due to non-parametric statistics, (3) insensitivity to impurities.

3.5. Evolutionary stable strategy in the context of the evolutionary game theory

When talking about the IoT implementation we are to consider two decision-making levels: (1) how a company decided on whether to implement the IoT or not, and (2) how many industry players decide upon implementing the IoT (group decision making)? Very often the answer to the question "Whether to implement IoT in supply chain" depends on what proportion of the entire industry population has already decided to pursue the "Implement" strategy. This leads us to the conclusion that in this regard we are trying to examine a behavioral strategy. Additionally, the tool should also serve the purposes and goals of the paper. Consequently, the research approach should incorporate such a tool, with which one is could analyze decision making taking into account cognitive and systematic constraints and providing quantitative (mathematical) analysis. Moreover, the Internet of Things is a technology which benefits become more obvious only when the majority of players in the market opt for the implementation strategy of such a technology. Additionally, the more game participants pursue the "Implement" strategy, the more profit maximization is ensured. Also, as it became clear from the previous chapters of the current paper, the implementation of the IoT is fraught with a great number of factors to be analyzed, considered of and mitigated. Such rationale means that companies are participating in some sort of Multi Criteria Decision Making (henceforward MCDM) in the analysis of alternatives for selection of enabling technology. Due to these conclusions, our next theoretical method for analysis should incorporate all these limitations and considerations.

In the article by Sanfrey (2007), the author argued to use the Game Theory techniques, as it helps "to better understand decision making by taking into account cognitive and neural constraints, as investigated by psychology and neuroscience, while using mathematical decision models and tasks that have emerged from economics". Classical game theory has been widely used to model factors which influence the decision making between supply chain stakeholders. Academics (Whang, 2010; Gaukler, 2011 and Xu et al., 2015) have used Stackelberg game framework to investigate different aspects of RFID application in supply chain (incentives, operational benefits, joint investments in RFID for a complex product production respectively). Moreover, evolutionary game theory is used to examine behavioral strategies (Chen, Hu, 2018) and represents a dynamic framework for players' behaviors (Mahmoudi, Rasti-Barzoki, 2017).

By itself, the Game Theory approach is useful for the MCDM analysis, which we partly touch upon in the current paper. Social interaction, particularly in its form of group decision making, is heavily associated with most actions in the MCDM. The Game Theoretical approach helps to account for social effects on decision making (Georgiadis, Mazzuchi, Sarkani, 2012)

Evolutionary game theory is the result of the application of the game theory to biological evolutionary context (Smith, 1982). Evolutionary games have the potential to help model economic issues with quite a detailed level of comprehensive prediction, however, such modelling may require some considerable framing (Friedman, 1998). The theory behind evolutionary games has been extensively used for modelling business, culture, and economic issues (Cai and Ned, 2009; Mattei, 2014; Antocia et al., 2014). Within the scope of the paper, we will consider two groups that are interested in the IoT application in SCM – the enterprises and suppliers. There is an evolutionary game existing between the core enterprises and suppliers, and the results of this game are influenced by many factors (Yan, 2018).

Evolutionary Game Theory consists of all the same items as any classical game theory model: game, players, strategy, payoff, information set, equilibrium. However, evolutionary game theory approaches the assumption about rationality differently. The classical game theory assumes that the participants are fully rational, and information is distributed symmetrically (Yan, 2018), however, such a layout is far from reality and no supply chain can satisfy these 2 assumptions especially with the given influences from the internal and external environments. On the other hand, evolutionary game theory operates the principle of bounded rationality – game participants should not be fully rational. Moreover, in the real economic activity, for actors it is impossible to behave in a perfectly rational manner, as they are under influence of both external and internal environment (Chen, Hu, 2018). The goal of the evolutionary game theory is not just to predict short-term economic equilibrium, but to provide an analysis of more long-term relationships related to the economic problems. To put it in a nutshell, the theory studies the strategy of the entire system under the assumption that only a limited number of participants are rational (Young, 2011). And thus, it is proven to be invaluable.

Applying these concepts to the Supply Chain Management field, we get that the information about the RFID application enterprises get is limited. Using the IoT, enterprises refer to (1) the behaviors of other enterprises, (2) adaptability of the population (Yan, 2018). Additionally, the evolutionary stable strategy (ESS) consists in the limitation of strategies of other enterprises and continuously learning how to adjust to them (Yan, 2018). ESS can be considered as a refinement of the Nash equilibrium where individuals (in our case – companies) use the same rule for communication and interaction with each other. Stability in ESS refers to the fact that the strategy cannot be invaded by an alternative course of action. An alternative course of actions, which violates the commonly accepted rule, in this case does not provide a better payoff. The evolutional component of ESS is related to the fact that it is a heritable trait that is subject to the natural selection. Within the scope of the current paper, we regard natural selection as the volatile and changing nature of the market, which forces its inhabitants to change courses of action and find new ways for corporate survival and profitability. ESS suggests that in the end the strategies will be chosen by the players who produce a better-than-average payoff (Mahmoudi, Rasti-Barzoki, 2017). Moreover, network externalities are also to be taking into account. Therefore, evolutionary game theory is highly applicable to the investigation of factors affecting the implementation of the IoT in supply chains.

Another factor which spurred the author of the paper to use the game theory approach was the requirement for the managerial application of the research. Game theory as a management tool has long ago exceeded its classic “prisoner’s dilemma” application to business decision making and can be classified as a powerful decision-making tool. Game theory holds a prominent place in a corporate strategy and has been used in business for more than 60 years already (McKinsey & Company, 2009). As a strategic decision-making tool Game Theory, provided that it has a sufficient amount of detailed inputs, can contribute unambiguous information to managers.

In order to understand the game payoff of core enterprises and suppliers, we are to bear in mind, that they can opt for one of the following strategies when talking about the IoT application: "Implement" or "Not Implement". Hereinafter the author will provide definitions for the mathematical model for payoff matrix.

Table 4. List of variables used for Evolutionary Game Theory equations

Variable	**Description**
π_m	Total returns for the core enterprises
π_s	Total returns for suppliers
x	The proportion of core enterprise which opt for the implementation strategy
y	The proportion of suppliers which opt for the implementation strategy
k	Proportion of RFID tags that enterprises share, $k \in [0, 1]$. The cost is distributed to the ration of k to $1 - k$.
$1 + a_1$	Profit increase of the expected return for core enterprises
$1 + b_1$	Profit increase of the expected return for suppliers
a_0	Core enterprises gain in suppliers choose "Not Implement" strategy
b_0	Gain of suppliers if they alone go for "Implement" strategy
a	Gain of core enterprises if suppliers alone go for "Implement" strategy
P	Punishment factor to prevent free-rider behavior from enterprises' side. If core enterprises do not implement RFID, they suffer punishment, but still might get some benefits from the fact that suppliers have opted for the "Implement" strategy
r	Risk factor
m, n	Expected rates of return without RFID for core enterprises and suppliers$m > n, m, n \in (0, +\infty)$
I	Investment cost, calculated as $I = I_0 + rp$, where I_0 is the investment costs, and rp is the cost of the implementation risk
p	Cost coefficient of the risk, directly proportional to the fixed investment cost
$C_r(v, f, t, q)$,	Cost of a tag, where t – type, f – frequency, v – volume of information stored, q – size of the purchase
$_m$	Maintenance costs, influenced by the general maintenance of facilities, some expenses related to the necessary RFID updates, as well as other costs like labor
z	Variable used to simplify equations, where $z = \frac{\alpha}{\alpha+\beta}$, where α and β are respective sizes of enterprises and suppliers
R	Average annual population return without IoT implementation
R_0	Average annual population return from the cooperation of enterprises and suppliers on daily basis.

With these descriptions given, we can state that the payoff matrix and its relative 4 quadrants of behavioral strategies will be described using the following 4 equations:

$$\begin{pmatrix}\pi_{1m}\\ \pi_{1s}\end{pmatrix} = \begin{pmatrix}(1+a_1)(1-r)\,mRz-(I_0+pr)\,z-kC_r\,(f,v,t,q)-ZC_m\\ (1+b_1)(1-r)\,nR\,(1-z)-(I_0+pr)(1-z)-(1-k)\,C_r\,(f,v,t,q)-Cm(1-z)\end{pmatrix} \tag{1}$$

$$\begin{pmatrix}\pi_{2m}\\ \pi_{2s}\end{pmatrix} = \begin{pmatrix}(1+a_0)(1-r)\,mRz-(I_0+rp)\,z-C_r\,(f,v,t,q)-C_m\\ nR\,(1-z)-R_0\end{pmatrix} \tag{2}$$

$$\begin{pmatrix}\pi_{3m}\\ \pi_{3s}\end{pmatrix} = \begin{pmatrix}(1+a)\,mRz-K\\ (1+b_0)(1-r)\,nR\,(1-z)-(I_0+rp)(1-z)-C_r\,(f,v,t,q)-C_m+P\end{pmatrix} \tag{3}$$

$$\begin{pmatrix}\pi_{4m}\\ \pi_{4s}\end{pmatrix} = \begin{pmatrix}mRz\\ nR(1-z)\end{pmatrix} \tag{4}$$

Additional assumptions for the model will be stated in the Chapter 4, based on the empirical results of factor analysis. Basically, the abovementioned equations are linked to the following quadrants of the Evolutionary Game Theory payoff matrix (Table 5).

Table 5. Correspondence of equations with the payoff matrix

Enterprises		Suppliers	
		Implement	**Not Implement**
	Implement	(π_{1m}, π_{1s})	(π_{2m}, π_{2s})
	Not Implement	(π_{3m}, π_{3s})	(π_{4m}, π_{4s})

By modifying and solving these equations, we can obtain 5 equilibrium points of the Evolutionary Game, namely, $(0,0)$, $(0,1)$, $(1,0)$, $(1,1)$ and (x_0, y_0) in the plane $M = \{(x,y)|0 \le x, y \le 1\}$,

$$x_0 = \frac{(1-z)\,[(C_o+rp)+nR(r-b_0+rb_0)]+C_r+C_m-R_0-K}{(1-z)(1-r)\,nR\,(b_1-b_0)+C_rk+C_mz-K} \tag{5}$$

$$y_0 = \frac{(1-r)\,a_0mRz+mRrz+C_r+C_m+(C_0+rp)\,z}{(1-r)(a_1-a_0)\,mRz+(1+k)\,C_r+C_m\,(1-z)+K} \tag{6}$$

The question whether all of the five equilibrium points are the ESS are outside of the stated scope of the current research.

3.6. Survey creation and description of the developed method for data analysis

The stage of quantitative research in the present paper was performed by the creation of a survey, which aim was to evaluate both industry-wide and company-specific factors which promote and withhold the implementation of IoT in SCM. Based on the idea the partial least squares method, the following requirements for the scale of evaluation had to be considered:

– The scale should be in command to capture the difference in respondents' thoughts and feelings regarding the benefits and challenges they anticipate.
– Evaluators' marks should be clear to the examiner/researcher.

Based on these simple criteria, the survey focused on the Likert scale as an instrument of quantitative data collection. One of the advantages of the Likert scale is that it provides a broader variance of quantitative scores, thus allowing assessors to provide a more detailed overview of factors at hand. At the same time, Likert scale has a drawback since the scale has 5 dimensions, the process of evaluation becomes time-consuming.

The developed survey included 33 questions in total and was divided into 2 logical parts with 9 and 24 questions respectively. In the first part respondents had to answer to general questions related to their working experience, the current position occupied and specialization field, the size of a company they are currently working in, and their involvement in the IoT-related projects. The second part of the survey was used for the empirical research, where respondents were asked to rank the list of technological, organizational and environmental benefits and challenges which stop them from the implementation of the IoT based on the Likert scale. After that, the quantitative data is analyzed using the PLS method. The calculations are processed in XLSTAT – a statistical software add-on for data analysis in Excel. As a result, the weight-coefficients estimations are calculated for each factor, which allows to figure out which benefits and which challenges are the main driver for the IoT implementation.

Industry-wise a different set of outputs, was obtained, which will tell the super-industry bodies, what should be their next steps and what barriers should be eliminated if they want to ensure the mass-implementation of the IoT in the industry.

3.7. Deming Cycle justification

Based on the Gartner's (2018) research we have found out the technologies (IoT) included are developing and emerging in a 5-step cycle. This is why it is unreasonable to stop the research at the level of Game Theory without even theoretically including the necessity of further re-calibration and re-calculation of the status quo. For this purpose, the Deming Cycle was included in the research approach. As a decision-making tool, the Deming Cycle can be described as a constant process of iterations based on observation, imitation, and learning.

4. Application of developed research approach to the telecom industry

The following chapter aims to demonstrate the results of the conducted empirical study which hopes to provide a comprehensive analysis of the factors affecting the implementation of the IoT in Supply Chain Management and also outline the steps for additional models of further research using the Evolutionary Game Theory and Deming Cycle. The chapter is structured in the following way. Firstly, the data collection process is illustrated. Then the sample of the survey is described. Later the chapter elaborates on the theoretical model and provides a detailed description of dependent and independent variables which are used for the evaluation. Finally, the empirical results based on the PLS method are reviewed, interpreted and incorporated in the ESS equations.

4.1. Industry case data collection

For the purposes of the current paper, the Russian telecom industry was chosen as a digital pioneer in the IoT implementation in the country. The questionnaire was developed for Russian Telecoms and those above-industry bodies which are involved in the practical research regarding the state of the IoT in Russia (iot.ru, 2018). The questionnaire, designed in the Russian language for the convenience of participants, was distributed via emails, network, and personal contact.

The survey lasted for 2 weeks and during this period 16 responses were collected. Although the number might seem insignificant in the research field there is an example of a work using the PLS method for analysis using only 6 subjects. Nevertheless, the work of Tenenhaus et al. (2004) is approved by the research society (ResearchGate, 2014) and its results are considered significant. Since the proposed PLS method can be used for the evaluation of experts' opinion, such number of filled questioners can be considered sufficient for further data analysis.

After the finalization of data collection and preliminary processing, the analysis was performed in accordance with the procedures of the PLS method in XLSTAT.

4.2. Survey sample description

In order to conduct the empirical study, a data sample of 16 responses from employees of the Russian telecom companies was obtained via survey. In order to obtain the 16 responses more than 150 e-mails and messages were distributed via digital communication means. As far as the target group for the survey is concerned, two considerations were introduced. Firstly, the survey targeted Russian telecom companies, as they are the largest vendors and solution providers of IoT-related technologies and RFID tags. Within the companies of interest the author manually and specifically selected those potential respondents, who are directly involved in various activities related to the IoT implementation and who have an established track record of working for the IT industry.

For the sample surveyed the author managed to distribute the questionnaire among large companies. The majority of companies (56%) have between 2000 to 5000 employees.

As far as the industrial belonging of the employees surveyed is concerned, the questionnaire was distributed among the right target audience, where 63% of the respondents work in IT / Telecom.

Regarding the occupied positions of the respondents, half of them are currently working as managers. Additionally, the author also managed to distribute the questionnaire to business owners and/or shareholders (19%).

Additionally, for the purposes of the current paper, it was also important to understand the specialization profile of the respondent. 81% of them are working for the Information technology and Digital transformation departments, while only 19% of the respondents are occupied with marketing and finance-related activities.

One can conclude that the sample managed to include quite experienced employees, as 50% of them have been occupying their position between a year till five and 31% have been working in the position between six to ten years.

The majority of respondents have up to 5 years of work in their primary industry, with some of them working in the industry for up to 20 years.

To conclude, one can see that the survey managed to collect responses of the right audience. Namely, managers with a vast working experience in the IT / Telecom field, who know about the IoT and who frequently work on the IoT projects within their tasks on information technology and digital transformation.

4.3. Theoretical model and variables description

For the purposes of the current research the PLS method was chosen in order to evaluate factors which affect the implementation of the IoT in SCM. In order to make sense of the data computed in XLSTAT software, there are several important metrics one has to consider: VIP score, VIN, as well as R^2 and Q^2 for the estimation of significance of the model. All these metrics and ways of their interpretation are discussed below.

PLS model description. PLS takes into account both dependent data Y and independent data X, for which principal scores of Y and X are calculated based on matrices (Palermo, 2009). Matrix X is decomposed into matrix T and matrix P' which are referred to as X-score and X-loading respectively. Similarly, the calculation of matrix Y can be dissected into Y-score and Y-loading, which are represented by matrices U and Q'. Additionally, the model also has to take into the error matrices: E and F for both equation sets.

$$X = TP' + E \tag{7}$$

$$Y = UQ' + F \tag{5}$$

Putting it all together, Palermo (2009) states that the main ideas of the PLS algorithm is to minimize the norm of F through the limitation of the correlation between X and Y by the means of the inner relation of the diagonal matrix. In the equation 8, D represents the diagonal matrix.

$$U = TD \tag{8}$$

In order to infer data from the PLS regression we are to compare the performance of the so-called variable importance in the projection (VIP) scores with PLS regression coefficients. Such a comparison will allow us to select most relevant variables for the further usage within the developed framework. One of the methods for variable selection based on the PLS modeling is the so-called Variable Importance in Projection (VIP) (Wold, Johansson, Cocchi, 1993). VIP score of a predictor is the summary of the importance for the projections to find latent variables. In turn VIP values are calculated via summing variable influence (VIN) over all model dimensions. For a given PLS dimension a, ${(VIN)_{ak}}^2$ is equal to the squared PLS weight $(w_{ak})^2$ of that term, multiplied by the percent explained of residual sum of squared be that PLS dimension. By performing this steps the software manages to obtain the accumulated overall dimensions value:

$$VIP_k = \sum_a \left({(VIN)_{ak}}^2\right) \tag{9}$$

The dimension values are subsequently divided by the total percent explained of residual sum of squares and them multiplied by the number of items in the model. According to Chong and Jun (2005) VIP scores can be used to select relevant predictors according to the magnitude of their values. A variable or variables with the VIP value close to or greater that 1 can be considered significant to the model.

There are several indicators one has to pay attention to in order to understand the significance of the model. In the case of the PLS method used for the paper at hand, these factors are coefficient of determination (R^2) and cross-validated redundancy (Q^2) (Hair Jr. et al., 2014). R^2 is a measure of a predictive accuracy of the model, which at the same time can be viewed as a factor which represents he exogenous variable's combined effect on the endogenous variable (Hair Jr. et al., 2014). The range of R^2 varies from 0 to 1, where 1 is complete predictive accuracy. R^2 is widely accepted be a variety of disciplines, and scholars take the values of R^2 as a universal "rule of the thumb". Regarding R^2 vales of 0.75, 0.50 and 0.25 are respectively considered substantial, moderate or weak for predicting the model's accuracy. Hair et al. (2011), however, warns not to rely too much on the R^2 for the estimation of a model's accuracy, since R^2can increase even if a nonsignificant but slightly correlated construct is added to the model. Q^2 is a metric for assessing the inner predictive relevance of a model. A Q^2 value larger than 0 indicates the path model's predictive relevance for a particular construct. Also, one has to note that while Q^2 says whether an endogenous construct can be predicted, it does not say anything about the quality of prediction (Rigdon, 2014).

Description of dependent variables. For the purposes of the current paper both dependent and independent variables were selected in accordance with the TOR framework. Dependent variables were selected as a result of the aggregation of various factors which influence the IoT implementation in SCM. As a result, the following list of variables and their codes was produced (Table 6). Coding was necessary for the simplification of the calculation process of the researcher.

Table 6. Dependent variables used for the research

Code	**Dependent Variable (based on TOE framework)**
BT0	Technological Benefits
BO0	Organizational Benefits
BE0	Environmental Benefits
CT0	Technological Challenges
CO0	Organizational Challenges
CE0	Environmental Challenges

As a way of measurement, the respondents had to allocate a number to each of the dependent variables in accordance with the Likert scale (1 – 5).

Description of independent variables. In total, the research incorporated 18 independent variables, which were assessed by the respondents based on the Likert scale. The selection process of the independent variables consisted of 2 parts – the aggregation of those factors which are most frequently related to in the academic literature and scientific society, as well as the validation of the selected variables based on the interview with the expert. Independent variables were chosen in the respect that they are most likely to be the factors which can influence the perception of the technological, organizational, environmental benefits and challenges for companies in the market. As a result of such considerations, the following list of independent variables and their respective codes was drafted (Table 7).

Table 7. Independent variables used for the research

Benefits		***Challenges***	
Code	**Independent Variable**	**Code**	**Independent Variable**
BT1	Increasing data processing in SCM	CT1	Poor understanding of IoT-related technologies and their benefits to the business regarding SCM
BT2	Integration of business processes	CT2	Long and difficult integration of IoT with the current SCM system
BT3	Data storage and data flow management in SCM	CT3	Technological immaturity of IoT
BO1	Improvement of business processes within the company	CO1	High cost due to the reorganization of human resources
BO2	Increased SC transparency and procurement accuracy improvement	CO2	High cost of the technology and integration
BO3	New product development and life cycle management by the introduction of IoT in SCM	CO3	Serious changes to the current business processes
BE1	Increased competitiveness	CE1	Suppliers are not ready to implement IoT in SCM
BE2	Increased client satisfaction	CE2	No basis for IoT implementation created by the government
BE3	Expand the client base	CE3	Incapability of managing increasing demand from customers' side

4.4. Empirical results based on the PLS method

This part of the paper provides the results of the empirical study conducted regarding the dependent and independent variables, including their respective measures of statistical significance and VIP Scores.

Technological Benefits. As far as the Technological Benefits are concerned, the model has showed an R^2 of 0.72 (almost substantial significance) and Q^2 of 0.10 (greater than 0), which means that the model is relevant and can be trusted. Having competed and analyzed the VIP score, we can see that factors BT1 and BT2 are the main motivators for the companies to implement IoT in SCM form the technological standpoint.

Table 8. VIP scores for technological benefits analysis

Variable	VIP
BT1	1.449
BT2	0.949
BT3	0.000

Organizational Benefits. As far as Organizational Benefits are concerned, the model showed a substantial value for R^2 of 0.72 and a Q^2 of 0.13 (greater than 0). The VIP values analysis showed that factor BO1 has the most significance to companies in terms of its motivation power, with BO2 factor following.

Environmental Benefits. The R^2 value for the analysis of environmental benefits was the highest, 0.83 (substantial), with the respective Q^2 value for the model being

Table 9. VIP scores for organizational benefits analysis

Variable	VIP
BO1	1.487
BO2	0.888
BO3	0.024

greater than 0 as well (0.14). For the VIP scores BE1 showed the highest value of 1.4, with BE3 factor following.

Table 10. VIP scores for environmental benefits analysis

Variable	VIP
BE1	1.384
BE3	0.816
BE2	0.646

Technological Challenges. Now, as far as the technological challenges are concerned, we have managed to obtain the results for the analysis of the Technological Challenges with R^2 value of 0.83 (substantial) and Q^2 of 0.26 (significant). The VIP scores calculation showed that the CT3 factor had the greater influence.

Table 11. VIP scores for technological challenges analysis

Variable	VIP
CT3	1.666
CT2	0.475
CT1	0.000

Organizational Challenges. For the analysis of Organizational Challenges, we have obtained the model significance of a substantial level with R^2 of 0.75 and Q^2 of 0.50. The VIP analysis showed high values (above and around 1) for all the independent variables used.

Table 12. VIP scores for organizational challenges analysis

Variable	VIP
CO3	1.060
CO2	1.045
CO1	0.886

Environmental Challenges. Computation of the PLS model for the analysis of Environmental challenges showed the R^2 value of 0.61 (moderate significance) and a Q^2 of 0.27 (predictive). The analysis of VIP values shows that CE3 factor is the main bottleneck on the way toward successful IoT implementation.

The results of the empirical analysis can be summarized in the following table (Table 14), which shows the most significant factors propelling or impeding he IoT implementation in SCM.

Table 13. VIP scores for environmental challenges analysis

Variable	VIP
CE3	1.614
CE2	0.602
CE1	0.180

Table 14. Sum up of the main motivating and impeding factors influencing the IoT implementation in SCM among Russian telecoms

	TOE Element	**Factor**	**VIP Score**
Benefits	Technology	BT1	1.449
	Organization	BO1	1.487
	Environment	BE1	1.384
Challenges	Technology	CT3	1.666
	Organization	CO3	1.060
		CO2	1.045
	Environment	CE3	1.614

4.5. Analysis of the obtained results

From the PLS model and the VIP scores obtained, we can derive those factors which have the most influence on the IoT implementation in SCM both from positive and negative standpoints.

From the technological standpoint, the main motivating factors for companies is that the implementation of RFIDs will ensure faster data processing in SCM. The main organizational benefit perceived by companies lies in the field of increased operational effectiveness of supply chain management. Environmentally speaking, companies believe that the implementation of the IoT will help them improve their competitiveness in the market and be stronger than competitors.

However, the challenges are the one factors that stop companies from the IoT implementation. Our analysis has shown that from the technological standpoint companies are not rushing towards the IoT implementation in such a complex process as SCM because they believe that the IoT technology itself is immature. Organizational bottlenecks seem to be the most severe and crucial for the IoT implementation, as the IT executives collectively have produced a statistical answer that organizationally, in terms of business processes, companies are not ready for further modernization. If the current business system works by a "Garbage In Garbage Out" (GIGO) model, then the implementation of the IoT will not benefit the company. Technology only helps to increase the efficiency of a business process, but cannot rewrite a trashy process into an efficient one. Secondly, organizationally companies are repelled by the factor of the high cost of the RFID and the IoT implementation. Finally, in terms of environmental bottlenecks we see that although the IoT implementation in SCM helps better response to customers' needs and wants, companies are afraid that such a technology will lead to excessive demands from customers and companies will not be able to cope with them. To sum up, during the factors gathering stage we have noticed and hypothesized that the main bottlenecks for the IoT implementation lie in the field of the organization. Our statistical PLS analysis has proved this hypothesis to be right.

In this way, discussing the managerial applications of the current paper, we can conclude that the decision-making authority within the company when assessing the strategical goal of IoT implementation should consider the following risks. First of all, there needs to be a clearer research undergone in order to understand what IoT technologies even at the current state of their development can be of use to the business. Secondly, the IoT as a disruptive technology required a significant audit of the current business processes. A company has to understand its inner need for modernization and further development and prepare for inevitable changes.

4.6. Assumptions for game-theoretical model

Having analyzed the data at hand with the PLS method and having understood the main motivating benefit and stop-factors in form of the main challenges for the industry, we can theorize on the next step approaches for further analysis using the Evolutionary Game Theory approach. For such purposes we are to identify several model assumptions, research might be using for further mathematical calculations.

1. Supply chains are motivated to improve their efficiency, as otherwise not implementing the IoT in SCM they are running the risk of losing the product market and market share.
2. We will consider that in our population, numerous supply chains occupy the horizontal orientation, while core enterprises will be occupying vertical orientation.
3. In order to understand the willingness of a single supply chain implement RFIDs and adopt the IoT, we are to consider network externalities. Namely, we are to understand what proportion of the entire supply chain population is opting for the implementation strategy. If the proportion is high and the majority are in favor of adopting and one supply chain decided to give up the RFID implementation, it is running the risk of losing both possible profits generated through RFID implementation, loses benefits of decreased costs and improved efficiency, and also loses its current product and market share. This is due to the fact that other companies, implementing the IoT, can propose increased efficiencies and lower costs.
4. The core enterprises in the market, if they have a high compelling force, can make suppliers adopt and apply the RFID technology. Or else, they can cancel out those suppliers who refuse to cooperate in the technology implementation strategy.
5. The return on implementation is allocated to core enterprises implementing RFID proportionally with the size and scale of the enterprises, and the cost of the RFID tags is also distributed accordingly.
6. In our current model, based on historical data of Walmart, Metro Group and Amazon, we assume that the implementation of RFID leads to profit increase. However, suppliers get nothing if only core enterprises opt for the RFID implementation strategy.
7. Having analyzed works of Yan (2018), Ruan, Wu and Wu (2012), and Haddud et al. (2017) we came to a conclusion, that RIFD cost is mainly influenced by several facts that can either increase or decrease a tag's price. Such factors as the type of a tag, frequency used, the volume of information stored in a tag push its price up. The volume of the order made by a company (for example, bulk purchases allow lower costs) can reduce the price of an RFID.

8. If the compelling force of enterprises is moderate, the results of the evolutionary game between enterprises and suppliers are influenced by an alternative list of factors.

5. Conclusion

The main goal of the current paper was to develop an approach for the evaluation of motivating and impeding factors for the IoT implementation in supply chain management and to identify assumptions and variables for an evolutionary stable strategy model. In order to attain the goal stated, a number of objectives were met.

First of all, the paper has provided an overview of the current state of the IoT technologies and potential for their implementation is supply chain management, including the analysis of their further development towards the Industrial Internet of Things and Logistics 4.0. Secondly, a comprehensive list of factors which influence the IoT implementation in supply chain management was derived and later analyzed based on two topic levels and frequency analysis in literature. Already at this stage of the research, it was clear that the organizational-related challenges and benefits are prevailing. Thirdly, the work has included an empirical part which provides the assessment of factors based on PLS model calculation in XLSTAT. Finally, the author has elaborated on assumptions and variables needed for the evolutionary stable strategy estimation and derived theoretical and managerial applications.

The constantly increasing level of competition in business has transformed the evaluation of various technological applications to business functions into a compulsory part of the business process. Such process allows enterprises to identify those perceived technological, organizational and external benefits that motivate them to opt for an implementation of a particular technology not only in the supply chain management but also into other business practices. The evaluation helps enterprises understand the existing technological, organizational and external bottlenecks and challenges that can impede the implementation of the desired technology.

Since the Internet of Things has a huge potential in the supply chain management domain, it was important both to analyze inherent benefits and challenges based on the TOE framework in order to derive managerial implications. The empirical part, based on the PLS method showed that perceived benefits do not always match with the real challenges related to the implementation process. The designed research approach had to take into account several major assumptions: the cyclical nature of the IoT and IoT-related technologies, the profit maximization goal of a business, as well as the unstable business environment, where actors adhere to certain behavioral rules. In this regard, the evolutionary game theory approach became necessary, as it allows to smoothly incorporate all these assumptions in a structured model and provide a scientific evaluation of strategies. The market is always changing: new players appear on the market, old players adopt new technologies and new rules, which implies that the competitive nature is changing. The profit obtained due to the IoT integration in supply chain management is maximized when the majority of market players (both enterprises and suppliers) go for the "implement" strategy in their actions. The author has proposed an equation model which could help estimate whether the current status-quo in the market is optimal for a specific industry. The model includes 8 assumptions which are based on the evolutionary game theory approach and literature review and incorporates 20 variables, which are to be taken into consideration.

The list of advantages of the developed framework include:

– Possibility to use continuous Likert scale during the stage of data collection.
– Simultaneously take into account the most relevant factors of the TOE framework both from challenges and benefits perspective based on VIP scores.
– Opportunity to proceed non-numeric, inexact and incomplete information.
– Simplified process of calculations, performed with the use of PLS regression in XLSTAT.

The proposed method also has a potential for application in real-life business cases due to the simplicity of performed calculations and possibility to adjust the list of assessed quality attributes to the necessity and strategic focus of a particular organization.

Based on the results of the research, the following theoretical and managerial implications can be derived.

Theoretical Implications

There are several factors that indicate that the current work contributes to contemporary academic literature.

First of all, it expands the theoretical research identified in the research gap section. The research brings together concepts of TOE framework, partial least squares analysis, evolutionary stable strategy and evolutionary game theory. The work has managed to create an extensive list of factors, narrow them down to the most relevant for the purposes of the research and industry and empirically interpret them.

The main theoretical contribution of the current paper is based on the development of a comprehensive, holistic and complex method for benefiting and challenging factors evaluation and further mathematical model for the evolutionary stable strategy. It is also possible to conclude that the proposed method is not specific for supply chain management and logistics field only. On the contrary, the developed approach may be implemented for identification and analysis of factors motivating to implement and impeding the implementation of any new technological breakthrough in any business process of any sector, and the only adjustment necessary is the incoming identification of relevant factors. It may be suggested that the developed method aims to support the decision making on prioritizing bottlenecks for improvement in accordance with their significance.

Managerial Implications

As far as the managerial implication is concerned, the current paper ensures several conclusions. Companies do really think that the implementation of the IoT in supply chain management can benefit the business process and improve effectiveness. Such an improvement is tracked to all three levels of the TOE framework and is related both to suppliers and core enterprises.

The prospects of the IoT integration in the supply chain are obvious, while the analysis of challenges is not that straight-forward. Organizational unpreparedness of enterprises and suppliers acts as the main bottleneck for a complex IoT integration. This unpreparedness is reflected in the perceived high costs associated with new technologies and the necessity of business process transformations. Technologically companies are repelled by the seeming immaturity of the IoT and low understanding of how to implement the technology. However, the most surprising challenge is related to the environmental part. Although companies strive for personalization and better product development, they are afraid that once the IoT is implemented and the informational flow from the customers becomes clear and evident, companies will not be able to cope with customers' demands and growing needs.

The evolutionary game theory implies that it is important to monitor the market situation and chose a time when to go for the implementation strategy. In this regard managers should pay attention to the fact, that the implementation of the IoT can maximize profit in accordance with the relevant size of a company (namely, the bigger the company, the bigger chunk of the generated profit it can gain), and the free-ride strategy will impose some monetary punishment on the company.

By the prioritization and elimination of the organizational bottlenecks, namely process modernization and cost concerns, companies will be able to increase their digital savviness and improve supply chain efficiency. Additionally, the elimination of these factors will allow the telecom industry in the name of core enterprises and suppliers to ensure profit maximization. In order to eliminate the challenges listed the following cost of action can be recommended. Technology- and operations-wise it is possible to find those technologies that are both mature and suitable for the current business processes. Such an approach will not disrupt the existing supply chain flows but will help to enhance and develop those elements of the process which produce stable and optimized results. A gradual implementation can be seen as a way of mitigation of major risks associated with IoT integration.

Limitations and Opportunities for Further Research

Several limitations associated with the conducted research are necessary to be discussed. Firstly, the results obtained from the application of the developed framework for the Russian telecoms may be questioned due to small sample size. However, the current sample size can be considered of high quality, as it consists of top and middle managers with more than 5 years of experience who are dealing with IoT-related projects on a daily basis.

In addition, due to the overall comprehensiveness of the research and time limitations from respondents' side, the questionnaire covered only the main topics, pains and challenged associated with the IoT implementation in SCM. However, the empirical part of current research is still appropriate even taking the described limitations into account, as the main objective of it was the justification of the overall applicability of the developed method. For the purposes of in-deep company or industry analysis, it is possible to extend the questionnaire and include more questions and independent variables associated with the topic.

The list of described limitations provides researchers with opportunities for further method development. Future research is suggested to enhance the understanding of the evolutionary game theory modelling.

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