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# A Conceptual Framework for the Identification of Food Safety Risks in Global Commodity Flows Exemplified by Agricultural Bulk Commodities

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## ABSTRACT

**Globalization of agricultural trade has led to food supply chains becoming increasingly complex. A high number and diversity of entities, processes, and localisations can create food safety risks and vulnerabilities at all stages of the food supply chain. To date, food safety measures have focused mainly on production, processing, and retail. However, the dimension of commodity flows embedded in the logistics sector, which links the main stages, has largely been neglected. The resulting knowledge gaps pose a challenge to risk assessors concerned with consumer health protection. To map the research area of global commodity flows and investigate their impact on food safety, a conceptual framework (CF) was developed using agricultural bulk commodities (ABC) as an example. The construction of the CF is based on a qualitative text analysis of multidisciplinary literature, adapted from the Grounded Theory approach. Here we determined and illustrated different levels of the main concepts inside and outside of ABC flows relevant for the investigation of logistics in terms of food safety. The main internal concepts are *Key processes* and *Management*, *Key actors* and *Cooperation*, *Routes and Nodes*, and their *Quality and Capacity*. The external concepts can be divided into *Logistics-related conditions* and the associated *Diversity*, as well as *Drivers of change* associated with the *Dynamics* of globalization. The developed CF represents a first model for holistically investigating logistics in terms of food safety by defining, structuring, and delimitating logistics as a new field of investigation in risk assessment. It offers suitable concepts and application-oriented theories related to food safety that serve as a basis for empirical studies, such as the identification of critical factors in the logistics sector. Further, it serves as an aid to practitioners in dealing with complex food safety problems in the context of risk management.**

**Keywords**: *logistics, agri-food, globalization, food supply chain, risk*

## 1. INTRODUCTION

Food safety risks related to the globalization of trade and food safety management along agri-food supply chains are identified as one of the most critical issues of today's food safety (Codex Alimentarius Commission, 2016). Agri-food supply chains comprise all productive and logistical measures from primary production to consumption of the final product. Due to the constant growth of international trade in the last decades and the resulting increased geographical segregation of food production, processing, and consumption, agri-food supply chains have become longer and more complex (Hertel, 2013; Marucheck *et al.*, 2011). Outsourcing and offshoring have led to more diversity and a higher number of entities, processes, and localization as well as complexity in product and information flow (Dreyer *et al.*, 2009; Matopoulos *et al.*, 2004; Rodrigue *et al.*, 2016). Characterized by supply, demand, and price variabilities as well as by a limited shelf life, agri-food supply chains can be more complex than other commodities (Ahumada and Villalobos, 2009; Bhat and Jõudu, 2019; Lowe and Preckel, 2004).

As a consequence, the global and highly interconnected agri-food supply chain creates food safety risks and vulnerabilities at multiple points at all supply chain stages (see red arrow in **Fig. 1**) (Chammem *et al.*, 2018; Zhao *et al.*, 2020). A single safety incident in a certain stage can have a significant impact on consumer health on a global scale (Kruse, 2015; Marucheck, 1987). This has been confirmed in the past by serious food safety incidents (e.g. Dioxin contaminated animal feed in 2003, Escherichia coli (EHEC) contaminated fenugreek seeds in 2011, Salmonella Enteriditis in 2014, Aflatoxin milk contamination in 2013, Fipronil egg contamination in 2017), with the result that consumer awareness and concern have increased and food safety has become an increasingly important public health issue. Over the past two decades, food safety authorities have therefore had to face the challenge of assessing and managing food safety risks in consumer health protection. On the other hand, traders and the food and feed industry have also been challenged to avoid or minimize food safety issues. Consequently, numerous measures have been taken to manage and handle food safety risks along global supply chains**.**

Based on the supranational "Food Code" Codex Alimentarius, the EU, for instance, has set the principle "from farm to fork" (EU-Regulation No 178/2002) to guarantee a continuous control and protection of food safety along the supply chain. Additionally, the food and feed industry, as well as non-governmental organizations, have established a large number of private standards and guidelines that include hazard analysis and critical control points (HACCP) and cover the entire food supply chain such as Good Agricultural Practice (GAP), Good Manufacturing Practices (GMP), Good Handling Practices (GHP), Good Trading Practices (GTP) as well as international food safety standards (e.g. ISO 22000, FSC 2200). However, food safety incidents still occur despite respective regulations, standards, and correspondent measures (Marucheck *et al.*, 2011). This implies that there are still unknown and unmanageable vulnerabilities in the food chain and leads to the assumption that the exclusive focus on internal critical control points for food safety within the diverse stages of the global agri-food supply chain is insufficient in times of globalized trade. Instead, it can be assumed that the more complex the system, the higher the probability of food safety risks (Chammem *et al.*, 2018; van Asselt *et al.*, 2010).

In response to serious food safety issues, the European Food Safety Authority EFSA, as well as international organizations such as the UN Food and Agricultural Organisation FAO have set focus on the development of Emerging Risk Identification (ERI) and Early Warning Systems (EWS). Based on a holistic approach, these systems emphasize the influential sectors of the food production chain such as market trends, technology and science by integrating these external factors in the identification of food safety risks (Noteborn *et al.*, 2005). However, international foodborne disease outbreaks in the past have demonstrated the lack or limited availability of data and information required for clarification of complex food safety cases or related risk assessment. The revealed knowledge gaps resulting from the complexity of global food supply chains lead not only to uncertainties in the assessment of safety risks in the entire food system but also in health risk assessment (Manzini and Accorsi, 2013). In this context, the new Regulations (EU) 2019/1381 amends the EU General Food Law (EU-Regulation No 178/2002) to increase transparency in the EU risk assessment in the food chain.

One area that showed several data gaps and lack of information while the clarification of occurred food safety incidents is the logistics sector. It has become apparent that the transportation sector, for instance, lacks an oversight about food being moved. In the complex web of the supply chain, this lack results in generally little data and analysis (LeBlanc *et al.*, 2015). In fact, the focus of food safety improvement measures, i.e., in risk management and risk assessment, has so far been on the supply chain stages "(primary) production", "processing" and "wholesale and retailing". The logistical processes such as transportation, interim storage, and handling that crosslink the major agri-food supply chain steps and characterize global commodity flows (**Fig. 1**) have yet received comparatively less attention (Ryan, 2017). However, logistics play a crucial role when considering global supply chains from a food safety perspective. It is known that during transport, storage and handling, food safety can be compromised by chemical, physical and biological contamination. Little is known about how the quantitative and qualitative expansion of logistics with increasing internationalisation, such as the number of actors, distances, means of transport, documents and information, as well as the logistics-relevant framework conditions, affect food safety (Göpfert and Braun, 2013). Furthermore, as a global sector, logistics is subject to dynamic developments and global competition in the course of globalisation, which further increases the complexity.

Against the background of the complexity of global supply chains due to the interaction between multiple factors within and between tiers of the chain (Pope, 2020), it should not be assumed that food is being safely moved throughout global supply chains in general. However, as supply chain "risks" commonly refer to potential losses incurred by the companies in the supply chain due to disruptive events, most of the research lies in this area (Hudnurkar *et al.*, 2017). Consequently, the knowledge and research gaps of logistics concerning food safety increase the uncertainties in risk assessment. Therefore, the questions arise: What is the impact of global commodity flows on food safety, and how can this be assessed?

To date, risk assessment lacks a strategy to evaluate global commodity flows or logistics regarding food safety. New comprehensive approaches are needed to capture logistics in its complexity and the context of food safety beyond the already known and practised HACCP in logistical processes such as transportation, handling, and interim storage. The phenomenon "global commodity flows" needs to be further defined and better understood in the context of food safety to be integrated into the corresponding risk assessment and ERI systems.

Therefore, the aim of the present study was to develop a comprehensive and holistic conceptual framework (CF) of the phenomenon "global commodity flows" in the context of food safety. It should illustrate the complexity and - at the same time - characterize, structure and delimitate the phenomenon as a new field of investigation in risk assessment.

It should provide information about the following key questions concerning global agri-food commodity flows:

- What are the physical boundaries?
- What are the key processes?
- Who are the key actors?
- What are the major influential sectors in terms of food safety?

In addition, the CF is expected to offer suitable concepts related to food safety that serve as application-oriented theories/propositions that can systematize further research to fill the knowledge by, for example, identifying critical factors related to food safety. In addition, it is intended to serve as an aid to practitioners in dealing with complex problems in the context of risk management. In the present study, the CF is exemplified using the dimension of global procurement/sourcing of agricultural bulk commodities (ABC), marking the first phase of agri-food commodity flows throughout global supply chains. The global sourcing/procurement segment within the agri-food supply chain defines the very boundary and scope of the present study, for which a CF was developed (**Fig. 1**) (Pfohl, 2010). ABC, such as cereals and soy beans, intended for human nutrition and animal feeding, are the primary traded agricultural raw materials worldwide with rising trade volumes (USDA, 2018). In the EU, most of the imported ABC is intended for the animal feed sector (FEFAC, 2018; Schmid and Goldhofer, 2017). For example, about 800 shiploads or 58,000 containers of soy reach Europe every year. From this, 26.5 million tons of feed are produced in 5,000 feed mills. This dimension already shows how complex the logistics of agricultural commodities are (Baaken and Lehnen, 2015).

We have developed and constructed a CF for global ABC flows for the identification of critical factors related to food safety through a process of qualitative text analysis of multidisciplinary literature, adapted from the Grounded Theory methodology.

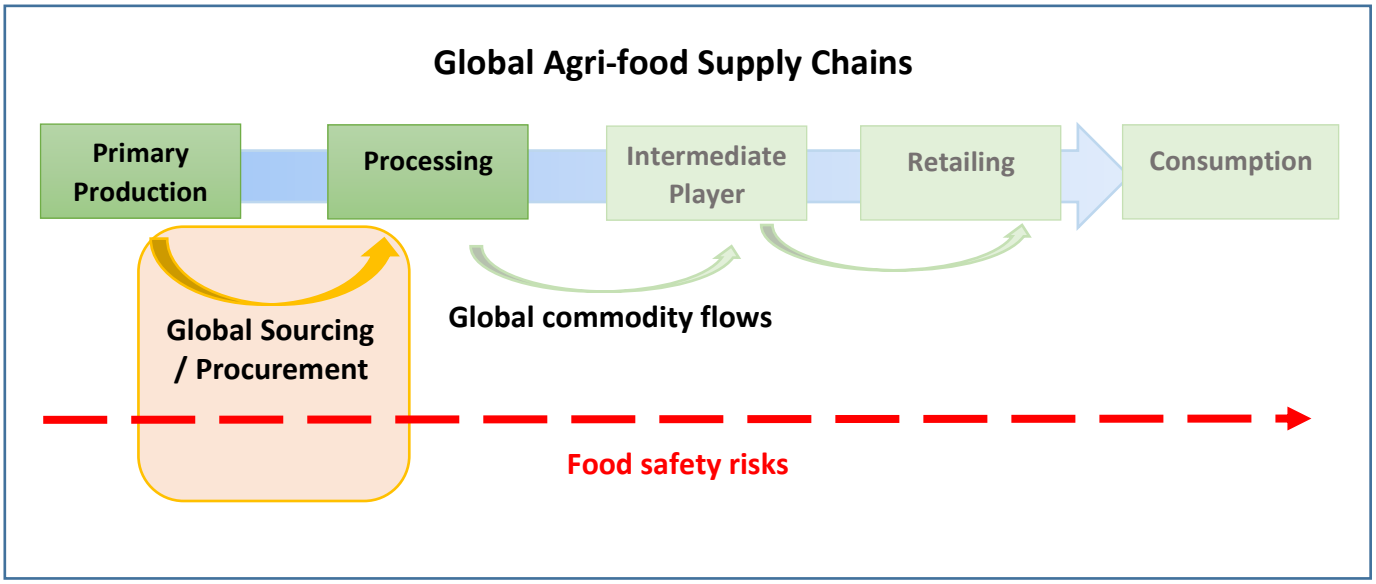


**Fig. 1.** Food safety risks in 'Global Sourcing / Procurement' - marking the first phase of global commodity flows of agri-food supply chains - represent the focus of the study.

# 2. METHODOLOGY

## *2.1 Conceptual Framework Building*

Based on the identified research gap and the intended knowledge contribution of the present field of work, the qualitative approach CF-building appears to be an adequate tool to study global commodity flows in the context of food safety. It is used to better understand a complex phenomenon that is linked to multidisciplinary bodies of knowledge. It, therefore, includes a holistic approach that is also used in the scope of ERI by European food safety bodies and international organizations such as the FAO. Situating the study in the relevant knowledge fields allows demonstrating the importance of a problem (Rocco and Plakhotnik, 2009). Furthermore, the development of a CF aims at defining and structuring ideas about a complex phenomenon of reality and supporting the formation of presumed effects. Accordingly, it forms the starting point for developing the concrete research model of empirical studies that must be connected to literature or concepts. Therefore, a CF not only provides the foundation but also serves as a reference point for the interpretation of findings of further studies. Hence, knowledge generation through CF building has a normative dimension. It seeks to identify the best concepts and, through this, be able to provide recommendations on the concepts that should be used (Aven, 2018).

The construction of the present CF is based on a qualitative text analysis of multidisciplinary literature, adapted from the Grounded Theory approach. Grounded Theory is a process of inductive theorization, which seeks to discover a theory from systematically obtained data by generating and identifying a phenomenon's main elements and concepts (Glaser and Strauss, 2005). The emerging theory results from a steady interplay between data collection and analysis characterized by discovering patterns through constant comparison of data. Grounded Theory contains the

fundamental and analytical pursuing of the interpretation of data rather than an objective and static description of the data and the phenomenon.

## 2.2 Information Sources and Data

Data collection should be a comprehensive and complete "scoping" in order to ensure validity and a holistic mapping (Morse and Mitcham, 2002). Whereas data collection is unstructured and open at the beginning, it gets controlled by the emerging theory in the further course.

The literature selected for the CF analysis represents the diverse and relevant elements of ABC flows, such as technological, political, environmental, and cultural aspects. Moreover, multidisciplinary literature that has a link to ABC flows was chosen. An important point is that the literature should also represent practices that are related to global commodity flows. The data come from a variety of information sources. Research articles were found via a systematic keyword search (e.g. "logistics", "risks", "food safety") on Google Scholar and Web of Science. Reports about global agricultural trade and logistics from international organisations such as Organization for Economic Co-operation and Development OECD (e.g. International Transport Forum), United Nations Conference on Trade and Development UNCTAD (e.g. Transport and Trade Facilitation Newsletter), World Trade Organization WTO, and World Food Programme WFP, as well as books about international logistics and traffic/transportation geography, were included as well. Further, practical guidelines from European trade and logistics associations such as COCERAL (European association, representing the trade in cereals, rice, feedstuffs, oilseeds, olive oil, oils and fats, and agro-supply) and standards such as GMP and QS were also used as a basis for data. Moreover, data of initial conversations with practitioners from a European logistics association and an international organization involved in food logistics were used. The sources of data reveal theories that belong to specific disciplines. These discipline-oriented theories served as the empirical data of the CF analysis.

## 2.3 Data Analysis

The specific technique of inquiry requires coding paradigms *(open coding, axial coding, and selective coding)* to ensure conceptual development (Strübing, 2004). In the present study, Qualitative Data Analysis Software MAXQDA (VERBI Software GmbH, Germany) was used for the (iterative) process that includes the constant comparative method:

1. Open coding: Categorizing the selected data, i.e. similar data are grouped by discovering patterns and given conceptual labels (interpretation step).
2. Axial Coding: Making comparisons at the concept and sub-concept level, i.e. defining relationships between the concepts.
3. Selective coding: Integrating, renaming, relocating concepts to key categories until the researcher recognizes a general CF that makes sense.

The process is accompanied by memo writing that includes reflection on the process and the content and consequently builds the research infrastructure.

# 3. RESULTS

To map the research terrain of global ABC flows for investigating their impact on food safety, a CF was developed through qualitative text analysis, adapted from the Grounded Theory technique. The identified main concepts characterizing global ABC flows from a food safety perspective are illustrated in a graphical representation (**Fig. 2**). The CF presents ABC flows as a system in which the phenomenon is influenced by a complex environment. The phenomenon "ABC flows" is thereby divided into three aggregation levels: The micro-level concerning the logistical *Key Processes* of the individual company, the meta-level related to the *Key Actors*, and the macro-level that comprises *Routes and Nodes,* as part of the physical infrastructure of an economy. The phenomenon is surrounded by influential sectors, divided into two categories, namely *Logistics-related conditions* on the country level and *Drivers of change* on the global level. Moreover, respective food safety concepts for each of the identified key categories or levels from inside and outside ABC flows were identified (e.g. *Management* concerning *Processes*).

In the following, the results are presented according to the key questions that were used for model development.

### *Physical Boundaries*

ABC flows take place between the delivery point, at which the goods are provided (source), and the receiving point, at which the goods are used (sink). The source might be the procurement warehouse at the production site or a supply warehouse at the export harbor in country A. The sink represents the food or feed industry in country B. In analyzing the transportation channels between the source and the sink, two elements of the infrastructure service are identified (Rodrigue *et al.*, 2016; Thakur and Hurburgh, 2009).

- **Routes**: The ABC flows' main route of is by sea, followed by the land route.
- **Nodes**: Seaports are the most important logistical nodes that represent links in the network of ABC flows. ABC are temporarily stored or transferred to another route through the network.

This way, ABC is moved through a network of routes and nodes belonging to different economies' infrastructure services/freight transportation systems.

### *Key Processes*

The framework is built around the key processes of ABC flows. Key processes in global ABC flow primarily serve the transformation of goods in time and space with related facilities and devices. Five core processes defined as a bundle of tasks/activities are identified as relevant for ABC flows:

- **Consolidation:** ABC flows from the same origin with different destinations are consolidated on their route to the node/hub and are combined with ABC flows that have different origins but the same destination. Consolidation refers to segregation and aggregation or rather comingling of different (grain) lots to meet buyer specifications (Thakur and Hurburgh, 2009).

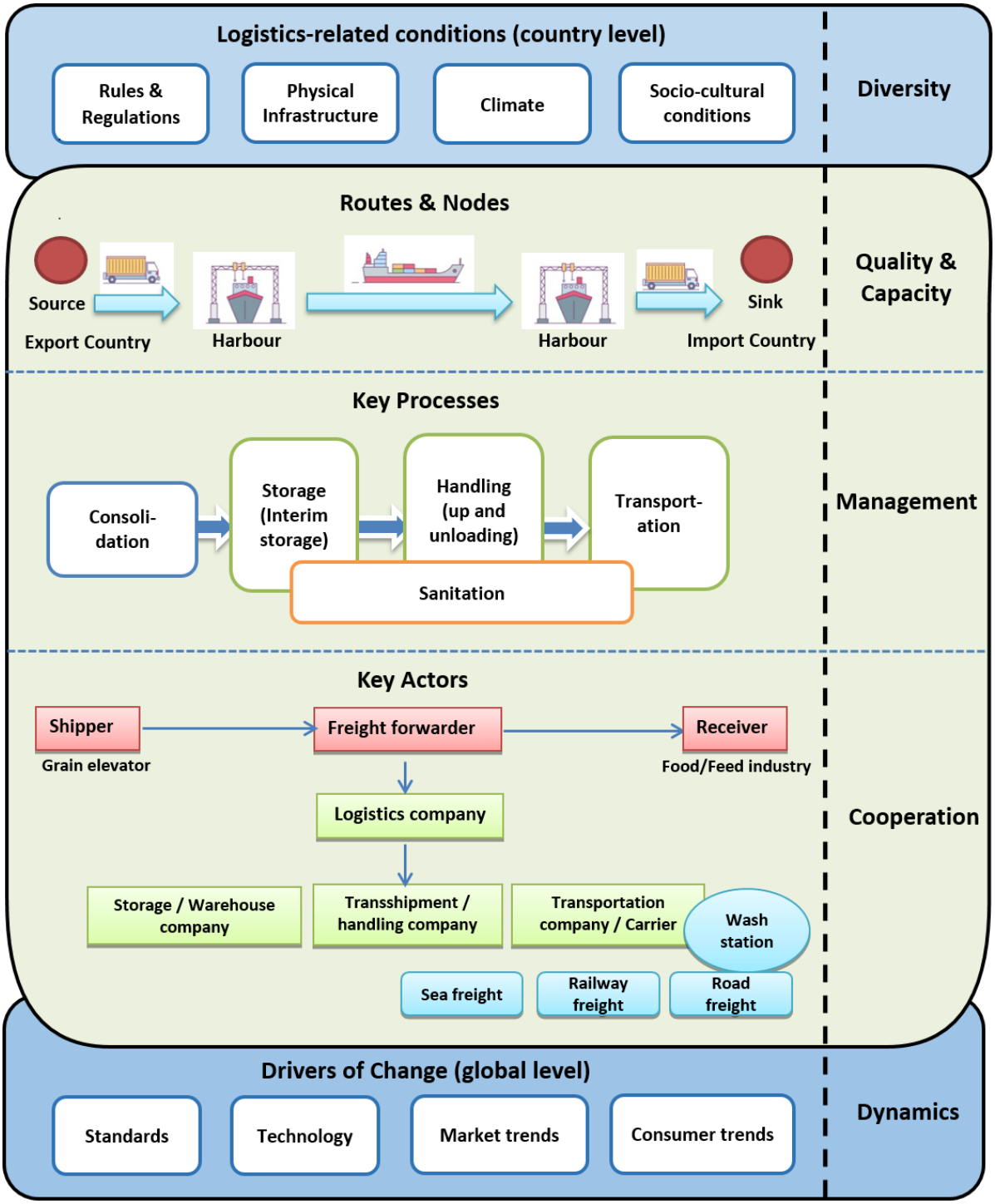


**Fig. 2.** Conceptual framework for the identification of critical factors related to food safety in global agri-bulk commodity flows – focusing on the segment of 'Global Sourcing / Procurement' as the first phase of global commodity flows (see **Fig. 1**).

- **(Interim) Storage**: Storage can take place temporarily at nodes when capacities and schedules in the transportation chain of different transportation modes are not coordinated or when ABC has to be organized in terms of volume and weight to guarantee full capacity of transportation mode. Storage can also extend over longer periods when business objectives and processes require the operation of storage systems (Pfohl, 2018).
- **Handling**: Load and unload operations are carried out by belt conveyor, digger, and pneumatic systems at transitions points between transportation modes or between storage and transportation (Pfohl, 2018).
- **Transportation**: External relocation of ABC by waterborne (bulk carrier/vessels and container vessels) or overland transportation (trucks and railway). Transportation starts and ends with handling activities (Schieck, 2008).

- **Sanitation:** Refers to cleansing logistics-related equipment and devices such as transportation means and handling equipment. Sanitation specifications / standards such as time and temperature are established by the carrier or freight forwarder.

### *Key Actors*

The core processes relate to the key actors. These are actors directly involved in carrying out the processes and actors who initiate and organize the processes. The identified core group enters into contractual commitments. The following four key actors that coordinate mainly on tactical levels via contracts and specifications were identified:

- **Shipper/Receiver**: Contracts freight forwarder for planning, preparing, and post-processing of global ABC flows. The shipper can either be the ABC producer or grain elevator in country A or the receiver/buyer from the food or feed industry in country B (Pfohl, 2018).
- **Freight forwarder**: Acts as a bridge between the shipper and the logistics company. Plans and prepares ABC flows and contracts logistics companies for logistics services (Pfohl, 2018).
- **Logistics Company**: As the supplier of logistics services such as transportation, handling, and storage, the logistics company takes the leading role in carrying out the physical movement of goods.
- **Wash and maintenance station**: Company in charge of sanitation and maintenance of transportation modes. Contracts between the wash station and the freight forwarder or the carrier regulate sanitation specifications/standards (Pfohl, 2018).

### *Influential Sectors*

A variety of relevant influential sectors of global commodity flows were identified that can be differentiated into two categories. The first category comprises *Logistics-related conditions* sectors that show country-specific differences characterizing the diversity of the logistics sector. We identified four influential sectors at the country level that determine the nature of the logistical processes and the behavior of the key actors:

- **Rules and Regulations**: Dimension of technical related regulations for logistics activities such as dimension of transportation means (from loading unit size to vehicle size) and food safety regulations and national laws related to the logistics sector (Nuhn and Hesse, 2006).
- **Physical Infrastructure**: Relates to elements of freight transportation service such as routes and nodes and geographical aspects such as topographic conditions (surface form) of a country. Further, it relates to logistics-related equipment and devices such as transportation means (Schieck, 2008).
- **Climate**: Includes climate-related factors such as weather (e.g. temperature, humidity), climate change, seasonality etc., that affect transportation flow and environmental conditions during logistics activities (Pfohl, 2018; Woitschützke, 2006).
- **Socio-cultural conditions:** Relate to culture and language, as well as to training landscape, technical level capacities, and working conditions in the logistics sector of a country (Neumair *et al.*, 2012; Schieck, 2008).

The second category of influential sectors comprises *Drivers of change* that are related to the process of globalization. Drivers of change relate to changes in global commodity flows and can be categorized into four groups:

- **International Standards**: Refer to public and private standards related to food safety in the logistics sector and are developed by regulatory agencies (e.g. ISO), public organization (e.g. Codex Alimentarius), or industry associations (e.g. FEFAC) (Webb, 2015).
- **Technology**: Relates to progress and innovations within the scope of Industry 4.0 (Abdirad and Krishnan, 2021), including information and communication technology (ICT) such as Internet of Things (IoT) technology in food safety (Bouzembrak *et al.*, 2019) but also new development trends in technical processes, procedures, and practices, such as sanitation practices and handling practices and to the equipment and devices, such as the size of transportation modes.
- **Market trends**: Relate to (emerging) key market players in the global market of ABC, and associated traffic flows/corridors (USDA, 2021); also refers to fuel and commodity availability and corresponding prices as determinant factors of transportation costs (Taghizadeh-Hesary *et al.*, 2019).
- **Consumer trends:** Refer to consumer consumption patterns in different regions such as western countries, emerging countries, and developing countries associated with demographic trends and food safety and environmental awareness.

For each of the five identified key categories (Processes, Actors, Routes and Nodes, Logistics-related, conditions and Driver of change), respective concepts were identified with a linkage to food safety.

### *Management*

In the context of the EU food safety concept, logistics companies are regarded as food business operators and consequently carry responsibility for food safety. Management covers quality control of both processes and the product. Whereas sanitation, maintenance, and traceability of equipment and devices are general elements of process control, product control in terms of safety and quality incorporates dimensions of prevention, mitigation, and recovery (Marucheck *et al.*, 2011). Management is estimated to cause up to 85% of quality and food safety problems (Ryan, 2017).

### *Cooperation*

The high number and diversity of participants with conflicting objectives are considered a major challenge for collaboration (Hu *et al.*, 2019; Rodrigue *et al.*, 2016; Singh and Power, 2009; van der Vorst *et al.*, 2009) and thus potentially threatens food safety. Commodity flows usually are not designed in agreement with a risk evaluation, and risk assessment as efficiency and effectivity constitute the major targets in coordination and collaboration (Manzini and Accorsi, 2013).

### *Quality and Capacity of Routes and Nodes*

Quality and capacity of port infrastructure include, e.g. facilities, sanitation services, landside connections, and sea interface (Bolat *et al.*, 2020; Notteboom and Rodrigue, 2017). Route infrastructure includes, e.g. route and railway network and capacity, road surface conditions, and canal widths (El-Wakeel *et al.*, 2018; Jensen *et al.*, 2017). The quality and capacity of routes and nodes determine traffic conditions and consequently affect the transportation flow.

### *Diversity*

Diversity in logistics-related conditions can lead to unpredictable and/or uncertain events that result in disruptions throughout global commodity flows and thus challenging food safety (Narasimhan and Talluri, 2009).

### *Dynamics*

Dynamic shifts of global commodity flows can lead to huge uncertainties in supply and demand, disrupting global supply chains and posing challenges for the international logistics sector that require a high degree of flexibility (Ahlqvist *et al.*, 2020). Thereby, food safety problems can often be traced back to changes in global food supply chains (Marucheck *et al.*, 2011).

From these concepts, the following application-oriented hypotheses/propositions can be derived that can serve as the basis for further research:

- The type and number of logistical processes and actors involved in global commodity flows can have an influence on food safety.
- The management of logistics service providers, as well as the cooperation between the different actors of global commodity flows can have an influence on food safety.
- The quality and capacity of transport routes and nodes (harbours) can have an influence on food safety.
- Through the interaction with influential sectors, differences in logistics-related conditions at country level and dynamic changes at the global level can have an impact on ABC flows and thus on food safety (e.g. different socio-cultural conditions could influence the quality management of logistics service providers and market fluctuations could influence the choice of cooperation partners).

# 4. DISCUSSION

In the present study, we developed a comprehensive CF by identifying and defining concepts that commonly characterize ABC flows in the context of food safety. The phenomenon "ABC flows" is illustrated by three key categories, namely *Key Processes*, *Key Actors,* and *Routes and Nodes*. The context *Influential sectors* are differentiated into two categories, i.e. *Logistics-related conditions* (*Rules and Regulations, Physical Infrastructure, Climate, Socio-cultural conditions*) and *Drivers of change* (*Standards, Technology, Market trends, Consumer trends*) that are linked to the globalization process. The following food safety concepts related to each of the five key categories were identified: *Management* of logistical processes, *Cooperation* between the key actors, *Quality and capacity* of routes and nodes, *Diversity* of logistics-related conditions, and *Dynamics* of drivers of change. The identified concepts were put in context in the graphical representation, and in this way map, the research field for a structured and holistic analysis of the impact of global agri-food commodity flows on food safety. While a range of theoretical models of supply chain management aim to minimize the cost of the entire supply chain system (Liao and Widowati, 2021), the herewith developed CF presents a first model for holistically investigating logistics in terms of food safety risks.

## *4.1 The Phenomenon: ABC Flows*

The CF gives an overview of the key actors in ABC commodity flows. Since approximately 70% to 80% of logistics operations are carried out by external actors (Schieck, 2008), it can be assumed that third-party logistics service providers also play a crucial role in global agri-food commodity flows. As companies generally are more interested in working and focusing on their core business, outsourcing logistics activities has enormously enhanced the growth of third-party logistics service providers/companies (Khan *et al.*, 2017). Logistics outsourcing has been widely adopted by organizations as it allows cost reduction and flexibility, which makes companies more competitive in the market (Zhu *et al.*, 2017). Due to the fact that different logistics services are carried out by different subcontractors, the logistics industry can hardly be grasped (Pfohl, 2010). In addition, as the global economy and trade grow, the demand for international logistical services will further increase (Göpfert and Braun, 2013). The economic growth of a country can be both the consequence of the logistics sector development and the stimulator of the logistics sector (Muslija *et al.*, 2021).

The present CF shows the (logistical) processes relevant to researching ABC flows regarding food safety. Transportation, the key factor in logistics activities, is considered one of the most vulnerable links to cross-contamination in the food chain (Ryan, 2017). This seems relevant to ABC as they are shipped in bulk and come in direct contact with the vehicle. Next to transportation, handling is a predominant logistical activity, whose importance increases with the internationalization of the agricultural industry. Handling activities are considered critical in food safety as damage, loss, and adulteration can occur (Schieck, 2008). Further, storage processes can lead to port congestions when cargoes reach up to quantities that are more than the port's handling and storage capacity (Bolat *et al.*, 2020), which can have a negative impact on food safety, taking into account time as a determinant factor for food safety. Sanitation, a supplementary service in the transportation process, proves to be considerably important, as adulteration and cross-contamination occur in the case of poor quality of sanitation processes (Ryan, 2017).

Corresponding to the high relevance of the transportation process within global commodity flows, the transportation mode deserves particular attention. Sea transportation represents the main run in global ABC flows and is used for long distances, whereas rail and road transportation is used for regional transportation within the scope of pre-and onward carriage (Schieck, 2008). As part of inland transportation, road transportation is by far the

dominant transportation mode. Hence, the resulting traffic congestion, for example, in the EU, leads to envisaged shifts from road freight to rail or to inland waterway transportation, which accounts for a relatively small share in overland transportation (European Commission, 2011). This policy objective faces thereby the trend of decreasing demand for rail freight by bulk shippers (Jonkeren *et al.*, 2019).

Maritime transport plays a pivotal role in international logistics chains and also represents an essential supply chain component in the world food system (Godfray *et al.*, 2011; Lim *et al.*, 2019). In terms of world trade, seaborne trade accounts for up to 90% of global trade in terms of volume (tons). With a general increase in international trade, seaborne trade worldwide has grown a lot over the decades, from 500 million tons in 1950 to 10.3 billion tons in 2016 (UNCTAD, 2008, 2017). Therefore, global economic development correlates with the growth of seaborne shipments (Berle *et al.*, 2011).

Maritime transport, however, is among the most important sources of uncertainty in global supply chains (Sanchez-Rodrigues *et al.*, 2010). Ports and shipping are exposed to higher risks because of rapidly changing environments (Notteboom and Siu Lee Lam, 2014), which could also have an effect on food safety. Port performance, which is strongly linked to a country's market power/economic development, has a great impact on "smooth" transportation flow (Haralambides, 2017) and can be considered another potential key factor for food safety.

Port performance requires continuous investments in port facilities due to continuous technology development, such as growing ship sizes (Ryan, 2017). Differences in port performance are reflected in port rankings (Jeschke, 2011). Whereas many developing regions are struggling with poor transport infrastructure and service impairing transportation flow (Munim and Schramm, 2018), ports of emerging countries, first of all China, are among the worldwide top 20 seaports (J. Chen *et al.*, 2019; Wahyuni *et al.*, 2020). Nevertheless, if the port capacity does not keep pace with trade growth, port congestion affects transportation flow, implicating an increased risk of goods deteriorating (Balliauw *et al.*, 2020; Schieck, 2008; UNCTAD, 2008). Considering transportation routes, infrastructure constraints, such as unfavorable road surfaces in developing countries, are a potential limiting factor for the transportation flow, especially in connection with challenging weather conditions (C. Chen *et al.*, 2019; Ryan, 2017).

## *4.2 The Context: Influential Sectors*

The present CF takes a holistic view of global commodity flows by integrating influential sectors in order to investigate their direct and/or indirect impact on food safety. In this regard, the present study has identified challenging logistics-related conditions with assorted characteristics and differences at the country level. Transportation and food safety-related legal and regulatory frameworks are among these challenging conditions. The various legislative frameworks in the transportation system (such as limits for transportation equipment) exist in different countries, making the international logistics sector highly opaque (Jeschke, 2011; Thakur and Hurburgh, 2009; Watanuki, 2015). A lack of international harmonization of loading units due to different legislative limits for transportation equipment in different countries, for example, may represent a threat to the transportation flow (Jeschke, 2011). Further, differences in the legal framework for food safety in the logistics sector exist across countries, such as in traceability (Thakur and Hurburgh, 2009). Compared to the EU, the USA regulations are less rigorous in the field of food traceability systems and registration of food transportation entities (Ryan, 2017). Apart from that, there is a lack of international harmonization of safety management practices (Aruoma, 2006; Handford *et al.*, 2015). The great variety of policies between countries is also a challenge for coordination among participants of global commodity flows (Rodrigue, 2017). In this context, also socio-cultural differences, expressed, for instance, by cultural misunderstandings, turn out to be another challenge (Marucheck *et al.*, 2011).

Adverse weather conditions are also critical as they do not only cause a potential interruption in global commodity flows affecting the process itself. The importance of weather and climate is revealed in the direct impact on the environmental conditions (e.g. temperature, humidity) in vehicles and warehouses and consequently on food safety. Although the impact might be reduced through available temperature-controlled techniques, extreme or unexpected climatic conditions have a negative impact on the supply chain (Manzini and Accorsi, 2013). Further, tropical countries have to face major challenges in this respect than countries of temperate zones. However, impairments of food safety are to be expected when crossing different climate zones, which is unavoidable, especially in maritime shipping along with global commodity flows (Evans *et al.*, 2019; Schieck, 2008; Wareing *et al.*, 1993).

Next to logistics-related conditions, the present CF takes into account dynamic developments triggered by globalization within global commodity flows for investigating ABC flows in the field of food safety. For example, ICT (Industry 4.0) is the subject of permanent change and is one of the most interesting and debated research topics for global supply chains. ICT permits information exchange that is a requirement for collaboration and better coordination and monitoring of agri-food supply chains. However, new technologies related to safety in food supply chains mainly refer to the field of traceability and monitoring of food safety and quality, which has gained considerable importance nowadays (Bouzembrak *et al.*, 2019; Folinas *et al.*, 2006; McKean, 2001; Mirabelli and Solina, 2020). Recurring food safety issues in the past indicated limitations in existing traceability tools and create incentives for constant development, also with regard to public pressure (Fearne *et al.*, 2001; Thakur and Hurburgh, 2009). In the EU food safety regulation, for example, traceability is covered by recording trace-back and trace-forward data of the trading unit by all supply chain participants. However, traceability system development goes far beyond this EU obligation that is described as a "shortsighted concept" in literature (Ryan, 2017). Current traceability tools are used to achieve transparency/visibility of global supply chains at various levels. Important traceability components/objects are transportation modes (e.g. location, route), food commodities (e.g. temperature), procedure (e.g. sanitation), and environmental conditions (e.g. temperature, humidity) (Ryan, 2017). Further,

information systems are being developed that aim at combining safety, sustainability, and efficiency in supply chains that require integrating different data types from different data sources (Manzini and Accorsi, 2013). However, handling and analyzing the resulting large-scale databases remain a challenge for most companies (Ryan, 2017).

Further, emerging technologies in terms of faster and (semi-) autonomous transportation modes, especially in road and sea transportation, are being discussed as determining factors shaping future freight transportation systems (Batalden *et al.*, 2017; Csiszár and Földes, 2018). Changing design and size of transportation modes, such as increasing ship sizes and longer and heavier trucks, serve to move larger quantities of goods and are mostly driven by cost reduction (Ryan, 2017; Valentine *et al.*, 2013). These developments mainly represent a challenge for the infrastructure (Jeschke, 2011) and have to be discussed in terms of their potential impact on food safety.

Whereas developments in technology and standards provoke primarily internal changes regarding the design and operations of supply chains (Ahumada and Villalobos, 2009), market and consumer trends additionally create shifts of global commodity flows. Consumer trends relate to consumer demand for food depending on shifts in consumption patterns, which show regional differences. In developed countries, consumers increasingly pay attention to the health, safety, and quality aspects as well as sustainability of products (Borsellino *et al.*, 2020). The higher awareness and subsequent ethical requirements of Western consumers are not limited to the production but also comprises the transportation of food. Consequently, the better-informed consumer requires the ethical behavior of all supply chain actors (Ahumada and Villalobos, 2009). This clearly shows the power of consumer demand shaping the future of transportation systems. The trend towards sustainable transportation modes that emerges from the environmental awareness of consumers serves as an example. For example, to reduce the port's impact on its carbon footprint, Los Angeles has forced the trucking industry to meet new environmental requirements (Ryan, 2017). Further, the trend towards sustainability leads to increasing demand for locally produced goods that is stated in literature as "re-regionalization" of trade (Dörrenbächer *et al.*, 2021; Melgar and Burke, 2021). In contrast, the fast-growing middle-class in developing and emerging countries, especially in Asia, increases import demand for consumption goods, especially animal-based products (Hansen, 2020).

To sum up, changing consumer consumption patterns manifest themselves in shifts in demand or rather demand variability (Manzini and Accorsi, 2013). Consequently, the resultant shifts in global commodity flows impose challenges and require flexibility from the logistics sector (Jeschke, 2011; Kovács and Kot, 2016). Market trends relate to growing shifts in the global economy. These derive from the growing food demand in emerging countries, such as the BRIC countries (Brazil, Russia, India, and China) and from increasing trade between developing countries (South-South-trade) (Jeschke, 2011; Valentine *et al.*, 2013). Trade volumes are shifting towards these markets, implicating the expansion of new trade corridors, as between Brazil and China, and therefore the reorientation of global commodity flows (Lesnic and Crudu, 2019).

Another potential factor co-responsible for imbalances of commodity flows is the variability of transportation costs. Energy/fuel prices are important variables determining transportation costs and, consequently agricultural commodity prices and are characterized by high volatility (Taghizadeh-Hesary *et al.*, 2019). Higher oil prices or the shock of energy prices are further discussed as another factor that could reverse globalization (Rubin and Tal, 2008; Valentine *et al.*, 2013). In addition, fuel price is considered the number one factor defining the future of the transportation industry. It has a broad impact on different variables, such as the design of transportation modes, the type of transported goods, selection of routes, and transportation modes, which in turn have an impact on food quality and safety (Jeschke, 2011).

### *4.3 Limitations, Strengths and Implication of the Developed CF*

Apart from the identification of the main concepts, relations, and the discussed current developments in the logistics of the procurement sector of ABC, the limitations of the developed CF also have to be mentioned. It should be underlined that concept identification derives from literature not always specified to ABC or even food due to the limited data availability. Therefore, general literature about international logistics or related to agricultural fresh products such as fruits and vegetables also served as a basis for concept generation. Agricultural fresh produce is treated with much more attention in food logistics literature due to its lower shelf life and the resulting higher vulnerability in food safety compared to ABC (Manzini and Accorsi, 2013). Consequently, the identified concepts and their importance discussed above have to be reviewed in terms of their actual relevance for ABC flows.

The present CF should not be considered a complete composition of relevant concepts. Financial aspects, for example, such as transactions within the scope of trading in which (logistical) processes are embedded (Schieck, 2008), along with wholesalers, are not part of the investigation field. Along with CF building, there is uncertainty about the scope of the desired conceptual integration of the respective phenomenon. The development of concepts is based on interpretation. Different researchers might have different conceptions of the same phenomenon and may create different CFs, as a conceptual analysis requires a different type of thinking such as creativity, divergent thinking, comparative reasoning, integrative, and logical thinking (Aven, 2018). Also, using different suitable literature and data due to availability may materialize in different results. Therefore, a CF never provides knowledge of hard facts but rather soft interpretations (Jabareen, 2009). However, here also lies the advantage of a CF: It is based on flexible conceptual terms rather than rigid theoretical factors and causal relations. This permits the possibility of modification. As a result of literature that was not available at the time the framework was first developed, the CF can be re-conceptualized and modified accordingly. This also applies to new data gained from the CF application in the field (Jabareen, 2009) and in particular to the influential sectors

forming the relevant context of the study. The recording or identification of the influential sectors and respective dimensions prove to be especially difficult since the causality/relevance for both global commodity flows and food safety is hard to identify. Consequently, the concept dimension or characteristics of the influential sectors must be checked in further investigations.

In the present study, we developed a CF that illustrates the main concepts regarding ABC flows, allowing us to understand the complexity of logistics in the procurement and frame future research about ABC flows in the context of food safety. Generally, it provides a starting point for formulating research questions and serves as a reference for data analysis. The internal structure of the CF enables a systematic procedure: It leads to the selection of methods and helps to structure, focus and limit the collection of data. The CF helps to increase the understanding of the complex phenomenon and its context through a generic and differentiated approach. The differentiation of the phenomenon "ABC flows" and its contexts "influential sectors" in multiple consideration levels help to break up the complexity. The phenomenon "ABC flows" is divided into three aggregation levels, commonly used in logistics literature: The micro-level concerning the logistical *Processes* of the individual company, the meta-level related to the *Cooperation* between key participants, and the macro-level that comprises the *Routes and Nodes,* as part of the physical infrastructure of an economy (Pfohl, 2010). Moreover, the differentiation of the influential sectors of ABC flows in two levels reflects the *Diversity* (country-related conditions) and *Dynamics* (drivers of change) and, therefore, captures the complexity of the ABC flows of the global procurement sector. Country-specific differences are an important subject in the literature concerning international logistics (Göpfert and Braun, 2013). The concept *Driver of change* refers to trends and dynamics that are not country-related and have to be considered in the scope of globalization.

Although the provided concepts and correspondent characteristics or dimensions seem general and abstract, they nevertheless represent a vast narrowing of the relevant data and can be used across different applications (Yin, 2013). The CF was validated through continuous exchange within the research team, by "outsiders" at intra-institutional seminars, and by presenting and discussing the CF at an international conference. The next validation step was the empirical application or testing of the CF in a case study that has verified and complemented conceptual knowledge (concepts and application-oriented hypotheses) based on literature with practical/real-world experience from different stakeholders (Zupaniec *et al.*, 2021). The structure or design of the CF and the concept definitions served as a guideline for formulating interview questions used for expert interviews, which are a common method in case studies. However, the CF had to be further developed or even modified during data collection due to the openness of qualitative research. Further, as the CF is very broad/comprehensive and covers several elements, it always depends on the feasibility, available time, financial resources as well as access to experts if the CF needs to be further narrowed or priorities have to be identified for future investigation.

# 5. CONCLUSION

By developing a CF, the present study highlights important elements of global commodity flows/logistics in the global procurement of ABC and discusses current developments that could potentially affect food safety and therefore need to be taken into account for the empirical investigation of global commodity flows about food safety. First, the CF illustrates the phenomenon "ABC flows" by differentiating three aggregation levels: *Quality and capacity* of *Routes and nodes*, *Management* of (logistical) *Key Processes* such as interim storage, handling, transportation and sanitation, and the *Cooperation* between *Key Actors* such as the shipper/receiver, the freight forwarder, the logistics company, and the wash station. Then, the CF underlines the importance of influential sectors of the global sourcing sector of ABC that could have a potential impact on food safety. The identified influential sectors were differentiated and presented in two categories: the *Diversity* of *Logistics-related conditions* at the country level such as *Rules and Regulations, Physical Infrastructure, Climate and Socio-cultural conditions,* and the *Dynamics* of *Drivers of change* related to the globalization process such as *Standards*, *Technology*, *Market trends,* and *Consumer trends* were identified as relevant concepts for investigating food safety in ABC flows.

Since logistics - in all its complexity - has been covered only to a very limited extent in food safety research, the CF developed here represents a first conceptual and theoretical basis or reference model for a holistic and empirical investigation. The chosen differentiated perspective not only contributes to a better understanding of the complex field of global commodity flows/logistics where to date, many knowledge gaps in terms of food safety have existed in risk assessment and ERI. It also structures, delimitates, and holistically defines this new research area providing the basis for the identification of critical factors in terms of food safety in the global sourcing sector beyond the already known critical points (HACCP) in logistical processes such as transportation, handling, and interim storage. The developed CF clearly shows the multifaceted nature of global commodity flows, providing evidence that future research should focus on studying logistics in its complex context concerning food safety. This way, the developed CF can be seen as a contribution to reducing current uncertainties in risk assessment resulting from the globalization of agri-food trade, especially in the field of logistics. The CF is designed to assist not only researchers but also practitioners in better understanding the complexities of the logistics sector in terms of food safety and thus serves as an aid in dealing with complex food safety problems in the context of risk management.

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