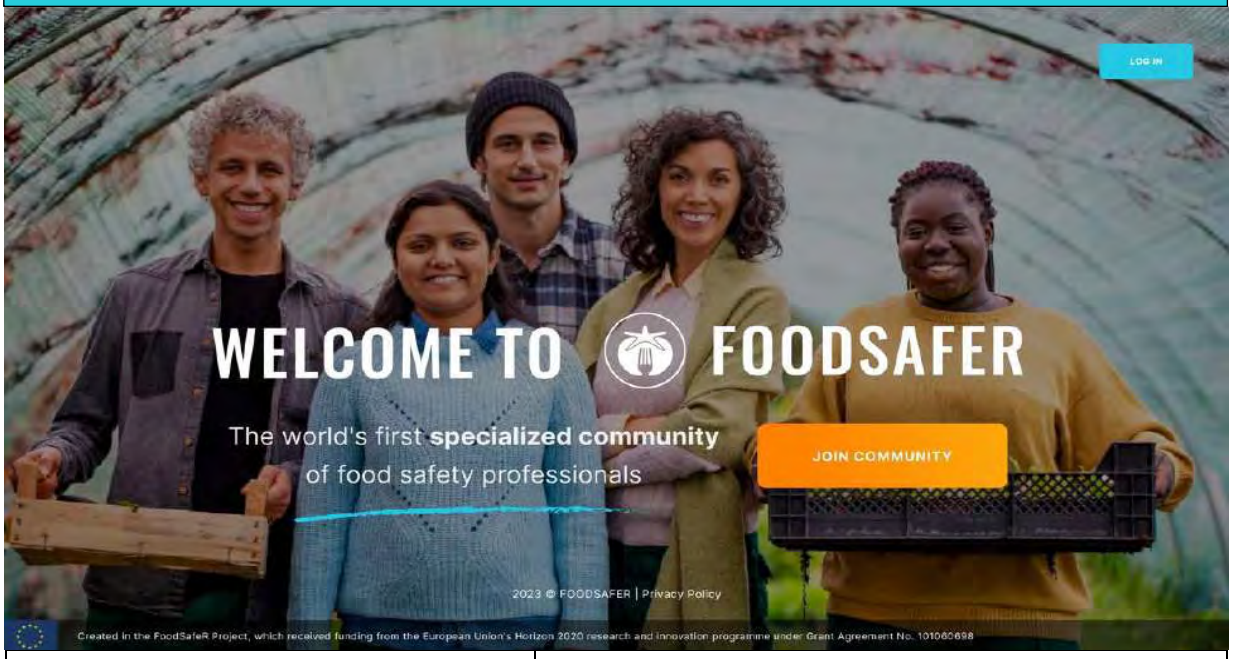
Deliverable **1.1**

FOODSAFER

Report on drivers & key factors for food safety emergence in food system

#EVERYBODY'S BUSINESS

Deliverable D1.1: Report on drivers & key factors for food safety emergence in food system



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Contents

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1. Introduction

The FoodSafeR project aims to develop an innovative and holistic proactive food safety warning and management system, with emerging risks a central focus. To create this system, it is necessary to first identify anticipated changes in the European food safety arena.

Foodborne diseases (FBDs), also known as foodborne illnesses or food poisoning, are caused by eating contaminated food. These include a wide range of illnesses such as diarrhoea and cancer and can ultimately lead to death (World Health Organization, 2023). In the EU in 2019, there were 49,463 cases of illness and 60 deaths associated with foodborne outbreaks reported (Sarno *et al.*, 2021).

FBD can originate at any stage along the food chain and the causes are multiple and can include bacteria, parasites, toxins, and allergens. Food safety monitoring and management systems are used to prevent and reduce FBD and their impact. For example, the EU's Rapid Alert System for Food and Feed (RASFF) allows food safety organisations across countries to expeditiously share information relating to food safety and health risks derived from food or feed. While valuable, such systems are typically reactive, meaning that individuals and organisations may already have been affected by the reported food safety risks. To prevent food safety incidents, there is a need for a proactive approach and systems which use signals associated with the development of a hazard and emerging risks are preferable (Marvin *et al.*, 2009). An 'emerging risk' has been defined as "a risk resulting from a newly identified hazard to which a significant exposure may occur, or from an unexpected new or increased significant exposure and/or susceptibility to a known hazard" (EFSA Scientific Committee, 2007; EFSA, 2016). Such 'emerging risk' systems could decrease illness, fatalities, and economic loss associated with FBD (Marvin *et al.*, 2009).

The presence and development of many food safety risks are driven by factors within and outside the food supply chain, such as climate, economy, human behaviour, and geopolitical instability. For example, the Russia-Ukraine conflict led to supply issues for products such as sunflower oil, which could open up opportunities for food fraud and consequently increase food safety risks (Jagtap *et al.*, 2022). The interactions between these factors and the supply chain are complex and a system or holistic approach is needed to reveal cause-effect relationships and to be able to perform effective mitigation actions to minimise food safety risks. This approach is essential for implementing efficient strategies that can effectively counteract and diminish the risks associated with food safety (Bouzembrak and Marvin, 2019) .

Earlier research identified eight categories of drivers of food safety risks, based on expert interviews: Economy, Science/technology/industry, Culture/demography, Nature/environment, Consumer behaviour, Government/policies, and Agriculture (Noteborn et al., 2005, as cited in (Havelaar *et al.*, 2010)). More recent research identified demographic change, economic aspects, resource shortages, environmental aspects, increased complexity of the food supply chain, water security, and malevolent activities as key drivers of existing and emerging food safety risks (Kendall *et al.*, 2018). The complex interactions between drivers and that they should not be considered in isolation has been noted (Kendall *et al.*, 2018). Furthermore, a more recent EFSA report (Afonso *et al.*, 2020) states that changes in consumer behaviour were a driver for more than half of identified emerging food safety issues in 2019. For example, a trend towards minimally processed food using sous-vide cooking leading to risks around adequate heat treatment and subsequent increased exposure to hazards. In addition, issues were most often identified as microbiological or chemical.

As previously mentioned, to create a proactive food safety system it is essential to first identify drivers of food safety risks. The current task (Task 1.1) of the FoodSafeR project aims to identify trends and derive drivers and sub-drivers, i.e. key influencing factors, in relation to food safety, and how these might increase or decrease the emergence of food safety hazards. The task will use a variety of methods to achieve this.

1.1. Background

This section provides an overview of terminology used in this report. It defines the terms food systems, megatrends, trends, drivers, barrier/stressors, emerging risk, hazard, indicator and the STEEP(LE) framework.

Food systems: The definition of **food systems** goes beyond the production and delivery of sufficient food for all (quantity) to include the provision of safe and nutritious food for healthy and sustainable diets (quality). Underpinned by sustainability, linking land and sea, encompassing the entire "food value chain":

- the sustainable use of land, soil, inland and marine waters, and biodiversity as providers of ecosystem services upon which food production relies;
- primary production practices of agriculture, aquaculture and fisheries providing food and animal feed, including production-specific inputs of nutrients, energy, seeds, plant protection issues, and equipment, harvesting, and storage;
- food processing of primary and value-added food and feed products, including packaging, distribution and logistics;
- food preparation and consumption;
- the handling of food and related non-food waste streams" (European Commission, 2016, pp. 3–4).

Megatrends: Trends which occur **at global or large scale**. Megatrends are long-term developments that shape all sectors of society and the economy and will very likely affect the future" (Larsen, 2006).

Criteria for becoming a megatrend:

- Duration: The trend has a duration of several decades.
- Ubiquity: The trend shows effects in all areas of society, in the economy, in consumption, in the change of values, in the coexistence of the people, in the media, in the political system etc.
- Globality: Megatrends are global phenomena. Even if they are not strong at the same time in different locations, sooner or later they can be observed all over the world.
- Complexity: Megatrends are multi-layered and multi-dimensional trends. They also create their dynamics and their evolutionary pressure through their interactions.

The term "megatrends" goes back to the founder of modern future studies, John Naisbitt, who wrote the world bestseller "Megatrends. Ten New Directions Transforming Our Lives" in 1982 (Naisbitt, 1982).

Trends: A trend is a development or change over a long time which is likely to affect society or parts of it after a few years (less than 10 years). A trend cannot easily be influenced in a mechanical way by individual organizations, players, or nations. It often becomes visible only in retrospect ((Wepner *et al.*, 2018), based on efp, 2023). There is no guarantee that a trend observed in the past will continue in the future.

In the EFSA publication (Marvin *et al.*, 2019) trends are considered as change or development in a certain direction, restricted to a detectable change over time, such as an inclining or declining graph line depicting the frequency or intensity of occurrence of a certain observation per time unit (e.g. the number of reports on a certain hazard in food, such as a chemical residue, measured during inspections; or the occurrence of food poisoning outbreaks). The definition is not limited to food hazards and risks per se but also including, for example, indicators within influential sectors.

Drivers: In this project drivers are seen more specifically focused on the onset of emerging risks. They may act as modifiers, namely they can either amplify or attenuate the magnitude or frequency of risks arising from various sources (Richardson *et al.*, 2016). According to the publication by EFSA (Marvin *et al.*, 2019), drivers are "issues shaping the development of a society, organisation, industry, research area, technology, etc.", which can be classified in social, technological, economic, environmental, and technological political (STEEP) categories. Drivers should be described as neutral, while trends can give a direction.

As drivers in this project were identified on a broader scale, *key influencing factors* for each driver were identified, grouped and labelled as *sub-drivers*.

Barriers or Stressors can be considered as negative connotation or direction of a driver.

Emerging risk: A risk resulting from a newly identified hazard to which a significant exposure may occur, or from an unexpected new or increased significant exposure and/or susceptibility to a known hazard

Hazard: Agent in, or on the food, or a condition of the food that potentially could cause adverse human health effects upon consumption of the food. Such agents can be **chemical**, **microbial** or **physical**. The difference between hazards and risks is explained by (EFSA, 2016).

An *emerging hazard* may cause an emerging risk. This may include new hazards that have not occurred before (e.g. new synthetic man-made substances), hazards that are present in the non-food area and are entering the food domain, or known hazards that re-occur in the food chain. Furthermore, hazards that have previously occurred in food, but that have only recently been discovered, can be regarded emerging hazards as well (Marvin *et al.*, 2009).

Indicator: A measurable factor (with a unit e.g. temperature in Celsius) that indicates or is directly or indirectly related to the possibility of the occurrence of a (re)-emerging hazard or risk (e.g. 'storage and transport conditions'), or in this project a driver (Dekkers and et al., 2008). An indicator provides information on the nature of the hazard or driver and source of risk, ideally it is reliable, sensitive and quantifiable, but can either be qualitative or quantitative in nature (Marvin *et al.*, 2019; EFSA Scientific Committee, 2007).

STEEP(LE) framework: The STEEP(LE) framework is a strategic planning tool used to analyze the external influences that may impact an organization or a specific project (Szigeti *et al.*, 2011). Drivers are sorted according to the following categories, though often political, legal and ethical issues are clustered, as was the case in this project:

- Socio-cultural,
- Technological,
- Economic,
- Ecological,
- Political, Legal, and Ethical.

2. Materials & Methods

Several tasks and various methods were used to complete task 1.1 (Figure 1). Firstly, three separate literature reviews were conducted to identify and collect drivers of emerging food safety risks and hazards while capturing as many different angles as possible. Second, the results of the reviews were condensed to 11 key drivers considering the STEEP framework and the different levels of granularity; each driver had at least two and at maximum five sub-drivers. Third, this list of drivers & sub-drivers was externally validated with three semi-structured online interviews with food safety experts and internally discussed within the work package team. Forth, this final list was used as input in the online workshop with food safety experts. The results of the workshop were the base for, fifth, identifying indicators, and sixth, analysing microbiological hazards further. Further details on each stage of the research are described below and outlined in Figure 1.

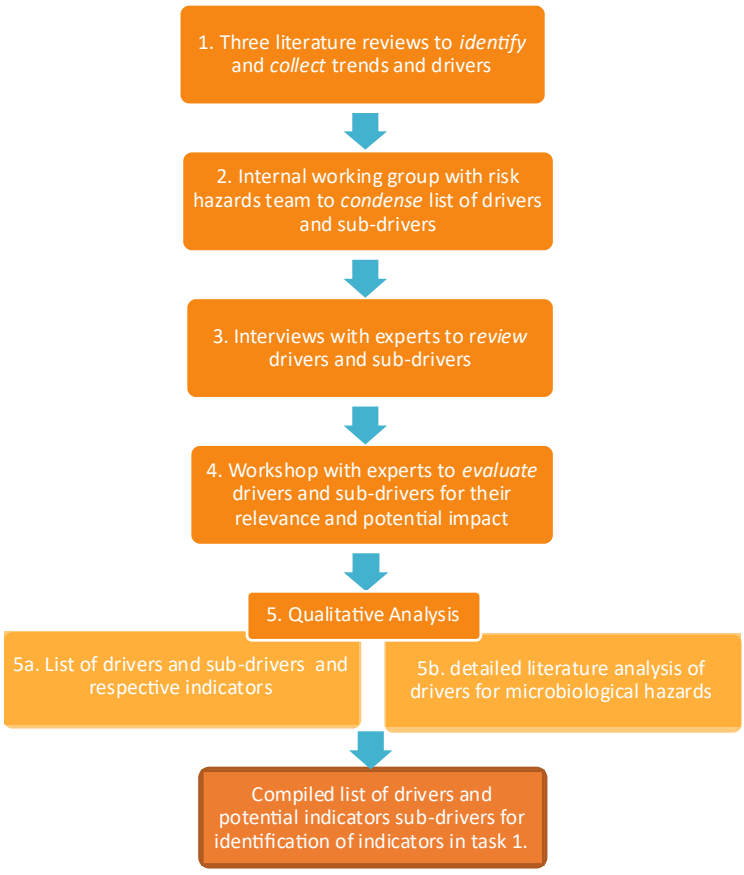

Figure 1: Overview of methods for Task 1.1

2.1 Identification and collection of drivers and sub-drivers

As briefly outlined above, prior to understanding the key drivers relating to food safety risk emergence, it was necessary to identify and collect established drivers and sub-drivers. The literature review of grey and scientific literature was undertaken from different perspectives

in October 2022- February 2023. One approach focused on the food system point of view to capture a broader picture and the two others focussed on each a different side of food safety, namely chemical or biological hazards.

As a first step, literature was screened for the general terms “trends”, “drivers”, “barriers”, “developments” in combination with “Food System*”. For this, publications on Web of Science and grey literature were searched. The results were filtered for most recent literature from January 2017- February 2023 and the most relevant publications screened in detail for trends, drivers and barriers matching the topic of FOODSAFER. As trends and barriers have a tendency and connotation to be positive or negative effects, the aim of the final list was to formulate neutral influencing factors, that can develop in both directions, i.e. drivers.

For the hazard focused approach, a scientific literature reviews was done for each of known chemical and microbiological hazards to identify influential factors, i.e. factors mentioned in scientific literature underlying or influencing the potential presence or emergence of the hazard. Systematic literature searches regarding the chemical and microbiological hazards were conducted separately for each of these two hazards groups by respectively Wageningen University and Ghent University, however, both followed a similar methodology.

The Rapid Alert System for Food and Feed (RASFF) portal was used to identify the known chemical hazards, and known microbiological hazards, classified as ‘pathogenic micro-organisms’. The selected hazard categories are shown in *Table 1*. The systematic literature searches were conducted using Scopus or Web of Science, with a search string containing “food”, “hazard” and the specific hazard category. The results were limited to the publication time between 2017 and 2022 to focus on emerging hazards. Only English-written reviews were included. Screening was conducted in three steps: First, the title, abstract and keywords were checked for every search, followed by duplicate removal, and a full-text read. Records with focus on (i) hazard identification, or (ii) exposure assessment (host and related susceptibility) were included, while records mainly focussing on (i) hazard characterization, (ii) (bio)technological innovations, or (iii) analytical methods were excluded. If relevant, further articles were collected via citation search and snowballing. Screening decisions were cross-checked among researchers for random samples to perform quality control.

Table 1: List of selected pathogenic micro-organisms used for search string microbiological hazards, classified as foodborne pathogenic (i) vegetative bacteria, (ii) spore forming bacteria, and (iii) viruses, and list of selected chemical hazard categories used for search string for chemical hazards, identified from the RASFF reports.

Chemical hazards	Microbiological hazards	
– Pesticide residue	(i) vegetative bacteria	– *Campylobacter* spp.
– Food additive		– *Listeria monocytogenes*
– Mycotoxin		– pathogenic *E. coli*
– Food contact material		– *Salmonella* spp.
– Natural/ plant toxins		– *Yersinia enterocolitica*
– Environmental pollutants		– *Brucella* spp.
– Process/industrial contaminants		– *Cronobacter* spp.
– Heavy metals		– *Shigella* spp.
– Unauthorized substance		– *Staphylococcus aureus*

– Illegal dyes		– *Vibrio* spp.
– Too high content – Veterinary medicinal product residue – Phytochemicals	(ii) spore forming bacteria	– *Bacillus cereus* – *Clostridium botulinum* – *Clostridium perfringens*
– Non protein amino acid – Organic contaminants – Personal hygiene and grooming products	(iii) viruses	– *Norovirus* – *Hepatitis A virus*

2.2 Condensing drivers and sub-drivers (internal working group)

Following the identification of individual drivers, the identified drivers were classified according to the categories of the STEEP framework and three different levels of granularity to achieve the same level of detail throughout the three reviews. The levels ranged from low to high granularity, where high is the highest level of detail with a limited generality. E.g. specific technologies like "in-vitro meat" address a higher level of granularity than the broader term "new technologies in food production". The level of granularity was discussed across the three literature reviews which resulted in a list of drivers of low granularity with corresponding sub-drivers of high detail, i.e. a condensed list of drivers and sub-drivers. To ensure that as many details as possible was considered from the literature reviews, a lot of information obtained was used to describe the drivers and sub-drivers in section 3.1.1-3.1.5. The condensed list of drivers and sub-drivers was then presented to three experts in interviews.

2.3 Review of drivers and sub-drivers (expert interviews)

The condensed drivers and sub-drivers were reviewed via semi-structured interviews with three food safety experts. The experts were asked to ensure that the drivers and sub-drivers were appropriate and suggested any potential amendments or additions.

Participants were first presented with a table containing the drivers and sub-drivers and allowed time to study these. Three topics per interview were discussed, namely how fitting the terminology of the drivers and sub-drivers was, the expert opinion of the relative importance of each driver and finally the completeness of the list. Finally, participants were asked to suggest appropriate indicator(s) for each driver. The full interview guide and procedure is available in Appendix 1.

2.4 Evaluation of drivers and sub-drivers (online workshop, LL3)

The reviewed list of drivers and sub-drivers from the interviews was then brought forward to an online workshop with food safety experts, as part of Living Lab 3 (WP 4.3.). The purpose of the workshop was to assess and discuss the relevance for and potential impact of each driver on emerging food safety hazards.

A total of 35 individuals participated in the workshops. Participants were recruited from the project consortium and the advisory board and consisted of food safety experts including 10 people from universities/research organisations, 15 representatives from food safety authorities, and 9 participants from industry. One person participated as "consumer". For the

discussion part of the workshop, participants were grouped so that members of each organisation type were represented in each group. This resulted in 5 groups, each containing 6-7 individuals.

The workshop agenda was structured around group discussions of approximately 90 minutes, punctuated with a 15-minute break. Within the discussions, each group discussed two drivers and their sub-drivers (with the exception of one group which discussed three). Discussions focused on the condensed drivers and sub-drivers to evaluate their relevance and impact on the emergence of food safety hazards. Finally, potential indicators for each sub-driver were discussed.

Answers were posted on the whiteboard by participants and additional notes were taken by the moderators. The workshop was organised online using Zoom Meeting and Mural, an online digital whiteboard platform, for collaboration and to share thoughts. An example of the template of one of the drivers and related sub-drivers is given in Figure 2. The full workshop protocol is available in Appendix 3.

Figure 2: Example of workshop template

2.5. Qualitative analysis

2.5.1. Inductive coding of workshop results

Moderator notes and the written input on the whiteboard from the discussion were analyzed using NVivo R1 (2022, 1.7.1) (October 2022, Lumivero). Inductive coding was performed by

three researchers with the aim of extracting relevant topics in each sub-driver and identifying indicators. In that sense, re-occurring topics of different sub-drivers could be related to each other. Following this initial coding, similarities and differences in the coding were discussed between the researchers and a final coding frame was developed. This coding frame was then used deductively by the researchers to code the data once more.

2.5.2. Coding of literature review of microbiological hazards

The drivers and their corresponding sub-drivers derived from *Section 2.2* were used for deductive coding of the literature on microbiological hazards and to extract more information and indicators. During full-text reading of the microbiological review papers, relevant influential factors, related to the hazard and connected to the identified drivers for the emergence of food safety issues, were extracted from each article. Next, all extracted data was combined to provide an overview of influential factors, merged in drivers and sub-drivers, for each known hazard. This qualitative data analysis was performed using NVivo 14 (March 2023, Lumivero). Specific influential factors, potentially driving the emergence of (i) *Listeria monocytogenes* and (ii) *Bacillus cereus* were investigated in detail, Section 3.3, as examples of respectively vegetative and spore forming foodborne pathogenic bacteria.

3. Results

3.1 Identification and collection of drivers and sub-drivers (literature review and interviews)

The chemical literature review search resulted in 575 articles, which were reduced to 185 after screening and reading. 140 drivers were identified and classified according to STEEP. The distribution is as follows: 47 (33.8%) drivers in societal-cultural, 46 (33.1%) in technological, 13 (9.6%) in economical, 27 (19.4%) in the environmental category and finally 6 (4.3%) drivers in political categories.

The microbiological literature review search resulted in a total of 1658 articles, whereof the 100 most relevant articles per known hazard were included for further screening (n = 1023). Of these 1023 records, 847 did not meet the predetermined inclusion criteria *(Section 2.1.2)*; Finally, after duplicate removal (n = 46), 130 articles were included for data collection.

Analysis of grey literature resulted in in-depth analysis of 15 out of 50 reports that were shortlisted from the internet research and a list of 166 drivers and trends with a distribution as follows: 40 (24.1%) drivers in societal-cultural, 38 (22.9%) in technological, 34 (20.5%) in economical, 26 (15.7%) in environmental, 14 (8.4%) in political categories, and additionally 14 (8.4%) megatrends were identified.

Results of the three literature reviews together resulted in a combined total of 163 drivers at different levels of granularity across the categories from the STEEP framework. Combination and aggregation of these 163 drivers with thematic analysis reduced the long list to the following 11 drivers with 3-5 sub-drivers each. This list was then discussed in the expert interviews and amended according to their input.

Table 2: Number of drivers and sub-drivers identified

Classification	**Compiled drivers for workshop**	
	Number of drivers	Total number of sub-drivers
Society	3	12
Technology	2	8
Economy	1	4
Environment	3	9
Policy	2	6

The final list of drivers (as given in Figure 3 below) was used as the starting point for the online workshop for discussion, providing the short description of drivers and their respective sub-drivers as in chapter 3.1.1 to 3.1.5. In the remainder of this section, the STEEP drivers and related sub-drivers are described in more detail based on the literature reviews. This description was also the basis for discussion during the workshop.

Figure 3: Overview of divers and sub-drivers

3.1.1 Social Drivers

Consumer behaviour

The behaviour of individual consumers can influence nutritional habits/individual diets. (Changed eating habits can lead to potential exposure or development of new hazards).

- **Dietary choice**: What food consumers choose based on nutrition and preference; e.g., vegetarian, fast food, red meat
- **Consumer knowledge**: The individual and common knowledge of consumers in relation to food (including education & training); e.g., cooking at home, hygiene practices
- **Consumer awareness/attitude**: Change of attitude drives choices; e.g., animal welfare, natural equals safe, herbal tea is good for you
- **Public awareness**: The awareness on foods, diets and related hazards via governmental communication, news, social media, NGOs; e.g., high fibre, low salt, bird flu, antimicrobial resistance

Demographic development

Demographic development strongly influences dietary and nutritional needs in Europe through:

- **Population change**: Change in the size of a population between a given time period (usually one year); e.g., birth/deaths, age/population pyramid
- **Prevalence of vulnerable groups**: Composition of the population considering e.g., ageing, immunocompromised people
- **Urbanisation**: Proportion of people living in towns and cities

- **Social welfare**: The welfare of society, esp. of those segments of society that are underprivileged or disadvantaged because of poverty, poor education, unemployment, etc.
- **Migration**: Migration movement, and on a small scale also tourism and travelling of people lead to cultural changes; e.g., exposure to different foods/hazards

Health and wellbeing (of human beings)

Human health and wellbeing can affect the susceptibility of the general public to food safety risks.

- **Human health condition**: A person's wellbeing influenced by proportion of non-communicable diseases; e.g., depression, diabetes or obesity
- **Perceived human health condition**: E.g., allergies, intolerances, herbal teas, supplements
- **Resistant pests and diseases**: Pests and diseases can develop different resistances; e.g., antibiotic use and related antimicrobial resistance

3.1.2 Technological Drivers

Technologies in food production

Technological cross-overs may lead to new products and production systems. While some technologies can decrease the risk of hazards, others may cause unwanted side effects.

- **Primary production:** Technologies used for the production, rearing or growing of primary products; e.g., industrialized, traditional, intensive - extensive (incl. fishing, hunting and harvesting of wild products)
    - Plant-derived food production
    - Animal-derived food production
- **Products for food production:** Products used in food production to increase the health of livestock or for protecting and enhancing crops; e.g., food yield increasing measures (pesticide, fertilizers and its alternatives), insects for feed, measures to clean the stables
- **Bioengineering:** Bioengineered foods have been modified through genetic techniques; e.g., enzymatic engineering and GMO's: GMO maize, golden rice, lab grown meat
- **Novel food sources:** Production of e.g., insects, algae for human consumption

Technologies in food processing

Innovative technologies lead to improved, more sustainable food products with longer shelf lives within whole supply chain. Some technologies may bear the risk of unwanted side products, or on the other hand may decrease the risk of hazards.

- **Processing techniques and scale:** 'Processing' means any action that substantially alters the initial product; e.g., heating, smoking, curing, maturing, drying, marinating, extraction, extrusion, novel and alternative techniques and industrial and traditional processes or a combination of those processes, risk of cross-contamination

- **Food packaging:** Containment of food; e.g., primary/secondary contained, food packaging material, type and duration of contact, smart packaging
- **Upcycling for food:** Using of side streams in the food chain; e.g., coffee grounds to grow mushrooms
- **New technologies:** Monitoring processes and products; e.g., AI, big data, blockchain analysis

3.1.3 Economic Drivers

Distribution

Across the food sector, a significant horizontal and vertical restructuring is happening which effects distribution along the food supply chain.

- **Global trade:** The exchange of capital, goods, and services across international borders or territories, including trade agreements; e.g., jute bag for food contact material, imported fish
- **Distribution channels:** Well-established paths to move products from the manufacturer to the consumer; e.g., supermarkets, local farmers' market, wholesale
- **New distribution channels:** New paths to move products from the manufacturer to the consumer; e.g., digital marketplaces, ghost kitchens, pop-up stores
- **Food fraud:** Any deliberate action of businesses or individuals to deceive others in regards to the integrity of food to gain undue advantage; e.g., melamine in milk, incorrect veterinary drug use, racemic mixtures

3.1.4 Environmental Drivers

Environmental contamination

Environmental contamination influences competition for land and shortage of available water due to over-exploitation, pollution, the impact of climate change.

- **Agricultural pollution**: Pollution of air, land and water caused by agriculture; e.g., leaching of chemicals, veterinary product residues, plastic waste and eutrophication
- **Pollution**: Pollution from the original extraction and use of non-food raw material in the primary production or manufacturing of goods; e.g., metal mining, fossil fuel use
- **Sewage treatment**: Sewage treatment plant, both industrial and municipal; e.g., incomplete treatment or effluents released into the environment
- **Waste management**: Personal, local, regional, industrial management of waste (collection, separation, processing and storage) which can be organized or unorganized (open dumping or burning) and can cause leachates into the environment

Management of (natural) resources

The availability, accessibility and usability of natural resources are prerequisites for prospering economies including the agricultural sectors. High quality land and the availability of water and nutrients are the basis for food and renewable energy production.

- **Recycling**: Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes; e.g., removing heavy metal, smelting of e-waste
- **Use of waste stream**: Using of other water sources and reusing waste including sludge, manure and fish effluent to recapture the nutrients still present for agriculture
- **Water and soil management**: The planning, developing, distributing and optimum use of water resources and application of operations, practices, and treatments to protect soil; e.g, nutrient sourcing and use

Bioprocesses

The increase in zoonotic diseases running along with an increase in resistance to drugs, such as antibiotics, increase the threat to both humans and nature and thereby influence the food system.

- **Transboundary pests and diseases**: Pests and diseases which spread between farms, countries and continents (due to climate) in a OneHealth society; e.g., swine flu
- **Bio-accumulation**: Bio-accumulation is defined as the net accumulation of a contaminant in or on an organism from all sources including water, air, and diet; e.g., heavy metal in fish

3.1.5 Political Drivers

Legislation, policies and governance

Standardization, legislation, policy and governance directly and indirectly influence production and consumption of food.

- **Monitoring and communication of food safety:** Food safety monitoring is the mechanism that routinely checks for safety hazards, manages compliance adherence, and ensures procedures are being correctly implemented and communicated openly; e.g., inspectors, food business operators recalls, RASFF
- **Good practices and standards:** Practices that have been proven to work well and produce good results, and is therefore recommended as a model; e.g., ISO standards, hygiene
- **Food legislation:** Legislation which regulates the production, trade and handling of food across the entire food chain, from the provision for animal feed to the consumer; e.g., HACCP, food contact material
- **Food information:** Information concerning a food and made available to the final consumer by means of a label, and other accompanying material through modern technology tools or verbal communication; e.g., nutritional labelling, ingredient list, private labels of quality, source, etc.

Geopolitical instability

Advancing economic globalization is currently hampered through newly established/changed borders, barriers, and limits.

- **War and conflict:** Disruptions of diplomatic relations and global markets; e.g., Russia-Ukraine raw materials
- **Fragmentation between nations:** Political stand-off/ trade embargos; e.g., BREXIT in EU, computer chips

3.2 Evaluation of drivers and sub-drivers (online workshop, inductive coding)

Drivers and sub-drivers in the workshop were discussed for their impact on emerging food safety hazards and potential risks. Furthermore, sub-drivers were assessed for their importance or highest potential for emerging risks and hazards and measurable indicators were retrieved where possible. An example from the online whiteboard is given in Figure 4 where the end results of discussing one driver and respective sub-drivers can be seen. Upon a request of a participant, the impact of sub-drivers was also assessed on a scale from 1-10, the higher the number, the stronger their suggested impact and thus relevance of the driver.

Figure 4: Example of workshop results

Workshop participants suggested to add three new sub-drivers to the initial list, namely, (1) Antimicrobial resistance from food chain perspective (added to driver "Health and wellbeing"), (2) Cell based food (added to driver "Technologies in food production", but also considered in the sub-driver "Bioengineering"), and (3) Food safety emergency response plan

and crisis coordination (added to driver "Legislation, policies and governance"). These additional sub-drivers were discussed in line with the initial list and, hence, also considered for further analysis. Inductive analysis of the workshop results in NVivo led to the following list of codes as given in Table 3, where the number of times a specific code was mentioned within all working groups is listed.

Table 3: Codes derived from inductive coding of workshop results

Name	Specific Codes	Times mentioned
Harmful substances	Allergens	6
	Antimicrobial or antibiotic resistance	7
	Biological or microbiological toxins	18
	Contamination (Microplastics, traffic fumes, chemicals,...)	29
	New potential pathogens	7
	Zoonotic diseases	10
Stage in value chain	Primary production	29
	Processing, production, manufacturing	57
	Technology	15
	Shelf life and storage incl. packaging	19
	Distribution and trade	46
	Consumption	39
	Recycling	13
Emerging Food Trends	In vitro meat	2
	Insects	1
	Other Novel Foods	10
	Plant Based Foods	3
Grand Challenges	Climate Change	9
	Population change*	12
	Management of (natural) resources - Soil Management	9
	Management of (natural) resources - Water Availability	6
	Urbanisation	3
	Geopolitical instability (war and conflicts)	5
Legislation & Policy		25

Indicators		14
Direction	Decrease	16
	Increase	59
	Unknown or not clear	6

*including increasing population, migration, demographic change, and war & conflict as this causes migration & population change

As already mentioned, the workshop results were analysed to identify indicators of specific drivers/sub-drivers and to derive common issues across drivers. Through cross-referencing codes with each other, we received an overall picture of potential impact at different stages in the value chain or links to specific foods.

Harmful substances that were considered to increase in occurrence were (chemical and industrial) contamination, biological hazards, antimicrobial substances, zoonic diseases and allergens (Figure 5). As risks regarding chemical and biological contamination *recycling and re-use of waste streams* were named, because an *accumulation of harmful substances* may occur if they are not fully removed in the recycling process. Among the named substances were *heavy metals* (e.g. arsenic in brown rice), *per- and polyfluoroalkyl substances (PFAS)*[1], *mycotoxins* and yet unknown potential new hazards. Also, the risk of *pathogenic microorganisms* or viruses splashed onto or taken up in crops increases with wastewater stream reuse. *Bioaccumulation* was also strongly linked to climate change since there are new *environmental pollutants* being accumulated in the food chain. Sufficient treatment for new microbial or viral risks and removal of chemical substances is a necessity, but maybe new risks cannot be captured.

A higher intake of plant-based food and higher use of plant-based feed may lead to *accumulation of plant-born (natural) toxins, such as alkaloids*, which may lead to cross-contamination also in milk and meat in case of more intensive animal production. The higher use of hemp seeds or herbs and their extracts was named as unknown risk for introducing harmful substances to the food system.

Overuse of *antibiotics* by humans and in animal production, the accumulation of antibiotics through reuse of wastewater side streams and associated increased antibiotic resistance was mentioned as “a problem, and if practices of sewage treatment and antibiotic use does not change, then this will remain a problem”, especially if the antibiotic resistance reduction is not tackled globally.

The emergence of new potential microbial or viral pathogens and *zoonotic diseases* was reflected as climate change and is already being the cause for *new pathogens* in plants, animals, and humans that are spreading in food production systems. Furthermore, new agricultural practices are also facing new pathogens. As an example, crop-rotation was named as having a significant impact on food safety. Zoonotic diseases may also spread from exotic pets in close proximity to humans.

Alongside potential new toxins and chemicals through novel food sources, *new allergens* may occur with the introduction of yet unfamiliar food and extracts. Especially vulnerable groups, foremost children, were mentioned in the discussion as high-risk groups.

[1] e.g. Ritscher, A., et al. (2018). "Zürich Statement on Future Actions on Per- and Polyfluoroalkyl Substances (PFASs)." Environmental Health Perspectives 126(8): 084502.

harmful substances X directional	direction		
harmful substances	Decrease	Increase	Unknown or not clear
Allergens	0	1	2
Anbtimicrobial or antibiotic resistance	0	4	0
biological or microbiological toxins	1	11	0
Contamination (Microplastics, traffic fumes, chemicals,...)	0	14	2
New potential pathogens	0	2	0
Zoonotic diseases	1	3	0

Figure 5: Cross-coding of workshop results harmful substances and their expected directional development

The cross-code analysis of the codes “harmful substances” with “stage in the production chain” gives an indication as to where the focus points for further analysis and search for indicators could be (Figure 6). Primary production and processing and manufacturing are considered as focus points for occurrence and accumulation of harmful substances. Recycling and re-use of side streams bear risks by accumulation of chemical or microbiological substances as stated above. Workshop participants expect an escalation in biological contaminants, toxins, and various chemical pollutants, including microplastics and traffic-related emissions.

In primary production the above-mentioned contaminants were of concern and specifically mentioned in the context of animal feed. The safety of using contaminated feedstock in animal feed and subsequently in food production, such as the presence of dioxins or mycotoxins, remains a significant concern. Recycling practices in animal feed raise notable concerns, partly due to lesser public awareness regarding feed as opposed to finished food products.

The cultivation of resistant plants and the adoption of modified crops carry the potential risk of giving rise to emerging mycotoxins and the unintentional transfer of genetic traits to non-modified crops. The manipulation of genes through methods like GMOs has generated both benefits and concerns, raising questions about citizen awareness and understanding.

Additionally, the use of fertilizers leading to water contamination and harmful algal blooms has highlighted the production of phycotoxins in seafood, posing a potential risk for food safety. Urban gardening and agriculture, seen as innovative practices, may be sources of environmental pollutants in heavily industrialized areas. The expansion of food production into contaminated regions and the use of tainted soils are another source of contamination in food. Moreover, urbanization's destruction of native ecosystems may facilitate the return of invasive species along with their associated pathogens.

Although new technologies such as the use of side streams for biogas and other upcycling practices hold promise for alternative uses, they also carry the potential of introducing contaminants. The problem of antibiotic resistance in the food chain poses significant challenges to human health services. Drying is emerging as an important preservation technique yet challenges in maintaining quality and addressing technological limitations remain, particularly in warmer and more humid nations. Similarly, fermentation and home-

based methods like smoking hold promise, although a lack of knowledge and toxicological understanding present hurdles to their effective adoption.

Efforts to reduce packaging come with increased risks, as effort to prevent food waste may lead to the elimination of shelf-life dates, potentially raising concerns about microbiological safety. While reducing plastics for packaging material meets sustainability goals, it could result in less durable packaging, giving rise to challenges such as heightened food waste and again microbial-related issues.

Considering the stage of consumption, shifting dietary patterns can introduce novel risks, potentially exposing consumers to new allergens and heightened levels of plant toxins. Furthermore, the globalized nature of food trade can facilitate the transfer of viruses and pathogens across regions. As diets incorporate more whole grains, there's a concern that this could inadvertently elevate mycotoxin intake due to the intrinsic association of mycotoxins with grains.

harmful substances X value chain	stage in value chain						
harmful substances	Primary production	processing, production, manufacturing	Technology	Distribution and trade	Recycling	shelf life and storage incl. packaging	Consumption
Allergens	0	2	0	0	0	0	2
Anbtimicrobial or antibiotic resistance	2	1	0	0	0	0	3
biological or microbiological toxins	3	1	1	2	2	1	4
Contamination (Microplastics, traffic fumes, chemicals,...)	8	11	2	0	5	2	5
New potential pathogens	2	3	0	0	0	0	1
Zoonotic diseases	2	2	0	0	1	0	0

Figure 6: Cross-coding of workshop results harmful substances and their occurrence along the value-chain

The emergence of novel food sources poses challenges in formulating testing methods for contaminants within unfamiliar substrates. There is a need for research to enhance the capability of identifying contaminants in these new foods, including addressing background effects and matrix interactions. Comprehensive safety testing and the ability to effectively detect potential hazards within upcycled foods require big effort in research.

Indicators were identified on dietary choices, attitudes (trends), and overall consumer behaviours. Going from quantitative indicators (surveys, polls, data bases) to a pool of recent medical and societal related studies on consumer behaviour. Indicators for changed consumer behaviour are also the increase of delivery services both for fresh ingredients / market products as well as for restaurant meals and take aways.

The RASFF system, which monitors rapid alerts on food risks, is considered as a key component. Here, indicators such as mycotoxins, other plant-based toxins or heavy metals can be monitored. Indicators like food waste, reflecting potential discards, and the EFSA network's tracking of food fraud alerts offer insight. Consumer reports and profit changes in specific companies provide additional perspectives, although their applicability can be challenging. Metrics such as the cost of storage, commercial premises, energy consumption, cost of logistic and distribution and imports further contribute to the assessment. Data sharing platform users and notification counts play a role, while technical measurements of legal standards, blacklisting or ranking chemicals by environmental concentration, control programs for chemicals, and emissions provide specific insights.

Other indicators named related to environmental pollution, where research on pollution levels is deemed necessary, monitoring of soil pollution should be taken on by food safety authorities.

(Food) legislation encompasses various aspects, including consumer information, but faces challenges in adapting to industry innovation. Existing regulations often lag behind the rapid pace of technological advancements like GMOs and NextGen sequencing, which calls for a more scientifically informed framework. Striking a balance between proactive and reactive approaches is vital, as emerging technologies can outpace regulatory measures, potentially resulting in risks. Moreover, the influence of legislation beyond the food sector can also introduce hazards.

The need for legislation to address the dynamics between large and small-scale operations, including macro farms, underlines the global versus local debate. While such considerations arise, European legislation encounters complexities driven by political motivations. This influence can have far-reaching consequences, even impacting other continents like Africa, where hesitancy to adapt is influenced by fears of contamination when exporting to Europe. This highlights how European legislation impacts the regulatory landscape on a global scale.

The implementation of virtual techniques for **official controls** presents uncertainties, as methods like virtual inspection and risk profiling primarily rely on historical data and might not capture current behaviours effectively. While digitization of inspections could increase their frequency, it may compromise quality until fully integrated. The application of AI for control prioritization at ports shows promise but may overlook emerging issues lacking historical data. Emerging challenges involving origin, traceability, and declarations pose food fraud risks.

Legislative gaps exist for emerging concerns like PFAS and microplastics, necessitating research before regulation. The concept of recalls and unit mixing raises a tension between safeguarding human health and protecting the environment. Clashes between good practices and standards from various perspectives, such as food safety versus environmental concerns, require adaptations due to changing dietary patterns. Transferring good practices without adaptation can introduce risks. Third-party standards have the potential to enhance food safety oversight but may also lead to overreliance and inspection prioritization issues.

Geopolitical instability, war and conflict lead to increased disruptions in the food supply chain and thus may drive nations to seek new markets with looser regulations, potentially jeopardizing food safety standards. The complex connection between transboundary pests and diseases and geopolitical instability shows how they affect each other, particularly when considering alternate import and export routes during times of conflict. Furthermore, fragmentation of nations due to conflict can lead to a patchwork of divergent food-related regulations, thereby fostering an environment of uncertain and unsafe food practices. Finally, instabilities also affect social welfare, healthcare and education systems, further worsening challenges posed by food hazards.

The complex interactions underscore the need for informed decisions, heightened public awareness, and proactive measures to ensure the safety and sustainability of our food systems.

3.3 Qualitative analysis of literature on microbiological hazards

Literature review of the relevant microbiological review papers was undertaken to extract relevant influencing factors connected to the identified drivers for the emergence of food safety issues. This combined all extracted data to provide an overview of influential factors and potential indicators, merged in drivers and sub-drivers, for each known hazard. The results of the NVivo coding regarding *Listeria monocytogenes* are combined in *Figure 7*. All drivers and sub-drivers related to *L. monocytogenes* are given, with a chart area relative to the number of coded references to each driver or sub-driver. It is clear from *Figure 7*, that the **social** drivers, including consumer behaviour, health and wellbeing and demographic development, and **technological** drivers, including technologies in food production and food processing, are most evident in literature for the emergence of *L. monocytogenes*. These two are followed by **environmental** and finally, **economic** and **political** drivers, being less important. 207 influential factors were identified across 28 review papers considering *L. monocytogenes*.

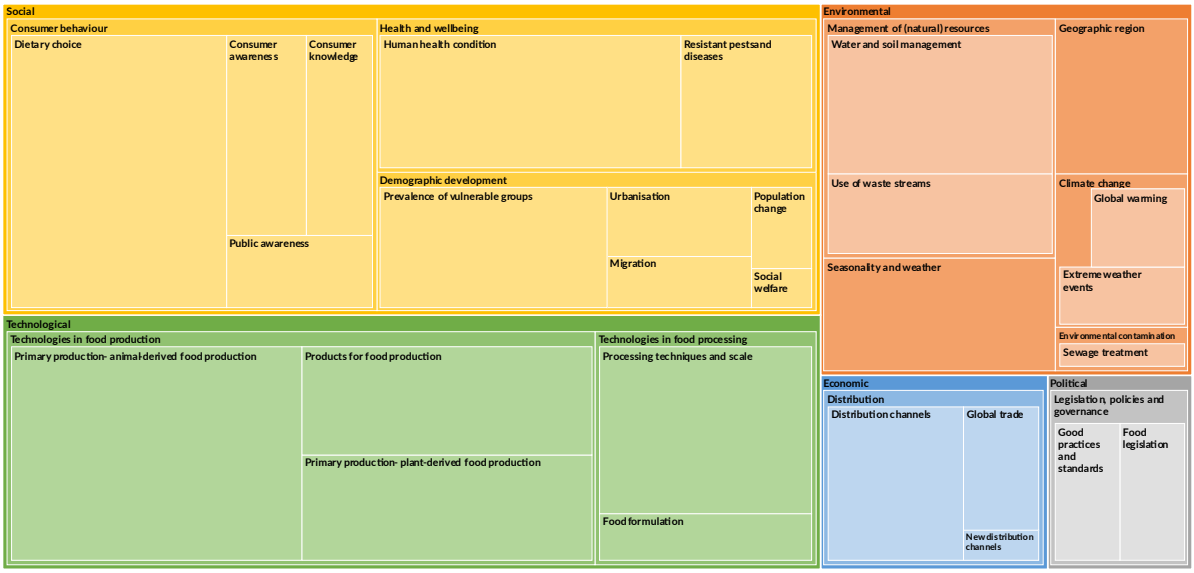

Figure 7: NVivo chart showing related drivers and sub-drivers to Listeria monocytogenes. Drivers are classified according to the STEEP principle. The chart area is relative to the number of references coded for each driver or sub-driver.

Similarly, as for *L. monocytogenes*, the results of the NVivo coding regarding *Bacillus cereus* are combined in *Figure 8*, demonstrating the drivers and sub-drivers relevant for this spore-forming bacteria. Overall, at STEEP level, the **technological** and **social** aspects were mostly coded either by the number of review articles or the number of influential factors, indicating the most referenced STEEP aspects available in literature are from technological and social aspects. The **technological** drivers include technologies in food processing and food production, whereas the **social** drivers include consumer behaviour, health and wellbeing and demographic development. **Environmental**, **economic** and **political** drivers are less coded to *B. cereus* in literature reviews. In total, influential factors were identified 116 times from 19 articles associated with *B. cereus*.

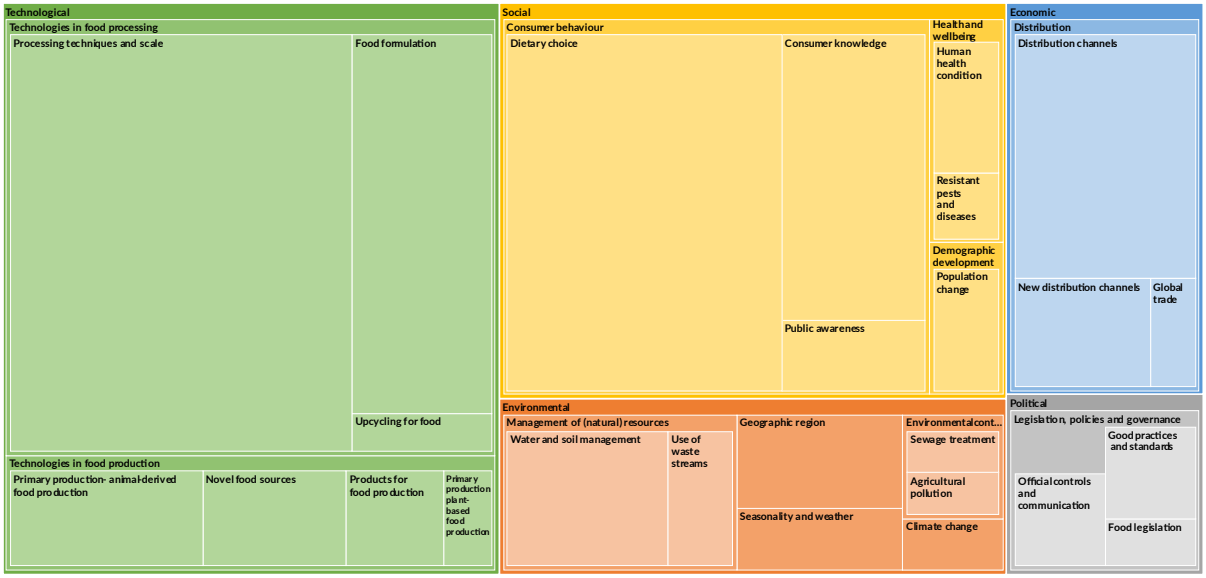

Figure 8: NVivo chart showing related drivers and sub-drivers to Bacillus cereus. Drivers are classified according to the STEEP principle. The chart area is relative to the number of references coded for each driver or sub-driver.

A total of 15 known microbiological hazards were included in this research. The outcome of NVivo, for example *Figure 7, 8*, show which drivers and sub-drivers are relevant for which pathogenic micro-organisms by combining reported influential factors as available in literature reviews. Considering *L. monocytogenes*, social drivers, focussing on dietary choice and the prevalence of vulnerable groups, followed by the technological aspects from the primary production level, were identified as most important. Respectively, (i) the evolution in ready-to-eat and/or high-convenient food products, and (ii) the future of farming and the current trend towards organic farming, with related agricultural practices are identified as important influential factors underlying these drivers. Regarding *B. cereus*, technological drivers were considered most prevalent, focussed on food processing. The ongoing trends towards traditional food technology, minimal processing and mild preservation are important influential factors for *B. cereus* emergence. Like *L. monocytogenes*, the social driver 'consumer behaviour' highlights the importance of ready-to-eat (chilled) foods regarding *B. cereus*.

The in-depth analysis and discussion considering all known foodborne pathogenic micro-organisms is currently in preparation for publication.

3.4. Compilation of drivers, sub-drivers and indicators from qualitative analysis

The safety of our food system is under pressure from a number of external factors. The complexity of factors leading to foodborne hazards requires good co-operation within the (international) food system. Identifying drivers and linking them to indicators is an important step in enabling evidence-based and future-proof data-driven risk management. Drivers for food safety emergence were identified, based on existing literature, and completed using expert judgements. Furthermore, related indicators were identified from the discussions and in the literature reviews, which can be regarded as first results for task 1.2. and hints where the search for further indicators should focus. Table 4 summarizes the drivers and their

respective sub-drivers and the indicators, that were discussed in the stakeholder workshops and during interviews or identified in literature review.

Table 4: Driver and sub-driver results used in the workshop with potential indicators suggested

STEEP Driver	Subdriver		INDICATORS (to be further refined in task 1.2)
Societal-cultural	Demographic development	Population change	Population size and growth, distribution of age groups, gender etc. and their development over time, etc. e.g. https://data.oecd.org/pop/population.htm, (United Nations, 2013)
		Prevalence of vulnerable groups	Social vulnerability index, prevalence of vulnerable groups
		Urbanisation	Destruction of native ecosystems and land sealing
		Social welfare	
		Migration	Spread of (zoonotic) diseases, immigration rates
	Health and wellbeing	Human health condition	Number of allergies, antimicrobial or antibiotic resistance
		Perceived human health condition	Overuse of antibiotics in human medicine and animal production
		Resistant pests and diseases	
	Consumer behaviour	Dietary choice	Increase risk to heavy metals with increased plant based food eg. monitor Arsenic in brown rice accumulation of (plant-based) toxins as alkaloids Overdose of certain vitamins or minerals (due to intake of supplements or herbal teas) Dietary patterns
		Consumer knowledge	

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		Consumer awareness/attitude	
		Public awareness	
technological	Technologies in food production	Primary production	Price fluctuations, price of fuel, inflation, occurrence of dioxin and mycotoxins in feed, overuse of fertilizers leading to harmful algal blooms, increase of phytotoxins in seafood amount of urban gardening & agriculture leading to polluted food in heavily industrialized areas rate (and use) of contaminated soil size of farms indoor – outdoor production rates rates of organic farming
		Products for food production	Price fluctuations, price of fuel, inflation, changes in production technologies (e.g. increase in fermented products)
		Bioengineering	Use of genetic modified plants may give rise to emerging mycotoxins, transfer of genetic traits
		Novel food sources	Overdose of certain vitamins or minerals (due to intake of supplements or herbal teas)
		Cell-based food	
	Technologies in food processing	Processing techniques and scale	Increase of minimally processed foods, amount of convenience food
		Food packaging	Price fluctuations, inflation
		Upcycling for food	Residues in recycled material, accumulation of harmful substances
		New technologies	Emergence of new technologies
		Food formulation	e.g. Use of pasteurized milk, minimally processed or raw ingredients
economic	Food Distribution and networks	Global trade	
		Distribution channel	Price fluctuations, price of fuel, inflation

		New distribution channels	Market share of delivery companies (if they are growing)
		Food fraud	Amount of alerts in EFSA network
		Storage	Price fluctuations, inflation, cost of storage (commercial premises per m2), Energy and electricity consumption
		Data sharing	Amount of users of data sharing platforms
		Competition between FBO	
environmental	Environmental contamination	Agricultural pollution	Level of soil/water pollution: rates of water infiltration, surface runoff, cohesion, aeration, and root density, erosion, infiltration rate, and water holding capacity
		Pollution	
		Sewage treatment	Use of manure for fertilizing, irrigation practises
		Waste management	Food loss / Food waste index, accumulation of harmful substances
	Management of (natural) resources	Recycling	Accumulation of harmful substances (mycotoxins, PFAS, heavy metals), recycling rates
		Use of waste stream	Accumulation of harmful substances (mycotoxins, PFAS, heavy metals)
		Water and soil management	Level of soil/water pollution: rates of water infiltration, surface runoff, cohesion, aeration, and root density, erosion, infiltration rate, and water holding capacity
		Shelf life labelling	
		Side stream management	Chemicals measured in environment in ppm
		Consuming raw material	
	Bioprocesses	Transboundary pests and diseases	
		Bio-accumulation	
	Climate change	Global warming (temperature)	

		Extreme weather events (rainfall, storms, floodings)	
Political	Legislation, policy and governance	Monitoring and communication of food safety	Emergence of recalls
		Good practices and standards	Changes in regulation & policy e.g. regarding GMO
		Food legislation	Number of technical measurements for legal standards
		Food information	
		Food safety emergency response plan and crisis coordination	
		Official controls and communication	Availability of surveillance data
	Geopolitical instability	War & conflict	Monitoring of war & conflict zones
		Fragmentation between nations	

4. Conclusion and outlook

The literature reviews and condensing of the sub-drivers and drivers and expert interviews resulted in a list of drivers and sub-drivers. This initial list was quite comprehensive as only three sub-drivers were added by the participants during the workshop.

The analysis of data from the workshop, and particularly the cross-referencing of codes, allowed for the most common sub-drivers discussed by experts to be identified and thereby provided insight into potential areas of concern for food safety. In line with a recent report from EFSA (Afonso *et al.*, 2020) which identified many emerging risks as microbiological or chemical, the experts in the workshop particularly felt that contamination and biological or microbiological toxins have a likelihood of increasing the emergence of food safety hazards. This included a range of aspects of contamination from production through to packaging and pollution, and plant-based toxins through to recycling. Further analysis revealed that primary production and processing or manufacturing could be critical stages in the value chain for contaminants. The consumption stage was also identified as important, with consumer attitudes and behaviours subsequently influencing dietary choices and thereby impacting upon food safety risks.

The prominence of consumer behaviour (and particularly dietary choice) as a factor in food safety was also evident in the literature review analysis, having been commonly identified in relation to both *Listeria monocytogenes* and *Bacillus cereus*. This also aligns with the EFSA finding that changes in consumer behaviour were a driver for more than half of food safety issues identified in 2019 (Afonso *et al.*, 2020). For both microbiological hazards, technologies in food processing and production were also commonly mentioned as sub-drivers in the literature. In terms of environmental sub-drivers, water and soil management was mentioned most, with seasonality and weather mentioned more for *L. monocytogenes*. Economic and political sub-drivers were less commonly identified from scientific literature.

While not a focus of the current task, initial ideas for indicators for the sub-drivers were also identified in the workshop and literature reviews. These included a range of indicators from quantitative measurements such as price fluctuations and inflation through to more qualitative measurements such as changes in regulation and policy. It is acknowledged that the initial list of indicators listed in Table 4 must be regarded as suggestions and will be investigated in depth in task 1.2. For future work, it is important that these indicators can be linked to reliable (and open resource) databases, so that they can be integrated in the intended hub in this project.

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6. Appendix

Appendix 1: Interview procedure

Individuals were approached to participate via an invitation email which outlined the purpose of the study and a range of potential interview dates. A date and time were then confirmed with interested individuals and the consent form was sent for review.

At commencement of the interview, participants were provided with information on the overall project, the study, and the purpose of their participation. Following an opportunity to ask questions, the recording began and the interview took place according to the interview guide. Participants were thanked both verbally and later via email. Interviews lasted approximately an hour.

Appendix 2: Interview protocol

1. Sending invitation

Dear INSERT NAME HERE,

We are currently conducting a study in collaboration with research partner across Europe within HORIZON Europe to develop a pro-active and holistic food safety warning and management system. This first part of the project focuses on the impact specific drivers will have on the probability of emergence of the hazards.

For this purpose, we would like to schedule an **interview** with you to discuss drivers likely to affect the emergence of food safety hazards. Would you be available for an interview (60-90 minutes via MS Teams) between INSERT DATE SUGGESTIONS HERE?

Your participation in this study is completely voluntary and your responses will remain anonymous. We will offer you a summary of the results upon completing the study.

We would appreciate your participation. If you have any further questions regarding our request, please feel free to contact us via email (INSERT EMAIL ADDRESS).

Best regards,

Insert signiture here

XXX and the FoodSafeR project team

2. Sending calendar invitation for interview appointment

3. Sending email with consent form for review

We will send the informed consent form to the participants once the interview date is set to allow a prior reading of the document (see informed consent form).

4. Conducting interview

At the start of the interview, we will summarize the background of the study, the purpose of the interview and allow to ask questions. We will inform them that they have to provide consent to allow processing of interview data.

This study is part of the FoodSafeR research project. The study aims to analyse and design the building blocks of a pro-active and holistic food safety management system with a focus on resilience in the face of emerging hazards. We ask you for your insights on drivers and food safety management tools and strategies. The results of the study will be specifically used to prepare a workshop for project partners regarding ***drivers and sub-drivers of emerging food safety hazards.*** *In the long run, this study will inform stakeholders in European food systems, such as researchers, food business operators and farmers, about external drivers, emerging hazards and food safety management tools.*

The interview will take approximately XX minutes. Feel free to interrupt and ask questions anytime. Do you have any questions at this point?

Ask on interviewees background

If answered no: **start recording the interview!**

According to EFSA (EFSA, 2010b), drivers are "Issues shaping the development of a society, organisation, industry, research area, technology, etc.". Drivers may act as modifiers on the onset of emerging risks, namely they can either amplify or attenuate the magnitude or frequency of risks arising from various sources (EFSA,2011).

They can be classified in ***social****,* ***technological****,* ***economic****,* ***environmental****, and* ***political*** *(STEEP) categories.*

We conducted a literature review to identify drivers related to emerging food safety hazards and associated risks. We classified them according to the STEEP categories and grouped them to arrive at drivers and sub-drivers. We plan to discuss each driver in a small group to create different future scenarios and arrive with the most important sub-driver for each scenario. ***We would like you to review our initial list of drivers and sub-drivers to discuss in the workshop.***

Present table

Take you time to read through the table shortly and then we'll discuss each driver in detail.

Is everything clear?

Is the list of drivers complete regarding the emergence of food safety hazards // emerging food safety risks?

What is missing?

Where is it missing?

Start with first driver:

Does the name of the driver match with the sub-drivers?

Are there additional sub-drivers you can think of in this driver?

What is the most important sub-driver in your opinion?

What would be an appropriate indicator for that driver?

Providing consent can be done oral or by signing the provided consent form. In either case, we allow them to provide consent after completing the interview by recording

"I, first name surname, have understood the information regarding data privacy and provide consent to process this data in the FoodSafeR project"

or by signing and returning the consent form. This allows participants which are less familiar with being interviewed to become familiar with the procedure before providing consent. There is the risk, that participants deny consent after completing the interview or simply forget to sign and return in. We will contact and inquire the reasons of not providing consent in such cases.

5. Sending thank you email and collecting signed informed consent form

Appendix 3: Informed consent form for interviews

Informed Consent Form

You are being invited to take part in a research study that is being conducted by AIT Austrian Institute of Technology and the Wageningen University & Research. Before you decide, it is important that you understand why the research is being done and what it will involve. Please take time to read the following information carefully and then decide whether or not you wish to take part. In case you have any remaining questions, you can contact Sabine Neuberger. You can find her contact details below.

Study name: Pro-active food safety management considering data and economic aspects, which is part of FoodSafeR – A Joined-up Approach to the Identification, Assessment and

Management of Emerging Food Safety Hazards and Associated Risks

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This Informed Consent Form has two parts:

1. Information regarding Data Privacy (according to Art. 13 GDPR)
2. Declaration of Consent

Part 1: Information regarding Data Privacy

Aim of the study: This study is part of the FoodSafeR research project. We conduct interviews. The study aims to analyse and design the building blocks of an pro-active and holistic food safety management system with a focus on resilience in the face of emerging hazards. The expert and participants will be asked to prove insights on drivers and food safety management tools and strategies. The results of the study will be used to inform stakeholders in European food systems, such as researchers, food business operators and farmers, about external drivers, emerging hazards and food safety management tools.

What will you be asked to do in the study: In this study you will be asked to participate in surveys/interviews/group discussion.

Risks and discomforts: We do not foresee any risks or discomforts in participating in this study, since you will not be asked for sensitive personal information.

Your data will be made anonymous before results will be published. An association of this personal information with the evaluations of the experiential knowledge of the interviewed experts in the evaluation report does not take place. However, it is not possible to guarantee anonymity in all cases, as persons close to you may guess that some input came from you. But we will not disclose your identity.

The study will be documented by video recordings and audio recordings for the purpose of analysis. The video and audio recordings will be erased once the project has been concluded. For the purpose of transcriptions, only the audio track file will be used.

Benefits for you and benefits of the study:

Benefits for you: If you are interested in the results of the study, you can leave your email address. We will provide you with a summary the study results with useful insights in the emerging food safety hazards and the management thereof.

Benefits of the study: The insights you provide will contribute to improving the food safety management in Europe which is a complex system with many external forces and different actors. The study will inform actors from research, industry, and government and other agricultural stakeholders who work in European food systems.

Confidentiality: We will keep all information that is collected during the course of this study strictly confidential and anonymous.

Data storage: You have the right to request information about your personal data processed by us and to have any incorrect data rectified or erased. Subject to the provisions of the General Data Protection Regulation, you also have the right to request the restriction of the processing or the transfer of your personal data. In cases of suspected violation of the data protection provisions you can contact the Data Protection Authority (www.dsb.gv.at).

Your collected information will be stored on sharable managed storage options at university and personal storage. Your data will only be anonymously shared with selected other researchers of the FoodSafeR project. After finishing this research, all data underlying publications will be archived for ten years and registered in the data library.

Voluntary participation: Your participation is completely voluntary and you may choose to stop participating at any time. Your decision not to participate will not influence your relationship with any of the affiliated Universities either now, or in the future.

Withdrawal from the study: You can stop participating in the study at any time, for any reason, if you decide so. In the event you withdraw from the study, all associated collected data will be immediately destroyed. If you require further information about your rights or wish to exercise your rights, please contact Sabine Neuberger (sabine.neuberger@ait.ac.at).

Funding of the study: The FoodSafeR project, which is conducted under the scope of Farm2Fork: Identification, assessment and management of existing and emerging food safety issues. It is financed by the Horizon Europe, Grant agreement ID: 101060698.

PART 2: DECLARATION OF CONSENT ACCORDING TO DATA PROTECTION LAW

I declare that, as a participant of the research of AIT Austrian Institute of Technology and Wageningen University & Research:

1. I have received the explanation of the research in which I will participate, I have understood what this participation involves, and that I have had the opportunity to ask questions which have been answered fully.
2. I have received enough information about this study.
3. I understand that my participation is voluntary, and I am free to withdraw at any time without giving any reason.
4. I agree to take part in the above study and that my anonymised data collected as part of this study may be archived at the end of the project in a public data repository.

Name of the respondent:

_____

Date Signature of the respondent

Appendix 4: Workshop procedure and ethical approval

All individuals from the FoodSafeR project consortium were informed of the aims of the workshop, the proposed date, and invited to participate. Those who expressed interest were then sent a consent form which outlined the workshop in further detail and a Microsoft Teams meeting link. At the beginning of the workshop, participants were welcomed, and a brief introduction was given. This introduction outlined the purpose of the workshop and the agenda. Participants were then given a presentation on the drivers and sub-drivers including definitions and meanings. Following this, participants entered their groups in breakout rooms, along with a moderator. Within these groups, individuals introduced themselves and participated in a short 'icebreaker' (e.g. what is the strangest food that you have ever eaten?). The first driver (and its sub-drivers) allocated to the group was then discussed. Specifically, each group discussed the relevance and impact of the driver and sub-drivers, potential indicators for each sub-driver, and scored each driver (scale 0-10) in terms of impact. Mural, an online digital whiteboard platform, was used for collaboration and to share thoughts. Following a short break, participants then discussed the second (and third if applicable) driver and its sub-drivers. All participants then re-joined the main workshop room. Individuals from each group then summarised their breakout group discussions to the whole group. The workshop was not recorded, however, moderators of each group made notes on the discussions.

Appendix 5: Workshop agenda

WHEN	What
13.00	*Start of the workshop:* Welcome & introduction
13:15	Short participant's introduction *(breakout rooms)*
13:20	*Presentation:* Drivers & sub-drivers
14:05	*1st Group discussion:* Discussion of one driver, respective sub-drivers and measurable indicators per group *(breakout rooms)*
15:00	*Break*
15:15	*2nd Group discussion:* Discussion of a second driver, respective sub-drivers and measurable indicators per group *(breakout rooms)*
16:00	*Reflection:* Short presentations of group work
16:55	Wrapping up & next steps