The Willingness to Adopt Blockchain Based Traceability Systems in the Dutch Fish Industry

MSc Thesis Report

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Abstract

Background: A review done by Oceana on more than two hundred studies found that twenty percent of the globally tested seafood samples were mislabelled (N= 25000). Of these studies, sixty-five percent included clear evidence that economic incentives lead to the mislabelling. Mislabelling of products does economically deceive consumers and may also have negative consequences on the sustainability of the fish industry. Blockchain traceability could prevent fraud related to fish mislabelling. The blockchains ability to share and store immutable data entries makes the subject of traceability within the food supply chain an interesting application area, as it promises to simply the detection of fraud.

Method: The willingness of the Dutch fish industry to adopt a blockchain based traceability system has been investigated, using Roger's theory on the diffusion of innovations and Ajzen's theory of planned behaviour. A questionnaire was developed based on these theories. Chain participants were selected to take part in an online questionnaire covering all factors of the previously mentioned models. Answers were reported on a five-point Likert scale. Respondents data were analysed using binomial logistic regression.

Result: Sixty-one chain participants completed the questionnaire. Results indicated that thirty percent of the participants have the intention to adopt blockchain traceability within the next five years. None of the respondents currently employed a blockchain traceability system.

Regarding the current state of traceability in the Dutch fish industry, forty-four percent of the companies said to use a traceability system that contains a mix of paper and digital processes. Forty-one percent of the respondents used a paper-based traceability system, while fifteen percent strictly used a digital system.

Modelling the total Likert score of all eight factors of the theory of planned behaviour and theory on the diffusion of innovations using binomial logistic regression was found to have the best capacity to predict one's willingness to adopt blockchain traceability. The factors Attitude towards the behaviour, Subjective norm, Observability and Complexity were found to have a significant correlation with the intention to adopt.

Conclusion: Practitioners offering blockchain traceability services should consider focusing on the constructs that had a significant correlation with the intention to adopt, which were: attitude towards the behaviour, subjective norm, observability, and complexity. Furthermore, results signified that digital traceability systems give their users significantly more satisfaction than paper-based systems. It remains for further research to conduct a total supply chain enveloping study with an international focus, as differences in the willingness to adopt blockchain traceability at different locations or cultural backgrounds could impact the potential of the innovation.

Main limitations: Potential participants were contracted through internet search. This might have caused a coverage error as companies that did not have any online presence were excluded from the sampling pool. This could possibly have tilted the sample to the more technological interested part of the population.

Statistical validation of the used questionnaire instrument was planned to take place using factor analysis. However, the number of datapoints for the number of variables to be tested in the factor analysis was too low. Due to a lack of statistical evidence backing the validation of the used questionnaire, the only validity to the used instrument is granted by extensive use of variables previously used in validated instruments.

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1. INTRODUCTION

The first chapter of this report provides information about the status of traceability in the European food industry. The problem statement focusses on current traceability issues and fraud within the fish supply chain. Subsequently, the research objective and the research questions are provided.

1.1 BACKGROUND

In 2002 the European Union's General Food Law entered into force. The General Food Law is comparable to a constitution for food law inside the European Union. Article 18 of the General Food Law compels food business operators to implement a food traceability system in their businesses (Regulation (EC) 178/2002; 18.1). It states that businesses must be able to pinpoint both the origin and destination of their products. Furthermore, they must be able to present this information on request of the competent authorities (Regulation (EC) 178/2002; 18.2 & 18.3). Traceability is the main tool businesses and authorities possess to swiftly remove products from the market that are unsafe or do not meet pre-set quality criteria. In addition, it allows for targeted withdrawals and the sharing of more precise information with the consumer (European Commission, 2007).

Article 18 of the General Food Law possesses a goal-oriented formulation; it does not prescribe with what tools traceability must be achieved (European Commission, 2010). This more lenient approach gives the industry the flexibility to implement the most suitable system on a case by case basis. Two main types of traceability systems can be discerned: paper-based and computerized systems (Olsen & Borit, 2018). According to Olsen and Borit most traceability systems in the food industry are currently computerized but manual paper-based systems were common practice until few years ago (Olsen & Borit, 2018).

Recent innovations caused a third traceability system option to be explored; blockchain based traceability systems (Tian, 2017). Blockchain technology was initially developed as the driving force behind the cryptocurrency Bitcoin (Yli-Hummo, Ko, Choi, Park, & Smolander, 2016; Nakamoto, 2008). Blockchain technology has wider applicability than just digital currency alone (Pilkington, 2016); it allows for unique pieces of digital property to be distributed, but not copied, in such a way that the transfer is guaranteed to be secure (Andreessen, 2014). It is ''monitored by everyone, and owned and controlled by no one" (Swan, 2015, p. 1). As ledger entries cannot be changed or removed (Peters & Panayi, 2015; Crosby, Nachiappan Pattanayak, Verma, & Kalyanaraman, 2016), blockchain technology can be a tool to prevent fraud and defeat counterfeit products in the food industry (Goverment Office for Science, 2015).

1.2 PROBLEM STATEMENT

The ever-increasing globalisation of trade partners (Trienekens, Wognum, Beulens, & van der Vorst, 2012) and the rise of marketable products call for trustworthy and reliable methods to verify product claims (Espiñeira & Santaclara, 2016). In addition, the increase of available certification schemes for food products may cause an escalation in the amount of food fraud (Ge, Brewster, Spek, Smeenk, & Top, 2017). Furthermore, other stakeholders such as the government and consumers are demanding transparency in their supply chain (Trienekens, Wognum, Beulens, & van der Vorst, 2012). Paper-based traceability systems may not possess the capabilities to efficiently cater to these demands. While computerized systems are better equipped, they still require a certain level of trust between stakeholders, as input data can be changed or manipulated afterwards. In addition, this information is stored either on paper or in a central database. This method is costly, and in the case of paper-based storage, highly inefficient. It is known as a source of fraud, there is also a potential of data corruption (Ge, Brewster, Spek, Smeenk, & Top, 2017).

Seafood is a global commodity. Of the seafood consumed in the European Union 54 percent is imported (EUMOFA, 2017). The American Food and Drug Administration identified 1,700 different seafood species that are likely to be sold in the United States (Warner, Timme, Lowell, & Hirshfield, 2013). With similar numbers to be expected on the European market, it is difficult for the consumer to independently determine what species of fish they are buying. In the United States 33% of seafood products have been found to be mislabelled (N=1215) (Warner, Timme, Lowell, & Hirshfield, 2013). A review done by Oceana on more than 200 studies found that 20% of the globally tested seafood samples were mislabelled (N= 25000). Of the 200 studies 65% included clear evidence that economic incentives lead to the mislabelling (Warner, Lowell, Geren, & Talmage, 2016). Efforts of the European Union to curb fraudulent trades caused the amount of mislabelled seafood items in the EU to drop from 23% in 2011 to 8% in 2015. Mislabelling of products does economically deceive consumers (Warner, Lowell, Geren, & Talmage, 2016) and it may also have negative consequences on the sustainability of the fish industry (Jacquet & Pauly, 2008). Because of the increasing complexion and obscurity in the seafood supply chain not much is known about where the mislabelling fraud actually happens (Warner, Timme, Lowell, & Hirshfield, 2013). According to Rejeb the advent of blockchain traceability could prevent fraud related to fish mislabelling (Rejeb, 2018). The blockchains ability to share and store immutable data entries makes the subject of traceability within the food supply chain an interesting application area (Francisco & Swanson, 2018).

Previous studies looked at the promising prospects of blockchain use as a traceability tool. To date, no research has been conducted towards the attitude of the fish industry towards the use of blockchain technology. The implementation of blockchain technology is a potential paradigm shift in traceability (Ge, Brewster, Spek, Smeenk, & Top, 2017). Because blockchain is a relative new technology it is poorly understood and the intent of the food industry to adopt it in supply chain traceability is unknown (Francisco & Swanson, 2018). Blockchain traceability in the seafood sector is deemed to be highly suitable (McEntire & Kennedy, 2019). However, transferring to a different traceability system is expensive and intensive work (Kher, et al., 2010). These drawbacks can be an obstacle in the adaptation of this new system (Bosona & Gebresenbet, 2013). Additionally, as stakeholders have different interests and priorities regarding transparency and traceability (Wiese & Toporowski, 2013) . As such, the onset of blockchain based systems might not be as desired by the fishing industry as blockchain enthusiasts believe.

Existing literature on blockchain traceability predominantly consist of exploring workable concepts. Empirical studies towards actual adoption in the industry is lacking (Ying, Jia, & Du, 2018). Consequently, it is of interest to study the industries attitude towards factors that determine the willingness to adopt blockchain traceability that might improve its diffusion rate (Francisco & Swanson, 2018) (Kamble, Gunasekaran, & Arha, 2019). The factors that will result from this study will help blockchain marketers and traceability professionals to devise a better implementation program.

1.3 Research Questions

The objective of this study is to assess the willingness to adopt a blockchain based traceability system among different actors in the fish industry. The following research questions will be answered:

1. What are the relative advantage and disadvantages of a blockchain traceability system in comparison to paper-based and computerized systems?
2. What is the current state of traceability in the seafood sector?
3. What is the willingness of companies in the Dutch fish sector to adopt a blockchain based traceability system, and which behavioural factors influence this willingness?

1.4 Thesis outline

After the introduction of the issue at stake the subsequent literature review focuses on two main subjects. The first chapter considers the literature review centring around the theory of blockchain technology, traceability requirements in the fish supply chain and an overview on the key differences between paper-based, computerized and blockchain traceability systems. Chapter three discusses the methods applied during research. The results of this study are presented in chapter four. The results of this study are further analysed in the discussion of chapter five. The conclusions of this study are drawn up in chapter six.

2 MATERIALS AND METHODS

2.1 RESEARCH MODEL

To give better insight into the research methodology a research model was conceptualized (Figure 1). The research model is divided into different phases. The following phases will be completed to reach the final conclusions:

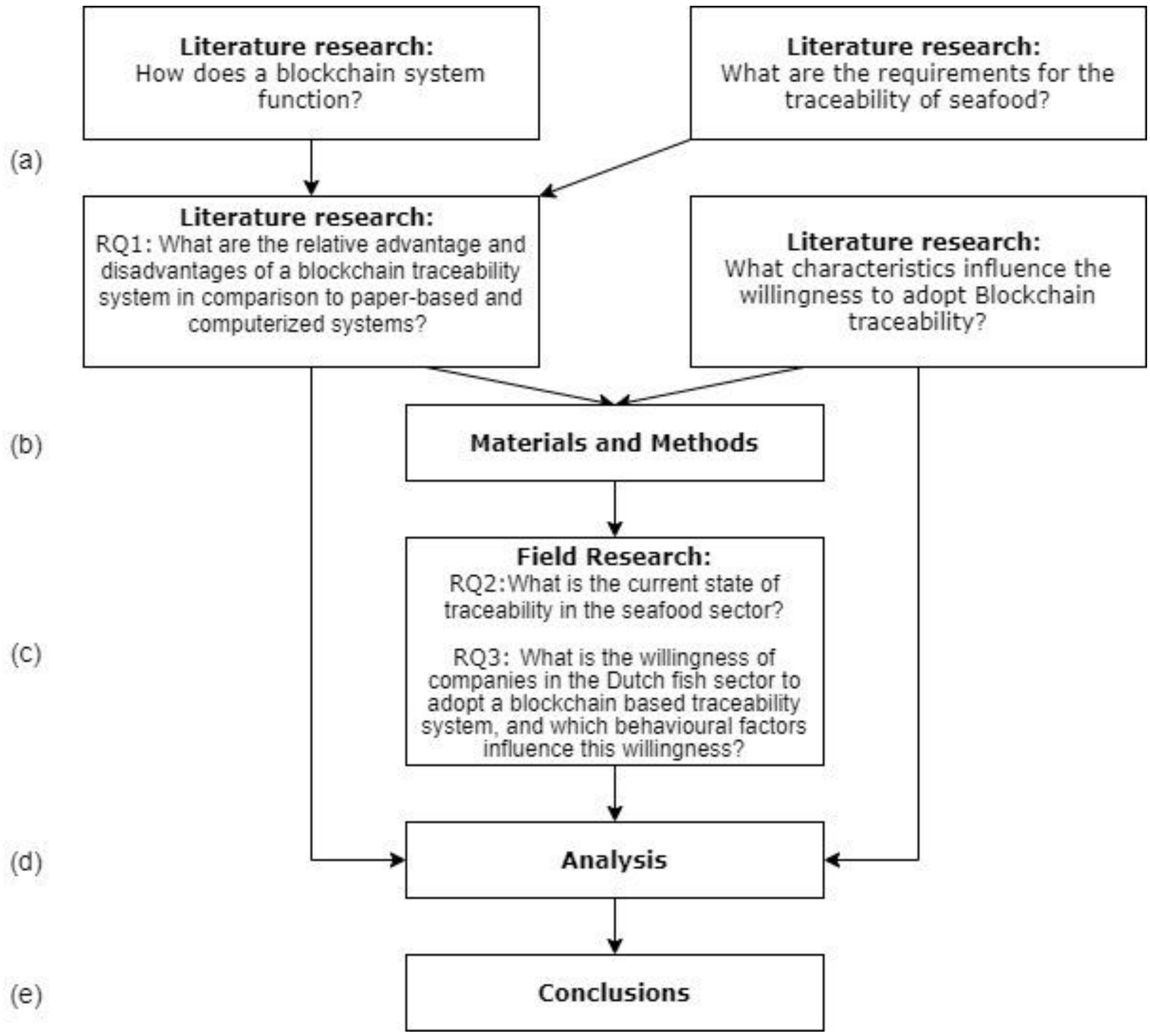

Figure 1. Research model

a) Literature research consisted of three different subjects. First basic exploration of the technical workings of a blockchain system took place. This allowed a deeper understanding of literature regarding the advantages and disadvantages a blockchain traceability system might possess. Subsequently, the legal requirements for traceability in the Dutch fish industry were examined to see if a blockchain system could adhere to them. This resulted in answering the first research question. Finally, a literature study was conducted on the specific factors that influence the characteristics that influence the willingness to adopt. These characteristics were analysed and adapted for use in the field research.
b) Designing the research methodology.

c) The second and third research question have been answered by a combination of literature research to form a reliable research instrument and applying this instrument in the form of a survey in the Dutch fish industry.
d) Analysis of the results and comparison with literature results.
e) With all steps completed the final conclusions on the willingness of the Dutch fish industry to adopt blockchain traceability systems were formulated.

2.2 LITERATURE REVIEW

RQ1 was answered through literature review. As blockchain traceability in the food industry is still in its infancy, an understanding of the technical fundamentals and pros and cons regarding the use of blockchain technology in a food traceability system was deemed an essential part of this study. Literature research towards the technical fundamentals of blockchain technology were kept to the basic aspects as the traceability features of blockchain do not differ substantially between its established use as monetary traceability system and for traceability of foodstuffs.

Insights into the relative advantages and disadvantages were of importance as an innovation without benefits will have little to no viability. As the adoption of blockchain traceability outside of monetary assets is still a small market its potential use case as traceability system in the food supply chain is still not fully explored. Observations regarding this topic were gained from literature research and a first-hand accounts of actual use cases. The gained observations were of help in determining what technical and/or practical elements are of hindrance to blockchain adoption in the Dutch fish industry.

2.3 SURVEY MODEL JUSTIFICATION

RQ2 and RQ3 are answered through conducting a survey under food business operators in the fish supply chain in the Netherlands. The questions drawn up for the survey are based on the complementary principles of Ajzen's Theory of Planned Behaviour and Rogers' Diffusion of Innovations. Using these two models, the series of processes that determine the willingness to adopt can be explained in more detail. The two models have been used extensively in explaining the adoption of information systems as their basic factors are significant determinants in the adoption process (Weigel, Hazen, Cegielski, & Hall, 2014).

While Ajzen's Theory of Planned Behaviour has been extensively used to gauge the decision process of consumers, there is a certain logic that is not suitable for use in organisational settings with its dynamic evaluation progression by multiple persons and departments (Johnston & Lewin, 1996). If the subject matter concerns small businesses this logic is flawed because small business decisions are predominantly made by a single person (Southey, 2011). In 2018, 236 cutter fishery businesses were active in the Netherlands (Mol, 2019a). These businesses employed 1313 fishermen (Mol, 2019b). Of these relatively small size companies it can be expected that business decisions are made by one single decision maker. Therefore, Ajzen's theory was considered well suited for the current case of fisheries in the Netherlands, in which the average cutter fishing business has 5.6 employees. Thompson and Panayiotopoulos have shown that the predecessor of the theory of planned behaviour, Ajzens' theory of reasoned action, can indeed be successfully applied to small businesses (1999). In this study Ajzen's theory is deemed to be a valuable tool to evaluate the willingness to adopt on the primary supplier level. Ajzen's Theory of Planned Behaviour has been widely used to analyse the willingness to adopt a large number of innovative technologies (Kamble, Gunasekaran, & Arha, 2019).

Rogers' Diffusion of Innovations concentrates on the adoption process in an organizational setting. Rogers' theory is not only commonly used to discuss adoption at the organizational level, but also at the individual level (Taherdoost, 2018). Rogers' Diffusion of Innovations can be described as a macro model. Macro models assume the population to be rather homogenous in their inclinations. Although such a model is suitable to generate insights in the willingness to adopt emergent innovations, a micro level model is better suited to analyse the excitement on the market for a product. Micro level models such as Ajzen's Theory of Planned Behaviour are better equipped to deal with the heterogeneous social network structures that might be present at a business level. Combining the two different models has proposed to gain a clear insight in the processes at a large and small scale (Tumasjan & Beutel, 2019).

Ajzen's Theory of Planned Behaviour and Rogers' Diffusion of Innovations were thus combined into one workable model by following the innovation adoption-behaviour model proposed in the work of Weigel, Hazen, Cegielski & Hall (2014). This model is little more than the combination of the previously two mentioned models (Figure 2).

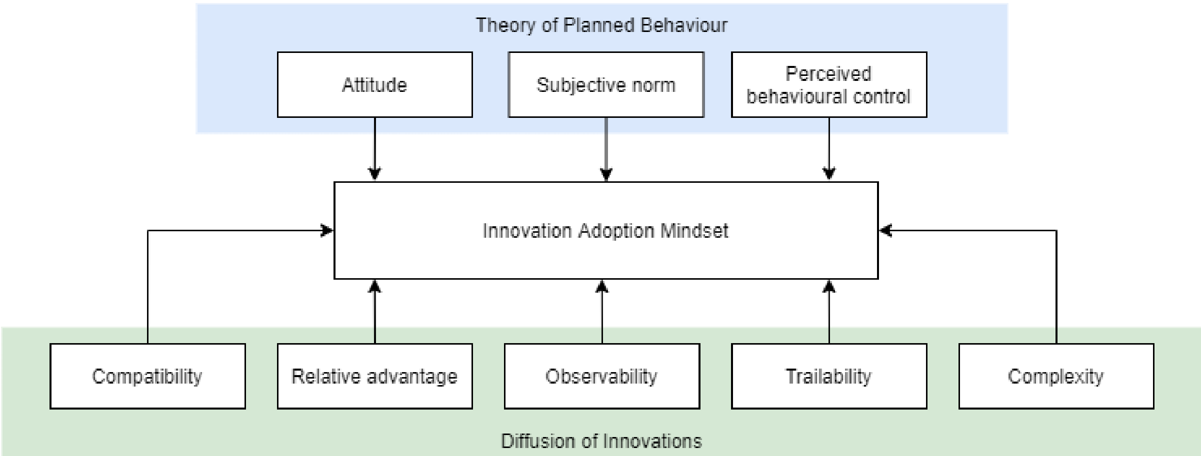

Figure 2. Innovation Adoption mindset model

Adapted from Weigel, F. K., Hazen, B. T., Cegielski, C. G., & Hall, D. J. (2014). Diffusion of innovations and the theory of planned behaviour in information systems research: a meta-analysis. Communications of the Association for Information Systems, 34.

As the construct of complexity, which is a factor in Rogers' diffusion of innovations, is the only construct negatively related to the intention to adopt, the trait was transformed to represent simplicity in some instances. Simplicity is the opposite of complexity (Rogers, 2003). Transforming the construct of complexity into a positive related trait causes equal comparison opportunities as all the other constructs are also positively defined. The models of the theory of planned behaviour and the diffusion of innovations are described in more detail in the literature review.

2.4 SURVEY

2.4.1 Survey participants

In this study, the supply chain has been divided into consecutive stages. The following list shows a summary of the various stages and their main cooperatives in the Netherlands:

- Primary producer (1)
    - VisNed
    - Coöperatieve Visserij Organisatie
    - Nederlandse Vissersbond

- Producer (2)
    - De Visfederatie
- Wholesale (3)
    - De Visfederatie
    - Nationaal Overleg Visafslagen
- Retail (4)
    - Centraal Bureau Levensmiddelenhandel

The listed cooperatives were contacted and asked to distribute the link to the survey to their members. If the cooperative was not responsive to the request, e-mails of the relevant businesses were manually procured through thorough scanning of the internet. A complete overview of communication towards (potential) participants, including e-mail, survey preface and the questions themselves is presented in Appendix A. Businesses in small scale fisheries category where omitted from the survey as their main mode of catching is with rod or standing rigging or traps, which has a very low catch volume compared to cutter fishing (Mol, 2019c). The total population of companies in the Dutch seafood sector are presented in Table 1.

Table 1. Registered number of companies per supply chain link in The Netherlands

Supply chain links	Number of companies in chain
(1) Cutter Fisheries	236*
(1) Fish farms	50**
(2) Fish and/or shellfish processing plants	125***
(3) Fish auction houses	35***
(3) Fish wholesalers	515***
(4) Fish specialty shops	625***
(4) Supermarkets	3270***
Total	4856

* (Mol, 2019a)
** (NVWA, 2017b)
*** (CBS, 2019)

2.4.2 The case for using a 5-point Likert scale

The attitude to the various constructs was measured using a 5-point Likert scale. A 5-point scale has the advantage over 2- and 3-point Likert-type scales as it allows for the intensity of the statement to be determined. The original 5-point format also yields better quality results than 7-point or more Likert-type scales (Revilla, Saris, & Krosnick, 2014).

2.4.3 Data analysis

For all Likert items the original 5-point scales were used, being: ‘’Strongly agree,’’ ‘’Agree,’’ ‘’Neither agree, nor disagree,’’ ‘’Disagree,’’ ‘’Strongly disagree’’. The 5-point scale of every Likert item in the questionnaire was numerically scored from 2 for ‘’strongly agree’’ to -2 for ‘’strongly disagree’’. As such, ‘’neither agree, nor disagree’’, was numerically presented by a zero.

Likert scales were formed by combining and averaging all numeric scores given to the Likert items belonging to a construct. This resulted in a Likert scale score for every participant ranging from -2 to +2. The main response variable of this study was the willingness to adopt blockchain traceability. The answer categories to this question were: ‘’Yes’’ and ‘’No’’, numerically presented by 1 or 0, respectively. As the dependent variable is on a dichotomous scale, binomial logistic regression was used to identify the probability that a respondent would or would not like to adopt blockchain traceability based on the respondent's answers to the constructs. The constructs, i.e., the Likert items grouped by behavioural factor, were mainly used as independent factors, and were treated as interval data. In addition to the constructs, the respondent's self-reported blockchain knowledge was also used to predict the willingness to adopt using binomial logistic regression. The possible responses: ''Extensive'', ''Some'', and ''No'' were treated as ordinal data.

2.5 STATISTICAL ANALYSIS

The significance level of all performed statistical tests was set at α=0.05. Data analysis was performed using IBM SPSS 26.

2.5.1 Interpreting Likert scales using parametric statistics rationale

The statistical treatment of Likert scales have been a long-standing controversial topic in scientific debate (Knapp, 1990) (Carifio & Perla, 2008). There is no current consensus on whether Likert scales solely produce ordinal data or if the data may also be treated as interval data. In other words, there is no generally agreed view on whether Likert scales produce answers were only the order matters (ordinal), or if the difference between the data points can also be measured (interval). This distinction is important as opting for interval data would allow for use of more powerful parametric tests (Allen & Seaman, 2007). Several researchers have shown that combining several ordinal data points can produce good interval data (Allen & Seaman, 2007) (Boone & Boone, 2012) (Carifio & Perla, 2008) (Sullivan & Artino, 2013). In this study, the Likert scales were treated as interval data. In the words of Norman (2010): ''Parametric statistics can be used with Likert data, with small sample sizes, with unequal variances, and with non-normal distributions, with no fear of coming to the wrong conclusion''.

However the statistical treatment of a single Likert items was achieved through non-parametric tests as the data from a single item are commonly accepted as being ordinal (Carifio & Perla, 2008) (Boone & Boone, 2012).

2.5.2 Parametric tests

2.5.2.1 Research question 2

User satisfaction with the currently employed traceability system was collected and rated on a five-point scale between -2 and +2. Subsequently, the satisfaction scores were compared for the different type of traceability systems. To test for significant satisfaction differences a one-way ANOVA was performed. To check if the assumption of homogeneity of variances was not violated Levene's test for homogeneity of variance was conducted. Significant outcomes of the ANOVA test were followed up with a Post-Hoc analysis.

- If homogeneity violated: Welch's ANOVA
    - Post-Hoc equal sample sizes: Games-Howell
    - Post-Hoc unequal sample sizes: Games-Howell
- If homogeneity correctly assumed: traditional Fisher's ANOVA test
    - Post-Hoc equal sample sizes: Tukey
    - Post-Hoc unequal sample sizes: Hochberg's GT2

2.5.2.2 Research question 3

To test if the average response value of a construct (interval variable) is influenced by whether or not participants in the survey indicated the willingness to adopt (nominal variable) an independent samples t-test was used. For the constructs that violated the assumption of homogeneity of variance the Welch's t-test was used.

2.5.3 Non-parametric tests

2.5.3.1 Research question 2

Research question 2 was evaluated using question 3 of the survey : '' What characterizes your company's current traceability system?'' and question 4 of the survey: '' How satisfied are you with your company's current traceability system?' To analyse if differences in used traceability system exist, based on what level of the supply chain the company functions at (both nominal data), Fisher's Exact Test was performed. This this is more appropriate for small sample sizes than the Chi-square Test.

2.5.3.2 Research question 3

Fisher's exact test was conducted to test for a relationship between intention to adopt blockchain traceability and the different level of supply chain links discerned (both nominal data).

2.5.4 Validity

Construct validity

Because the composed questionnaire has not been field tested before, statistically testing the validity of the composed constructs is of importance, as the survey must be reliable and valid for the study results to be credible (Sullivan, 2011).

To check the validity of the questionnaire, exploratory factor analysis was used. Exploratory factor analysis can be used to test how many factors are in play. Ideally, this should be the same as the number of constructs in the model. Subsequently, it tests if Likert items that are grouped in the survey also get grouped in the same factor. Exploratory factor analysis was deemed appropriate especially since the Likert items in this study have been partly procured from other studies on a similar subject and have been translated. To check if the collected data is fitting for exploratory factor analysis the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO-test) was used. A KMO value lower than 0.5 would indicate that the dataset would be unsuitable for factor analysis (Field, 2018). Factor extraction is set at the Kaiser's criterions eigenvalue of greater than 1. The results of the Kaiser's criterion extraction will be tested by determining the point of inflexion in a scree plot. Only data points above the point of inflexion are meaningful factors (Field, 2018).

Additionally, theory suggests that more thorough validity evidence can be obtained using confirmatory factor analysis. However, confirmatory factor analysis should not be performed on the same data as the exploratory factor analysis has been performed on (Knekta, Runyon, & Eddy, 2019). As the questionnaire was only conducted once, no confirmatory factor analysis was performed.

2.5.5 Testing for reliability: Cronbach alpha

To check if the Likert items that are grouped together to measure a construct are consistent with each other Cronbach's alpha was calculated. Calculating Cronbach's alpha is common practice to test if the Likert items are sufficiently intercorrelated to combine them together into a Likert scale (Sullivan & Artino, 2013). For this purpose four to six Likert items were combined into one scale, the amount of items per construct were limited to six as a higher number of items may inflate the alpha score (Hinkin, Tracy, & Enz, 1997).

To calculate Cronbach's alpha, a sample size greater than 30 is required. For psychological constructs an alpha score greater than 0.7 is acceptable (Samuels, 2015), while a score of 0.8 should be considered a reasonable goal (Gliem & Gliem, 2003). A Cronbach alpha score was calculated separately for each of the eight constructs.

2.5.6 Pearson correlation

To test the strength of association between the constructs of relative advantage, observability, trialability, complexity, compatibility, attitude towards the behaviour, subjective norm, perceived behavioural control, and the variable of the willingness to adopt blockchain traceability Pearson's correlation coefficient was calculated. Constructs with a significant correlation to the willingness to adopt were later used in a binomial logistic regression analysis.

2.5.7 Binomial logistic regression

Binomial logistic regression analysis was employed to predict the outcome of the dependent variable, which is the willingness to adopt, using multiple independent variables in the form of the composed constructs. Three different models to predict the willingness to adopt were examined: Individual scores of all eight construct scores of the innovation adoption mindset model, individual scores of all Pearson correlated constructs, self-reported Blockchain knowledge of survey participants.

Peduzzi's et al. guidelines were employed to determine the number of covariates that could be appropriately included in the analysis, in relation to the sample size. In the work of Peduzzi et al. the following sample size guideline was introduced; [N = 10 k / p] wherein p represents the smallest proportion of the dependent variable and k the number of covariates to be included (Peduzzi, Concato, Kemper, Holford, & Feinstein, 1996). When the guideline indicated the sample size as inadequate, constructs were combined until conditions were satisfied.

The capacity of binomial logistic regression models to explain for the variance in the willingness to adopt was explored using Nagelkerke $R^{2.}$ The goodness of fit of the model to the data was subsequently explored using Hosmer and Lemeshow.

2.5.8 Hurvich and Tsai's criterion (AICc)

Multiple different binomial logistic regression models were analysed. To select the best model to predict the willingness to adopt blockchain traceability, the Hurvich and Tsai's criterion (AICc) was used. AICc is a goodness of fit measure that is based on Akaike Information Criterion but is more suitable for small sample sizes. The model with the smaller AICc value better fits the data (Field, 2018). In the AICc equation, k represents the number of parameters and n the number of observations.

$$AICc = -2LogLikelihood + 2k + (2k(k+1))/(n-k-1)$$

2.6 LIMITATIONS OF RESEARCH DESIGN

The survey mainly consisted of Likert items. Answers to Likert items are known to be susceptible to distortion by several factors. These factors include the inclination to agree with statements, also known as the acquiescence bias (Nadler, Weston, & Voyles, 2014). The effects of this bias have been party negated by formulating 20% of the questions in a negative way. This is not a balanced proportion of positively and negatively formulated items, which might be required to fully negate the bias (Hinz, Michalski, Schwartz, & Herzberg, 2007). Another likely occurrence is the central tendency bias, this effect is caused by respondents avoiding to answer on the extreme edges of a Likert scale (Nadler, Weston, & Voyles, 2014).

Under ideal conditions a new survey is first tested for reliability and validity by employing the survey to some individuals of intended population before being used to sample the remainder of the intended population. Due to time constraints it was decided to use the survey to sample the population directly. Pretesting frequently reveals flaws in that were not apparent to the researcher.

This could for example have caused questions to have been interpreted differently by the respondents than was intended. To possibly negate negative effects of the lack of pretesting it was decided to adapt survey questions from other studies that had validated their instrument. The survey in this study, excluding demographical questions, consists of 38 items. Of these items 9 were drafted for the purpose of this study without the use of reference material. The other 29 questions were adapted from other studies (see appendix A). The fit of the 29 referenced questions for use in the questionnaire of this study could not be further validated as individual results of the referenced studies were not acquired.

Before conducting the questionnaire, no information was available that indicated the degree of knowledge the respondents might have about blockchain traceability. To negate the risk that most respondents lacked any knowledge about what blockchain traceability entails, basic information about the system was included before the start of the survey. This method might be considered flawed as respondents could have been influenced by the information they have been given. However, it seemed suitable to provide respondents that had no previous knowledge about the topic at least some insight into the matter.

3 LITERATURE REVIEW

3.1 BLOCKCHAIN

Blockchain technology is still in its infancy (Murphy & Stafford, 2018) and currently has a low adoption rate among the food industry. Several different use cases for the technology are still being explored. Yet, enthusiasm for the technology is strong. Some see blockchain as the biggest invention since the internet and electricity (Metry, 2017) and say that it will have a big influence in the years to come (Webb, 2015). Blockchain technology is coined a potentially disruptive technology in information exchange which requires authentication and trust (Yli-Hummo, Ko, Choi, Park, & Smolander, 2016). A survey conducted by the World Economic Forum under more than 800 executives and experts in the computer technology sector said blockchain technology to be among six computing 'megatrends' that are likely to reach a tipping point within next decade (World Economic Forum, 2015).

A certain base level understanding of the blockchain mechanics are important fully grasp its potential use in food traceability. This chapter will define the key technological properties of blockchain technology and assess these properties to explore its possible advantages and disadvantages. While there are more than two dozen different blockchain protocols available today (Tecsynt Solutions, 2018), none of them is as commonly accepted as the original. Nakamoto's original blockchain, called the Bitcoin blockchain, will be used in this chapter to describe the theory of blockchain technology in more detail. While the Bitcoin blockchain is the most widely recognised example of a blockchain, blockchains can operate without the need of a cryptocurrency (Greenspan, 2015).

3.1.1 Distributed ledger technology

Blockchain technology, also commonly referred to as distributed ledger technology, is based on shared access to a record keeping system without the need for a third party. With the advent of blockchain technology the first trusted environment for distributed computing was created that did not need a mediator (Christidis & Devetsikiotis, 2016) (Olnes, Ubacht, & Janssen, 2017). Blockchain technology did so by solving the double-spending problem that was previously associated with digital tokens (Valkenburg, 2016). Before solving this issue, the tokens, that consist of a regular digital file, used to be as easily manipulated or duplicated as a regular computer file (Jha, 2017). By preventing unwanted manipulation, the distributed ledger technology enables supply chain parties to interact with each other without the need for mutual trust (Christidis & Devetsikiotis, 2016).

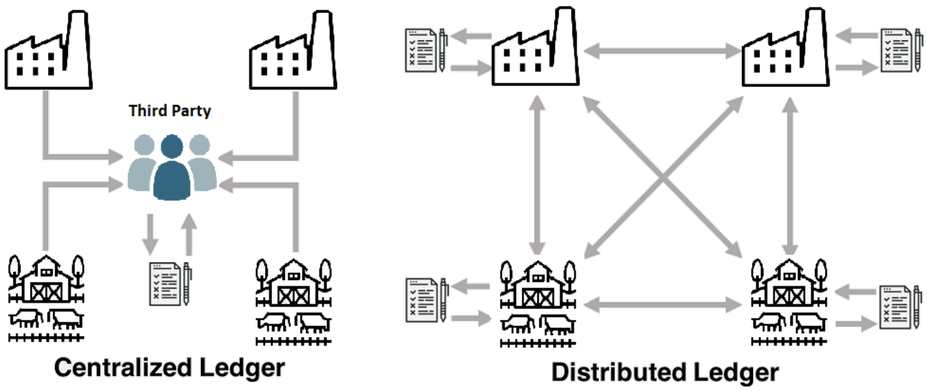

Figure 3. Centralized ledger vs Distributed ledger

Distributed ledger technology has become synonymous for blockchain technology because of the technologies three main traits (Figure 3). First, transactions take place directly between actors instead of via a trusted third party. Second, transactions are confirmed by the actors themselves instead of by a third party. Lastly, an up-to-date ledger of all confirmed transactions is in possession of all actors in the system instead of in one central database. These qualities make distributed ledger technology fundamentally different from the traditional structure (Allessie, 2017).

3.1.2 Blocks in a chain

As previously discussed, the Bitcoin blockchain created an entirely new way of data exchange between computer systems. This section will go into the details of how this new form of data storage functions.

The name blockchain is a suitable considering how the technology operates. The term refers to the way how information is saved, namely by packaging them into blocks. These blocks are then linked together, forming a chain of blocks (Christidis & Devetsikiotis, 2016). Blocks are essentially tiny snippets of information that are bundled together. In the Bitcoin blockchain these bundles can reach a maximum of 4 megabytes. A 4-megabyte block allows for a maximum of 27 transactions per second to take place. It takes about 10 minutes to form one block (Croman, et al., 2016).

The procedure of adding a new block to the blockchain is referred to as mining. Miners, people who try to create new blocks, do so because the Bitcoin blockchain rewards them if they succeed by granting them the transaction fee paid for by the users of the transactions that are included in the block, as well as a set of newly minted Bitcoins (Eyal & Sirer, 2018). When a user sends information to the blockchain it is not added to a block instantaneously. Instead, it is added to the transaction pool. This pool consists of all data sent to the blockchain that is not yet incorporated into a block. Miners bundle this data together into a candidate block. The candidate block is then described using metadata, which is information used to describe the data within the block. The miner then adds a nonce to the metadata. A nonce is a number that is varied each time by the miner as it tries to add a block to the blockchain. The metadata and nonce is subsequently run through a hash function. Lastly, the result of the hashed metadata is compared to a target value. When the calculated hashed metadata is lower than the target value the candidate block is accepted and added to the blockchain. When the calculated value is higher than the target value, the process repeats again only this time with a different nonce value. Differentiating the nonce value will result in a different result for the hashed metadata (Chaudhary, Fehnker, Pol, & Stoelinga, 2015). Solving the required nonce value is thus the key to publish a new block on the blockchain.

To achieve an average block time of 10 minutes, regardless of how many miners try to solve for the nonce, a difficulty factor is included which makes getting below the target value easier or harder depending on the average solve time of the previous 2016 blocks (Chaudhary, Fehnker, Pol, & Stoelinga, 2015).

Once information is stored in a block, the information in this block cannot be modified without changing vital data in every block created ever since. This feature, which makes blockchain principles so secure, is the result of a unique cryptographic key, also called a hash, imbedded in every block. To create such an identifying key all information from the previous block is put into a formula to establish the new identifying key (Drescher, 2017) (Figure 4). The necessary interaction between blocks makes them dependent of each other, essentially creating a chain.

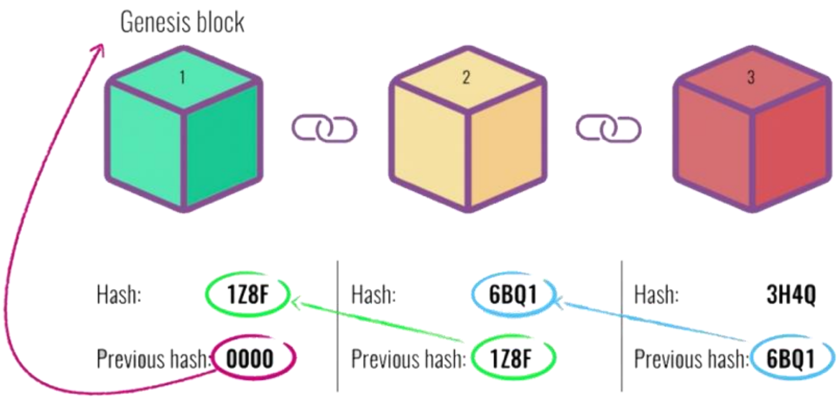

Figure 4. Linking of blocks in a blockchain
(Untitled illustration of a blockchain. Retrieved April 11, 2019 from https://medium.com/predict/hashes-are-unique-9af14fe3796a)

A blockchain operates using a peer-to-peer network. As the name implies, peers are equally privileged participants of a network who distribute the workload among themselves instead of to a central server. In jargon these individual peers are called nodes. Each node is made up of one single computing unit who receives input from other peers. The node then processes this information before distributing it to other nodes on the network.

3.1.3 Permissionless and permissioned blockchains

While the Bitcoin blockchain is the most widely recognised example of a blockchain (Greenspan, 2015), some of the characteristics of the Bitcoin protocol are not suitable for use in the food industry. For example, anyone can anonymously (Xu, et al., 2016) join the Bitcoin blockchain, make transactions on it and read all existing data (Zhang & Lin, 2018). These traits are seen as undesirable in the industry (Hendrix Genetics, 2018). As such, for blockchain technology to be employable in the food industry several key adjustments are required. For one, access to the network should be exclusive to trusted entities simply because enterprises do not want sensitive information visible to everyone. Even among the trusted entities access to sensitive information should be limited and role-based (Hendrix Genetics, 2018). To make the blockchain protocol useful for things other than currency transfer, several variations have been developed.

Generally, two different classifications can be distinguished: permissionless blockchains and permissioned blockchains. With permissioned blockchains being split in private blockchain and consortium blockchain (Zhang & Lin, 2018). The Bitcoin blockchain is an example of a permissionless blockchain. As the name suggest anyone can join this network anonymously without any set condition or need for permission. Entities on a permissionless blockchain can perform all available actions on the network. On a permission blockchain only registered entities are allowed to operate. Consortium blockchains operate with multiple different external stakeholders, whereas private blockchains are operated within one single trust domain, i.e. within one company (Cachin & Vukolic, 2017)

3.2 Traceability

A typical supply chain (Figure 5) is a network of various entities in which materials move downstream from supplier to the end customer (Slack, Brandon-Jones, & Johnston, 2013). Subsequently, information and financial means make their way from the consumer to the supplier in an upstream fashion. The flow of Information is regarded as equally important for both ends of the supply chain (Seungjin, 2000).

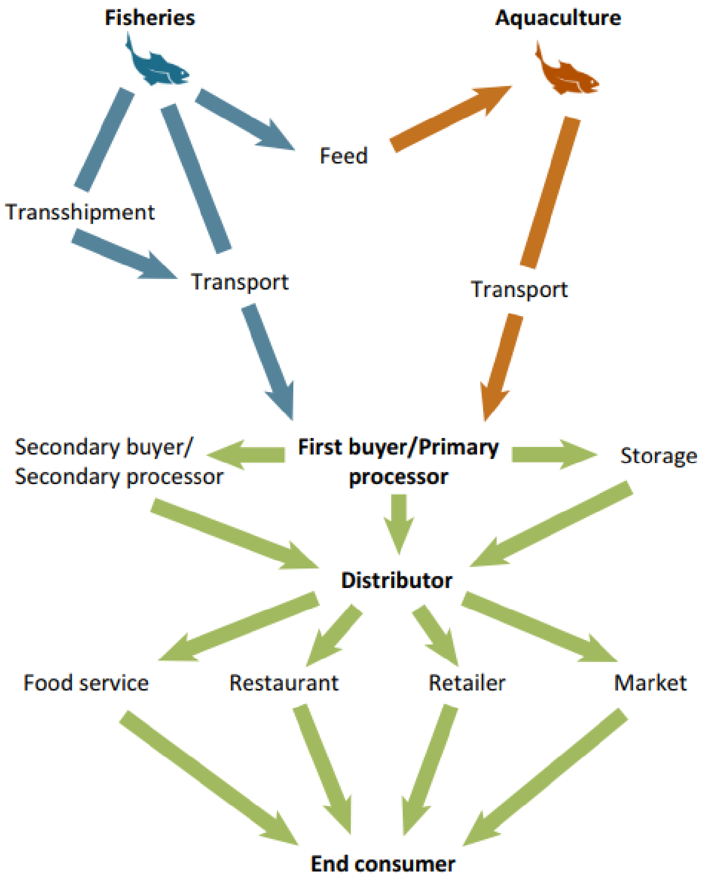

Figure 5. A generic seafood supply chain
Note. Reprinted from "Seafood traceability: current needs, available tools, and biotechnological challenges for origin certification.", by Leal, Pimentel, Ricardo, Rosa & Calado, 2015, *Trends in biotechnology*, *Volume 33, Issue 6*, p. 331-336. Doi: 10.1016/j.tibtech.2015.03.003

The flow of information plays a vital part in any food traceability system. For traceability to be viable all chain participants, but also stakeholders like the government, need a procedure in place to establish a means of information exchange (Trienekens & Van der Vorst, 2006). The outcome of a reliable traceability system is accurate information about the origins of an item by backwards tracing, and information about the current location of the item by forward tracking (Luning & Marcelis, 2009).

Two traceability categories can be distinguished:

- External traceability: must ensure link management and correct information exchange between the links of the supply chain. This is the basic level of traceability the fish industry must uphold (Nguyen, 2004).
- Internal traceability: secures link management and information exchange for every traceable unit used during each step from raw material to final product within one processing plant (Nguyen, 2004).

The strict function of a traceability system is limited to tracking and tracing items with the sole purpose of recalling them because of quality or safety issues. The basic elements are (Goulding, 2016):

- Documenting incoming foodstuffs and their origin.
- Documenting information on processes linked to these items or batches throughout the processing and storage stages.
- Documenting outgoing items and their destinations.

3.2.1 Traceability requirements of seafood

The European Union has special requirements for seafood traceability. Article 58 of EC 1224/2009 reinforces the requirements set in Article 18 of Regulation 178/2002 and states that all lots of fisheries and aquaculture products should be traceable at all stages of production; from catching or harvesting to processing, distribution, and retail.

The entities who are to ensure that seafood is traceable at all these stages are so called ‘’food business operators’’ (Regulation No 178/2002 - Article 18(2,3)). In accordance with the Regulation these entities are those who imported, produced, processed, manufactured or distributed food. Or those who undertake retail or distribution activities which do not affect the packaging, labelling, safety or integrity of the food or feed (Regulation No 178/2002 - Article 19(1,2)).

Food business operators must be able to identify their immediate suppliers and customers. Additionally, they should have a system in place to withdraw/recall unsafe products (Regulation No 178/2002 - Article 18(2,3)). The EU legislation does not dictate what method must be used to adhere to the traceability requirements. Neither does the legislation obligate the use of an internal traceability system.

With the advent of legislation number 1224/2009, which established a community wide control system to ensure compliance with the rules of the common fisheries policy, every link from fisheries to retail must possess the same information in their traceability system (Table 2). All the information presented in Table 2 must be attached to all lots of fishery products by means of labelling, packaging or by a document physically accompanying the lot. The information may also be added by code, barcode, electronic chip or a similar device (Regulation No 404/2011 - Article 67 (5). A lot is defined as “a batch of sales units of a foodstuff produced, manufactured or packaged under practically the same conditions” (Directive 89/396 – Article 1(2)).

Table 2. information required to be tracked along the entire fish supply chain

Legally required information present in a traceability system	Legislative reference
1. The identification number of each lot	1224/2009 Article 58, 5 (a)
2. The external identification number and name of the fishing vessel or the name of the aquaculture production unit;	1224/2009 Article 58, 5 (b)
3. The FAO alpha-3 code of each species	1224/2009 Article 58, 5 (c)
4. The date of catches or the date of production	1224/2009 Article 58, 5 (d)
5. The quantities of each species in kilograms expressed in net weight or, where appropriate, the number of individuals	1224/2009 Article 58, 5 (e)
6. Operators must be able to identify their immediate supplier, and their immediate buyer, except if they are the final consumer	1224/2009; Article 58, 4
7. The commercial designation of the species and its scientific name;	1379/2013 Article 35,1 (a)
8. The production method, in particular by the following words “… caught …” or “ … caught in freshwater…” or “ farmed…”	1379/2013 Article 35,1 (b)

9. The area where the product was caught or farmed, and the category of fishing gear used in capture of fisheries as laid down in the first column on Annex III to this regulation;	1379/2013 Article 35,1 (c)
10. Whether the product has been defrosted	1379/2013 Article 35,1 (d)
11. The date of minimum durability, where appropriate	1379/2013 Article 35,1 (e)

For sale to the final consumer additional information must be provided (Table 3).

Table 3. Legally required Information for any sale to the final consumer

Legal minimum of the information to be provided to the consumer	Legislative reference
1. The commercial name of the food	1169/2011 Article 9, 1 (a)
2. The list of ingredients	1169/2011 Article 9, 1 (b)
3. Any ingredient or processing aid listed in Annex II or derived from substances listed in Annex II causing allergies or intolerances used in the manufacture or preparation of a food and is still present in the finished product	1169/2011 Article 9, 1 (c)
4. The quantity of certain ingredients or categories of ingredients	1169/2011 Article 9, 1 (d)
5. The net quantity	1169/2011 Article 9, 1 (e)
6. Date of minimum durability or the 'use by date'(note could already be covered as per above)	1169/2011 Article 9, 1 (f)
7. Any special storage conditions and/or conditions of use	1169/2011 Article 9, 1 (g)
8. the name or business name and address of the food business operator referred to in Article 8 (1) (the importer or EU company marketing the product)	1169/2011 Article 9, 1 (h)
9. The country of origin or place of provenance where provided for in Article 26 (i.e product of PNG)	1169/2011 Article 9, 1 (i)
10. the instruction for use where it would be difficult to make appropriate use of the food in the absence of such instructions	1169/2011 Article 9, 1 (j)
11. A nutrition declaration	1169/2011 Article 9, 1 (l)
12. The date of freezing or the date of first freezing in cases where the product has been frozen more than once.	1169/2011 Annex III

In addition to the mandatory information retailers may also provide additional information on a voluntary basis such as the port at which the products were landed or more detailed information about the fishing gear used (EC 1379/2013 Article 39).

3.2.2 Electronic recording and reporting system (ERS)

To combat illegal fishing the EU has implemented new legislation in the form of regulation 1224/2009. This regulation obliges fishing ships that are longer than 10 metres to keep a logbook of their activities (1224/2009, article 14).

Food business operators responsible for the first marketing of fisheries products have to electronically record the information referred to below and have to electronically send this information within 24 hours to the competent authorities of the Member State (EC 1224/2009 Article 67 (1)). Food business operators with a turnover lower than EUR 200 000, have to submit, if possible electronically, within 48 hours after the sale (EC 1224/2009 Article 62 (1)):

1. the external identification number and the name of the fishing vessel that has landed the product concerned;
2. the port and date of landing;
3. the name of the fishing vessel's operator or master and, if different, the name of the seller;

4. the name of the buyer and its VAT number, its tax identification number, or other unique identifier;
5. the FAO alpha-3 code of each species and the relevant geographical area in which the catches were taken;
6. the quantities of each species in kilograms in product weight, broken down by type of product presentation or, where appropriate, the number of individuals;
7. for all products subject to marketing standards, as appropriate, the individual size or weight, grade, presentation and freshness;
8. where appropriate, the destination of products withdrawn from the market (carry-over, use for animal feed, for production of meal for animal feed, for bait or for non-food purposes);
9. the place and the date of the sale;
10. where possible, the reference number and date of invoice and, where appropriate, the sales contract;
11. where applicable, reference to the take-over declaration referred to in Article 66 or the transport document referred to in Article 68;
12. the price.

As of October 1st 2017, The Netherlands goes beyond the legislative requirements of the European Union by also demanding the use of a digital logbook for vessels smaller than 10 meters. This additional requirement causes all fishing vessels that are registered in the Dutch Register of Fishing Vessels (Nederlands Register van Vissersvaartuigen) to report using the digital E-lite logbook, which replaces the paper logbook (Rijksdienst voor Ondernemend Nederland, 2016). Catch statements are only reported to the competent authorities and must be regarded separately from any food traceability obligations.

3.3 Benefits associated with an innovation, and the willingness to adopt

Human factors play a significant role in successful introduction of new initiatives. A strong relationship between the stakeholders, such as the ICT-supplier, users and management, are critical for a successful implementation of blockchain traceability. Hendrix Genetics, a Dutch company in the animal breeding business, experienced setting up a blockchain traceability system in their supply chain to be 90% social and 10% technical (Hendrix Genetics, 2018). According to Kevin McMahon ‘’The technology part isn't really all that difficult … the real challenge is building out that network – finding people who want to participate and want to share data amongst themselves and are committed to maintaining the infrastructure necessary." (Mearian, 2019). Enthusiasm to implement new innovations are key to success as it affects all other elements in of the adoption process (Karlsen, Sørensen, Forås, & Olsen, 2011).

The drive for advancement in food traceability practices can be categorized by a desire for increased capacity to control quality, food safety, inventory control or to meet regulatory and market requirements (Wang & Li, 2006). Other catalysts can be more for sophisticated recall systems, improved process control, potential to optimize the production process or government requirements (Moe, 1998).

Two models have been explored to better understand the impact of behavioural motivation on the willingness to adopt blockchain traceability systems in the Dutch fish industry.

3.3.1 Theory of planned behaviour

The theory of planned behaviour (TPB) has proven to be a solid indicator for intention in a large array of research areas (Ham, Pap, & Stimac, 2018) (Ajzen, 2005). Based on this theoretical framework the attitudes of members of the fish supply chain towards adopting blockchain technology where evaluated.

The principle of TPB assumes that humans act in a rational manner. Implying that all available information is considered and one has contemplated the implication of the possible actions (Ajzen, 2005). For an individual to possess a certain intent and show subsequent behaviour, the TPB assumes three characteristics to be of equal importance (Figure 6). The attitude of an individual towards a certain behaviour can be positive or negative. It is seen as a determinant in intent and behaviour that relies heavily on personal nature. The perception of external social pressure also influences behaviour and is termed in the model as the subjective norm. The last characteristic deals with the individual's ability to perform the behaviour and self-efficacy, it is termed perceived behavioural control. Thus, the model assumes that individuals intend to act in a certain way when have a positive attitude towards the behaviour, experience social pressure and believe they have the capacity to act on the intention (Ajzen, 2005).

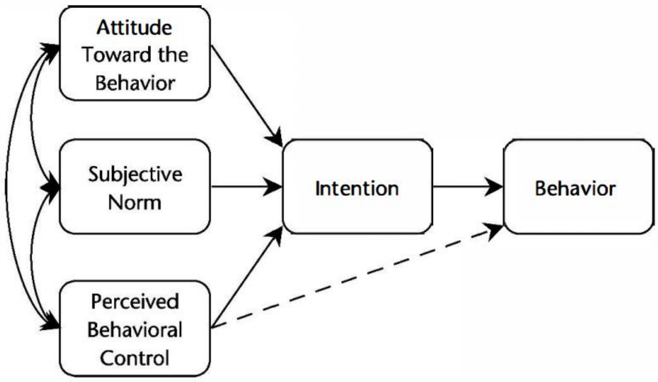

Figure 6. The theory of planned behaviour
Note. Reprinted from "Attitudes, Personality and Behaviour*", by Ajzen, 2005, p.118, New York: Open University Press.*

This study will particularly look at the intention to adopt blockchain technology and will not perform a follow up check if the intension was acted upon. The fit of the chosen model to predict future behaviour will not be verifiable and thus solely relies on its extensive successful use in in a large array of research areas. However, the model does make a good fit to determine the motives that drive the willingness to adopt blockchain technology.

3.3.2 Diffusion of innovations

The willingness to adopt refers to the motivation to embrace a different innovation, technology, and/or practice than currently in use (Anderson, 1993). In this study the willingness of companies to innovate plays a central role. Extensive research exists on the adoption process of a new innovation, one of the most famous theories is the *diffusion of innovations* by Rogers (Sherry & Gibson, 2002).

The adoption of an innovation is characterised by four key elements. Rogers describes the process as follows; '' *Diffusion* is the process by which an *innovation* is *communicated* through certain *channels* over *time* among the members of a *social system.''* (Rogers, 2003).

3.3.2.1 The element of innovation

According to Rogers, innovations can frequently be described as to possessing one or two components: the hardware aspect which embodies a physical object and/or a software part which retains information. According to Rogers, innovations that only consist of a software component possess a slower rate of adoption than other innovations because the results of a software only innovation are more difficult to spot for others. The observability of an innovation is one of the five characteristics that individuals can discern which Rogers theory uses to evaluate the different rates of adoption. Other characteristics are trialability, relative advantage, complexity, and compatibility. The characteristics are explained as followed (Rogers, 2003):

1. Observability describes how visible the results gained from usage of an innovation are to others. The easier it is to visually witness the effects, the more likely the adoption of the technology will become. Visibility is a trigger to discussion, as peers of an adopter are more likely to inquire information if the results are clear to see.

2. Trialability describes the extent a new technology can be tested before adopting it. The ability to run trials with a new technology will reduce the uncertainty the adopter has in the new technology which will generally lead to a swifter adoption.

3. Relative advantage explains the perceived benefits of the innovation in comparison over the other options. The perceived benefits can have a wide scope, from financial gain to convenience and social prestige. The more significant an individual perceives the relative advantage of an innovation the quicker its adoption will be.

4. Complexity explains how the different levels of difficulty that new innovations possess has influence on their rate of adoption. Innovations which are perceived to be difficult to learn and use are adopted slower.

5. Compatibility explains the fit of an innovation in an existing social and technological environment. If an innovation fits well within the needs, existing values, and past experiences of a social system its adoption rate will be higher than when its incompatible with some of these values.

3.4 IDENTIFYING ADVANTAGES AND DISADVANTAGES OF BLOCKCHAIN TRACEABILITY

Next to adhering to the strict functions a traceability systems must possess, it can also be employed in a broader perspective wherein it is used to control and optimize processes on a company or chain level (Trienekens & Van der Vorst, 2006). To better understand the pillars that could potentially give incentive to adopt blockchain traceability, several key characteristics of paper, digital and blockchain traceability systems are reviewed.

3.4.1 Relative advantage and the six supply chain objectives

According to literature the functioning of a supply chain can be described by several key characteristics such as quality, costs, speed, dependability and flexibility (White G. , 1996) (Slack, Brandon-Jones, & Johnston, 2013). With growing concerns about the environment a sixth characteristic has also been discussed in the form of sustainability (Rao & Holt, 2005) (Aref, Helms, & Sarkis, 2005). Quality means the conformance to the expectation of the customer by having the ability to keep processes free of errors. In supply chain management speed is described as the pace at which goods and services are delivered. Dependability means delivering good or services at the time they are needed. Flexibility means being able to change a process in some ways. To companies that compete on price the costs of the implemented system will be of major influence. Sustainability is the objective that focuses on the possible social or environmental ramifications of system processes (Slack, Brandon-Jones, & Johnston, 2013).

As explained in chapter *2.3.1*, Rogers identified five key components that drive the willingness to adopt new innovations: relative advantage, complexity, observability, compatibility and trialability. To assess the compatibility of blockchain technology for use as traceability system in the Dutch fish sector, its relative advantage in comparison to the current systems must be evaluated. The outcome of the relative advantage comparison is presented in the next paragraphs. The outcome of this evaluation may also be used to argue why blockchain technology might be chosen over current traceability systems. Further on in this chapter the compatibility, complexity, observability and trialability will also be discussed.

According to Rogers two of the five key components have the most influence on the willingness to adopt, these are the relative advantage the new innovation has over the other options, and the compatibility with the current work environment (Rogers, 2003). These two components will be described in more detail than the others.

3.4.1.1 Relative advantage: Quality

Table 4 presents some characteristics of traceability systems in regards to keeping processes free of errors.

Table 4. Blockchains relative advantage concerning quality

Relative advantage	Case
Unchangeable ledger	Blockchain ledger entries cannot be changed or removed (Peters & Panayi, 2015; Crosby, Nachiappan Pattanayak, Verma, & Kalyanaraman, 2016). Paper traceability systems and current IT systems are known to suffer from alteration, corruption and loss of stored data (Ge, Brewster, Spek, Smeenk, & Top, 2017). However, blockchains are vulnerable 51% attacks where an attacker owns more than half the computing power of the network. The attacker would be able to manipulate the blockchain information from the point of the attack onwards (Li, Jiang, Chen, Luo, & Wen, 2017). No such incident has been recorded on a private blockchain.
Improved traceability	In paper-based traceability systems the downside of written documents is human error, no quick sifting of information and slow track and tracing. Current IT-systems are not connected throughout the supply chain (Galvez, Mejuto, & Simal-Gandara, 2018). Data put on the blockchain is saved almost instantly. Once stored, the information can be requested by all those who have access (Nakamoto, 2008). This enables pinpointing the location of a product in near real time. Generally, every link in the chain stores its own product information. This causes limited access to important data and makes it hard to establish a trustworthy overview of a supply chain. Blockchain traceability systems allow for monitoring of the supply chain, which would ensure better safety and quality products for the consumer (Montecchi, Plangger, & Etter, 2019). Blockchain traceability systems may have the edge over legacy systems as it has the enhanced ability to provide provenance by providing the

	framework required to effectively create, save, and manage product data (Casey & Wong, 2017).
High transparency	Current paper and IT systems have at times exacerbated the low levels of transparency and trust in agri-food chains (Ge, Brewster, Spek, Smeenk, & Top, 2017). Furthermore, other stakeholders such as the government and consumers are demanding transparency in their supply chain (Trienekens, Wognum, Beulens, & van der Vorst, 2012). With blockchain it is possible to give regulatory and third-party certification bodies access to oversee all transaction details in real-time (Shrier, Iarossi, Sharma, & Pentland, 2016). Blockchain traceability systems are a step up from many existing systems in its transparency and security (Abeyratne & Monfared, 2016). Being able to open traceability data can generate favourable business circumstances (Svensson, 2009). Transparency can lead to a positive reputation (Carter & Rodgers, 2008). Every transaction can be made visible to other links in the chain (Deloitte, 2017).
Unified document administration	Blockchain allows for a shared system of records across all supply chain actors without centralisation of data (Nakamoto, 2008). With blockchain all documentation of an entire supply chain can be shared through one tamper-resistant unified system. With current systems information comes from multiple sources, using different formats and can be incomplete (Unuvar, 2017).

3.4.1.2 *Relative advantage: Speed*

In supply chain management speed is described as the pace at which goods and services can be finalized. Table 5 presents some characteristics concerning traceability systems and speed.

Table 5. Blockchains relative advantage concerning speed

Relative advantage	Case
Improved information flow	Blockchain technology allows almost real-time access to transaction data throughout the entire supply chain (Nakamoto, 2008). Decreased risk of taking wrong decisions with up to date data.
Improved traceability	The speed of the required procedures can be increased by replacing the labour-intensive and bureaucratic paper process into a digital one (Kshetri, 2018) (Lehmacher, 2017). Walmart has indicated that their pilot tests with blockchain technology has proven to reduce the tracing of the origin of mango's, from a pack of sliced mangoes, from 6 days, 18 hours and 26 minutes using traditional techniques, down to 2.2 seconds using blockchain (Forbes, 2017).

3.4.1.3 Relative advantage: Dependability

Table 6 presents some characteristics of traceability systems regarding dependability.

Table 6. Blockchains relative advantage concerning dependability

Dependability	Case
Decentralization of power	Information asymmetry between levels of the supply chain may be reduced with an integrated blockchain traceability system. As all links in the chain will have access to the same information at the same time (Kim, Hilton, Bruks, & Reyes, 2018). Depending on which blockchain protocol is used, blockchain projects are often open source (Deloitte, 2017).
Diminish paperwork and simplify data management	All documentation of an entire supply chain can be made visible on one shared and searchable overview. No more need for paperwork (White M. , 2018).
Dependable access	Information stored on a blockchain can be made readily accessible from anywhere through mobile devices. Current paper based and digital traceability systems are prone to corruption and loss of stored data (Ge, Brewster, Spek, Smeenk, & Top, 2017). Blockchain technology is robust as it does not have a single point of failure (Wang, Zhang, & Zhang, 2018) (Deloitte, 2017). The shared synchronised ledger ensures prevention of loss of data (Crosby, Nachiappan Pattanayak, Verma, & Kalyanaraman, 2016).

3.4.1.4 Relative advantage: Sustainability

In a study conducted by Oceana, 20% of globally samples seafood products were found to be mislabelled (Warner, Lowell, Geren, & Talmage, 2016). Fraudulent fishing activities may have negative consequences on the sustainability of the fish industry (Jacquet & Pauly, 2008) as protected fish species are sometimes mislabelled as an unprotected species (Warner, Lowell, Geren, & Talmage, 2016). Table 7 focuses on some aspects that traceability systems can have on sustainability.

Table 7. Blockchains relative advantage concerning sustainability

Sustainability	Case
Fraud reduction	Blockchain alone will not eliminate fraud as long as human input is used (Ge, Brewster, Spek, Smeenk, & Top, 2017). However, used as a tool it will become simpler to detect fraud (Goverment Office for Science, 2015). The near impossibility to change or remove recorded data will likely reduce offenses such as fraud and corruption in the supply chain (Kshetri & Voas, 2018).
Simplified auditory process	Blockchain traceability systems simplify audit processes because of its immutable ledger (Banerjee, 2018). The distributed nature makes access to data more straightforward. Obtaining full traceability data stored on legacy systems required compelling reasons as obtaining full provenance data from legacy systems is resource intensive. Information stored on blockchain databases can be made easily accessible to external auditors.

	Investigation into illegal, unreported and unregulated seafood fraud would be greatly facilitated by blockchain traceability systems (McEntire & Kennedy, 2019).
Electricity consumption	The Bitcoin blockchain makes use of the proof-of-work consensus mechanism to approve transactions. This consensus mechanism is a very energy intensive mechanism as miners compete with computer power to be the first to calculate the required nonce (Mendling, Weber, & van der Aalst, 2018). It is estimated that a single transaction on the Bitcoin network equals an electricity consumption of 750 kWh (Digiconomist, 2020), which is vastly greater than legacy ICT systems use. By shifting to a proof of stake consensus mechanism, rather than having millions of processors handling the same transaction at the same time, a proof of stake mechanism would randomly choose only one processor to handle the transaction, which would decimate the energy requirements (Fairley, 2019). With the move to more energy conservative consensus mechanisms blockchain technology is predicted to significantly reduce its energy use over time (European Union Blockchain Observatory and Forum, 2019).

3.4.1.5 Relative advantage: Cost

The central concern of companies looking to adopt blockchain technology is the desire for a long-term cost savings and an upturn in productivity and efficiency. However, adoption of blockchain technology may bring sizeable initial costs (European Commission, 2020). Table 8 observes some characteristics relating to the cost of traceability systems.

Table 8. Blockchains relative advantage concerning costs

Cost	Case
Ease for regulatory audits	Auditory processes are conducted with more ease as ledgers are more extensive and are unlikely to be tampered with. This could cut compliance costs (Deloitte, 2017) (Kshetri & Voas, 2018) (Banerjee, 2018). This is especially true in comparison to paper based systems, which are known for their high cost and inefficiency (Ge, Brewster, Spek, Smeenk, & Top, 2017).
More focused recall processes	Detailed traceability systems lower the costs incurred when recalls are issued (Fritz & Schiefer, 2009).
Low running costs	No reconciliation of data required (Deloitte, 2017). Less use of intermediate parties (Deloitte, 2017).
Paperless system	Eliminating paperwork reduces costs and risks present in supply chain processes (Lehmacher, 2017). Blockchain systems have diminished administration costs in comparison to legacy systems (White M. , 2018).
Investment cost	It is likely that most companies will incur sizable initial costs as part of the adoption process (European Commission, 2020). These costs are to cover investments in new hardware and software components required to operate the blockchain (Mougayar, 2016).

3.4.2 Compatibility

Successful compatibility of blockchain technology with current work standards consist of two main factors. For one, the technology needs to be compatible with current legacy systems. A successful integration with legacy systems often involves a complete overhaul of the existing legacy system. The current lack of ICT personnel with experience in blockchain integration requires companies to heavily rely on external parties, which comes at a significant investment of resources (Meijer, 2020). Several service providing companies, like Modex and Fluree, currently offer packages that make digital legacy databases interoperable with blockchain databases. No cases have been publicly documented wherein blockchain traceability system functions interoperable with a paper-based food traceability system.

In addition to legacy systems, separately developed blockchain traceability systems need to be compatible with each other. Even though compatibility between different distributed legers is far easier to achieve than compatibility between legacy systems and blockchain networks (Hoskinson, 2017) , a lot of work still has to be done. In the current absence of standards developers have the freedom to customize each blockchain network to individual needs. This has led to the existence of many different blockchain networks that vary in key characteristics like their consensus method and code language used that may hinder their ability to share data with other blockchain networks. Many different options exist to obtain network interoperability, but at the current state of development it is still considered a key element necessary for broad adoption of the technology (European Commission, 2020). At present, interoperability between different blockchain networks is uncommon. This requires businesses that wish to setup a chain wide traceability system to make use the same service provider to ensure compatibility. Currently a lot of research and standardization programs are being worked on, with the expectation that interoperability will greatly increase in the time to come (European Union Blockchain Observatory and Forum, 2019).

Although interoperability is an integral part of a seamless full chain traceability system, the seafood industry currently lacks the means of chain wide interoperability. This is partly due to inadequate funds and capacity to tackle the issue. The notion of tracing foodstuffs is relatively new which causes chain wide interoperable databases to sound imaginary, long-term, or uncertain to seafood executives even if they are aware of the possibility (Hardt, Flett, & Howell, 2017).

3.4.3 Complexity

Blockchain technology is built upon three core principles which are a decentralized database, consensus on data acceptation and cryptographic security. This combination of elements makes the technology rather challenging to grasp (Friedlmaier, Tumasjan, & Welpe, 2017). A complete understanding of the core principles would be unnecessary if blockchain traceability would be easily obtainable through instalment plans. However, blockchain traceability is currently not yet at the stage of development were fully developed business cases can be readily implemented by businesses. This makes it troublesome for businesses to visualize the fit of blockchain traceability to their particular business case (Galvez, Mejuto, & Simal-Gandara, 2018). Next to a shortage of fitting business cases, the lack of standards on best practices also reduce the ease of adoption (Mougayar, 2016). All together it makes the accessibility of blockchain traceability low for the average company, as development support is lacking and the complex software is not user friendly (Mendling, Weber, & van der Aalst, 2018) (European Commission, 2020). The widespread lack of awareness and knowhow of blockchain technology makes companies put off any investments into its adoption (European Commission, 2020). Although blockchain traceability is believed to be a rather complex innovation, it could overcome this aspect with the help of governmental support (Rugeviciute & Mehrpouya, 2019).

3.4.4 Observability

Blockchain technology is an innovation based on software. This makes the innovation have less observability than a hardware-based innovation would have. Software innovations have a relative slow adoption rate as they are not so likely to be observed by outsiders (Rogers, 2003). At this stage of development the consequences of blockchain adoption are not easily distinguishable to the untrained (Friedlmaier, Tumasjan, & Welpe, 2017). Current adoption of blockchain technology remains low (Clohessy, Acton, & Rogers, 2019) (Chen & Furlonger, 2018) (Rijksdienst voor Ondernemend Nederland, 2019). As such, current probability of observing the innovation within a business's social system can be deemed as low.

3.4.5 Trialability

At present time, the highest profile blockchain provider is IBM with its ''Food Trust'' blockchain system (Gupta & Madhur, 2018) (Holden & Moar, 2018). Businesses can readily start exploring the blockchain technology through IBM. Other high profile blockchain providers such as Accenture, and Deloitte (Gupta & Madhur, 2018) do not provide a ready to go solution. However, Microsoft's ''Azure'' blockchain environment is the only provider apart from IBM who allows for instant trialability (Holden & Moar, 2018). As Robert Handfield, Distinguished Professor of the Bank of America University, noted: ''There aren't many blockchain "trials" that people can go and try for themselves'' (Handfield, 2018). The current lack of trialability might hinder the adoption of blockchain traceability as research has shown that the more experienced businesses are the more positive they asses blockchain usability. Small scale trialability of blockchain traceability are crucial for thorough comprehension of benefits and limits associated with blockchain adoption (Hackius & Petersen, 2017).

3.4.6 Current impediments to blockchain adoption

The International Standards Organisation (ISO) is currently working on setting standards for the use of blockchain technology in a business environment. The standards are expected to arrive no later than 2021 (ISO, 2018). Standards on blockchain traceability would improve interoperability. Knowledge gained on implementation would also be more widely applicable. As of present, regulatory agencies do not have explicit statements on blockchain traceability. As such, legal certainty is currently regarded as a key barrier which hinders adoption (European Commission, 2020). Compliance with the law is a primary consideration when implementing a food traceability system as noncompliance would make the products unsellable (McEntire & Kennedy, 2019). Subsequently, a low adoption rate makes it difficult for regulators to explore regulatory needs. Current policies concerning Bitcoin are a matter of worry for the traceability market as they worry about broader impact on the application of blockchain technology for other business cases (Mougayar, 2016). However, with the European Union having subsidised blockchain technology projects with over 380 million euro by 2020 (European Commission, 2018) it seems to embrace the technologies potential for traceability issues (European Commission, 2019).

Several elements have been identified that hinder blockchain adoption. For one, companies are hesitant to share product information that could be of use to competitors (Girard & Payrat, 2017) (Galvez, Mejuto, & Simal-Gandara, 2018). Secondly, primary producers are generally slow on technological developments (Galvez, Mejuto, & Simal-Gandara, 2018). In a case study Karlsen et al. discovered that companies closer to the end consumer found higher value in an advanced traceability system than primary producers. Subsequently, the costs of increased traceability are relatively greater for the primary producer than at retail level, making chain wide adoption processes a rather imbalanced proposition (Karlsen, Sørensen, Forås, & Olsen, 2011).

In general, blockchain technology does not yet possess the capacity required to process all traceability related transactions (Saberi, Kouhizadeh, Sarkis, & Shen, 2018). Currently, the Bitcoin blockchain can handle only a maximum of 7 transactions per second while the credit card companies can handle a peak of 10,000 transactions per second (Vukolic, 2015). It is expected that food traceability information takes up more digital space than a financial transaction would as it could potentially include information related to process practices (Saberi, Kouhizadeh, Sarkis, & Shen, 2018). Several different blockchain protocols already exist that are capable of higher transaction throughputs than the original Bitcoin blockchain (European Union Blockchain Observatory and Forum, 2019). For example, IBM's ''food trust'' blockchain solution for the food industry uses the Hyperledger blockchain, which can theoretically handle up to 20,000 transactions per second (Gorenflo, Lee, Golab, & Keshav, 2019).

4 RESULTS

4.1 SAMPLE SIZE

The cooperatives listed in paragraph 3.4.1 had been contacted and asked to distribute a link of the survey to their members. This resulted in rejections or non-responses from all the seven contacted cooperatives. As alternative, the relevant e-mail addresses were procured through internet search. A total of 1206 contacts were procured. These contacts were approached twice through SendinBlue, an e-mail campaign provider. The entire questionnaire is available in appendix A.

Of the 2412 e-mails send, 162 bounced and 1009 were opened. The opened e-mails registered 72 clicks to the survey. Of which 61 respondents (partly) completed the survey (Table 9).

Table 9. Survey sample size break down per supply chain link

Supply chain links	Number of companies in chain	Number of companies who received an invitation	Complete survey responses
(1) Cutter Fisheries	236*	17	5
(1) Fish farms	50**	7	2
(2) Fish and/or shellfish processing plants	125***	53	12
(3) Fish auction houses	35***	10	1
(3) Fish wholesalers	515***	153	11
(4) Fish specialty shops	625***	382	21
(4) Supermarkets	3270***	584	9
Total	4856	1206	61

* (Mol, 2019a)
** (NVWA, 2017b)
*** (CBS, 2019)

4.2 CURRENT STATE OF TRACEABILITY

Research question 2: '' What is the current state of traceability in the seafood sector'' can be readily evaluated using question 3 of the survey : '' What characterizes your company's current traceability system?'' and question 4 of the survey: '' How satisfied are you with your company's current traceability system?''. Of all the 61 respondents, 44% indicated that they use a traceability system that contains a mix of paper and digital processes. 41% of the respondents use a paper-based traceability system, while 15% uses a digital system. None of the contacted companies are (partly) employing a blockchain system. To analyse if differences in used traceability system exist, based on what level of the supply chain the company functions at, Fisher's Exact Test was performed. The test indicated no significant difference exists between the position of the company in the supply chain and the type of traceability system it employs (p=.405).

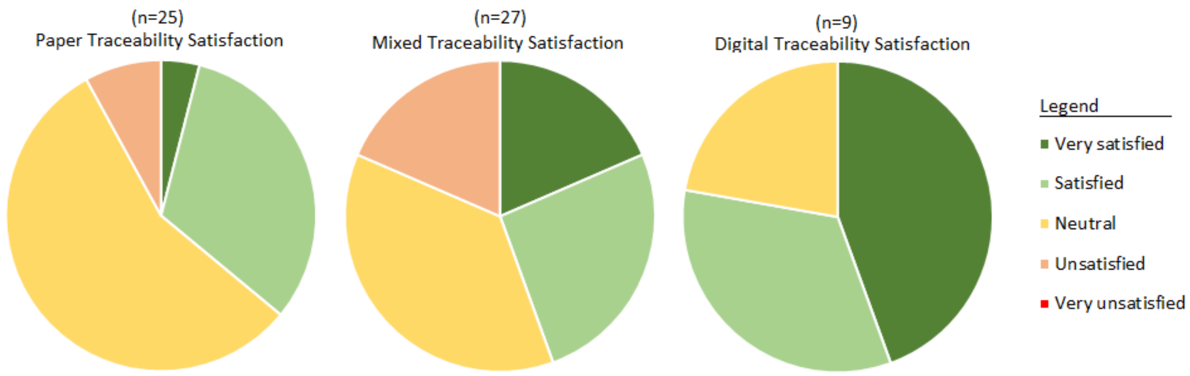

Figure 7. User satisfaction of every traceability system discerned

A one-way analysis of variance was conducted to check if a difference occurs in user satisfaction based on the traceability system employed (Figure 7). Levene's test showed equal variances for system satisfaction, $F(2,58) = 1.74$, $p = .185$. The subsequent ANOVA found a significant difference between the satisfaction for paper, digital or a mix of both at the $p<.05$ level [$F(2, 58) = 3.71$, $p = .031$]. Post hoc comparisons using Hochberg's GT2 test for unequal sample sizes indicated that the satisfaction score for digital traceability systems was significantly different from the paper-based systems ($p = .029$), but not significantly different from the mixed traceability systems ($p = .068$). The satisfaction for mixed traceability systems does not differ from paper-based traceability systems ($p = .938$).

4.3 Willingness to adopt blockchain traceability

In the first question of the survey all respondents were asked about their intention to adopt blockchain technology as part of their traceability system within the next 5 years. A minority of 29.5% indicated the intention to do so (Table 10). Fisher's exact test was conducted to test for a relationship between intention to adopt and the different level of supply chain links discerned, no significant difference was reported (p=.763).

Table 10. Intention to adopt blockchain traceability

Supply chain links	Companies with the intention to adopt blockchain within the next 5 years	Companies that expect blockchain traceability to eventually be widely adopted
Cutter Fisheries (n=5)	3 (60%)	3 (60%)
Fish farms (n=2)	0	1 (50%)
Fish and/or shellfish processing plants (n=12)	4 (33%)	6 (50%)
Fish auction houses (n=1)	0	0
Fish wholesalers (n=11)	3 (27%)	5 (46%)
Fish specialty shops (n=21)	5 (24%)	11 (52%)
Supermarkets (n=9)	3 (33%)	5 (56%)
Total (n=61)	18 (29.5%)	31 (50.8%)

4.4 Analysing construct reliability: Cronbach's alpha

Research question 3 requires use of the eight composed constructs. Before using these constructs in analysis their validity and reliability must first be analysed. To evaluate construct reliability the items of the survey were tested using Cronbach's alpha. Several items failed to load reliably into their designed construct as their Cronbach's alpha scores did not reach the accepted 0.7 threshold (Table 11). To reach the threshold several items had to be omitted from the constructs of PBC, SBN, TRL and CTB. All omitted items had an item-total correlation of <0.3.

Table 11. Cronbach Alpha scores per construct

Construct	Cronbach's Alpha	Items	N
Attitude toward the behaviour (ATT)	.848	5	43
Perceived behavioural control (PBC) if PBC1 omitted + PBC2 omitted	.419 .610 .754	4 3 2	40
Subjective norm (SBN) If SBN1 omitted	.670 .725	5 4	48
Relative advantage (RLA)	.842	4	45
Observability (OBS)	.834	5	44
Trialability (TRL) If TRL1 omitted	.488 .716	4 3	48
Simplicity (Complexity (CLX))	.862	4	46
Compatibility (CTB) If CTB4 omitted + CTB5 omitted	.421 .526 .702	5 4 3	45

4.5 ANALYSING CONSTRUCT VALIDITY

Because the composed questionnaire has not been field tested before, statistically testing the validity of the composed constructs is of importance. To check the validity of the questionnaire exploratory factor analysis was considered. To check if the collected data is fitting for exploratory factor analysis the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO-test) was employed. The KMO-test returned a non-positive definite matrix, which means at least one of the eigenvalues was negative. The KMO-test relies on positive values to be able to compute for sample adequacy. In an effort to return a positive definite matrix, missing values were replaced by the average value of the construct instead of being deleted listwise. Using this strategy KMO-test no longer encountered a negative eigenvalue and thus could be computed. However, the resulting KMO-value of 0.572 is categorized to be ''miserable'' (Kaiser & Rice, 1974), and deemed unfit for further analysis. Further discussion of construct validity testing can be found in chapter 5.3.

4.6 PEARSON CORRELATION

Linear correlations between the different constructs were analysed. The resulting correlation coefficients ranged from -0.37 to 0.45 (Table 12). In addition, the dependent variable (intention to adopt) has been included. The constructs of attitude toward the behaviour, subjective norm, observability, and complexity showed a significant linear correlation with the intention to adopt.

Table 12. Pearson correlation coefficient by construct

Construct	Mean	Std. Deviation	1	2	3	4	5	6	7	8	9
1. Intention to adopt			1								
2. Attitude toward the behaviour	0.21	0.76	0.45**	1							
3. Perceived behavioural control	-0.6	0.85	0.10	0.04	1						
4. Subjective norm	-0.46	0.63	0.40**	0.37*	0.17	1					
5. Relative advantage	0.41	0.71	0.26	0.14	0.24	0.27	1				
6. Observability	0.25	0.73	0.43**	0.18	0.07	0.37*	0.18	1			
7. Trialability	0.01	0.82	0.25	-0.12	-0.03	-0.25	0.05	-0.02	1		
8. Complexity	-0.02	0.81	-0.37*	-0.30	-0.21	-0.23	-0.13	-0.23	0.11	1	
9. Compatibility	-0.21	0.73	0.28	0.02	0.16	0.11	0.18	0.33*	0.03	-0.05	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

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4.7 Constructs

In this paragraph all construct related survey results are visualized using divergent stacked bar charts. These charts feature dual X-axis to concurrently present the average response value for each Likert item as well as show the distribution of Likert responses using Gannt percentages. Regardless of the number of item responses, all items are scaled to fit the Gannt bars length of 100%. Within the divergent stacked bar charts the individual response groups are colour labelled (Figure 8). Figure 9 to 16 offer insight into each construct and its individual Likert items. After presenting all constructs individually Figure 17 features the concluding scores for every construct.

Figure 8. Legend referring to Figure 9 to 20

4.7.1 Relative Advantage

The construct of relative advantage explains the perceived benefits of the innovation in comparison over the other options. This construct was composed of four questions (Figure 9).

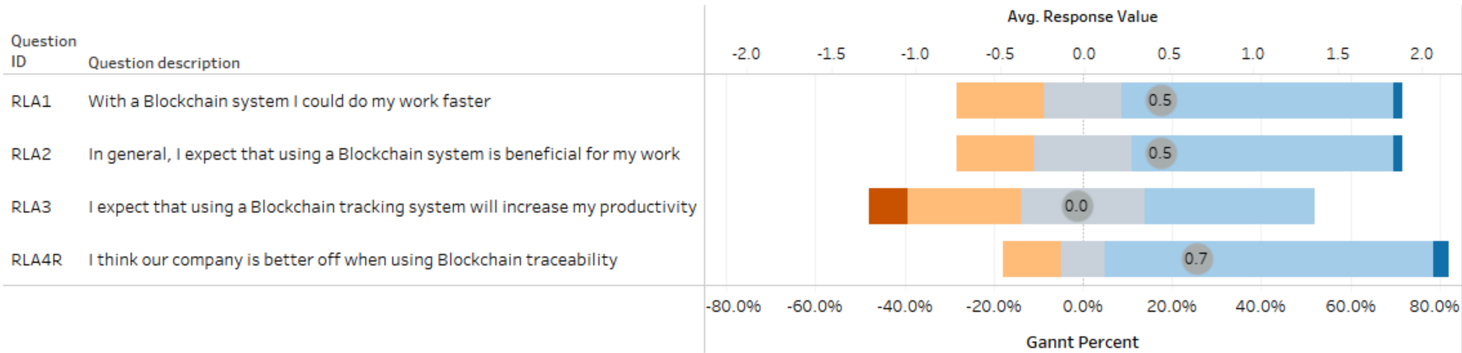

Figure 9. Likert scale responses to items categorized as Relative Advantage

4.7.2 Observability

Observability describes how visible the results gained from usage of an innovation are to others. The perception of observability of the technology was assessed in the survey (Figure 10).

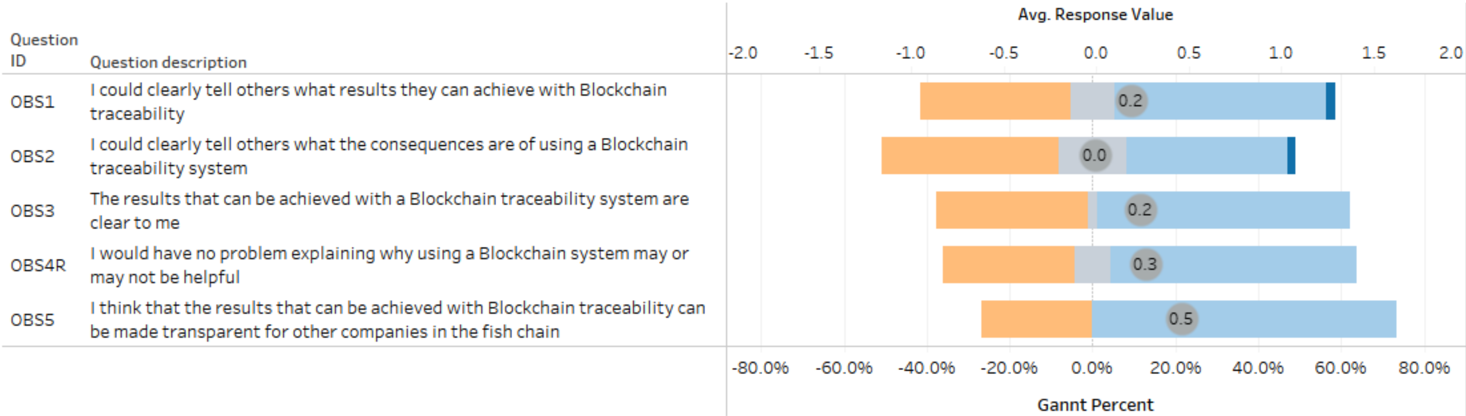

Figure 10. Likert scale responses to items categorized as Observability

4.7.3 Trialability

Trialability describes the extent a new technology can be tested before adopting it. Possible concerns towards trialability were examined in the survey using four items (Figure 11).

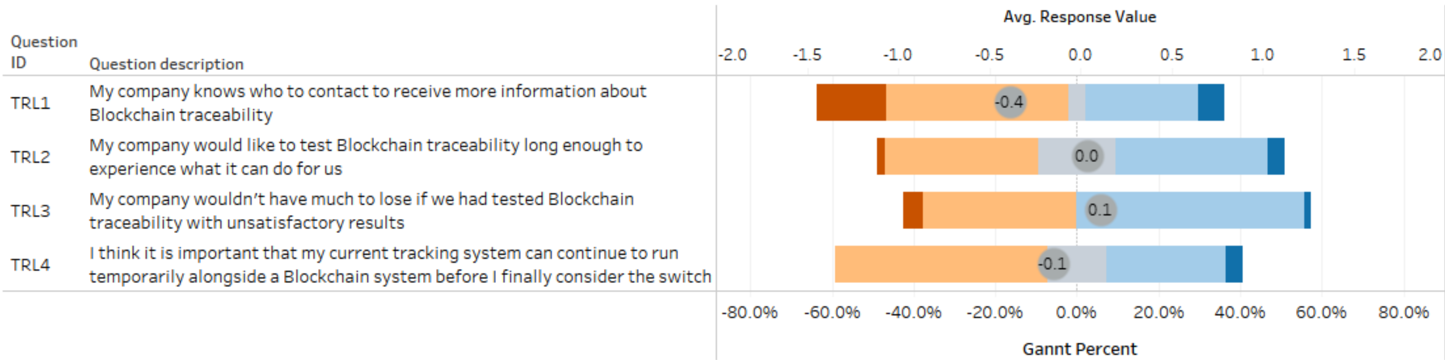

Figure 11. Likert scale responses to items categorized as Trialability

4.7.4 Complexity

Complexity explains how the different levels of difficulty that new innovations possess has influence on their rate of adoption. The perceived complexity of blockchain traceability was assessed using four Likert items (Figure 12). As previously described, the construct of complexity has been transformed to represent simplicity. Simplicity is the opposite of complexity.

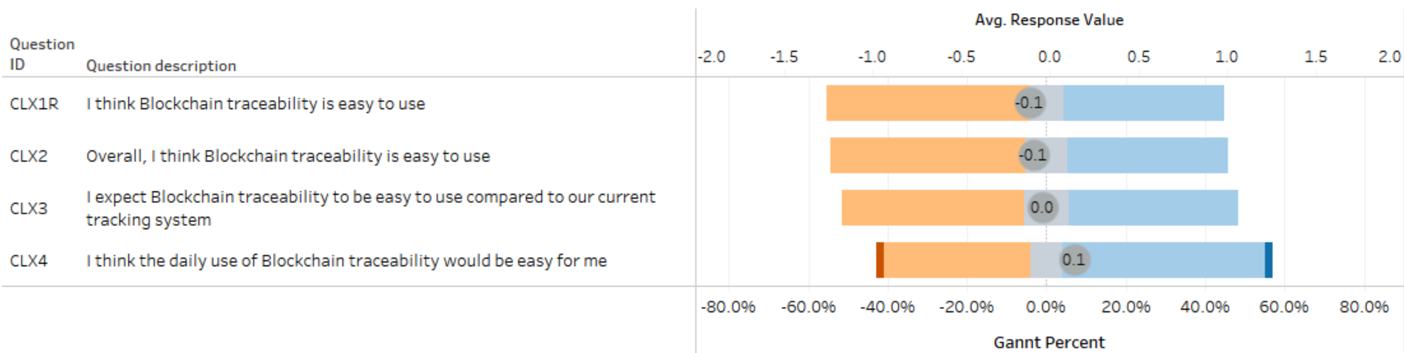

Figure 12. Likert scale responses to items categorized as Complexity

4.7.5 Compatibility

The construct of compatibility explains the fit of an innovation in an existing social and technological environment. It has been assessed by five Likert items (Figure 13).

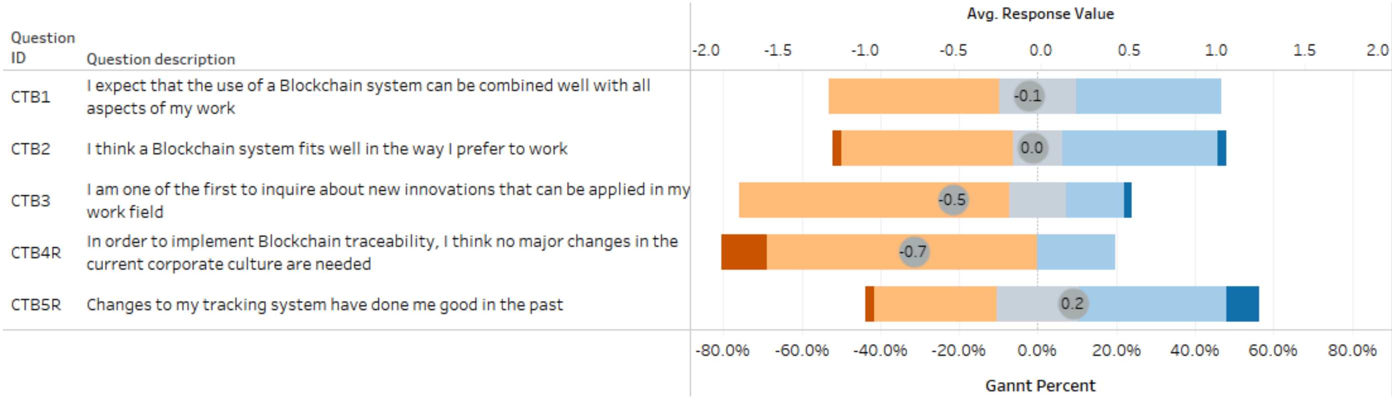

Figure 13. Likert scale responses categorized as Compatibility

4.7.6 Attitude towards the behaviour

The general attitude towards blockchain technology was assessed in the survey (Figure 14).

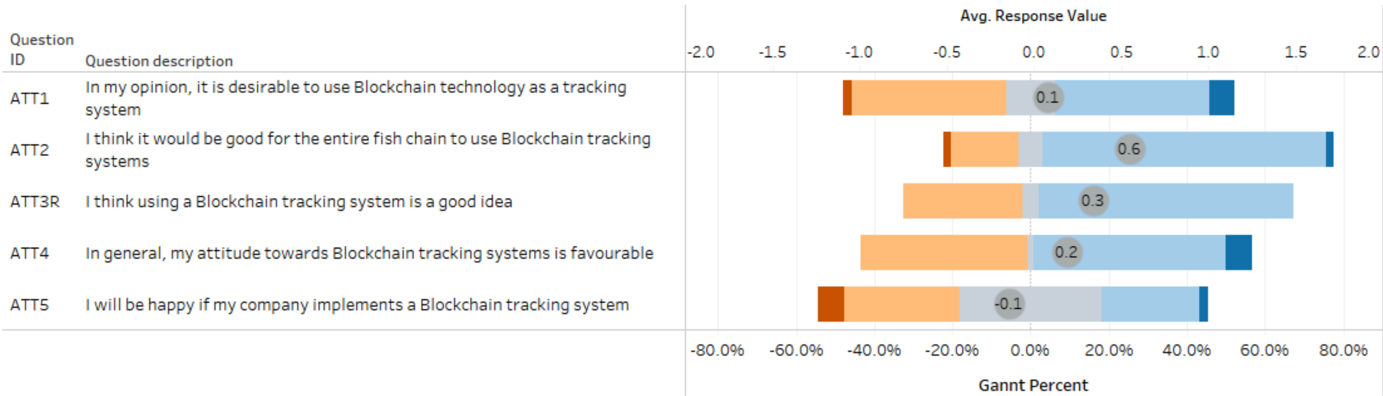

Figure 14. Likert scale responses categorized as Attitude toward the behaviour

4.7.7 Subjective norm

The perception of external social pressure whether to adopt blockchain traceability was evaluated (Figure 15).

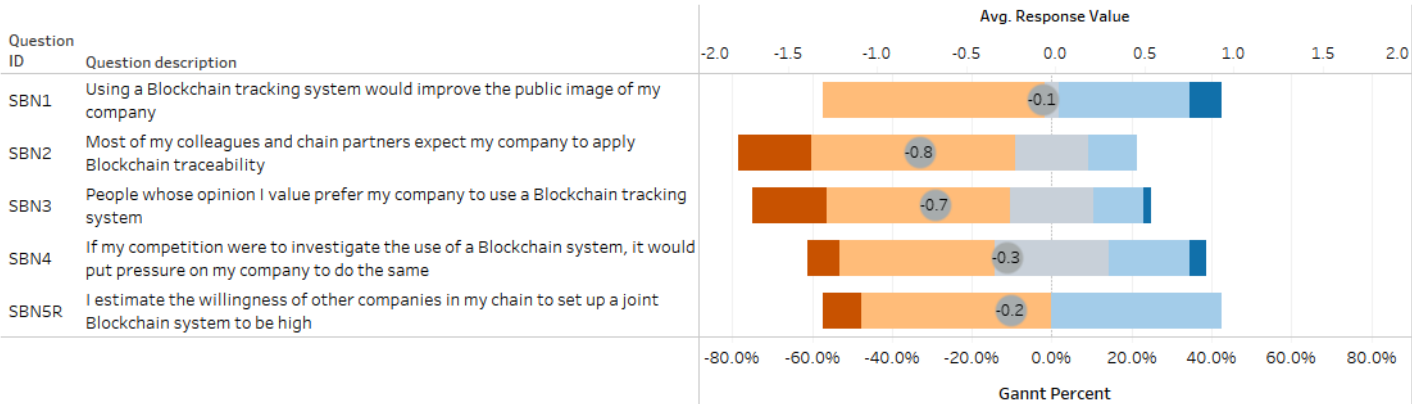

Figure 15. Likert scale responses to items categorized as Subjective norm

4.7.8 Perceived behavioural control

The construct of perceived behavioural control deals with the individual's ability to perform the behaviour and self-efficacy. It has been evaluated using four Likert items (Figure 16).

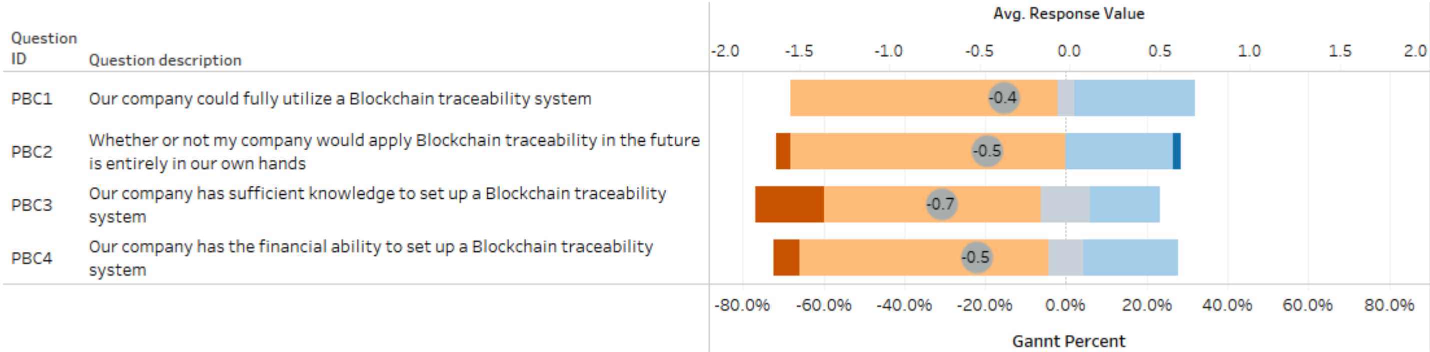

Figure 16. Likert scale responses to items categorized as Perceived behavioural control

4.7.9 Concluding construct results

After presenting the individual Likert times, the final Likert scale has been drafted by combining the individual Likert items into their respective scales. Likert items that have failed for reliability, as shown in Table 11, have been excluded from the final construct score. The constructs are arranged from top to bottom according to their average score, with the highest score on top. The 95% confidence interval of the mean response value is represented by black bars (Figure 17). The construct of complexity represents the items shown in Figure 12, and thus represents simplicity instead of complexity in this overview.

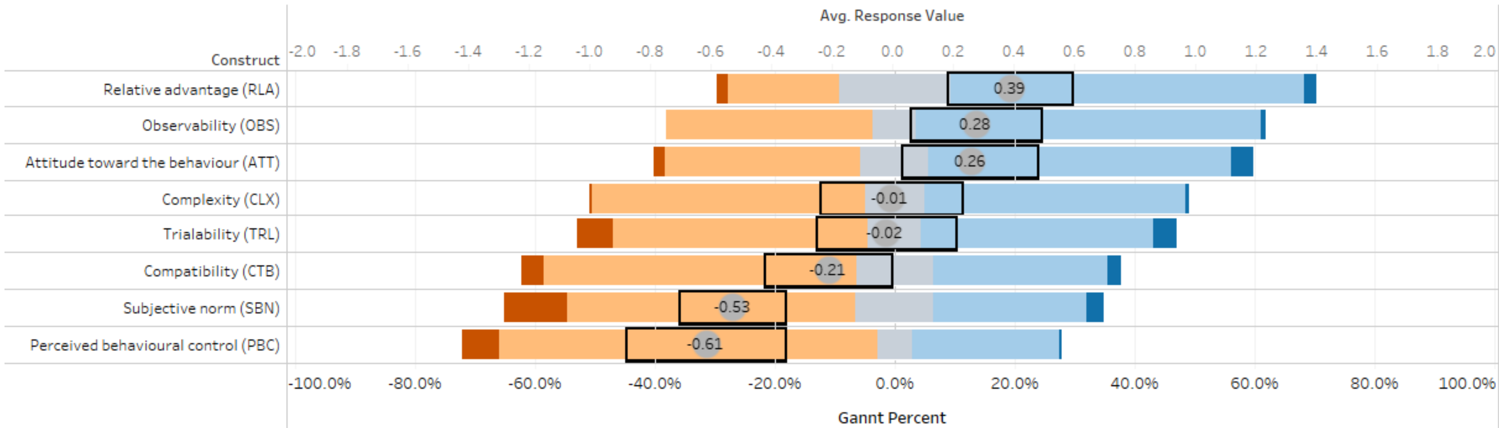

Figure 17. Concluding results of combined Likert responses by construct

4.7.10 Score difference between adopters and non-adopters

Figure 18 shows the discrepancies between the final construct scores by separating participants with or without the intention to adopt blockchain traceability within the next 5 years.

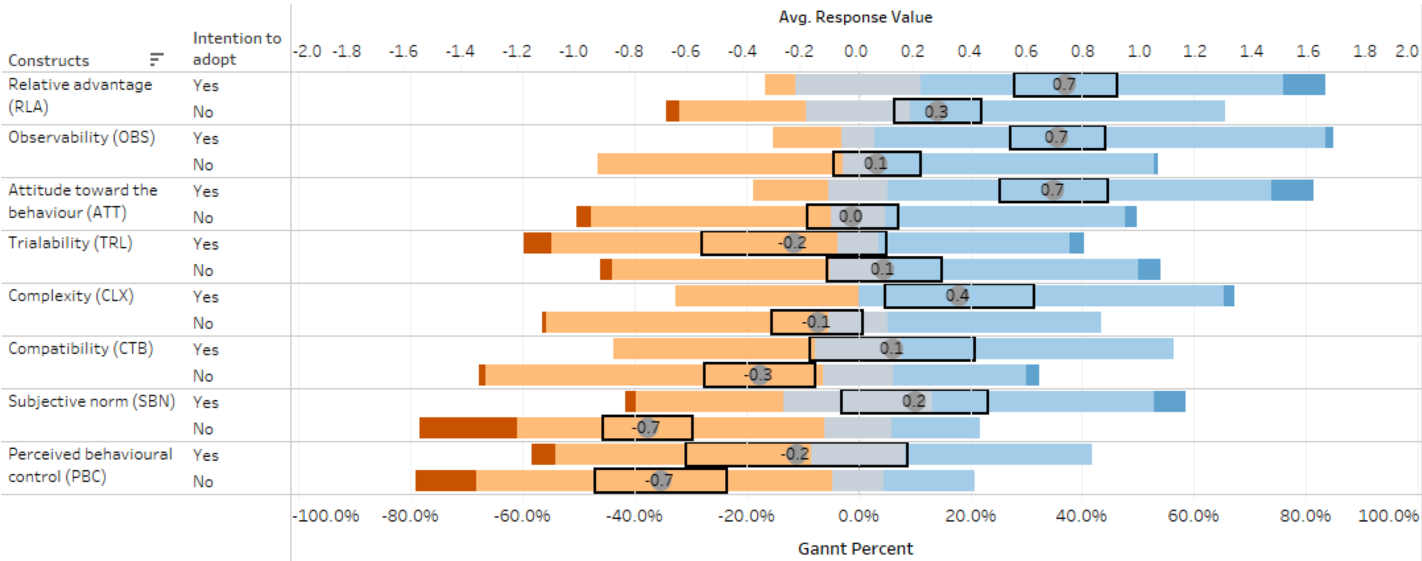

Figure 18. Construct scores separated by intention to adopt

An independent samples t-test was conducted to compare the effect that the intention to adopt has on average response values of a construct (Figure 18). Levene's test showed that homogeneity of variances were violated by the constructs of attitude toward the behaviour; $F(1,41) = 10.73$, $p=<.05$ and the construct of observability $F(1,42) = 7.06$, $p=<.05$. For the constructs that violated the assumption of homogeneity of variance the Welch's t-test was used. The subsequent t-tests, that were performed within the construct, found several significant differences on the effect that the intention to adopt has on the average response value of the tested construct. The constructs of relative advantage ($p= .071$) trialability ($p= .300$), compatibility ($p= .055$), perceived behavioural control ($p= .571$) and were found not to have a significantly different average response value when segregated by the intention to adopt. The remaining constructs of observability, attitude toward the behaviour, complexity and subjective norm all had a p-value $<.05$ indicating a significant difference.

Simplifying the analysis by discarding construct associations and thus condensing the response values to only be sorted by the respondent's intention to adopt, gives a more distinct overview (Figure 19).

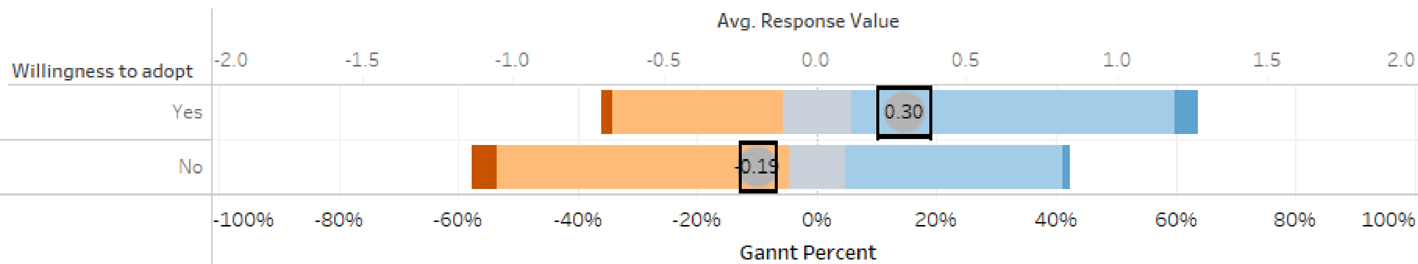

Figure 19. Condensed total item scores separated by intention to adopt

A subsequent independent samples t-test was conducted to compare the effect that the intention to adopt has on the overall mean response value of items. Levene's test showed equal variances for both groups $F(1,1818) = 2.28$, $p= .13$. The subsequent t-test reported a significance level of $<.01$, indicating a significant difference between the overall item scoring of respondents who are willing to adopt blockchain traceability and the respondents who indicated not to be willing to do so.

4.7.11 Blockchain knowledge and construct score

Fifty-five valid responses were received concerning the blockchain knowledge of the respondents. Of the respondents 40% had no prior knowledge of blockchain traceability, 47% had some knowledge and 13% reported to have extensive knowledge of the subject.

The average item response values separated by blockchain knowledge were observed (Figure 20).

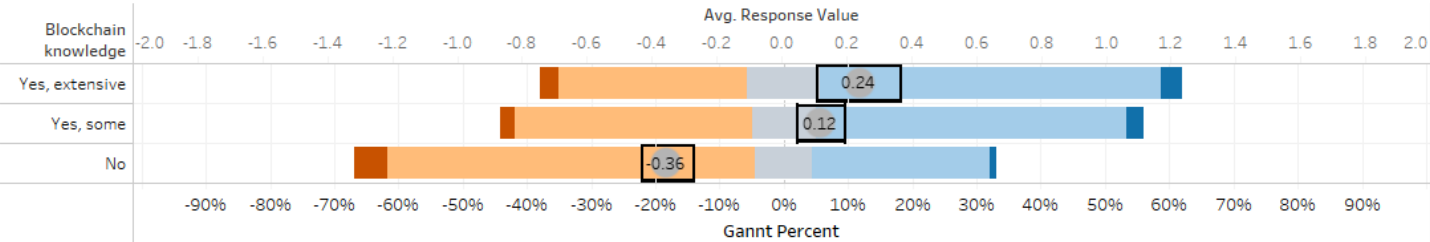

Figure 20. Effect of self-reported blockchain knowledge on overall item response values

One-way analysis of several different variances was conducted to compare the effect that self-reported knowledge has on average response values. Levene's test showed that homogeneity of variance was violated. The subsequent Welch ANOVA signified significant differences [F(2, 1655) = 50.21, p = >0.01]. Post hoc comparisons using Games-Howell between the reported values for extensive (p=>0.01) and some (p=>0.01) reported blockchain knowledge in regard to the respondents who answered to have no previous knowledge on the subject. No significant difference was found between the answers of respondents reporting to have extensive or some knowledge of blockchain traceability (p=0.27).

4.7.12 Blockchain knowledge and the intention to adopt

Considering that one's inclination to adopt blockchain traceability had a significant effect on construct score (Figure 18) and blockchain knowledge had a significant effect on construct score (Figure 19) a possible pattern was observed. Figure 21 shows the responses of self-reported blockchain knowledge separated by the intention to adopt.

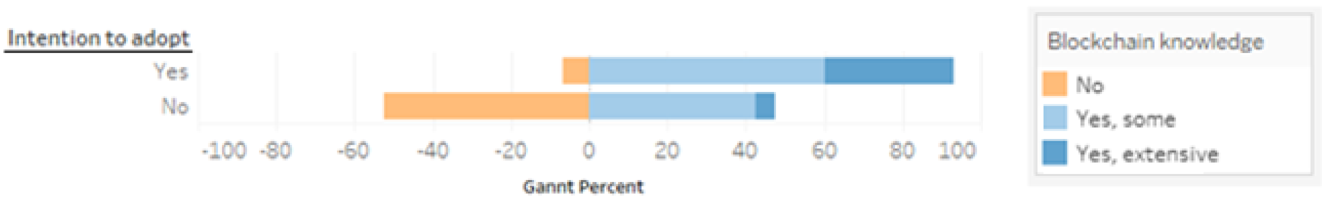

Figure 21. Intention to adopt separated by reported blockchain knowledge

Testing for differences of blockchain knowledge between participants with and without the intention to adopt blockchain traceability was proceeded with Fisher's exact test. Of the respondents with no self-reported knowledge of blockchain traceability 52.5% indicated no intention to adopt blockchain traceability. For the respondents who indicated to be knowledgeable about the subject 93.3% indicated to be willing to adopt blockchain traceability within the next 5 years. Fisher's exact test reported a p-value <.002, indicating that the difference in proportions observed is significant. Participants with the intention to adopt had significantly more knowledge about blockchain traceability than participants who had no intention to adopt. There was no statistically significant association difference between the willingness to adopt when participants possessed ''some'' knowledge in comparison to having ''extensive'' knowledge as assessed by Fisher's exact test, p =.10.

4.8 Predicting the willingness to adopt

4.8.1 Average construct scores

Binomial logistic regression analysis was employed to predict the outcome of the dependent variable, which is the willingness to adopt, using multiple independent variables in the form of the composed constructs. Because of missing data 26 cases could potentially be included in a binomial logistic regression that includes all eight individual constructs. Following Peduzzi et al. guidelines, as set out in the Materials and Methods, would imply the need for 271 cases (10*8/0.295). Accordingly, no additional regression analysis could be conducted that uses the individual eight constructs as the data density was deemed too low.

To achieve the necessary data density, combining all eight constructs to form a single new Likert scale representing the total score of the eight constructs was considered. The new variable consisted of 26 valid cases. A preliminary t-test indicated a significant difference (*p=>.05)* in the values of the newly formed scale of ''total construct scores'' grouped by the indicated willingness to adopt. Fitting a logistic regression model with the intention to adopt as the dependent variable and the new variable of ''total construct scores'' (Figure 22) had enough data density to continue the analysis. The subsequent binomial logistic regression model was statistically significant, $\chi^2(2) = 11.91$, $p= .001$. The model explained 50% (Nagelkerke R^2) of the variance in willingness to adopt. Hosmer and Lemeshow test results confirmed that the model was a good fit for the data χ^2 (df=7, N=26) = 8.89 $p= 0.26$. The positive predictive value was established at 90% That is, of all cases predicted to possess the willingness to adopt blockchain traceability, 90% were correctly predicted. The negative predictive value, meaning of cases predicted not to be willing to adopt, 87.5% were correctly predicted by looking at the total score of the eight constructs.

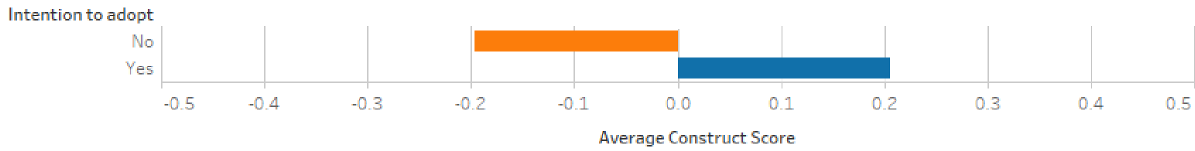

Figure 22. Average score of all combined constructs, separated by the intention to adopt

According to the model the odds of a respondent reporting to want to adopt blockchain technology within the next five years is more than twice as high when the value of the ''total construct scores'' increases by one point (Table 13).

Table 13. Logistic Regression, modelling willingness to adopt to total construct score

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	95% C.I.for EXP(B) Upper
Step 1[a]	Total construct scores	.828	.352	5.537	1	.019	2.288	1.148	4.560
	Constant	-.279	.510	.299	1	.584	.757		

4.8.2 Average scores correlated constructs

The same binomial logistic regression analysis was repeated. Instead of using all eight constructs, only the constructs that were found to have a direct correlation to the willingness to adopt were included. The new independent variable consisted of the constructs attitude towards the behaviour, subjective norm, observability, and complexity. A preliminary t-test indicated a significant difference (*p=>.05)* in the values of the newly formed scale grouped by the indicated willingness to adopt. The newly formed variable was modelled using a logistic regression with the intention to adopt as the dependent variable. The subsequent binomial logistic regression model was statistically significant, $\chi^2(2) = 4.90$, p= .027. The model explained 18% (Nagelkerke R^2) of the variance in willingness to adopt. Hosmer and Lemeshow test results confirmed that the model was a good fit for the data χ^2 (df=6, N=35) = 3.56 p= .74. The positive predictive value was established at 55.6%. That is, of all cases predicted to possess the willingness to adopt blockchain traceability, 55.6% were correctly predicted. The negative predictive value, meaning of cases predicted not to be willing to adopt, 69.2% were correctly predicted by looking at the total score of the four correlated constructs.

According to the model the odds of a respondent reporting to want to adopt blockchain technology within the next five years is almost twice as high when the value of the combined variable of the four correlated constructs increases by one point (Table 14).

Table 14. Logistic Regression modelling willingness to adopt to correlated construct score

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Step 1[a]	Correlated constructs score	.554	.273	4.110	1	.043	1.741	1.019	2.975
	Constant	-.630	.385	2.682	1	.102	.533		

a. Variable(s) entered on step 1: Correlated constructs score.

4.8.3 Blockchain knowledge

Binomial regression analysis of intention to adopt blockchain traceability and reported blockchain knowledge was considered. With 55 included cases this analysis complies with the previously stated guidelines, as the desired 34 samples are reached (10*1/0.295). The subsequent logistic regression model was statistically significant, $\chi^2(2) = 14.40$, p= .001. The model explained 34% (Nagelkerke R^2) of the variance in willingness to adopt. The positive predictive value was established at 71.4%. That is, of all cases predicted to poses the willingness to adopt blockchain traceability, 71.4% were correctly predicted. The negative predictive value, meaning of cases predicted not to be willing to adopt, 79.2% were correctly predicted by looking at their self-reported knowledge of blockchain traceability. Taking the category of ‘’no knowledge’’ as a baseline, both the categories of extended knowledge (p = > .05) and ‘’some knowledge’’ (p = >.05) significantly differ in their willingness to adopt than the respondents who reported no prior knowledge. According to the model the odds of a respondent’s willingness to adopt blockchain traceability is eleven times higher when the respondent possesses some knowledge over no knowledge on the subject at all (Table 15). Having extensive knowledge increases those odds to be more than fifty times more likely. However, as the sample size is restrictive the reported odd ratio’s come with substantial confidence intervals (Table 15).

Table 15. Logistic Regression, modelling willingness to adopt to blockchain knowledge

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	No			8.979	2	.011			
	Some	2.409	1.103	4.764	1	.029	11.118	1.279	96.661
	Extended	3.961	1.322	8.977	1	.003	52.500	3.935	700.530
	Constant	-3.045	1.024	8.848	1	.003	.048		

5 DISCUSSION

5.1 POPULATION SAMPLE

Of the 2412 e-mails send, 162 bounced and 1009 were opened. The opened e-mails registered 72 clicks to the survey. Of which 61 respondents (partly) completed the survey. This resulted in a click-through rate of 3.2%, which is similar to reported averages for the food industry of 2.9% (Mailchimp, 2019) and 3.8% (IBM, 2018). The 61 survey responses correspond to 1.3% of the total number of businesses active in the Dutch fish supply chain and correspond to 5.1% of the total amount of companies that were contacted.

5.2 PEARSON CORRELATION

In previous work, Weigel et al. conducted a meta-analysis of construct correlation for both the theory of planned behaviour and the diffusion of innovations in relation to the willingness to adopt (Weigel, Hazen, Cegielski, & Hall, 2014). The 95% confidence intervals that this study reported are included in Table 16. As can be seen from the data the tested construct of perceived behavioural control fails to fit within the reported confidence intervals (Table 16). The score for the construct of perceived behavioural control was determined by only two Likert-items, and thus was the construct made up of the lowest number of items. Item PBC3 questioned participants on whether they assess their company to possess sufficient knowledge to establish a blockchain traceability system within their company. PBC4 assessed the financial ability of the company to adopt blockchain traceability. No indication of required knowledge or financial means were communicated, all participants made their own assessment. Overall uncertainty in assessing these requirements is likely to have led to the discrepancies in the correlations found in this study compared to the literature values.

Table 16. Construct correlation to the propensity to adopt, compared to literature values

Theory	Construct	Found correlation	Wiegel et al. ρ: 95% CI LL	Wiegel et al. ρ: 95% CI UL
Theory of planned behaviour	Attitude Toward Behavior	0.45**	0.37	0.69
	Perceived Behavioral Control	<u>0.10</u>	0.39	0.44
	Subjective Norm	0.40**	0.15	0.52
Diffusion of innovations	Compatibility	0.28	0.24	0.62
	Relative Advantage	0.26	0.20	0.63
	Observability	0.43**	0.16	0.60
	Trialability	0.25	0.14	0.50
	Complexity	-0.37*	-0.54	-0.03

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

5.2.1 Research question 1

Information regarding research question 1:''What are the relative advantages and disadvantages of a blockchain traceability system in comparison to paper-based and computerized systems?'' was gathered by conducting a literature review whereof the results are presented in chapter 3.

In essence: Paper traceability systems and current IT systems are known to suffer from alteration, corruption and loss of stored data while Blockchain ledger entries cannot be changed or removed. The immutable ledger eases auditory processes and simplifies fraud detection. Blockchain technology is robust as it does not have a single point of failure. The shared synchronised ledger ensures prevention of loss of data.

In paper-based traceability systems the downside of written documents is human error, no quick sifting of information and slow track and tracing. Blockchain allows for a shared system of records across all supply chain actors without centralisation of data.

Generally, every link in the chain stores its own product information. This causes limited access to important data and makes it hard to establish a trustworthy overview of a supply chain. Blockchain traceability systems allow for monitoring of the supply chain, which would ensure better safety and quality products for the consumer. Walmart has indicated that their pilot tests with blockchain technology has proven to reduce the tracing of the origin of mango's, from a pack of sliced mangoes, from 6 days, 18 hours and 26 minutes using traditional techniques, down to 2.2 seconds using blockchain. As such, Blockchain technology allows almost real-time access to transaction data throughout the entire supply chain, greatly aiding response capabilities during foodborne disease outbreaks.

The current lack of ICT personnel with experience in blockchain integration requires companies to heavily rely on external parties, which comes at a significant investment of resources. Only a few service providing companies currently offer packages that make digital legacy databases interoperable with blockchain databases. No cases have been publicly documented wherein blockchain traceability system functions interoperable with a paper-based food traceability system.

As of present, regulatory agencies do not have explicit statements on blockchain traceability. As such, legal certainty is currently regarded as a key barrier to blockchain traceability. Currently, ISO standards for blockchain traceability are still being drawn up. Without international standards interoperability between different kinds of blockchain networks are far from the norm.

In addition, companies closer to the end consumer found higher value in an advanced traceability system than primary producers. Subsequently, the costs of increased traceability are relatively greater for the primary producer than at retail level, making the chain wide adoption processes of Blockchain technology a rather imbalanced proposition.

Blockchain technology is a novel way of achieving traceability of foodstuffs with the potential to greatly increase traceability and transparency efforts. Current adoption of blockchain technology is low as awareness, knowledge, compatibility, and legal certainty are lacking.

5.2.2 Research question 2

The results regarding research question 2: ''What is the current state of traceability in the seafood sector?'' showed that of the 61 respondents 44% of the Dutch seafood industry currently employs a mix of paper-based and digital means to secure their food traceability requirements. 41% of the respondents say their business relies solely on a paper-based traceability system. The remaining 15% says that they use a digital traceability system. Unfortunately, no suitable sources can be cited that have profiled the usage of the different approaches to product traceability within the (sea)food sector. One source of reference cites that 81% of traceability systems are either paper-based or are only partially digital (Bruno & Ellis, n.d). This is near the value found in the survey, which was at 85%. This could signify that the Dutch fishing industry does not differ in its approach to food traceability than other companies in the food industry. Another source reported that 61% (N=94) of companies in the seafood sector of North America employ a digital traceability system. However, according to the researchers their sample was rather biased towards companies committed to sustainability, and thus with a higher likelihood of using digital traceability systems (Hardt, Flett, & Howell, 2017). The only point that can be concluded from this point of reference is that the Dutch sector is far from as digitized as American seafood companies that have a focus on sustainability.

Even as one could hypothesize that fisheries could have higher engagement with digital traceability systems because of their obligation to digitally report their catch statement to the authorities (see paragraph 2.2.2 on ERS), no significant difference between the fisheries and other supply chain links was detected (p=.405). As such it appears that the obligation for all commercial Dutch fishing vessels to report their catch statements digitally to the authorities has no direct impact on the way they handle their food traceability system. The fishing industry has long described to be very conservative (Shepherd, 1981) (Nooitgedagt, 2007) (Nooitgedagt, 2017) (Krome, 2019), this is a notion that has also been commented on by some of the questionnaire respondents. This might be a clue as to why digitalization primarily occurs when it is mandated.

Furthermore, the results signified that digital traceability systems give their users significantly more satisfaction than paper-based systems (p =.029). Unfortunately, the cause of the significantly higher satisfaction was not identifiable because of a lack of complementary questionnaire items. Subsequently, no comparable studies have been conducted regarding food traceability systems and their corresponding user experience. The reason why digital traceability systems gave users significantly more satisfaction than their paper-based counterparts thus remain up for debate.

In essence: in its current state the traceability systems in Dutch fish industry consist of 15% digital, 41% paper-based and 44% of a mixture of paper and digital processes. The users of a digital traceability system reported a significantly higher user satisfaction in comparison to paper-based traceability and/or the users who employ a mix of paper and digital processes.

5.2.3 Research question 3

Research question 3:''What factors influence the willingness of companies in the Dutch fish sector to adopt a blockchain based traceability system?'' has been explored from several different angles.

As previously observed in Figure 18, some discrepancies exist between the final construct scores of respondents who indicated the willingness to adopt versus the respondents who did not possess the willingness to adopt. Subsequently, a more distinct overview was made in Figure 19 by comparing the overall item scores of respondents with and without the willingness to adopt. It turned out that respondents who were positive about adopting blockchain traceability rated their Likert items significantly higher than those who did not. These preliminary results showed that the constructed instrument had the potential to model for the willingness to adopt blockchain traceability.

Subsequently, the use of binomial logistic regression analysis was explored to predict the willingness to adopt using the composed constructs. Unfortunately, because of missing data only 26 cases could be included in the analysis. The data density was deemed too low to continue modelling with more than one variable at a time. As previous analysis showed significant Likert-item score differences between the adoption propensities, a compromise was explored to solely model with a new variable consisting of the average score of the eight constructs for each respondent (Figure 21). The subsequent binomial logistic regression model was statistically significant. And was shown to predict the willingness to adopt with 90% accuracy, while predicting the rejection to adopt with 87.5% accuracy. According to the model the odds of a respondent reporting to want to adopt blockchain technology within the next five years is more than twice as high when the value of the ''Total construct scores'' increases by one point. Subsequently, a similar model was explored. However, for this analysis only the four constructs that were found to be significantly correlated to the intention to adopt were transformed into a new independent variable.

Another model was explored predicting willingness to adopt using the respondents' self-reported knowledge of the subject. Participants with the intention to adopt had been found to have significantly more knowledge about blockchain traceability than participants who had no intention to adopt. To select the best predictive model the use of Hurvich and Tsai's criterion (AICc) was used. The combined averaged score of all eight constructs was selected as best fitting model to predict one's willingness to adopt blockchain traceability.

Figure 13 showcased the results to the Likert item which questioned respondents on whether they think corporate culture requires no major changes for the implementation of blockchain traceability to take place. This item is one of the lowest rated questions on the questionnaire, indicating that 80% thinks changes to corporate culture are needed for interoperable traceability to come to fruition. These results are in support of the findings of Hardt et al. who indicated that the fish industry is strongly competitive, whereas blockchain traceability fairs well by interoperability, which requires collaboration between parties (Hardt, Flett, & Howell, 2017). The notion of exchanging traceability data is perceived as risky and is contradictory to predominant fish industry believes (Hardt, Flett, & Howell, 2017).

This study also gained insight into the factors, which were based on Roger's Diffusion of innovations and Ajzen's Theory of planned behaviour, that contribute to the intention to adopt blockchain traceability. Modelling variables to predict the willingness to adopt showed that a respondents blockchain knowledge or the combined score of all constructs are an explanatory factor for the willingness to adopt. Statistical modelling with a binomial logistic regression approach gave the best results when using the combined average score of the constructs of relative advantage, observability, attitude toward the behaviour, trialability, complexity, compatibility, subjective norm, and perceived behavioural control. The model was shown to predict the willingness to adopt with 90% accuracy, while predicting the rejection to adopt with 87.5% accuracy. Unfortunately, due to a restrictive sample size the eight constructs could not be individually modelled.

In essence: The constructs of attitude toward the behaviour, subjective norm, observability, and complexity showed a significant linear correlation with the intention to adopt. The combined averaged score of all eight constructs of the Innovation Adoption mindset model were proven to be the best model to predict one's willingness to adopt blockchain traceability.

5.3 Result limitations

5.3.1 Construct validity testing failure and subsequent rationale

As described in 3.4.2.2, the Kaiser-Meyer-Olkin measure of sampling adequacy was conducted in paragraph 4.6 to determine if the data was fit for Exploratory Factor Analysis. The KMO-test returned a non-positive definite matrix, which means at least one of the eigenvalues was negative. The most probable cause of this error is a lack of data density, i.e. too few datapoints for the number of variables being included (Field, 2018). A considerable amount has been written about the required sample size for factor analysis. A common rule of thumb states that at least 10–15 participants per variable is recommended (Field, 2018). As this study used 36 individual items to anticipate the willingness to adopt, application of this rule would implicate the need for 360 to 540 survey participants. However, others state a more conservative response ratio. According to Habing having 5 times the amount of responses than having variables should be sufficient (Habing, 2003). This would still implicate the need for 180 survey respondents to conduct a meaningful exploratory factor analysis. The currently reached ratio of 1.7 respondents to 1 variable (61 respondents to 36 variables) is thus likely the cause of the non-positive definite matrix.

In an effort to return a positive definite matrix, missing values were replaced by the average value of the construct instead of being deleted listwise. Using this strategy KMO-test no longer encountered a negative eigenvalue and thus could be computed. The resulting KMO-value of 0.57 is categorized to be ''miserable'' (Kaiser & Rice, 1974). Even though this strategy returned a positive value, averaging is not recommended as it can greatly underestimate the variance which will impact subsequent correlation and covariance computations (Pituch & Stevens, 2015).

If prompted for continuation of the factor analysis, even though the data could be classified as being a miserable fit, the results would be misleading. Costello and Osborne examined the ratio of respondents to variables needed to produce correct factor structures. They concluded that only 10% of samples with a ratio of 2:1 formed the appropriate results when compared to the tested population (Costello & Osborne, 2005).

Because the composed questionnaire has not been field tested before, statistically testing the validity of the composed constructs was of importance. As the procured data failed to be fit for factor analysis no validity test was completed. Justifying the validity of the procured results thus remains limited to the extended use of survey questions that were based on previously conducted peer reviewed studies.

5.3.2 Sampling method

The used sampling method differs from the originally intended sampling process as previously outlined. As described in paragraph 4.1, the respective cooperatives were contacted, but were not interested in distributing the survey to their members. Alternatively, business e-mails were procured through internet search. This might have caused a coverage error as companies that do not have any online presence to be excluded from the sampling pool, causing more technologically savvy members of the population to have a higher sampling probability. As a very considerable proportion of the businesses had no online presence (Table 9), the sampling bias could have had a significant impact on the survey results. The voluntary nature of participation might also have had impact on the results. Voluntary response surveys are more inviting to people who maintain a strong opinion on the subject (Moore & Notz, 2017).

5.3.3 Reflecting on individual models

Due to a restrictive sample size the constructs of the theory of planned behaviour and the theory on the diffusion of innovations could not be individually modelled in a reliable manner. As such, only a combined score off all constructs were modelled to predict the willingness to adopt.

5.4 Further research

5.4.1 Building upon research results

Results signified that digital traceability systems give their users significantly more satisfaction than paper-based systems. Unfortunately, the cause of the significantly higher satisfaction was not identifiable because of a lack of complementary questionnaire items. Secondly, no comparable studies have been conducted regarding food traceability systems and their corresponding user experience. The reason why users of digital traceability systems rated their satisfaction significantly higher than their paper-based counterpart thus remains for further analysis.

5.4.2 Regarding result application and charting the entire supply chain

Of the seafood consumed in the European Union 54 percent is imported. Because this study limited itself to the Dutch fish industry only a small part of the seafood supply chain is explored. As fish is a global commodity research towards the willingness to adopt blockchain technology should preferably encompass the full supply chain and thus have an international focus. Addressing the willingness of the fish industry to adopt in a different location and business culture could therefore be of interest.

6 CONCLUSION

The main goal of this study was to assess the willingness to adopt a blockchain based traceability system among different actors in the fish industry. Of the 61 respondents, who were active in fisheries to retail, 29.5% indicated the intention to adopt blockchain traceability within the next five years. Of the respondents, 50.8% indicated to expect blockchain traceability to eventually be widely adopted in the industry.

Information about the current use and sentiment on paper, digital, and blockchain traceability systems was obtained. Of the 61 respondents 44% of the Dutch seafood industry currently employs a mix of paper-based and digital means to secure their food traceability requirements. 41% of the respondents say their business relies solely on a paper-based traceability system. The remaining 15% say that they use a digital traceability system. Unfortunately, no suitable sources could be retrieved that have profiled the usage of the different approaches to product traceability within the (sea)food sector. Furthermore, the results signified that digital traceability systems give their users significantly more satisfaction than paper-based systems.

The factors that resulted from this study could help blockchain marketers and traceability professionals to devise a better blockchain implementation program. Based on the conclusions of this study, practitioners should consider focusing on the constructs that had a significant correlation with the intention to adopt, which were: attitude towards the behaviour, subjective norm, observability, and complexity.

Of the seafood consumed in the European Union 54 percent is imported. Because this study limited itself to the Dutch fish industry only a small part of the seafood supply chain is explored. It remains for further research to conduct a total supply chain enveloping study with an international focus, as differences in the willingness to adopt blockchain traceability at different locations or cultural backgrounds could impact the potential of the innovation.

Furthermore, results signified that digital traceability systems give their users significantly more satisfaction than paper-based systems. Unfortunately, the cause of the significantly higher satisfaction was not identifiable because of a lack of complementary questionnaire items. The reason why users of digital traceability systems rated their satisfaction significantly higher than their paper-based counterpart thus remains for further analysis.

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APPENDIX A: SURVEY INVITATION EMAIL, PREFACE & QUESTIONS

This appendix gives an entire overview of communication towards (potential) participants of the survey. The communication can be partitioned in three different sections:

- Part 1: The e-mail sent to potential participants (Figure A1 & A2).
- Part 2: Once the link to the survey was opened the questions were prefaced by a general introduction on blockchain traceability (Figure B).
- Part 3: The questions of the survey started right below the preface:
    - Table A contains all questions regarding demographics.
    - Table B contains all questions regarding Ajzen's Theory of Planned Behaviour and the Intention to Adopt.
    - Table C contains all questions regarding Roger's theory of Diffusion of Innovations.

From : Alex Mors <alex.mors@wur.nl>
Subject : Bent u klaar voor het gebruik van Blockchain traceerbaarheid in de Nederlandse visketen?

WAGENINGEN
UNIVERSITY & RESEARCH

100years
1918 — 2018

Wat is uw mening over het traceren van vis met Blockchain technologie?

Voor mijn scriptie aan de Wageningen Universiteit doe ik onderzoek naar de bereidheid van de Nederlandse visketen om Blockchain technologie toe te passen in hun traceersysteem. Hiervoor ben ik geïnteresseerd in uw mening over deze nieuwe technologie. U zou mij enorm kunnen helpen met het invullen van deze vragenlijst!

De gegevens zullen gebruikt worden om de huidige stemming ten opzichte van Blockchain traceerbaarheid te peilen. De gevonden knel- en pluspunten kunnen steun bieden aan bedrijven om tot een beter implementatieplan te komen.

Op het eind van de vragenlijst kunt u aangeven of u een samenvatting van de resultaten wilt ontvangen, tevens kunt u kans maken op een Bol.com tegoedbon ter waarde van €100.

Naar de vragenlijst

Nog niet bekend met Blockchain technologie als nieuw traceersysteem? Dat is niet erg! In het begin van de vragenlijst staat een korte beschrijving klaar. Bij verdere vragen mag u contact met mij opnemen.

Alle informatie wordt vertrouwelijk behandeld en kan niet worden herleid tot individuele bedrijven of personen.

Alvast hartelijk dank voor uw medewerking!

Met vriendelijke groet,
Alex Mors
MSc Food Safety Student
Wageningen University & Research
Alex.Mors@wur.nl

PS: Werkt de blauwe knop niet? Dan kunt u gebruik maken van onderstaande link:
https://www.surveygizmo.eu/s3/90213184/WUR-Adoptie-van-Blockchain-techniek-in-traceersystemen-van-de-Nederlandse-visketen-1-3

Figure A1. Invitational e-mail. Part 1 of 2.

Voorbeelden van Blockchain traceerbaarheid

Diepzeeheek traceren met Blockchain

Benieuwd hoe traceer informatie voor de eindconsument eruit kan komen te zien met Blockchain technologie? Dat kan! Zie hier een voorbeeld van Antarctische diepzeeheek gevangen nabij Antarctica

Naar het voorbeeld

Sinaasappelsap op de Blockchain

Een voorbeeld dichter bij huis? Albert Heijn heeft zijn sinaasappelsap op de Blockchain gezet

Naar het voorbeeld

Naar de vragenlijst

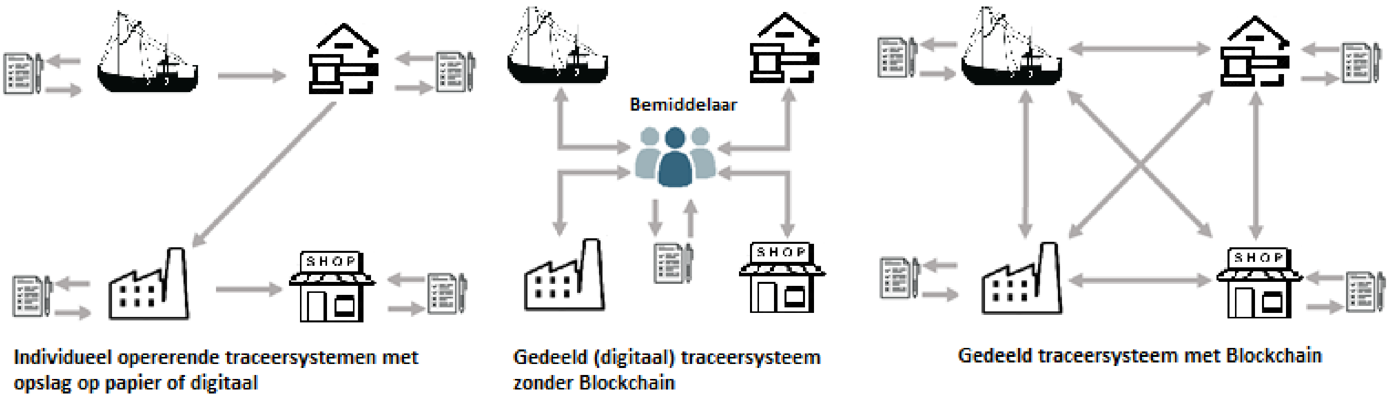
View in browser

This email was sent to {{ contact.EMAIL }}, zoals vermeld staat op uw website

Figure A2. Invitational e-mail. Part 2 of 2.

Informatie: Traceerbaarheid en blockchain

Blockchain technologie, u heeft er misschien wel eens van gehoord in relatie met de digitale munt Bitcoin. Maar wist u dat deze technologie ook nieuwe mogelijkheden biedt als traceersysteem voor voedingsmiddelen?



Een blockchain is een gedeelde database waar geen bemiddelende partij aan te pas komt, maar waar iedere deelnemer in het netwerk een kopie bezit van een constant geüpdatete database. In onderstaand figuur staan de verschillen tussen de drie methoden van traceersystemen weergegeven.

- Traceerinformatie op een blockchain systeem kan, anders dan op papier of digitaal, niet meer verwijderd of veranderd worden. Dit zou fraude kunnen reduceren.
- Doordat een blockchain systeem in verbinding staat met (een deel van) de vervolg schakels kan de herkomst en huidige eigenaar van een product binnen enkele seconden vastgesteld worden. Dit zou het productieproces kunnen stroomlijnen en recalls vergemakkelijken. Tevens krijgen vroege schakels in de keten inzicht in waar hun product uiteindelijk belandt. Deze informatie kan afgeschermd worden voor onbevoegden.
- Een op blockchain technologie gebaseerd traceersysteem benodigd een gedeelde administratie op vlak van track en trace gegevens met andere schakels in de keten om tot zijn recht te komen. Het opzetten van een dergelijke samenwerking vergt de nodige inspanning.
- Het opzetten van een blockchain systeem vergt meer kennis/geld/inspanning dan bijvoorbeeld een op papier gebaseerd traceersysteem.
- Als bijkomend gevolg van een gedeelde database van traceergegevens kan er effectief gekeken worden naar het stroomlijnen van de gehele keten. In seconden kan ingezien hoe lang het product zich in transport processen bevindt. Ook certificaten zouden veilig en gemakkelijk beheerd en ingezien kunnen worden. Met een directe link naar huidige en gearchiveerde certificaten.

Figure B. Survey preface (In Dutch)

Table A. Survey questions regarding Demographics

Demographics (DMG)		
DMG1	Mijn bedrijf wordt het best omschreven als	A. Kwekerij B. Visserij C. Visverwerker D. Visveiling E. Visgroothandel F. Detailhandel G. Anders…
DMG2	Heeft u vóór het ontvangen van deze vragenlijst kennisgenomen van een traceersysteem op basis van blockchain technologie?	A. Ja, ik heb mij erin verdiept B. Ja, ik heb er wel eens over gehoord C. Nee
DMG3	Wat kenmerkt het huidige traceersysteem van uw bedrijf?	A. Bestaat voornamelijk op papier B. Bestaat voornamelijk digitaal C. Bestaat uit een mix van papier en digitaal D. Wij werken voor een deel van onze producten met een blockchain systeem E. Wij werken met een volledig blockchain systeem
DMG4	Hoe tevreden bent u over het huidige traceersysteem van uw bedrijf?	A. Zeer tevreden B. Tevreden C. Neutraal D. Ontevreden E. Zeer ontevreden
DMG5	Bent u in de positie om invloed uit te oefenen op het traceersysteem beleid van uw bedrijf?	A. Ja B. Misschien C. Nee D. Weet ik niet
DMG6	Wat is uw geslacht?	A. Man B. Vrouw
DMG7	Wat is uw hoogst behaalde onderwijsniveau?	A. Basisonderwijs B. Vmbo C. Mbo D. Havo, vwo E. Hbo-, wo-bachelor F. Wo-master, doctor G. Anders…

Table B. Survey questions regarding Ajzen's Theory of Planned Behaviour and the Intention to Adopt. Reverse scored items are marked with an underlining of the variable name.

Construct	Likert item	Adapted from
Intention to adopt (ITA)		
ITA1	Het is de intentie van ons bedrijf om binnen vijf jaar met een blockchain traceersysteem te werken	
ITA2	Ik denk dat blockchain technologie op termijn breed geadopteerd gaat worden in de visketen	
Attitude toward the behaviour (ATT)		
ATT1	Naar mijn mening is het wenselijk om blockchain technologie als een traceersysteem te gebruiken	
ATT2	Ik denk dat het goed zou zijn voor de gehele visketen om blockchain traceersystemen te gebruiken	
<u>ATT3</u>	Ik denk dat het gebruik van een blockchain traceersysteem een slecht idee is	(Kamble, Gunasekaran, & Arha, 2019)
ATT4	Over het algemeen is mijn houding ten opzichte van blockchain traceersystemen gunstig	
ATT5	Ik zal mij gelukkig voelen als mijn bedrijf een blockchain traceersysteem implementeert	
Perceived behavioural control (PBC)		
PBC1	Ons bedrijf zou een blockchain traceerbaarheidssysteem vol kunnen benutten	
PBC2	Het feit of mijn bedrijf wel of geen blockchain traceerbaarheid zou toepassen in de toekomst ligt volledig in onze eigen handen	(Kamble, Gunasekaran, & Arha, 2019)
PBC3	Ons bedrijf heeft voldoende kennis in huis om een blockchain traceerbaarheidssysteem op te zetten	
PBC4	Ons bedrijf heeft het financieel vermogen om een blockchain traceerbaarheidssysteem op te zetten	
Subjective norm (SBN)		
SBN1	Het gebruik van een blockchain traceersysteem zou het imago van mijn bedrijf verbeteren	(Moore & Benbasat, 1991)
SBN2	De meeste van mijn collega's en keten partners verwachten van mijn bedrijf dat we blockchain traceerbaarheid zullen gaan toepassen	
SBN3	Mensen wiens mening ik waardeer geven er de voorkeur aan dat mijn bedrijf een blockchain traceersysteem zal gaan gebruikt	(Kamble, Gunasekaran, & Arha, 2019)
SBN4	Als mijn concurrentie het gebruik van een blockchain systeem zou onderzoeken zet dat druk op mijn bedrijf om hetzelfde te doen	
<u>SBN5</u>	Ik schat de samenwerkingsbereidheid van andere bedrijven in mijn keten bij het opzetten van een gezamenlijk blockchain systeem laag in	

Table C. Survey questions regarding Roger's theory of Diffusion of Innovations. Reverse scored items are marked with an underlining of the variable name.

Construct	Likert item	Adapted from
Relative advantage (RLA)		
RLA1	Met een blockchain systeem zou ik mijn werk sneller kunnen uitvoeren	(Moore & Benbasat, 1991)
RLA2	Over het algemeen verwacht ik dat het gebruik van een blockchain systeem bevorderlijk is voor mijn werk	
RLA3	Ik verwacht dat het gebruik van een blockchain traceersysteem mijn productiviteit zal verhogen	
<u>RLA4</u>	Ik denk dat ons bedrijf er met een blockchain traceersysteem er op achteruit gaat ten opzichte van ons huidige traceersysteem	
Observability (OBS)		
OBS1	Ik zou anderen duidelijk kunnen vertellen welke resultaten zij kunnen verwachten met een blockchain traceerbaarheidssysteem	(Moore & Benbasat, 1991)
OBS2	Ik zou anderen duidelijk kunnen vertellen wat de consequenties zijn van het gebruik van een blockchain traceerbaarheidssysteem	
OBS3	De resultaten die geboekt kunnen worden met een blockchain traceerbaarheidssysteem zijn duidelijk voor mij	
<u>OBS4</u>	Ik zou moeite hebben om uit te leggen waarom het gebruik van een blockchain systeem al dan niet nuttig kan zijn	
OBS5	Ik denk dat de resultaten die geboekt kunnen worden met blockchain traceerbaarheid inzichtelijk te maken zijn voor andere bedrijven in de visketen	
Trialability (TRL)		
TRL1	Mijn bedrijf weet bij wie het te rade kan om meer informatie te ontvangen over blockchain traceerbaarheid	(Moore & Benbasat, 1991)
TRL2	Mijn bedrijf zou blockchain traceerbaarheid lang genoeg willen testen om te ondervinden wat het voor ons kan doen	
TRL3	Mijn bedrijf zou niet veel te verliezen hebben mochten wij blockchain traceerbaarheid met onbevredigende resultaten uitgetest hebben	(Atkinson, 2007)
TRL4	Ik vind het belangrijk dat mijn huidige traceersysteem tijdelijk kan blijven draaien naast een blockchain systeem voordat ik definitief de overstap overweeg	
Complexity (CLX)		
<u>CLX1</u>	Ik denk dat blockchain traceerbaarheid omslachtig is in het gebruik	(Moore & Benbasat, 1991)
CLX2	Over het algemeen denk ik dat blockchain traceerbaarheid gemakkelijk in gebruik is	
CLX3	Ik verwacht dat blockchain traceerbaarheid gemakkelijk in gebruik is in vergelijking met ons huidige traceersysteem	(Kamble, Gunasekaran, & Arha, 2019)
CLX4	Ik denk dat het dagelijks gebruik van blockchain traceerbaarheid mij makkelijk af zou gaan	
Compatibility (CTB)		
CTB1	Ik verwacht dat het gebruik van een blockchain systeem goed te combineren is met alle aspecten van mijn werk	(Moore & Benbasat, 1991)

CTB2	Ik denk dat een blockchain systeem goed past binnen de manier waarop ik het liefst werk	
CTB3	Ik ben een van de eerste toe toehapt als er nieuwe innovaties toepasbaar zijn in mijn werkgebied	(Al-Jabri & Sohail, 2012)
CTB4	Om blockchain traceerbaarheid in te voeren denk ik dat er veel veranderingen in de huidige bedrijfscultuur moeten plaatsvinden	
CTB5	Aanpassingen in mijn traceersysteem hebben mij in het verleden geen goed gedaan	