LANDTECHNIK 74(4), 2019, 81–97

DOI:10.15150/lt.2019.3210

LANDTECHNIK
AGRICULTURAL ENGINEERING

Acceptance and usage of navigation software by agricultural contractors – an application of the technology acceptance model

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Literature about the adoption of navigation systems of agricultural contractors is scarce. Based on an online survey with 134 German agricultural contractors, a technology acceptance model (TAM) was applied to the usage and acceptance of navigation systems. The TAM was estimated using partial least squares structural equation modeling and was based on the navigation software Whats3Words. Furthermore, we collected information about agricultural contractors' satisfaction with navigation software currently available. Agricultural contractors are partly satisfied with the navigation software currently available. They wish to receive information about bridge clearances and weight restrictions via the navigation software. This article is of interest for agricultural contractors, developers of navigation software as well as researchers in the field of logistics.

Keywords
Agricultural contractors, navigation software, partial least squares structural equation modelling, technology acceptance model, What3Words

Agricultural contractors are service providers for farmers. In 2016, 3,400 agricultural contractors with 18,500 permanent employees and 18,500 temporary employees generated a turnover of € 3.5 billion in Germany; € 2.3 billion explicitly for agricultural and forestry purposes. The German Farmers' Federation expected that the turnover would increase to € 3.6 billion in 2017 (DBV 2018). The increasing investment cost for agricultural machinery forces investors to offer services for other farmers in order to keep the deployment of the machinery rentable. Moreover due to an increase in farm sizes, distances between the fields as well as farms and fields are increasing too. Likewise the demands for an efficient agricultural logistical system are increasing (Mederle et al. 2015, Bernhardt et al. 2018, Götz et al. 2011). Most crucial, transportation costs are of one the most important factors in the agricultural enterprises (Gaese et al. 2013).

Agricultural logistic differs from general logistic with cars and trucks. Thus, technological innovations of the general transport logistic cannot be applied in agriculture. In the general transport logistics starting and endpoints are well defined, while harvest machinery is in a steady movement on the field as well as between different fields. Moreover, vehicles for the agricultural logistic have to be capable of driving on the field and on the road. Furthermore with respect to heavy agricultural machinery like combine harvesters, weight and height limitations play a central role. The Federal Ministry of Transport and Digital Infrastructure (BMVI 2018) also emphasizes that conventional navigations systems do not consider the special features of the rural areas and are therefore not applicable in agricultural logistics. Nevertheless, common goals in general transport logistics as well as agricultural

received 14 January 2019 | accepted 13 June 2019 | published 16 August 2019

logistics are to reduce transaction and transportation costs and to increase profitability and efficiency of transportation (Lamsal et al. 2016, Heizinger and Bernhardt 2011, Götz et al. 2014, Götz et al. 2011).

Existing studies mainly rely on computer models to increase the performance of logistics (e. g.Ebadian et al. 2011, Amiama et al. 2015, Springael et al. 2018). Only a few studies have yet paid attention to the operators of navigation systems. For instance, Perdana (2012) showed that dealers of agricultural products expect that navigation software solutions increase the profitability in logistics. Yet, no study has paid attention to which features in navigations systems are explicitly missed and if the operators are satisfied by the systems currently available. Furthermore, agricultural contractor are seen as important investors in precision agricultural technologies and users of navigation systems but were less in focus up until now (Fountas et al. 2005, Kutter et al. 2011, Reichardt et al. 2009).

The individuals' attitudes and beliefs about technology also play a central role in decision making (e. g. Austin et al. 1998) as the decision about adopting does not only depend on economic reasoning. The Technology Acceptance Model (TAM) is the most applied model to study acceptance and adoption of a technology (Verma and Sinha 2018). The TAM proposed that an individuals' intention to use a technology (IU) is influenced by the key latent constructs perceived usefulness (PU) and perceived ease of use (PEOU), which are measured by directly observable indicators. IU in the TAM is the well-established predictor of the actual adoption decision (Davis 1989). Nevertheless, the TAM has not been applied in the field of logistics in general and for the adoption of navigation systems by agricultural contractors in specific.

The aim of this article is therefore to close this research gap by investigating the acceptance and use of navigation systems by agricultural contractors after applying a modified TAM for this field of research. Furthermore, the study aims to evaluate the operators' satisfaction with current navigation systems. The article adds to the literature as follows: This is the first article extending the TAM to navigation systems and focusing thereby on agricultural contractors. In general, this is first article to extend the application of the TAM to the fields of logistics. Therefore this article is of interest for agricultural contractors, developers and providers of navigation systems as well as researchers in the field of logistics. The evaluation of the TAM is based on the Software Whats3Word (W3W) which can be installed on smartphones and tablets. W3W is available free of charge and is able to navigate precisely the location of fields and field entrances in rural areas and therefore a suitable representative of navigation software which takes specific characteristics of rural areas into account. The article is based on an online survey with 134 agricultural contractors in Germany.

The remainder of the article is structured as follows: the hypotheses for the modified TAM are derived in the next section. The following section presents the applied material and methods followed by the discussion of the results. The article closes with concluding remarks.

Literature and hypotheses generation

Navigation systems can assist contractors in reducing transaction and transport costs. While economic reasoning is an important driver of adoption decisions, literature in the field of farmers' decision making shows that economics reasoning is not the only factor for innovation adoption (Mzoughi 2011, Vanclay and Lawrence 1994). Attitudes and beliefs of a decision maker play also a central role in the decision process (e.g. Austin et al. 1998). The TAM is based on the Theory of Reasoned Action (TRA) which proposes that the attitude of an individual plays a central role for their actual behavior (Fishbein and Ajzen 1975). The TAM, as an extension of the TRA is the most applied model for the adoption and use of a technology (Verma and Sinha 2018; for an overview of studies applying the TAM see Maranguni and Grani 2015). The TAM for the intention to use navigations system by agricultural contractors is displayed in Figure 1 and will be explained in the following.

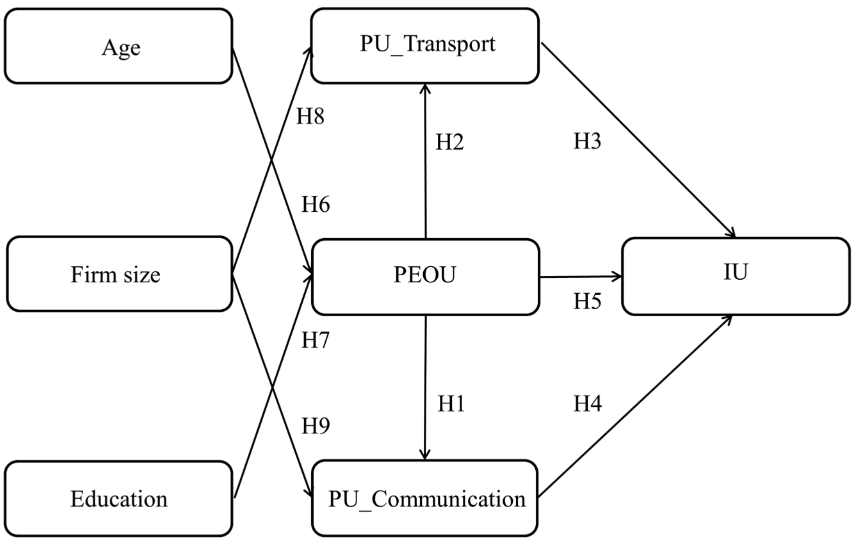

Figure 1: Structural equation model and presentation of hypotheses

PEOU = Perceived ease of use, PU_Transport = Perceived usefulness to reduce transport cost, PU_Communication = Perceived usefulness to improve communication, IU = Intention to use

In the TAM, the IU technology depends on the key constructs PU and PEOU. PU is defined as the degree an individual thinks technology is useful for their job performance. The IU is positively influenced by the PU, since the higher the PU the higher is the IU, ceteris paribus (Davis 1989). Aubert et al. (2012) showed the cost reduction is of great importance in agriculture. Likewise, incentives to reduce cost also occur for transportation in agriculture (Lauer and Zipf 2010) since an effective navigation system can aid reducing cost for fuel (Heizinger et al. 2016). Increasing numbers of customers and distance to customers decrease local knowledge of agricultural contractors in their job areas. Navigation systems can offset missing local knowledge and therefore reduce transport costs. Thus, we assume that PU of reducing transport costs (PU_Transport) has a positive effect on IU for navigation, ceteris paribus.

Fecke et al. (2018) showed that farmers expect to communicate in the near futures via cloud services as well as smartphone and tablet apps with agricultural contractors to transmit location of the fields. Improved communication can also help to improve production processes (Kumar and Zahn

2003). Thus, if the location of interest can be easily transmitted to the navigation system or target coordinates, it can be easily retrieved with the navigation system and communicated to a third party; the study assumes that the perceived usefulness to improve communication (PU_Communicatin) between customers and agricultural contracts has a positive effect on the IU for navigation, ceteris paribus. PEOU refers to the extent an individual believes using a technology is more or less effortless. PEOU has a positive effect on IU, since the easier a technology is in use, the higher is the IU, ceteris paribus. Moreover, PEOU has a positive effect on PU, since the easier a technology is in use; the higher is the PU, ceteris paribus (Davis 1989). Consequently, we assume the easier a navigation system is to use, the higher the PU_Transport and PU_Communication is. The following hypotheses represent the proposed relationships:

H1: PEOU has a positive effect on PU_Communication
H2: PEOU has a positive effect on PU_Tranport
H3: PU_Transport has a positive effect on IU for navigation
H4: PU_Communication has positive effect on IU for navigation
H5: PEOU has a positive effect on IU for navigation

The TAM can be extended with several exogenous variables which can have an effect on the key constructs PEOU and PU. One of the main drivers of technology adoption is the age of an individual (Ghadim and Pannell 1999). Younger farmers are more accustomed to digital technologies (Rose et al. 2016). Therefore we assume that also younger agricultural contractors perceive using an innovative navigation system more effortless than their older colleagues. Education enables an individual to decode information faster and take better advantage of information (Nelson and Phelps 1966). With respect to the adoption of computers in agriculture, Amponsah (1995) showed that more educated farmers perceive handling a computer more easily than farmers with a lower level of education. We therefore assume that the age and education of an agricultural contractor influence PEOU as also shown by the following hypotheses:

H6: Age has a negative effect on PEOU
H7: Education has positive effect on PEOU

Daberkow and McBride (2003) showed that farm size is positively associated with the adoption of precision agriculture technologies since larger farms are considered to be more innovative and also can bear high investments costs due to economies of scale (Fountas et al. 2005, Kutter et al. 2011). With respect to firm size of an agricultural contractor, it can be assumed that with an increase in the number of customers and employees, the demand for an effective management is increasing too. Furthermore, a larger number of customers also imply higher distances to the fields. If a customer can easily transmit the location of the field to the agricultural contractor, it is likely that the agricultural contractor will be able to reduce transportation costs. Consequently, we assume that larger agricultural contractors are mostly likely to benefit from using a navigation system which can facilitate communication with the customer and therefore helps to reduce transport and transaction costs. Thus, firm size has a positive effect on PU_Communiation and PU_Transportation as shown in the hypotheses below:

H8: Firm size has a positive effect on PU_Transport
H9: Firm size has a positive effect on PU_Communication

Material and methods

An online survey was conducted from June to October 2018 with German agricultural contractors. The agricultural contractors were contacted via an e-mail distribution list from the Federal Association of German Agricultural Contractor (BLU e. V.). After the removing all uncompleted surveys, 134 fully answered surveyed remained for this study.

The survey was divided into three parts. In the first part of the survey, the software W3W was explained to the participants. In the second part of the survey, the participants were asked to indicate their approval to 14 random statements. Their approval measured on an equally spaced 5-Point Likert scale (1 = high disagreement; 5 = high agreement). The statements are shown in Table 1. The wording was adapted from Davis (1989) as well as Venkatesh and Davis (2000), but was changed to fit this field of research. In the second part of the survey, agricultural contractors were asked to indicate problems performing their tasks. Moreover, participants were asked for information about applied navigation systems and how satisfied they were with their use. In the final stage of the second part, agricultural contractors were asked which features they miss in navigation systems. The third part contained questions regarding socio-demographic and firm characteristics.

W3W is a geocoding system for the communication of locations. The world is divided into a grid of 3 m x 3m. Every square is assigned by one unique 3 word address. The app is available in 26 languages and can be installed on smartphones and tablets for free. The app can connect for instance to Google Maps and uses the unique 3 word address to guide an individual to the desired location. Furthermore, locations can be shared via messenger services (Jiang and Stefanakis 2018, What3Words 2018). Figure 2 shows the address system of W3W.

Figure 2: Representation of the address system via the W3W app. The shown field entry has the address „studied.rotate.cohorts“

The app was chosen as a representative for navigation software that is able to consider characteristics of rural areas since for instance; a field entrance can be precisely located with its 3 word address as shown in Figure 2. Moreover, locations can be shared very easily with this app. Furthermore, this app was chosen as it was assumed that not all respondents knew a specific navigation system. By choosing W3W which is a relatively new app, it was assumed that all of the respondents did not know this app; only 3% of participants (5 agricultural contractors) in our sample knew the W3W app before the survey. Therefore, it was believed that all respondents had the same knowledge answering the survey after reading the introduction to the software W3W. Furthermore Fecke et al. (2018) as well as Bonke et al. (2018) showed that a large share of German farmers use a tablet or smartphone for business purposes. Moreover, Fecke et al. (2018) provided evidence that farmers expect to communicate more often in the future via apps and cloud services with agricultural contractors. Thus, usage of W3W can be described as valid for the research purpose. Respondents were informed that the survey was conducted without any financial affiliations to the software W3W.

Table 1: Presentation of the statements and the associated indicators and constructs

Construct	Indicator	Statement
IU		
	iu1	I think I will use a navigation system like W3W in the future.
	iu2	I could well image to integrate a navigation system like W3W into my business.
PEOU		
	peou1	Handling a navigation system like W3W seems easy to me.
	peou2	I think it would be easy for me to learn how to use a navigation system like W3W.
	peou3	A navigation system like W3W would be an easy to use system for the development of the route plan and communication.
	peou4	Learning how to use a navigation system like W3W would be no problem for me.
PU_Transport		
	pu_t1	Usage of a navigation system like W3W could improve designing the route maps for my business.
	pu_t2	Usage of a navigation system like W3W could help to avoid unnecessary ways.
	pu_t3	Usage of a navigation system like W3W could help to reduce transportation costs with improved route plans.
	pu_t4	Usage of a navigation system like W3W could help to improve the organization of the jobs in my business.
PU_Communication		
	pu_k1	Usage of a navigation system like W3W could help my employees and colleagues to gain fast local knowledge.
	pu_k2	Usage of a navigation system like W3W could help to improve the communication with my customers.
	pu_k3	Using a navigation system like W3W could help to improve the communication with respect to the site-specific problems in the field like wet zones.
	pu_k4	Usage of a navigation system like W3W could help to reduce miscommunication between customers and employees/colleagues of our business

PEOU = perceived ease of use, PU_Transport = Perceived usefulness to reduce transport cost, PU_Communication = Perceived usefulness to improve communication, IU = Intention to use

Results

In the following, the results of the survey will be presented. The next section contains the descriptive results. Evaluation results of the TAM are presented in the last part of the results section.

Descriptive statistics

Table 2 shows the descriptive statistics of the sample. The average respondent is 35 years old. On average the agricultural contractors have 13 employees, 133 customers and 11 tractors. Most of the respondents in the sample have a university degree (26%). 94% of the respondents in the sample are male and 52% of the respondents are the business manager. Lastly, 54% of the respondents in the sample are also engaged in farming activities besides their duties as an agricultural contractor.

Table 2: Descriptive statistics of the results of the online survey among German contractors (n = 134)

Variable	Description	Mean	Standard deviation	Min	Max
Age	Age in years	35.00	12.49	19	65
Education	1, if the respondent finished an agricultural apprenticeship; 0 otherwise	0.16	-	0	1
	1, if the respondent finished an agricultural master apprenticeship; 0 otherwise	0.09	-	0	1
	1, if the respondent received a degree from an technical college; 0 otherwise	0.12	-	0	1
	1, if the respondent received a university degree; 0 otherwise	0.26	-	0	1
	1, if the respondent finished an agricultural service apprenticeship; 0 otherwise	0.04	-	0	1
	1, if the respondent finished an agricultural service master; 0 otherwise	0.13	-	0	1
	Other	0.20	-	0	1
Gender	1, if the respondent is male; 0 otherwise	0.94	-	0	1
Farm Business	1, if the respondent is engaged in farming besides his duty as an agricultural contractor; otherwise 0	0.54	-	0	1
Customer	Number of customers	132.92	130.97	1	600
Staff	Number of employees	13.34	16.03	0	99
Position	1, if the respondent is the business manager; otherwise 0	0.52	-	0	1
	1, if the respondent is an employee; otherwise 0	0.34	-	0	1
	1, if the respondent has another position in the business; otherwise 0	0.14	-	0	1
Tractors	Number of tractors	10.78	8.99	1	50

91% of the agricultural contractors are responsible for jobs with respect to the harvest. Moreover, the most stated jobs are the application of organic fertilizer (78%), sowing (72%) and soil cultivation (66%). The results are also shown in Figure 3.

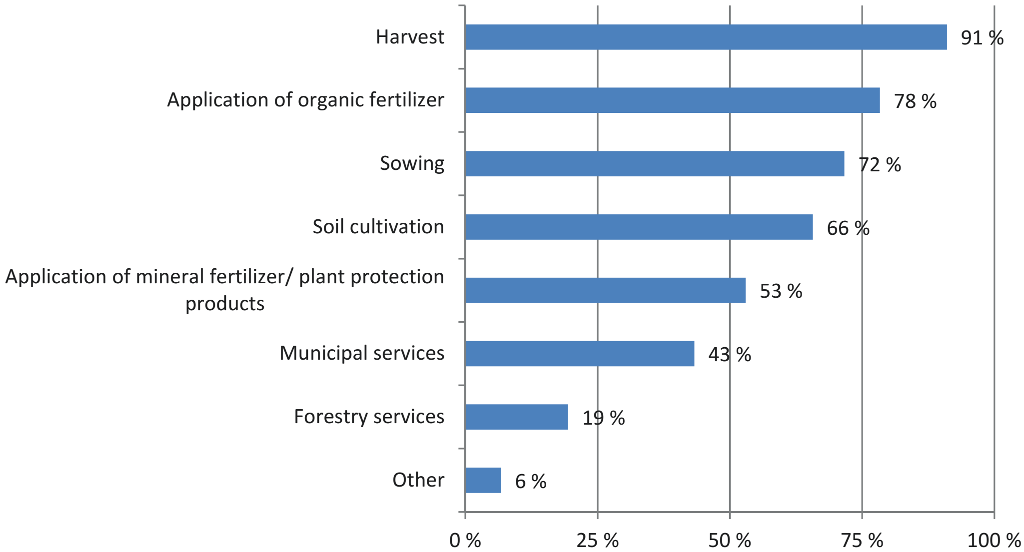

Figure 3: Important fields of activity based on the online survey of German contractors
(n = 134; note: multiple answers were possible)

Figure 4 shows the current applied navigation systems used by the agricultural contractors. 87% of the agricultural contractors use a navigation system. Google Maps is used by 74% and Apple Maps by 19%. Thus, most of the agricultural contractors use software which is free of charge. Moreover, Figure 5 shows that half of the agricultural contractors in this sample are partly satisfied with their current applied navigation system. Nevertheless, 40% of the agricultural contractors are satisfied or very satisfied (11% very satisfied; 29% satisfied).

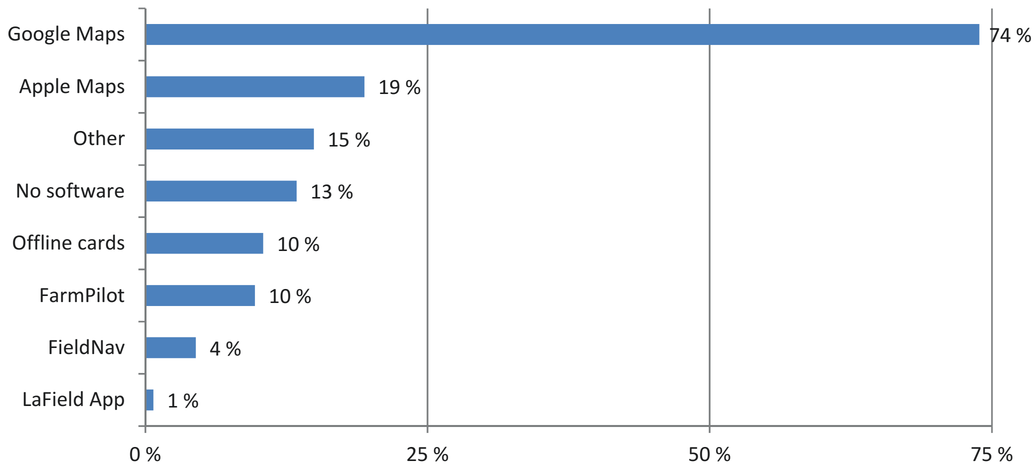

Figure 4: Navigation software used based on the online survey of German contractors
(n = 134; note: multiple answers were possible)

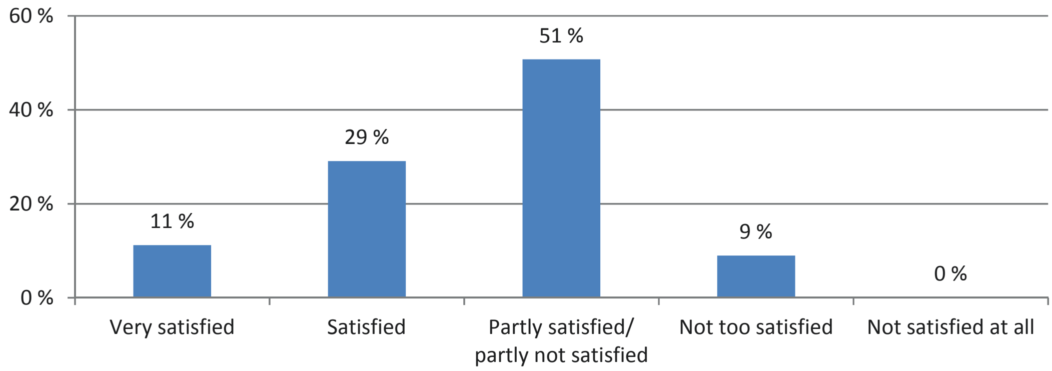

Figure 5: Satisfaction with the navigation software offered based on the online survey of German contractors (n = 134; 5 points Likert scale, 1 = very satisfied; 5 = very dissatisfied)

Figure 6 provides information about problems which occurred during job performance as an agricultural contractor. 72% of the agricultural contractors stated that finding the correct field or unnecessary ways due to missing knowledge is a problem. Moreover, 57% named location of the correct field access as a problem.

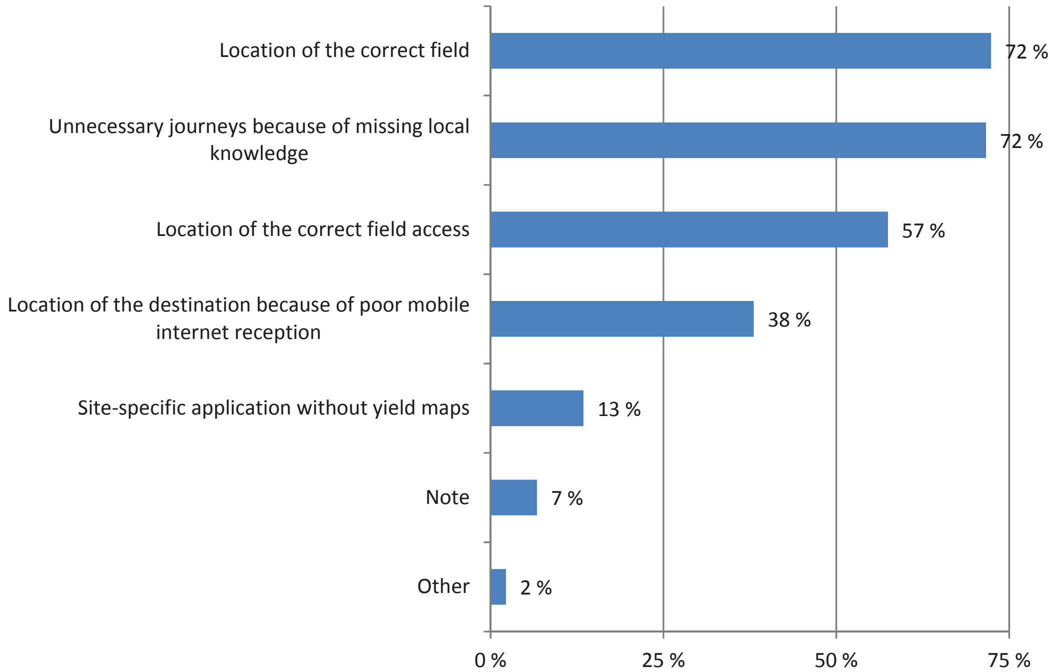

Figure 6: Problems in carrying out activities based on the online survey of German contractors (n =134; note: multiple answers were possible)

Figure 7 shows the requested function in navigation systems. Agricultural contractors wish to receive information about bridge clearances and weight restrictions. Moreover, road width should be accessible in the navigation system.

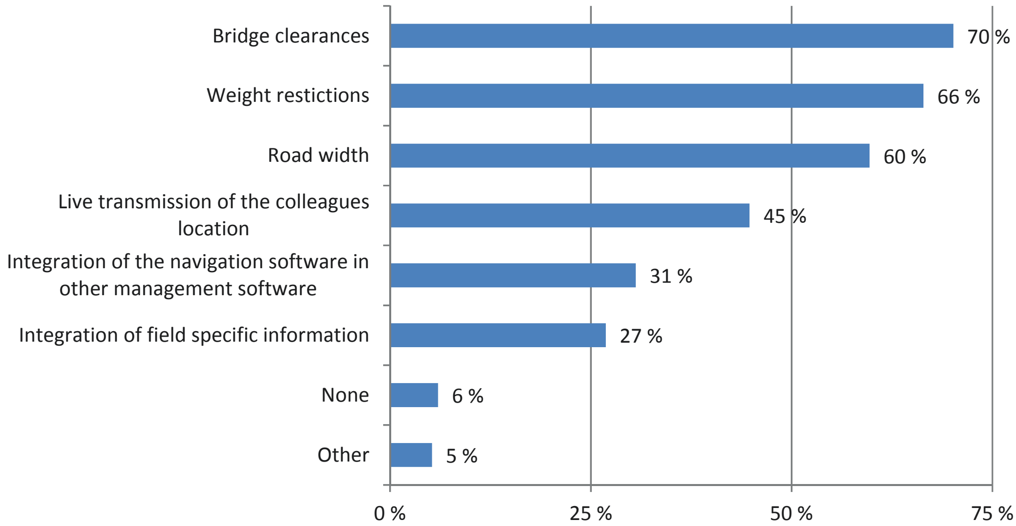

Figure 7: Desired features in navigation software based on the online survey of German contractors (n = 134; note: multiple answers were possible)

Evaluation of the technology acceptance model

For the estimation of the TAM the variance-based PLS structural equation modelling techniques was applied. The PLS approach is less restrictive than covariance-based estimation techniques. PLS structural equation modelling is the simultaneous estimation of an inner and outer model. The outer model estimates the relationship between indicators and constructs and the inner model the relationship between the constructs (Hair et al. 2016). All indicators in a TAM and single indicators are estimated as reflective indicators (Venkatesh and Bala 2008). Firm size is estimated as a formative construct following Schaak and Musshoff (2018). The formative construct is based on number of employees and customers. Evaluation of inner and outer model is based on several quality criteria. The path-coefficients and respective t-statistics were estimated using a bootstrapping approach (Hair et al. 2016). The model was estimated using SmartPLS 3 (Ringle et al. 2015).

The first step contains the estimation of the relationship between indicators and constructs. The estimation results for the outer model are shown in Table 3 and 4. The applied quality criteria are the indicator reliability, internal consistency, convergent reliability as well as discriminant validity via the indicator loadings, Cronbach's α, Dillon-Goldstein's ρ_c, Dijkstra-Henseler's ρ_α and the average variance extracted (AVE). Discriminant validity is established with the Heterotrait-Monotrait (HTMT) criteria. Cut-off levels for Cronbach's α, Dillon-Goldstein's ρ_c and Dijkstra-Henseler's ρ_α are a value of 0.7. AVE should be above a value of 0.5 (Hair et al. 2016). All quality criteria are approved by the model used. Furthermore, HTMT ratios between the constructs should be below 0.85 which also holds true for the model used (Hair et al. 2016). Therefore, the validity of the outer model is given.

Table 3: Evaluation results of the external model on the basis of the online survey of German contractors (n = 134)

Construct	Indicator	Loading	Cronbach's α	Dillon-Goldstein's ρ_c	Dijkstra-Henseler's ρ_α	AVE
IU			0.841	0.926	0.842	0.863
	iu1	0.930***				
	iu2	0.928***				
PEOU			0.775	0.853	0.782	0.593
	peou1	0.803***				
	peou2	0.786***				
	peou3	0.726***				
	peou4	0.762***				
PU_Transport			0.846	0.896	0.854	0.684
	pu_t1	0.800***				
	pu_t2	0.869***				
	pu_t3	0.821***				
	pu_t4	0.816***				
PU_Communication[1)]			0.800	0.882	0.821	0.713
	pu_k2	0.812***				
	pu_k3	0.836***				
	pu_k4	0.885***				
Firm size[2)]			-	-	-	-
	Number of employees	0.843**				
	Number of customers	0.790**				

PEOU = Perceived ease of use, PU_Transport = Perceived usefulness to reduce transport cost, PU_Communication = Perceived usefulness to improve communication, IU = Intention to use
Cut-off level for indicator loadings > 0,7; Cronbach's α > 0,7; Dillon-Goldstein's ρ_c > 0,7; Dijkstra-Henseler's ρ_α > 0,7; AVE > 0,5
*(**,***) means p < 0,1 (p < 0.05, p < 0.01)

[1)] Indicator pu_k1 is removed, because the indicator loading is below 0.7.
[2)] Formative construct.

Table 4: Discriminant validity of the external model - Results of the HTMT criterion based on the online survey for German contractors (n = 134)

	IU	PEOU	PU_Communication	PU_Transport
IU				
PEOU	0.397			
PU_Communication	0.554	0.603		
PU_Transport	0.637	0.665	0.762	

PEOU = Perceived ease of use, PU_Transport = Perceived usefulness to reduce transport cost, PU_Communication = Perceived usefulness to improve communication, IU = Intention to use
Cut-off level for the HTMT-criterion < 0.9

In the second step, the quality of the inner model is evaluated (Table 5) and the path coefficients between the constructs and respective t-statistics are estimated (Table 6) and evaluated. Explained variance of the endogenous constructs (R^2) should exceed a value of 0.1 and the predictive relevance (Q^2) should have a value above 0 (Hair et al. 2016). R^2 for the construct IU has a value of 0.318, which can be described as satisfying. Therefore, the model explains 32% of the variance in the construct IU. Furthermore, R2 amounts to 0.330, 0.271 and 0.157 for the constructs PU_Transport, PU Communication and PEOU, respectively. The predictive relevance for all constructs is above 0 (Hair et al. 2016).

Table 5: Explained variance (R^2) and forecast relevance (Q2) of the model on the basis of the online survey of the German contractors (n=134)

Construct	**R^2**	**Q^2**
IU	0.318	0.250
PU_Transport	0.330	0.204
PU_Communication	0.271	0.166
PEOU	0.157	0.089

PEOU = Perceived ease of use, PU_Transport = Perceived usefulness to reduce transport cost, PU_Communication = Perceived usefulness to improve communication, IU = Intention to use
Cut-off level $R^2 > 0.1$ and $Q^2 > 0$

Table 6: Results of the hypothesis test on the basis of the online survey of German contractors (n=134)

H_0		**Path coefficient**	**t statistics[1)]**	**Support H_0**
PEOU→PU_Communication	H1	0.492***	6.666	Supported
PEOU→PU_Transport	H2	0.558***	7.420	Supported
PU_Transport→IU	H3	0.417***	4.314	Supported
PU_Communication→IU	H4	0.193**	2.020	Supported
PEOU→IU	H5	0.006	0.071	Not Supported
Age→PEOU	H6	-0.399***	4.296	Supported
Education→PEOU[2)]	H7	-0.011	0.125	Not Supported
Firm size→PU_Transport	H8	-0.082	0.926	Not Supported
Firm size→PU_Communication	H9	-0.118	1.383	Not Supported

PEOU = Perceived ease of use, PU_Transport = Perceived usefulness to reduce transport cost, PU_Communication = Perceived usefulness to improve communication, IU = Intention to use
*(**, ***) means $p < 0.1$ ($p < 0.05$, $p < 0.01$)
[1)] Bootstrapping results (5.000 Sub-Samples).
[2)] Education was integrated as a dummy (1 = participant has a university degree; otherwise 0).

Bootstrapping was applied with 5,000 subsamples to derive t statistics for the path coefficients. Hypotheses 1 and 2 address the effect of PEOU on PU_Communication and PU_Transport. The path coefficient PEOU→PU_Communication is statistically significantly different from zero and has the expected positive sign. Likewise, the path coefficient PEOU→PU_Transport has the expected sign and is statistically significant from zero. Hence, we cannot reject Hypothesis 1 and 2. The results imply that, ceteris paribus, the more easily a navigation system is to use, the higher is the perceived usefulness to reduce transport cost and improve communication. Developers of navigation system should therefore keep the interface of a navigation system as simple as possible. Furthermore, coordinates of target destination should be easy to read and share.

Hypothesis 3 addresses the effect of PU_Transport on the IU. The path coefficient PU_Transport→IU has the expected positive sign and is statistically significant form zero. Hence, the model supports Hypothesis 3. The higher the perceived usefulness of the navigation systems to reduce transport costs the higher is the intention to use a navigation system, ceteris paribus. Hypothesis 4 is also given support by the model used since the path coefficient PU_Communication→IU is statistically significant from zero and has the expected positive sign. Hence, if the communication is improved by using the navigation system the higher is the intention to use a navigation system, ceteris paribus. The result can be used for marketing activities by providers of navigation systems. Marketing should highlight for instance the feature to easily share a location with costumers or the agricultural contractor.

The path coefficient PEOU→IU is not statistically significant from zero; therefore no support can be given to Hypothesis 5. A possible explanation can be found in the choice of W3W as a representative of a navigation system. Even though, the software was explained in detail it could be possible that agricultural contractors had difficulties evaluating the perceived ease of use. Furthermore, an anonymous referee gave the hint that a high perceived ease of use could also not provide an incentive for an agriculture contractor to use a navigation system. In line with that, it can be concluded that the perceived usefulness is the most important factor for the adoption of a navigation system. The results are of interest for other research areas in logistics since the main goal in logistics is to reduce transport- and transaction costs (Lamsal et al. 2016, Heizinger and Bernhardt 2011, Götz et al. 2014, Götz et al. 2011).

Hypothesis 6, 7, 8 and 9 extend the original TAM with firm and socio-demographic characteristics. The model used supports Hypothesis 6 since the path coefficient Age→PEOU is statistically significant from zero has the expected negative sign. Younger adults show more experience with digital technologies (Gerpott et al. 2013, Rose et al. 2016), it is therefore assumed that older agricultural contractors may perceive using new software as being difficult. Agricultural contractors should therefore consider that older employees might need more time to accustom to the new software. Furthermore, providers should consider offering training courses.

Hypothesis 7, 8 and 9 cannot be given support by this model since all path coefficients are not statistically significant from zero. Education has no effect on PEOU. Likewise to the explanation of the missing statistical significant effect of PEOU on IU, education may not help to evaluate the perceived ease of use of W3W as a representative for navigation systems considering characteristics of the rural areas. Furthermore, firm size has no effect on the perceived ease to reduce transport cost and improve communication. Even for smaller firms, applying a navigation system could help to improve its organization and communication. This is especially important since a lot of the navigation systems currently in use are free of charge. Smaller firms have relatively lower investment power but may also rely on navigation systems. Thus, developers should consider offering products with fewer functions suitable for smaller firms in order to also gain smaller firms as customers.

Conclusions

Agricultural contractors experienced an economic growth in the last years resulting also in an increasing number of customers and employees. Likewise, the demand for an effective management with respect to the logistics increased too. Several software programs are available to assist agricultural contractors. Nevertheless, literature about the usage of navigation systems by agricultural contractors is scarce. This study aims to close this research gap and is based on an online survey conducted in 2018 with 134 agricultural contractors. The results show that agricultural contactors had problems performing their jobs due to difficulties finding the right field or field access. Furthermore, missing local knowledge was also stated as a problem. This underlines the demand for navigation systems considering the characteristics of rural areas by agricultural contractors. The results show that agricultural contractors are partly satisfied with the existing navigation systems. Moreover, agricultural contractors wish to retrieve information about bridge clearances, road width and weight restrictions in the software which should be considered by developers in the further development of navigation systems.

This study also tests an extended version of the TAM for the usage of navigation systems by agricultural contractors. The TAM was estimated using PLS structural equation modelling. Most of the hypotheses of the TAM could be supported by our model. Only the hypothesis that the perceived ease of use has a positive effect on the intention to use a navigation system could not be given any support. This result might be explained by the effect that even though all respondents were given a detailed explanation of the software W3W, they had difficulties evaluating the perceived ease of use of the software. These results are therefore of interest for all research areas with respect to logistics since this is the first study extending the TAM to the adoption of navigation systems since all logistics including agricultural logistics aim to reduce transport and transaction accost.

The results of the TAM also imply that, ceteris paribus, the higher the perceived usefulness to reduce transport cost and to improve communication, the higher is the intention to use a navigation system. The results are of great importance for developers and providers as well as coordinators of marketing activities. Furthermore, the results imply that the interface of a navigation system should be kept as easy as possible. The study could also show that the respondents' age has a negative effect on perceived ease of use. Agricultural contractor should give older employees enough time to accustom to the navigation systems. Providers of navigation system should consider offering training courses. No statistically significant difference was found for the firm size on the intention to use a navigation system. This showed that also smaller agricultural contractors have also high interest in navigation systems which should be considered by developers and providers.

A limitation of the study is that the study mainly focused on the aspect of navigation. Existing software is also capable of several management functions like the coordination of the fleet of machines. Perceived usefulness of these management functions should also be evaluated in future studies. Moreover, the willingness to pay for navigation and management systems should be investigated. The financial value user express for a specific software is of great importance for further development of the software. This study leaves one point open: the study did not assess the actual behavior with respect to navigation systems by agricultural contractors in the TAM used which should also be considered in further studies. Likewise, this could be integrated by using further theories like the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003).

References

Amiama, C.; Pereira, J.M.; Castro, A.I; Bueno, J. (2015): Modelling corn silage harvest logistics for a cost optimization approach. Computers and Electronics in Agriculture 118, pp. 56–65; https://doi.org/10.1016/j.compag.2015.08.024

Amponsah, W.A. (1995): Computer adoption and use of information services by North Carolina commercial farmers. Journal of Agricultural and Applied Economics 27 (2), pp. 565–576; https://doi.org/10.1017/S1074070800028595

Aubert, B.A.; Schroeder, A.; Grimaudo, J. (2012): IT as enabler of sustainable farming. An empirical analysis of farmers' adoption decision of precision agriculture technology. Decision Support Systems 54 (1), pp. 510–520; https://doi.org/10.1016/j.dss.2012.07.002

Austin, E. J.; Willock, J.; Deary, I. J.; Gibson, G. J.; Dent, J. B.; Edwards-Jones, G.; Morgan, O.; Grieve, R.; Sutherland A. (1998): Empirical models of farmer behaviour using psychological, social and economic variables. Part I. Linear modelling. Agricultural Systems 58 (2), pp. 203–224; https://doi.org/10.1016/S0308-521X(98)00066-3

Bernhardt, H.; Mederle, M.; Treiber, M.; Wörz, S. (2018): Aspects of digization in agricultural logistics in Germany. Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering (7), pp. 215–220; http://landreclamationjournal.usamv.ro/pdf/2018/Art38.pdf

BMVI (2018): Das Navigationssystem für die Landwirtschaft - AgriNAVI. Bundesministerium für Transport und Infrastruktur, https://www.bmvi.de/SharedDocs/DE/Artikel/DG/mfund-projekte/navigationsysstem-fuer-landwirtschaft-agrinavi.html, accessed on 8 December 2018

Bonke, V.; Fecke, W.; Michels, M.; Musshoff, O. (2018): Willingness to pay for smartphone apps facilitating sustainable crop protection. Agronomy for Sustainable Development 38 (51), pp. 1-10; https://doi.org/10.1007/s13593-018-0532-4

Davis, F. D. (1989): Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, pp. 319–340; https://www.jstor.org/stable/249008

Daberkow, S.G.; McBride, W.D. (2003): Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies in the US. Precision Agriculture 4 (2), pp. 163–177; https://doi.org/10.1023/A:1024557205871

DBV (2018): Situationsbericht 2017/18. Deutscher Bauernverband, https://media.repro-mayr.de/00/709600.pdf, accessed on 8 December 2018

Ebadian, M.; Sowlati, T.; Sokhansanj, S.; Stumborg, M.; Townley-Smith, L. (2011): A new simulation model for multi-agricultural biomass logistics system in bioenergy production. Biosystems Engineering 110 (3), pp. 280–290; https://doi.org/10.1016/j.biosystemseng.2011.08.008

Fecke, W.; Michels, M.; von Hobe, C.-F.; Mußhoff, O. (2018): Wie kommunizieren Landwirte in Zeiten der Digitalisierung? Berichte über Landwirtschaft-Zeitschrift für Agrarpolitik und Landwirtschaft 96 (2); http://dx.doi.org/10.12767/buel.v96i2.194

Fishbein, M.; Ajzen, I. (1975): Belief, attitude, intention and behavior. An introduction to theory and research. Reading, MA: Addison-Wesly

Fountas, S.; Blackmore, S.; Ess, D.; Hawkins, S.; Blumhoff, G.; Lowenberg-Deboer, J.; Sorensen, C. G. (2005): Farmer experience with precision agriculture in Denmark and the US Eastern Corn Belt. Precision Agriculture 6 (2), pp. 121–141; https://doi.org/10.1007/s11119-004-1030-z

Gaese, C. F.; Bernhardt, H.; Popp, L.; Wörz, S.; Heizinger, V.; Damme, T.; Eberhardt, J.; Kluge, A. (2013): Entwicklung eines Planungssystems zur Optimierung von Agrarlogistik-Prozessen. In: Clasen, M.; Kersebaum, K. C.; Meyer-Aurich, A; Theuvsen, B. (Eds.), Massendatenmanagement in der Agrar- und Ernährungswirtschaft – Erhebung – Verarbeitung – Nutzung. Bonn: Gesellschaft für Informatik e.V., pp. 91–94; https://subs.emis.de/LNI/Proceedings/Proceedings211/91.pdf

Ghadim, A.K.A.; Pannell, D.J. (1999): A conceptual framework of adoption of an agricultural innovation. Agricultural economics 21 (2), pp. 145–154; https://doi.org/10.1016/S0169-5150(99)00023-7

Götz, S.; Holzer, J.; Winkler, J.; Bernhardt, H.; Engelhardt, D. (2011): Agrarlogistik-Systemvergleich von Transportkonzepten der Getreidelogistik. LANDTECHNIK–Agricultural Engineering 66 (5), pp. 381–386; http://dx.doi.org/10.15150/lt.2011.898

Götz, S.; Zimmermann, N.; Engelhardt, D.; Bernhardt, H. (2014): Influencing factors on agricultural transports and their effect on energy consumption and average speed. Agricultural Engineering International: CIGR Journal, pp. 59–69

Hair, J. F.; Hult, G. T. M.; Ringle, C.; Sarstedt, M. (2016): A primer on partial least squares structural equation modeling (PLS-SEM). Thousand Oaks: Sage Publications

Heizinger, V.; Bernhardt, H. (2011): Algorithmic Efficiency Analysis of Harvest and Transport of Biomass. Journal of Agricultural Machinery Science 7 (1), pp. 95–99; http://www.tarmakder.org.tr/images/stories/MAKALELER/2011/2011_vol7(1)/2011_vol7(1)_95-99.pdf

Heizinger, V.; Mederle, M.; Huber, S.; Bernhardt, H. (2016): Abschätzung des Kraftstoff-Einsparpotentials in der Infield-Logistik bei der Ernte von Biomasse. In: Ruckelshausen, A.; Meyer-Aurich, A.; Rath, T.; Recke, G; Theuvsen, B. (Eds.), Informatik in der Land-, Forst- und Ernährungswirtschaft 2016. Bonn: Gesellschaft für Informatik e.V., S. 65-68; https://dl.gi.de/handle/20.500.12116/769

Jiang, W.; Stefanakis, E. (2018): What3Words Geocoding Extensions. Journal of Geovisualization and Spatial Analysis 2 (1), pp. 1-18; https://doi.org/10.1007/s41651-018-0014-x

Kumar, S.; C. Zahn (2003): Mobile communications: evolution and impact on business operations. In: Technovation 23 (6), pp. 515–520; https://doi.org/10.1016/S0166-4972(02)00120-7

Kutter, T.; Tiemann, S.; Siebert, R.; Fountas, S. (2011): The role of communication and co-operation in the adoption of precision farming. Precision Agriculture 12 (1), pp. 2–17; https://doi.org/10.1007/s11119-009-9150-0

Lamsal, K.; Jones, P. C.; Thomas, B. W. (2016): Harvest logistics in agricultural systems with multiple, independent producers and no on-farm storage. Computers & Industrial Engineering 91, pp. 129–138; https://doi.org/10.1016/j.cie.2015.10.018

Lauer, J.; Zipf, A. (2010): A workflow for improving the availability of routable data (OSM) for lo-gistics in agriculture-using data from Telematics-systems and community-based quality management, http://koenigstuhl.geog.uni-heidelberg.de/publications/2010/Lauer/lauer-zipf-agro-logistics-agile2010.pdf, accessed on 8 December 2018

Maranguni, N.; Grani, A. (2015): Technology acceptance model: a literature review from 1986 to 2013. Universal Access in the Information Society 14 (1), pp. 81-95; http://dx.doi.org/10.1007/s10209-014-0348-1

Mederle, M.; Heizinger, V.; Bernhardt, H. (2015): Analyse von Einflussfaktoren auf Befahrungsstrategien im Feld. In: Ruckelshausen, A.; Schwarz, H.-P.; Theuvsen, B. (Eds.), Informatik in der Land-, Forst- und Ernährungswirtschaft 2015. Bonn: Gesellschaft für Informatik e.V., pp. 113–116; https://dl.gi.de/handle/20.500.12116/2597

Mzoughi, N. (2011): Farmers adoption of integrated crop protection and organic farming. Do moral and social concerns matter? Ecological Economics 70 (8), pp. 1536–1545; https://doi.org/10.1016/j.ecolecon.2011.03.016

Nelson, R.R.; Phelps, E.S. (1966): Investment in humans, technological diffusion, and economic growth. The American Economic Review 56, pp. 69–75

Perdana, Y. R. (2012): Logistics information system for supply chain of agricultural commodity. Procedia-Social and Behavioral Sciences 65, pp. 608–613; https://doi.org/10.1016/j.sbspro.2012.11.172

Reichardt, M.; Jürgens, C.; Klöble, U.; Hüter, J.; Moser, K. (2009): Dissemination of precision farming in Germany. Acceptance, adoption, obstacles, knowledge transfer and training activities. Precision Agriculture 10 (6), pp. 525-545; https://doi.org/10.1007/s11119-009-9112-6

Ringle, C. M.; Wende, S.; Becker, J.-M. (2015): SmartPLS 3. Boenningstedt. SmartPLS GmbH

Rose, D.C.; Sutherland, W.J.; Parker, C.;Lobley, M.;Winter, M.; Morris, C.; Twining, S.;Foulkes, C.; Amano, T.; Dicks, L.V.; (2016): Decision support tools for agriculture: Towards effective design and delivery. Agricultural Systems 149, pp. 165–174; https://doi.org/10.1016/j.agsy.2016.09.009

Schaak, H.; Mußhoff, O. (2018): Understanding the adoption of grazing practices in German dairy farming. Agricultural Systems 165, pp. 230–239; https://doi.org/10.1016/j.agsy.2018.06.015

Springael, J.; Paternoster, A.; Braet, Jo. (2018): Reducing postharvest losses of apples. Optimal transport routing (while minimizing total costs). Computers and Electronics in Agriculture 146, pp. 136–144; https://doi.org/10.1016/j.compag.2018.02.007

Vanclay, F.; Lawrence, G. (1994): Farmer rationality and the adoption of environmentally sound practices; a critique of the assumptions of traditional agricultural extension. European Journal of Agricultural Education and Extension 1 (1), pp. 59–90; https://doi.org/10.1080/13892249485300061

Venkatesh, V.; Bala, H. (2008): Technology acceptance model 3 and a research agenda on interventions. Decision Sciences 39 (2), pp. 273–315; https://doi.org/10.1111/j.1540-5915.2008.00192.x

Venkatesh, V.; Davis, F. D. (2000): A theoretical extension of the technology acceptance model. Four longitudinal field studies. Management Science 46 (2), pp. 186–204; https://doi.org/10.1287/mnsc.46.2.186.11926

Venkatesh V.; Morris, M. G.; Davis, G. B.; Davis, F. D. (2003): User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly 27 (3), pp. 425–478; https://www.jstor.org/stable/30036540?seq=1#metadata_info_tab_contents

Verma, P.; Sinha, N. (2018): Integrating perceived economic wellbeing to technology acceptance model. The case of mobile based agricultural extension service. Technological Forecasting and Social Change 126, pp. 207–216; https://doi.org/10.1016/j.techfore.2017.08.013

What3Words (2018): Weltweites Adresssystem, https://what3words.com/de/, accessed on 7 December 2018

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Acknowledgment

We thank two anonymous reviewers for their helpful comments. Furthermore, we wish to thank Dr. Wilm Fecke, Vanessa Bonke and Gregor Bensmann for their assistance during the design and conduction of the study.