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Electronic Markets – The International Journal on Networked Business

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Abstract

The second-hand automotive market is one with the least trust from consumers. Customers on the second-hand car market suffer from such problems as the car being in worse condition than initially indicated, accident damage that is not disclosed, fraud, etc.

Akerlof, described the market for used cars as an example of the problem of information asymmetries and resulting quality uncertainty. In order to cope with quality uncertainties, used car buyers actively engage themselves in information seeking. Blockchain technology promises to automatize the tracking of cars through their lifecycles and provide reliable information at any point in time it is needed. In our study, we investigate the problems car buyers face during information seeking and propose requirements for the design of a blockchain-based system to address these.

Introduction

The used car market is characterized by uncertainty and lack of trust. A consumer study, conducted in Germany in 2017, found that the automotive market is among the least trusted ones (followed by banks/insurances, and telecommunications industry) (Lades, 2017). In used car markets in particular, consumers experience such problems as fraud, the dishonest behavior of sellers and having no way to verify information about used vehicles (European Union, 2014). In Europe alone, mileage fraud in used cars costs between €5.6 and €9.6 billion per year (Brousmiche, Heno, Poulain, Dalmieres, & Hamida, 2018).

There are several ways to check the accuracy of parameters such as mileage, being accident-free, if services have been done appropriately, etc., but often they need to be conducted by experts which can be costly, time-consuming and requires additional effort. Blockchain technology (or a distributed ledger) promises to automatize the tracking of cars through their lifecycles and provide reliable information at any point in time it is needed (Notheisen, Cholewa, & Shanmugam, 2017). Due to such characteristics as distributed operation, authentication, immutability of records and cryptography, there is a possibility to address the problem of fraud and lack of transparency in the used car market by creating a blockchain-based vehicle history report. The problem with second-hand cars is a long-standing one and was used as an illustration in Nobel laurate G.A. Akerlof's theorization about quality uncertainty, information asymmetry and their outcomes in his "Market for 'Lemons': Quality Uncertainty and the Market Mechanism" (Akerlof, 1970). Akerlof's paper refers to the used car market as an example of the problem of asymmetry of information, quality uncertainty and, as its consequence, the decreasing value generated in those markets because quality goods are undervalued and thus sold elsewhere. Indeed, if the buyer of a used car does not have information about the car they intend to buy to the same extent as the seller does (normally as a consequence of several not-always-traceable variables, such as the owner's driving style, quality and frequency of maintenance, and accident history), then "bad" cars (called "lemons"– defective cars) supersede good ones to their complete extinction in the used car market.

The problem of information asymmetry and product quality uncertainty manifests itself in two ways: (1) at the micro level of buyers and sellers coping with uncertainty. This can be studied by checking what practical strategies to reduce information asymmetries are put in place, for instance: calling a friend, checking reviews and reading specialized magazines; and (2) the broader market effect of bad products driving out good products. In order to deal with the effects of quality uncertainty, institutions develop measures to counteract the effects of quality uncertainty such as warranties, certifications, brand names and chains of organizations.

The present study takes the micro-level view outlined in point (1): rather than on the whole market, we focus on individuals' information seeking behaviors. More precisely, we focus on how second-hand car buyers try to reduce the asymmetry of information they are exposed to. Then, we make proposals about how those insights can be used to formulate requirements for a blockchain-based system to increase trust between involved parties. In our study, we state the following research questions:

RQ1: What problems do car buyers face in the used car market during the information seeking phase?

RQ2: What requirements should be placed for the design of a blockchain-based system to address these problems?

Given the novelty of blockchain-based solutions, this paper takes an exploratory approach, which helps to create deep and rich understanding of the problem space and formulate generalizable requirements for an early prototype solution (Nunamaker Jr & Briggs, 2011). This study presents and discusses the results of interviews and a survey with second-hand car buyers on the problems they face during searches for necessary information. Regarding design implications, we discuss what requirements should be in place for a blockchain-based system that aims to mitigate information asymmetry between buyers and sellers in a second-hand car market due to its characteristics. Against this broad background, this paper focuses on the used car market in Switzerland.

The rest of the paper continues by defining our theoretical background, then presenting the research design and methodology we adopted. Then, we structure our findings around the above stated research questions. Finally, we discuss the implications of our research for theory and practice.

Related Work

Information asymmetries

In his work, Akerlof (1970) showed the effects of information asymmetries on markets relying, among other factors, on the example of the used car market. Information asymmetries lead to quality uncertainties, which on an individual level of buyers, cause higher costs and lead to overall dissatisfactions (Sureshchandar, Rajendran, & Anantharaman, 2002). To resolve information asymmetries, institutions traditionally develop measures to counteract the effects of quality uncertainty (e.g., warranties, brand names and chains of organizations). The situation, described by Akerlof, is often referred to as *Adverse Selection*. In markets, information asymmetries are characterized by scarcity of pre-purchase information about a product (i.e., the lack of reliable information

about product quality attributes), that hinders a consumer from assessing a product's quality before they buy it (Wells, Valacich, & Hess, 2011). A customer can then only assess the product, after they actually buy it and, thus, get post-purchase information clarity.

Stemming from the field of economics and marketing, information asymmetries and adverse selection are the focus of IS research as well. IS scholars mainly study how information systems change these problems in online markets and e-commerce relationships (Dimoka, Hong, & Pavlou, 2012; Dimoka & Pavlou, 2006; Ghose, 2009; Pavlou, Liang, & Xue, 2007; Wolf & Muhanna, 2005), where assessment of product quality is even more difficult due to inability to examine products physically (Wolf & Muhanna, 2005). It has been proven that information technologies influence transactions between buyers and sellers by lowering search costs (Kuruzovich, Viswanathan, & Agarwal, 2010) and by reducing buyers' uncertainties about a product (Dimoka et al., 2012) and its seller (Pavlou et al., 2007). Literature suggests that IT-enabled solutions may help reduce product uncertainties related to the description of a product and to its actual performance (Dimoka et al., 2012) (e.g. reputation and rating systems, certifications, and product descriptions). For example, if the buyers of used cars can gather enough detailed information independently from car sellers to determine the quality of the car, they can defy the problems of the adverse selection (Notheisen et al., 2017). The problem of quality uncertainty is caused not only by the risk of dishonest behavior of sellers, but also by the inability of honest sellers to provide an adequate, comprehensive and trustworthy description of their product (Pavlou & Dimoka, 2008). Though the economic and IS literature mentions vehicle history reports (like CarFax) as a means of reducing product uncertainty (Dimoka et al., 2012), no specific guidelines are provided as to how such a history report may be designed in an IT-supported setting (i.e., searching for information about a specific car online). Furthermore, these history reports are not always reliable in terms of data quality and in some countries are not applicable at all in terms of data privacy regulations (which is the case in European countries).

Information seeking in the used car market

Uncertainty exists when a framework for completing a task is in place, but necessary information to complete this task is insufficient or missing (Dennis & Valacich, 1999). One of the traditional ways buyers cope with uncertainties in the market is information seeking, that is aimed at gathering missing information to complete the task (i.e. to purchase a car) (Luo, Sia, Shi, & Chen, 2009). Information seeking has been studied from different perspectives. In IS, though definitions vary (Mai, 2016), researchers often refer to information seeking as an active search process triggered by a recognition of an information need (Case & Given, 2016). Consequently,

information seeking behavior describes the way or the strategy by which individuals act in this search (Mai, 2016). Byström and Järvelin developed a model of task-based information seeking and structured information seeking in three categories: subjective task, information acquired and information sources used (Byström, 1999; Byström & Järvelin, 1995). This structure leads us in our further analysis and presentation of the results. Given the context of this research—the purchase of a used car (the task to complete)—we study the latter two in more detail to show how used car buyers nowadays, in the "digitalization era" (Hinkelmann et al., 2016), seek necessary information and the problems they face.

In his research more than a decade ago, Smith (2006) compared consumer behavior in the automotive market in a traditional purchase process (without Internet) with an online purchase of a car. Amongst other things, he highlighted that use of the Internet in the research phase (or in other words, information gathering/seeking phase) increases the number of available information sources, giving more comprehensive understanding about a purchased car, and in general makes a car buyer's experience more convenient and time-saving (Smith, 2006). Figure 1 illustrates the difference in available sources of information presented in the study (Smith, 2006): while the traditional ones (past personal experience, publications and test drives) remain, new online sources (online publications, e-marketing activities, etc.) appear. In our study, we reconsider the information seeking process, identify what problems car buyers face nowadays, and look what requirements should be then placed on the design of an information system to address the buyers' needs. Worth mentioning is also the concept of 'price anchoring', as while searching for information, car buyers often try to evaluate the range of a reasonable price to pay in relation to something else (a friend's purchase, others deals, disposable income, etc.). Price anchoring describes the effect of giving the reference price for decision-making during a purchase (Tversky & Kahneman, 1974).

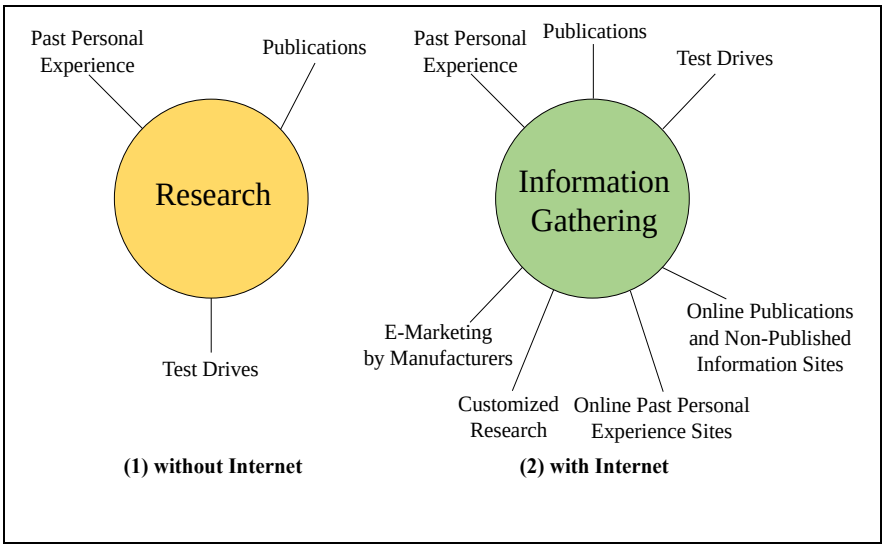


Figure 1. Information seeking of car buyers (1) without and (2) with Internet (adapted from (Smith, 2006))

Blockchain technology for the used car market

The popularity (rather the hype) of blockchain technology emerged from the famous cryptocurrency Bitcoin. At present, cryptocurrencies have a negative connotation due to speculation, related scandals and darknet activities, and extreme power consumption. However, cryptocurrencies are only an application of blockchain, so blockchain may move beyond its main 'killer-app', cryptocurrencies, by providing an infrastructure for other services. Depending on its design and configuration, it may bring value to resolve problems, in which different, unknown, and untrusted parties may be involved (Voronchenko, 2017).

In this subsection, we briefly explain the notion of blockchain technology, its key concepts and characteristics. It is important to note that the technology is still in the emergent phase; some say it is a solution in search of problems. Even though there are plenty of on-going projects in research and industry, most of the applications are in an experimental phase, and thus it is too early to say that they will fulfil its revolutionary promises (Tapscott & Tapscott, 2017). However, there are several studies that make steps toward developing understanding of the technology by conceptualizing and characterizing its capabilities.

A blockchain is a distributed ledger that is replicated and shared among nodes of a network (Christidis & Devetsikiotis, 2016). The use of asymmetric cryptography brings authentication, integrity, and immutability to blockchains (Christidis & Devetsikiotis, 2016). Once a transaction is certified by a node, it is broadcasted to other nodes in the network. These nodes verify the validity of incoming transactions and spread them further in the network. One of the most remarkable properties of blockchain is claimed to be trust (Beck, Stenum Czepluch, Lollike, & Malone, 2016), as nodes in the blockchain network do not have to rely on and trust each individual other because trust is achieved by putting transactions into the distributed ledger. However, even if transactors do not need to trust one another individually in order to transact with them, it is undeniable that they have to put some level of trust in the system overall. Furthermore, there is no 'one and only' blockchain technology: blockchain-based systems differ in terms of their design (for example, related to governance, data storage, etc.) (Bauer, Zavolokina, Leisibach, & Schwabe, 2019). Therefore, it is important to explore the design alternatives on both infrastructure and application levels.

Blockchain technology's promise of establishing a trusted environment while forming a decentralized network can be provided by six main mechanisms of blockchain: transparency, integrity of data, immutability and privacy; as well as system reliability and versatility (Seebacher & Schüritz, 2017). However, other researchers suggest that some blockchain characteristics also pose unique challenges to interpersonal trust management, in particular privacy of users (Casey, 2018; Seebacher & Schüritz, 2017). While blockchain technology can provide a tamperproof record of transactions, it cannot provide a guarantee that the other party will behave with integrity (beyond the compliance with the consensus algorithm). Blockchain systems operate in a wider context of economic and social transactions that require trust between individuals. Therefore, blockchain does not eliminate the need of trust between individuals, but serves as its enabler (Casey & Vigna, 2018). Although blockchain technology can bring certain value for service systems due to its design and inherent properties (like immutability, transparency, integrity of data, etc.) (Seebacher & Schüritz, 2017), the technology itself is not a holy grail that is able to resolve all emergent issues. Moreover, from the perspective of consumers, there are challenges of technological, organizational and human nature, that have to be first overcome before the technology may be utilized (Schlegel, Zavolokina, & Schwabe, 2018). These challenges include privacy issues (blockchains never forget; information is shared among participating nodes), lack of legal framework (e.g. for liability) (Schlegel et al., 2018). Furthermore, as the technology is getting more mature, it is important to differentiate between different possible configurations of blockchain systems (permissions, consensus, how and what transactions are stored). Therefore, it is mandatory to study how such a system should be designed to bring the promised value.

Blockchain technology, due to its characteristics discussed above, can provide a solution to mitigate information asymmetries and allow for better and more efficient ways of reducing quality uncertainty, therefore developing more reliable relationships between buyers and sellers. A few studies explore whether or not blockchain technology may reduce information asymmetries in the automotive market by creating a blockchain-based vehicle history. Odometer values can be securely stored in a public blockchain system to address the problem of odometer fraud by using sensor data from vehicles (Chanson, Bogner, Bilgeri, Fleisch, & Wortmann, 2019; Chanson, Bogner, Wortmann, & Fleisch, 2017). Notheisen et al. (2017) propose a public blockchain-based car register system and show that it is capable to reduce transaction risk resulting from immutability of blockchain transactions and minimize quality uncertainty by providing reliable, transparent, and complete vehicle history. Brousmiche et al. (2018) discuss benefits and challenges of enterprise blockchain for vehicle history, and

conclude that blockchain technology enables inter-organizational collaborations on car-related processes and therewith opens up new business opportunities.

Research Design, Methodology and Data Collection

The present study is part of a large action design research project, called the *Carcerti*[1], that focuses not only on the elimination of information asymmetries in the used car market in Switzerland, but also on improving the processes across the whole car-related ecosystem (which includes import, insurances, registration, repair works and services, etc.) with the application of blockchain technology. The *Carcerti* is a permissioned blockchain-based system, developed by a consortium of organizations (both private and public) from the automotive ecosystem[4]: a car importer and dealer, an insurance company, a car sharing company, a registration authority, a software provider, two universities[2]. The *Carcerti* is a platform for exchange of car-related data between participants in a life cycle of a car. A set of data events about a specific car comprises a full dossier about this car. Why did the consortium opt for a blockchain-based solution? First, they did not want to rely on one external provider (like Amazon or Google) to run the system for them or one company from the consortium, giving away decision powers to it. Second, data protection and privacy regulations in the EU do not allow to publish certain vehicle data publicly, therefore, a permissioned decentralized system which offers immutability and integrity of data seemed to be a good solution for the consortium. A series of publications report on different aspects from the research project: design for understandability and trustworthiness in blockchain platforms[3], business value of blockchain technology[3], token design[3], data quality in blockchain inter-organizational networks[3], blockchain consortium development[3,4]. Furthermore, a recent study has demonstrated a positive influence on transparency of the *Carcerti* on the used car market and value for buyers and sellers of used cars[3]. In our study, we focus on the consumers' perspective (i.e., the perspective of car buyers) and exclude organizational perspectives. Thus, we explore how requirements for a blockchain-based system should be formulated to fulfill the promises blockchain technology makes (Casey, 2018), and address the needs of buyers in 'markets of lemons'.

We take an mixed-method approach, including qualitative and quantitative methods (Dubé & Paré, 2003), that helps us to better understand the problems and needs of individuals, and how they relate to the emerging field of

[1] The project name was changed for the review process.
[2] By March 2019, the consortium founded a non-profit association, which included other organizations: data providers, a bank, a leasing association, etc.
[3] The reference was excluded for the review process in order not to disclose the authors of this manuscript.
[4] As of March 2019, the publication is under review and can be provided by request.

blockchain applications. Considering methodological advice not to overlook the difference between what people say they do and what they practice (Silverman, 1998), we triangulated different data sources (semi-structured interviews and surveys) to gain a reliable interpretation of used car buyers' information behaviors.

Interviews. We studied how actual buyers cope with asymmetry of information through information seeking to cut a better deal, or avoid a bad one, in the Swiss second-hand car market. Two rounds of semi-structured face-to-face interviews (Myers & Newman, 2007) were conducted with recent car buyers (last used car bought within the last year). 10 car buyers were interviewed in each of the rounds. For both rounds, the interviewees were recruited through advertising the study via social networks and flyers at the university. The only requirement for participation was having had experience with at least one purchase of a used car. Interviewees from the first interview round were aged between 25 and 63 (average age was 46), three interviewees (out of ten) were female. In the second round, interviewees were aged between 25 and 51 (average age was 31), one interviewee (out of ten) was female. The first round of interviews took place between May and June 2017, and the second round of the interviews took place between March and April 2018. A questionnaire was devised relying on Byström and Järvelin's work (Byström, 1999; Byström & Järvelin, 1995). The questions were open-ended to allow the interviewees to present their actual experiences without being required to fit into a tight, pre-defined analytical structure. The questionnaire used in the interviews as well as the introduced scenario can be found in the Appendix. We took special care to stay as close as possible to buyers' experiences and inputs. To achieve this, possible considerations for answers were only suggested in brackets, and were used only to elicit more articulate answers in cases where the interviewee misunderstood or digressed from our questions. Though the goal of both rounds was to identify the problems the buyers experienced, and to understand their needs and behaviors, in the second round a scenario and a mockup (developed during the course of the research project (Rosson & Carroll, 2009), see Fig. 2 in the Appendix) of a blockchain-based vehicle history application, were introduced to interviewees to validate the proposed requirements (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007). The interviews were conducted in German, then transcribed and coded (Flick, 2013; Saldaña, 2009). The codes were structured on the basis of the concepts from the information seeking model (Byström & Järvelin, 1995), quality uncertainty (Dimoka et al., 2012) and blockchain technology characteristics (Seebacher & Schüritz, 2017).

Online Survey. The interview responses served as the basis for the design of the survey. The survey was conducted in cooperation with one of the largest online platforms for used cars in Switzerland, in April 2018. The survey participants were users of the online care sales platform, who were contacted via a mailing list and were asked to fill out the survey. As compensation, each survey participant had the chance to win one of five

coupons worth approx. €42 each. 776 users participated in the survey, of whom 564 fully completed the survey. In this paper, we consider only the data from fully completed responses. 53% of all respondents were aged between 26 and 45, 34% between 46 and 60, 7% over 60 and 6% under 25. 93.8% of the respondents were male. 88.6% of the respondents had already found and bought a car through an online platform at least once. By "bought through an online platform" we mean the search, choice and contact processes, as the purchase in most cases still requires a personal contact and examination of a car. All participants received questions about the problems they experienced while searching for information about a car purchase, and we were able to rate them (on a 5-point Likert scale) according to their importance. Furthermore, they were asked to rate the importance of factors that influenced their choice of information sources in purchase, and criteria they paid attention to while examining certain information on a product. Finally, the respondents were asked to rate the importance of certain functionalities of a blockchain-based vehicle history, visualized on a mockup.

Findings

We structure our findings in line with the stated research questions. First, we explore the problems used car buyers face during the information seeking phase in a car purchase process, how their needs may be formulated, and then how these needs may be translated into functional requirements for a blockchain-based vehicle history.

RQ1: What problems do car buyers face in the used car market during the information seeking phase?

The identified problems can be structured along three main themes (which follow the concepts from the theory on information seeking behavior (Byström, 1999)): task, information, and source. In our study, we take an explorative approach with the goal of not only identifying the problems but also gaining a deeper understanding of them for the used car market case from the end consumers' perspective.

It is important to note that the study was conducted in Switzerland, where the average level of trust between individuals and between people and institutions is high in comparison to other countries (Delhey, Newton, & Welzel, 2011). While *Carcerti* project is based in Switzerland and primarily focuses on the Swiss used car market, we can assume that the obtained results can be transferred to the West European markets with similar characteristics.

Large effort for information seeking. As our results show, information seeking consumes most of a car buyer's time during the whole purchase process. 76% of survey respondents stated that they spent more than 2 weeks searching for a car and consulting various information sources. These information sources are both online and offline. Car buyers are forced to collect most of the available information themselves: on seller, on brand, on performance of the chosen model and on the specific car, that takes much time and effort in decision-making. To get a better understanding, second opinion or emotional support, buyers often involve third known parties in the search process. Interviewees confirmed that personal preferences play an important role in the search and selection process. However, the opinions of other trusted people may influence the decision (e.g. "*if my colleague says that he would not recommend buying this car, I would have doubts all the time, even if I liked it very much*"). Furthermore, personal contact and test drives are still an important or very important (86.1% of respondents) source of information during the selection process. Generally speaking, during information seeking, buyers try to come up with a comprehensive picture of the car's quality, its current and future expected performance and the effect of these on the price they pay. Therefore, we formulate the need (N1) accordingly.

Uncertainty of information quality. As our results show, car buyers struggle with the uncertainty of quality of information provided when searching for a car. The quality of information is hindered by several factors: missing information, falsified/incorrect information, and, in general, the difficulty of verifying the provided information.

As an example of missing information, one interview partner said: *"…some information on the car got lost. For example, a car with warranty was sold without the warranty just because the seller didn't know that the car still has the warranty. It was discovered first then, when the car was brought to the official vehicle service provider".* Thus, information may be forgotten, and documentation may be missing. However, it may also be hidden or falsified on purpose to achieve a better price for sale: *"Sometimes even photos, provided on online platforms, are photoshopped or just copied from the Internet and then uploaded on the platform"*. Interview partners and survey respondents claimed that the problem of falsified information (be it mileage, accident and service history, or general state) is still highly relevant and critical. Lastly, the fact that there is no way to directly verify the information provided on the platform, led to uncertainties and difficulties in the purchase process. One interview partner claimed: *"You can check the photos and the information about the car only by physically seeing and trying it".* Another one stated: *"To verify the checkups, you need to see the original service book or a proof from an authority"*. Thus, one of the biggest problems is the verification of documents that prove the quality of the car and the correctness of the data. Summing up, 67% of all survey respondents confirmed that the above-mentioned factors (missing information, falsified information, and difficult verification) are problematic in the current

situation. Therefore, we formulate the need (N2) for a complete history report reflecting events occurring during a car's lifetime, that cannot be manipulated and is visible to any interested party.

Uncertainty of quality of information source. Another aspect that is relevant for car buyers is the source of information about an offered specific car. As the information about the car is provided by the seller in most cases, its trustworthiness is questioned, as buyers believe that the seller always acts in the way that will maximize their profit ("*…the seller is the least reliable person—he just wants money*"). Thus, the information that is provided about a car is not reliable, as the source is often single and perceived to have a certain bias to manipulate the information. However, related to this, another problem occurs: not every seller is able to provide the needed information that is relevant for the buyer. It might be due to a lack of necessary expertise or a lack of willingness to invest the necessary time into tailoring the information for the needs of a certain buyer ("*sometimes they (sellers) do not really bother themselves with answering questions*"). Interview partners also added that they believed private sellers are less reliable than professional dealers because of the reputation dealers are afraid to spoil. Therefore, buying from a private seller, the information should be double-checked. 67.1% of respondents to the survey stated that they prefer a car offered by a professional dealer to one from a private seller. To sum up, in the presence of variety of information sources, car buyers still lack a reliable, trustworthy and independent source of information. Therefore, we formulate the need (N3) accordingly.

The results are summarized in Table 1.

Table 1. Problems and derived needs of used car buyers during information seeking

Information seeking concept	**Problems**		**Needs**
Task-related	Large effort for information seeking	• Evaluating the information is time-consuming and effortful • Involvement of third parties (e.g. friends, experts) is often needed	N1. Get assessment information on the car's quality, its current and future expected performance and the effect of these on the price they pay.
Information-related	Uncertainty of information quality	• Missing information • Falsified information • Verification of the information is difficult	N2. Get full history of a vehicle, which cannot be manipulated over time, and is visible to anyone interested.

Source-related	Uncertainty of quality of information source	• Choice of information sources is cumbersome • Trustworthiness of sources of information • Ability of the source of information to fulfill personal needs is questioned	N3. Have recognizable, reliable and trustworthy information sources that have no bias in providing wrong information.

RQ2: What requirements should be placed for the design of a blockchain-based system to address these problems?

In this subsection we translate the identified needs of buyers into functional requirements for a blockchain-based vehicle history application. These requirements were then discussed in the second round of interviews with car buyers on the basis of the presented scenario and mockup. Here we discuss the requirements for the design of a blockchain-based vehicle history, derived from the needs car buyers have during information seeking.

Information assessment. The first requirement emerges from the need (N1) for a comprehensive assessment tool that can be used to assess the quality of the information provided. Due to the fact that the level of experience and expertise in the assessment of information quality is heterogeneous, a tool that provides assessment of information quality is seen as useful. This tool may visualize the product quality, the completeness of the history, the effect of the information on the price of the car (*"It would be a cool feature if the price is directly indicated depending on the information inside")* and predict its future performance. 73% of survey respondents found the calculation for the effect of the information on the price important or very important. However, transparency over such analysis should be provided (e.g. one of the interviewees said: *"You cannot calculate it in numbers only; a number can mean much and nothing. It should be clear how the quality is assessed").* It is necessary to find a way to create such an information assessment as blockchain technology per se does not offer any additional information apart from the actual history of transactions. Furthermore, there is no single party in the decentralized setup which is responsible for provision of such an assessment. Therefore, it is important to create a setup where there might be parties offering such service (and probably even competing in it) and to foresee it in the system architecture.

Timeline. The second requirement emerges from the need (N2) to provide a timeline that reflects the current state of a car and the course of events in its lifecycle. 89.7% of survey respondents considered the timeline, with a chronological order of events, important or very important. Blockchain infrastructure implicitly provides

transparency over transactions in the ledger as well their immutability. Thus, on an application level the timeline should be visualized and represent the state changes and events in the lifecycle of each car. The timeline should include a timestamp, the record itself (i.e. event), as well as the provider of information. Clearly, it is crucial to ensure only high-quality information enters the system: blockchain system itself does not address 'garbage in, garbage out' problems. Worse than with other technologies, the garbage is immutable. Regarding the timestamp, it should be made clear if the technical or the business timestamp is visualized. Modeling the records in the timeline (events), it is helpful to pre-define standard events (like 'imported', 'registered', 'insured') so that the user can recognize them directly and relate to certain real events or activities performed (like 'repaired'). Depending on the record, records may include visual information attached (like photos of the repairs).

Independent parties. The third requirement emerges from the need N3. Information about the vehicle history should be provided, recorded and/or verified by independent providers. This will help to reduce information asymmetry between buyers and sellers, as one of the interviewees said: *"If information is provided by independent parties, then the seller will have less power, and the buyer will get more"*. At the same time, the information should be available not only to interested parties, but to everyone: 85% of respondents think it is important or very important that everyone has access to the stored information to create a fair system. This is where blockchain infrastructure and its decentralized character is very helpful.

Visibility. The fourth and final requirement also emerges from the need N3 and calls for making information providers visible and reflecting their past behaviors to ensure that they do not act maliciously. Only 22.2% of respondents found anonymity of information providers important or very important. Interviewees confirmed that the anonymity of car owners should be preserved, while the anonymity of organizations that provide data makes rather a negative impression: *"It's more trustworthy if I see the logo of a company I know, which verified the information"*. Another interviewee supported the idea of reflecting the percentage of entries verified by the government, which may further influence the overall evaluation of a car. In terms of the visual interface, this information can be either visualized by showing logos of companies or just their brand names next to the records, similarly to Zavolokina et al. (2019). This requirement is one of the reasons to decide for a permissioned blockchain system (as opposed to a public one), where the data providers should be known.

Table 2 summarizes the formulated functional requirements, derived from the needs (N1 – N3), discussed above.

Table 2. Functional requirements for blockchain-based vehicle history

Needs	Requirements
N1 →	*Information assessment:* Provide analysis of stored data from the past, its effect on an actual value of a car and prediction on its performance in the future.
N2→	*Timeline*: Provide a timeline, showing the current state of a car and the course of events in its lifecycle.
N3 →	*Independent parties*: Information about the vehicle history should be provided, recorded and/or verified by independent providers. *Visibility:* Make information providers visible and reflect their past behaviors.

Discussion

Though IS research on blockchain technology is still emerging, there are initial successes that show blockchain-based solutions may be feasible in cases where information asymmetries hinder the market and trust can be supported. The used car market in Switzerland is, as in many other places, a complex multi-party market defined by low trust between unknown traders. In a case such as this, general trust may be improved by the introduction of a blockchain-based vehicle history (Brousmiche et al., 2018; Notheisen et al., 2017) that does not require participants to trust one another, but supporting them with a system trusted by design (Seebacher & Schüritz, 2017).

The goals of this study were, firstly, to identify problems used car buyers face during information seeking (to answer RQ1); and secondly, to identify requirements that should be formulated for the design of a blockchain-based vehicle history to address and resolve these problems (thus, answering RQ2).

Our findings suggest that, despite measures taken to mitigate uncertainties (Dimoka et al., 2012), buyers still suffer from high levels of uncertainty around the quality of information available about cars they are researching during the purchase process. Although car buyers currently have access to a large number of information sources (which they may access conveniently online) (Smith, 2006), the more is not always the better. The choice of information sources often relies on different factors (e.g., the previous experiences and expertise of a car buyer). However, the problem buyers experience is the paradox of having a large variety of information sources available about brands, quality characteristics of certain models and their performance; while information about a specific car is not transparent and often even hidden. The credibility of information sources and the general

quality of the information found is then questioned by buyers. Furthermore, even now, as digitalization penetrates almost every part of our lives (Hinkelmann et al., 2016), car buyers do not give up traditional ways of finding information about a specific car: contacting the seller and taking a test drive, as well as the involvement of third parties (with more expertise). Therefore, we can argue that the existing mechanisms (online reviews, the reputation of sellers, etc.) (Dimoka et al., 2012) are not powerful enough to allow a used car purchase to be completed exclusively online. Buyers tend to ask people they trust personally and who they can rely upon. However, a novel blockchain-based vehicle history can compete with these sources and become a "faceless" experienced friend while buyers are searching for a car. It is important to note, that the blockchain solution in regard to the price of a car does not reflect the "real price", which does not exist per se, but can establish a price anchor by better reflecting the quality of a car purchased.

Additionally, we can observe that most car buyers experience a need for assessment of the information about a car, and its effect on the value of the car (which might be due to lack of experience, expertise or interest in technical characteristics and performance of cars). Thus, a comprehensive mechanism should be found to express these. Blockchain technology cannot intrinsically provide this assessment, however, because of the immutability and traceability of records (Seebacher & Schüritz, 2017), the overall quality of the information (discussed next) and, thus, outcomes of the assessment can be improved, not least because it dissuades poor data quality entry. Furthermore, we confirm that, given trust by design provided by blockchain architecture, on an application level assessment of available data and transactions still should be designed to resolve emerging trust issues and information asymmetries, this goes in line with the recent study of (Zavolokina et al., 2019).

Our research suggests that, currently, information seeking (Järvelin & Wilson, 2003; Wilson, 1981) leads to quality seeking: the quality of information and the quality of information sources are what really matter to buyers. From such a broad range of information, buyers struggle to build a comprehensive understanding of the car they are attempting to buy. This situation calls for a solution that integrates the full history of a vehicle, and, at the same time, ensures its high quality in terms of correctness, completeness of history in the system. This solution supports those honest sellers, unable to prove the quality of the car they are selling (Pavlou & Dimoka, 2008), while also helping to distinguish the honest sellers from the dishonest. Therefore, we may conclude that it is not the quantity of information but its quality that resolves information asymmetries. Thus, we claim that quality seeking can now be referred to as a dimension of information seeking.

As the design of a blockchain-based vehicle history mainly relies on data provision from different parties, it is crucial to set proper incentives for these parties to provide data of high quality. End users of the system (car

buyers and car owners) cannot perceive whether the provided data is correct or not when it enters the blockchain system. While the issue of data quality (before it enters the system) remains partly outside what blockchain can affect (Notheisen et al., 2017), the transparency of the process and data accessibility (Seebacher & Schüritz, 2017), which brings value to car buyers, are potential disincentives for free-riders and lemon sellers. Thus, future research should focus on designing incentive mechanisms for the provision of high-quality data.

Furthermore, as our results suggest, the information provided about a car should be verified by independent parties. While this apparently contradicts the need for a single source of truth, blockchain is the technology that may bring both sides together: from the one side, the creation of a single source of truth (the vehicle history), and from the other side, its decentralized character (Seebacher & Schüritz, 2017), which allows for verification of records by independent parties (e.g., an insurance company or a registration authority). Interestingly, though blockchain technology is always associated with its distributed and decentralized character, it is used to create centralized applications. They are centralized on an application level (e.g., one vehicle history for one car instead of various sources of information) that is based on a decentralized infrastructure. However, it requires a paradigm change in trust from buyers: trust in the application on top of blockchain technology must be developed before it may serve as an intermediary in trusting relationships between buyers and sellers, making them faceless.

Finally, the privacy promised by blockchains (Seebacher & Schüritz, 2017) should be studied further. From one side, due to the pseudonimity of its users, blockchain supports their privacy as identities are not disclosed (Seebacher & Schüritz, 2017). However, there is no unique version of blockchain; there are different configurations (e.g., public vs. private, on-chain vs. off-chain storage of data) that should be considered for the design of blockchain-based systems (Notheisen et al., 2017; Voronchenko, 2017). Our study suggests that the providers of information in a vehicle history should be visible (first, to allow differentiation between professional and private sellers, and also to show which records are verified by a trusted organization or institution, e.g., the traffic authority). This approach aligns with research on the influence of a brand on trust in markets (Akerlof, 1970). However, in this case, the design of the system should handle privacy (Brousmiche et al., 2018) and visibility differently for organizations and individuals.

As for transferability of our results, we believe that our findings are applicable primarily for: 1) permissioned blockchain systems, where participants are known, 2) for cases of handling valuable physical assets (such cars) and their traceability (e.g. real estate market, food industry, fashion industry). What does it mean in terms of requirements collection and formulation for such systems? Permissioned blockchain systems are frequently

designed by various businesses teaming up in a consortium (Bauer et al., 2019), where each of them may pursue their own interests and want to satisfy needs of their clients. Given various interests, it is crucial to identify the relevant end user group (like car buyers or car sellers in our case) which such a system should first serve, its problems and needs to later gain acceptance in the market. For this, a user-centered approach can be helpful for formulation of the requirements while keeping these problems and needs in mind. Various methods like interviews, workshops, focus groups, design thinking sessions involving this user group may be beneficial.

Limitations and Conclusions

The properties of blockchain technology can reduce the information asymmetry between buyers and sellers. Multi-party participation, data transparency, decentralization, transaction history, and immutability play an important role, thus, make blockchain technology suitable for use in the used car market. There are several challenges, such as the potential of falsification of data before it enters the blockchain and violation of privacy, which should be further studied and cautiously treated by practitioners.

We believe that the insights from this study can make a valuable contribution as they highlight the existing problems in the used car markets that are similar to processes from other markets where information asymmetries are in place (e.g., in real estate). Thus, we describe current problems in lemons markets, and contribute to information seeking literature the concept of quality seeking. This study also suggests the requirements for the design of a blockchain-based vehicle history, derived from the used car buyers' needs. Therewith, we extend the body of knowledge on blockchain technology in general but also inform its design implications. We see a high potential in developing studies to address other domains, where information asymmetries occur, and testing whether the formulated design requirements hold up there, too.

On the other hand, we acknowledge that further research is needed to make a stronger theoretical contribution from the micro-economic perspective and address the macro-economic perspective (a further study addresses it (Bauer, Zavolokina, & Schwabe, 2018)[4]). Some limitations should be highlighted, which should guide further study. The following aspects should be taken into consideration: Information asymmetries arise in markets where potential buyers rely on some statistical data to inform their purchasing decisions. These markets are populated by both dishonest as well as honest merchants who sell cars of variable quality. Honest sellers wish to signal credibility if dishonest sellers are present. This can be done in multiple ways (reputation, credentials, excludability from social groups, warranties, online reviews etc.). For a signal to be useful/relevant for the buyer,

the signal has to be credible and affordable. Saying this, we acknowledge that now the needs and the requirements for the system should be further examined. Early-on collection and validation of user requirements may also be helpful to address privacy issues, which frequently pose challenges in case of blockchain systems: understanding of end users' perception about privacy, their problems and needs, is again crucial for a careful design and later acceptance. However, these should be further explored in future studies.

Therefore, we hope to inspire further impactful research on blockchain technology, considering a large variety of aspects, from underlying cryptography, security and design, to growing blockchain-based ecosystems, their governance and business models.

Appendix

Questionnaire for the interviews of the first interview round

1. Did you have previous experience in buying a car?
2. Did you have any external constraints while seeking a car? (e.g. time constraints, wishes of family members)
3. What were your personal preferences/criteria for seeking a car? (e.g., color, price, location)
4. Describe in detail what kind of information you thought you needed in order to find a car.
5. Which channels and sources did you consider (mention also those you won't use; including your previous experience, friends, social networks, ratings, etc.)?
6. Which sources of information did you use? (Including yourself and your previous experience, friends, social networks, ratings, etc.)
    a. To what extent was the source reliable on your opinion?
    b. To what extent did information from this source lead you to success? (wholly, partly, not at all)
    c. Was information applicable? (wholly, partly, not at all)
    d. Was the whole of the information obtained (a) sufficient for the task or (b) insufficient for choosing a car?
7. Could you remember a situation when you felt uncertain about the information you needed? How did you cope with this?
8. How much time did you use in information seeking before you bought your car?

Questionnaire for the interviews of the second interview round

1. Have you already dealt with blockchain technology? In which context?
2. Could you imagine to trust a blockchain in the same way as e.g. the road traffic office?

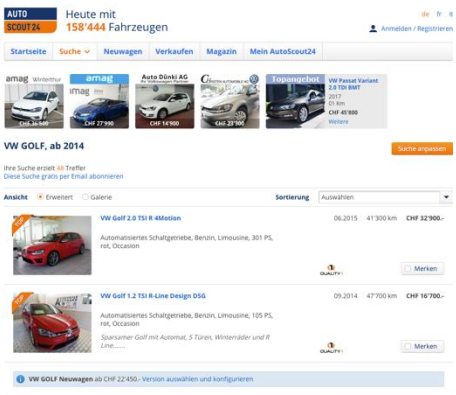
After the description of the Carcerti scenario (see below) and the screenshots of the prototype were provided:

3. Do you trust blockchain technology?
4. Do you trust the *Carcerti* more if it is based on blockchain technology?

If the interviewee has previous experience with blockchain technology:

5. What advantages do you hope to gain by using blockchain technology in this scenario?
6. What potential disadvantages do you fear from the use of blockchain technology in the scenario case?

Introduced scenario - Buying a second-hand car



Mary is 25 years old and she has just graduated from the master's program in psychology from the University of Bern. She has just got her driving license and is dreaming about buying a car. As a reward for her successful graduation, her parents decided to give her 17'000 Fr. so that she can buy a car. Mary also has her own savings, so she is ready to spent up to 20'000 Fr depending on the value of the found car. For sure, she wants the best what she can get for her money!

Mary have already looked what is there on the car market: she realized that she has to make some trade-off: for the amount of money she has, she can buy either a good second-hand car or go for not that well-equipped new car. She heard from her friends that normally second-hand cars in Switzerland are in a pretty good condition. So, Mary decides that she will look for a red VW Golf with automatic transmission which is not older than 5 years and its mileage should be ok. What exactly does "ok" mean? – Mary decides, that she will look on Autoscount24 to understand what kind of cars are being sold to what prices.

Mary goes on Autoscout24 webpage. She is sure that she'll find a car there easily. Her boyfriend already had good experience with searching for a car there. She types in needed characteristics (produced in 2012, automatic transmission, red color). She gets a list with 63 different cars from different providers.

Problem Scenario

Some are selling privately, some are garages that she hasn't heard about. The portal marks some as "Top", but what exactly does it mean? That they paid for the advertisement? Which dealer is better? A private or a commercial one? What other criteria should be considered? She thinks it would be nice that the car is eco-friendly and has not been used a lot.

Mary chooses 5 cars from the list and calls their owners. She talks to 3 private persons and 2 commercial dealers. After all she decides to go and look at one car as the deal was really attractive to her, the car was described on the website in detail, and she had a good feeling that this car will satisfy her needs. She goes to Zurich and meets Andy, who is selling his own car privately. Everything seemed great, because Andy said the car was in a good condition … and to prove it, he would pay for the inspections. However, he insisted they get the car inspected at a garage of his choice. Mary was thinking, "okay, at least I don't have to pay for an inspection". So, the garage passes her inspection, and she started driving home in her first car ever. She was excited, but then realized that the car isn't accelerating. She shrugged it off in hopes that the problem will go away.

Finally, four months later, Mary got sick of the problems which seemed to be getting worse, and took it to a different garage. They hooked it up to the diagnostics computer and told her she needs a new transmission and engine.

Solution scenario

Browsing Autoscout24, Mary notices that for some cars there are *Carcertis* available. Recently she has read in the newspaper "20 Minuten" that history of cars, driving on Swiss roads, will be available in some trustworthy manner. Mary contacts Mark, the owner of a car with such a *Carcerti*. She asks him to show the *Carcerti*, so that she can look into the car's history. Mark is interested in selling his car for the higher price than average on the market: he was a good driver, he made all the service checkups regularly, thus, he is sure that his car has a good condition. Mary sends an inquiry for the access – Mark gets a notification from the app on his mobile phone, accepts it and issues a temporary key so that Mary can access the overview on car's history. Mary sees the changes of mileage,

the results of checkups and insurance claims in there. Each of the lines in the history is marked by logos of organizations, who made these entries. So, Mary knows that AXA have inspected the accident, which happened last year in Luzern, when Mark crashed into another car at a parking space. She sees the photo of a scratch uploaded by Mark. The scratch was repaired in the official garage of AMAG. Mary is happy that she does not have to worry about any additional inspections she has to make before she buys the car.

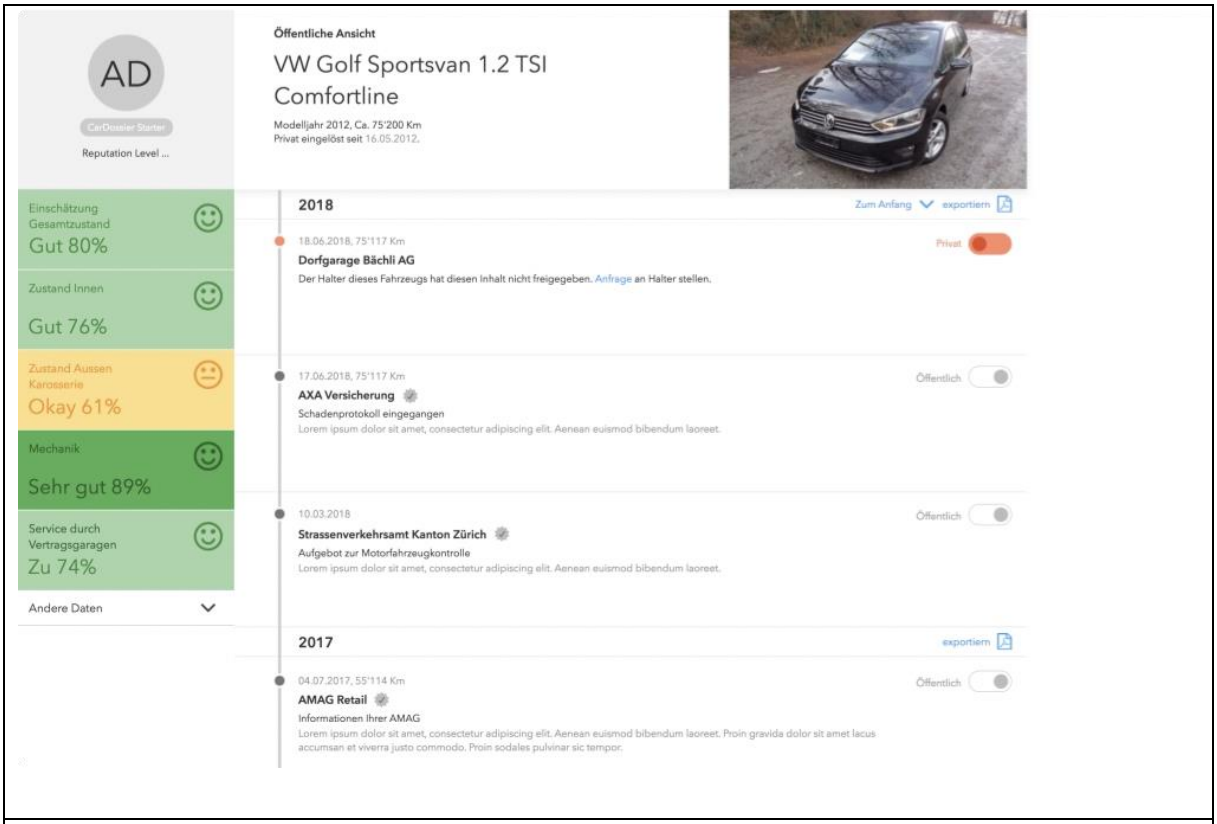


Figure 2. Screenshot of the prototype, used for the evaluation of the requirements

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