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Participatory Requirements Engineering − Using Factorial Surveys to understand Users' Attitude towards Emerging Technologies

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Abstract: In this century small villages face the great challenge to ensure the local supply with food and essential goods. Urbanisation and demographic change have caused many village stores and supermarkets to close their subsidiaries in rural areas. Thus, new concepts for village stores are needed. Based on a real situation this study presents a participatory research approach to gather the requirements for a multifunctional, digitalised village store. Together with the population in the reference village we conducted workshops, information events and an experimental vignette methodology (EVM) to gather the requirements of most citizens so that the design corresponds to the needs of the majority of the village population. The results show that the digital transformation of the village store has to be evolutionary to ensure a high users' acceptance. Besides, the use of new digital technologies is essential to contribute for the local long-term supply with food and indispensable goods in rural areas.

Keywords: experimental vignette methodology, EVM, village store, participatory design, user-centred design, requirements engineering

1 Introduction

Urbanisation and demographic change are the greatest challenges rural areas face in this century [Ge13, Un15]. In those areas these phenomena cause the population to decrease and the average age to increase. These changes in the population structure make existing structures for supply and care delivery insufficient. Due to the (very) low demand within a specific area it becomes difficult to make a profit with goods and services as the costs exceed the revenues. In the case of food and essential goods, supply supermarkets close their subsidiaries in some rural areas so that citizens have to drive to the next supermarket or run their own village store. By integrating existing and emerging technologies in the existing business models some of the main cost factors can be reduced so that the profit increases.

To date, the literature focusses more on the use of technology in cities than rural areas [NP11]. The contributions to Smart City research provide a good basis for rural areas but the requirements and problems regarding structural changes are very different.

In this paper, we contribute to the following research question:

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RQ: How can the requirements for the integration of (digital) technology into a village store be determined by means of a participatory design process attempting to actively involve all users (stakeholders) to best meet the users' (stakeholders') needs?

We conducted workshops and a survey involving stakeholders (citizens) living in a village of about 600 inhabitants to determine the requirements of the supply of food and other essential goods. As the survey implements the Experimental Vignette Methodology (EVM), vignettes presented the participants with shopping scenarios in which different technologies were used. By letting the participants judge on these vignettes we intended to examine their attitudes towards different shopping situations involving existing and emerging technologies. The vignettes encompassed a set of requirements in combination. In this way, the results of the survey can help create a design for the village store that fulfils the inhabitants' requirements.

By involving the citizens into the research process and making it transparent to the public, we achieved a great awareness in the village so that about 56% of the households participated in our survey. The survey showed that the citizens appreciate the existing structure in the form of a small store and demand technological changes to constitute improvements rather than digital disruptions. The findings provide insights about potential changes that could be transferred to similar rural areas. Moreover, we demonstrate how requirements engineering can be ensured, even though the future user did not know the presented technologies before.

First, we present the challenges of urbanisation and demographic change that rural areas face today. Second, we introduce the existing literature in context of user-centred and participatory design, requirements engineering and EVM. A description of the research approach of this study and how we motivated more than every second household to participate will follow. Afterwards, the survey results will be presented and analysed. We conclude with a summary of this research study and an outlook on how to use the identified technologies to design a digitised village store.

2 Theoretical Background

2.1 Impact of Urbanisation and Demographic Change on Rural Areas

In the latest report of the United Nations on World Urbanisation Prospects, the organisation presents statistics on people living in urban areas in the years 1950, 2014 and a prediction for 2050 [Un15]. While in 1950, 25-75% of the people in most developed countries lived in urban areas, the percentage increased significantly so that more than 75% of the population of most developed countries lived in urban areas in 2014. A great amount of young and highly-educated workers from rural areas were part of the people moving to cities to have better job opportunities and earn more money [Ar03].

At the same time the birth rate declines and the life expectancy rose in some European countries (e.g. Germany). This phenomenon is called demographic change and causes the society to age [Ge13]. In combination with urbanisation this presents a major challenge to rural areas. The care and supply structures are not adapted for this change in society.

In 2014, Trebbin et al. analysed ways to secure the local supplies in German rural areas. They found that most village stores are medium-sized wholesalers that use the logistics network of large retail cooperatives. In this way the medium-sized wholesaler acts as an intermediary and the large retail cooperative can save their image by supplying this area[TFH15]. But Trebbin et al. stated that there is a chance for new organisational forms, too [TFH15]. In this study, we intend to find such new models in cooperation with the inhabitants. We focus on a North-Western Germany village of about 600 inhabitants. The current village store is located in the center of the village. It has been run by the current owner for 13 years. In a few years, the owner will retire and the village faces the problem of securing the local food and goods supply. To tackle this problem, we present a new design for a multifunctional, digitalized village store designed in a participatory process with the inhabitants.

2.2 EVM in the Context of Participatory and User-Centred Design

In 2010, the International Organization for Standardization published the ISO 9241-210:2010 Standard "Human-centred design for interactive systems", which replaces the ISO 13407:1999 Standard. ISO refers to User-centred design (UCD) as Human-centred design (HCD) and describes the principles of HCD in ISO 9241-210:2010, i.e. how to plan it and the main activities of the HCD process [Is09]. In this process the user requirements take up an important role. The user requirements are specified, solutions are designed and in the end the design is evaluated against the requirements. Consequently, it is essential to specify the user requirements carefully. Linda A. Macaulay describes nine different approaches to requirements engineering: Marketing, Psychology and Sociology, Structured Analysis, Participative Design, Human Factors and Human-Computer Interaction, Soft Systems, Quality and Formal Computer Science [Ma96]. The Human Factors and Human-Computer Interaction approach mixed with the Participative Design approach enables researchers to design future solutions for and with the users. In context of the digitalization process, the integration of future users in the requirements engineering process might be difficult because they might not know which technology is available and how it can be used. Therefore, most of them cannot judge on the possibilities technologies will offer in the future. However, to achieve a UCD, the users have to express their beliefs about their willingness to use certain technologies. UCD contains different methods to satisfy user's needs by iteratively carrying out task analyses, requirements analyses, tests and evaluations. In contrast to most UCD methods, we do not only focus on the design of an interface, but rather expand the scope and focus on the interaction of the user and the technology system in a specified context. Eason identified and described three different types of users as followed [Ea05]:

1. *Primary Users,* who will actually/directly use the artefact.
2. *Secondary Users,* who will use the artefact occasionally.
3. *Tertiary Users,* who will be affected by the use of the artefact.

Applied to our case, primary users are regular customers; secondary users are occasional customers and tertiary users are a third party that will be affected indirectly (e.g. children whose groceries are bought by their parents). Due to these different kinds of users, it is necessary to ask as many people as possible to record and understand the needs and requirements of every kind of user. Abras et al. note that the way in which possible users participate can vary widely – from relatively slight (e.g. consultation) to very intensive participations [AMP04]. This must be considered by the design because the village store can be described as a social-technical system, consisting of social components (people-related) and technological components (e.g. self-checkout systems, online shop). Interdependencies between technology, people and context have to be considered to prevent errors or at least diminish their effects. Thus, the reality cannot be decomposed in a social and a technical subsystem [RBC14] but must be considered as a whole system. For the requirements engineering this means that the users have to be presented with a description of the whole system. This can be achieved by scenario-based methods. Since 1974, when Rossi et al. introduced the factorial survey to study human judgements [Ro74], the method has been widely used to better understand people's beliefs about social situations[CC04, LS13]. In a factorial survey, a respondent has to judge on a situation which is presented by a vignette. Each vignette consists of the same factors which have different levels and may influence the decision of the respondent. By analysing the respondents' judgements, the influences of the different factors can be examined. Factorial surveys are primarily used in sociology, but are also used in psychology [Hi84], criminology [JC98], healthcare [SK04], gerontology [Ba83] and many other fields.

As the use of information technology becomes part of our everyday life, technology will become essential for future social situations. For this reason, the factorial survey constitutes a convenient methodology to understand the user's attitude towards different technologies. Within the research discipline of Information Systems, factorial surveys have not found a lot of applications yet. Eargle et al. used the factorial survey to investigate influence of moral intensity and impulsivity on accountability of intentions to violate the access policy [EVL13]. Vance et al. evaluated the effect of user interface design artefacts increasing the accountability and the influence of increased accountability on the intention to violate access policies [VLE15]. Furthermore, other research examined the influence of perceived organisational injustice [WWJ11] and other characteristics on intentions of insider computer abuse [Wa12]. Lee et al. use the factorial survey to measure the effect of monitoring mechanisms on Bring Your Own Device adoption [LCW13]. Most recently, publications of Johnsten et al. and Moshki et al. show the topicality of factorial surveys in Information Systems research [Jo16, MB16]. All these publications try to measure people's intentions and judgments. We were unable to identify a study that applied the factorial survey for requirements engineering. Most of the requirements engineering processes focus on identifying

requirements separately. By using the factorial survey, a combination of requirements can be presented to the respondents and they can judge on the whole situation.

3 Research Approach

Based on the results from section 2 we designed a research approach which uses workshops, information events and a survey to best integrate the inhabitants. Fig. 1 summarizes the research approach with the different steps, a description of the participants, the topic and the achieved results to assist the comprehensibility.

To achieve a participatory design, it is necessary to understand the preconditions and to identify the stakeholders. In a first workshop, the participants described their thoughts on how the village store can be designed in the future. Additionally, the participants got a feeling for the actual situation which was presented by the village's major. During this workshop, we experienced that most of the people living in the village do not know emerging (digital) technologies and their application. Therefore, the factorial survey provides the possibility to explain the available technologies in the vignettes. Hereby, the citizens have to state in the design process of the digitalisation of the store where they will go shopping in the near future. Based on the decision to conduct a factorial survey, we began to review the literature and technologies that are currently available or introduced by the producer, to get a fundamental understanding of the current advancements in the context of emerging technologies for supermarkets. This review was complemented by an analysis of important factors for shopping in a village store.

	Participants	Topic	Results
Workshop 1	Major, researchers from the fields of ethics, information systems, logistics, business	•Discussing the research approach •Getting familiar with the village and the village shop	•Using factorial survey for requirements engineering
Pre-Test	Students	•Testing the EVM for requirements engineering	•Keeping factors and factor levels small to reduce vignette population
Information event	Citizens, major, researchers	•Informing citizens about research purpose •Presenting possible technologies	•Focussing an evolutionary technology implementation in village shop
Workshop 2	Major, researchers from the fields of ethics, information systems, logistics, business	•Deciding on factors and factor levels •Selecting additional questions	•Factors and factor levels for EVM •Additional questions
Workshop 3	Citizens, major, researchers froms the field of ethics, information systems, logistics, business	•Discussing final questionaire •Planning implementation	•Final questionaire
Survey	Citizens, researchers	•Citizens filled out questionaires •Analysis of the survey	•Survey results
Result presentation	Citizens, major, researchers	•Presentation of the results •Listening to citizens' feedback	•Citizens' feedback

Fig. 1: research approach

To gain first experience with the factorial survey, we used the collected data and conducted a pre-test with students. We used a *within-subjects design,* which presented all vignettes to each respondent [AS10]. The pre-test helped us to gain first experience with factorial surveys and their analysis and to see whether the concept of the survey was valid. The results showed that a lot of participants cancelled the survey and many respondents mentioned that they got bored as the survey took too much time. Consequently, the next survey has to (1) contain fewer vignettes and (2) not all vignettes should be presented after another. Rather, the vignettes should be split up in multiple parts. In an information event we presented the research approach as well as some of the identified products to the citizens. We received the feedback that some of the presented technologies were too futuristic (e.g. personnel free supermarket opened with a cell phone and monitored by cameras) and that the citizens were not willing to use theme in the near future. Based on the collected data and feedback, we conducted a second workshop with experts from the field of logistics, information systems and business as well as representatives from the region of interest. After a short introduction to the methodology of EVM, the participants discussed the factors as well as the factor levels for the study. Some of the identified products and concepts were described as unrealistic for a small supermarket in a village (e.g. indoor navigation). The workshop participants agreed on excluding technologies which the citizens described as too futuristic and focusing on technologies which continually evolve rather than disrupt. The resulting factors and factor levels are illustrated in Tab. 1. All factors represent influences on the customer's shopping. The factor *shipment* describes whether the goods from the shop will be shipped to the customer's home or whether the customer has to take the goods home on his own. *Contact to personnel* adds any contact to personnel in the vignette. The factor *goods registration* describes how the customer registers the goods he wants to buy.

Identifier	Factors	Factor Levels
A	Shipment	Yes No
B	Contact to personnel	Yes No
C	Goods registration	Conventional cash register Self-checkout Smart Cart Online

Tab. 1: Factors and factor levels for the factorial survey

	$C = c_0$		$C = c_1$		$C = c_2$		$C = c_3$	
	$B = b_0$	$B = b_1$	$B = b_0$	$B = b_1$	$B = b_0$	$B = b_1$	$B = b_0$	$B = b_1$
Set I								
$A = a_0$			$a_0b_0c_1$					$a_0b_1c_3$
$A = a_1$		$a_1b_1c_0$			$a_1b_0c_2$			
Set II								
$A = a_0$		$a_0b_1c_0$			$a_0b_0c_2$			
$A = a_1$				$a_1b_1c_1$			$a_1b_0c_3$	
Set III								
$A = a_0$				$a_0b_1c_1$			$a_0b_0c_3$	
$A = a_1$	$a_1b_0c_0$					$a_1b_1c_2$		
Set IV								
$A = a_0$	$a_0b_0c_0$					$a_0b_1c_2$		
$A = a_1$			$a_1b_0c_1$					$a_1b_1c_3$

Tab. 2: Confounded factorial 2 x 2 x 4 vignette design with four sets

Consequently, the vignette population results in 2 x 2 x 4 = 16 different vignettes. Due to the experience gained in the pre-test, the workshop participants decided on using a *mixed design* which divides the total vignette population into four subsets of four vignettes each which were given to a group of respondents [AS10]. We ensured to represent every factor level equally often in each subset. The allocation is shown in Tab. 2.

By this design, we made sure that three higher-order interaction effects were confounded with the set effect which describes the differences between the sets. The main effects were not confounded with the three higher order interaction effects [AS10].

The acquired insights were the inputs for a third workshop. Its purpose was to design the final questionnaire. The questionnaire[2] was complemented by additional questions which focussed on the citizens' current buying behaviour, their criticisms of the current village store, as well as their wishes for a future store. This time, more representatives from the village were present to verify that the questionnaire was comprehensive. Furthermore, the representatives were introduced to the conduction of the study so that they could help other citizens when questions arose. Having contact persons from the village appeared to be helpful because of the low inhabitation level to contact them. All participants agreed that it is beneficial to write the contact persons' addresses on the first page so that every respondent knew who to contact when they had a question. Additionally, the workshop consented to give everybody the chance to participate and keep the hurdles for participation as low as possible. Therefore, every household of the village (244 in total) received a questionnaire with the daily mail and had the possibility to send it by mail or throw it in ballot box which was placed at the local village store. The survey was completely paper-based so that the participants did not require any IT knowledge. The

[2] Our questionnaire and vignettes (factorial survey) will be provided to interested readers.

respondents had two weeks to fill out the questionnaire and send it back. Afterwards, the questionnaires were digitalised to prepare them for analysis.

4 Analysis of the Results

4.1 Survey Results

For the analysis we considered all returned surveys. As mentioned, we handed 244 questionnaires over to the different households. We received 138 responses, which corresponded to a response rate of ~56%. This high response rate might be ascribed to the citizens' large awareness of the survey due to the information events and citizen involvement. 70% of the respondents were female and 28% male. On average, the respondents shopped for 2.97 people including themselves. So, the higher proportion of female participants might be due to the fact that mothers are shopping most of the times for the family and filled out the questionnaire for the whole family. The participants' age ranged from 21 to 90 years. Additionally, we compared the age distribution in our survey with the official reports from the village and in great part it coincided. A high amount of the respondents 75% were working. Only 25.4% worked in the village. Further, we asked whether the participants needed help with shopping. 5.8% reported that they needed help and most of them mentioned that the goods were too heavy so that they needed help with carrying and transporting. One individual stated that she needed help finding goods in the store and another individual had problems with packing. Due to the digitisation intentions, we asked the participants what electronic devices they used and whether they had internet access. 92% stated that they owned a mobile phone; about 80% of them had access to the internet. Besides the mobile phone, 75% of the participants owned a computer, 23% a tablet and 18% a Smart-TV.

In addition to the questions regarding the person, we asked for improvements of and attitude towards the current village store. By now, the current village store was open from 6:30 a.m. to 6 p.m. with a two hour break six days a week. More than half of the respondents stated that they shop in the village store more than once a week. The average purchase value amounted to 5-30 € for a great majority of 77.8%. Another 13% pay between 30€ and 50€. We asked the participants where they bought certain types of goods to get an overview of whether they bought them in the village store, a supermarket outside the village, online or somewhere else. The results are presented in Tab. 3. For most of their goods, the participants visited a supermarket. The village store was preferred over the supermarket in *fresh baked goods* and *beverages*. Online shopping was not popular in the village. Just up to three people stated that they bought some of the mentioned goods online. Paying attention to the feedback of the first information event, we asked for additional services offered in at the village store. The respondents had to evaluate different services within a range from 1 (very unimportant) to 10 (very important): post office (avg: 7.23), café (avg: 6.23), repair service (avg: 4.76), laundry

shop (avg: 4.29) and hairdresser (avg: 4.16). These values show that offering a post office or a café at the village store might be a welcomed supplement.

		Shops			
		Village store	Supermarket	Online	Others
Type of goods	fruits & vegetables	27.5%	75.4%	0%	9.4%
	other groceries	63%	65.2%	0.7%	0.7%
	fresh baked goods	82.6%	21.7%	0%	8.7%
	beverages	64.5%	50%	0.7%	2.9%
	detergents	22.4%	73.9%	0.7%	5.1%
	body care products	10.9%	72.5%	1.4%	13%
	haberdashery	7.2%	49.3%	2.2%	9.4%
	magazines	38.4%%	37.7%	0.7%	5.1%

Tab. 3: Shops where certain types of goods are bought

In general, the results show that the citizens appreciate the current village store and at the same time realize the need for technological change. This corresponds with the results we got from the vignettes. Through the determination of our vignette subsets, all vignettes were systematically assigned to subsets. By deleting questionnaires with incomplete vignette answers, we cleaned up our collected data. We analysed our vignette data by using a linear regression model. The model is represented in Tab. 4 and lists the coefficients with standard errors (*** indicates high significance) shows goods registration - especially self-checkout - and contact to personnel have the biggest impact on the participants' ratings, followed up by shipment. Goods registration and contact to personnel are highly significant with a p-value < 0.001, whereas shipment is only slightly significant with a p-value of 0.86.

The use of a self-checkout system in a vignette led to a decrease by 2.55 points on the 10-point scale, compared to a decrease by 1.61 points for smart carts and 1.86 for online good registration. Moreover, the estimated model shows an increase of 2.00 points if the customer has contact to personnel. Furthermore, shipment reduced the agreement to the proposed concept by 0.52 points. At first glance, this might seem unusual, but in context with our results from the workshops and the open text fields in our survey, it is well comprehensible. The village store is not solely used for the shopping purpose, but functions as a "communication center" as well.

In addition to the linear regression model, we examined the answers for each factor. We used boxplots to obtain more insights in which way the answers are distributed [SC02]. Furthermore, we visualized the evaluation of the vignettes, where each answer is represented by a point. It is noticeable that the span width for each factor level ranges from 1 (minimum) to 10 (maximum). Especially the vignettes without the conventional cash register were evaluated significantly worse. Nevertheless, the data distribution shows evidence that additional *goods registration* options might be useful und should be

considered. Some of the proposed technologies used in the vignettes are not very easy to use if people have little knowledge on using technology. So, we asked the participants

	Conventional shopping	
	Coef.	Standard error
Constant	5.53	(.37)***
Shipment		
No (ref.)		
Yes	-.52	(.30)
Contact to personnel		
No (ref.)		
Yes	2.00	(.30)***
Goods registration		
Conventional cash register (ref.)		
Self-checkout	-2.55	(.43)***
Smart Cart	-1.62	(.43)***
Online	-1.87	(.43)***

Tab. 4: Linear regression model

whether they were interested in trainings focusing on how to use the introduced technology. The majority of 58.93% stated that they did not need special training. A reason for this might be that the younger participants were already familiar with using technology. The remaining 41.07% indicated interest in special trainings to use the new technology. Therefore, special training should be offered if any technology will be used in the village store.

One essential cost factor for running a village store is the salary for people working in the store. As we experienced in the vignettes, *contact to personnel* is very important for the customers. To reduce the costs for personnel, we asked the participants whether they can imagine working voluntarily. 61.5% stated that they are not willing to work voluntarily. This may be due to their jobs or that they feel too old. Working 1-5 hours a week is conceivable for 33.6%. Some respondents (5.9%) stated that they are willing to spend more than 5 hours working in the village store voluntarily. Two persons said that they could work 10 or more hours in the store. This willingness to volunteer is a reason to consider new business models where it is possible to leverage this potential. Additionally, we asked which kind of work they would volunteer for. Most people are willing to shelve goods (28%), deliver orders (16%), sell goods (16%) and clean the store (7%). Many people (47%), especially those who are not willing to volunteer, could imagine buying cooperative shares.

4.2 Design for the Village Store in the Example Village

The high ratings on the conventional scenario in the survey and the feedback from the information event show that the people appreciate the existing structures of the village store. Based on the results for the dimension *goods registration,* we experienced that the participants can imagine using technologies such as a *Smart Cart* or an *online shop*. The high standard deviation for the different types of goods registration seems to indicate different opinions on this topic. Therefore, the technologies have to be advantageous instead of disruptive. Additionally, the technologies should constitute a supplement to the existing structure. So, the people should be able to order online, shop with the Smart Cart or go to the village store as they are used to. Offering all these possibilities gives the people the opportunity to test and get used to them. Thus, technologies seen as too futuristic in the first place could be implemented in the next phase.

Besides using technology for goods registration, we see great potential in using it to support the communication and organization of volunteering. The great willingness to voluntarily work in the village store can be used efficiently by distributing the available tasks over the volunteers. This can be realized by a communication website because at least 80% have access to the internet and for those who do not, access can be provided in the village store. On this website people could see open tasks and undertake as many as they are willing to. By leveraging the willingness to volunteer additional expenses for full- or part-time employees in the village store can be avoided.

We observed that people prefer the supermarket over the village store in the goods *fruits/vegetables*, *detergents*, *body care products* and *haberdashery*. A future study should analyse the purchased goods and ask the people which products they prefer to better understand the reasons why they are buying some goods in the supermarket instead of the village store. By better understanding the buying behaviour, the assortment of the village store can be fitted to the people's' needs. In this way, the narrow shop area can be used more efficiently. Furthermore, the right number of perishables can be in stock so that fewer goods must be thrown away.

The questions regarding additional services provided evidence that the village store might be a good location for providing additional services. Many people stated that they would like a post office or a café. By adding services to the village store, this place becomes a central contact point where people can not only buy their groceries but also use different services (e.g. repair service, laundry shop). This would be a great advantage especially for people who are not very mobile and can go to the village store to get different things done.

All these small changes help to cut some costs which can be avoided by using technology and can help to attract more people to go shopping in the village store than the supermarkets.

5 Conclusions

Urbanization and demographical change are presenting major challenges for the infrastructure - not only in cities but especially in rural areas, which are affected heavily. The supply with food and everyday goods is of paramount importance to remain an attractive place of residence. New technologies can be useful in securing the supply, but must be carefully selected to not overstrain the users. Otherwise, (especially older) citizens can be overstrained and might refuse to use the village store completely.

Based on our research, we recommend the use of technological features as additional offers, not as replacements. With respect to HCD, we decided to offer different participation opportunities, so everyone in the village has the chance to participate. The primary goal of this paper is to determine the requirements for a village store, while aligning the technological possibilities with the needs of the citizens. The use of the factorial survey helped to present a set of requirements to the respondents, in contrast to ordinary surveys. By using the factorial survey, a combination of requirements could be presented to the respondents and they could judge on the whole situation. Integrating the people in the research approach turned out to be a great advantage. Even though the population was very sceptical about the research the ongoing dialogue and inclusion in the research process helped to motivate a majority to participate in workshops and surveys so that the result matches the needs of the population.

Due to different preconditions these results cannot easily be transferred to other villages. But the research approach can be adopted anywhere else to design a multifunctional, digitalised village store in collaboration with the citizens. During the public presentation of the survey results, we experienced great approval and the citizens signalled willingness to participate in the future implementation of the village store.

As this research focussed the requirements engineering for a multifunctional, digitalised village store, future research needs to determine the participative implementation and evaluation of the village store. Additionally, the connection with other services such as laundry and a café needs to be determined, so that the village store becomes a social hub where people meet each other and spend their time. This will promote the village store and it will be more likely that it makes a profit.

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