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ORIGINAL PAPER

Using Information Technology for an Improved Pharmaceutical Care Delivery in Developing Countries. Study Case: Benin

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Abstract One of the problems in health care in developing countries is the bad accessibility of medicine in pharmacies for patients. Since this is mainly due to a lack of organization and information, it should be possible to improve the situation by introducing information and communication technology. However, for several reasons, standard solutions are not applicable here. In this paper, we describe a case study in Benin, a West African developing country. We identify the problem and the existing obstacles for applying standard ECommerce solutions. We develop an adapted system approach and describe a practical test which has shown that the approach has the potential of actually improving the pharmaceutical care delivery. Finally, we consider the security aspects of the system and propose an organizational solution for some specific security problems.

Keywords Public health · Pharmacy · Ecommerce · Developing countries · Benin · Medicine ordering · Security

Introduction

In most countries of Africa there exists more or less no comparable health system such as that in developed countries, with the corresponding technical instruments, personnel and its expert knowledge. Many of the investigations carried out by the WHO showed that poverty of the population, lack of political will, bad national finances and not least the bad organization are the main deficiencies that underlie the enormous problems for the health systems particularly in Sub-Saharan Africa (SSA) countries [1].

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Usage of ICT in public health care

A typical aspect of the health system situation in these countries is the strongly limited use of information and communication technology (ICT). In nearly all cases patient data processing is carried out manually using paper documents. Other ICT systems applications, such as data mining or communication platforms are also mostly absent in the African health sector. Medical statistics are rarely conducted [2]. A group of researchers has examined the Kenyan health system and detected a “Digital Divide” in African countries [3]. Even for South Africa, a Study [4] found major obstacles for a successful introduction of ICT in the health sector. The HISP project [5] worked for more than 10 years to develop the DHIS system [6, 7].

Therefore, the question arises, whether the health system situation can be improved by ICT introduction. Important aspects are: Is it possible to transfer concepts, solutions and systems from developed countries? Are the necessary prerequisites for an ICT introduction available? Is it possible to do a stepwise ICT introduction? Is it possible to introduce ICT in different sectors of the health system and in different regions independently?

We investigated these questions for the example of Benin. A comprehensive study [8] has been performed, examining problems and solutions in fields such as telemedicine, education, and statistics processing, and also including financial, legal, and social aspects. In this paper we present one specific problem and a possible solution for it supported by ICT.

Problems in Benin public health system

General problems

The problems in the public health system are manifold. They range from a general functional deficit to problems in training, communication, procurement, data processing and information exchange [9]. In addition the public health system today is also still confronted with the problem of unnecessary expenditures.

Specific aspects are the absence of continued education, deficient infrastructure of medical care delivery systems in the country, illiteracy, organization and management problems, energy supply system problems, absence of health insurance, problems in telecommunication services and systems, and no patient data protection [8].

The "pharmacy tourism" problem

One specific problem, in addition to those named above, is the insufficient supply of pharmaceutical products for the population. For the individual patient a high time and effort is required to get all medicine prescribed by a physician.

Oriented towards the methods described by, e.g., Yin [10] and Eisenhardt [11] we conducted a case study by analyzing literature and conducting interviews to build a hypothesis about the reasons. This resulted in the following problem description.

Klein [12] observes: "Although in the meantime 83% of the population has access to the national health care delivery, only 36% of the population makes use of it." (situation in 2004, own translation). Although not the only problem, the distance to medical facilities, in particular in rural regions, represents a major problem for the access to the health care delivery system and facilities. This also applies to pharmacies [13]. A study in 2007 concluded, that the pharmaceutical care delivery system in Benin is severely underdeveloped [14].

In Benin there are three sources of pharmaceutical products: public pharmacies and dispensaries, private pharmacies, and the black market.

"All the public health facilities have dispensaries; so access to a public health facility should theoretically mean that geographic access to essential medicines exists within the public sector. In fact, 86% of the population has access to a health facility (…). Access to private pharmacies and pharmacy retail outlets is more limited. Approximately 80% of the urban population and only 15% of the rural population in Benin had access (within 5 km) to a pharmacy/pharmacy retail outlet in 2001. (…)" [13]

Public pharmacies and dispensaries are relatively frequent, however, they only provide a limited selection of medicine for common therapy, such as against fever or malaria. Often, a prescribed medicine can only be purchased in a private pharmacy [15].

"In the private sector there is a major discrepancy. In Atlantique [south of the country] there is about one pharmacy per 12,000 inhabitants. In Atacora [north of the country] one pharmacy is registered per 400,000 inhabitants. 45% of all pharmacies in the country are located in Cotonou [the capital]." (own translation) [13]

An own survey done in 2011 confirms these numbers. We found that more than 90% of all private pharmacies are located in the smaller southern part of the country. If we also count public pharmacies and dispensaries in the public medical centers, still 45% are located in the south of Benin and still only 86% of the population has access to them [8, 16].

In addition to the low density of pharmacies, our survey found that the supply inventory in the pharmacies is not sufficient. In large cities as well as in rural regions, it is often difficult to purchase all medicine on a prescription in a single pharmacy, since it is not in stock [15]. Then the patient has to travel to several different pharmacies and sometimes does not succeed to purchase all prescribed products at all. We call this phenomenon "Pharmacy Tourism". Many pharmaceutical products are very difficult to get in the country, not only in rural regions but also in large cities. The main reason for this situation is the high price of the medicine and a relatively low demand [17].

As a consequence, even if they have access to a legal pharmacy or dispensary, patients use alternatives: the black market or traditional healing approaches which do not use modern medicines [16].

From these findings we derived the hypothesis that the bad medicine supply of the population is mainly caused by the sparse distribution of pharmacies and the insufficient supply inventory, leading to "Pharmacy Tourism".

Problem analysis

When we analyze the "Pharmacy Tourism" problem from the viewpoint of computer science, the main aspect is missing information about where medicine is in stock. A second aspect is the patient's high expenditure for purchasing the medicine. Both aspects have a simple and standard ICT based solution: an ECommerce system [18]. However, we found that it is not possible to solve the "Pharmacy Tourism" problem in Benin by simply introducing an ECommerce system for several reasons.

More detailed, the use case here is the following. A prescription for one or more medicine products has been filled by a physician. The goal for the patient is to buy and apply all prescribed medicine. The necessary steps are: searching for one or more pharmacies where the products

are in stock, ordering the products at these pharmacies, delivering the products to the patient, transferring the payment from the patient to the pharmacy. The ECommerce system is most effective, if it supports all four steps.

In the search step, the search criteria are dynamic and the user can specify them as needed. For example the user can set the product price or an alternative product with same effect or the distance to the pharmacy as criteria. By default the distance to the closest pharmacy is the standard search criterion. This corresponds to the motivation and/or primary goal of the system.

We found the following obstacles for introducing such an ECommerce system in Benin. All of them are most severe in rural regions, where also the "Pharmacy Tourism problem" is most severe.

1. Missing communication infrastructure. Internet and even traditional phone lines are sparsely existent and only concentrated in the larger cities.
2. Most patients have no ICT equipment. A large percentage consists of analphabets and can only use ICT equipment in a strongly limited manner.
3. Most pharmacies have no ICT equipment.
4. There is no reliable electricity supply for operating ICT equipment.
5. There is no reliable delivery service. Postal transport is unreliable, too slow and too expensive.
6. There is no electronic payment infrastructure. Most patients do not even have a bank account.

Every single of these obstacles hinders the successful introduction of a standard ECommerce system. Therefore, the solution consists of two steps: first adapt the system concept and infrastructure to meet all identified obstacles, then introduce the adapted ECommerce system.

ePharmacyNet as solutions approach

We now present ePharmacyNet, a solution for the "Pharmacy Tourism" problem based on ICT which can be effectively introduced in Benin and other African developing countries.

Adapting the system concept

In the first step we treat each of the obstacles found, and adapt the system concept accordingly.

Problem 1: In the last years, a mobile communication infrastructure has been installed in Benin, which is applicable as basis for the system. Using mobile phone is an efficient and safe way regarding the energy delivery and internet traffic problems in Benin. MTN, a mobile phone company, covers more than 90% of all regions in Benin. Compared to other telecommunication service providers its services exhibited a sufficiently high availability.

Problem 2: The system must be accessible for all people living in Benin. This is possible by supporting a wide variety of access interfaces to the system. The first class of interfaces is a standard PC equipment. It may be owned by the patient or it may be used in an Internet cafe. It is also recommended that health centers provide equipment which can be used by their patients to search and order pharmaceutical products. The second class of interfaces consists of voice interfaces and SMS and/or MMS, typically via mobile phone. The voice interface is operated as a call center. It can be used by patients with a mobile phone as equipment. A SMS/MMS template has to be used, because in addition to the medicine name, additional data are required for automatically processing all steps in the use case.

The third class is assisting persons. They are necessary for illiterate patients who cannot read the prescription or patients not owning a mobile phone. It is an important component of the system to build an infrastructure of trusted persons who can assist patients in using the system. Possible candidates are village teachers, health station personnel or specific service centers. An assisting person can also be the physician who prepares the prescription and inputs it directly into the system.

Problem 3: Pharmacies without ICT equipment can manage their stock using paper lists and communicate updates to the system via telephone. On this basis it is possible to integrate both pharmacies with and without ICT equipment into the system.

Problem 4: There must be backup solutions to keep the system working when no electricity is available. This may be backup for electricity supply, such as a generator or solar power modules, or it may be a fallback mode based on paper and mobile phones. Additionally, ICT components must have automatic recovery functions which allow a restart after an electricity outage without damage to the system.

Problem 5: This is the most difficult part, since no trusted delivery service exists. One possibility is to organize (collective) transports by zémidjan (also called "zem" or "taxi moto"). This is a type of motorcycle based taxi found in Benin. The highest concentration is found in the largest city, Cotonou, where there are an estimated 40,000 [19].

Problem 6: The system must always support cash payment as an alternative. In combination with a working delivery service cash on delivery can be used or trust systems as an alternative to credit cards.

Problem 5 (and as a consequence problem 6) cannot be solved completely. However, even if only the first two steps according to the use case are used (search and order) and the patient then travels to a single pharmacy where he can be sure to buy all required medicine, the situation is improved.

Resulting concept

The resulting ePharmacyNet system is composed of a supplier system, of a "trade center" with a central database as well as of consumers (patients). The suppliers represent the pharmacies that are participating in the system. They provide to the trade center information about the availability of requested pharmaceutical products. The trade center is the direct communication partner for the consumers. It processes every request using its database or polling suppliers for up to date information. The result is sent to the consumer. Additionally, the trade center supports ordering, delivery and payment steps by forwarding necessary information to the involved partners and coordinating and supervising activities.

System components and infrastructure

The trade center

The trade center, a public service, is the central system component. It is implemented as an application server using a database system. The frontend consists of a Web based interface, an SMS interface, and a call center providing the voice interface and handling SMS messages which do not conform to the template. The call center personnel uses either the Web based interface or a graphical user interface (GUI) which directly accesses the trade center and provides additional "expert" support.

The basic information is a list of all available pharmaceutical products in Benin. This list (called red list) is generated as a version and/or variant of the red book. The red list contains a set of information for every product; it must be defined by physicians and pharmacies. Based on this list the trade center maintains and updates the central database containing the information, which pharmacies currently have the product available and what amount of it.

Search

This system component is used for performing the first step in the use case: searching for one or more pharmacies where the prescribed products are in stock. The backend function executes the corresponding queries in the central database and filters the results according to user criteria. The results will be either shown over a web browser or over a graphic user interface (GUI). For users without direct access to the system, the search is initiated by the call center personnel and the results are communicated to the user via the communication channel used for contacting the call center.

Ordering

This component is used for purchasing pharmaceutical products over ePharmacyNet. In the simplest case the patient enters the product as specified on the prescription after searching a pharmacy that corresponds to his needs. Additional information for following steps, such as a delivery address and payment mode must be entered. This corresponds to the standard ordering functionality in ECommerce applications. As additional support for entering the product, a menu based on the red list can be provided where the patient selects the prescribed product.

If the patient has no access to the Web based interface, the call center personnel enters the ordering information.

If the patient is illiterate and cannot read the prescription, an assisting person is required for entering the order information. Here we consider an interesting special case: the assisting person may be the physician who prescribes the product. The physician has expert knowledge and will possibly perform the use case in a different manner: he may already know where the product is on stock nearby, he can easily switch to alternatives, if products are not available, and he may use specific navigation in the red list and read additional information about the products. This should be supported by the interface, hence, a corresponding "expert" GUI should be available, either as a Web interface or even as a GUI of an auxiliary application which has been installed locally. This GUI may be identical with the GUI used by the call center personnel.

Of course, it is also a useful option for other patients, who are not illiterate, to have a safe and easy ordering be entered by the physician.

The trade center forwards the ordering information to the corresponding pharmacy. If the pharmacy has been fully integrated into ePharmacyNet, this is done in a predefined format (possibly based on XML). An ordering component at the pharmacy receives the data and processes the order according to a predefined workflow. In case that the pharmacy has not (yet) been fully integrated, or the communication channel or the component is currently not available, other possibilities must exist for forwarding the order to the pharmacy, such as email, SMS, or telephone.

Delivery

If the patient cannot collect the product directly at the pharmacy, a transport logistics must be involved for

delivery. The logistics can be operated by the pharmacy or it can be delegated to a courier service. In both cases, the logistics system should be connected to the trade center, to provide a status inquiry functionality which can be accessed in the same way as the other components, i. e., also through the call center. Then the customer can inspect the status of his order. The logistics provider must store the necessary information for the pursuit of the product and make it available for the trade center. This service is today already standard and is offered by many courier services.

It may be more profitable if the delivery logistics is operated by a separate organization. It is responsible for cash-on-delivery payment as well as the security of the delivered products, vis-à-vis the pharmacy (supplier).

In Benin, courier services like UPS or DHL exist, whose services are expensive and are based mainly on express courier abroad. These courier services work exclusively with motorcycles. A similar structure for the delivery of medicine could develop. Since the logistics is already available and there exists several experience, it could be efficient and costs saving, if the existing courier service structure is used for delivery of medicines. Another variant of the delivery logistics is the use of taxi moto, as described above. Here the pharmacy directly delegates delivery to the taxi moto.

Billing

The billing component produces the bill. After the order, a bill will be generated and can be printed out and/or sent to the customer. The bill contains the usual billing data as well as information about the payment, for example "per eCash paid". This is a standard function of ECommerce systems and needs no adaptation.

Payment

All payment modes need to adhere to the rules and regulations of the bank and financial system in Benin. They need to be usable throughout the country—in large cities as well as in rural regions. Major payment modes are: e-payment (using the internet or telephone to pay a bill), cash on delivery (suited particularly for rural regions) and trust systems.

E-payment is a standard functionality of ECommerce systems. A component of ePharmacyNet will be responsible for the e-payment processing. There the bank account data will be verified and at the same time also the credit worthiness of the customer will be tested. The e-payment component then forwards the data to the pharmacy which submits the payment request to its bank, or according to the structure of the ePharmacyNet, the e-payment component forwards the payment request to the bank and notifies the pharmacy. E-payment is also possible using a credit card.

A major problem for the use of e-payment is the fact that not all people in Benin have a bank account and/or a credit card [20, 21]. The reason is in most cases the absence of regular income due to unemployment and missing social security structure. Therefore, other payment modes are needed.

If the patient collects the ordered products directly in the pharmacy, the easiest mode is to pay it there in cash. No involvement of the ePharmacyNet is needed. If the product is delivered to the patient, a cash-on-delivery mode can be used. Here, the delivery service is delegated to collect the money upon delivery. The patient confirms by a signature the receiving of the medicine, the delivery personnel confirms by a signature receiving the correct amount of money.

In both cases payment can also be done by a check, however, for this option again a bank account is needed by the patient.

Communications infrastructure

The ePharmacyNet system requires two main logical communication channels: connecting the trade center with the patient (customer) and with the pharmacies (supplier). As already described, several different communication channels are necessary to reach all potential patients. The same holds for the communication with the pharmacies. Especially in the early phase of ePharmacyNet, pharmacies may have different electronic equipment and applications or none at all.

In the system, data exchanged between pharmacies and the trade center can be classified into two groups of information:

- information about medicine, including price and availability
- information about an order, possibly including personal customer data

In the ideal case, the information from the first group is handled as follows: a pharmacy replicates in real time its inventory in the central database of the ePharmacyNet or grants an access right to the central database. If all pharmacies do this, a nationwide database of medicine supply can be maintained. Only a database system configuration will be necessary if the suppliers already use a database system.

Several interfaces should be supported for this kind of business-to-business communication: Standard EDI (Electronic Data Interchange; web or/and classical) as well as Web Service and generic XML interfaces are among the most useful ones. As technologies for information exchange, at least HTTP protocol, email, fax, and SMS should be supported.

These methods all provide automatic processing of the information on both sides. To be able to integrate also pharmacies without the necessary equipment, these methods must be complemented with support for manual information provision by the pharmacies. This can be done with the help of forms to be filled. Thus no pharmacy needs to install an expensive EDI system or database. The form contents can be converted to EDI format and automatically processed at the trade center. This type of EDI is known as Internet EDI [22].

Pharmacy support

The most important prerequisite for a successful implementation of the system is the participation of as many pharmacies as possible. The first requirement for reaching a high participation rate is a low entry barrier. For any pharmacy it must immediately and easily be possible to become a supplier in ePharmacyNet. Additionally, the system has the potential to provide support and other advantages to the pharmacies. This is an important incentive for them to participate in the system.

First of all, the resulting marketplace has the potential to improve the revenue for the pharmacies, since they can reach more customers, resulting in a higher business volume. The transport costs need not be paid by the pharmacies, since for the patients the system already reduces the transportation costs in most cases so that they can pay the remaining costs.

Second, when the trade center supports ordering, delivery, and payment, it decreases the workload for the pharmacies. For example in an online payment, the trade center verifies the bank data of the customer. The trade center can also process the organization and the delivery of the ordered pharmaceutical products. The pharmacy receives the order per mail or another communication channel and prepares the product. The trade center may also prepare the invoice and process the delivery certificates.

Finally, if a pharmacy uses own ICT equipment for its inventory management, it can further reduce its overhead for participation in ePharmacyNet by replicating in real time (push mode) its inventory into the central database of ePharmacyNet. Another variant of participation is to grant access for the trade center to the supplier's system for querying updates (pull mode).

Additional applications

When the ePharmacyNet system is in place, it has the potential to support several additional applications which are not crucial for its main goal, however, they may further improve the situation for the participants.

Teleconsultation and telediagnosis

EPharmacyNet can be extended to provide simple forms of teleconsultation and telediagnosis (telehealthcare), as investigated in the Greenland Healthcare system [23, 24]. A patient living as far as 10 km from a medical care delivery center, particularly in rural regions, can get a prescription from a physician using a mobile phone. Alternatively, the physician can directly enter the prescription into ePharmacyNet as an order for the patient, with a confirmation by the patient.

Statistic data collection

If the system is widely used, the trade center can provide useful data about the demand and supply of pharmaceutical products in the country. This can be used for automatic statistics processing about certain medicines and optionally its transmission to the health authorities. For health authorities, information about the availability and amount of certain medicines or vaccines is an important basis for planning in epidemic and/or pandemic cases, for example in critical times of malaria.

Patient information

As a communication platform, the system can be used to distribute information to patients. The patient has the possibility to subscribe to a newsletter using this functionality. He then gets regular information about certain medicines either by mail or SMS. Information about opening of pharmacies close to him or new approved medicines for chronic diseases are announced to the subscriber. This function can be implemented by an additional system component running on the server of the trade center.

Platform for communication and cooperation

The communication channels of ePharmacyNet can also be used for connecting the other participants in the system and support their cooperation. physicians, health authorities, pharmacies and even health insurance companies and other participants in the health system can use the ePharmacyNet in order to communicate about pharmaceutical products. The communication can be organized in groups and communities. For example, a physician can discuss with a pharmacist or with other physicians the applicability of a new medicine.

AfricaPharmacyNet as B2B-pharmacy market place

The national ePharmacyNet could be complemented by an international African B2B-Pharmacy market place, that we call AfricaPharmacyNet. It will be a business-to-

business (B2B) system, that supports product orders and delivery directly between pharmacies and/or between trade centers from different African countries. The main idea is to buy drugs at a foreign pharmacy using this structure. This means, if the ordered medicine is not available in Benin, the trade center or a pharmacy can use this structure to buy the medicine from a pharmacy in another African country. A corresponding delivery system needs to be implemented.

AfricaPharmacyNet is an approach to get a medicine quickly and cheaper from a neighbor country than to order or purchase a medicine from European or American countries. Medicine like Chloroquine (against Malaria) is produced only for African countries, it may easily be available in neighboring countries.

AfricaPharmacyNet can even be connected to pharmacies outside of Africa for two extensional cases:

- Vital medicines, that are not available in Africa, can be ordered directly in a western pharmacy and can be quickly delivered by a courier service within 24 h. Here the pharmacy can order single piece and/or packing of a medicine instead of a larger lot from the pharmaceutical industry.
- The African pharmacies can use this structure to check whether a medicine is legally traded in western countries, before it is ordered.

The high delivery costs may be prohibitive for a regular use, hence the system should either be restricted to exceptional cases, or it must be funded by supporting organizations.

On-site tests

In January 2010 we carried out a practical test on site in Benin. Its main design consisted of a mocked ePharmacyNet implementation which provided the use case functionality to volunteers in the population. It was accompanied by presentations, interviews and questionnaires and had several different objectives.

Test objectives

A first objective was to improve the problem understanding. By implementing the mocked system in the real application environment, we wanted to get more information about the situational context of the process and about additional problems which may affect solutions, in particular ICT based solutions. This is a continuation of our earlier case study as described in "The "pharmacy tourism" problem".

A second objective was to test the technical and economic feasibility of the ePharmacyNet concept. This concerned, among others, the use of the mobile phone network for communication, the use of the local facilities for medicine delivery, and the participation of the pharmacies.

A third objective was to test for resistance to the ePharmacyNet concept in the population. It is well known [25] that resistance to information technology implementation is an important source of information about system deficiencies.

Finally, the test was also designed as a simple form of action research [26]. The action here was to change the process of purchasing pharmaceutical products by implementing the ePharmacyNet concept. The purpose of the action was to reduce time and effort for the purchase. The expectation was, that the system was accepted and used and led to a higher satisfaction, thus supporting our hypothesis.

Test design details

Test areas and personnel

Three test areas (three cities, five villages and two poor quarters) were chosen according to their geographic positions and particularly according to the severity of poor pharmaceutical care delivery in those regions and quarters. In addition to one of the authors, who coordinated the test, ten persons, each responsible for one test sub-area (village, city or quarter), were employed to conduct the tests, supervise the tests and at end to collect the test results. Table 1 shows the test areas with their locations, characteristics, and number of patients participating in the test.

Test Area II (Porto-Novo) has been chosen, since here the medical black market is very active. This is due to its geographic position close to the border to Nigeria from where the black marked is fed. Hence, in this area we could test our hypothesis against the hypothesis that the black market is used simply because it offers medical products for a lower price. If the ePharmacyNet concept was used in this area, the price could not be the major reason for seeking alternatives to legal sources of medical products.

Test Area III (Cotonou) is the largest city in the country. Its medical infrastructure is substantially better and the density of the pharmacies is higher than anywhere else in the country. It has been chosen for testing whether the eParmacyNet concept provides a benefit here for patients (do they use the system?) and pharmacies (are they interested to participate?).

Test Area I is situated in the north of the country and is much less developed than the southern part. It has a large rural population with the highest rate of illiterates. It has a poor medical infrastructure (pharmacies and hospitals) and poor city infrastructure. It has been chosen as a test region because here the problem is most severe and the ePharmacyNet concept is expected to be most effective.

Table 1 On-site test areas

Test area	Location	Kind of location	Distance to next pharmacy	Responsibles	Patients
I	Parakou	City	<4 km	1	12
	Kalale	Village	260 km	1	16
	N'dali	Village	52 km	1	203
	Nikki	Village	152 km	1	70
II	Porto-Novo	City	1–10 km	1	3
	Pobe	Village	9 km	1	50
	Ketou	Village	?? km	1	29
III	Cotonou	City	high density	1	1
	Djissoukpa	Slum in Cotonou	17 km	1	16
	Cecile/Ladji	Slum in Cotonou	9 km	1	34
Total				10	434

Test infrastructure

The test infrastructure consisted of mobile phones, Internet, laptops, and note pads. Most pharmacies have no Internet access and no database system and/or warehouse administration system. Also for the patients, which were of course not known in advance, we did not assume the availability of ICT equipment other than a mobile phone. Hence, for the test the trade center was implemented as a pure call center without electronic interfaces for customers or suppliers. This kind of trade center was mocked by persons on-site, who received the orders and searched for the medicines in the different pharmacies in Parakou, Porto-Novo, Abomey and Cotonou.

Order processing

In the mocked system the database was simulated by a list of medicines and pharmacies. This list was updated after every successful order. The orders of medicines were centralized and processed by the persons responsible for the test. All orders were processed by mobile phone. Every tester had a list that contained the names of products already bought and the name of the pharmacy which sold it. This simulated an updated database and thus the list constituted a data basis for a fast search in case of a new order.

Tele consultation

When it was indicated, a patient could take part either in a teleconsultation (via mobile phone) at the next large hospital or could directly consult a pharmacist. He was then assisted by test personnel.

Test evaluation

According to the test objectives, test evaluation was mainly qualitative. The most important question was, whether the system was used at all and which was the attitude the volunteer users had towards the concept. Thus, in addition to offering the mocked eParmacyNet functionality, we collected reports from the test sub-area responsible persons about their experiences. The responsible persons conducted interviews with most volunteer patients according to a question catalogue generated in advance. Additionally, in each test area, two pharmacies have been selected randomly for a telephone interview.

Most of the data collected was free form text, since we were interested in all kinds of experiences and suggestions to meet the test objectives. Numerical data were mainly collected about the test participants.

Test results

Problem understanding

We collected several information during the test, both from interviews and conversations and from own experience. A major part concerned security aspects. We present these aspects together with a proposed solution concept in "Security aspects".

Feasibility

The mobile phone network provided a sufficient communication basis for the system. Network coverage existed in all test areas. The test showed that mobile phones are appropriate for processing an order, particularly in rural regions or regions without cyber cafés. The communication costs are reasonably low.

The test also confirmed the problems of delivery and payment, especially in rural regions. One specific problem occurred with cash payment on delivery. For security reasons, pharmacies prefer to hand out ordered medicine to a carrier only against prepayment. However, often the carrier had not enough cash. The alternative would have been to first collect the money from the customer and then

fetch the medicine at the pharmacy. This may require additional tours by the carrier. The problem should disappear with an organized carrier service which is better trusted by the pharmacies.

Action research

The test was conducted for about 2 weeks simultaneously in the test areas. During this time, a total of 434 volunteer patients used the system (see Table 2). We interpret this as support for our hypothesis

95.6% of the test participants were villagers and a large number of them were women, predominantly mothers with small children from baby to children of 6 years of age. The highest participation was in test area I, as expected. However, the system was also used in the other two test areas and the participants were satisfied with the experience.

We also succeeded in the purpose of the system implementation. Compared to the normal process, when the patients had to search and purchase the medicines by themselves, time and effort were substantially reduced. Without the system, people, mainly in rural regions need one to three weeks to purchase a medicine. In addition they have to pay high transportation costs for travelling to several pharmacies. Using the system, the participants received the ordered medicine within two days. We thus reduced the time by up to 90%. Also the transport expenses have been reduced.

Resistance

We encountered relatively few resistance to EPharmacyNet usage. The women accepted the system sooner than the male patients and appeared very satisfied with it. Some cases of refusal to use the system were due to a lack of trust. We address the general aspect of trust in "The trustee concept".

Security aspects

If the ePharmacyNet system is implemented according to the concept described in the previous sections, it will be a highly sensitive system. It contains a large amount of personal health and financial data, the business and financial transactions supported by the system correspond to large amounts of money and the products may damage health and even risk lives of the customers. Hence, besides the usability of the system, its security is a crucial property and must be carefully designed and implemented.

Of course, most other ECommerce systems have similar security requirements and there exist standard solutions for providing security. However, since we adapted the standard ECommerce approach to the specific situation in developing countries, and specifically in Benin, we must analyze if standard solutions are still applicable and whether additional security risks have been introduced.

Safety and availability

A first group of aspects is not related with deliberate attacks. Instead, they deal with "natural" conditions which may disrupt system functionality. We identified three such safety aspects which are specific in the context of ePharmacyNet. One is the unstable electricity supply, which has already been addressed in "ePharmacyNet as solutions approach". The other two are specific for the delivery component.

Delivery may be affected by accidents. The streets in Benin are in bad condition. The annual mortality rate from street accidents is around 800, with increasing tendency [27]. The drivers must meet some quality standards and have a good knowledge of the area. The vehicles must be functional and regularly controlled, which is not a matter of course in Benin.

The other problem for delivery consists of the high temperature and the bad sanitary conditions which may damage the medicine products during transport. Specific packing measures must be applied when delivery is performed with local transport vehicles, such as motorcycles.

Attacks on the system

Although the safety problems are not easy to solve, we consider deliberate attacks to be the more severe problems. In this section we analyze and classify possible attacks and describe some simple solutions. Again, we concentrate on the specifics of ePharmacyNet. We will not consider in detail attacks

- which are common to information and communication systems used in the commerce and health sector and for which standard solutions exist, such as malware distribution or wiretapping confidential information, or
- which are not specifically made possible by the introduction of ePharmacyNet, such as pharmacy robbing or corrupting physicists to prescribe unnecessary products.

Table 2 Test participants

Participants	Genre	Large cities	Villages/Slum	Total
N=434	Females	6 (37,5%)	406 (97,13%)	412 (94,93%)
	Males	10 (62,5%)	12 (2,87%)	22 (5,07%)
Total		16 (100%)	418 (100%)	434 (100%)

We will begin the classification by classifying the attackers according to their participation in the system. The attacker may either be a system participant ("internal") or may be any other person ("external"). The standard means for preventing attacks by external persons is to require an authentication by all system users and design the system in a way that unauthorized users have no access. This can be done using standard solutions. However, all parts of the system must be considered. For ePharmacyNet this means particularly all communication channels introduced for supporting patient access to the system, including assisting persons. Assisting persons may be the target of social attacks with the goal of information disclosure or manipulation.

Additionally, although the patient is a system participant, we cannot expect the patient to be always authenticated. Any person must be able to use the system for buying pharmaceutical products, hence every external attacker has access to this functionality. This problem is also treated in a standard manner: give an unauthenticated user access only to the minimal set of interfaces absolutely needed for the use case. Then, design these interfaces in a way that no attacks are possible.

The remaining cases are internal attacks by authenticated system participants which may be: patients, pharmacy personnel, delivery personnel, and physicians and other health personnel. The target of the attacks is either the system itself or other system participants.

A common basic measure against these attacks is the logging of all activities of authenticated participants. This does not prevent attacks, but makes them traceable. The attacker can be identified afterwards, resulting in disadvantage or penalty. The consequences for an identified attacker can be usual punishment by law. However, due to weak authorities and high corruption rate, this may often be ineffective. As an alternative, the consequence may be the exclusion from the ePharmacyNet system. If the honest participation in the system provides for every participant a long term advantage that is higher than the gain of a single attack, internal attacks will be unattractive for most participants.

Now we analyze and classify the specific internal attacks possible for the ePharmacyNet system. Table 3 summarizes our findings.

Attack 1 may have several reasons. The attacker may be a hacker who wants to get self affirmation, or he may have political reasons for sabotaging the system [28]. Attack 2 may be a special case of sabotage, which renders the business interface of the attacked pharmacy unavailable, e. g., by a denial of service attack. It may also relay orders from the attacked pharmacy to the attacker for economic advantage. In most cases, the attack is directed against the infrastructure of the electronic system parts, hence it can be prevented by standard measures of IT security, such as firewalls and encryption. However, it may also be directed against assisting persons, who are corrupted to relay orders. Here, other prevention measures are required [28].

In attack 3, the pharmacy or delivery personnel collect a higher payment than was agreed in the ordering. This may be favored by the patient being illiterate or in urgent need or emergency. In attack 4 cash-on-delivery mode is used and the delivery personnel does not relay the money to the pharmacy. In both cases, if e-payment is used instead, the system must be attacked, which can be prevented by IT security measures. However, due to the situation of the patients, e-payment is often not possible.

In attack 5, the delivery personnel replaces the product by a different cheaper product, perhaps an imitation from the black market, and sells the ordered product for economic advantage. This attack could be prevented by using a sealing mechanism, such as a sealed packaging where the patient controls the seal, or a closed box which can only be opened when the patient is present, e.g., using a code or RFID card. A box can also be used for cooling and as a safety case against damage. However, these solutions are either expensive, if all potential patients must receive an individual code card, and/or insecure, if the patient loses his card or forgets the code.

Attack 6 is similar to attack 5, however, now the attacker is the pharmacy personnel. Here, the solutions for attack 5 are not applicable, since the product may be replaced before the sealing is done.

Finally, in attack 7 a criminal attacker orders a product and gives as delivery address an isolated place, where a driver has hardly a chance to defend himself. Upon delivery, the attacker robs the product and/or additional

Table 3 Internal attack cases

	Attacker	Attacked	Goal	Prevention
1	Any	System	Sabotage	IT security
2	Pharmacy	Pharmacy	Economical advantage over competitor	IT security
3	Pharmacy or delivery	Patient	Financial fraud by excess payment	Avoid external payment
4	Delivery	Pharmacy	Financial fraud by payment defalcation	Avoid external payment
5	Delivery	Patient	Product replacement	Sealing mechanism
6	Pharmacy	Patient	Product replacement	
7	Patient	Delivery	Robbery	

articles of value, such as the driver's vehicle. The driver is even in danger to be murdered. This is the only case where the attacker is an unauthenticated patient and may therefore not be identified by the system.

Note, that we did not identify any cases where physicians or health personnel are involved in an attack, either as attacker or as being attacked. These persons participate in the system either as assisting persons, or they are involved in attacks which are not specific to ePharmacyNet.

The trustee concept

As we have described in the previous section, there are several kinds of attacks which can be prevented by standard IT security or other easy security measures. However, there are some remaining cases: all attacks where assisting persons are involved, the attack cases 3 and 4, if external payment cannot be avoided, attack case 5, if sealing is not feasible, and the attack cases 6 and 7. We now propose a solution which is applicable for all these cases. We call this solution the trustee concept.

A trustee is a person who acts in place of the patient as participant in the ePharmacyNet system. A trustee directly interacts with the patient. A trustee must be trusted by the patient, to act as his agent, and the trustee must be authenticated to the system, hence he is "trusted" by the system insofar that his actions are logged and can be related to him.

Possible trustees are pharmacy personnel and physicians and health personnel. Pharmacies must always have the possibility to authenticate; otherwise they cannot participate in the system. Physicians and health personnel can be registered or can be given an electronic identity card for authentication. As usual, participation as a trustee in the system must be rewarded, i.e. paid, to make this role attractive and to make attacks by the trustee unattractive. If acting as a trustee is paid, also other persons may act as trustees, such as authorities or "trusted persons" such as a village teacher.

An important prerequisite is that the patient trusts the trustee. Therefore, the trustee system will only grow slowly and the population must be educated to have confidence into the system. This will need time because the African citizens are generally rather suspicious against such concepts. The reasons are the illiteracy, the numerous frauds, the powerlessness of the police to fight crime, and a high corruption rate. Therefore, politicians, local authorities and other organizations like welfare organizations and the church should help to establish the confidence in the system.

A trustee may act as an assisting person and support the patient in using the ePharmacyNet system. If all assisting persons are trustees, attacks involving assisting persons may be prevented. For preventing the attack cases 3 and 4, payment is processed with the help of the trustee: the trustee uses electronic payment on behalf of the patient. If external payment is necessary, it is only performed directly between patient and trustee.

Attack cases 5–7 are prevented by delivering the product to the trustee or to the patient in presence of the trustee. The trustee must have the knowledge to control the seal or have the code to open it. He should also have the knowledge to control the product whether it is correct and valid.

Conclusion

Among the problems of public health systems in developing countries, several are caused by a lack of organization. These could be addressed with the help of information technology, however, it is often not possible to directly apply solutions from developed countries.

In a case study in Benin we investigated the problem of the distribution of pharmaceutical products by pharmacies. We found several obstacles for introducing a standard ECommerce system and developed an adapted system. In a practical test we have shown, that the concept of the adapted system has the potential to improve the health care system in the country. It can be introduced in several steps and parallel to other improvements in the health care system. We presented a thorough security analysis and proposed solutions for a safe operation of the system.

The system also has the potential of reducing the costs for distributing pharmaceutical products in the country. These savings can be used to finance the system operation. The system implementation must be funded by the national health authorities. However, a cost analysis [8] showed that the required financial means are much lower than those needed for building and operating additional pharmacies.

A survey [8] showed that all Sub-Saharan African countries (with the exception of South Africa) suffer from similar problems and have a similar situation according to ICT introduction. The same holds for rural regions of North African countries. Hence, it can be expected that the ePharmacyNet approach can be transferred successfully to those countries.

References

1. Peters, D. H., Elmendorf, A. E., Kandola, K., and Chellaraj, G., Benchmarks for health expenditures, services and outcomes in Africa during the 1990s. Bull. W. H. O. 78, No.6, Genebra, 2000.
2. Toukourou, M., Utilisation des Moustiquaires Impregnees dans la Lutte contre le Paludisme: Cas du Benin. Table Ronde ReMeD: La Pharmacie et la Santé publique, ReMeD, Paris, 2003.
3. Rotich, J. K., Hannan, T. J., Smith, F. E., Bii, J., Odero, W. W. O., Vu, N., Mamlin, B. W., Mamlin, J. J., Einterz, R. M., and Tierney,

W. M., Installing and implementing a computer-based patient record system in Sub-Saharan Africa: The Mosoriot Medical Record System. *J. Am. Med. Inform. Assoc.* 10(4):295–303, 2003.
4. Mars, M., and Seebregts, C., Country case study for e-Health South Africa. 2008 http://www.amia.org/files/shared/County_Case_Study_for_eHealth_South_Africa.pdf.
5. Braa, J., Monteiro, E., and Sahay, S., Networks of action: Sustainable health information systems across developing countries. *MIS Quaterly* 28(3):337–362, 2004.
6. Braa, J., and Hedberg, C., The struggle for district-based health information systems in South Africa. *Inf. Soc.* 18(2):113–127, 2002.
7. Shaw, V., Health information system reform in South Africa: Developing an essential data set. Bull. W. H. O. 83, No 8, August 2005.
8. Edoh, T. O., ICT-Systeme zur Verbesserung der Gesundheitsversorgung im Gesundheitssystem des afrikanischen Entwicklungslands Benin. Doctoral Thesis (in German), Universität der Bundeswehr München, 2010
9. Institut National de Statistique et de l'Analyse économique (INSAE): Enquête Démographique et de Santé 2001, Macro International Inc. Calverton, Maryland USA, Cotonou Bénin, June 2002.
10. Yin, R. K., *Case study research: design and methods*. Sage Publications, Newbury Park, 1989.
11. Eisenhardt, K. M., Building theories from case study research. Acad. Manage. Rev. 14, No. 4, Oct., 1989.
12. Klein, T., Befindensweisen und therapeutische Wege in Dendougou, Benin. Doctoral Thesis (in German), Universität zu Köln, 2005.
13. ReMeD: Politique pharmaceutique du Benin. 2009 http://www.remed.org/html/politique_pharmaceutique_benin.html.
14. Idiaquez, M., and Koenig, P., La distribution de produits pharmaceutiques au Bénin. Mission Économique de Cotonou, 2007.
15. Tougher, S., Patouillard, E., Palafox, B., Goodman, C., and Hanson, K., The private commercial sector distribution chain for antimalarial drugs in Benin. ACTwatch and London School of Hygiene and Tropical Medicine, 2009.
16. Adeya, G., Bigirimana, A., Cavanaugh, K., and Miller Franco, L., Rapid Assessment of the HealthSystem in Benin, April 2006. Submitted to the U.S. Agency for International Development, 2007.
17. Badarou, S., Les médicaments de rue au Bénin: Un problème de santé publique au Bénin. APIDPM Santé Tropicale, July 2007.
18. Cunningham, J., Paurobally, S., Diacakis, A., Lorenzen, L., Gross, G., and McConnell, S., Satisfying requirements for electronic commerce. In: Lamersdorf, W., and Merz, M. (Eds.), *Trends in Distributed Systems for Electronic Commerce (Proceedings TREC'98, Hamburg)*. Springer LNCS 1402, 1998.
19. BOAD: Atelier Regional sur l'impact du Transport urbain a deux roues et ses perspectives de developpement dans les pays de l'UEMOA (Benin, Niger et Togo). Rapport de synthèse des travaux. West African Development Bank, Lomé, Togo, November 2002. Available at http://www.la-sagesse.cafe.tg/dossier/2roues/.
20. Lohento, V. J. R., Contribution à la promotion de l'utilisation des cartes bancaires comme moyens de paiement au Benin. Master Thesis, Université d'Abomey-Calavi-Maitrise Sciences de Gestion, 2009. Available at http://www.memoireonline.com.
21. Gansinhounde, A. J., Les déterminants de la faible bancarisation dans l'UEMOA. Master Thesis, Université Catholique de Lille (France)/Université Polytechnique Internationale du Benin, September 2007.
22. ECOM Electronic Commerce Promotion Council of Japan: Internet XML/EDI Introduction Guidebook March 8, 2003.
23. Stensgaard, T., Arnfjord, M., Karlsen, K., and Mulvad, G., E-mail contact between patients and doctors in primary health care. *Int. J. Circumpolar Health* 63(Suppl 2):133–134, 2004.
24. Stensgaard, T., Telemedicine in Greenland—from the early beginnings to the making of a business plan. *J. Telemed. Telecare* 6(Suppl 1):158–159, 2000.
25. Lapointe, L., and Rivard, S., A multilevel model of resistance to information technology implementation. MIS Quarterly, 29 No. 3, September 2005.
26. Baskerville, R., and Myers, M. D., Special issue on action research in information systems: Making IS research relevant to practice—FOREWORD. MIS Quarterly 28 No. 3/September 2004.
27. Fayomie, E. B., and Zohoun, T. H., Les Accidents de Trajets: un Enjeu Socio-Sanitaire Au Benin. Médecine d'Afrique Noire 40 No. 11, 1993.
28. Huber, M., Sunyaev, A., and Krcmar, H., Security analysis of the health care telematics infrastructure in Germany. In: ICEIS 2008—Proceedings of the Tenth International Conference on Enterprise Information Systems, Vol. ISAS-2, pp. 144–153. Barcelona, Spain, 2008.