Sustainable Healthcare Systems. A holistic perspective on the use and impact of medication management robots in home healthcare

Sarfraz Iqbal  
*Linnaeus University, Växjö/Kalmar, sarfraz.iqbal@lnu.se*

Päivi Jokela  
*Linnaeus University, Växjö/Kalmar, paivi.jokela@lnu.se*

Tora Hammar  
*Linnaeus University, Växjö/Kalmar, tora.hammar@lnu.se*

Anna-Lena Nilsson  
*Linnaeus University, Växjö/Kalmar, anna-lena.nilsson@lnu.se*

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Sustainable Healthcare Systems

A holistic perspective on the use and impact of medication management robots in home healthcare

Sarfraz Iqbal, Päivi Jokela, Tora Hammar, Anna-Lena Nilsson
Linnaeus University Växjö/Kalmar, Sweden.
sarfraz.iqbal@lnu.se, paivi.jokela@lnu.se, tora.hammar@lnu.se, anna-lena.nilsson@lnu.se

Abstract. This study focuses on medication management robotic system (MMR) in home health care, which is part of a complex medication management system that in addition to patients, their families, care personnel, municipal health and social care managers, and technology also includes prescribers and dispensing pharmacies. Successful medication management requires communication, coordination and effective information sharing among the network actors and across different settings. Information ecology perspective is used to describe and understand the whole system, the network of people, technology, and information systems, as well as the impact of MMR system on patients and caregivers’ relationships, roles, and responsibilities. This qualitative case study aimed to explore the impact of implementation and deployment of MMR system, as part of a pilot project in municipal eldercare in the south of Sweden. This research work elucidates the holistic perspective of medication management system for home care services, and highlights the processes and situational complexities, as well as the role of the personnel and key stakeholders involved in these processes. This research work is in line with UN’s sustainable development goals to develop a reliable, sustainable and resilient regional infrastructure, to support human well-being, with a focus on affordable and equitable access for all.

Key words: medication management robot, elderly care, medicine dispenser, home healthcare.

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1 Introduction

The global demographic is changing towards ageing society. Old-age dependency ratio (OADR) is a commonly used indicator that calculates the number of persons aged 65 or over per 100 persons of working age, i.e., 20-64 years. In 2019, the global OADR was 16 and it is estimated to increase to 28 by 2050. The OADR in Europe and Northern America in 2019 was 30, and by 2050 it is predicted to be 49. Japan is the country that has the highest ratio of older people in the world, in 2019 the OADR was 51, and Japan is anticipated to keep the lead position, reaching OADR of 81 by 2050 (Okamoto 2019; United Nations 2020). The global demographic change implies that a lot of research and practical work is needed to guarantee well-being and quality of life for the ageing society. One of the initiatives that is aimed to support this endeavor is the Decade of Healthy Ageing, 2020-2030, a global collaborative, multisectoral action led by the World Health Organization (WHO 2020). Moreover, the demographic transition and request for healthy ageing have strong implications across the United Nations’ 17 Sustainable Development Goals (SDG’s). In this paper, the focus will be on promoting good health and well-being (goal #3), empowering lifelong learning (goal #4) as well as fostering health care innovation that is responsive to the needs of older adults, their families and their communities (goal #9) (United Nations SDGs 2020).

In countries, where the share of elderly in population is increasing rapidly, such as, Sweden and Finland, welfare technology is introduced as a tool to manage the increasing demand on municipal health and social care services. One essential ambition of such technology is to provide and support suitable home environments where the elderly people can continue to live dignified lives and perform their daily routine tasks in a better way (Frennert and Östlund 2018). The implementation and use of technology at home is not only important for the elderly users and their families, but it also impacts other stakeholders including care personnel, municipal health and social care managers as well as health sector policymakers. All involved parties should be provided adequate support and learning opportunities in order to encourage new skills and to enhance technology adoption. In addition to that, the managers and policymakers should foster strategies to counteract exclusion and marginalization. It is also important to acknowledge that there is no universal solution that would suit all older people and their families (Coco et al. 2018; Östlund et al. 2015). An integral part of healthy ageing is that the environments, including health and social care systems and services, should support each individual’s intrinsic capacity and functional ability. The ultimate goal of the research is to provide insights into what kind of welfare innovations can be considered as both desirable and feasible and how the decisions can best be guided by different perspectives (Moerenhout et al. 2018; Stahl and Coeckelbergh 2016; WHO 2020).
Telemedicine and e-health devices are mostly designed with the aim to enhance the patients’ quality of life (Garai et al. 2019). The fundamental principle of the sustainable development phenomenon is to meet people’s needs, for instance, providing good health care services for the elderly community. Many elderly suffering from different diseases want to live in their own homes independently. However, it is a complicated issue due to several factors attached to elderly person and their health status. Healthcare has increasingly moved from hospitals into patient’s homes in order to cope with the increasing global burden of aging and growing population (Schildmeijer et al. 2019). Hence, research on the issue of developing sustainable healthcare systems is very important for elderly community. Since, it will not only provide resources for the current elderly community to stay healthy and independently in their homes as long as possible with assisted care technologies but it will also prepare and teach the future generations about the benefits of such technologies. One such welfare technology is medication management robot system (MMR) for patients that need regular medication. Currently, the healthcare personnel are visiting patient’s homes on daily routine basis to provide medication. However, the use of MMR at the patient’s home could prove to be a vital part of a sustainable solution in the medical arena of home healthcare system. Consequently, the use of MMR to assist elderly is not only important for the elderly community but it impacts other stakeholders including health sector policymakers, elderly care managers, care personnel and family members (Kachouie et al. 2014).

Recent developments in the use of digital technologies for healthcare purposes suggest (Goundrey-Smith 2019) that the use of technologies to handle information on medications can lead to improve patient safety, increase service efficiency and contribute to the provision of high-quality patient care. In this article, we adopted Information Ecology (IE) (Nardi and O’Day 1999) perspective for holistic understanding. We present the case study from a municipality in the south of Sweden and these results could be valuable for the rest of the 289 municipalities of Sweden and other Nordic countries. The aim of this research is to study the impact of implementation and deployment of MMR system in municipal eldercare and in particular with a special focus to explore the following research question: How local municipalities and healthcare personnel can make use of the MMR system in home healthcare services and what are the situational complexities?

The rest of the article has been arranged as follows. We describe the related research in section 2. Section 3 portrays theoretical framework. Section 4 highlights the methods we adopted for this research project. Section 5 provides a summary of findings. We discuss the results in section 6 and conclude the article with further research suggestions.
2 Related research

Aging is a complex and unavoidable phenomenon which includes various biological, biomedical and psycho-social aspects. Aging leads towards a progressive functional decline or a gradual deterioration of physiological function with age which could further lead to impaired functionality and increased vulnerability (López-Otín et al. 2013; Partridge and Mangel 1999).

2.1 Medication management process

Medication is a crucial part of any health care system. Medication management is a complex process that requires communication, coordination and effective information sharing among many actors and across different settings. Prescribers, healthcare professionals and dispensing pharmacies must collaborate concerning assessing and making decisions on medication, prescribing, ordering and dispensing, administering and use, monitoring and evaluation of treatment (Avery et al. 2002; Classen and Metzger 2003; Topinková et al. 2012). This complexity, and especially the lack of correct and adequate information at the right time and in the right form, can lead to medication errors and drug-related problems (DRP) (Bates et al. 2001; Forni et al. 2010). Medication management that includes elderly patients can be particularly challenging due to an increased prevalence of multi-morbidity, as well as changes in pharmacokinetics and pharmacodynamics. In addition, many older people may have difficulties handling their medication due to physical disability and cognitive impairment. (Mulder-Wildemors et al. 2020; Spinewine et al. 2007; Topinková et al. 2012).

In the medication management process, information and communication technology (ICT) can be used in several steps, e.g., ordering and prescribing in health care, electronic transfer and storing of prescriptions, processing and dispensing of prescriptions at pharmacies, accessing information on a patient’s current prescriptions, and support for decision making and detection of potential DRP. During the last decades, the prescribing of medications and handling of information in the medication management process have gone through a major transition from paper to electronic based (Hellström et al. 2009; Odukoya and Chui 2013). Clinical decision support systems have been shown to be a useful tool to reduce potentially inappropriate medications in the elderly and are used by physicians in health care and by pharmacists in pharmacies (Mulder-Wildemors et al. 2020). A new register for a nationally shared medication list that will be available for all prescribers, pharmacists, and patients is currently being developed based on a new law put into force in 2021 (Lag (2018:1212) om nationell
låkemedelslista). During the years to follow health care and pharmacies will implement this into their systems.

2.2 Multi-dose drug dispensing and medication management robot system in home healthcare

The use of MMR system requires that the patients medication is delivered in a multi-dose form. Multi-dose drug dispensing (MDDD) (also known as automated dose dispensing, ADD) is a service in which patients receive their medication machine-packed into unit dose sachet for each time of administration (Johnell and Fastbom 2008; Sinnemäki et al. 2013; Sjöberg et al. 2011; Wallerstedt et al. 2013). Patients that receive MDDD are often old, have several diseases and many different medications. The service aims at improving medication safety and adherence as well as to reduce workload in health care (Cheung et al. 2014; Wekre et al. 2011). In Sweden, only physicians can prescribe MDDD and the prescriptions are primarily handled using a different digital tool in a separate system. MDDD prescription information is usually not automatically transferred to the medication list in the regional electronic health record (EHR), which is the parallel prescription system. In contrast to patients with ordinary prescriptions, the medication list for patients with MDDD is shared between all health care providers which could be anticipated to improve the quality of drug treatment (Sinnemäki et al. 2013; Sjöberg et al. 2011). However, several Swedish studies have indicated that patients with MDDD have a lower quality of drug treatment than other patients, an increased number of drugs after a patient’s transition to MDDD (Johnell and Fastbom 2008; Johnell and Klarin 2007; Sjöberg et al. 2011, 2012; Wallerstedt et al. 2013). There also seems to be fewer changes in drug treatment, and it can take time before the correct dosing sachet are delivered through the system. Another challenge in the MDDD service is to handle medications that should be taken when needed (non-continuous treatment). In one study, physicians described that it was not always recognized at hospitals that a patient coming in had MDDD, sometimes resulting in medications from an outdated and inaccurate medication list being administered among other things (Hammar et al. 2014; Johnell and Fastbom 2008; Johnell and Klarin 2007; Sjöberg et al. 2011, 2012; Wallerstedt et al. 2013). A study about health care professionals perspectives on MDDD concluded that professionals generally had a positive attitude towards MDDD but described some problems that could be improved (Bardage et al. 2014). That study together with others indicate that some of the problems and safety risks described with MDDD service do not seem to be the result of the dose-dispensing itself, but rather due to the fact that the tools and procedures for handling prescriptions are different than
those used for ordinary patients and that they are not integrated (Hammar et al. 2014; Bardage et al. 2014).

Research from different countries describe problems and complexity with medication management in home care and nursing homes. Lindblad et al. (2017) suggest that the medication management process in specialized home healthcare is quite complex, dynamic and error-prone process with unclear boundaries of responsibilities, inadequate information systems and fluctuating work conditions. They further claim that a safe medication management process in home healthcare requires that the healthcare professionals adapt to fluctuating conditions and create bridging strategies through several parallel activities distributed over time, space and actors (Lindblad et al. 2017). There is a need for improvement and innovation to support both professionals and patients with medication management at home (Lang et al. 2015; Moen and Flatly 2005; Nakrem et al. 2018).

Different approaches to support and monitor medication management in home care or nursing homes are described in the literature (Mira et al. 2014; Nakrem et al. 2018; Rantanen et al. 2017; Reeder et al. 2013; Shtrichman et al. 2018; Siu et al. 2017; Suzuki and Hasegawa 2018). Level of development and results vary but many report potential or improvement in adherence, monitoring or level of independence. Some of these approaches still require the medication to be dispensed or the machine to be filled by patients, nurses or other personnel.

Medicine dispensing robots have been introduced successfully in the pharmacy settings, in order to re-engineer the pharmacy services and to improve the safety and efficiency of medicine management processes (Goundrey-Smith 2019). The care in geriatrics is gradually shifting from a traditional hospital-centered model towards an advanced ICT supported home-based solution, which creates opportunities for using telepresence with robotic systems in home telecare (Boissy et al. 2007; Rantanen et al. 2017). Recently a study was conducted to examine the safety profile and usability of a robotic device to promote medication adherence for elderly home-care patients; the results show that overall performance of medication management system was satisfactory (Rantanen et al. 2017). Nakrem et al. (2018) concluded that digital medicine dispensers can improve efficiency and enhance patient independence when introduced in a way that empowers patients, safeguards trust and service quality.

There seems to be an immediate need for general scrutiny and evaluation of how medication quality and safety can be improved for patients with MDDD service. When implementing medication management robots in home healthcare, it is important to consider medication management process in a larger perspective to make sure the medication treatment is safe and appropriate for the patient before being delivered to the
dispensing robots. This will further guide us to understand the value-added services created by this intervention in addition to the changing relationships between caregivers (homecare personnel) and the elderly (patients). This knowledge will be useful to develop an understanding of the feasibility of such sustainable solutions for the elderly community and the local healthcare municipality services. This knowledge can be adapted and shared by the adjacent municipalities. The municipalities struggle a lot to develop and adopt such solutions, since, they require setting up additional work routines for the care personnel, the adjustment towards another type of telepresence relationship between patients and care personnel, management and maintenance issues of the MMR system and other additional support services. We briefly present our theoretical premise in the next section, and its relevance to understand the information ecosystem in which the MMR is embedded.

3 Theoretical framework

As we are dealing with implementation and deployment of MMR system in municipal health care, we adopt systems thinking for this research project (Peters 2014). A system is “a coherent set of interdependent components that exists for some purpose, has some stability and can be usefully viewed as a whole” (Beynon-Davies 2020). Most systems are embedded as parts of a larger system, which in turn is also part of a wider system (Koestler 1967; Mella and Gazzola 2017). The ability of the system elements to perceive the whole, as well as to interact and communicate with the other parts at different systems levels, is a crucial part of systems thinking (Peters 2014). The interactions between the parts also imply that systems must be considered as complex entities with emergent properties that do not belong to their constituent parts. Another consequence of the connectivity of the parts, is that changes in one part of the system can affect other parts, and lead to larger changes throughout the system (Peters 2014).

The complex nature of interaction between different components of a system and their coevolution can also be studied using approaches such as the metaphorical concept of information ecology (IE) (Nardi 1998; Nardi and O’Day 1999). Information ecology is characterized by its diversity, i.e., it comprises a number of interconnected people, practices and technology, but its core value is defined by a human purpose, and shaped and re-shaped by the joint human activities. The evolution of the IE as a whole thus implies that its various social and technical aspects must co-evolve and adapt together to respond to changes. Moreover, when people with different knowledge and skills and their various tools interact and cooperate throughout the IE, this joint effort requires a lot of coordination and communication, which is usually managed by human
mediators. The mediators are able to grasp the system as a whole, and they can also help other people to navigate through the complex activities and processes. These mediators are called keystone species, which accentuates their essential role in the information ecology. An additional distinctive feature is that although IE is based on the holistic concept of system that implies strong interrelationships and dependencies of the system parts, it also acknowledges the importance of local settings. The locality implies that people define the identity and habitation of any specific technology independently in different settings. (Nardi and O’Day 1999).

IE concept has been widely used in different research contexts, including education sector (Thapa and Sein 2018), and welfare services projects (Pekkarinen et al. 2020). In this study, we use the theoretical lens of IE to understand the interconnected human activity systems, ICT systems and information systems to make the whole system work. The main elements of information ecology are summarized in table 1 (Nardi and O’Day 1999).

<table>
<thead>
<tr>
<th>Key Elements</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System</strong></td>
<td>Information ecology is a system of people and tools that have strong interrelationships and dependencies. Change in ecology is systemic: when one element changes, the effects can be felt throughout the whole system.</td>
</tr>
<tr>
<td><strong>Diversity</strong></td>
<td>Various kinds of people and various kinds of tools work together in a complementary way.</td>
</tr>
<tr>
<td><strong>Coevolution</strong></td>
<td>Information ecologies evolve as innovative ideas, tools, activities, and forms of expertise arise in them. The social and technical aspects co-evolve and adapt to each other when change occurs. The ecology finds a balance in motion, not in stillness.</td>
</tr>
<tr>
<td><strong>Keystone species</strong></td>
<td>Ecology is marked by the presence of certain keystone species whose presence is crucial to the survival of ecology itself.</td>
</tr>
<tr>
<td><strong>Locality</strong></td>
<td>Local context of the ICT intervention and the meaning that people give to the technology. The participants within an information ecology system can establish the identity and place of the technologies.</td>
</tr>
</tbody>
</table>

Table 1. Important elements of information ecology adapted from (Nardi and O’Day 1999)
4 Data collection and analysis methodology

Qualitative research approach was adopted in this research project. Qualitative approach is considered beneficial for research on assistive technology to support elderly people (Müller et al. 2012). This research is based on a qualitative case study which provides the opportunities to explore and describe phenomenon in context using a variety of data sources. The flexibility and rigor of this approach assists the researchers to explore individuals or organizations, through interventions, relationships, communities, or programs and supports the deconstruction and the subsequent reconstruction of various phenomena (Yin 2003). Data was collected between June 2019 and August 2020 using different techniques (see table 2).

<table>
<thead>
<tr>
<th>Number of Participants</th>
<th>Participants</th>
<th>Data collection method</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Care personnel (3 management personnel + 2 nursing staff members)</td>
<td>Focus group meeting/interview</td>
</tr>
<tr>
<td>1</td>
<td>Nursing personnel</td>
<td>Individual interview</td>
</tr>
<tr>
<td>2</td>
<td>Nursing personnel</td>
<td>Meeting/interview + practical robotic system demonstration</td>
</tr>
<tr>
<td>2</td>
<td>Social care management personnel</td>
<td>Meeting/interview</td>
</tr>
<tr>
<td>3</td>
<td>Care personnel</td>
<td>Individual meeting/interview</td>
</tr>
<tr>
<td>16</td>
<td>Participants including care personnel, nursing personnel and social care managers</td>
<td>Workshop/Focus group interview + discussion</td>
</tr>
</tbody>
</table>

Table 2. Overview of interviews

Data was collected by individual interviews as well as focus group interviews with healthcare personnel and management personnel within a local municipality located in southern Sweden. Documents related to processes and practices for using medication management robot devices and service description documentation including service architecture and data security related issues were reviewed. Observations and participation in the practical demonstrations of the MMR system and tele-medicine system by the trained nursing personnel provided valuable feedback to the researchers. The researchers developed a semi-structured open-ended interview guide. Questions during
the interviews were focused to capture the whole experience of using MMR and to further determine the system’s usability, reliability, suitability for elderly patients, data security and any problems/issues or damages that could arise as a result of misuse of robotic system. In addition to that we focused on the responsibility structure, relationships between nursing staff and patients and how the decisions are made to develop and implement such projects.

Data analysis in qualitative research is considered as inductive and iterative process with the purpose to examine the whole, in a natural setting, to get the ideas and feelings of those being interviewed or observed (Creswell and Poth 2017). We used the key elements of IE (see table 1) to analyse the data. Following the iterative process, the data was transcribed, read several times to develop codes, the codes were arranged into meaningful categories which finally lead towards the development of themes presented in next section.

5 Findings

The findings have been organized according to the IE elements depicted in table 1. The findings include the development of an overall picture to provide a holistic perspective of using MMR system and associated processes. This will also help us to understand the fundamental components and stakeholder relationships that need to be considered in context.

5.1 System

Information ecology is characterized as a system of people and tools that have strong interrelationships and dependencies (Nardi and O’Day 1999). The analysis reveals that the MMR system at home comprises a complex and dynamic network of patients, family members, professional caregivers, municipal management and technology. Many parts of the system are controlled by laws and regulations, but in the daily practice the overall behaviour and performance are the result of many interactions and decisions that are made of individual participants of the network, guided by the rules.

The precondition for the use of MMR systems, capable of dispensing medicine, is that automated multi-dose drug dispensing (MDDD) service can be utilized. This implies that solid oral dosage forms, i.e., tablets and capsules, are machine-packed into disposable unit dose sachets, one sachet for each time of administration. To improve the medication safety, the dose sachets are individually labelled with essential information, concerning patient data, medication content and administration schedule. A MDDD
delivery can contain dose sachets for 1-4 weeks. As the majority of the MDDD users are elderly patients with several diseases, many of them may also need assistance with medicine delivery and handling, often several times a day. In traditional home care setting, the assistance is usually provided by the home care staff or family carers. In the municipality for this case study, the majority of patients needing support with medications use MDDD.

The MMR system that is explored in this paper, involves a non-invasive medicine dispenser and a telecare system; the service is intended for continuous and regular use of medicine. The medicine dispenser can only administrate machine-packed dose sachet. This kind of medicine dispenser is classified as class I medical device, i.e., it has the lowest perceived risk (European Commission 2010). Figure 1 below shows an overall picture how multi-dose drug dispensing service can be used in home care setting. The figure also illustrates another system that is parallel to the MDDD system, and that must be used if the patient is prescribed medication that cannot be included in the MDDD service.

Figure 1. Holistic perspective of medication management system at home
When the patients utilize the MDDD service, the overall process can be described as follows:

1. Patients that need multi-dose medication live at home, sometimes with family carers.
2. The municipal authorities decide what kind of help will be provided to the patient.
3. After consultation, physician prescribes medications for multi-dose drug dispensing.
4. Physician enters prescription information into a dedicated MDDD system, that is separated from the system for ordinary prescriptions. The national MDDD database, and consequently the medication lists for patients with this service, can be accessed by all health care providers.
5. (5a) The nurse who is responsible for medication (5b) can access the patient’s medication list in the MDDD system.
6. The authorized pharmacy personnel and MDDD provider can access the same information about MDDD prescriptions but through another system (pharmacy information system).
7. The prescribed multi-dose medication is delivered to the nurse.
8. a) The multi-dose medication is administrated by the nurse. The nurse records this in the Signeringslistor i.e., medicines administration records (MARs).
   b) The nurse may delegate the administration of medication to home care staff, provided that their training and skills meet the requirements for good and safe care. In this case, the home care staff delivers the multi-dose medication sachet to the patient, and records this in the MARs.
   c) If the patient has a MMR at home, the nurse or the delegated home care staff inserts the medicine sachets into the medicine dispenser automat of MMR and enters the patient’s medication information in the MMR software. The MMR dispenser delivers the medication sachet to the patient. In this case, it is not recorded in the MARs, when the sachet is delivered. The nurse and the patient can also send basic messages to each other, using the MMR’s display.
9. The nurse administers the communication with the telecare system.
10. The telecare system monitors the MMR, and may alert the caregivers if needed.

Some medicines prescribed for a patient cannot be delivered or administrated by the MDDD service and MMR, for example medicines that are only used when necessary,
liquids or ointments, sensitive medications that need to be stored in other ways, short treatments like antibiotics, or the anticoagulant warfarin that needs frequent monitoring and adjustments of the dosing. These medicines are most often prescribed using the same system (Pascal) as for MDDD. These packages with medication can be picked up at the pharmacy or delivered to the nurse. Sometimes this kind of medicines are prescribed in a parallel system (11), i.e., electronic health record (EHR), and sent as an ordinary prescription to the national prescription repository. Pharmacists at any pharmacy can upon request see all of a patient’s prescriptions in the national prescription repository (12a) and dispense the medication, which requires a letter of appointment. The nurse who is responsible for the medication can view the medication list in the EHR (12b), which is a separate list from the MDDD prescribing system. The prescribed medication is delivered to the nurse (7, see comment before) and administered by the nurse (8a) or the home care staff (8b), in both cases this is documented in the MARs.

When the nurse is handling a patient’s medication, i.e., putting medication in a dosage administration aid (dosett) or administering medication to patients, their most important source of information is the patient’s list of current medications most often in printed form. This can be either a list from the MDDD prescribing system (Pascal) or from the electronic health record (EHR). It is the nurse’s responsibility to make sure the printed list is up to date with any changes in treatment.

5.2 Diversity

Information ecology is characterized by different kinds of people and tools who work together in a complementary way (Nardi 1998). In the case of the studied MMR system, the diversity can be described through a nested model, where the core is the patient living at home, supported by a medicine dispenser. The patient’s nearest human interaction is with the frontline care providers that includes the health care professionals, home care personnel and also the family carers. The overall system is supported by the organizational infrastructure of municipal home health care and home help, and the available technical infrastructure and resources. The system is also embedded in a larger context that involves pharmacy services, including MDDD provider, municipal decision makers, as well as the web-based systems: the telecare system that is connected to the medicine dispenser, and the prescription systems.

Healthcare generally, and specifically the medication management, rely on collaboration between multiple actors in a multilevel ecosystem. Moreover, the system is also
dynamic, implying that the roles, activities and responsibilities of service users and professionals keep changing (Pekkarinen et al. 2020).

For instance, when the medication is delivered by an automated MMR system, instead of healthcare or home care personnel, an important requirement is to provide an uncomplicated and safe process with respect to the ease of use. This indicates that the operation should not require an excessive effort from the patient. The machine user interface is clear and simple, consisting of a touch screen, a large button that changes colour and the medicine sachet dispensing slot. When it is the time to take medicine, the machine displays the message “it is the time to take your medicine, please click on the button”. This entails a tactile interaction, i.e., the user must click the large button that is now illuminated by green light. After this action, MMR dispenses the medicine sachet, and it is quite effortless to open the sachet and access the medicine. MMR also reminds the patient to take the medicine with a glass of water.

The MMR can also mediate remote communication between patient and the healthcare personnel. However, the ways of communication are different for different users, as the patient can receive a written message from healthcare personnel but can reply back only via emojis using MMR screen. Another example of diversity, i.e., when people with different skills work together and interact with technology, is the differentiation of the training level and work tasks concerning the MMR system. The evidence from the empirical data shows that the safety measures during the administration of the telecare system, as well as the refilling and use of the MMR are implemented in a professional standardized manner. One of the trained nursing personnel explained and demonstrated the safety measures, which include user management, user authentication, user login, appropriate user rights management and careful handling of the MMR’s medicine sachet refilling process. The safety measures also make sure that the patients have no direct access to the sachets that are stored in the machine, including the ones that have been retracted, if they were not accessed in time. Only authenticated nursing personnel can unlock the MMR using the electronic key together with appropriate password authentication mechanism. The empirical evidence also proves that during the implementation and pilot project of MMR in patients’ homes, “no problems have been reported due to double dosage coming out of the medicine dispenser”.

5.3 Co-evolution

To find the balance in motion, the social and technical aspects of information ecologies co-evolve and adapt to each other to accommodate changes (Nardi and O’Day 1999). The introduction of MMR system in home healthcare invokes the need for co-evolu-
tion of innovative ideas, tools, activities, and different forms of expertise. For instance, the issues such as the need for training and awareness, selection of suitable candidates that can successfully operate and use MMR, organizational adaptation to the change, changing relationships, roles and responsibilities, matters of privacy and need for enhancement in the MMR design to improve effectiveness and monitoring process become prominent issues to accommodate this co-evolving situation.

Training and awareness

Appropriate training and awareness are considered important aspects for the successful operation of any system, and MMR is not an exception. Due to the relatively uncomplicated procedure, a three hours training is considered sufficient for a home care staff member to understand and operate the medicine dispenser successfully. However, this basic training does not include the refilling of the MMR’s dispenser nor the administration or use of the telecare system—these tasks are only conducted by the trained nurses and delegated personnel, and this requires additional training hours. The patients and their family carers get basic instructions on how to use the robotic device, but they do not undergo any specific education or training program to use the system, since it is assumed that as the end users of the system their interaction with the system will be minimal.

Selection of suitable candidates that can successfully use MMR

When the MMR is used, the patient is considered responsible for the interaction with the machine, and also consuming the medication. Therefore, the proper choice of suitable candidates for using the automated MMR is an important part of a successful process. The goal is to identify the patients that have a potential to become empowered and more independent in their daily life, when supported by the MMR, and they are willing to use the technology. When the role of the patient becomes more autonomous, this can also be seen as an example of learning and adaptation to the change in the co-evolving system.

Changing relationships, roles and responsibilities

In a routine home medication system where the nurses visit patient’s home for medication adherence, the nurses use MARs/Signeringslistor. Signeringslistor/MARs is a timestamp signed by responsible nurses, and it documents the administration of med-
When medicine is consumed by the patient, and it may also include a note if the patient refuses to take the medication. However, when the medicines are dispensed using the automated MMR system, there is no documentation for medication adherence. The patient is considered solely responsible for the interaction with the medicine dispenser as well as actually taking the medication (see previous section). The MMR system generates a log file regarding the dose sachet going out at a given time, and also if the sachet is removed from the machine.

MMR system can on one hand provide more flexibility for the patients and the organization, as at least some of the home visits can be replaced by the automatic medicine dispensing. The medication routines can also be planned together with the patient, in order to find the most appropriate daily schedule. On the other hand, the flexibility of the automated system is not optimal when there is a disruption in the ordinary schedule and routines, for instance if the patient is going to travel, and a larger number of medication sachets must be dispensed from the machine. This kind of spontaneous situations can be handled, but the process is perceived as quite lengthy and tedious, and sometimes also stressful for the patient and their relatives.

Organizational adaptation to the change

The decrease in number of hours as a result of automated drug dispensing via MMR system is relevant so that the nurses and home care staff can use the freed-up time to other purposeful tasks. Therefore, implementation of MMR may also become organization’s internal change driver, concerning scheduling and work processes. From the systems point of view, this can also be an example of adaptation to the change in the system. For instance, if MMR system delivers the medication sachet to the patient at their home, a number of working hours could be saved and used for other tasks within the organization.

Issues of privacy and security

In case of MMR system, naturally, some patient’s might have data security and privacy concerns regarding the 24X7 presence of a technological tool (MMR) at their homes instead of a nurse. The role of key stakeholders such as health care managers and ICT personnel is very valuable and important to ensure the patient’s about the security and privacy of their data. The analysis of empirical data reveals the nursing personnel’s claim that “there were no serious concerns by any patients at the moment regarding the security of their data”. The patients might perceive the security of their data with the MMR
system in similar way as dealing with any other system within local healthcare center. The complete medication management system consists of MMR and the web-based telecare system. Standardized encryption and security methods such as firewalls, antivirus software and SSL certificate encryption are used to secure communication between MMR and the telecare system. Data back-up is given appropriate importance: two tiers data back-up policy is adopted in which the data is automatically backed-up on both online and off-site servers. Data archiving scheme is also used for the telecare system and according to this scheme the data can be archived for upto 12 years or more as per requirement. Customers can always request the copy of the archived data, if needed. Telecare system and the MMR both collect data about system behavior to maintain the log files and audit trail. Only the authenticated personnel with special privilege has access to this data. The system also maintains the care related events in the telecare system such as MMR refill information. The nursing and management personnel informed during interviews that the data resides in the systems of the MMR provider and they get access to the data via this system. Telecare system, all devices and components in the datacenter and the MMR are updated on regular basis to protect against any security threats. The regular service breaks can be commissioned to update the systems including MMR system. Although, the MMR system can be updated using a USB-stick, however, the update process does not cause any delays or breaks in medicine dispensing process. Overall, the telecare system and MMR are considered secure both in operation and for the handling of patient’s data.

5.4 Keystone species

Information ecology is marked by the presence of certain keystone species, whose presence is crucial to the survival of ecology itself (Nardi and O’Day 1999). In information ecologies, this kind of crucial key actors are often human mediators, people who can understand different parts of the system, and help other people to communicate and cooperate across the organizational and professional boundaries, as well as between the different system levels. We concur with Nardi and O’Day (1999) and Pekkarinen et al. (2020) that when new technologies are added in an information ecology, this implies enhanced interactions between humans and technology, and the role of skilled mediators becomes even more important.

In the context of MMR system, the apparent keystone species would be found among the frontline care providers that have the nearest and most frequent interaction with the patients and their medicine dispensers. What is more, it is the nurse that is responsible for the medication that communicates and interacts with the prescription
systems and the pharmacy, and sometimes also directly with the physician if there are issues with the prescriptions. This co-operation is crucial to ensure that the MMR is filled with correct medicines. Additionally, even if some of the practical tasks can be delegated to other personnel, the nurse is responsible for the practical procedure of re-filling the medicine sachets in the machine, as well as the administration of the telecare system. Consequently, the nurse responsible for medication can be considered as one of the key species that ensures that the system can achieve its core goal, i.e., to help patients to manage their medication in a safe way at home.

It is also pertinent to point out that in the MMR system, all the human actors and technologies, including physician, MDDD provider, ICT personnel and patient, as well as the technology (MMR, telecare system, MDDD service), are necessary and fundamental parts of the ecology. Their combined knowledge, skills, actions and functions make the system work, and we should never take their contributions for granted. The special role of the key stone species is based on the ability to understand and coordinate the different parts, and to align their efforts towards a common goal. The role of such mediators in conveying reliable information and operationalizing the medication flow is crucial for the successful operations of home healthcare systems such as MMR.

### 5.5 Locality

Locality is a particularly important attribute of information ecology. Only the participants within an information ecology system can establish the identity and place of the technologies. Moreover, this is conducted locally so that the users integrate the technology in their own setting and thus define its particular role and meaning (Nardi and O’Day 1999). The combination of different views maybe challenging, especially vertically between different system levels, as is described in Pekkarinen et al. (2020). This was also the case in the studied MMR system; the results from the workshop and discussions with the relevant stakeholders including health care management personnel and nurses both from social care and home care departments revealed how situational complexities arise with the introduction of MMR in addition to the existing system.

In the studied MMR system, the local municipality healthcare system, which is also the primary owner of the MMR system, defines the context of home healthcare focusing on the individual patient’s needs. The analysis reveals that the healthcare managers perceive MMR system intervention as an attempt to digitalize and automate the medication process at patient’s home. Generally, the MMR system seems to work well for medicines that can be delivered and administrated in dose sachet, i.e., through the MDDD service, and when the patient’s medication is consistent and unchanging over a
long period of time. However, when these conditions are not met, situational problems must be coped with in different local settings.

One complexity is the fact that it is very common that patients with MDDD also need to use medications that cannot be included in the dose sachet. This kind of medication still requires help from personnel for administration. It is possible to use the MMR to remind the patient for example, to take their medication from the fridge, but this procedure requires more effort from the patient. Having medicines besides the dose sachet also requires that the medication is picked up at the pharmacy or delivered together with the dose sachet. It also requires that there is a medication list with clear information about which medications to use besides the dose sachet from the MMR. The participants at the workshop perceived that the MMR could still be of help because it could reduce the number of visits needed, so that the patient could manage with one or two visits per day instead of four visits. The above-mentioned analysis is in-line with the suggestion that establishing the identity of a technology is a responsibility not just an opportunity (Nardi and O’Day 1999).

To summarize, the patients receiving care and help from the municipality could be of three different types, as shown in figure 2. Different regions might use different systems for prescriptions; in the case we studied, the region involved in this project uses the regional EHR Cosmic to prescribe the regular medication for patients. However,
the complexity arises when the patients with MDDD are also prescribed medications using the regional EHR. Physicians use MDDD prescription system to prescribe medicines that can be packaged in the appropriate dose sachet used in the MMR system, and they can also use the same system for medications that cannot be included in the sachet. However, other systems such as Cosmic are sometimes used to prescribe medication which is non-MDDD. According to the workshop participants, this may become a problematic situation. The management and nurses think that MDDD prescription system is adequate; however, the physicians are not always well aquainted with this system. This may lead to human mistakes, such as using an inappropriate system for prescriptions.

We have identified several issues (barriers) that can prevent the MMR success; issues that did not directly arise from the implementation of new technology. These are issues that are part of the MDDD system in itself, either within or outside the organization, and they need to be controlled for the safe medication management process and the successful operation of MMR.

Another example of a problem scenario is when there is a need for a change in the medication. It enacts certain other activities. This can be exemplified with two different settings. The first one is, when the patient has an infection, and the primary care physician prescribes an antibiotic treatment. This is most often done using the MDDD prescribing system, but the medication is given separately from the dose sachet and only for a short period. A second setting is, when the patient needs to be admitted to the hospital for a certain period. During the hospital visit, the MDDD system cannot be used to administer medications, instead the medication list in the electronic health record must be updated. If changes are made to the medication during the hospital stay, for example ending one treatment and adding one new medication, this has to be updated also in the MDDD system, when the patient is being discharged. Since MDDD medications are delivered in sachet, for two weeks at a time, there is a need for another solution during the time until the new sachet arrives. One way of doing this (preferred by the subjects in our study), is that the physicians at the hospital order new acute sachet according to the new medication list. If this is done correctly, it only takes two days for the new correct sachet to arrive. This is sometimes solved in other ways, for instance, by ordering complementary sachet or medication package for the new medication to be given on the side. However, the situation could be more challenging, if a medication has been removed. In the sachet it is not always straightforward to identify which pill is which. Since medications are often changed between different brand names (so called generic substitution), the appearance of the medication may also change. Therefore, it may be difficult to visually determine what the medication sachets actually contain.
Even though it is not recommended (not allowed), personnel sometimes has to take out the medication (or the pill they believe to be it) that should not be given any more until the new sachet arrives. This is done due to the lack of better options as a way of trying to provide the patient with the right medications. In both these settings, personnel in municipalities describe that the procedure differs between different physicians and health care units, in how they handle the changes in treatment but it is quite common that the changes in treatment are not done in the most optimal way.

With all scenarios, where the treatment is changed, there is a risk that the nursing staff could miss the changes, which becomes a source of worry among responsible nurses. The responsible nurses would prefer that when the doctors make changes to the medication treatment, they also send a separate message to alert the nurses. In this way, the nurses will be able to pay attention to the changes in the medication list, and make sure the changes are implemented in an appropriate way.

We also identified issues concerning communication, for instance as physicians at hospitals are not always familiar with the MDDD system (Pascal). The prescriptions are sometimes made in an incorrect way, such as labelling medication as “when needed” when it is actually for continuous treatment, and could have been delivered in the sachet. Moreover, it happens that the ordinary EHR is used, even if the prescription should be in the MDDD system as described above. Other issues are more directly linked to the decisions about a safe and appropriate treatment. The prescribing physician is responsible to ensure that the treatment is safe and appropriate, but sometimes the physician does not check for drug-drug interactions. It may also happen that the prescriber does not have a complete medication list for the patient, and therefore prescribes something that might be inappropriate to combine with another medication that the patient receives or prescribes something that the patient already has. When the nursing staff or the patient see both medicines in the system, they may think that the patient needs to take both, which is a risk to patient safety. In this case, nurses who are experienced with medicine and know the patient, can recognize the problem. The nurses do not have the right to change medicines on their own in the system, but they must contact the physician to get a correct prescription. In addition to risk for inappropriate treatment, this could also lead to wastage of time and resources.

Another risk situation occurs, when the medication is collected at the pharmacy. In Sweden, the national prescription repository is separated from the local EHR, and the physicians are not allowed to view all prescriptions for a patient. Therefore, incorrect or old prescriptions may be included among a patient’s prescriptions. At the same time, it is crucial that the personnel collecting the medication has correct and updated information about which medications the patient is supposed to take.
Even with the issues described above, the personnel that is handling medication in the municipality appreciates the MDDD system (and the MMR). The system is perceived as safer, and it also saves time to get the dose dispensed medication, instead of having the nurses to dispense medications themselves for all patients. The MDDD prescribing system (Pascal) is also considered easier to use. Generally, the personnel would prefer if the MDDD system could be used for the most patients, but the system can only be used if the patient agrees. The MDDD system in itself, gives all of the involved doctors and nurses and other involved stakeholders access to the complete medication list, in contrast to patients with ordinary prescription, where there is no shared medication list for the patient.

6 Discussion
The use of technologies in healthcare sector can transform the way the health services are provided today, and an efficient and secure medication management process has the central role for the effective use of medicines in healthcare (Goundrey-Smith 2019). This process encompasses several stages such as prescribing, dispensing and administration of medicine in all settings, including the transfer of medicines and information about these medicines across care settings (Avery et al. 2002; Classen and Metzger 2003; Topinková et al. 2012). Understanding the whole medication management process is of core importance regarding successful implementation of medication management robots for elderly patients in their home settings. Systems thinking approach (Peters 2014) and the concept of information ecologies (Nardi and O’Day 1999; Pekkarinen et al. 2020) imply that we can consider the medication management system as a complex and dynamic network of patients, family members, professional caregivers, municipal management and technology that are aimed to work together to achieve common goals. The systemic approach also entails that the interrelated parts need to co-evolve when the system adapts to the changes. In addition, the information ecology approach puts forth the idea of mediators as key actors, who are needed to bridge the different parts and coordinate their actions. Another main property of information ecologies is locality that stresses the importance of properly integrating the new technologies and practices in the local context. (Nardi and O’Day 1999).

This research work contributes to the existing body of knowledge in several ways. This study illustrated the complex and dynamic multilevel structure of the medication management robotic system (see figure 1), wherein the patient and MMR dispenser are embedded. Sustainable and safe medical support process relies on the the effective cooperation of people with different skills, and ultimately the medication adherence
depends on the patient’s ability and willingness to interact with the technology and actually consume the dispensed medicines. These findings also corroborate the results of several other studies that describe the organizational and inter-organisational complexity, as well as the extreme importance of information and communication quality in medication management in home healthcare. (Hammar et al. 2014; Lindblad et al. 2017; Lang et al. 2015; Nakrem et al. 2018)

The results from this study suggest that the nurses consider the tamper-resistant storage and automated delivery of the medication sachet as relatively safe procedure. The MMR can improve patient’s medication adherence, as the multi-dose prescriptions are continuously filled in the dispenser, the MMR delivers the medication sachets according to the individual dose schedule and it also reminds and alerts the patient to take the medication on time. Similar results concerning safety and usability have been obtained by Rantanen et al. (2017). However, the assessment of medication management robot systems is still limited and more quantitative and qualitative long-term studies are needed to obtain conclusive evidence of the devices’ safety, usability and performance.

We must also consider that while the MMR system can register that the medicine sachet is delivered and removed from the machine, it cannot monitor or confirm that the medicine is actually consumed. This issue is studied by Aldeer et al. (2018), and there are several suggestions for technical solutions that can support the medication adherence. However, we should not only consider this as a technological issue; it is also important to address the fact that when the MMR is used, the patient is considered responsible for the interaction with the machine, and also consuming the medication. Due to the diversity of patients, an automatic medicine dispenser does not address the needs of all older people and their families and the proper choice of suitable candidates for using the automated MMR is an important part of a successful process. The goal is to identify the patients that can become empowered and more independent in their daily life, when supported by the MMR, and who are willing to use the technology. Findings indicate that when the pilot project started, the nursing personnel used a specific checklist—provided by the company that manufactures the MMR system—to choose the patients that would be the suitable candidates for using the automated MMR. However, during the project, the nurses have gained more experience, so that they can now also utilize their own assessment of the potential users’ intrinsic capacity and functional ability. This will be important input for the decision makers, when they allocate resources and decide who would be best supported by the automated MMR’s drug dispensing service. Thus, the implementation of MMR at patient’s home entails co-evaluation, learning and adaptation on multiple system levels: the patient becomes more autonomous, and at the same time, the care personnel and the decision makers
gain experience of the suitability of welfare technology in different settings and situations.

From the organizational point of view in home care settings, it would be desirable to reduce the number of visits that are only aimed to hand out medication bags for MDDD users. Less visits of nursing staff to patients’ homes implies less usage of the vehicles, which is environment friendly, sustainable and cost-effective in terms of work and life balance and overall impact on the society. Moreover, in the cases where home visits are necessary for other reasons, these visits are anticipated to be more effective, as the staff can focus on other tasks than delivering medication bags. When we consider the potential workload reduction as a result of automated drug dispensing, it is important to keep in mind that MDDD can only deliver solid oral dosage forms, i.e., medical liquids as well as medicine that is administered parentally (e.g., injections) or topically (e.g., creams and lotions) require other ways of dispensing. Moreover, some tablets and capsules are not allowed to be repackaged in unit dose sachets. Another issue that cannot be solved by using MDDD is medicine that is not taken regularly, but should only be taken when needed. It is also important to point out that from the organizational point of view, the decrease of number of hours is relevant only if the nurses and home care staff can use the freed-up time for other purposeful tasks. Therefore, implementation of medication management robots may also become organization’s internal change driver, concerning scheduling and work processes, i.e., it may facilitate a learning and co-evaluation process on the organizational level.

Secondly, this study elucidates aspects concerning key stone species and locality: The theme locality is an important part of the information ecology (Nardi and O’Day 1999; Pekkarinen et al. 2020), and in this study this topic is illustrated by situational complexities and barriers within and outside the organization while introducing the MMR system. This theme is also related to the consequence of the connectivity of the system parts, as well as interactions and communication between different system levels and subsystems (Peters 2014). The situational complexities that we focused on are due to the facts that the medicine dispenser can only accommodate MDDD sachets, and that the whole medication management system manifests inertia in situations, where the medication is changed, especially if the change is temporary. Moreover, previous research has shown that drug related problems and potentially inappropriate drugs are common in nursing homes and patients with MDDD may have a lower quality in medication treatment (Johnell and Fastbom 2008; Johnell and Klarin 2007; Sjöberg et al. 2011, 2012; Wallerstedt et al. 2013). This kind of problems cannot be solved by introducing MMR. Instead, they need to be addressed with other approaches, directed at improving quality and safety in prescribing. What is more, the issues with parallel
systems and poor communication between prescribers and nurses in home care are not solved with the MMR either. Previous research has concluded that some of the problems with quality in medication treatment with MDDD patients may be the result of different systems being used for those patients and patients with ordinary prescriptions. Future development, like the nationally shared medication list that is on its way to be implemented in Sweden, may improve parts of this problem, if all patients can be handled in one system and there is only one medication list with a patient’s current medication that is shared by all involved actors. For a safe and effective use of medications in home healthcare it is important that the information handling and the decisions are correct and appropriate in the entire process. Otherwise, the MMR will just deliver the wrong medications that can make the patient’s condition worse. Previous research also identifies the need for system integration to improve medication safety in home care, due to issues with transition of care in other countries (Lang et al. 2015). In the future endeavor of making medication management more effective it is important that patients’ safety and well-being is not compromised. For example, it is clear that would be more simple to have as many medications as possible in the sachet instead of handling them on the side. However, it is important to put the patient needs and well-being first so that medications that are only needed occasionally (like pain medication or medication for insomnia) are not prescribed as continuous treatment and put in the sachet just to make the process more simple or save time. Hughes et al. (2009) describe the importance of involving patients in the nursing home setting in decisions about prescribing and self-administration as far as possible, although this is not easy to manage without affecting control within the nursing home.

Findings propose that in order to cope with the situational complexities, the role of nurses as key stone species and mediators is crucial. The mediator can coordinate the different system parts and convey reliable information between them, as well as to be able to operationalize the safe medication flow in the system. In the medication management system, the care organization and its national context are controlled by laws and regulations, but in the daily practice the overall behaviour and performance of the system are the result of many interactions and decisions that are made locally, by individual participants of the network, guided by the rules but also based on the proficiency and practical expertise.

Additionally, this study shows that the information security issues can also become complicated, if not handled appropriately since the sensitive personal data regarding patients is flowing between stakeholders including municipalities, MMR system, and the third-party service providers. Issues of privacy and security (see 5.3.5) apprehends and elucidates the data security procedures for MMR system and the associated web-
based telecare system. The empirical evidence suggests that the MMR system is reliable, secure and maintained in a timely manner to avoid any security concerns.

We conclude that MMR systems can be considered as one potential method to support and enhance home healthcare services for elderly community, and that the core objectives of the MMR system are closely aligned with several UN sustainable development goals (SDG:s). The above mentioned results suggest that MMR system have the capability to address the SDG #3, i.e., to promote patients’ good health and well-being in home care settings, by improving medication safety and adherence. In addition to the immediate benefit to patient’s physical health, a successful implementation of MMR at patient’s home also brings about co-evaluation, learning and adaptation on multiple system levels, including enhanced personal responsibility of the patients, which can be seen as part of the SDG #4, empowering lifelong learning. On the other hand, we have also discovered that successful medication process relies on people with different skills that can cooperate and utilize the technology in a constructive way. It is also important to acknowledge that the medication adherence depends heavily on the patient’s ability and willingness to interact with the technology and actually consume the dispensed medicines. These facts are related to the necessity of properly integrating the technology in local settings, where the users are able to define its particular role and meaning. Another perspective to consider this would be the SDG #9 that sets forth the need for fostering health care innovation that is responsive to the needs of older adults, their families and their communities.

It is clear that more studies are needed to establish the comprehensive ecology of medication management system in home care settings. We suggest that the further research should focus on the effects of the value-added services on the patient-caregiver relationships and the effects of using MMR in home healthcare sector on local municipality resources. Further research shall also explore the patient’s perspective.

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