

Socio-technical Approach to Agricultural Information Systems Development

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Abstract—Agricultural information interacts with and influences agricultural productivity in informing decisions regarding land, labour, livestock, capital and management. Relevant, reliable and useful information and knowledge can arguably improve agricultural productivity. The creation of information systems to disseminate information to farmers has become a necessity. Farmers can make better decisions in order to take advantage of market opportunities and manage continuous changes in their production systems. In Indonesia, several information systems to support agricultural activities has been initiated by government bodies and private entities, from providing agricultural extension services to supporting access to market. Most existing publications looking at the initiatives are based on prototype testing and with technology based approach, little attention was given social aspect or economic impact. Socio-technical design is an approach that give equal weight to technical and social issues when designing new system. Socio-technical approach has been used extensively in organizational settings and particularly in the field health information systems. This paper will look at the approach in the context of agricultural information systems design and implementation in Indonesia focusing on the livestock management systems.

Keywords—disseminate information, farmers, agricultural productivity

I. INTRODUCTION

Based on the results of the 2014 BPS survey, the livestock sub-sector contributed to 12.74 percent of the Gross Domestic Product (GDP) of Agriculture [1]. This contribution increased slightly compared to the contribution in 2004, which was 12.35%. During the period 2004-2014 the livestock subsector increased from around 3% to almost 5%. Until now, the increase in consumption of farm commodities has not been offset by domestic production. As a result Indonesia must import beef and milk commodities. In the span of 2009-2014, although beef commodity production increased by 21.6%, cow milk decreased by 3.2%, and even goat meat fell by 11.8%. As a result, the trade balance of livestock commodities in Indonesia tends to be negative.

Livestock sub-sector performance in Indonesia is influenced by the management pattern of livestock business in Indonesia. At present most of the livestock commodities are produced by simple household businesses with small and medium ownership. Although the livestock sub-sector contributes to absorbing around 4.2 million workers, the income earned is relatively low [1]. This is because the cost of animal husbandry production in Indonesia is not yet efficient. Soedjana & Priyanti (2017) reported that the cost efficiency of Indonesian beef production was ranked fourth

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in ASEAN, while the meat of goats was ranked third and fourth for broilers [2]. Therefore Indonesia must improve the efficiency of livestock production to achieve better competitive status [2].

Among livestock businesses, the management of sheep and goat farms in Indonesia is the least developed, compared to poultry and dairy cows [3]. The Indonesian BPS has reported the 2014 livestock business household survey. This survey includes beef cattle, dairy cattle and poultry, while surveys of sheep and goat farms are not included in this document. Institutions that handle sheep and goat breeders have not played an optimal role. HPDKI is the largest institution that houses the Indonesian sheep and goat breeders association (HPDKI), but it needs to strengthen its functions and roles [3]. In addition the meat market of goats is constrained by unequal distribution and an unpredictable meat market. So far, the need for lamb and goat meat is only sufficiently fulfilled by the production of the surrounding areas. While there is no integration between the goat market between regions in Java, Sumatra and other regions outside Java. Due to the unintegrated market information, Indonesia cannot accommodate export requests for meat from sheep in ASEAN and the Middle East [3]. While on the other hand due to the free market, people's livestock will face increasingly sharp competition. Hence, finding the right balance to face this competition is imminent if Indonesia aims to have decisive role in the globalization of world trade in 2020-2025Indonesia must find [3].

There are several initiatives to build livestock management systems in Indonesia. However almost all still based on prototype testing, there is no indication as product research and implementation. In addition, almost all existing systems are purely technology-based, do not pay attention to social aspects and scale of implementation economics. This article will look at socio-technical design in developing livestock management systems as it is an approach that give equal weight to technical and social issues. Combined with participatory processes and the right systems development framework the proposed approach potentially provide solution for LiMas implementation in Indonesia and other developing context. The paper will consist of several sections. First, it will provide the state of the art of livestock management systems implementation in Indonesia followed by brief overview of socio-technical systems design. Subsequent section will discuss how participatory process is closely related to socio-technical systems design and suitable systems development framework namely Lean startup. The paper will conclude by emphasising how the combination of concepts can work well towards socio-technical design of Livestock Management Systems.

II. LIVESTOCK MANAGEMENT SYSTEMS (LiMAS)

There are several LiMaS developments in both developed and developing countries. LiMaS development includes the design of the graphical user interface (GUI) and integration with RFID [4]–[6]. Some of the LiMaS infrastructure has been cloud-based computing that can be accessed anywhere and anytime [4], [6]. In Indonesia the development of LiMaS was carried out as a prototype to support poultry farming [7]–[9], dairy farming [10], enclosure mapping based on geographical information system [11], beef distribution supply chain management [12] and livestock disease inspection information system [13]. Almost all existing publications are still based on prototype testing, there is no indication as product research and implementation. In addition, almost all existing systems are purely technology-based, do not pay attention to social aspects and scale of implementation economics.

Development and Commercialization of LiMaS products has grown abroad, but is still considered as a recent development in Indonesia. For example, the state of Victoria, Australia in 2017 requires all farmers to use the Electronic Identification Device (EID) so that all livestock can be monitored by farmers and the government [14], [15]. With the implementation of EID, the Victorian government can monitor their livestock commodities not only to meet market needs but for disease prevention.

The application of LiMaS in developed countries is quite different compared to developing countries like Indonesia. Characteristics of breeders in Australia for example, are dominated by farmers with a production of more than 200 head per year [16], so that the development of livestock technology can be applied more easily because of economies of scale, infrastructure availability and more ICT literacy levels of farmers good. While the development of LiMaS in Indonesia must pay attention to the structure of farmers which are mostly produced by household businesses [1]. Therefore, in this study, LiMaS, especially integration with various IoT farm technologies will be developed by taking into account the social aspects, digital literacy and economic aspects of farmers in Indonesia.

Studies related to the development of livestock information systems are still relatively new. Some literature develops systems ranging from PC-based applications using simple databases such as Microsoft Access [5], [10], client-server based [17], web-based [12], [13], [18], [19], based on mobile applications [20], based on cloud computing [4], [6]. All papers that focus on aspects of prototype development have no indication of how far this system is used in real farms. The system developed by Bonnet et al. is more about sharing statistical information on farms in South African countries [18]. This system is implemented for 6 months but is constrained by the small number of users and is very dependent on a small number of strong leaders. Teng et al. (2012) developed a cloud-based LiMaS system that was tested involving 3000 dairy cows in Central Washington State, USA, but there was no further explanation whether this system was implemented or not [4].

LiMaS consists of a main database for livestock management. Most of the references focus on livestock cultivation management to facilitate the introduction of livestock. The system developed by Fitrianti almost covers all aspects of agribusiness including input (preproduction),

cultivation and output (marketing) [10]. Ismail and Ismail develops information systems for livestock cultivation that include aspects of breeding, feeding, dairying and slaughtering [5]. Some information system applications focus on one aspect of agribusiness management such as marketing [12], or animal health monitoring [13]. So far there is no one system that covers all aspects of agribusiness management as described by Rahim & Hastuti (2005) which include pre-production, (cultivation) process, supporting systems and post-production [21].

Technological developments have encouraged LIMAS development efforts that are integrated with various supporting technologies such as RFID for animal identification, sensors for health monitoring, scales, robotic devices for cow milking purposes. Only a small part of the paper focuses on developing a stand-alone database [10]. Most papers report developed systems integrated with RFID [4]–[6], [17], [19], [20]. The use of RFID allows the process of identification, tracking and storing livestock data in an RFID chip that is hung or pierced in the ears of cattle. The use of RFID can facilitate the tracking process of animals; improve data accuracy and quality; improve the efficiency of data collection; save farmers time and effort; facilitate the flow of information along the livestock supply chain from breeding, enlargement, distribution and slaughter [15]. Because of this advantage since 2017, the state of Victoria, Australia requires all of its livestock to use RFID.

LiMaS is developing from just storing data (recordkeeping) to real-time monitoring that focuses on improving the level of animal health, so that farmers can act immediately when there are problems. This management system is known as precision livestock farming (PLF). To go to PLF, livestock management information systems must be connected with devices that replace farmers' eyes and ears [22]. Saravanan & Saraniya (2018) developed a system integrated with animal necklaces containing temperature, humidity, heart rate and motion sensors [6]. With this sensor, farmers can monitor animal health in real time. The other system is equipped with a camera and microphone, so that farmers can monitor the movements and sounds of animals [22]. However, using this monitoring device in real time will increase the cost per farm animal. So far there has been no analysis related to the profit and loss of using this device compared to the benefits obtained.

Characteristics of farmers are very different from one country to another. One of the challenges in implementing LIMAS in Indonesia is the variety of types of livestock businesses ranging from part-time businesses (household breeders), business branches (along with other agricultural or livestock businesses), principal businesses and legal entities (Rahardi and Hartono, 2000 as cited by [21]. So far there is no clear data on the proportion of the number of these types of businesses. In addition, Indonesian livestock is dominated by farmers with elementary school graduates, 23% over 60 years old, and family workers/labourers. Based on the above challenges, it is necessary to understand the social aspects of the farmer's structure, the level of digital literacy (technical) in addition to the business scale, therefore in this article it is proposed that LiMaS should be developed by taking into account the socio-technical aspects. The following section provides a preview of socio technical design systems.

III. DESIGN OF SOCIO-TECHNICAL SYSTEMS

The socio technical design (SDST) system is an approach to design that takes into account human, social and organizational factors, as well as technical factors in organizational system design [23]. SDST has a long history and is intended to ensure that the technical and organizational aspects of a system are considered. The result of applying this method is a better understanding of how human, social and organizational factors influence the way the work is carried out and the technical system used. This understanding can contribute to the design of organizational structures, business processes and technical systems.

The premise underlying socio-technical thinking is that system design must be a process that takes into account social and technical factors that affect the functionality and use of computer-based systems [23]. The rationale for adopting a socio-technical approach to system design is that failure to do so can increase the risk that the system will not make the expected contribution to organizational and / or community goals.

In the information system design process, the socio-technical design relates to advocacy for direct participation of users. This system includes user networks, developers, existing information technology, and the environment in which the system will be supported and used. The process includes the design of human computers interface and pattern of human-computer interaction. This stands contrary to traditional systems or software engineering design methods that focus attention exclusively or primarily for the activities of system engineers who design computing functions and features of the new system, and those that use computer-aided design tools notation to capture and formalize the results of the design process.

Although many managers realize that socio-technical problems are important, socio-technical design methods are rarely used. Baxter & Sommerville (2011) suspect that the reason for the lack of use of the socio-technical approach is, mainly because of difficulties in using this method and the difficulty of connecting between these methods and technical problems and the interaction between individuals and systems [23].

Cherns (1993) describes the principles of SDST [24]. There are 9 important principles given, including: the design process conformity must be in accordance with its objectives, only provide important specifications and at a minimum, control all variations, provide space for redundancy, define boundaries both for the required skills or the team involved, the main information aimed at the work needed for action, social support is needed to strengthen expected social behaviour and understanding that design is an iterative process . Design never stops. New demands and conditions in the work environment mean rethinking sustainably the structures and goals needed.

It is interesting to note how very little discussion in the design and development of software IS in the leading literature explores the capacity or ability to use data and information. Sen (1993) explains how decisions are made depending on the information base and the selected indicator [25]. The ability to search, obtain, understand and process information is very important to be owned by actors involved in developing IS. This paper proposes that research and implementation of LiMaS should pay attention to the aspects

stated above and should also look at the social structure and literacy level of the farmer community.

IV. PARTICIPATORY DESIGN OF SOCIO-TECHNICAL APPROACH

Socio technical design is very closely related to action and participatory research or better known as participatory action research [26]. This approach describes a process and set of humanistic principles which in this case are associated with technology and change. SDST can be used to contribute to problem solving in work situations, provided that both innovators and users are willing to use a democratic approach. It will be difficult to succeed if the parties involved cannot work together or are not interested in developing a joint strategy. As the name suggests, the research approach has a component of action: either research is intended to cause changes in work situations or result in accidental changes because action research has taken place. STS designs can be said to be prescriptive, but some fields such as the field of human-computer interaction (human-computer interaction, HCI) prefer studies based on empirical results with descriptive results of "action research" [27].

Although participatory design of IS in the West often uses a socio-technical approach is it not common in the context of developing countries. This is surprising given that social aspects are thicker in these communities. Puri et al. (2004) suggested several important points from IS development observations in developing countries [28]. First, that is important for pay attention to local culture and traditions in participation and communication as well as decisions that are usually collective. Second, paying attention to the hierarchy in decision making, they see that in India for example a strong bureaucracy in the network of government institutions such as central / state government ministries, scientific institutions, and district administrative institutions has historically influenced development programs. Third, the importance of the role of the mediator. Mediators such as academics have an important role in fostering a participatory process. They can function as change agents that effectively translate local government interests and work styles and align them to support transparent and decentralized governance. Building capacity and creating a conducive environment to facilitate participation are also a major focus in socio-technical IS-based design in developing countries.

A. Participatory Action Research

Participatory action research provides opportunities for problems in the field to be raised and discussed and allows partners to create shared solutions.

There are several main characteristics of participatory research. First, there is an increase in capacity. When talking about research, there is a lot of capacity that needs to be built - who are the partners and individuals involved because it needs to be considered whether they have knowledge about the method of a research project and how the research is carried out. This is important in participatory research because partners will be invited to determine the problem and the course of the research. Targeted and specific training can provide local partners with knowledge about research. Training also needs to see and adjust to the individual backgrounds that participate.

The next important thing in PAR is empowerment. It is hoped that there will be an empowerment process from this research project, not only for the local partners involved but also for the community of farmers in general. Giving votes and opportunities to identify problems and solutions for change in the participants involved will provide better results.

Another important element of participatory research is ownership and this is one of the goals from the beginning that is for partners to feel ownership and responsibility for the input given to and actions taken in the research. "placing people responsible for how they represent themselves and how they describe their situation [29]. Recommendations for actions arising from this research tend to be locally based but are expected to have implications for other situations. We intend to support partners when they play a role as a pioneer of livestock management systems.

Then there is accountability. The main way to maintain accountability is an ongoing effort to keep all parties up to date during the research process. In terms of good communication and making information more accessible, it is very important. We will conduct practice reviews with partner organizations to explore what has been done and worked well so far. We also collaborate in the research framework and contextualize it if needed.

Finally, of course there needs to be sustainability. The advantage we have here is that researchers are members of the local community, with a thorough understanding of the language and cultural context. Therefore, participants can be understood in a conducive context and enable them, together with their families and communities, to not only identify problems but also discuss solutions and actions taken by the community for change. Also, the process of forming partnerships for this research has created important relationships between organizations - linkages that can provide opportunities for sharing ideas in the future.

Stages of a PAR (see figure 1) started with the negotiation process between the stakeholders involved, equating perception and jointly identifying problems. In this stage it is important to provide understanding to all involved in this methodology. The democratic process needs to be adopted to provide a conducive environment for all participating groups. Bergold & Thomas (2012) argue that in democratic concept research projects the participants form the design and research process [30]. The authors point out that people's understanding of democracy - as consensus democracy or majority democracy - has consequences in the level of participation, questions and research objectives, and research results. Often in the PAR process, especially those involving rural communities, capacity building is needed in terms of data and ICT literacy. The next process is to decide on real solutions and actions for the solution. Not only that the team involved must also express a desire to implement the action decided. Data retrieval is intended to evaluate the results of the action. Disseminating research results and their relevance to research participants, the community and related institutions is also an important component of the PAR process.



Fig. 1. PAR stages adapted from Bergold & Thomas [30].

In ICT for development research projects, the implementation of actions in PAR often involves developing the system. There are several system development methods that can be used such as SDLC, Agile, Lean software development, Lean Startup. Considering the characteristics of the system and organization involved in many of LiMas development in Indonesia, lean startup is considered more appropriate because: 1) user needs oriented, 2) not tied to a particular business model and 3) a lean and efficient process. The next section will describe the lean startup process in more detail.

V. LEAN STARTUP

Lean Startup is based on lean software development principles that promote the creation of more value with limited resources. The main idea of Lean startup is to avoid making a product that is not functioning or not needed by people. This idea is more towards finding a problem that is worth solving first and building a business model that is running. If lean software development focuses on products, Lean Startup, adopts lean software development and also includes business models. Lean Startup is ideal for entrepreneurs and beginners who are still looking for a business model or product that is valuable so that it is very suitable to be applied in this study considering LIMaS as a new breakthrough in the world of livestock in Indonesia. The advantage of Lean Startup is that it has the flexibility to respond quickly to new information and listen to customer needs.

With lean startup product development cycles can be shortened by adopting a combination of business-based hypothesis testing, repeated product releases, and validated learning. The rationale for this method is that if startup companies invest their time to iteratively build products or services to meet customer needs from the start, they can reduce market risk and avoid failure, the need for large amounts of initial project funding and expensive product launches. The main activity of a startup is to transform ideas into products, measure how customers respond, and then learn whether to switch or survive.

The goal in the early stages of Lean Startup is not to build software but more to do with meeting customer needs and satisfaction [31]. Figure 2 presents the Lean Startup validation process. A core component of the Lean Startup methodology is the build-measure-learn feedback loop. The first step is to find out the problem/solution fit and then develop a minimum but feasible product (MVP) to begin the learning process as quickly as possible. After the MVP is built, using prototype, startups can refine the product by involving measurement and learning. The output of this process is known as Fit (Product / launch Fit). When the measurement and learning process is done correctly, it will be clear whether the startup is moving the business model or not. Otherwise, it is a sign that it's time to correct or change and test a new fundamental hypothesis about a product.



Fig. 2. Lean startup validation process [31].

VI. CONCLUSION: TOWARDS SOCIO-TECHNICAL DESIGN OF LIVESTOCK MANAGEMENT SYSTEMS

We have seen from the above discussion the interlinked challenges and solution in implementing livestock management systems in developing countries, paying particular attention to the characteristics of individuals, communities and organisations involved in the process. As discussed, the challenges in implementing LiMaS in Indonesia include the variety of types of livestock businesses and there are not clear data on the proportion of the number of these types of businesses. This requires an in-depth understanding of each business type practices and come up with a standardise yet highly customisable solution. In addition, Indonesian livestock is dominated by farmers with lower education, older population and family workers/labourers which indicate the need for an approach that takes into account social issues such as ICT and data literacy and family as well as community dynamics.

To address those problems, this article proposes **socio-technical design approach** coupled with **participatory process** and **Lean Startup** system development. The socio-technical design approach lent itself to a robust approach whereby many social issues can be uncovered and at making sure that any technical solution will address those issues. Meanwhile, in the information system design process, the socio-technical design relates to advocacy for direct participation of users. This system includes user networks, developers, existing information technology, and the environment in which the system will be supported and used. By using participatory process, the all stakeholders in PAR research is emphasized and that this involvement will depend on the challenges faced in the context of the community. This is because cultural practices are deeply embedded in the ethos of the community, and the participatory paradigm in this situation is limited by cultural traditions and practices. PAR provides opportunities for problems in the field to be raised and discussed and allows partners to create shared solutions. Finally, considering

LiMaS as a new breakthrough in the world of livestock in Indonesia, the Lean Startup is suitable system development framework as it contains principles that promote the creation of more value with limited resources. The lean startup will ensure flexibility to respond quickly to new information and listen to customer needs.

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