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A System Dynamics Approach to ERP Adoption in SMEs: A Case Study of Banyumas

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ABSTRACT

Small and Medium Enterprises (SMEs) are pivotal to economic development, particularly in Indonesia, where they contribute significantly to employment and Gross Domestic Product (GDP). However, the adoption of sophisticated technologies such as Enterprise Resource Planning (ERP) systems remains a challenge due to constraints in resources, resistance to change, and implementation costs. This study aims to develope a system dynamics methodology to develop an ERP adoption model specifically tailored for SMEs in Banyumas. The model synthesizes mental models derived from a comprehensive review of literature and semi-structured interviews with relevant stakeholders, culminating in the creation of a Causal Loop Diagram (CLD). This diagram identifies key feedback loops influencing ERP adoption, including reinforcing loops related to awareness and business benefits, and balancing loops that address implementation challenges such as cost and complexity. The findings underscore the critical role of government support, the development of cost-effective ERP solutions, and the importance of training programs in facilitating ERP adoption. The proposed model provides practical insights for policymakers and ERP providers to enhance digital transformation within SMEs.

Keywords: *Banyumas, Causal Loop Diagram, ERP Adoption, SMEs, System Dynamics.*

A. INTRODUCTION

Micro, Small, and Medium Enterprises (MSMEs) play a strategic role in the Indonesian economy, especially as a major contributor to job creation and poverty alleviation. Based on data from the Ministry of Cooperatives and SMEs (2022), MSMEs contribute more than 60% to Indonesia's Gross Domestic Product (GDP). However, in facing the challenges of globalization and the industrial revolution 4.0, MSMEs are often left behind in adopting technology, including information technology such as Enterprise Resource Planning (ERP)[1] [2].

ERP is a system that allows the integration of various business functions in one platform, such as accounting, inventory management, and supply chain management. Studies show that implementing ERP can improve operational efficiency and company competitiveness [3]. However, the implementation of ERP in MSMEs in Indonesia, including in the Banyumas area, faces various challenges, such as limited resources, resistance to change, and lack of understanding of technology [4].

In the era of digitalization, the implementation of Enterprise Resource Planning (ERP) has become a solution for MSMEs to enhance operational efficiency and competitiveness.

However, ERP adoption among MSMEs, particularly in Banyumas Regency, faces various challenges, such as limited resources, lack of technological understanding, and resistance to change[4]. Therefore, this study aims to develop an ERP adoption model tailored to the characteristics of MSMEs in Banyumas. The key issues addressed in this research include identifying the factors influencing ERP adoption among MSMEs in Banyumas, assessing their readiness for ERP adoption, and designing an ERP adoption model that aligns with their needs and characteristics. Furthermore, this study seeks to evaluate the effectiveness of the proposed ERP adoption model in improving the efficiency and performance of MSMEs. By addressing these aspects, this research is expected to contribute to the promotion of more optimal ERP implementation among MSMEs in Banyumas.

Dynamic system modeling is an effective method to analyze factors that influence technology adoption holistically. This approach allows for a deep understanding of the interactions between variables, such as government policy support, implementation costs, and technology readiness [5]. Using this approach, this study aims to describe the system dynamics that influence ERP implementation in Banyumas MSMEs and provide data-based policy recommendations to support sustainable digital transformation.

The results of the study are expected to contribute to the literature on technology implementation in MSMEs and provide practical guidance for stakeholders at the local and national levels.

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B. LITERATURE

The development of an ERP adoption model for SMEs in Banyumas is carried out by synthesizing mental models from various system dynamics frameworks related to technology adoption and SME operational systems [5]. The mental model formulation is derived from multiple sources, including comprehensive literature reviews and semi-structured interviews with relevant stakeholders, as presented in Table 1.

In developing an ERP adoption model for SMEs in Banyumas, contributions from various stakeholders and subject-matter experts are crucial. Additionally, identifying and validating variables and their interconnections are necessary to construct the Causal Loop Diagram (CLD). The process of ERP adoption in SMEs is distinct from conventional technology adoption frameworks, which primarily target large-scale enterprises with established infrastructure. For SMEs, the adoption journey typically encompasses three key stages: awareness, implementation, and post-adoption evaluation, reflecting the progression of ERP system integration. The primary focus of ERP adoption in SMEs is to streamline business operations, improve efficiency, and support more informed decision-making.

Table 1. Adaptation of Research Model to Model Formulation

References	Author(s)	Purpose	Adoption
[6]	Gholamzadeh Chofreh et al.	To develop a sustainable ERP implementation roadmap incorporating environmental, social, and economic sustainability.	Proposed a Sustainable ERP (S-ERP) roadmap validated through expert reviews for various industries.
[7]	Haddara et al.	To analyze challenges in adopting Cloud-ERP systems in SMEs, focusing on implementation barriers and strategies.	Identified Cloud-ERP adoption challenges like data security and network dependency, offering mitigation plans.
[8]	Baykasoğlu & Gölcük	To develop a structured model for evaluating critical success factors (CSFs) in ERP implementation.	Proposed a two-phase structural model using ISM and FCM to analyze and prioritize ERP CSFs.

References	Author(s)	Purpose	Adoption
[9]	Gessa et al.	To examine real-world ERP adoption cases in SMEs and the motivations behind their decisions.	Highlighted SAP Business One as a popular solution and identified short-term and strategic motivations.
[10]	Paulsson & Johansson	To address architectural challenges in Cloud-ERP adoption using a sociomaterial perspective.	Identified six key challenges, including data security and scalability, and proposed architectural solutions.
[11]	Yang et al.	To investigate the evolution of managerial mental models and their influence on ERP project outcomes.	Utilized Causal Loop Diagrams (CLDs) to represent mental model dynamics affecting project decisions.
[12]	Kaveh M. Cyrus et al.	To identify and mitigate 'mortal loops' in ERP implementation dynamics that lead to project failures.	Developed a System Dynamics Model to address interrelations among CSFs and avoid negative feedback loops.
[13]	Abdalwali Lutfi	To examine the role of environmental uncertainty in moderating institutional pressures for ERP adoption in SMEs.	Applied Institutional and Contingency Theories to analyze external forces influencing ERP adoption.
[14]	Manuka Lakdinu et al.	To model leadership decisions in change management for successful ERP implementation.	Used System Dynamics Modeling to evaluate leadership strategies and their impact on ERP outcomes.
[15]	Radoslav Hrischev	To utilize simulation and modeling to optimize ERP implementation and operation.	Leveraged System Dynamics and Vensim PLE for process analysis, cost management, and security enhancement.

The adoption of Enterprise Resource Planning (ERP) in Micro, Small, and Medium Enterprises (MSMEs) has been widely studied, with research highlighting various adoption frameworks, success factors, and challenges. Existing models have been used to analyze ERP adoption. However, most studies focus on large enterprises, with limited research addressing the unique constraints of MSMEs, particularly in developing regions like Banyumas. Several studies emphasize factors such as cost, technological readiness, organizational culture, and external support as key determinants of ERP adoption in MSMEs. Nevertheless, there is a gap in developing a context-specific adoption model that considers the local business environment, resource limitations, and digital literacy levels of MSMEs in Banyumas. This study aims to bridge that gap by developing a tailored ERP adoption model that integrates existing theories with empirical findings specific to MSMEs in Banyumas, providing a more practical and applicable framework for successful ERP implementation.

C. RESEARCH METHOD

This study applies the System Dynamics approach utilizing Causal Loop Diagrams (CLD) to investigate the complex cause-and-effect relationships influencing the adoption and implementation of ERP systems in Small and Medium-sized Enterprises (SMEs). The CLD method is particularly advantageous in modeling feedback loops and interdependencies within

complex systems, offering a comprehensive understanding of the factors driving or hindering the success of ERP implementation.

Data were collected through a combination of primary and secondary sources. Primary data involved semi-structured interviews with key stakeholders, including SME managers, IT personnel, and ERP consultants. These interviews aimed to identify key factors such as technological readiness, management commitment, ERP system complexity, resistance to change, and government support. Secondary data were derived from literature reviews and reports on ERP implementation, providing a foundational understanding of the systemic dynamics involved [9].

The development of a mental model was undertaken to represent the shared understanding of ERP implementation processes and challenges [16]. This initial mental model, derived from data analysis, served as the conceptual framework for mapping the systemic interactions between key variables. Expert validation was conducted to refine the model, ensuring its relevance to real-world contexts and its accuracy in reflecting the dynamics of ERP adoption in SMEs [17] [18].

The mental model was further translated into a Causal Loop Diagram (CLD) to illustrate the causal relationships between the identified variables [19] [20]. The CLD includes reinforcing loops, which amplify positive outcomes, such as the realization of business benefits leading to increased investment in ERP systems, and balancing loops, which counteract adoption dynamics, such as high implementation costs or user resistance that slow down adoption rates. This detailed mapping of feedback structures provides insights into both the drivers and barriers of ERP adoption [7], [21].

Validation of the CLD was conducted through Focus Group Discussions (FGDs) involving ERP practitioners, SME representatives, and academics[22] [23] . These discussions ensured that the model accurately captured the systemic dynamics and relationships among variables, enhancing its reliability for further analysis. Validation also included iterative refinement of feedback loops and causal connections based on expert input, aligning the model with observed behaviors in ERP adoption scenarios.

The finalized CLD was utilized to simulate various scenarios of ERP implementation, allowing for the evaluation of potential interventions[24]. For instance, the model explored the impact of financial incentives, training programs, and simplified ERP modules on improving adoption rates and reducing resistance. These simulations provided actionable insights into effective strategies for overcoming adoption barriers and enhancing ERP implementation outcomes in SMEs [5].

To support the construction and analysis of the CLD, this study employed tools such as Vensim PLE. This software facilitated the visualization of feedback loops and the identification of leverage points within the system. Through these analyses, the study not only captures the systemic complexities of ERP adoption but also offers a foundation for crafting informed and strategic policy recommendations.

In conclusion, the application of the CLD methodology is expected to yield a comprehensive understanding of the causal relationships influencing ERP adoption. By identifying key reinforcing and balancing feedback loops, the study aims to provide actionable policy recommendations, such as targeted subsidies or capacity-building programs, to promote successful ERP implementation in SMEs.

D. RESULT AND DISCUSSION

D.1. Creating mental model

The mental model was constructed through a review of relevant literature and supported by semi-structured interviews with stakeholders. Subsequently, expert perceptions are necessary to validate the mental model to ensure that it accurately represents the actual

conditions of the ERP adoption system to MSMEs in Banyumas. Expert discussions are also crucial in determining system boundaries and validating the appropriate model structure.

The experts validating this model are stakeholders with over seven years of experience in their respective fields, including the Banyumas MSMES Department, representatives from small and medium enterprise sector that addopt ERP system, and some consultant in the field of ERP. Based on the collection of mental models obtained through expert interviews, several system perceptions were identified that could be utilized to construct the research model.

The model validation process involves interviewing experts using the model developed from the mental model. The experts then validate or revise each loop in the causal loop diagram used in the model. This validation process resembles a Focus Group Discussion (FGD) since each expert's perspective on the constructed model remains critical. Experts are extensively engaged in building this model, with multiple FGDs conducted, from collecting the mental model to validating the model. Occasionally, the activity of gathering mental models involving experts must be consulted separately for some stakeholders, requiring additional time for data collection.

The mental model and expert input yield conclusions in the form of a dynamic research hypothesis. This dynamic hypothesis aims to provide representative results from a formulated model based on the variables involved and the relationships between these interacting variables

D.2. Actor Analysis

The creation of a system diagram necessitates an initial actor analysis to delineate the roles and responsibilities of each actor or stakeholder involved[25], as presented in Table 2. This analysis further elucidates the influence of each actor or stakeholder on achieving the defined objectives and aids in establishing the boundaries of the system.

Table 2. Actor Analysis

Actor	Roles/Responsibilities	Problem Perception	Objectives
SMEs (Small and Medium Enterprises)	- Adopt ERP technology in business operations.	- Lack of awareness regarding the benefits of ERP. - High costs and implementation complexity.	- Improve operational efficiency and business profitability through ERP adoption.
	- Enhance human resource (HR) capacity to operate ERP technology.	- Limited HR capability to operate ERP systems.	- Increase HR capacity to effectively implement and utilize ERP technology.
Local Government and Institutions	- Provide support through policies, incentives, and training programs for ERP adoption.	- SMEs struggle to afford ERP implementation costs. - ERP complexity hinders adoption.	- Provide financial incentives and subsidies. - Facilitate training and promotion of ERP benefits.
	- Reduce barriers to ERP affordability for SMEs.	- Lack of collaboration among stakeholders to accelerate ERP adoption.	- Promote digital transformation in the SME sector through effective policies.
ERP Technology Providers	- Offer ERP solutions tailored to the needs and affordability of SMEs.	- Technology is often too complex and inflexible for small-scale SMEs.	- Develop ERP systems that are simpler, more flexible, and affordable for SMEs.

Actor	Roles/Responsibilities	Problem Perception	Objectives
	- Provide technical assistance and support during ERP implementation.	- Limited post-implementation support and after-sales services.	- Ensure successful ERP implementation through continuous technical support.
SME Associations and Communities	- Build networks among SMEs to share experiences and recommendations on ERP adoption.	- Limited dissemination of information and recommendations regarding ERP implementation successes.	- Increase awareness and knowledge about ERP benefits among SMEs through positive recommendations.
SME Human Resources (HR)	- Learn and operate ERP systems effectively.	- Lack of technical skills and knowledge related to ERP.	- Improve technical capabilities in ERP usage through intensive training programs.

Explanation of the Table

1. SMEs: Serve as the primary actors expected to adopt ERP technology. Their main challenges include cost constraints, lack of awareness, and low HR capacity.
2. Local Government and Institutions: Responsible for providing policy support, incentives, and training programs to encourage ERP adoption among SMEs. Focus areas include subsidies, awareness campaigns, and skills training.
3. ERP Technology Providers: As technology suppliers, they need to ensure ERP solutions are simpler, more flexible, and affordable for SMEs. Providing after-sales technical support is equally crucial.
4. SME Associations and Communities: Play a key role in fostering collaboration and sharing success stories of ERP implementation to raise awareness and encourage adoption.
5. SME Human Resources (HR): Tasked with learning and operating ERP systems effectively. Addressing the lack of technical skills through structured training programs is essential for successful ERP adoption.

D.3. System Diagram Framework

To gain a comprehensive understanding of the factors influencing ERP adoption in SMEs, particularly in Banyumas, the System Diagram Framework is constructed. This framework systematically represents the interactions between key components, such as policy interventions, technological infrastructure, and the roles of various stakeholders. By mapping the feedback loops and interdependencies, the framework elucidates both the reinforcing dynamics that drive ERP adoption and the balancing factors that act as barriers, including high implementation costs and system complexity. Figure 1 shows the diagram that provides a structured analysis of how these elements interact and influence the overall adoption process, offering critical insights for the formulation of targeted interventions aimed at facilitating the successful implementation of ERP systems within SMEs.

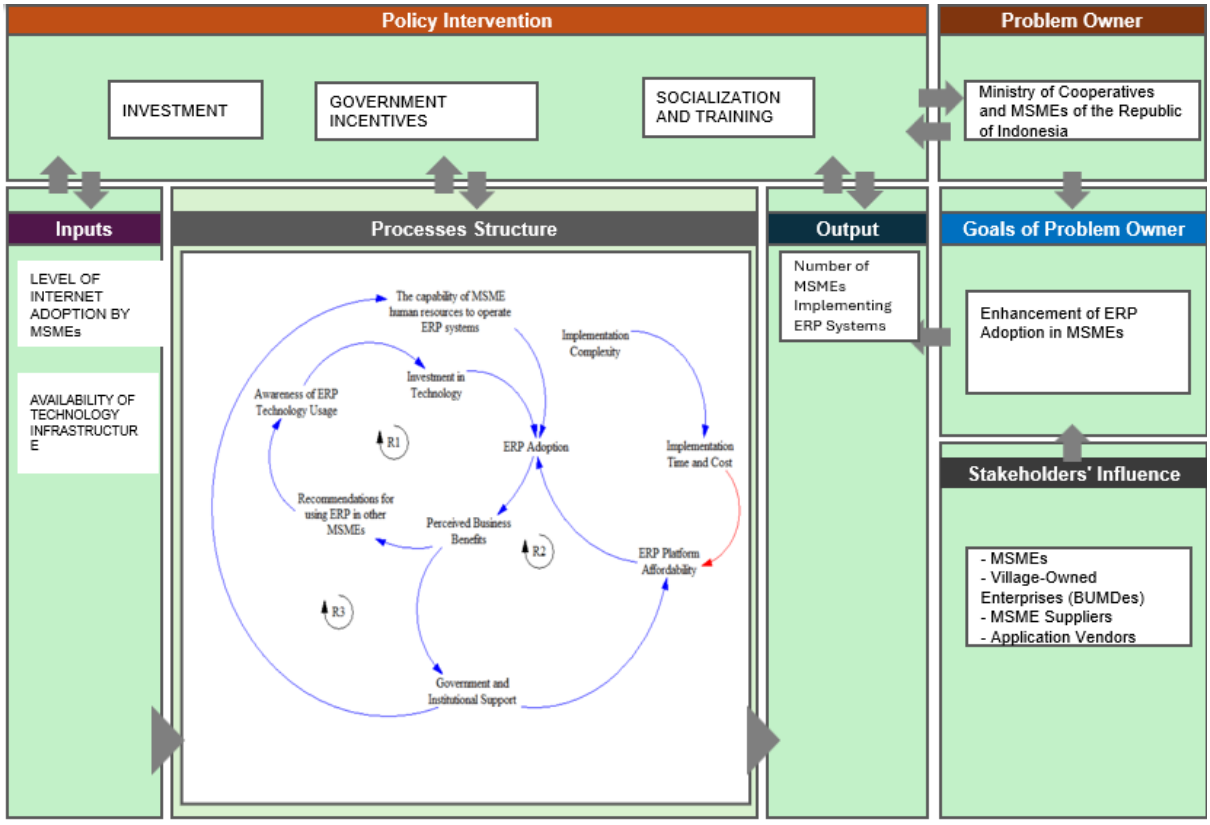

Figure 1. System Diagram

This system diagram provides a comprehensive overview of the factors influencing ERP adoption among SMEs. Below is a detailed explanation of each key component within the diagram:

1. Policy Intervention

   This section highlights policy measures that can be implemented by the problem owner (Department of Cooperatives and SMEs) to promote ERP adoption. The interventions include:

   - Investment Budget: Allocating funds to support ERP implementation in SMEs.
   - Incentives: Providing financial or non-financial incentives to encourage SMEs to adopt ERP.
   - Socialization and Training: Conducting outreach programs and training to enhance awareness and skills for ERP adoption.

   Purpose: To address barriers to ERP adoption and create favorable conditions for SMEs to implement ERP.

2. Inputs

   This section identifies the critical inputs that influence the ERP adoption process, including:

   - Level of Internet Adoption by SMEs: Access and utilization of internet infrastructure, which is a prerequisite for ERP implementation.
   - Availability of Technological Infrastructure: Adequate hardware, software, and connectivity to support ERP systems.

   Significance: Without sufficient infrastructure and internet access, ERP adoption among SMEs becomes impractical.

3. Process Structure

This section serves as the core of the system diagram and includes a Causal Loop Diagram (CLD) that captures the dynamics of ERP adoption. The key loops include:

a. Main Causal Loops:
   - Adoption of ERP is influenced by several factors, such as HR capability, government support, technology investment, and ERP platform affordability.
   - Positive feedback loops (R1 and R3) occur through increased ERP awareness, perceived business benefits, and recommendations to other SMEs.

b. Positive Dynamics:
   - Government and Institutional Support → leads to increased investment in technology → drives perceived business benefits → generates recommendations to other SMEs → accelerates ERP adoption.

c. Negative Dynamics:
   - Implementation Time and Costs → reduce ERP affordability → hinder ERP adoption.
   - Implementation Complexity also slows down the adoption process.

Core Process: ERP adoption is shaped by a combination of enabling factors (e.g., government support, business benefits) and barriers (e.g., complexity and cost).

4. Output

The output represents the result of the processes within the system:

- Number of Implementing SMEs: The total number of SMEs that successfully adopt ERP technology.

Purpose: This serves as a measurable indicator of the success of policy interventions.

5. Goals of Problem Owner

The problem owner, identified as the Department of Cooperatives and SMEs, has a primary goal:

- Increase ERP Adoption among SMEs: To accelerate digital transformation in the SME sector through ERP implementation.

6. Stakeholders' Influence

This section identifies key stakeholders that influence ERP adoption:

- SMEs: The primary actors expected to implement ERP systems.
- Village-Owned Enterprises (BUMDes): Entities supporting rural economic development that can influence SMEs.
- SME Suppliers: Suppliers of goods and services that interact with SMEs.
- ERP Vendors: Technology providers offering ERP solutions tailored for SMEs.

Role: Collaboration among stakeholders is crucial to building a supportive ecosystem for ERP adoption.

This system diagram illustrates the interactions between policy interventions, inputs, process structure, stakeholders, and output in promoting ERP adoption among SMEs. A comprehensive approach—including government support, HR capacity building, and affordable technology solutions—is necessary to overcome barriers and achieve the main goal: increasing the number of SMEs implementing ERP systems.

D.4. Causal Loop Diagram

The causal loop diagram (CLD) model developed in this study represents a formulation that captures the reciprocal relationships influencing ERP adoption in SMEs. This model systematically outlines the key variables, such as awareness, government support, human resource capacity, and implementation costs, and demonstrates how changes in these factors affect the adoption dynamics. The formulation of this ERP adoption model for SMEs is

grounded in mental models derived from comprehensive literature reviews and semi-structured interviews with relevant stakeholders. The causal loop diagram illustrating these interdependencies is presented in Figure 2.

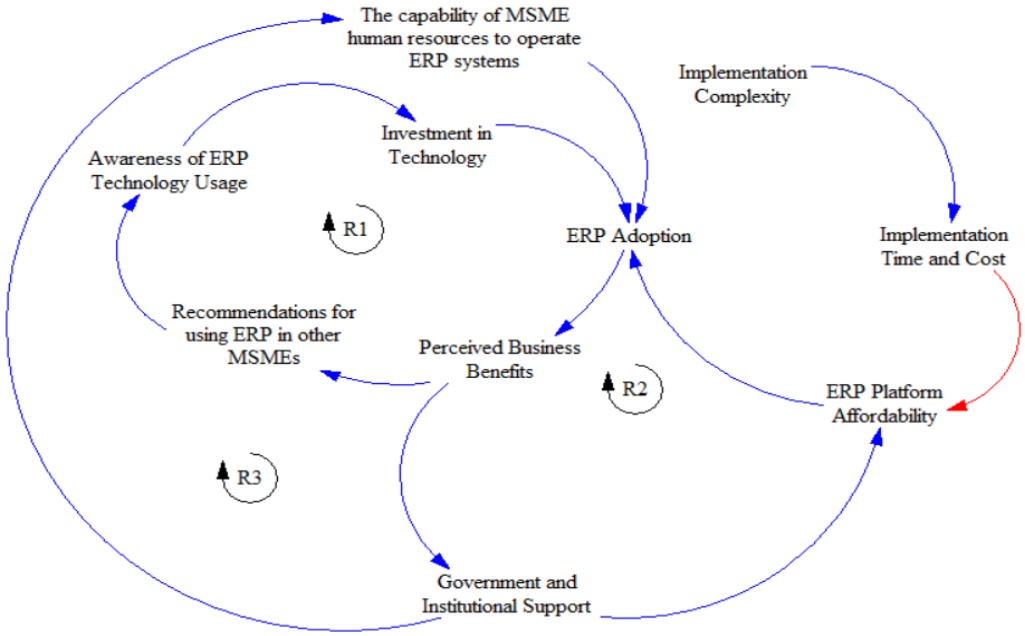

Figure 2. Causal Loop Diagram

Loop R1 (Reinforcing Loop – ERP Technology Awareness and Investment in Technology)
Flow:
Awareness of ERP benefits among SMEs → Increased investment in ERP technology → Improved HR capability to operate ERP → Higher ERP adoption → Greater awareness of ERP technology.
This loop indicates that the greater the SMEs' awareness of ERP benefits, the more they invest in the technology, ultimately encouraging ERP adoption. This is a reinforcing process, meaning that as awareness and adoption grow, the number of ERP users among SMEs increases rapidly.

Loop R2 (Reinforcing Loop – Perceived Business Benefits)
Flow:
ERP adoption → Increased perceived business benefits → SMEs recommend ERP to other SMEs → Greater awareness of ERP technology → Increased ERP adoption.
This loop illustrates that when SMEs adopting ERP experience its benefits, they are likely to recommend ERP to other SMEs. This, in turn, broadens ERP adoption. It creates a snowball effect where the growing number of SMEs adopting ERP amplifies its influence within the SME community.

Loop R3 (Reinforcing Loop – Affordability and Implementation Barriers)
Flow:
ERP implementation complexity → Increased implementation time and costs → Reduced ERP platform affordability → Lower ERP adoption.
This loop shows that the high complexity and cost of ERP implementation can act as barriers for SMEs to adopt the technology. Affordability is a critical factor in ensuring that more SMEs can access ERP systems.

Interaction Between Loops

1. Government and Institutional Support
   External factors play a significant role in influencing both reinforcing loops (R1 and R2). Support such as subsidies, training programs, or policies that improve ERP affordability can accelerate technology adoption.
2. Balancing vs Reinforcing Dynamics
   While loops R1 and R2 reinforce ERP adoption, loop R3 acts as a constraint if issues related to cost and implementation complexity are not addressed.

The diagram highlights the importance of mitigating the barriers in loop R3 (cost and complexity) to accelerate the positive impacts generated by loops R1 and R2. Government support and collaboration with technology providers are crucial to ensuring the successful implementation of ERP systems among SMEs.

E. CONCLUSION

This research presents a system dynamics model to analyze the factors influencing ERP adoption among SMEs in Banyumas, highlighting the complex interplay between drivers and barriers such as ERP awareness, business benefits, implementation costs, and government support. The Causal Loop Diagram (CLD) developed in this study illustrates the reinforcing feedback loops, which accelerate ERP adoption, and the balancing feedback loops, which constrain it, notably the high complexity and costs associated with implementation.

The study emphasizes that overcoming the barriers to ERP adoption requires strategic policy interventions, including targeted financial incentives, comprehensive training programs to enhance SME capabilities, and the development of simplified ERP solutions that cater to the unique needs of SMEs. Addressing these challenges will foster a conducive environment for ERP adoption, thereby enhancing the operational efficiency and competitiveness of SMEs.

The model developed through this research offers a conceptual framework for understanding ERP adoption dynamics and provides actionable recommendations for stakeholders, including policymakers, ERP vendors, and SME support organizations. These insights can guide future efforts to promote digital transformation and foster sustainable growth within the SME sector. This research can be continued by using system dynamics simulation through SFD (Stock and Flow Diagram) to simulate and test policies that can be taken by stakeholders[5].

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