Towards a Methodology for Modelling Interdependencies between Partners in Digital Business Ecosystems

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***Abstract*—Digital business ecosystems rely on interdependencies for value co-creation. Thus, the success of a digital business ecosystem is inextricably linked to how well interactions are understood, aligned, and supported. Therefore, it is essential to comprehensively understand the interdependence types, structure, substances, and participants in digital business ecosystems. However, in information systems research, limited understanding exists on how to model interdependencies in digital business ecosystems. This paper seeks to fill this gap by developing an interdependence modelling methodology that provides a systematic approach to capture and represent interdependencies in digital business ecosystems. To demonstrate the potential of the methodology, we illustrate its applicability through a case study of Ghana's import digital business ecosystem.**

Keywords—digital business ecosystem; interdependence; modelling; methodology

I. INTRODUCTION

The current business landscape is witnessing an increased interdependence between various organisations due to insufficient resources to match the growing sophistication in customer preferences. As such, organisations are establishing alliances beyond their traditional industries. These alliances are referred to as ecosystems. Indeed, it is now widely accepted that participating in ecosystems is no more optional for many organisations [1]. Digital business ecosystem (DBE), a type of ecosystem, refers to a sociotechnical network of individuals, organisations, as well as information and communication technologies (ICTs) that collectively co-create value [2]. DBEs are dynamic, self-organising, and heterogeneous in nature; as such its partners are independent and responsible for their own survival [3]. In DBEs, participants are viewed as partners because of the "win-win" nature of interactions. A DBE partner is an individual or organisation that contributes direct inputs into core processes or exchanges key resources with another partner.

Interdependence refers to a dependent relationship between entities such as processes [4], actors [5] and technologies [6]. As such, some processes, organisations, and technologies may rely on others to successful execute their tasks. Thus, for key stakeholders such as focal organisations, systems developers, policy makers etc., it will be a welcoming idea to have a comprehensive understanding of all interactions in their DBEs. However, due to multiplicity of interactions, this ideal understanding is difficult. It is argued that interdependencies permeate most interactions in DBEs, yet, their manifestation is sometimes difficult to assess and represent [4]. Thus, for a better understanding, interdependencies can be evaluated through analysis, modelling, and measurement. In this paper, the focus is on modelling DBE interdependencies from the partners' perspective.

Despite the availability of intuitive knowledge on interdependence, little empirical evidence exists now as to how we can model interdependencies in DBEs [4]. Moreover, in extant information systems literature on DBEs, research focus has been on platform, governance, and capability development while interdependence modelling remains under-researched [7]–[10]. We argue that modelling interdependence is important for the following reasons. Firstly, modelling interdependencies provides a comprehensive view of the structural, functional, and behavioural dynamics of a DBE to support systems analysis, developments, alignment, and decision-making. Secondly, interdependence modelling provides the premise for other interdependence evaluation activities such as analysis and measurement. Lastly, as there is an agreement in the information management literature that interdependencies are important in organisational success, it is only prudent to devise a way to capture this critical business element.

Based on these pertinent positions, this study seeks to develop a methodology for modelling interdependencies in

DBEs. The main research question motivating this study is: *How can we model interdependencies between partners in DBEs?* In addressing this research question, our study makes the following contributions. First, our study extends DBE and interdependence research by providing a methodology to articulate and represent interactions between partners. This DBE interdependence modelling methodology will support analyst and developers in designing, aligning, and maintaining information systems. Our methodology also offers a lens to understand structural and functional dynamics between DBE partners towards improved decision-making. Lastly, our study provides a foundation for other studies into the relatively under-researched area of DBE interdependence.

The rest of the study is organised as follows. Section II presents related research on DBE and interdependence. Section III presents the research methodology whilst Section IV presents our proposed DBE interdependence modelling methodology. Thereafter, Section V demonstrates the applicability of our methodology through a case study of Ghana's import DBE. Section VI presents discussions while Section VII concludes the papers and provides limitations as well as future research directions.

II. Related Research

A. The Digital Business Ecosystem

The concept of DBE can be viewed as an evolution of business ecosystem [11]. While both DBE and business ecosystem draw inspiration from biological ecosystem, ICT plays a key role in the orchestration of DBEs. In this study DBE is defined as a network of individuals, organisations and digital technologies that collectively co-create value [2]. DBEs comprise business ecosystem and digital ecosystem. Business ecosystem refers to a network of loosely-coupled interacting organisations, who produce valuable goods and services for customers [1]. On the other hand, digital ecosystem refers to a collection of technologies that support business ecosystems to co-create value in DBEs [12].

Moore [1] posits that actors in ecosystems include governmental institutions, media, customers, lead producers, competitors, suppliers, and leadership companies. On the other hand, Iansiti and Levien identify the roles of ecosystem partners as keystones, niche players, and dominators. Keystones or focal firms are organisations with leadership position within an ecosystem [3]. As such, they are responsible for advancing the growth and survival of the ecosystem through reduction of entry barriers, acquiring, and retaining of partners and filling niche gaps. Niche players on the other hand, are partners that complement the efforts of keystones. Niche players focus on creating assets and capabilities within specialised domain of the ecosystem. The platforms owned by the keystones are the source of capabilities and opportunities for niche players to develop new products and services. As a result, niche players are always in close relationship with keystone partners. Dominators are partners that integrate others vertically or horizontally to own their assets. Dominators mainly seek ownership of key assets for value extraction. Drawing from the literature, we can argue that partners in DBEs fit into the roles of keystones, complementors, and customers. It is important to note that not all these actor roles may be present in every DBE.

DBE research is fairly new and gradually witnessing some amount of studies. To ground DBE in contemporary information systems research, most of the studies have focused on providing fundamental understanding of the building blocks such as concepts, processes, and structure [2,12]. Alternatively, other DBE studies have focused on capability development [8], platforms [7,13], and governance issues [9,14]. Notwithstanding the contributions from these studies, a critical area like DBE interdependence modelling is still open and less researched. Considering the stream of earlier DBE studies, we can argue that only a section of DBE research has been covered. As such, there is a need for further studies into under-researched areas to consolidate understanding. Therefore, this study seeks to fill this gap by developing a DBE interdependence modelling methodology.

B. Conceptualising Interdependence in DBES

We combine Thompson [15] as well as Håkansson and Snehota [16] conceptualisation to extend interdependence research to the DBE level. From Thompson's theory of interdependence, three types of interdependencies have been proposed–pooled, sequential, and reciprocal (see Fig. 1). Even though some additions have been made to Thompson's classification of interdependence, the focus has been on units within a single organisation. As such, we draw on the widely-utilised classifications to conceptualise interdependence in DBEs. Pooled interdependence describes a loosely coupled relationship where different entities produce individual outputs that contribute to the entire system.

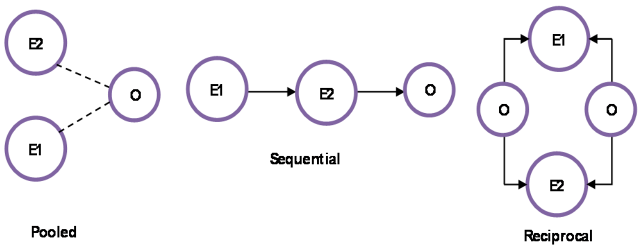

Fig. 1. Interdependence types.

For instance, in a DBE, the provision of banking services and development of applications are directly unrelated, but the two functions must be undertaken to ensure a smooth running of the DBE. Sequential interdependence describes a setting where the outputs from some entities are necessary inputs for others to perform their work. The provision of Internet service to a bank by another organisation to support its operations demonstrated sequential interdependence in a DBE. Without the Internet service, it will be difficult for the bank to operate. Lastly, reciprocal interdependence refers to a cyclical arrangement where there is a mutual flow of inputs and outputs between entities. Fig. 1 shows the three-main interdependence conceptualisation. E1 and E2 represent the entities such as partners within the interdependencies while O represent the outcome of each interdependence type.

Exchanges between entities largely trigger interdependencies. We argue that interdependencies in DBE can be triggered by the exchange of a substance. Substance refers to something that causes interdependence among entities

[16]. Thus, without a substance, there will be no interdependence. Adapting from Snehota [16], we classify substance as either a resource or an activity. Resource refers to an input needed to perform an action [5] while activity comprises series of steps to accomplish a task [17]. Resources include technology, finance, knowledge, materials and so on. Activities on the other hand can be technical, administrative, commercial, and other tasks that can be connected in diverse ways to other organisations. Digital technologies represent one key resource that is inextricably linked to DBEs. Therefore, we propose that in modelling interdependencies at the ecosystem, the role of digital technologies such as platforms must be clearly delineated [7].

In summary, we can posit that interdependencies in DBEs can be pooled, sequential, and reciprocal whilst the substance of an interdependence can be resource and activity. However, one resource that is inseparable from DBEs is a digital platform.

C. *Ecosystem Modelling Approaches*

At the ecosystem level, only a few modelling approaches exist. For instance, Tian et al. proposed the business ecosystem analysis and modelling framework to analyse business models design at the business ecosystem level [18]. In this paper, focus is on a framework for business model design through analysis and modelling activities. In another vein, Battistella et al. developed the methodology for business ecosystem network analysis to analyse, model and forecast business ecosystems with much focus on relational and network structure as well as dynamic foresight analysis [19]. Also, Marin et al. proposed the business ecosystem modelling approach for business interaction [20]. The approach seeks to investigate the propagating influence of a local relationship on the entire business ecosystem. While the insights from these studies are acknowledged, some limitations still exist. First, current modelling approaches have paid limited attention to modelling of interdependencies instead, much focus has been on analysis of business ecosystem interactions, structure, and behaviours. Also, existing approaches are not tailored for DBEs, they largely focus on the business ecosystem level where some key DBE elements such as digital platforms, and process are not well represented. As such, there is a need for a methodology tailored for and focused solely on modelling DBE interdependencies, a gap this study seeks to fill.

III. Research Methodology

This study adopts the design science research approach in its quest to develop a DBE interdependence modelling methodology [21]. We argue that developing an artefact such as the DBE interdependence modelling methodology is a logical process, thus must be underpinned by a sound approach. As such, we leveraged the processes of the design science research approach, namely awareness, suggestion, development, evaluation, and conclusion to ensure solid contribution to knowledge as well as finding a solution to a problem of DBE interdependence modelling. The design science approach is chosen due to its support and applicability in answering the research question. We utilised data from semi-structured interviews with key players in Ghana's import DBE as well as secondary data sources such as websites, and reports to support our case illustration.

IV. DBE Interdependence Modelling Methodology

The DBE interdependence modelling methodology aims to provide a systematic approach to model interdependencies at the ecosystem level. It derives inspiration from DBE, and interdependence literature. This methodology is motivated by the need to represent interactions in DBEs towards further analysis and measurement as well as understanding. The methodology also seeks to provide practitioners such as systems developers and analysts a tool to model interdependencies as DBEs have become widespread. The methodology, as presented in Fig. 2 comprises three stages. Further elaboration on each of the stages is presented below.

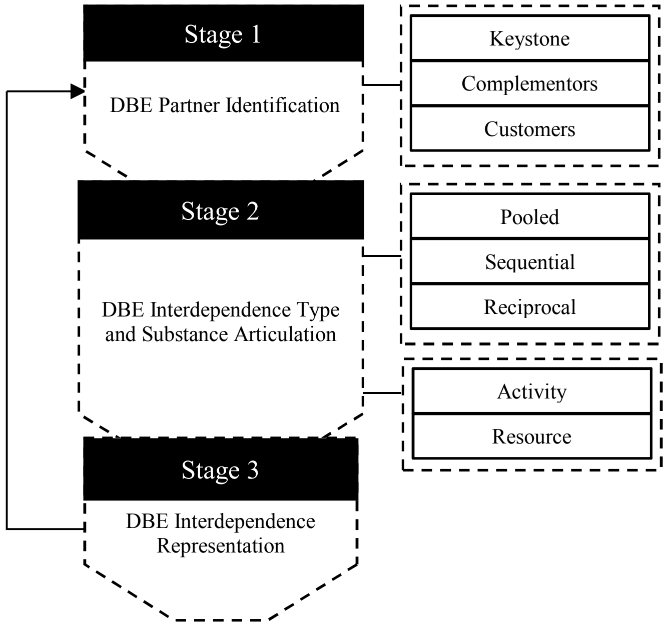

Fig. 2. DBE interdependence modelling methodology.

Stage 1: This stage of the methodology enables partner identification in a DBE. Identifying partners in DBEs can be a challenging task. In fact, Iansiti and Levien allude that it is impossible to identify all partners of an ecosystem [3]. Thus, they suggest that partners with whom the future of an organisation intertwines should then be considered in partner identification. Drawing on this proposition, we argue that classifying partners in predefined roles can help in systematic identification. Thus, the methodology defines three partner roles in DBEs. These roles are expressed as:

Partners= Keystones |Complementors| Customers

Keystones are partners with major influence and power over a DBE due to ownership of critical resources such as platforms. Depending on the dynamics of a DBE, there could be more than one keystone [3]. Therefore, in a DBE, keystones are expressed as: K = {K1, K2..., Ki} where K1, K2, and Ki represent number of keystones within the DBE. Complementors refer to partners that utilise assets in a DBE to create or improve their product and service innovations [8]. However, complementors could be niche players, or dominators. We express complementors as: CoM = {CoM1, CoM2..., CoMi} where CoM1, CoM2, and CoMi represent number of complementors within a DBE. Lastly, customers refer to the ultimate recipients of interdependence efforts. They refer to individuals and organisations that consume value created in DBEs. Customers represent strategic partners of DBEs, as they are the source of revenue for the value created. We therefore express customers as: C = {C1, C2..., Ci} where C1, C2, and Ci represents the number of customers in a DBE. Customers may be directly linked to keystones or complementors in DBES. Thus, we view customers to be functionally depended on keystones and other complementors. Therefore, partners in DBE can be expressed as: P= {Kw, CoMw, Cw} where w is the number of partners (P) representing each role.

Stage 2: In this stage, we perform interdependence articulation. To aid in the interdependence articulation, we develop a matrix that maps the partners on each other to determine their interdependencies. The matrix as presented in Table I is a two-dimensional table where at each point, a partner (e.g., Partner X) is mapped onto others (e.g., P1, P2… Pn) in the DBE. The partners are articulated based on three types of interdependencies (pooled, sequential, and reciprocal) [15] as well as the substances (resource and activity) [16] of their interdependencies. Resource and activity represent the substances of each interdependence. Substance refers to an object that causes dependency [16]. Resource as an element of substance in DBE refers to an input necessary to perform an action [5]. It comprises technology, finance, knowledge, and so on. In DBEs, the key resource that links other resources and partners together is digital platform. Platform refers to a digital artefact with a set of ICT capabilities to provide some core services and also interfaces with complementary external models to enable collaboration, information sharing and collective action [7]. Activity on the other hand, refers to a series of steps to accomplish a task which could be technical, operational and can be connected in different ways to other partners [17].

TABLE I. INTERDEPENDENCE ANALYSIS MATRIX

	Partner X					
	Pooled		***Sequential***		***Reciprocal***	
	Resource	***Activity***	***Resource***	***Activity***	***Resource***	***Activity***
P1						
P2						
Pn						

At the DBE level, we conceptualise pooled interdependence as when partners contribute distinct efforts to achieve an overall goal through indirect relationships. Failure to properly coordinate pooled interdependence may affect achievement of the overall goal. Sequential interdependence describes serially structured contributions from partners as necessary inputs for other actions in a DBE. In the same vein, reciprocal interdependence is conceptualised as a situation where outputs from cyclically structured entities become inputs for others and vice versa in a continuous arrangement. Thus, a change in one partner may result in changes in other partners at any time. By correctly mapping types of interdependencies along with their respective substances, DBE interdependencies can be derived to support the modelling process.

Stage 3: This last stage of the methodology is the DBE interdependence representation. The purpose is to model the various interdependence types and substances identified from stage 2 of the proposed methodology. Fig. 3 presents a sample interdependence representation detailing the partners, their interdependencies, and substances. The rounded rectangle shape represents the partners whilst their interdependencies are represented by a dotted line, single-headed arrow, and double-headed arrow for pooled, sequential, and reciprocal interdependencies respectively. The rectangular shape represents the substances of the interdependencies. The modelling starts with naming the DBE as well as all its functionally dependent interdependencies. Thereafter, the partners are represented, followed by their interdependencies and substances.

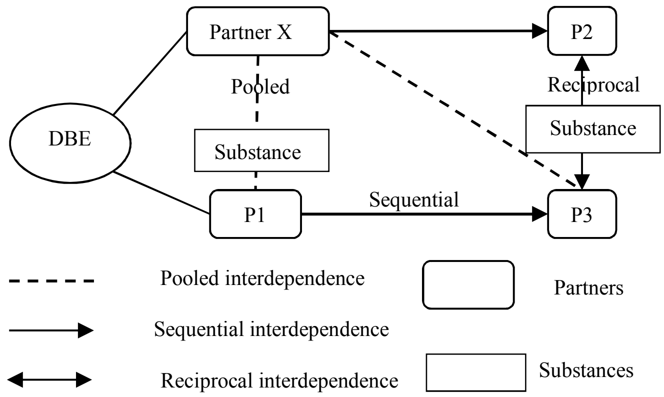

Fig. 3. DBE interdependence representation.

V. CASE STUDY: GHANA'S IMPORT DBE

To illustrate our DBE interdependence modelling methodology, we used Ghana's import DBE as a case study. We selected this case because it provides an empirical instantiation of a DBE, featuring the characteristics, dynamics, and operations. We present a high-level view of the vehicle clearing procedure at Ghana's main port, Tema Harbour. The procedures are: (1) Upon arrival of a vehicle from abroad, the *importer* submits import declaration forms, invoices, and bill of lading to *Customs* through a digital platform, named the *single windows system* for valuation, (2) Customs valuate the declaration and makes a determination of import duty to be paid, (3) the importer pays import duty at the *bank*, (4) the bank notifies Customs of duty payment using the single window system and (5) Customs performs physical examination and releases the vehicle. We now proceed to apply our proposed DBE interdependence methodology to the case study based on the scenario above.

Stage 1: The partners identified in the vehicle clearing procedure are an importer, Customs, and a bank. The import clearing procedures revolve around Customs. As such, we view Customs as the keystone of the DBE. Besides, the single window system that the importer uses to submit his/her application and documents belongs to Customs. This single window system can be referred to as the digital platform of the DBE. The bank is a complementor in the DBE since it relies on the keystone for service innovation. Lastly, the importer is the customer in the DBE since he/she is the final beneficiary of the processes in the vehicle clearing procedure. The importer remains the source of revenue for Customs and the bank.

Stage 2: Using the interdependence articulation matrix, we map the partners identified in stage 1 with each other to determine their interdependencies and their respective substances. First, we mapped the importer with the bank and Customs. Table II shows the various interdependencies.

TABLE II. IMPORTER, BANK, AND CUSTOMS INTERDEPENDENCE ANALYSIS

	Importer					
	Pooled		*Sequential*		*Reciprocal*	
	Resource	*Activity*	*Resource*	*Activity*	*Resource*	*Activity*
Bank		✓				
Customs			✓	✓		

Per the interaction between the importer and the bank, we can say that their interdependence is pooled as the payment of import duty (activity) only contributes to the larger procedure of vehicle clearing. On the other hand, the importer has a sequential interdependence with Customs, as the submission of import clearing documents (activity) through the single window system (resource) is a needed trigger for Customs to perform the valuation.

For the interaction between the bank, the importer, and Customs (see Table III), we can say there is a pooled interdependence between the bank and the importer on the receipt of import duty payment (activity) on behalf of Customs. However, the bank and Customs have a sequential interdependence with respect to import duty payment confirmation (activity) through the single window system (resource) because, Customs will only proceed to other procedures until they receive payment confirmation from the bank.

TABLE III. BANK, IMPORTER, AND CUSTOMS INTERDEPENDENCE ANALYSIS

	Bank					
	Pooled		*Sequential*		*Reciprocal*	
	Resource	*Activity*	*Resource*	*Activity*	*Resource*	*Activity*
Importer		✓				
Customs			✓	✓		

The last interaction as presented in Table IV between Customs, bank, and importer shows that there is a sequential interdependence at both ends. The submission of import clearing documentation (activity) by the importer to Customs through the single window system (resource) triggered the other interdependencies. As such, the submission of the documents represented an input needed by Customs to begin the import clearing procedure. Again, the notification of Customs from the bank of import duty payment (activity) through the single window system (resource) demonstrates a sequential interdependence. Because, without the notification, Customs will not proceed with other clearing procedures.

Stage 3: Based on the results from Stages 1 and 2, we model the interdependencies in Ghana's import DBE. The model as presented in Fig. 4 shows the pooled and sequential interdependencies between the partners in a high-level orchestration of a vehicle clearing procedure based on the symbols proposed in Fig. 3.

TABLE IV. CUSTOMS, BANK, AND IMPORTER INTERDEPENDENCE ANALYSIS

	Customs					
	Pooled		*Sequential*		*Reciprocal*	
	Resource	*Activity*	*Resource*	*Activity*	*Resource*	*Activity*
Bank			✓	✓		
Importer			✓	✓		

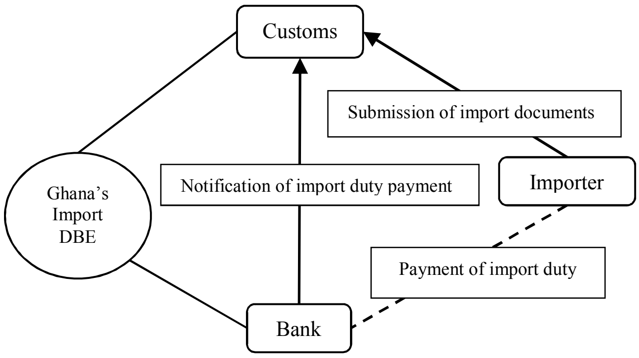

Fig. 4. Ghana's import DBE interdependence representation

In sum, the import DBE demonstrates the presence of pooled and sequential interdependencies. However, for processes within the DBE to be successful, there is a need for reciprocal interdependence between the importer, bank, and Customs. As such, we argue that reciprocal interdependence forms the foundation for all interdependencies the fuel value co-creation in DBEs.

VI. DISCUSSION

In this study, we focus on modelling interdependence between partners in DBEs since limited approaches and understanding exists on this perspective in information system literature. This perspective is important because it provides a systematic approach for systems analysts, and developers as well as decision-makers to understand the structural, functional, and behavioural dynamics between DBE partners. Given that there are sparse interdependence modelling approaches at the DBE level, we consider our approach a foundation for further studies into unexplored aspects. While interdependence is generally investigated between organizational routines [4] and units [5, 15], this research provides another perspective to represent interdependence between heterogeneous individuals and organisations with varied level of influence.

By presenting the interdependence articulation matrix, our study seeks to provide an intuitive template to capture various DBE interdependencies through their substances towards further representation. As such, we make the interdependence articulation simpler, even in complex DBE environments. Apart from aiding interdependence modelling, our methodology also provides some insights. First, the methodology points that interdependence modelling must consider not only physical link between partners, but also the substances that mediate the interactions. Second, the methodology highlights the need to differentiate between the interdependence types in DBEs as they may require different coordinating strategies to achieve objectives. Lastly, the study confirms that reciprocal interdependence forms the basis of DBE interactions since inputs and outputs must continuously traverse various partners, processes, and technologies cyclically to co-create value.

In the case illustrated, we observe the presence of different interdependence types between partners and how various substances mediate these interdependencies, confirming the position that partners exhibit varied interdependencies in dynamic environments [5]. Even though we used a high-level view of Ghana's import DBE to demonstrate the applicability of our methodology, its interdependence articulation and representation capabilities demonstrate external validity beyond the illustrated DBE.

VII. Conclusion

In this study, we argue that modelling interdependencies among partners is a crucial step to fully understanding DBE interactions as well as developing, aligning, and maintaining DBE information systems. To this end, we developed a DBE interdependence modelling methodology that supports systematic articulation and representation of DBE interactions. Our methodology provides a three-stage approach to modelling interdependencies, starting from partner identification, interdependence type and substance articulation as well as interdependence representation. We illustrate the methodology through a case study of Ghana's import DBE. The methodology addresses two critical aspects of DBE interdependencies. First, it provides a systematic approach to capture key relationships through an interdependence articulation matrix. Lastly, the methodology provides some insights necessary for better understanding as well as further evaluation of DBE interdependencies.

We see this study as a stepping point into further analysis, and measurement of other aspects of DBE interdependencies such as depth, structure, and value. As we have only illustrated the methodology with the import clearing processes, future studies can perform a full cycle of modelling. Also, future studies can develop a comprehensive interdependence evaluation methodology with inbuilt capabilities for analysis, modelling, and measurement.

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