# A conceptualization and system dynamic modeling of Business Ecosystems

Merel Bijkerk
University of Twente
P.O. Box 217, 7500AE Enschede
The Netherlands
m.e.e.bijkerk@student.utwente.nl

**ABSTRACT**

Business ecosystems have received a raise in attention over the last few years. Interaction between organizations has influence over the collective value of these organizations. The variation of studies concerning many different aspects of business ecosystems currently lacks coherence. Through reviewing current literature on the structure of business ecosystems, we define 12 core components of business ecosystems. The lifecycle of the business ecosystem and symbiotic relationships are key characteristics that are linked to the dynamic nature of the ecosystem. We use the components and characteristics to create a system dynamics model to illustrate the relations of these components and how that influences the business ecosystem as a whole. This research is meant to create an understanding of the concept of business ecosystems, and develop a business modeling technique for business ecosystems to assist in future research.

**Keywords:** business ecosystems, business modeling, organizational interaction, Insight Maker, industrial symbiosis

## 1 INTRODUCTION

Companies need suppliers, customers, and partners to create enough value to gain profit. In 1993, Moore suggested that instead of focusing on the individual industries, companies should be focusing on the industry boundary crossing networks they are a part of, the business ecosystem [1]. Moore defines the business ecosystem as *'An economic community supported by a foundation of interacting organizations and individuals [...]'* [2]. The interaction between the different actors is a key characteristic in a business ecosystem. A business ecosystem focuses on relationship between the supply chain actors, competitors, and complementors of the ecosystem [3]. Each of these parties brings their own value into the ecosystem through resources and/or capabilities. The joint value offering is much greater than what the individual actors can ever offer which makes the actors interdependent [4]. According to Adner, the creation and capture of a company's value can be explained in a business model [5]. As a business ecosystem consists of businesses and individual actors, a business model must show the balance between the overall profit and profitability for all parties involved [6]. An actor will not enter a business ecosystem if it cannot be sure that its value capture is greater than the value it brings into the system [7].

It is still unclear where the boundary of a business ecosystem lies, but research has made it clear that a business ecosystem crosses industry boundaries [1], [8]. The actors of the ecosystem come from different industries to work together to realize the value proposition. Several studies have defined ecosystem as symbiotic relationships [9], [10]. In a symbiotic relationship, two separate entities are related and one or both entities benefit from this relationship. Relationships in an ecosystem usually only exist when one or both of the actors can benefit from it, either through sharing resources or information [7].

There are three types of symbiotic relationships: commensalism, mutualism, and parasitism [9]. With commensalism, one of the actors benefits from the relationship. The other has a neutral place. Only in a later stage, these other actors will benefit from this relationship. In a mutualism relationship, both actors benefit from each other. The actors co-create value and will co-evolve [11]. By exchanging knowledge or resources, mutualism gives opportunity for competitive advantages [12], [13]. Lastly, a parasitism relationship negatively effects one of the participants and positively effects the other[9], [11].

Due to the dynamic nature of a business ecosystem, the relationships between the actors change over time. For example, a commensalism relationship can transform into a mutualism relationship. Or an actor in the position of a parasite can be removed from it. Moore found that business ecosystems have a lifecycle that consists of 4 stages [1], [2]. The first stage is Birth. In this stage, the purpose of the business is defined. What does the customer want and how is this best delivered? The second stage is Expansion. As the name reveals, this stage is when the ecosystem expands to reach a broader market and form new partnerships. Stage 3, Leadership, is when the companies are looking for control and stability. The structure of the ecosystem can change in this stage, as companies with most control and important resources take the leadership roles. The



*TScIT 38, February 3, 2023, Enschede, The Netherlands*

last stage, Self-Renewal, happened when the ecosystem is threatened by innovation or upcoming competitive ecosystems. Ecosystems have to keep innovating and evolving to stay relevant. If this does not happen, the ecosystem will fall apart.

The concept of business ecosystem is broad and there are still many gaps and discrepancies in the current knowledge and understandings of it [3], [5], [14]–[16]. Research about the design of ecosystems specifically is currently lacking [15]. There have been several studies about business models for business ecosystems, but most of these focus on only one or a few aspects, like individual actor relationships or revenue generation [15], [17]–[19]. Additionally, the dynamic nature of business ecosystems is rarely included. According to several studies, the dynamic nature is a key characteristics of business ecosystems [11], [20]–[22]. In order to understand the entire concept of business ecosystems and how it changes over time, there needs to be a dynamic model of business ecosystems. The aim of this study is to create a conceptualization of business ecosystems and use this to create a system dynamics model that takes the lifecycle stages into account and can be used to understand how the core components of an ecosystem relate to each other over time. To keep the scope of this research limited, we only focus on business ecosystems in the IT industry.

### 1.1 Research Question

To reach our goal, we define the following research question:

**RQ**: How can a dynamic business model be defined to show the relations between the core components of business ecosystems?

To answer this question, we must first find out what the important characteristics of business ecosystems are. Business ecosystems are a broad concept and there are many different kinds. In this research we will focus on the business ecosystems in the IT industry. Therefore we define the following sub-question:

**SQ1:** What are the core components of business ecosystems in the IT industry?

Next, we have to define the model using these components. System Dynamics is a modeling method used to study industrial or social systems [23]–[25]. Feedback loops are an important part of the model. A feedback loop shows the cause and effect between different elements of the system, so it can be used to get insight into the system behavior [25]. A system dynamics model can help us understand the effect that the lifecycle and relationships have on the ecosystem.

To create this model, we will use the Insight Maker webtool. Insight Maker is a tool that supports system dynamics modeling and agent based modeling [23], [26]. Since we are looking at the ecosystem as a whole, and not the individual components, we will be using the system dynamics modeling tool.

Here we define the sub-question:

**SQ2:** How can we show the relations between the core components of business ecosystems in a dynamic model using Insight Maker?

## 2 METHODOLOGY

Several different methods will be used to answer the research question.

### 2.1 Methodology Sub-Question 1

First of all, we used theory synthesis on the definition space of business ecosystems and its characteristics to answer SQ1.

In a theory synthesis paper, literature review is used to reveal the different components of a concept [27]. These components will be used as building blocks to conceptualize business ecosystems in the IT industry. In a similar way, Vial reviewed literature to develop a unified definition of Digital Transformation, and used building blocks to represent the process of Digital Transformation [28].

The method that we used for the literature review will be based on the guidelines from Wolfswinkel et al. [29]. These guidelines consist of five steps:

1) Define the inclusion/exclusion criteria to mark out the scope.
2) Search for the literature.
3) Select the appropriate texts.
4) Analyze the texts.
5) Present the findings.

The search query for SQ1 that was used is
*TITLE-ABS-KEY(business AND ecosystem AND (structure OR concept) AND characteristic*).*
Additionally, the search was limited to show only peer-reviewed articles and conference papers, and the focus keyword must be 'Business Ecosystem'.

The papers that met these requirements were thoroughly read and mentioned key components or characteristics of business ecosystems were noted. All components that were mentioned in multiple studies, and their relations to each other were put in a matrix (see Table 1).

### 2.2 Methodology Sub-Question 2

After the conceptualization was made, we answered SQ2 by developing a system dynamics model based on the components found for SQ1. To create this model we will use the tool Insight Maker. Insight Maker is an online model making tool that can be used to create System Dynamics or Agent Based models To understand this tool, we use the Manual of Insight Maker, and the paper of Fortmann-Roe in which the tool is explained and

demonstrated [23], [26]. The System Dynamics tool has four building blocks with each a unique function, called primitives: Stock, Flow, Variables, and Links.
Stocks are blocks that store material, like money or water. Flows show the movement of material between stocks, for example deposits and withdrawals of a bank account. Variables are blocks that represent dynamically calculated values or constants. Finally, Links transfer information between the other primitives. They show that the two primitives are related in some way.
The components found as results for SQ1 will be shown as Stock and Variables, depending on what they present.. The relations between the components will be visualized by the Links, since these can show a positive or negative relation.

Based on the goal of this research and the research question, the model has to meet several criteria:

1. The model should include all core components of the business ecosystem.
2. The model should be able to be used through all 4 lifecycles: Birth, Expansion, Leadership, and Self-Renewal.
3. The model should be able to show all 3 different symbiotic relationship types: Mutualism, Commensalism, and Parasitism.
4. The model should be able to forecast lifecycle and relationship changes.

### 2.3 Evaluation of the Model

This model was evaluated by using it on two cases: the data center – greenhouse combination, and Apple Inc. These cases are completely different in terms of actors and lifecycle stage.

The data center – greenhouse case is about creating a business ecosystem with two companies in the center [30], [31]. The public is only a complementor that benefits from the result of the ecosystem. This ecosystem includes a commensalism relationship and is in the first stage of the lifecycle, Birth, so with this case we can evaluate if the model works in this stage and with a different type of relationship than the ideal mutualism.

The case about Apple Inc. does include the public directly as the customer[32], [33]. This company has a special control over the customer and many of the complementors because of their integrated products and services, and their high ranking competitive position. This control results in a parasitic relationship between the keystone firm and the complementors. This business ecosystem has existed for a while now and is in the Leadership stage of the lifecycle.
With these two cases, we can evaluate the model we created to answer SQ2 for these different symbiotic relationships and for the different lifecycle stages. In order for the model to be valid, it must work for ecosystems in these different stages and with several types of relationships, because an ecosystem is dynamic. The roles of the actors, the types of relationships, and the lifecycle stages are constantly changing for better or worse so in order to trust that this model can represent reality, it must be able to cope with these changes.

### 2.4 Methodology Research Question

By combining the results of sub-question 1 and 2, we can answer of the research question.

## 3 RESULTS

### 3.1 Components of Business Ecosystems

From the search query, we found 23 articles. After reading the Abstract of the articles, 12 were found to be relevant. The others either did not mention anything about the characteristics or components of business ecosystems, or focused on business ecosystems outside of the IT industry.
From the literature we identified 12 components that make up a business ecosystem, divided into 4 sections.

| | | *Actors* | | | | *Lifecycle* | | | | *Value Input* | | *Value Output* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Row has influence on column | Competitor | Complementor | Customer | Keystone Firm | Co-evolution | Diversity | Ecosystem Health | Innovation | Bottlenecks | Collective value creation | End Product / Service | Value appropriation |
| *Actors* | Competitor | | | | | | | | | | +/- | | |
| | Complementor | | | | + | | + | | | | + | | |
| | Customer | | | | | | | | | | | + | |
| | Keystone firm | + | | | | | | + | | | + | | |
| *Lifecycle* | Co-evolution | | + | | | | | | | | | | |
| | Diversity | | | | | | | + | | | | | |
| | Ecosystem health | | | | | + | | | | | | | |
| | Innovation | | | | | + | | + | | | | | |
| *Value Input* | Bottlenecks | - | | | | | | | | | + | | |
| | Collective value creation | | | | | | | | | | | + | + |
| *Value Output* | End Product / Service | | | + | | | | | | | | | |
| | Value appropriation | | + | | | | | | | | | | |

The first section is Actors. One of the key characteristics of business ecosystems, is the interaction between the actors [1], [3]–[5], [7], [8], [14]. The actors in the business ecosystem are divided into four groups: Competitor, Complementor, Customer, and Keystone firm.

The second section, Lifecycle is based on another key characteristic, the dynamic nature of business ecosystems [11], [20]–[22], [34], [35]. In his first article about business ecosystems, [1] mentioned the lifecycles of an ecosystem: birth, expansion, leadership, and self-renewal. During these different stages of the ecosystem, the internal relationships and roles of the actors can change. The changing of roles, especially the keystone firm, can cause some instability during the transformation of the lifecycle phases, but a healthy ecosystem should be able to easily handle these changes [4]. The components of the lifecycle section are: Co-evolution, Diversity, Ecosystem health, and Innovation. These four components can cause the ecosystem to move between the four lifecycle stages.

The third section is Value Input. The two components in the Value Input section are Collective Value Creation, and Bottleneck. In order for the business ecosystem to be able to produce a product or a service, the members need to create value. In a business ecosystem, the value is created by all the members together. It is not possible for one of the linked companies to create all this value on its own [4], [7], [36]. The companies add to this collective value creation by providing capabilities and/or resources. A special capability or resource is the bottleneck. Ina business ecosystem, this is a scarce product or service that brings a lot of value to the ecosystem and strengthens its competitive position [7].

The last section is Value Output. The two components belonging to this section are End Product / Service, and Value Appropriation. The members of a business ecosystem collectively produce a product or service that meets the customer's requirements. According to Gueler and Schneider, a company will only join a business ecosystem if it can get more value out of it, than it has to create for it, so the value appropriation must be bigger than their individual value creation [7].

The components and their relation to each other are shown in Table 1.

In the following section we will explain the components as building blocks of the system dynamic model and their relation to each other.

### 3.2 Building blocks

We used the components of the business ecosystems as building blocks for the system dynamic model. Figure 1 presents the model of the building blocks and their relations to each other. In this section we explain what the different components mean and how they relate to each other.

In the model we make use of the System Dynamics primitives. The blue rectangles represent the stocks and the orange ovals represent the variables. The flows are represented by the blue arrows, and the links are the grey dotted arrows. The different sections are separated in dotted rectangle boxes with rounded corners. Insight Maker defines these as folders that group together similar primitives.

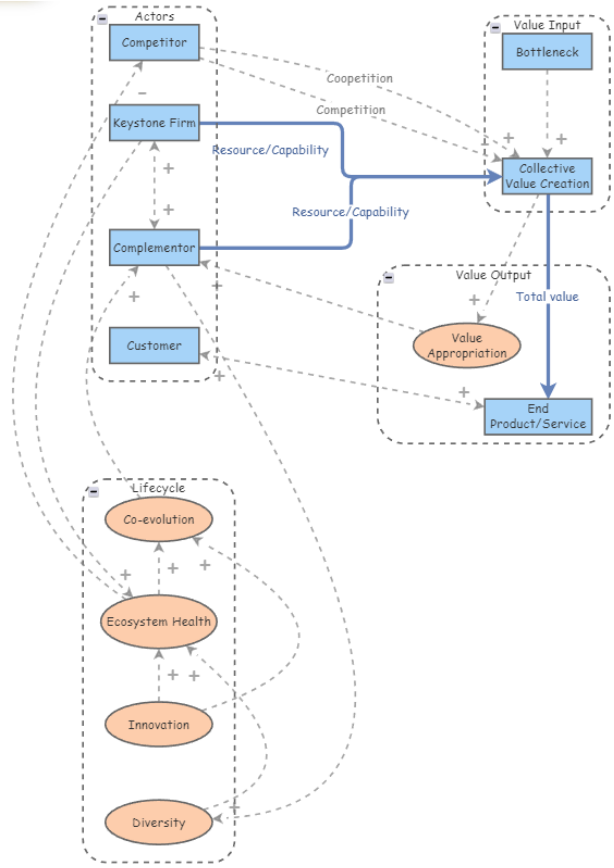


*Figure 1: Relations between core components of business ecosystems*

#### 3.2.1 Competitor

A competitor of the ecosystem is seen as another ecosystem, or a company that has the same or a very similar value proposition. There are two types of relations between a competitor and an actor from within the ecosystem that we identified in the literature: competition and coopetition. With competition there is no collaboration. Other ecosystems or companies can compete with prices, or they can even have something better to offer the complementors and cause them to leave their current ecosystem [14]. So, competition can cause the ecosystem to lose value.

With coopetition there is a certain degree of cooperation that creates value for the ecosystem. Coopetition is also one of the main characteristics of a business ecosystem [37]. It creates the possibility for organizations to share resources or information with competitors to strengthen both businesses. According to Gueler & Schneider, a healthy ecosystem has the right balance between competition and coopetition [7].

#### 3.2.2 Complementor

The complementors are actors that independently add value to the ecosystem through the resources and/or capabilities that they offer [14]. The complementors can be partners of the keystone form, or of other complementors. In an ideal ecosystem, the relationships between the actors are mutual, so all complementors benefit from their relationships [9]. An ecosystem cannot thrive of all the same resources, so more complementors means that the ecosystem becomes more diverse. To keep the competitive advantages, the ecosystem actors must constantly re-negotiate specifics like prices with their partners [17].

#### 3.2.3 Customer

The customer has big influence on the ecosystem as their preferences can change the value proposition [20][38]. The relationship between the customer and the rest of the ecosystem needs to be strong in order to meet all of the customer's needs.

#### 3.2.4 Keystone Firm

The keystone firm is seen as the leader of the ecosystem [1]. This actor is usually the central point of the ecosystem and has the biggest influence on the value proposition [22]. Due to their central position, part of their role is to regulate the ecosystem, which has consequences for the co-evolution of the actors and the collective health of the ecosystem [35] [39].

#### 3.2.5 Co-Evolution

Co-evolution is a key characteristic of business ecosystems. Caused by the lifecycle of the ecosystem and innovation, actors within the ecosystem change in regards to their role in the ecosystem and the capabilities and/or resources that they offer. The interdependent nature of a business ecosystem cause actors of the ecosystem to change with each other and because of each other. According to Stanczyk, the keystone firm has a big influence on the co-evolution, as this is the company that takes the lead [35].

#### 3.2.6 Diversity

A diverse set of actors and resources expands the abilities of the ecosystem to meet the needs of more customers [20]. It also brings more room for value creation when external factors suddenly change, so it can keep up the health of the ecosystem [40].

#### 3.2.7 Ecosystem Health

According to Iansiti & Levien, the keystone firm is supposed to make sure the ecosystem stays healthy by making sure every actor stays active in their role [22]. A healthy ecosystem is also good for the individual actors [35]. As self-organization is also a key characteristic of the business ecosystem, it is important that both the whole system is doing well, as well as the individual parts. A healthy ecosystem has a greater competitive position, which means that the competitors have less influence over the ecosystem.

Lappi et al. have created a model to assess the health of a business ecosystem [41]. The model contains four dimensions: size of the anchoring actor's business network, number of moderator actors in the ecosystem, number of strong relationships in the ecosystem, and the number of weak relationships in the ecosystem. The study also defines a model to identify the anchoring and moderator actors of the ecosystem.

#### 3.2.8 Innovation

As the world outside the ecosystem changes, the inside of the ecosystem must also change. Innovation keeps up the health of the ecosystem and helps the ecosystem stay relevant [40].The interdependency of the actors cause that innovation at one of the actors often causes others to evolve too [35].

#### 3.2.9 Bottlenecks

In the business ecosystem setting, bottlenecks refer to scarce resources or capabilities that actors bring to the ecosystem to create value. By providing those bottlenecks, companies move into a stronger competitive position within the ecosystem . Ecosystems with bottlenecks in their value proposition have less competition among other ecosystems [7].

#### 3.2.10 Collective value creation

Another key characteristic of business ecosystems is collective value creation. In order to deliver the value proposition and actually create the end product or service, the combined created value of all actors is needed. No individual actor has all the capabilities and/or resources [7]. Determining the collective value that these companies can capture together is important for each company to understand their position within the business ecosystem [42].

#### 3.2.11 End Product / Service

The value proposition describes what product or service the ecosystem creates and how this is valuable for the customer [1]. The final product or service that a business ecosystem comes out with is the whole reason that the ecosystem even exists, so it is extremely important that

the value proposition includes all the necessary information for the outcome to be a success. This product or service is determined by the requirements of the customers and comes together by the value created by all of the other actors of the ecosystem.

#### 3.2.12 Value *Appropriation*

In an ecosystem, organizations come together to create value for customers as well as each other [33]. For an organization to join a business ecosystem, the value appropriation must be higher than the effort and value the organization has to give [7]. The more value an ecosystem creates, the more value the individual companies can make use of.

### 3.3 Model evaluation

To evaluate the model from Figure 1, we use two different cases. First, we discuss the business ecosystem of combining data centers and greenhouses in the subarctic region. Then, we discuss the Apple Inc. business ecosystem.

#### *3.3.1 Data center – greenhouse ecosystem*

In this evaluation, we use the study of Cáceres et al. to see how the previously collected components of business ecosystems relate to each other when there is a commensalism relationship [30]. Cáceres et al. discuss the possibility of combining data centers and greenhouses in the subarctic region to share resources [30]. Due to the extreme cold weather in these places, greenhouses need a lot of extra energy to create enough heat to produce food. This is very expensive and most of the time unsustainable which has caused the area to rely mostly on import. As a result, the local food production has decreased over the past few decades [30], [31].

On the other hand, the climate in subarctic regions is a reason why it is a popular destination for important data centers [43]. In the past years, there have been a studies where different purposes have been researched for the excess heat, for example to heat indoor swimming pools [44].
In this case, the excess heat from the data centers will be used to heat the greenhouses. The local food production in the region will increase, which creates job opportunities. The climate will reduce the need for extra cooling systems in the data centers, so the energy use of both the data centers and the greenhouses will be much lower. Figure 2 depicts the model corresponding to this case. The green rectangles contain information from the case.

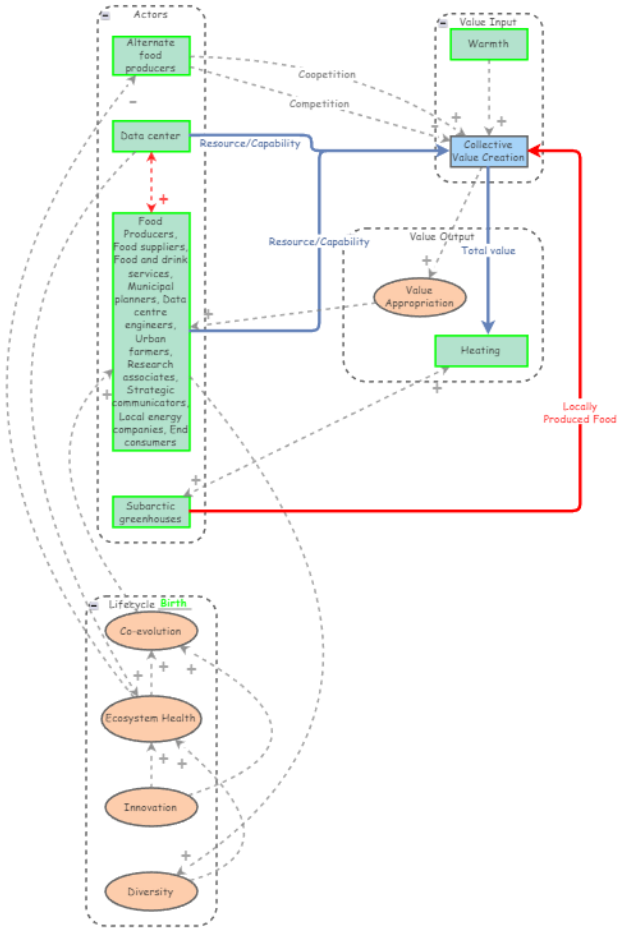


*Figure 2: Model of the Data center - Greenhouse case*

The bottleneck resources are high temperatures and sunlight. The data centers use their excess heat to supply the high temperatures. The competitors in this ecosystem are the alternative local food producers. They can either compete with the greenhouses, or share their knowledge or resources. In this ecosystem there are many complementors that are needed to share their knowledge and capabilities and/or resources for this system to work. In their paper, Cáceres et al. mention that there is not much information and experts for thermal management and cooling control with data centers [30]. Expertise from many different fields needs to be collected for this ecosystem to be successful. As Figure 2 shows, this ecosystem is only in the lifecycle stage Birth. In this stage, the focus is on what the customer wants, and what the best way of delivering this is [1]. When all of this has been decided, the ecosystem will go into the next stage, Expansion. The idea will actually be brought to life and more partnerships will form.

Differences between Figures 1 and 2, is the connection between the customer and collective value creation in Figure 2, and the connection between the keystone firm and the complementors.

With commensalism, the value creation comes from one side, but there are no negative consequences for the other. The data centers give the extra heat to the greenhouses, which can grow more local food because of this. This new way of local food production has social and environmental benefits, like less energy use, and more job creation. However, since the extra food production does not benefit the data center directly, this is not a mutualism relationship.

### *3.3.2 Apple Inc.*

The Apple Inc. business ecosystem aims to provide products and services for the public. Figure 3 shows the model of this ecosystem.

Apple has been one of the biggest electronics companies for years now. The company not only provides many different devices like the iPhone, MacBook and iPad, it also combines these devices with their own content platforms like iTunes, Apple Books, and Apple TV+. Apple's services are only available for their own products, so it becomes more expensive for customers to transfer to a different brand. The seamless integration of all Apple's different products, also means that using Apple products for all your electronics is an entire experience in itself. With the use of Apple's cloud service iCloud, the consumer can access everything they want on all of their separate devices.

Having control over all these platforms and products, means that Apple has a big influence over both their suppliers and consumers [32]. This influence has many perks for Apple itself, but it can have negative results for other actors in the ecosystem. It has been known for a while that the working conditions in the Chinese factories where Apple's products are made are bad [33]. This is where we find a parasitic relationship in this ecosystem. Apple controls its manufacturers and make it clear that even their key suppliers can be replaced [36]. So the relationships between the suppliers and Apple can have negative effects on the supplier, like large amounts of stress and insecurity. Additionally, the workers of the manufacturing plant are not treated well and have to work way too much for what they get paid [45]. Apple has nothing to lose, so almost all of the benefits of this relationship go to Apple. In Figure 3 we can see then that the difference in the model with the ideal mutualism relationship in Figure 1, is the relation between the keystone firm and the complementors. The complementors have a positive relation to Apple Inc., but Apple Inc. has a negative relation to the complementors.

In the lifecycle, the business ecosystem of Apple Inc. is in the Leadership stage. Right now, Apple is a leading company in the world of consumer electronics and with their constant innovation they keep this place [33]. However, their weak point is the public knowledge of the work environment in their factories. Apple's reputation has taken a hit and by ignoring the complaints, the company will only take more damage. The ecosystem will then move into the Self-Renewal stage. In this stage, Apple has to either build a whole new ecosystem, or incorporate new innovations, to survive [1], [2].

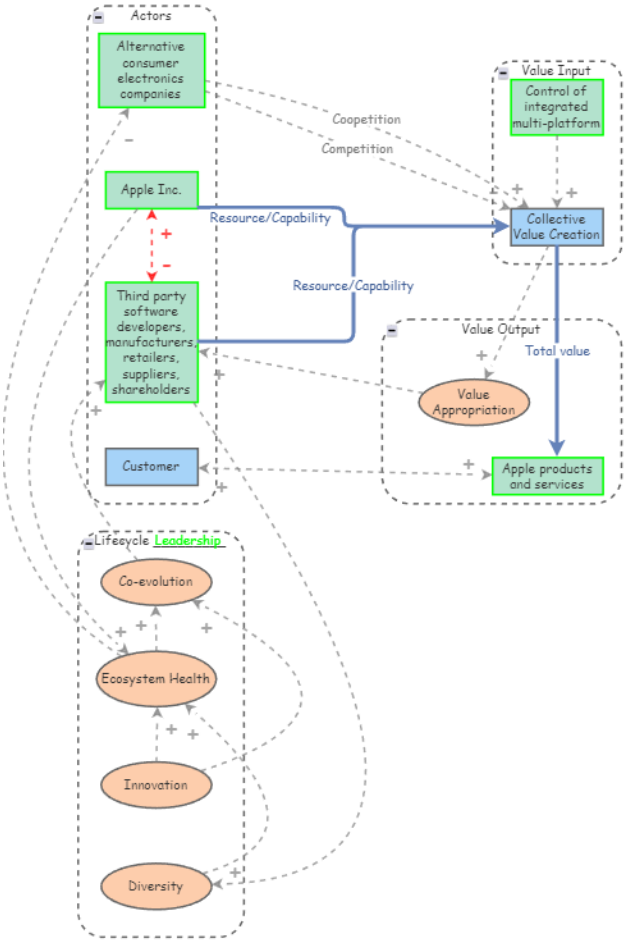


*Figure 3: Model of the Apple Inc. case*

## 4 DISCUSSION

Through the theory synthesis method, we defined 12 different components of business ecosystems, divided into 4 sections: actors, lifecycle, value input, and value output. These sections depict the importance of the relationships and dynamics of the business ecosystem. All literature was chosen based on the search query. Due to the strict search requirements, only a limited amount of papers was able to meet these requirements. Fortunately, these papers had a lot of information regarding the key components of business ecosystems. One thing that we were not able to conclude is how the co-evolution, innovation, and diversity components are calculated. Further research is needed to fill this gap.

By adding the relations between the components, we created the system dynamics model for business ecosystems. The lifecycle components give the model a dynamic structure and show the ways that the ecosystem can change over time. The different relations between the actors show the different types of symbiosis that can occur in an ecosystem.

In the end, a business ecosystem exists to offer a product or service to the customer. The model shows that all of the actors are needed to create this end product or service. In the model we can also see an interesting characteristic of business ecosystems, the importance of value appropriation. A study by Gueler & Schneider showed that a complementor will only join the ecosystem, if they get more value out of the ecosystem, than what they have to put into it [7]. So the value appropriation must be bigger for the complementor than their individual value offering.

One thing this model does not show, is how the individual relationships of the complementors can change within the ecosystem and how these individually affect the ecosystem. This is not included, because this study was focused on the business ecosystem as a whole, and not the specific individual actors of the ecosystem. Further research is needed to determine the importance of these individual relationships on the whole business ecosystem.

To evaluate the model, we used two cases that discuss business ecosystems, the case of the data centers and subarctic greenhouses, and the case of Apple Inc. Even though these two cases are completely different in regards to the type of actors they include, and the lifecycle stage they are in, they both fit into the model. With these two cases we could show the difference in the model between the different symbiotic relationships. Mutualism is the ideal type of relationship actors of the ecosystem can have, since everyone benefits from it. However, the nature of the relationships often change due to the dynamic nature of the ecosystem. In the case of the data centers, we can see a commensalism relationship between the two companies that are the central point of this ecosystem, the data center and the greenhouse. In the case of Apple Inc. where the business ecosystem has existed for a few decades, we can see a parasitic relationship between the keystone firm Apple and many complementors.

Before creating the model, we set four evaluation criteria:

1. The model should include all core components of the business ecosystem.
2. The model should be able to be used through all 4 lifecycles: Birth, Expansion, Leadership, and Self-Renewal.
3. The model should be able to show all 3 different symbiotic relationship types: Mutualism, Commensalism, and Parasitism.
4. The model should be able to forecast lifecycle and relationship changes.

The two cases worked well with the model. Both only had one relation extra, since they included different symbiotic relationships. From this, we can conclude that the model works for different symbiotic relationships and in different stages of the ecosystem lifecycle. However, due to time constraints, we only evaluated the model for these two cases, we cannot conclude that the model works for all business ecosystems. Future research is needed to prove whether this model can actually be considered valid and trusted.

The last criteria was not met by this model, because we were not able to calculate the value of all components yet. In order to find the values of the components co-evolution, Innovation, and Diversity, more research is needed.

## 5 CONCLUSION

This study aimed to create a conceptualization and system dynamics model of business ecosystems. The research question was defined as follows:

How can a dynamic business model be defined to show the relations between the core components of business ecosystems?

With the sub questions:

1. What are the core components of business ecosystems in the IT industry?

2. How can we show the relations between the core components of business ecosystems in a dynamic model using Insight Maker?

In this research we found 12 core components of business ecosystems divided into 4 sections. The first section is Actors, which include the components Competitor, Complementor, Customer, and Keystone Firm. The second section is Lifecycle, which includes the components Co-evolution. Diversity, Ecosystem Health, and Innovation. The third section is Value Input, which includes the components Bottleneck and Collective value creation. The last section is Value Output, which includes the components End Product / Service, and Value Appropriation.

With the use of Insight Maker's primitives and links we were able to create a model that displays the relations between the 12 core components of business ecosystems. In the model we can see the importance of the relationship between the actors, as well as how the lifecycle influences the rest of the ecosystem.

By using the positive and negative arrows, the model illustrates that there are several factors that make the ecosystem concept dynamic. The influence that the components have over each other is constantly changing and the symbiotic relationships transfer between mutualism, commensalism and parasitism.

This study has contributed to creating a clear understanding and design of the concept of business ecosystems. There are several steps to improve this work in the future, as stated in the discussion.

## 6 REFERENCES

[1] J. F. Moore, “Predators and Prey: A New Ecology of Competition Harvard Business Review,” 1993.

[2] J. F. Moore, *The Death of Competition: Leadership and strategy in the age of business ecosystems*. New York, NY: HarperCollins, 1996.

[3] M. Tsujimoto, Y. Kajikawa, J. Tomita, and Y. Matsumoto, “A review of the ecosystem concept — Towards coherent ecosystem design,” *Technol Forecast Soc Change*, vol. 136, pp. 49–58, Nov. 2018, doi: 10.1016/j.techfore.2017.06.032.

[4] C. Lu, K. Rong, J. You, and Y. Shi, “Business ecosystem and stakeholders’ role transformation: Evidence from Chinese emerging electric vehicle industry,” *Expert Syst Appl*, vol. 41, no. 10, pp. 4579–4595, 2014, doi: 10.1016/j.eswa.2014.01.026.

[5] R. Adner, “Ecosystem as Structure: An Actionable Construct for Strategy,” *J Manage*, vol. 43, no. 1, pp. 39–58, Jan. 2017, doi: 10.1177/0149206316678451.

[6] D. J. Teece and G. Linden, “Business models, value capture, and the digital enterprise,” *Journal of Organization Design*, vol. 6, no. 1, Dec. 2017, doi: 10.1186/s41469-017-0018-x.

[7] M. S. Gueler and S. Schneider, “The resource-based view in business ecosystems: A perspective on the determinants of a valuable resource and capability,” *J Bus Res*, vol. 133, pp. 158–169, Sep. 2021, doi: 10.1016/j.jbusres.2021.04.061.

[8] S. Wieninger, R. Götzen, Dr. G. Gudergan, and K. M. Wenning, *The strategic analysis of business ecosystems*.

[9] C. Yoon, S. Moon, and H. Lee, “Symbiotic Relationships in Business Ecosystem: A Systematic Literature Review,” *Sustainability (Switzerland)*, vol. 14, no. 4, Feb. 2022, doi: 10.3390/su14042252.

[10] R. C. Basole, “Visualization of interfirm relations in a converging mobile ecosystem,” in *Proceedings - 7th International Conference on Mobile Business, ICMB 2008, Creativity and Convergence*, 2008, pp. 65–74. doi: 10.1109/ICMB.2008.32.

[11] Y. Yao and H. Zhou, “The dynamic equilibrium and simulation of mobile internet platform innovation ecosystem: A symbiotic evolution model,” *Kybernetes*, vol. 45, pp. 1406–1420, 2016.

[12] M. R. Chertow, “INDUSTRIAL SYMBIOSIS: Literature and Taxonomy,” 2000. [Online]. Available: www.annualreviews.org

[13] A. Neves, R. Godina, S. G. Azevedo, and J. C. O. Matias, “A comprehensive review of industrial symbiosis,” *Journal of Cleaner Production*, vol. 247. Elsevier Ltd, Feb. 20, 2020. doi: 10.1016/j.jclepro.2019.119113.

[14] M. G. Jacobides, C. Cennamo, and A. Gawer, “Towards a theory of ecosystems,” *Strategic Management Journal*, vol. 39, no. 8, pp. 2255–2276, Aug. 2018, doi: 10.1002/smj.2904.

[15] M. S. Schoder and W. Utz, “BEDe: A Modelling Tool for Business Ecosystems Design with ADOxx,” in *IFIP Advances in Information and Communication Technology*, 2021, vol. 629 IFIPAICT, pp. 526–535. doi: 10.1007/978-3-030-85969-5_49.

[16] P. K. Senyo, K. Liu, and J. Effah, “Digital business ecosystem: Literature review and a framework for future research,” *International Journal of Information Management*, vol. 47. Elsevier Ltd, pp. 52–64, Aug. 01, 2019. doi: 10.1016/j.ijinfomgt.2019.01.002.

[17] V. Hoyer and K. Stanoevska-Slabeva, “Business models for digital business ecosystems: The case of the Open Negotiation Environment (ONE) platform,” in *2009 3rd IEEE International Conference on Digital Ecosystems and Technologies, DEST ’09*, 2009, pp. 181–186. doi: 10.1109/DEST.2009.5276683.

[18] R. Wieringa, W. Engelsman, J. Gordijn, and D. Ionita, “A business ecosystem architecture modeling framework,” in *Proceedings - 21st IEEE Conference on Business Informatics, CBI 2019*, Jul. 2019, vol. 1, pp. 147–156. doi: 10.1109/CBI.2019.00024.

[19] M. C. León *et al.*, “Designing a Model of a Digital Ecosystem for Healthcare and Wellness Using the Business Model Canvas,” *J Med Syst*, vol. 40, no. 6, Jun. 2016, doi: 10.1007/s10916-016-0488-3.

[20] K. Rong, Q. Ren, and X. Shi, “The determinants of network effects: Evidence from online games business ecosystems,” *Technol Forecast Soc Change*, vol. 134, pp. 45–60, Sep. 2018, doi: 10.1016/j.techfore.2018.05.007.

[21] B. Bai and Z. Guo, *Dynamic Complexity of Mobile Internet Business Ecosystem*.

[22] M. Iansiti and R. Levien, *The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability*. Harvard Business Press, 2004.

[23] S. Fortmann-Roe, “Insight Maker: A general-purpose tool for web-based modeling & simulation,” *Simul Model Pract Theory*, vol. 47, pp. 28–45, 2014, doi: 10.1016/j.simpat.2014.03.013.

[24] E. Pruyt, *Small System Dynamics Models for Big Issues Triple Jump towards Real-World Dynamic Complexity Title: Small System Dynamics Models for Big Issues: Triple Jump towards Real-World Complexity*. [Online]. Available: http://simulation.tbm.tudelft.nl

[25] J. Duggan, “Lecture Notes in Social Networks System Dynamics Modeling with R.” [Online]. Available: http://www.springer.com/series/8768

[26] Insight Maker, “Insight Maker Learn More.”

[27] E. Jaakkola, “Designing conceptual articles: four approaches,” *AMS Review*, vol. 10, no. 1–2, pp. 18–26, Jun. 2020, doi: 10.1007/s13162-020-00161-0.

[28] G. Vial, “Understanding digital transformation: A review and a research agenda,” *Journal of Strategic Information Systems*, vol. 28, no. 2. Elsevier B.V., pp. 118–144, Jun. 01, 2019. doi: 10.1016/j.jsis.2019.01.003.

[29] J. F. Wolfswinkel, E. Furtmueller, and C. P. M. Wilderom, “Using grounded theory as a method for rigorously reviewing literature,” *European Journal of Information*

*Systems*, vol. 22, no. 1. Palgrave Macmillan Ltd., pp. 45–55, 2013. doi: 10.1057/ejis.2011.51.

[30] C. R. Cáceres, S. Törnroth, M. Vesterlund, A. Johansson, and M. Sandberg, "Data-Center Farming: Exploring the Potential of Industrial Symbiosis in a Subarctic Region," 2022.

[31] H. M. Ljungqvist, L. Mattsson, M. Risberg, and M. Vesterlund, "Data center heated greenhouses, a matter for enhanced food self-sufficiency in sub-arctic regions," *Energy*, vol. 215, Jan. 2021, doi: 10.1016/j.energy.2020.119169.

[32] J. Montgomerie and S. Roscoe, "Owning the consumer-Getting to the core of the Apple business model," *Accounting Forum*, vol. 37, no. 4, pp. 290–299, Dec. 2013, doi: 10.1016/j.accfor.2013.06.003.

[33] B. Bergvall-Kåreborn and D. Howcroft, "The Apple business model: Crowdsourcing mobile applications," *Accounting Forum*, vol. 37, no. 4, pp. 280–289, Dec. 2013, doi: 10.1016/j.accfor.2013.06.001.

[34] S. Blasi and S. R. Sedita, "The diffusion of a policy innovation in the energy sector: evidence from the collective switching case in Europe," *Ind Innov*, vol. 27, no. 6, pp. 680–704, Jul. 2020, doi: 10.1080/13662716.2019.1616535.

[35] S. Stanczyk, "Organisational ecosystem and stakeholders view. In search of epistemological logic in management," *International Journal of Economics and Business Research*, vol. 14, no. 3–4, pp. 268–283, 2017, doi: 10.1504/IJEBR.2017.087498.

[36] M. G. Jacobides, T. Knudsen, and M. Augier, "Benefiting from innovation: Value creation, value appropriation and the role of industry architectures," *Res Policy*, vol. 35, no. 8 SPEC. ISS., pp. 1200–1221, 2006, doi: 10.1016/j.respol.2006.09.005.

[37] M. Peltoniemi and E. Vuori, "Business ecosystem as the new approach to complex adaptive business environments."

[38] P. K. Senyo, K. Liu, and J. Effah, "Digital business ecosystem: Literature review and a framework for future research," *International Journal of Information Management*, vol. 47. Elsevier Ltd, pp. 52–64, Aug. 01, 2019. doi: 10.1016/j.ijinfomgt.2019.01.002.

[39] E. Papanikolaou, J. Angelis, and V. Moustakis, "Which type of ecosystem for distributed ledger technology?," *Technol Soc*, vol. 72, p. 102143, Feb. 2023, doi: 10.1016/j.techsoc.2022.102143.

[40] X. Li, Y. Zhang, and H. Wu, "Construction of Industrial Ecosystem of an Electric Company under Ecological Perspective," in *IOP Conference Series: Earth and Environmental Science*, Jan. 2018, vol. 108, no. 5. doi: 10.1088/1755-1315/108/5/052033.

[41] T. Lappi, T.-R. Lee, and K. Aaltonen, "Assessing the Health of a Business Ecosystem: The Contribution of the Anchoring Actor in the Formation Phase." [Online]. Available: www.issbs.si/press/ISSN/2232-5697/6_27-51.pdf

[42] G. Hoeborn, R. Conrad, R. Götzen, C. Betz, and P. K. Neudert, "Understanding Business Ecosystems Using a Morphology of Value Systems: Companies can apply a morphology of value systems to help them leverage business ecosystems and co-create value.," *Research Technology Management*, vol. 65, no. 5, pp. 44–53, 2022, doi: 10.1080/08956308.2022.2095841.

[43] M. Wahlroos, M. Pärssinen, S. Rinne, S. Syri, and J. Manner, "Future views on waste heat utilization – Case of data centers in Northern Europe," *Renewable and Sustainable Energy Reviews*, vol. 82, pp. 1749–1764, Feb. 2018, doi: 10.1016/j.rser.2017.10.058.

[44] E. Oró, R. Allepuz, I. Martorell, and J. Salom, "Design and economic analysis of liquid cooled data centres for waste heat recovery: A case study for an indoor swimming pool," *Sustain Cities Soc*, vol. 36, pp. 185–203, Jan. 2018, doi: 10.1016/j.scs.2017.10.012.

[45] A. Chan, *China's Workers Under Assault: Exploitation and Abuse in a Globalizing Economy*. Routledge, 2001. doi: 10.4324/9781315502137.