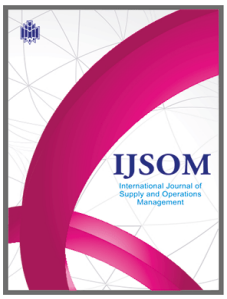
International Journal of Supply and Operations Management

IJSOM

November 2014, Volume 1, Issue 3, pp. 347-370
ISSN-Print: 2383-1359
ISSN-Online: 2383-2525
www.ijsom.com



System Dynamics Modeling in Entrepreneurship Research: A Review of the Literature

Mohammad Reza Zali [a], Mina Najafian [a], Amir Mohammad Colabi [a*]

[a] *Corporate Entrepreneurship, Faculty of Entrepreneurship, University of Tehran, Tehran, Iran*

Abstract

System dynamics is a strategic approach for modeling complex systems and analyzing their behavior. Dynamic behavior in entrepreneurial system can be modeled using System Dynamics Approach and dynamic hypotheses about the system`s behavior can be proposed and tested using simulation and computer aided tools. However, as the review of literature shows, studies which link system dynamics modeling with entrepreneurship are rare and fragmented. This article presents a review of studies on the subject followed by integration and discussion on main research issues that have been the focus of previous studies. The main aim of this review is to categorize the available research related to the application of system dynamics modeling in entrepreneurship to integrate research and enable recommendations for future research. The Results reveal that the previous research could be categorized under a two dimensional taxonomy composed of level of analysis and level of modeling. The Level of analysis has three categories: micro level, meso level and macro level. The Level of modeling has six hierarchical levels. This study identifies several gaps in the literature and discusses the future directions in this field.

Keywords: System Dynamics; Entrepreneurship; SME; Firm; Entrepreneurial Venture; Review.

[*] Corresponding author email address: A_golabi@ut.ac.ir

1. Introduction

What is entrepreneurship? And how can we understand it as social scientists? The order of the questions here is intentional. So we must begin with the issue of defining entrepreneurship. The knowledge base of entrepreneurship research has been generated by three founding disciplines: psychology, economics, and sociology (Zahra & Wright, 2011). Thornton (1999) indicates that the efforts to define entrepreneurship have resulted in two perspectives, including supply side perspective and demand side perspective. According to her framework, the supply side focuses on the individual entrepreneurs who are seen as the primary drivers of supply of entrepreneurship (Mezias & Boyle, 2002). The first class of definitions of entrepreneurship consists of definitions which emphasize the individual traits of entrepreneurs. This class takes its cues directly from theories of administrative rationality and the behavioral theory of the firm. These definitions married to observations that search for alternatives and discovering their costs and benefits is an important part of understanding outcomes of entrepreneurship: innovation, founding of firms, and the creation of new industries. This class has also borrowed from economic perspectives on searching and entrepreneurship, emphasizing the entrepreneurial choice that is resulted from searching for costs and rules (Battilana et al, 2009).

Second class of definitions relates to the kinds of behaviors that are included in the meaning of entrepreneurship. A common extension of the meaning of entrepreneurship is to encompass innovative behavior by existing organizations; which is called intrapreneurship or corporate entrepreneurship (Zahra & Wright, 2011). A major strain of these arguments directly relate to the level of analysis issue. Networks, alliances, and joint ventures have become integral to the creation of new firms and new industries. Indeed, this is an essential point of the system model of entrepreneurship (Van de Ven, 1993b).

In contrast to supply perspective, scholars in demand perspective try to emphasize community dynamics of entrepreneurship (Zahra, 2007). For Instance, in the light of demand side perspective, Mezias and Kuperman (2001) suggested a two-by-two typology of entrepreneurship based on whether a behavior produces economic innovation or the founding of a new firm is involved. The key point in these typologies as well as other studies is that the definition of the entrepreneurship is broader than the suggestion by the traditional great man approach.

The most important implications of these broader definitions -from the viewpoint of demand side- is that the existing organizations can be important participants in entrepreneurial activity, particularly the emergence of new industries which demonstrates the dynamic nature of entrepreneurship (Mezias & Boyle, 2002).

Most of the previous literature in the field of entrepreneurship is rooted in supply side perspective and so many of the theoretical and empirical researches in this field are based on static approaches, while entrepreneurship is an inherently dynamic phenomenon (Cope, 2005). Entrepreneurial process is a dynamic and holistic one because both the venture and the industry change over time (Bygrave, 2007). Thus, theory development about entrepreneurial process is possible only when its dynamic nature is conceptualized.

To date System Dynamics has been used in a wide range of domains such as corporate planning, public policy and policy design, medicine and biology, economic behavior, supply change management, energy and the environment, public management, decision making, software

engineering and theory development in the natural and social sciences (Angerhofer & Angelide, 2000).

In spite of these invaluable studies in the field of system dynamics, the body of knowledge in the context of entrepreneurship using system dynamics approach is fragmented and needs further structure and order (Cope, 2005). Regarding this situation and taking the supply side perspective to entrepreneurship as a complex dynamic phenomenon, this paper applies the literature review method to investigate previous research which links system dynamics with entrepreneurship and new entrepreneurial venture founding. The main aim of the present study is reviewing the previous literature in the field and highlighting the fragmentation and also integrating the current body of knowledge, in order to direct the future research in this field.

In the following sections, first theoretical background, nature and definition of system dynamics are described. Then the method of the study is introduced. In the result section the available papers relate to the field are summarized. Then the results are categorized, and a two level taxonomy of system dynamics modeling in entrepreneurship is proposed and several gaps in the literature and also recommendation for future research are underlined.

2. System Dynamics and its implications

System Dynamics is a strategic approach for analyzing problems in complex systems (Morecroft, 2007). This field of study was first developed by Jay W. Forrester during the mid-1950s at Massachusetts Institute of Technology and at the beginning it was called Industrial Dynamics (Radzicki & Taylor, 2008). It has its origins in control engineering (Angerhofer & Angelide, 2000). Forrester (1961) defines Industrial Dynamics as" *The study of the information feedback characteristics of industrial activity to show how organizational structure, amplification (in policies), and time delays (in decisions and actions) interact to influence the success of the enterprise."*

System Dynamics is a combination of theory, method and philosophy that may analyze the behavior of systems in almost every field of study. It is useful in science, medicine, law, education and other fields of study and can be helpful whenever we need to know how systems change through time. System Dynamics approach, as all the systemic thinking approaches seeks to conceptualize realities in such a way that is easier to understand and deal with (Harris & Williams, 2005). It uses some concepts from control engineering to organize the information from human mental models into computer models. Mental models are so important in System Dynamics approach. The information about the structure and relations in dynamic systems in the absence of written data are derived from mental models. After converting the information into computer models, these models are simulated and dynamic consequences are displayed. The first article using System Dynamics approach was published by Forrester in Harvard Business Review (Forrester, 2009).

Forrester (2009) claims that although social systems such as political, managerial and economic systems are more complicated than engineering systems, we can simulate these systems using subtle methodologies for system design which has developed during the last 50 years. Social and human systems are fundamentally similar to natural and physical systems but the degree of complexity in these systems are much higher than physical systems. Social systems should be analyzed by a holistic approach and this means that the total behavior of the system is not equal to

the cumulative behavior of the system components. One of the implications is that in a social system agents are not completely free and their actions are shaped by outside structure (Radzicki & Taylor, 2008).

Despite this complexity, in Forrester's view, social systems should be modeled using System Dynamics modeling concepts as flow rates and accumulations linked by information feedback loops involving delays and non-linear relationships (Forrester, 2009). In System Dynamics feedback and delay cause the behavior of systems and thus dynamic behavior is a consequence of the system structure. All the human actions and all the changes in the world occur through a network of feedback loops. Feedback exists in controlling anything that changes over time. In Forrester' opinion, the meaning of feedback in social systems is that the decisions derived from current situation cause changes in the current situation. These changes also change later decisions (Forrester, 2009). Lane (2001) states that empirical research without theory is blind and we must consider System Dynamics as a modeling approach which has some assumptions on how human agents use information and how empirical data are used for: modeling, how models are valid and how models are used practically.

3. Entrepreneurship and System Dynamics

Landstrom and Sexton (2000: 437) described the beginnings of the recent wave of attention to entrepreneurship: "In 1982, when the entrepreneurship field was beginning to emerge, the major topics were financing, growth, the process of entrepreneurship and research methodology. As these topics suggest, psychology and economics, which tend to be individual in their orientation, were first on the scene. The level of analysis of these disciplines was an individual person and they could not introduce entrepreneurship as a dynamic multilevel phenomenon. Sociology, for the most part, arrived late to the party, while each discipline had tended to speak mostly to its own. As a result, dialog in the field of entrepreneurship has been organized by camps, where the lack of cross-level and cross-disciplinary interactions tend to obscure the overall picture of what gives rise to entrepreneurship".

The contributions of organization theory in understanding entrepreneurship go beyond merely redefining the phenomenon. Most importantly, organization theory has provided dynamic frameworks for the empirical study of entrepreneurship that have produced systematic evidence to enhance our understanding of the phenomenon. Perhaps the most established of them is derived from the population ecology approach and addresses the population dynamics of the founding of new firms (Anderson et al., 2006). For example, the density dependence model predicts that founding will have a curvilinear relationship with the established firms. When the total number of firms in a population is small, increase in the number of firms will enhance the founding of firms (Mezias & Boyle, 2002).

In this situation, modeling entrepreneurship or startup process as a dynamic system has some benefits. Studying entrepreneurship at individual or firm level of analysis excludes those startup experiences that are not successful and lead to failure, so we do not understand unsuccessful entrepreneurship and thus do not have enough knowledge about the complete phenomenon. Furthermore, most of the researches conducted at the individual or firm level of analysis have used post hoc data and have analyzed a question about a part or some parts of the

entrepreneurship process without considering the process as a whole. Regarding the entrepreneurship as entrepreneurial startup system reflects both successful and unsuccessful activities and can show the behavior of the system as a whole through time (Yearworth, 2010).
As Houang and Kunc (2012) mentioned for the better use of System Dynamics models for startup system first of all the critical factors in running a successful startup need to be identified. Also other factors that shape the business characteristics should be determined. This could be done with the case studies in different industries. Inductive approach and grounded theory are suitable to attain this goal (Yearworth, 2010).The next step could be developing the resource map which is a set of strategic resources that determine the business performance in a special industry. These steps facilitate the System Dynamics modeling process (Houang & Kunc, 2012).

4. Methods

4.1. Research Method

This article uses literature review as the research method for investigation of the state of knowledge on the application of system dynamics in entrepreneurship. As Copper (1988) states, literature review helps in the definition of knowledge. There are different approaches for conducting a literature review based on the purpose of the study. Li and Cavusgil (1995) introduce three approaches. The first approach is Delphi method in which experts in the field are surveyed. The second is meta-analysis in which a statistical analysis is carried out on all papers on the same subject. The third approach is content analysis which is a technique for systematic qualitative and quantitative description of the content of previous research in the field (Li & Cavusgil, 1995).
In this study, we do not seek to synthesize the previous findings in a way done in meta-analysis. Neither do we follow a specific point of view for evaluating research designs and findings. Instead, we try to achieve neutral representation (Cooper, 1988). Thus, we use content analysis for conducting a systematic review of the literature.

4.2. Method Criteria

There are two critical steps in conducting a systematic review using content analysis, One of them is defining categories which permit the classification of papers. The other step is determining the type and number of databases that will be searched (Li & Cavusgil, 1995). A systematic search was done through two major sources of references: the proceedings of the annual international System Dynamics conferences from 2000 to 2014 and the back issues of the *System Dynamics Review* journal. The search was done with these keywords: System Dynamics, dynamic model, and dynamic system with entrepreneurship, venture, entrepreneurial venture, startup and SME. These keywords were searched in the title, abstract and keywords of papers. It led to a list of papers which was filtered in the next step based on the relevance of their abstracts. Also the reference sections of these papers were investigated for inclusion of potential relevant articles. The main objective of the final selected papers was any kind of application of System Dynamics in modeling and analyzing different aspects of the startup process.

5. Results

Searching through the previous issues of the System Dynamics Review journal and proceedings of ***International Conference*** of the ***System Dynamics*** Society led to 53 papers. After screening the papers 42 of them proved to be relevant. Figure 1 shows the trend of interest in the subject.

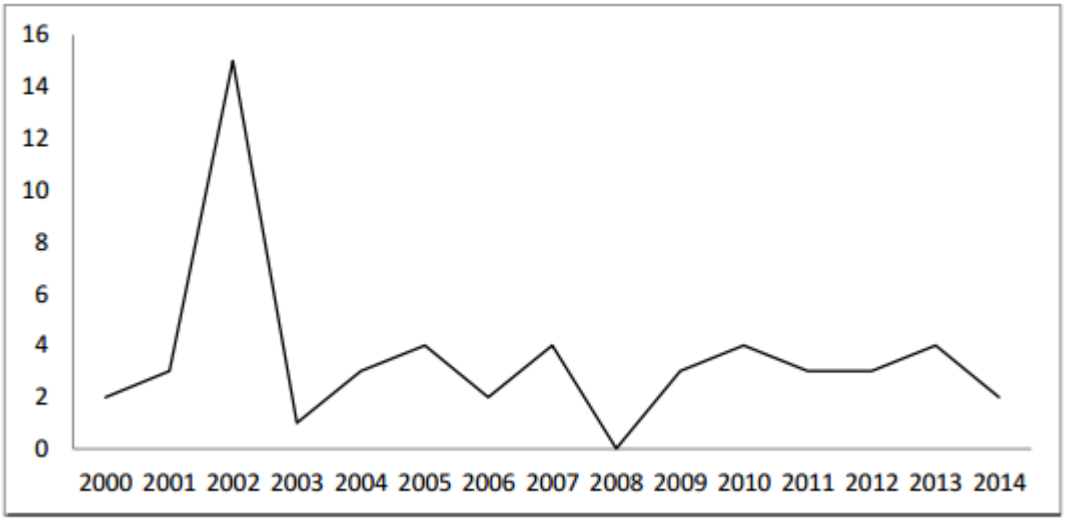


Figure 1. Trends of number of articles

The figure shows a significant increase of interest in the subject in 2002. After that there is an unstable trend with an average of 2 articles per year. Table 1 summarizes the number of articles indexed per year in each database. According to the table no relevant article was found in the archives of System Dynamics Review Journal from 2000 to 2014 except for 2002. In 2002 there was a special issue of system thinking and System Dynamics in small and medium enterprises and 5 articles were published. Compared to System Dynamics Review Journal, System Dynamics Conference proceedings show several articles per year on the subject except for 2008.

Table 1. Number of articles per year in each Database

Data base	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
System Dynamics Review Journal	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-
International System Dynamics Conferences	2	3	10	1	3	4	2	4	-	3	4	3	3	4	2

The scope of problems addressed in the previous literature linking System Dynamics with Entrepreneurship is wide. Different issues have been investigated in the papers. The lack of an

integrating taxonomy for unifying different features of the subject is evident. A unified taxonomy is necessary for organizing the body of research and helping the direction of future research. In this regard, deep literature review revealed that the previous research could be categorized in a two dimensional taxonomy of System Dynamics Modeling in entrepreneurship. The dimensions are (1) level of analysis and (2) level of modeling, each of which has some sub-categories as discussed below:

5.1. Level of analysis

5.1.1. Micro level

The first category of the first dimension of proposed taxonomy is micro level. Micro level in this study refers to the level of gathering information and analysis which deals with a part of a firm. Most of the previous research has focused on partial models that depict the dynamics of a problem or a part of a firm not the whole firm. Some of the issues and problems that have been the focus of this group are business planning, learning, impact of some factors on performance, customer acceptance, and financial issues. For example Bianchi et al., (1998) say planning and control in small and medium enterprises should be a learning-oriented process and in supporting this process System Dynamics modeling and simulation can play a critical role. They try to identify different actors involved in the process of planning and discuss the use of System Dynamics modeling can improve the strategic control process to support learning in business plan. They argue that entrepreneurs usually have different plans, ideas and mental models from what is submitted as a formal business plan to outside agencies. Formal plans are designed in the startup phase of the business and do not assist the entrepreneurs in dealing with the dynamics of the business. The firm operation is based on internal and informal plans. So, there is a potential danger of conflict of visions and interests of internal and external stakeholders. They offer a rationale for using System Dynamics modeling to fill the gap between internal and external plans. Their fieldwork admits the desirability of filling this gap.

Bianchi's another work (2002) is also on SMEs planning and control. He states that planning and control tools are very important in SMEs performance and some of the scholars insist on formal planning and using business plan for goal setting, production, monitoring operations and evaluating strategies and even communication with other stakeholders. Bianchi argue that although some of the scholars identify lack of planning as the primary cause of SMEs failure, empirical researches of others show some shortcomings of formal planning and control. He continues, SMEs do not have sufficient managerial and financial resources. Thus, they cannot use formal planning and control systems. On the other hand without these systems and relying only on business plan leads to a passive approach which prevents learning. Business plan is a product of a static approach and consists of scattered data on commercial, financial and also environmental issues. This static document does not show the dynamics of the business and real conditions. Bianchi points out that SME performance is not dependent on a business plan. Entrepreneurs should change their focus from forecasting to learning and should change their mental models with the dynamics of the situations. In his article, he discusses the importance of combining System Dynamics with accounting models with focus on learning. He argues some of the special characteristics of SMEs which are different from those of larger firms. Because of these

characteristics a unique approach for using System Dynamics modeling in SMEs planning systems is needed.

Suborto and Bivona (2009) argue that entrepreneurs need to consider the dynamic relationships between the day to day conditions and future outcomes. New firms cannot rely on conventional accounting models to monitor their performance. The accounting approach should be coupled with System Dynamics methodology so the entrepreneurs and policy makers can better analyze the consequences of current decisions and choose better managerial processes. They conduct a case study in leather industry in Indonesia with the purpose of supporting SME's through the use of System Dynamics modeling in planning. They aim to develop a step by step System Dynamics modeling process for SME's and claim that their study help entrepreneurs in understanding the cause and effect relations between financial and non-financial results.

There are several micro level dynamic mechanisms in an entrepreneurial venture which have great impact on the success and failure of a business such as an entrepreneur's decision making. These issues have not been addressed in previous research. Future research can model different types of micro mechanisms in entrepreneurial venture such as individual cognitive and individual behavioral dynamic aspects using system dynamics modeling in order to enhance the field's knowledge about the effect of these mechanisms on entrepreneurship.

5.1.2. The Meso level

The second category of the first dimension of proposed taxonomy is meso level. In the current study meso level refers to the firm level of analysis. Some papers in the review set have modeled the whole firm. Although some of these models are based on a single or few case studies, they are completely general. The models of the internal process of venture have been used for performance measurement, analyzing the effectiveness of different strategies, holistic analysis of the effect of different factors on the whole venture, also clarifying the main relations of the critical success factors by a business. For instance, Schwarz and Schöneborn (2002) seek to create a dynamic model of a firm. Their purpose is to propose the simplest possible model that includes the essential variables of the theory of the firm and also shows the growth of startup. They focus on an educational model that would help bringing dynamic perspective into different fields of management education.

Schwarz and Schöneborn (2002) argue that the traditional analysis of firm evolution consists of analyzing stock charts and balance sheets. These analyses which are used in econometric models do not consider the dynamics of evolution of the firm from one stage to the next. They count three theoretical approaches for analyzing the firm evolution: evolutionary economics, econometrics and System Dynamics. They use System Dynamics approach. They discuss that previous approaches use the production function and reduce a whole firm only to three or four variables and thus their analysis lead to unrealistic and often static models. They also state that previous evolution models are based on large firms and are not applicable to small firms. An evolutionary model should explain both growth and decline of the firm until bankruptcy. New startups have some critical stages in their evolution process that should be considered in modeling. They use a top-down approach for modeling small firms on the basis of theory of the firm. They use assets and staff as production factors and consider customer base as an intangible asset. They analyze the

cause and effect relations between production factors. Their model is for a smallest scale of a firm which they claim makes the falsification of the model easier. They simulate their model and conclude that the business dynamics is replicated. Their results have some implication for entrepreneurs too.

Houang and Kunc (2012) seek to lay the foundation stone for general models that help managers to deal with dynamic complexity of the startup process. They propose a general model for startup based on several case studies and using System Dynamics modeling approach in order to test the consequences of adopting different strategies. Their goal is to provide evidence with simulation for better understanding of the reasons of a startup failure. They argue that a typical startup system consist of eight critical resources which are customer base, potential customers, staff, product in process, service in process, cash and brand. Besides these resources, financial information is an important factor in the startup survival. They consider the eight main resources and financial information in an integrated dynamic model with feedback loops. They analyze the financial performance of a startup using this model with initial parameters. They also use eight variables of decision making and analyze the growth strategies with two scenarios of the best case and the worst case.

Hopp & Sonderegger (2014) in their research try to use system dynamics view to indicate the factors driving the successful founding of new firms, especially factors which indicate the dynamics of a nascent entrepreneurial venture. They link prestart-up experience and intentions of nascent entrepreneurs to the shape of the entrepreneurial gestation process and eventually to successful founding. Their findings show that when controlling for the possible endogenous activities carried out, a later temporal concentration of organizing activities enhances the probability of successful founding.

In sum, reviewing previous research with this level of analysis shows that previous studies have not paid much attention to the inherent internal processes of an entrepreneurial venture from the system dynamics viewpoint. Inherent processes such as how a nascent venture survives and transforms during the first years of existence, how to learn to growth and renew itself in the face of the market changes are the issues which have not received any attention from system dynamics viewpoint and it is up to future work in this area to develop a full-fledged research in this topic and enhance the insights about these issues.

5.1.3. Macro level

The third category of first dimension of proposed taxonomy is macro level. A few of the reviewed papers propose models which deal with issues in the macro level. These models deal with issues like SMEs sector development, important external factors in formation and growth of SMEs, supportive policies and financing systems. For example Yearworth (2010) introduces a new approach in dynamic modeling of entrepreneurship. He use grounded theory and System Dynamics together and name this new approach grounded system modeling. He argues the benefit of this approach compared to pure System Dynamics modeling is that all the variables, stocks and rates and parts of the system are based on facts and empirical data. Based on the empirical data of some technological firms in England he extracts the essence of an entrepreneurial system and the main problems which should be solved. He proposes three models (loop) from the data for

different phases of entrepreneurship process. The first loop deals with spotting and valuation of the opportunity and preparing the business plan. The second loop deals with financing the business through equity funding. The third loop deals with the growth stage and exit. He discusses that one of the main feature of the startup system is the existence of several reinforcing loops which leads to exponential growth in equity funded firm but some constraints exits. These constraints are lack of financial resources in the early stages, entrepreneurial drive and exogenous factors like equity funds. He states if at the macro level we do not see exponential growth of technological firms in a region, one of these constraints is in operation and it can be tested which one is in operation. He does not simulate and test his models but suggests that some longitudinal study should be conducted and also gives some hints on measurement units.

Suborto (2012) states that the number of SMEs in Indonesia has demonstrated a dynamic behavior and hence there is a need to provide information about market demands which will lead to better planning. His purpose is to identify variables that have whether direct or indirect effect on SME formation and survival. He analyses the data on small and medium enterprises in Indonesia and his model deals with the demand side of market and number of SMEs compared to large enterprises. The results of the simulation shows that in the macro scale using two kinds of policy levers will help to increase the number of SMEs: production coordination system and financing mechanism with profit-sharing principle of financing contract. Figure 2 shows the distribution of papers based on the level of analysis.

Although research at this level of analysis has some good implications for policy making both at industry level and at country level, such studies are too rare. In the current business environment in which entrepreneurial ventures are encountered by rapid changes, modeling of changes in technologies, industrial trends, markets, customer preferences and other environmental factors using system dynamics modeling can develop worthwhile implications both at the meso and macro levels.

In sum Figure 2 shows the distribution of reviewed papers based on level of analysis which is the first dimension of the proposed taxonomy.

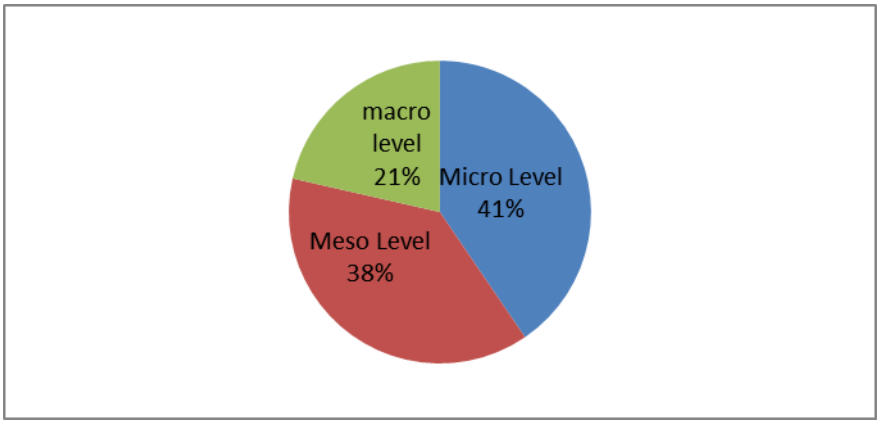


Figure 2. Distribution of reviewed paper based on the level of analysis

5.2. Level of Modeling

The second dimension of proposed taxonomy is the level of modeling. Level of modeling in this research is based on the prominent research of Forrester (1994). He defines six steps in the

process of System Dynamics modeling. At the first step the problem or the undesirable behavior in the system should be described and a conjecture should be proposed on how this behavior is produced. In the next step the model for simulation is designed. The description of the system is interpreted to System Dynamics equation (with rate and stock variables). If the description of the system from the previous step is clear and the essence of the system is identified properly, the interpretation to System Dynamics model equations will be done well. Writing the equation in this step sometimes shows some inconsistencies and gaps in the description of the system which requires a return to previous step (Forrester, 1994).

The third step is the simulation of the model. The prerequisite of simulation is the precise definition of the variables in the previous step and the consistent measurement units. The dynamic consequence is displayed via simulation and it shows how the problem is generated in the system. For a successful simulation there is often a need to revert to previous steps. At the next step the alternatives for improving the system are examined. System Dynamics is used for conceptualization of the reality with the goal of changing people's mental models which often leads to desirable conditions. Most of the times, the desirable conditions emerge as a result of changing the structure of the system. But alternatives for changing the structure of the system are not known completely and finding an alternative can be completely intuitive. System Dynamics is based on experience, art and skills of imagination of creative alternatives for the system. At the next step, further investigations and debates are conducted until the consensus on how the changes should be implemented is obtained. At the final step, the changes are implemented (Forrester, 2009).

It can be said that the first three steps deal with modeling and others deal with finding a better alternative for the system and its implementation. Most of the articles in the selected set had designed System Dynamics models and simulated their model (65%). Five percent of the researches were in the first stage of modeling by opening an issue and defining some problems to be taken into account. One fourth of the papers were in the second stage by proposing a model with causal relations and feedback loops and defining stock and rate variables. Only 5 percent of the papers had continued the modeling approach to level four and proposed alternative strategies for the model. Figure 3 shows the distribution of reviewed papers based on the level of modeling.

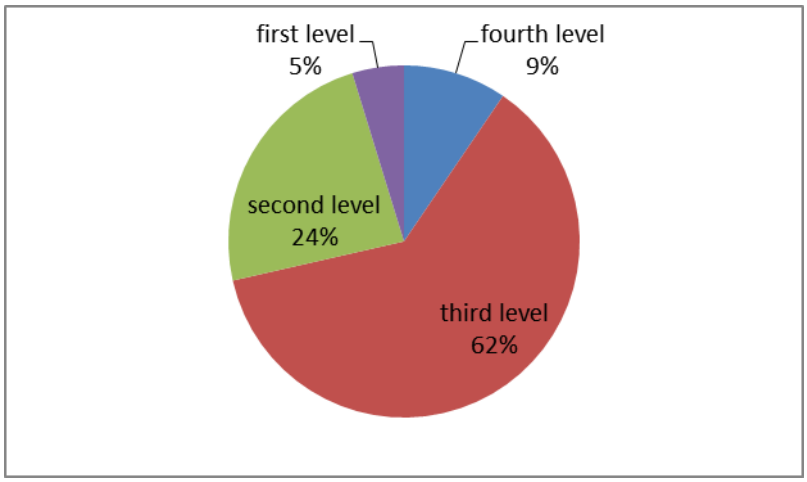


Figure 3. Distribution of papers based on level of modeling

Reviewing the literature reveals that there are few advantageous researches which model entrepreneurial venture's processes using system dynamic modeling and propose alternatives for problems and processes. Future research should focus on all stages of system dynamics modeling including simulation and designing alternatives in order to build a cumulative body of knowledge in the field of entrepreneurship from the viewpoint of system dynamics.
A summary of reviewed papers is listed in Table 2.

Table 2. Summary of reviewed paper

Author	**Year**	**sector**	**simulation**	**Purpose/Key findings**
Bivona	2000	Publishing	done	Used A System Dynamics modeling approach to understand the interrelationships of the business in a publishing company in order to assess strategies and also to provide a shared mentality between the entrepreneur and collaborators.
Kameyama et al.	2001	multiple	no	Build a model for SME sector development in Japan. They aim to examine incentive tools' effectiveness in development of this sector in order to give policy implications for the government planning.
Lofdahl & Lofdahl	2001	High tech	done	Present a model for product development based on a failed project in a high-tech industry. They test another strategy for the project with simulation and find the second strategy leads to better results.
Lee & Huh	2001	multiple	done	Propose a model of success factors in Korean ventures based on interviews with venture capitalists and also documented results of previous research.
Arthur & Winch	2002	--------	no	Discuss the importance of System Dynamics in strategic analysis and use of generic parameterized model for SMEs which can't afford to build their model from scratch
Bianchi	2002	--------	no	Argues a learning oriented approach for SMEs and using financial System Dynamics models in order to evaluate the results of business plans. He insists on the importance of combining System Dynamics with accounting models with the focus on learning.
Bianchi & Bivona	2002	Family firm	no	Analyze the driving forces of business success and failure through causal relations and feedback

				loops taking account different variables such as values and context culture.
Burelli	2002	Technological startup	no	Presents a dynamic model of startup failure based on a technology startup in which the style of leadership is the cause of failure. The over entrepreneurial drive and lack of trust to colleagues and lack of confidence in managerial topics are the barriers to grow.
Haroon & Wahba	2002	---------	no	Propose a generic model to monitor SMEs short term responses to non-stationary conditions using System Dynamics. This model is composed of five sub models: environmental, human resources, operational, Risk and financial and would help in taking action plans.
Kameyama & Kobayashi	2002	---------	no	Propose a model for development of SMEs based on micro financing. Their model considers the link between macro and medium level on micro level financing and development of SME sector and thus economic development in long term.
Lee & Huh	2002	-------	done	Develop a model dealing with the competitiveness of the venture industry and analyzing the economic efficiency, potential and growth of a venture business.
Schmidt & Gray	2002	High tech	done	Using system dynamic modeling and conjoint analysis they suggest a model for SMEs to evaluate different policy options. They use market research data and management judgment for defining the structure and parameterization of the model.
Schwarz & Schöneborn	2002	NA	done	Seek to create a dynamic model of a firm. Their purpose is to propose the simplest possible model that includes the essential variables of the theory of the firm and also shows the growth of startup. They focus on an educational model that would help bringing dynamic perspective into different fields of management education.
Winch et al.	2002	multiple	no	Use a simple system dynamic modeling tool to map and show the potential benefits of the deep niche strategy for entrepreneurs and small innovative firms.
Garzia	2003	NA	done	Presents a model to analyze the suitable

				condition for conducting internal corporate venturing and strategic innovations. The focus is on the context of organization and incentive system.
Arenas	2004	Tube producer firm	done	Presents a dynamic model which integrates financial and operational variables. The results show that for the growth and survival of SMEs an appropriate combination of access to credit and its conditions and financial and operational policies is needed.
Boyer & Elter	2004	NA	done	Propose a dynamic model for entrepreneurial firm to analyze and define the product development strategy which leads to profitability in the shortest time possible with regard to the resource constraints and market parameters
Ross	2005	Pork production	done	Discusses that entrepreneurial rent is difficult to measure thus he proposes a dynamic model using System Dynamics framework to reflect the dynamics of entrepreneurial rent and help its measurement
Chirico	2006	Family business	done	examines four different scenarios describing the evolution of paternalism in family business over three generations and the consequent impacts on the family inertia and capabilities
Juerging & Milling	2006	automobile industry	done	Show interdependencies between time to market and time to volume and compare different policies for the management of changes during manufacturing start-up.
Chirico & Colombo	2007	Family business	done	simulate the dynamic relations between knowledge, basic dynamic capabilities and advanced dynamic capabilities, entrepreneurial performance and trans-generational value
Juerging	2007	Automobile industry	done	Argues that many innovative firms try to reduce time to market but fail to control time to volume. He proposes a model to compare the effects of different policies for management of production ramp up.
Kunc	2007	Wine industry	done	Seek to show tradeoffs for SMEs in internationalization considering interactions between Network interactions, absorptive capacity, intention of becoming international and production function

Miller & Sterman	2007	Clean energy technologies	done	Develop a simulation model to investigate reasons of failure of ventures which seek to commercialize clean energy technologies
Harbich & Mateus	2009	NA	done	Present a market diffusion model that shows the adoption behavior of consumers in the future
House & Black	2009	Medical device	no	Discuss the causal relations between success of the entrepreneurial firm and the leader's attributes
Subroto & Bivona	2009	Leather industry	done	aim to develop a step by step System Dynamics modeling process for SME's to understand the cause and effect relations between financial and non-financial results
Colombo & Piantedosi	2010	Family firms	done	Propose a model based on dynamic capability and resource based view for family firm and investigate the impact of succession on firm performance
Garzia	2010	---------	no	Presents a model for strategic innovation and strategic renewal based on literature of corporate venturing. Their model deals with two feedback loop which are related to two dynamics: entrepreneurial orientation and resource allocation
Lerch & Selinka	2010	Capital goods industry	done	Build a model to present the dynamics and analyze the consequences of implementing new business models in order to reduce the uncertainty and risk of changing business model
Yearworth	2010	Technological businesses	no	Proposes three models for different phases of an entrepreneurial system with an inductive approach called grounded system modeling which combines grounded theory with business dynamics
Farouk & Saleh	2011	multiple	done	Build a dynamic model for stage growth of SME's base on literature and case studies
Garzia & Mollona	2011	Aluminium Downstream Industry	done	Propose a system dynamic model for business model renewal using empirical data from window industry in Italy
Huang & Kunc	2012	multiple	done	Propose a general model for startup based on several case studies and using System Dynamics modeling approach in order to test the consequences of adopting different strategies. Their goal is to provide evidence with simulation for better understanding of the reasons of startup failure.

Subroto	2012	multiple	done	Aims to identify variables that have whether direct or indirect effect on SME formation and survival. He analyses the data on small and medium enterprises in Indonesia and his model deals with the demand side of market and number of SMEs compared to large enterprises.
Wang	2012	Medical Software	done	Presents a dynamic model for firm growth and survival which depicts interactions of market and product development, growth strategies, attitudes toward growth, and the corresponding management actions in response to external and internal events
Bianchi et al.	2013	marketing	done	Build a dynamic model for performance measurement of SMEs which combines System Dynamics with traditional performance measurement frameworks in order to support learning processes
Garzia	2013	multiple	No	Aims to investigate strategic innovation through a System Dynamic based process model, which is based on case studies, which explains the dynamics of strategic renewal in firms.
Kővári & Pruyt	2013	NA	done	Presents a System Dynamics model for bank lending decision and monitoring SME credit portfolio
Khodabakhshian et al.	2013	NA	done	Propose a dynamic model which shows the consequences of tight bank measures leads to bad situation for both banks and entrepreneurial SMEs over time.
Capelo	2014	Energy service	done	Proposes a dynamic model for the startup of an energy service company and explains key variables
Ran et al.	2014	NA	done	Develop a dynamic model of technology adoption and diffusion from an entrepreneurship and business-model perspective

6. Conclusion and Recommendation

The study of entrepreneurship has traditionally focused on the founders of new organizations; especially those who have emerged as leaders in the creation of new industries. Studies of this type posit a causal link between founding and success of new venture and the personal attributes of the entrepreneurs. However, recent research has documented the many ways in which

successful entrepreneurship requires more than just the 'right' person; a multitude of factors, operating both at the organizational and environmental levels of analysis, also affect the success of entrepreneurial efforts (Mezias & Boyle, 2002). So the study of entrepreneurship is increasingly moving away to dynamic process that includes the consideration of other factors. Such models explicitly recognize that entrepreneurs do not exist independent of organizational, environmental and societal contexts; thus, their actions cannot be completely understood without paying attention to such dynamic contexts and factors (Hopp & Sonderegger, 2014).

This article presents a review of studies on the subject followed by integration and discussion on main research issues that have been the focus of previous studies. The main aim of this review is to categorize the available research related to the application of system dynamics modeling in entrepreneurship to integrate research and enable recommendations for future research. The Results reveal that the previous research could be categorized by a two dimensional taxonomy of level of analysis and level of modeling. Level of analysis has three categories: micro level, meso level and macro level. Level of modeling has six hierarchical levels.

First, we argue that in the first category of the first dimension of the taxonomy, namely micro level category, most of the previous research has focused on partial models that depict the dynamics of a problem or a part of a firm not the whole firm. Some of the issues and problems that have been the focus of this group are business planning, learning, impact of some factors on performance, customer acceptance, and financial issues. The study revealed that some micro dynamic mechanisms such as an entrepreneur decision making have not been modeled using system dynamics. So, Future research can model different types of micro mechanisms in entrepreneurial venture such as individual cognitive and individual behavioral dynamic aspects using system dynamics modeling in order to enhance the field's knowledge about the effect of these mechanisms on entrepreneurship.

Second, the present paper indicates that at meso level, some papers have modeled the whole firm. Although some of these models are based on a single or few case studies, they are too broad and general. The models of the internal process of an entrepreneurial venture have been used for performance measurement, analyzing the effectiveness of different strategies, holistic analysis of the impact of different factors on the whole venture, also clarifying the main relations of the critical success factors by a business. Reviewing this line of research indicates that previous literature did not pay much attention to the inherent internal processes of an entrepreneurial venture from the system dynamics viewpoint. Inherent processes such as how a nascent venture survives and transforms during the first years of existence, how to learn to growth and renew itself in the face of the market changes are the issues which have not received any attention from system dynamics viewpoint and it depends on future planning in this area to develop a full-fledged research program on this topic and enhance the insights about these issues.

Third, at the macro level category, there are few researches which deal with issues like SMEs sector development, important factors in formation and growth of SMEs, supportive policies and financing structures. This category of research has some prominent implications for policy making both at the industry and country levels. The number of this type of research is too scant. It is recommended that due to the fact that in the current business environment entrepreneurial ventures are encountered by rapid changes, future research concentrate on modeling the impact of changes in technologies, industrial trends, markets, customer preferences and other

environmental factors using system dynamic modeling in order to develop worthwhile implication both at the meso and macro levels.

Fourth, we argued that in the second dimension of taxonomy, namely the level of modeling, there are six levels based on the prominent research of Forrester (1994). Forrester (1994) presented six steps in the process of System Dynamics modeling, of which the first three steps deal with modeling and others deal with finding a better alternative for the system and its implementation. Reviewing the literature reveals that there are few advantageous researches which model entrepreneurial venture processes using system dynamic modeling and propose alternatives for problems and processes. Future research should focus on all stages of system dynamics modeling including simulation and designing alternatives in order to build a cumulative body of knowledge in the field of entrepreneurship from the viewpoint of system dynamics.

Finally our integrative review has some general implications for future research. First, approximately all the papers in this subject have focused on the early stages after the founding process or on established firms. One exception is Yearworth's (2010) work which proposed a model of startup process which starts with idea generation and argued if adequate sources of funding are available, these new ideas can evolve into product prototypes and then after further examination into business plans. He does not model any dynamics of how these ideas are related to business opportunities and how these ideas are evaluated or what other different factors affecting the process of exploitation. Furthermore, the dynamics of the time for exploitation has not been modeled in previous researches. This gap could be due to the lack of clarity of entrepreneurship main constructs. Many of the concepts related to individual and opportunity-two lines of inquiry in the field of entrepreneurship- such as entrepreneurial motivation, opportunity recognition or creation or alertness cannot be operationalized. If there was a consensus on definitions and numerical operationalization, we would be able to discuss the applications of System Dynamics models for studying entrepreneurial process.

Second, there is no rule for interpreting the real situation to System Dynamics models. Thus, solving a problem with this approach is somehow difficult. Many of the projects seeking to use System Dynamics modeling fail because they cannot understand the essence of the problem and therefore the essence of the model. The validity of a model in System Dynamics approach depends upon correct understanding of the main objective. Therefore, the first step should be clarifying the object. For modeling an entrepreneurial process the main source of information is undoubtedly the entrepreneurs' mind, whereas extracting data from mental models with regard to the objective can help us in this process.

Third, our review clears that by burgeoning of entrepreneurship research the demand side perspective deserves more rigorous analysis.

Fourth, the dynamics of learning in the emerging industries leads to complexity which affects the new entrepreneurial startup planning to enter these industries. Modeling such a complexity using System Dynamics, can enhance the chances of entrepreneurial SMEs to revitalize in emerging industries.

Fifth, system dynamic models should be used very cautiously in the case of corporate entrepreneurship which deals with corporate change, new corporate venture creation and organizational renewal in large, established firms. In this case, both external and internal environments change and different kinds of learning such as double loop learning are involved.

Hence, in defining the closed loop boundaries of the system, it is important to include all critical factors.

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