Applying Modelling Paradigms to analyse Organisational problems

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Abstract

Managing a company requires different tools and methodologies in order to successfully deal with its intangible resources and maintain a competitive advantage. Econometrics, Agent-Based Modelling (ABM) and System Dynamics (SD) are modelling paradigms which facilitate the building of dynamic models that are characteristic of the organisational context.

These three paradigms have important differences that can determine their suitability to analysing organisational problems. This paper firstly describes the Econometrics, System Dynamics (SD) and Agent-Based Modelling (ABM) modelling paradigms. Secondly, the paper studies how these three paradigms can analyse organisational problems by means of a model developed using each of the three paradigms. Finally, the paper provides some considerations towards a method for validating the assumptions of how the paradigms fit with the requirements to study an organisational problem.

1. Introduction

Soft Variables, as Intangible resources, have been recognised as a principal source of competitive advantage in business organisation environments. Even though many of the traditional management methods and tools deal with intangibles, they ignore their important interdependencies, dynamic features and the structural complexity underlying them.

In contrast, there are modelling paradigms which allow the building of dynamic models such as organisational systems, where these paradigms represent an alternative to improve the managers' mental models upon which decisions are actually based, and would offer more information that would strongly support the decision making processes.

At present, there are three main modelling paradigms, Econometrics, System Dynamics and Agent-Based Modelling, used to build dynamic models that represent the characteristics of organisational environments. Each modelling paradigm has a number of different features that can be used to determine their suitability for modelling an organisational problem. This paper can be considered as a starting point to assist in determining the suitability of the different modelling paradigms to the understanding and analysis of organisational problems.

2. Literature Review and Background

2.1. Management Context

The competitive environment in which business organizations operate has been continuously changing over recent decades. Some authors make reference to how a revolution from an industrial society to a knowledge information society has strongly influenced the principal sources of competitive advantage.

Hall (2000), Nonaka and Takeuchi (1995), Prahalad and Hamel (1990), Sveiby (1997), Kaplan and Norton (1997), and Tidd (2000) amongst others recognised authors, all incline to agree that the factors that generate sustainable competitive advantage are those of an intangible or soft nature.

The main characteristics of these soft factors can be summarised as:

1. They do not have physical substance
2. They can not be directly measured
3. They take time to establish themselves
4. Their dynamic changes over time depend on cause-effect relations that involve delays and non-lineal relations.

Additionally, the time delay associated with the value of intangible factors can cause unwanted side effects that may not be anticipated until it is too late and the original action cannot be corrected or modified as required. Various examples show that decisions, especially at management level, follow this pattern of behaviour.

These characteristics make it increasingly difficult for managers to take decisions that depend on intangibles and to identify relationships between decisions they make and how these in turn even a global system.

It is thus clear that managing a company requires different tools and methodologies in order to successfully deal with its intangible resources and to maintain a competitive advantage.

2.2. What should a dynamic modelling paradigm provide to Management?

Despite the efforts of several alternative approaches to manage intangible factors, none has been sufficient to fully incorporate relationships between variables, delays and feedback. So, managers continue to take decisions only supported by their own experience, and the knowledge that constitute their mental models[1].

Although there can be no argument that a manager's expertise and training constitute essential and valued resource, decision making processes can be influenced further by factors such as managerial relations, peer pressures, cultural perspectives and one's own selfish motives (Sterman, 2000).

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[1] Term used to refer to a mental image that people have about the world.

Sterman adds that despite mental models being more flexible and adaptable to new situations, they are extremely simple and incomplete. Computer models are explicit and allow the manipulation of more information.

If the problem to treat is too complex, dynamic, or if it shows high intrinsic uncertainties, there is often no established way to obtain a solution. Using a computer model that reproduces the relevant features of a subject may be the best way to treat such the problem.

Additionally, a point worth noting about developing organizational models is the benefits of the modelling process. In decision making processes, diverse people participate with different understandings of a subject, and thus it can be difficult to recognise the diverse points of view. A modelling procedure can be interpreted as an iterative process where the participants can discuss different interpretations, so it can help to gain a common understanding of relevant terms (Bradl, 2003).

In summary, a proper modelling procedure could improve the managers' mental models upon which decisions are actually based, and offer more information which will contribute better support to the decision making processes.

3. Methodology

Research is currently underway to provide a bridge between the modelling of systems and the dilemmas management that are constantly faced by organisations. With this goal in mind it is considered that a significant step is to identify the characteristics that differentiate the currently available modelling paradigms and the subsequent advantages and disadvantages that these characteristics impose when dealing with the problems that wish to be studied.

The methodology below was proposed to make steps toward this goal and to focus on a number of progressive tasks (Figure 1).

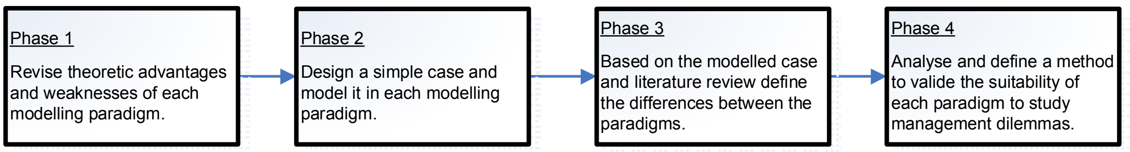

Figure 1. Preliminary methodology

This paper presents the study of the paradigms Econometrics, System Dynamics (SD), Agent-Based Modelling (ABM) and their application to organisational modelling.

In previous work, experimental models were developed to identify the differences between the paradigms. Based on the resulting assumptions the following sections describe the major characteristics of each of the above mentioned modelling paradigms and propose a method to validate the assumptions with a real case.

4. Modelling Paradigms

Even though the modelling paradigms share some commons concepts, they have their own particularities to model a system which could determine the paradigm capability to deal with a specific topic. Below is presented a summarised description of each paradigm.

4.1. Econometrics

Econometrics diverges from economic theory and utilises quantitative techniques and economic concepts and statistics to analyse economic events. Econometric models can be used for structural analysis to predict or to experiment with the effects of alternative proposals.

One of the principal characteristics of this paradigm is the statistical verification of the parameters and the structure of the model. This implies that in order to quantitatively estimate relationships between variables, every analysed variable in the model must have a sufficient number of historical measurements. This requirement leads to information being limited in the models due to lack of historic data, and this problem is prevalent with models that are closely related to the human behaviour that influences decision making.

The construction of an econometric model can be divided into two sequential phases. In the first phase the problem is identified and its trajectory is defined. Quantitative precision is not required at this stage, and in any case would be difficult to achieve as available information would not yet be sufficient to decide which system elements are of significant importance to the model and how they are interrelated (Pulido, 1989).

In the second phase, the relations between variables and the model structure are formulated and defined. The values of the equations from model parameters are estimated in this phase and quantitative precision has a much greater importance. The main technique used to obtain parameters of econometrics models is the estimation of least squares method. Least Squares is a method that generates a group of parameters that best fit to a general postulation of relations for historic data. These parameters also provide a quantitative measure of the adjustment of the postulation.

The theoretical and mathematical requirements of this method ensure that the econometrics models must follow linear equations and other structural restrictions.

Econometric models can be divided into two distinct groups depending on the number of equations that are used: single equation or multiple equation models. Single equation models, as their name suggests, are models of a single equation and include a general linear model as well as time series models such as autoregressive, moving average, ARMA[2] and ARIMA[3] models. Multiple equation models contain more than one equation and often consist of causal chain models, block-recursive models or simultaneous equation models. Table 1 summarises the classification of econometric models based on the number of equations that they employ:

Single equation models	Single equation linear model
	Time series models
Multi-equation models	Causal chain models
	Block recursive models
	Simultaneous equations models

Table 1: Econometrics models

[2]ARMA, Autoregressive moving average models.

[3] ARIMA, Autoregressive integrated moving average.

Econometrics models can manipulate feedback relationships through the use of delayed variables and the formulas that they use are not significantly different compared to those engaged by SD models. In SD the well known 'Smooth'[4] function is an example of similarity between the mathematical construction of SD and Econometrics.

The significant advantages of econometrics models are:

- Classification of variables: In econometric models there is a clear distinction between variables that are studied in the model (endogenous) and those that are not (exogenous).
- Use of statistical methods for validation: Due to the fact that historical data of the variables is used, it is possible to undertake statistical calculations to validate the model.

Besides the advantages, the principal drawbacks of using this paradigm are:

- Limitations of constructing models without real data: Most of business systems are influenced by factors that in reality are not measured or controlled. Variables that are important for the study of the system, and whose absence could lead to incomplete or partial solutions, are often omitted when constructing econometric models.
- Limitations of building complex relationships: The assumptions of homocedasticity[5] and correlations, amongst others, hinder the modelling of complex relations. As a consequence, econometrics models tend to represent closed models that are highly linear.
- Loss of global vision: Econometric modelling can result in a loss of the system's global vision when trying to represent systems that are adjusted to mathematical methods such as those used to calculate parameters and validate models.
- Complexity of dynamic models: The construction of a dynamic model in econometrics requires the manipulation of a large number of equations that include a large number of interrelated variables. This condition increases the complexity of the model and thus can become more difficult to understand.

4.2. Agent Based Modelling

Before describing the scope and use of the agent-based models it is important to clarify the different terms that are used to make reference to this concept (Hare and Deadman 2004).

When analyzing the sources of these terms two different applications can be found:

- Information Systems based on the interaction of software agents. Each part of a large problem is assigned to each agent which has the ability to solve it (Janssen and Verbraeck 2005). These types of systems are denominated "multi-agent systems."
- Mathematical Models. These models try to explain a behaviour observed in the real world using simulation (Epstein and Axtell 1996).

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[4]The Smooth function is utilised in System Dynamics to calculate mean perceptions or to represent expectations.

[5] Term used to disturbances that have constant variance.

Both disciplines share the definition of an agent: "autonomous entity able to evaluate its situation and make decisions based on some attributes and rules". Consequently, to define a model or system it is necessary to define three main types of elements; the agents, the environment and the rules. The agents are people or entities of the artificial societies. The environment is the framework or abstract space where the agents can interact, and the rules are behaviour patterns for the agents and for the environment. These rules can be agent-environment, environment-environment and/or agent-agent (Epstein and Axtell 1996).

The basic properties of the agents are also common in both disciplines (Wooldridge and Jennings 1995), (Weiss 1999):

- Autonomy: Agents can operate without external intervention and they have certain control over their actions and internal state.
- Social ability: Agents can interact with other agents using some kind of language.
- Reactivity: Agents can perceive the environment and respond to changes that happen in it.
- Pro-activity: Agents are able to exhibit goal-oriented behaviour by taking the initiative.

However, the real applications of agent based and multi-agent models are clearly different. For example, multi-agents systems have been used to facilitate the search and summary of information processes (Wu 2001), and to develop an intrusion detection system (IDS) to avoid attacks on an information system (Gowadia, Farkas et al. 2005).

Agent-Based Models, as will be explained later, have a wide range of application to social, environmental and management problems. ABM is presented as a useful method to study complex systems, similar to other disciplines used to develop mathematical and computational models (Segovia-Juarez, S. et al. 2004). The key supposition that manages this paradigm is that the system behaviour is based on the local interactions of the agents.

Also, the main benefits of ABM have been identified (Bonabeau 2002), (Goldstone and Janssen 2005):

- It provides a natural description of a system: ABM represents the systems as a group of entities that carry out activities according to their attributes and relationships.
- It adds heterogeneity and discontinuity to the agents: ABM allows agents to be defined with different attributes which can be modified over time or when an event occurs.
- It captures the emergency phenomena: ABM captures the emergency phenomena because it allows behaviour rules to be defined that make agents interact and generate the global behaviour of the system. This advantage offers ABM the ability to represent complex individual behaviours such as learning or adaptation.
- Flexibility: The flexibility in ABM is denoted by the possibility of defining rules or events that the agents' patterns of behaviour can modify over time.

- Space: ABM allows creating a space where the agents interact according to distance. This way agent networks or agent groups can be identified.

Some authors have also discovered other disadvantages of the agent-based models. In particular, the main disadvantage that ABM is a bottom-up approach and that it is not able to lead to theories applicable at system level. In this case ABM must be used along with a top-down approach based on state variables (Grimm 1999).

Social sciences researchers know that simple patterns of repeated individuals can lead to extremely complex social institutions. In a similar manner, ABM has been used to describe social phenomena (Borshchev and Filippov 2004). In these cases, models are used to build social structures from the bottom, simulating individuals by means of virtual agents and creating emergent organizations from the rules that govern the interactions between agents.

Several examples use ABM to reproduce social behaviours: Models that demonstrate how a local behaviour can generate a global polarization (Axelrod 1997); models that represent the civil violence (Epstein 2002); or models related with the LULC (Land Use/Land Cover) problem. It is even possible to develop more specific models, as the environmental impact of the people in the Grand Canyon (Roberts, Stallman et al. 2002).

Bonabeau (Bonabeau 2002) highlights four areas of ABM application:

- *Flow (evacuations, traffic, customers flow management, etc.):* For example, the model developed to simulate the movements of pedestrians in a city using the Swarm application and GIS tools (Haklay, O'Sullivan et al. 2001).
- *Markets (stock market, strategies simulation, etc):* Chaturvedi et al. (Chaturvedi, Mehta et al. 2005) developed a model with 100.000 agents that represents the labour market of 1,4 million individuals. The model's domain is the military recruitment of population between 18 and 24 years in the USA. The model objective is to experiment different recruitment strategies.
- *Diffusion (viruses, tumours, situations where people are influenced by the social context).* For example, Muller et al. (Muller, Grébaut et al. 2004) decided to use ABM to represent the diffusion of the sleeping sickness because ABM allows representation in a dynamic way of the space position of the system entities.
- *Organizations (operational risk, organizations design, etc).* Ma and Nakamori (Ma and Nakamori 2005) outlined an agent-based model to simulate the process of technological innovation, based on the principle that this process is an evolutionary process.

In summary, ABM is useful for modelling problems where the interactions among agents are complex; agents are heterogeneous; its localization in the space is key in the problem; or when the agents exhibit complex behaviours including learning or adaptation.

4.3. System Dynamics

System dynamics is a modelling paradigm of a natural structure that allows reproducing the behaviour of dynamics complex systems (Meadows, 1980). The global structure of models in SD is established through feedback loops that consist of closed circuits of causal relations that can be both negative and positive. The positive ones are named reinforcing loops and the negatives loops are known as balancing loops. The structure is composed of stocks, flows and auxiliary variables.

Stock variables represent the state of the system at any given time, flow variables are those which determine the actions that change the state of the system, and finally auxiliary variables are used to facilitate the intermediate steps in the formulation of the flows.

Mathematically, an SD model is a system of differential equations of the type:

$$\frac{dN_i(t)}{dt} = FE_i(t) - FS_i(t) \qquad \text{i=1.....n}$$

$$\text{ó } N_i(t) = N_i(0) + \int_0^t [FE_i(t) - FS_i(t)]dt$$

This equations are solved by mathematical methods such Euler's method.

Graphically, an SD model is represented as a process. Figure 2 shows an example:

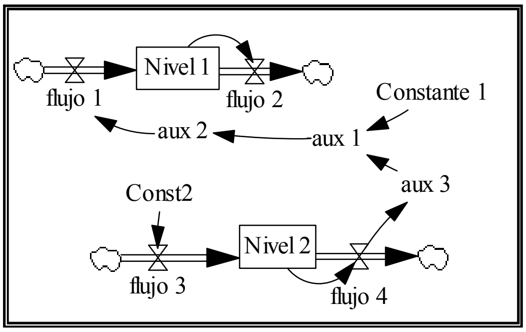

Figure 2. Graphical representation of a System Dynamics model

Due to the structural character of SD, the changing evolutions of the variables in the modelled system derive from the number of loops and the form in which they are combined in the system.

The principal advantages of SD are:

- Simplicity to building a model: For a skilled person, the task of constructing a model in SD is relatively straightforward. This characteristic facilitates the repeatability of model construction and easily permits the evaluation of problems.
- Global overview of the system and variable relations: SD uses a graphical representation of elements and relations between variables that produces a holistic view of the model.
- Flexibility: SD allows models to be constructed without historical data of the variables, and generates data by repeated simulations (calibration).
- Available tools: SD utilises specific methodologies to build the models with the participation of experts of the subject.

Amongst the disadvantages are the following:

- Representation of Heterogeneity: Although it is possible to construct models with heterogeneity in SD, they are often models that are difficult to manage and interpret due to the large number of needed stock and flow variables.

- Representation of the emergency concept: SD models handling with medium to high aggregation levels that invalidate the emergency concept.
- Ability to use software: The software used for the construction of models is simple to use and thus there is a risk that a person, without a solid grounding in the principles of the paradigm, could construct models that lead to erroneous conclusions or to incorrect interpretation of the problem.

4.4. Existing comparisons between modelling paradigms

Several recent research papers have suggested the main differences between modelling paradigms as Econometrics models (EM), Systems Dynamics (SD), Discreet (DE) and Agent Based Modelling (ABM).

With respect to Econometrics and SD paradigms, those in favour of econometrics models criticise the 'lack of rigour of SD for the 'operationalisation'[5] of concepts and statistical uncertainty. In contrast, the perspective of SD modellers recalls the faithfulness of the econometrics models.

Borshchev and Filippov (2004) and Morecroft (2005) include in their work comparisons between SD and Discreet Event (DE) paradigms. They state that the principal difference between SD and DE is that in SD the models are deterministic, i.e. it is the structure of the models that generate their behaviour. On the contrary the complexity of behaviour in DE is determined more by the randomness of the model variables. The paradigm of modelling DE is not analysed in detail in this paper as it is considered as a precursor of ABM, a method of hybrid simulation that is seen as an evolution of DE.

Scholl (2001) lays the groundwork for discussions and research into the differences between SD and ABM.

Schieritz and Gröber (2002) argue that ABM is the most appropriate paradigm for manipulating concepts of 'emergency and complexity'. Consequently, Lorenz and Bassi (2004) accept that ABM can be a valid paradigm that functions better in what is known as adaptation processes, but at the same time, the authors strongly favour SD for its simplicity of language, a characteristic that often referred to as 'comprehensibility'. Conversely, the understanding of relationships between variables and the general functioning of the ABM paradigm is harder to understand.

Rahmandad (2004) in his paper contributes further to the concepts of heterogeneity and network structure to the comparison between SD and ABM. This author points out that models of ABM incorporate heterogeneity in the agent attributes and in the structure of interactions. The low level of aggregation used by ABM allows capturing of the learning, the behaviour and the dynamics of complex systems. However, this same characteristic could potentially reduce the comprehensibility of the results that are obtained.

5. Evaluating the suitably of the modelling paradigm

The preceding discussion has emphasised the advantages and disadvantages of the Econometrics, ABM and SD modelling paradigms. The question now is how to determine where one modelling paradigm may be more appropriate than another. It is pointed out that it depends on what purpose it will serve and what the characteristics of the system are to be modelled.

With respect to this purpose, two types of models are possible: (1) models primarily aimed at producing "acceptable results" (prediction) and (2), models geared towards an "adequate representation" of the system (explanatory)[6]. Prediction models are typically found in technical sciences, whereas explanatory models are more convenient in respect to analysing systems that are complex, and where the underlying theory is confusing or data retrieval is difficult.

Organisational systems involve many soft variables which date is difficult to locate and it is complex to define a way of measuring them. This peculiarity allows us to think that an explanatory modelling paradigm could be more useful to explore the organisational problems than paradigms focus on prediction.

Paradigms models orientated to produce explanatory models have a great potential for:

- Be understandable.
- Allow experimenting different scenarios.
- Embody accurately the concerned problem.

Besides, the characteristics of the system that we want to model are another important aspect to determine the suitably of a modelling paradigm. According to the features of the modelling paradigms we could determine if a paradigm model could appropriately represent the analysed system. Table 2 shows how paradigms feature are related to the important aspects that determine the suitably of a modelling paradigm.

	Distinctive paradigm features					
	1	2	3	4	5	6
Explanatory purpose	•					
System Characteristics		•	•	•	•	•

Table 2: Correspondence features with the purpose and system characteristics

Representation (1), Handling of time (2), Comprehensibility of cause-effect relations (3), Aggregation level (4), Handling of space (5), Capture of heterogeneity (6).

These paradigms features are used to describe differences between the three modelling paradigms analysed. So, related to accomplish the phases 3 and 4 of the methodology (Figure 1) the next steps are propose:

Step 1: Define the different between Econometrics, ABM and SD paradigms.

Step 2: Determine the hypotheses to analyse the paradigms' suitability for modelling organisational problems.

Step 3: Design some questions to validating the hypotheses using the participation of a management expert.

[6] Source: Contributions to the epistemology of modelling http://www.complexityscience.org/NoE/epistemoloyofmodelling.pdf

5.1. Step 1: Defining the differences between the paradigms

Based on a case modelled in Econometrics, SD and ABM paradigms (Ortiz, et al. 2005) and the distinctive features of paradigms shown on table 2, we identified the differences between the paradigms (Table 3).

Distinctive features of paradigms	Econometrics	SD	ABM
Purpose	Prediction	Explanatory	Explanatory
Handling of time	Static or continuous	Continuous	Hybrid (Continuous with Discreet)
Representation	Equation	Feedback loop	Agent structure
Comprehensibility of cause-effect relations	Complex	Visual structure	Implicit loops
Unit of analysis	Parameters	Structure	Rules
Level of aggregation	High	Medium-High	Low-High
Origin of Dynamics	Variables relations	Levels	Events
Handling of space	Not treat	Not treat	Employ
Capture of heterogeneity	Not treat	Complex	Employ

Table 3: Differences between the modelling paradigms

Some of the differences could be explained as:

- Representation: In Econometrics, differential equations the central element as well as the representation is. In addition, SD and ABM use graphical representation of the models that facilitate the understanding of relations. The representation by the structure of agents of ABM is more natural compared with SD representation, but is more difficult to establish the relations between the variables.
- Comprehensibility of the cause-effect relations: SD is a consolidated paradigm, where different tools have been developed with the goal of improving the problems that result from the modelling of systems. The causal diagrams are a good example of the tools that are offered by SD and greatly assist the comprehension of the relations between key variables of the studied systems.

  On the other hand, ABM has greater focus on the concept of emergency. In SD and Econometrics the model structure is defined, whereas in ABM the rules that govern the behaviour of the agents in an environment are identified. The general behaviour of the model emerges from the interactions between the agents as determined by its behaviour rules. This condition results in the models of ABM being more natural, but at the same time it can be seen as a disadvantage as it is harder to determine the causes and their effects.
- Unit of analysis: SD is characterised by giving greater importance to the definition of the model structure and establishes the relations between variables of stock, flow and auxiliaries. ABM also gives importance to the structure, but is more focused on the definition of rules, events or functions that can potentially modify the state of the agents, and therefore the behaviour of agents in the complete environment.

- Level of aggregation: The objective of constructing the model and its expected capability determines the most appropriate level of aggregation. While in Econometrics there is a high level of aggregation, SD and ABM offer the possibility to work with both high and low levels of aggregation. However, this could became a complicated model and be more difficult to understand especially for SD.
- Origin of dynamics and heterogeneity: Econometrics and SD models are dynamic models, where each instance of time, variables are calculated as a function of their relationships with others and their assigned values in the past. This feature arguably constitutes the most important characteristic of ABM.

  ABM is given the named hybrid simulation since it combines continuous simulation with the event-discreet simulation. The possibility of being able to offer the combined types of simulation has the advantage that continuous behaviour of a system can be redirected or modified by the occurrence of a single event. It is known that it offers the possibility of defining different states for the agents, which modify the behavioural rules of agent-agent or agent-environment.

5.2. Step 2: Determining the hypothesis

Once the differences of each paradigm have been defined, the next step consists of investigating and defining the requirements that users would most desire in a model and how the paradigms fit with these requirements. In order to accomplish these two aims, this work suggests modelled a system with Econometric, ABM and SD paradigms. Through which it could be possible to value the theoretical differences between the paradigms that are commented throughout the paper.

We have identified two groups of hypothesis to validate. The first group aiming at identifying the requirements of the systems analysed and a second group focus on value the suitable of each paradigm to represent the analysed system. This distinction allows us to set up following hypothesis:

- Hypothesis about the requirements of the system analysed.
- Hypothesis about the suitable of each paradigm.

In order to arrangement the hypothesis, we will characterise they with some defined features of paradigms (table 3): purpose, handling of time, representation, comprehensibility of cause-effect relations, level of aggregation, handling of space and capture of heterogeneity.

5.2.1. Hypothesis about the requirements of the system

This first group of hypothesis try to identify the requirements of the systems analysed. So, it is necessary define a specific system to be modelled.

Since the increasing importance of soft variables in management context and the possibility to use different levels of aggregation to analyse the system, we have selected to model a system about “Management projects”.

On the one hand, Management projects involve soft variables as: organisational climate, staff capacity, staff pressure, work quality, clients and employee satisfaction, reputation for quality among others, all of this that are difficult to measure. So, a model could be broaden the managers point view and offer more information to making strategic decisions.

On the other hand, depending of the required detailed level, Management projects should be analysed with a high, medium or low level of aggregation. For example, a low level of aggregation should be necessary if the considers necessary to study individually or by clustering, how interactions (such as staff moral on individual productivity) affect the development of a project. If a high level of aggregation were used, the manager may only wish to know average influenced of the staff moral on averaged productivity.

The ability to use different levels of aggregation allows one to study substantial differences between paradigms, with respect to characteristics of heterogeneity, handling of time, emergency.

In consequence, the hypothetic requirements to model a management project system are summarised on table 4:

Features of paradigms	Requirements to build a Management project model
1.Purpose	Explanatory
2.Representation	Understandable
3.Handling of time	Hybrid
4.Comprehensibility of cause-effect relations	Understandable structure
5.Aggregation level	Low
6. Handling of space and emergency	Employ
7. Capture of heterogeneity	Employ

Table 4: Requirements to build a Management project model

Finally the hypotheses about the requirements to build a Management project are defined as:

- H1: Because the characteristics and difficulties that involve soft variables in management project models, it could be more benefit focuses on modelling with an explanatory purpose.
- H2: The representation need to be enough understandable in order to use the model to making decision process about management projects.
- H3: Hybrid simulation (combination of continuous and discreet event simulation) offers benefits to represent the management projects models because allow defines discontinuous events as layoff of employees, or other important events.
- H4: It is important that the cause-effect relations in the model can be easily recognize to understand the performance of the system.
- H5: The aggregation level should be low in order to know the influence in the general behaviour from the soft variables.

- H6: The model should employ the handling of space to represent how the general behaviour is influenced by physical position of the persons or where people are influenced by their context.
- H7: In Management projects the heterogeneity of the persons is an important aspect because each individual is different and they use to form social networks and clusters.

5.2.2. Hypothesis about the suitability of each paradigm

The second group of hypothesis focus on value the suitable of each paradigm to represent the project management models. The assumptions presented are based on previous discussion about the differences between the paradigms. The hypotheses are:

- H1: While the purpose of the Econometrics is to focus on prediction, SD and ABM are better to explanatory purpose what is more useful to study organizational problems.
- H2: The representation by the structure of agents of ABM is more natural than that of SD and Econometrics models.
- H3: The hybrid simulation of ABM is more useful because permits the modeller define specific functions for the occurrence of certain discontinuous events through which the overall behaviour could be modify.
- H4: The use of feedback loops in SD to describe the system is very useful to demonstrate the causes and effects and aids the comprehension of results.
- H5: The aggregation level of Econometrics is high. SD and ABM deal with both high and low levels, however this could become a complicated model.
- H6: Describing a physical position represent a benefit to study complex systems.
- H7: The ABM possibility to define heterogeneity and different states for the agents who modify their behavioural rules is very useful to study organisational topics.

5.3. Step 3: Validating the hypothesis

In order to validate the previous hypotheses about the characteristics of the project management model and the suitability of each paradigm to represent the systems it is considered more appropriate to take into account the participation of a management expert. Hence, once the model in each paradigm has been built and presented to the management expert, the following sequence of design questions are to asked to evaluate the hypotheses:

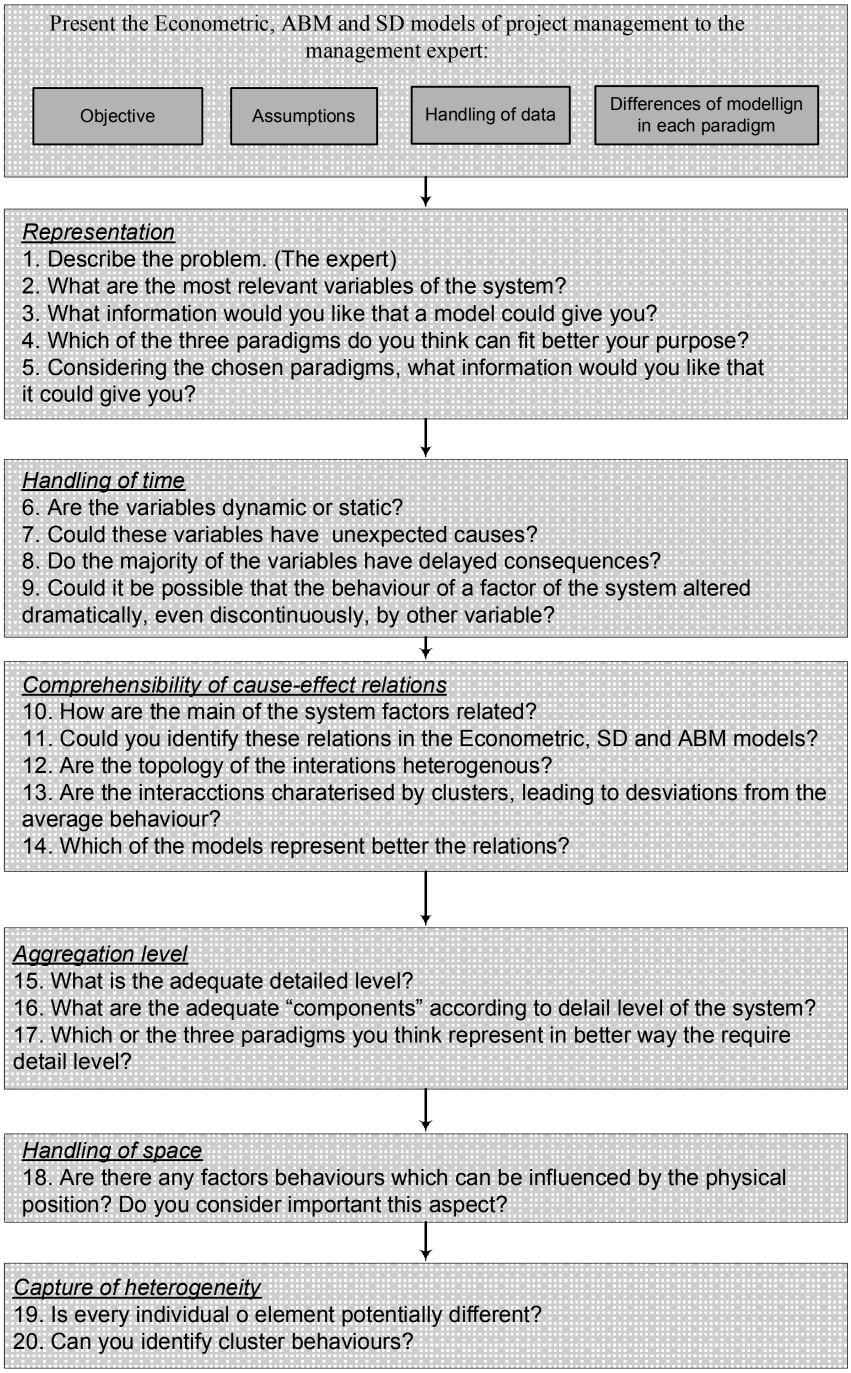

Figure 3: Design questions to value the hypotheses

6. Conclusions and Implications for Future Research

The purpose of this paper was contributed to determine the suitability of Econometrics, ABM and SD modelling paradigms for study organisational problems. We point out that a modelling paradigm is considered suitability to study a specific problem if it fulfils two requirements: represents accurately the analysed system and be useful for the purpose to the model will serve. Besides, these requirements are related with nine features of paradigms which have been identified. Seven out of the nine features will be considered in a project management model that will be developed and presented to a management expert according to a sequence of design questions.

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