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DEFINITION OF THE COLLABORATIVE SIMULATION SYSTEM (CM&SS) FROM A SYSTEMIC PERSPECTIVE IN VEHICLE INDUSTRY CONTEXT

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Abstract

During the last decades modelling and simulation technics has grown in importance in the product development context. For example, from an industrial point of view, simulation models seem to be an excellent alternative on vehicle construction and more specifically, in the decision making process. Nevertheless, the simulation activity becomes more difficult with the complexity of the product, highlighting more and more often a collaborative problem on the organization of the product development. But, how can this problem be defined? Several collaborative approaches have been proposed in this field. However, the majority of those approaches concern only one dimension of the problem. This paper introduces the Collaborative Modelling & Simulation System (CM&SS) from a systemic perspective in vehicle industry context. The systemic approach enables the definition of different dimensions of the system aiming at a successful performance of a collaborative simulation.

Keywords: Collaborative design, Organization of product development, Process modelling Collaborative simulation, Systemic approach.

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1 INTRODUCTION

The present work has been developed in SIM project context (French acronym for Multidisciplinary Simulation and Engineering) at the Research Institute of Technology (IRT) SystemX in partnership with Industrial Engineering Laboratory (LGI) from Ecole Centrale Paris. Since the project has two industrial partners: *Renault and Airbus Group*, the main framework of this research is related to vehicle construction for both, automotive and aeronautics industries.

Vehicle construction is a complex universe based on real or simulated tests. Simulated tests take part in Modelling and Simulation (M&S) technics, those technics have grown in importance in the last decades in different fields. In aeronautic and automotive industry context, M&S technics, along with packages of documents and applications describing the vehicle at different stages of the development, make part of the virtual representation of the vehicle, also called *Virtual Vehicle.* A subassembly of it, is the *Behavioural Virtual Vehicle: BVV*. Since this research is related to both aircrafts and cars, this work states BVV even if the aeronautic industry already refers to as BDA, Behavioural Digital Aircraft (CRESCENDO Consortium Members, 2012).

BVV is obtained by processing elementary objects. This processing is insured by collaborative capacities such as support and organisation. However, those capacities have a value in the organization only if they are performed by a team. The team, the processing of the capacities and the virtual objects (simulation models, documents, applications, etc.) constitute a complex technic society. The need to organize the simulation models, people and capacities is the heart of our research.

Several collaborative approaches have been proposed in modelling and simulation field. Nevertheless, the majority of those approaches concern only one dimension of the problem, such as interoperability problem or monitoring difficulty (Roa Castro & Stal-Le Cardinal, 2014). In the same work a definition of collaborative characteristics in M&S context was proposed. The present paper introduces the *Collaborative Modelling & Simulation System (CM&SS)* from a systemic perspective in vehicle industry context. The systemic approach enables the definition of the system from different axis, allowing a better description of the dimensions and highlighting the relationship between them. This approach will favour a successful performance of a collaborative simulation.

This document is divided into 4 sections. Section 2 introduces the systemic approach and the CM&SS, Section 3 presents the four main axes of the CM&SS and section 4 is dedicated to conclusions and future work.

2 COLLABORATIVE MODELLING AND SIMULATION SYSTEM: CM&SS

Since a lot of collaborative M&S works can be found in the literature, and given the variety and the complexity of its definition, it was necessary to find a holistic and extensive approach, convenient to the industrial partners and allowing a characterisation of the collaborative simulation as complete as possible. The *systemic approach* seems to answer that need. The CM&SS (Collaborative Modelling and Simulation System) proposed in this work is then based on the systemic approach. Subsection 2.1 presents an overview of the systemic approach. Subsection 2.2 presents the CM&SS principles.

2.1 Systemic Approach

The traditional systemic approach was proposed by Jean-Louis Le Moigne in his book *Approche systémi*que (Le Moigne, 1990). J.L. Le Moigne perceived the complex system as a structure irreducible to an analytic, causality or deterministic model. The complex system is constantly evolving and is defined by four main axes: teleological, genetic, functional and ontological. The teleological axis refers to the objectives of the system. The genetic axis concerns the evolution through time of the system. The functional axis describes the functions of the systems: what the system is supposed to do. Finally, the ontological axis characterization is about the resources of the system. Figure 1 illustrates the vision of the complex system from J.L. Le Moigne.

In 2009, A. Schindler (Schindler, 2009) proposes an adaptation of systemic approach, based on one of the teaching program at Ecole Centrale Paris. This adaptation presents the four axes as a directional method in the construction of a complex system. In addition, once the system has been built, a verification of each item should be done by going backward. A. Schindler adaptation is presented in Figure 2. In order to have a better illustration of the equivalence between both approaches, the four rectangles on Figure 2 point out the four axis proposed by J.L Le Moigne (1990).

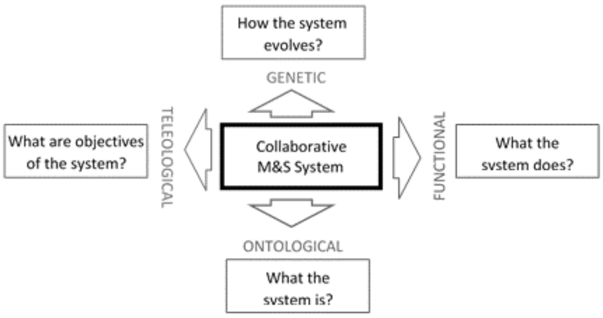

Figure 1 : Systemic Approach. (Le Moigne, 1990)

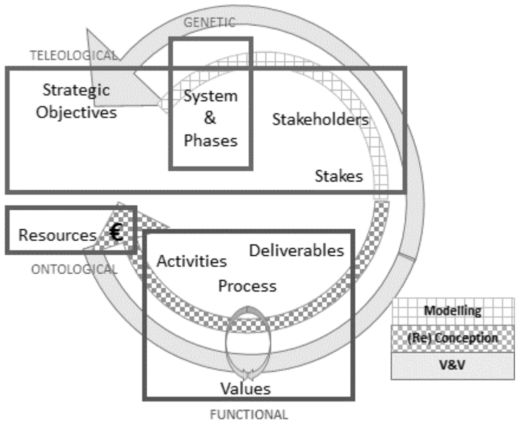

Figure 2 : Systemic Approach (Schindler, 2009) and correspondence with systemic approach (Le Moigne, 1990)

2.2 The CM&SS: Collaborative Modelling and Simulation System

Based on both approaches, this paper aims at defining a Collaborative Modelling and Simulation System. From this point forward called CM&SS. This section presents the basics of each of the four system axes: teleological, genetic, functional and ontological. Then, in section 3, a deeper presentation of all axes will be done.

Teleological axis defines the environment of the CS&SS and the added value expected from the system. The environment is represented via four features:

- Stakeholders of the system
- Organizational stakes
- Principal objectives
- Perimeter

The added value of a system is usually related to the product or service given by the system. The service supposed to be delivered, in a future, by the CM&SS is related to the orchestration of different elements of the collaborative system in order to have quality solution for the decision maker as soon as possible.

Genetic axis has two main objectives. The first one is the definition of the lifecycle of the system itself. The second one is related to the way of how the system will evolve in the future. For now, the work is concentrated on the definition of the lifecycle of the CM&SS.

The functional axis of the CM&SS is supported by the definition of the valued-added collaborative process. The process is linked to indicators in order to manage the collaboration and to have a return of experience.

Finally, the ontological axis refers to the means and resources of the systems, it could be material or human. The materials resources of the CM&SS are related to the IT platform as a system support. The human resources refer to the actors who act on the system.

The CM&SS from a systemic point of view is represented in Figure 3. The bold arrows represents the links between the different axes. Those links refine the description of the system, making its interest clear and improving its comprehension. The links can be understood as follow: The CM&SS aims at processing of the simulation artefact (virtual object). The processing is carried out taking into account the organizational stakes, the perimeter of the system and the stakeholder points of view.

The execution of the CM&SS is done by the human resources (actors). The actors make part of the stakeholder. Their skills allow the construction of the simulation artefact. This construction keep their *Knowledge print* on it. In addition, they make part of a big network, involving important relationships.

The execution, the sharing and the control of the CM&SS is founded on collaborative process. Those process support the added value creation by means of IT tools.

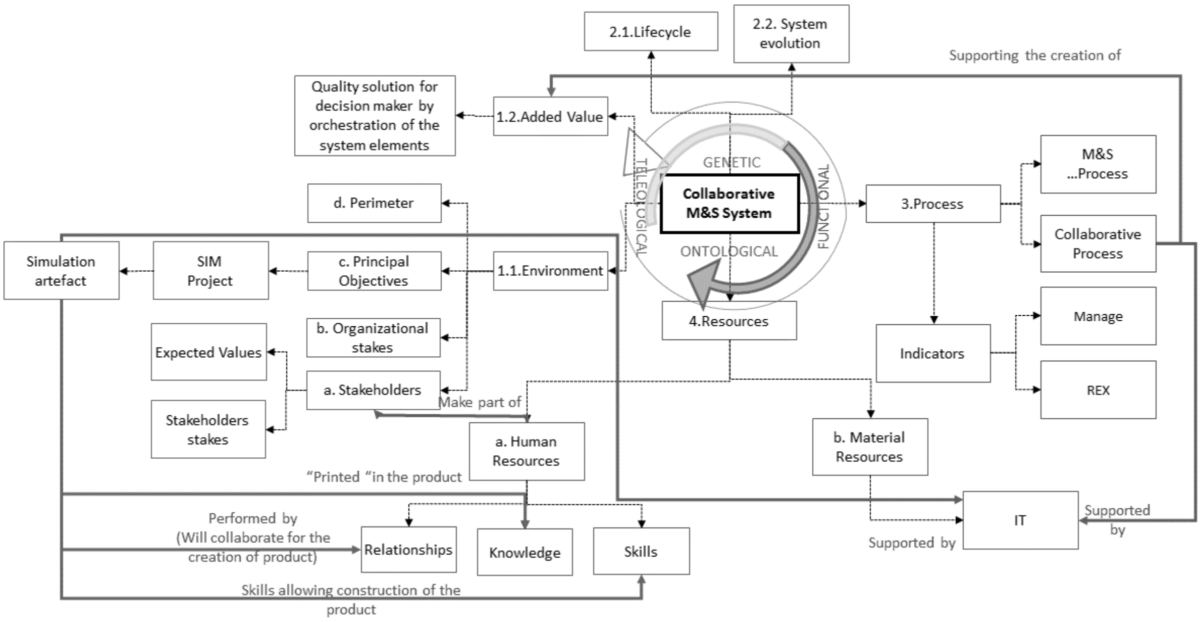

Figure 3: Systemic representation of the Collaborative Modelling and simulation System CM&SS

3 CM&SS AXES

3.1 Teleological axis

As mentioned in subsection 2.2 the environment of the CM&SS is represented via four features. This sub-section is dedicated to the explanation of those characteristics.

3.1.1 The stakeholders

Because the simulation practice helps in the decision making process and the decision are taken by people, the most important part of the system environment are the stakeholders. At the end, a success collaborative simulation serves to decision maker. An analysis has been done aiming at finding the principal stakes and attended values of the stakeholders. This analysis was built on the work of (Roa Castro & Stal-Le Cardinal, 2015) and is briefly presented in this paper.

Considering different interpretations of *stakeholder* and system actors, two definition founded on the literature are settled for this research so as to avoid misunderstanding of their meanings.

- Stakeholders: Individuals and groups who affect or are affected by organizations' actions. (Smudde & Courtright, 2011)
- Actor: anything with behaviour that acts on the system. A primary actor initiates interaction to achieve goal. A supporting actor: performs sub-goals to help use case (Cockburn, 2000)

In CM&SS context, the actors will be referred as a *human resources* of the system. Likewise, in this case the actors of the CM&SS make part of the stakeholders but all the stakeholders are not necessary actors.

The choice of the stakeholders of CM&SS was done regarding *Renault and Airbus Group* organisation. Both companies have a hierarchical structure for their engineering department. Moreover, they both implement a matrix organization for a given programme (e.g. A320 program). For the engineering department, this organization means that some of their people will work a limited quantity of time for a given program. The program organization has a particular structure for the simulation process. (Sirin, et al., 2014) Propose three view points for the detailed model design phase: System architect, model architect and model supplier. Those points of view correspond a three roles in the organization program. Figure 4 from (Roa Castro & Stal-Le Cardinal, 2015) illustrates the matrix organization and the main roles. The cross in the table illustrate the simulation organization for a given program. Program organization is temporary, whereas engineering organization is longer-lasting. The simulation requirements for a program are fulfilled by calling people from engineering organization. Then, people that usually works in different engineers department is summoned to work together during the program. A detailed definition of the stakeholder, their values and their stakes in the CM&SS can be found in the same work.

	Role	Main stake	Eng. Organization / Program Organization	Vehicle manufacturer: Program director	Engineer expertise A	Engineer expertise B	Engineer expertise C	Engineer expertise D	Engineer expertise E	Research and technology	Strategy, process, methods and tools
Vehicle manufacturer	Program management	Fulfil all requirements (cost, quality, time)	Vehicle Engineer (Programme director)	x							
	Project view		Chief Engineer								
	Functional view of the system	Fulfil system requirements (cost, quality, time)	System Architect		x						
	Structural and Behaivoral view	Succesfully M&S plug and play process	Model Architect (simulation skills)			x	x	x	x	x	x
	Physical view	Deliver the good model (quality and cost) at the right time	Model Supplier (simulation skills)			x	x				
OEM	Project view	Fulfil customer needs	Project leader			x	x	x			
	Functional view of the system	Fulfil system requirements (cost, quality, time)	System Architect	x							
	Structural and Behaivoral view	Succesfully M&S plug and play process	Model Architect	x							
	Physical view	Deliver the good model (quality and cost) at the right time	Model Supplier	x							
			Project\Eng. Organization**	R&D dept.	Operations	Marketing	Sales	Human resources	Finance and controlling		

** Generic Company Organization

Figure 4: Matrix organization, stakeholders and actors

3.1.2 Organizational Stakes

A general context of the organization objectives concerning CM&SS have been defined. The reference organizations for this research are *Renault and Airbus Group*. Those stakes were established by a common agreement during some project meetings.

The main stake is related to the development of a vehicle such as aircraft or a car by processing elementary objects by which the BVV (Behavioural Virtual Vehicle) is obtained. This development requires, amongst others, the collaboration of different engineer's teams. The collaborative capacities such as support and organisation insure the processing of the elementary objects. The team, the processing of the capacities and the virtual objects (simulation models, documents, applications, etc.) constitute a complex technic society. Bold captions in Figure 5 represent the three main elements of interest for the organization. The principle need will be the organization of the simulation models (objects), people and capacities in a vehicle development.

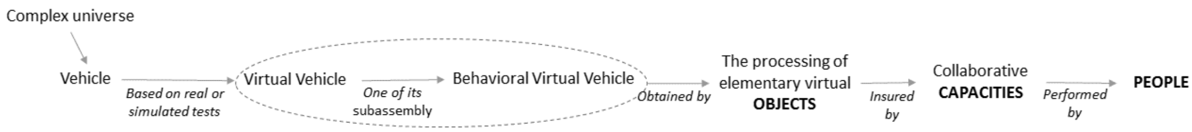

Figure 5: Organizational stakes

3.1.3 Principal Objectives

The principal Objectives are mainly related to the project. SIM project has a very specific needs and is the frame of reference of this research. The existence of SIM project can be explained by using two categories:

- Category 1: The stakes
  Three main stakes have been identified as essential for the project: the management of the intellectual property constraints, the low maturity of the current standards for simulation exchange and the interoperability problems.
- Category 2: The objectives
  Concerning the collaborative simulation problem, two main objectives have been identify:
  - Need to provide end to end collaborative process and tools, from the conception of the model architecture until the results analysis.
  - Need of a unified framework for model sharing (exchange process, a common management model including configuration management, common representation standards, co-simulation standards).

3.1.4 Perimeter

Since modelling and simulation technics are practiced in different development phases, the choice of one or two interest phases helps to focalized the research. From this point forward it will be very important to make the difference between the product lifecycle, simulation lifecycle and simulation process.

At *Airbus Group and Renault* industries, the term *product lifecycle*, makes reference to the complete life cycle of the product, from the first idea until product removal and is represented by the upper chevron illustration in Figure 6. In the other hand, the term *simulation lifecycle*, in the same context, is associated to simulation models evolution through product lifecycle. For example, in phase 0 (Need identification and mission analysis) the simulation models are less detailed and precise that in phases C (Detailed definition). The simulation lifecycle is represented by the bottom chevron illustration in Figure 6.

Finally, the term simulation process is related to the activities needed for models creation. Those activities are represented by a V cycle. Several V cycle are illustrated in Figure 6 because the models created throughout different phases are not the same but they all created based on the same process

Figure 6 represents the three lifecycles that this research deals with: product lifecycle, simulation lifecycle and simulation process.

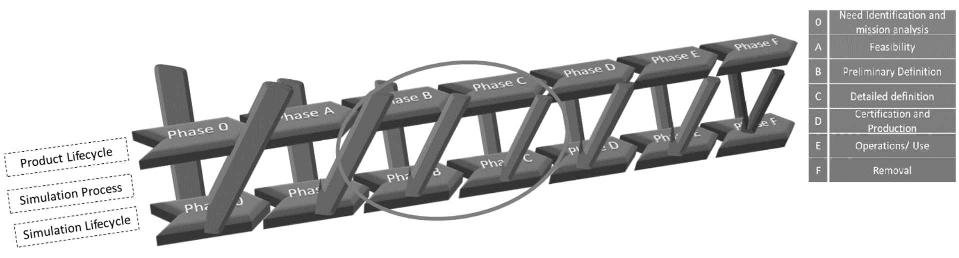

Figure 6: Research perimeter according to product development and simulation phases

Regarding all the phases, the scope of this research has been defined taking into account three factors and is delimited by the circle in Figure 6 :

- The gap in the literature: This gap evidenced in the work done by (Roa Castro & Stal-Le Cardinal, 2014) suggest a positioning of the research in the early product development phases (before fabrication) in others words, phases 0, A, B and C (0: need identification and mission analysis. A: feasibility. B: preliminary definition. C: detailed definition).
- The potential collaborative gain: A collaborative interest comes when two or more entities are presented (Bedwell, et al., 2012). As long as more and more people participate, more collaborative actions will be required. The very early phases of the development process (Phases 0 and A) concern less people and then the characteristics related to collaboration, such as communication, interaction and awareness, are easier to handle.
- The industrials needs: The engineering teams dedicated to simulation development in very early phases (0 and A) at *Airbus Group and at Renault* are about ___ and ___ respectively. However, the number of people dedicated doing the same task in phases B and C are about __ and __. Collaborative stakes seems more interesting in phases B and C (preliminary definition and detailed definition).

According to those three factors, the CM&SS will be developed by centring the attention on phases B and C, regarding carefully the variation of the collaborative process between different phases.

3.2 Genetic Axis

As explained in sub-section 2.2. Even if genetic axis has two main objectives. For now, the work was concentrated on the definition of the lifecycle of the CM&SS.
Simulation process is common expressed by using a V cycle diagram, some example can be found in the system and software engineering and systems and lifecycle process standard (Standard: ISO/IEC 15288:2008 , 2008). Figure 7 presented below, proposes an adaptation of the standard to the simulation process. The variation regarding other adaptations presented before (ProSTEP iViP, 2014) or (Sirin, et al., 2014) is the difference made between the system level and the model and simulation level, already proposed by (Chen, et al., 2014) and the inclusion of the main stakeholders. In addition. The circles on the figure highlight the main adaptation regarding the standard ISO15288.

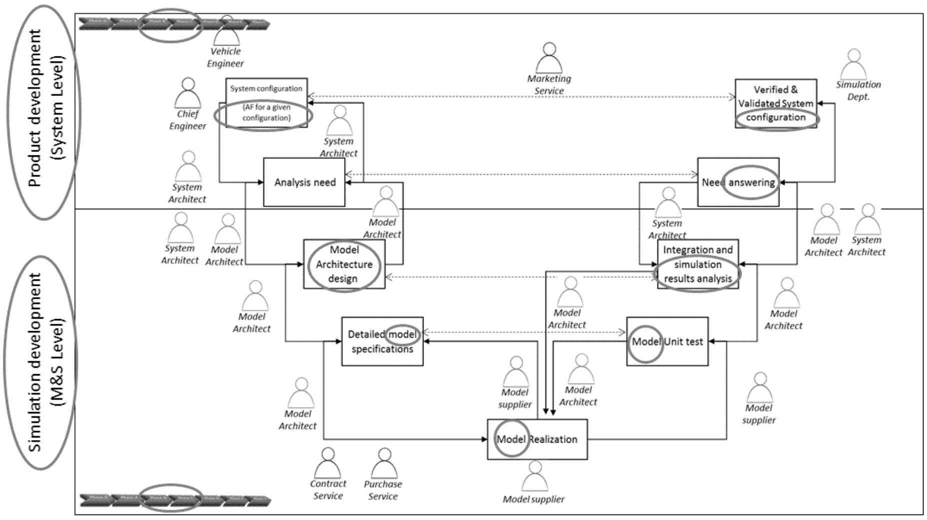

Figure 7: Simulation process

3.3 Functional axis

This axis is focused on the creation of the added- value collaborative process and the indicators linked to the process allowing collaboration management and retour of experience.

3.3.1 Process

Two main process are of the special interest of the system: modelling and simulation process and collaborative process for modelling and simulation. Modelling and simulation process concerns the development of the model itself. This process was identified from several workshops at *Renault* Company. An outline is presented in (Roa Castro & Stal-Le Cardinal, 2014). From this work, a summary of industrial needs on collaborative work in M&S domain was presented.

The collaborative process for M&S, will be defined in future work using coming industrial audits

3.3.2 Indicators

Once the process will be proposed, some indicators will be defined concerning mainly: the management of the collaboration process and the retour of the experience. This indicators will be determined regarding also the expected values of the stakeholders.

3.4 Ontological axis

As explained before, ontological axis is related to the resources of the system. CM&SS has two kind of resources: human resources and material resources. A concisely description is presented in subsection 3.4.1 and 3.4.2 respectively.

3.4.1 Human Resources

The human resources of the CM&SS can also be called the *actors* of the system. As defined on section 3.1.1, an actor will be the person acting on the system. The primary actors of the CM&SS will initiate the collaboration to achieve a goal. The supporting actor will perform sub-goals to help according with the global objective. The notion of primary and supporting actor has been proposed by (Cockburn, 2000). Another important mention in CM&SS is the relationship between an actor and a stakeholder. The actors of the CM&SS make part of the stakeholders but all the stakeholders are not necessary actors.

For the moment, we propose three main attributes of the actors: their relationship, skills and knowledge.

- The relationship: The relationship of the actors will be extremely related to their main stakes. This attribute is also associated to some collaborative features such as team cooperation, coordination, communication interaction and awareness. A deeper description of those features is proposed in the literature by (Bedwell, et al., 2012) and (Salas, et al., 2000).

Skills and knowledge features are closely linked to Modelling and simulation problem.

- The skills: An evaluation of the skills concerning the persons within organization, will be necessary in order to define the actors of the CM&SS because modelling and simulation process requires a very specific expertise according to the system to be developed.
- The knowledge: this attribute constitute a key point for the simulation organization because of two main reasons: First, a model is a representation of a system, used to understand the reality (behaviours), built on a solid scientific basis. The scientific basis makes reference to the skills. The understanding of the behaviours makes reference to the knowledge put in the model as fingerprint. A model externalizes the comprehension of a system, revealing the potential scientific clues. This leads also to the second reason: the intellectual property (IP) constraints. When the model exchange takes place in the extended enterprise, IP problem regarding the disclosure of specific contents is more delicate. Some approaches as a withe, grey and black box has been proposed aiming at the protection of this knowledge. (Lee & Kim, 2013).

3.4.2 Material Resources

In the future, CM&SS will be supported by an IT platform, this application should materialize the concepts developed during the research and will be tested by the partners of the project: *Renault and Airbus Group*.

4 CONCLUSION AND FUTURE WORK

The systemic approach presented in this paper permits the characterization of the Collaborative Modelling and Simulation System (CM&SS) and allows us to succeed in a global vision of the system.

By adapting the traditional systemic approach to this research, four main axes of CM&SS have been introduced (teleological, genetic, functional and ontological). The four axes have been split in elementary items related to our system, the systemic approach highlights the relationship between them, giving us a complete vision of what the CM&SS should be.

The Systemic representation of the CM&SS in Figure 3, introduced in subsection 2.2 shows the complete system. Figure 8 presented below, is focused on the main elements of the system and their relationship. Those elements have been chosen under interconnection criteria, that is, the elements interconnected from different axis. From this figure, we conclude that: the CM&SS is an actor based methodology, aiming at the performance of a simulation object (simulation artifact), supported by added-value collaborative process implemented through an IT platform. It will be developed by focusing on phases B and C of the product development (B: preliminary definition. C: detailed definition). But regarding carefully the variation of the collaborative process between different phases. The orchestration of different elements of the system will lead to a quality solution for the decision maker as soon as possible.

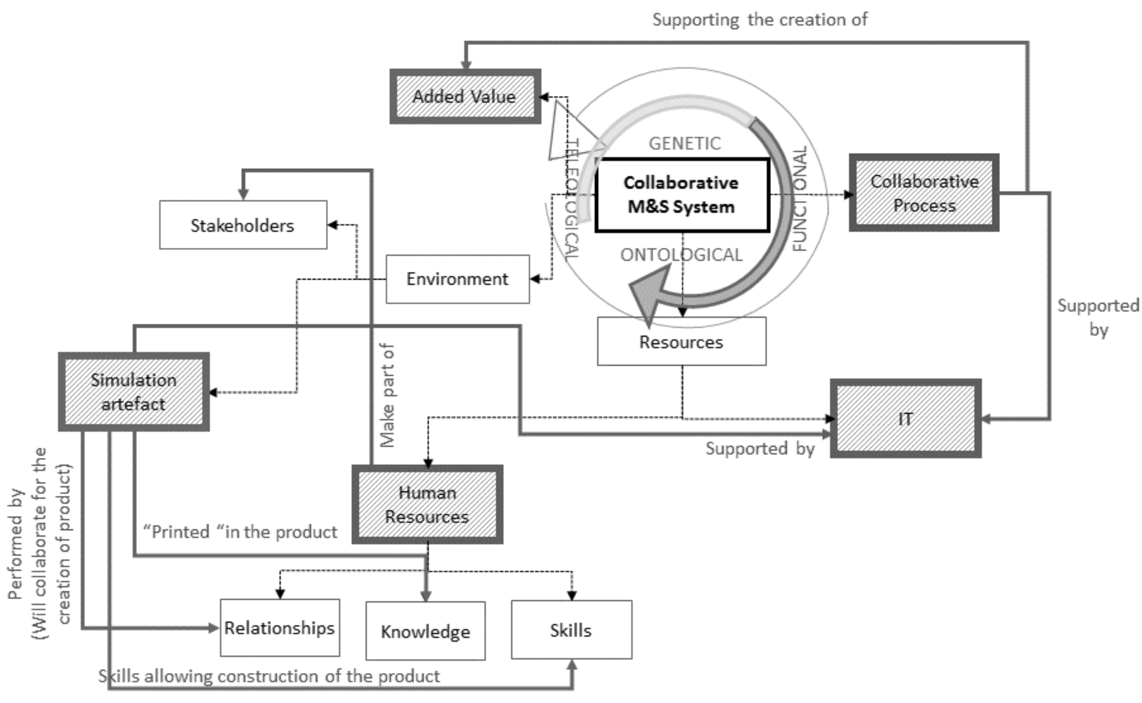

Figure 8: CM&SS principal elements and main relationship

Future work will be emphasized first, in the definition of added-value collaborative process and its indicators, regarding the simulation artifact and the human recourses (Actors) description. We also plan to study in depth, the actors, since CM&SS will be an actor based system, their relationship, knowledge and skills that deserved to be widely considered. In a second time, an IT platform will be proposed based on the methodology.

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