A Multi-Agent Approach for modeling a Quality Management System with UML Class and Sequence Diagram

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Abstract

In this article, a multi-agent approach modeled by the UML (Unified Modeling Language) is used to solve the piloting problem of Quality Management System QMS. Indeed, this multi-agent modeling of QMS proposes the use a micro framework via a dynamic diagram and macro through a static diagram for the agents development. From this modeling, an information system can be implemented in order to ensure the QMS conformity and effectiveness to the requirements of the series standards ISO 9000, ISO 9001, ISO 9004. In this context, an industrial company example will be proposed and the improvement prospects will be illustrated there.

1. Introduction

In an increasingly competitive international context,the companies constantly need to adapt and optimize their industrial tools in order to increase their productivity. In particular, the QMS piloting is evaluated according to several parameters (cost, time, customer satisfaction, performance indicators, audit score, quality control, etc....) taking account its contribution to defining the yield and hence the company competitiveness. The need increased for flexibility, agility and effectiveness of QMS results in a growing complexity which it is necessary to know the model and so to control it. In this context, the object oriented modeling is a method which already proved its worth [1]. Indeed, the software and systems designers have a modeling methodologies and languages for the various components system design. For that, the standard modeling UML name was imposed since it is known the most and more used modeling languages [2].

In addition, the Multi-Agent Systems (MAS) designers use another language Agent UML which is not other than an extension of UML language [3] [4]. Indeed, the agent-oriented simulation replaces gradually the various techniques of objects oriented simulation. This is due to several factors that are: (a) its capacity to apprehend many different individual models, from very simple entities to more complex entities; (b) its facility with which various representation levels can be handled by one of the various models. This diversity makes MAS the choice support for the complex systems simulation.

Moreover, the UML agent modeling integrates the differences which exist between the agents and objects [5]. We can cite: (a) the *MOTIV-PTA* application evoked by [6] which uses the UML agent concept to a real application presenting the behavior concepts inside an agent and its relationship with outside; (b) the UML Agent application to the logistics chain management in order to define a methodology and tools to help the designers, to evaluate and to show that UML agent can be applied to the real applications [7]; (c) the multi-agents piloting through a holonic approach for a manufacturing system of safety glass [8].

To manage a QMS, a MA approach is used since the correspondence existing between the physical entities (process) and the agents [9]. It is thus possible to represent, analyze and study the MA piloting for a QMS [16].

This paper is organized as follows. Section 2 presents a brief recall on the new multi-agent approach for modeling QMS. Section 3 proposes UML class and sequence diagram. In section 4, we present a real case as an example to validate our model.

2. A brief recall on the new multi-agent approach for modeling QMS

Referring to the identified requirements of ISO 9000, ISO 9001 and ISO 9004 [10] [11] [12] and the foundations of the process approach; we can identify five types of processes namely:

- A direction process that will listen to customer expectations, setting objectives, providing resources, decision-making and confirmation of actions for improvement.

- A resource process that cares about the identification of necessary resources, ensuring the competence of human resources and maintaining infrastructure and working environment.
- A realization process that will take into account customer requirements and ensure the production planning in meeting the product requirements.
- A monitoring process that will focus on controls of products, performance measurement processes and detecting non-conformity.
- An improvement process that will be useful for the analysis of monitoring results and propose corrective and preventive actions and adequate improvement.

All these processes will interact to ensure the effectiveness of the organization.

From this identification, we can create structuring model QMS-MAS. Indeed, we can see similarities between the concept of a process and an agent. In one hand, the processes that have objectives, interact, communicate, monitor and improve through action plans. In another hand, the agents that have objectives, cooperate, coordinate and act to achieve their goals.

The multi-agent modeling of a QMS processes is to define a distribution of competences and knowledge (agents), to provide a tool for restructuring (interaction) and to clarify the rules of reorganization (the organization). Therefore, the idea is to modelize each internal process QMS as the concept of the Deming wheel which is structured as PDCA (Plan, Do, Check and Adjust). Each stage of PDCA will be symbolized by four agents knowing that this representation differs from one process to another. This approach is diagrammed in Figure 1.

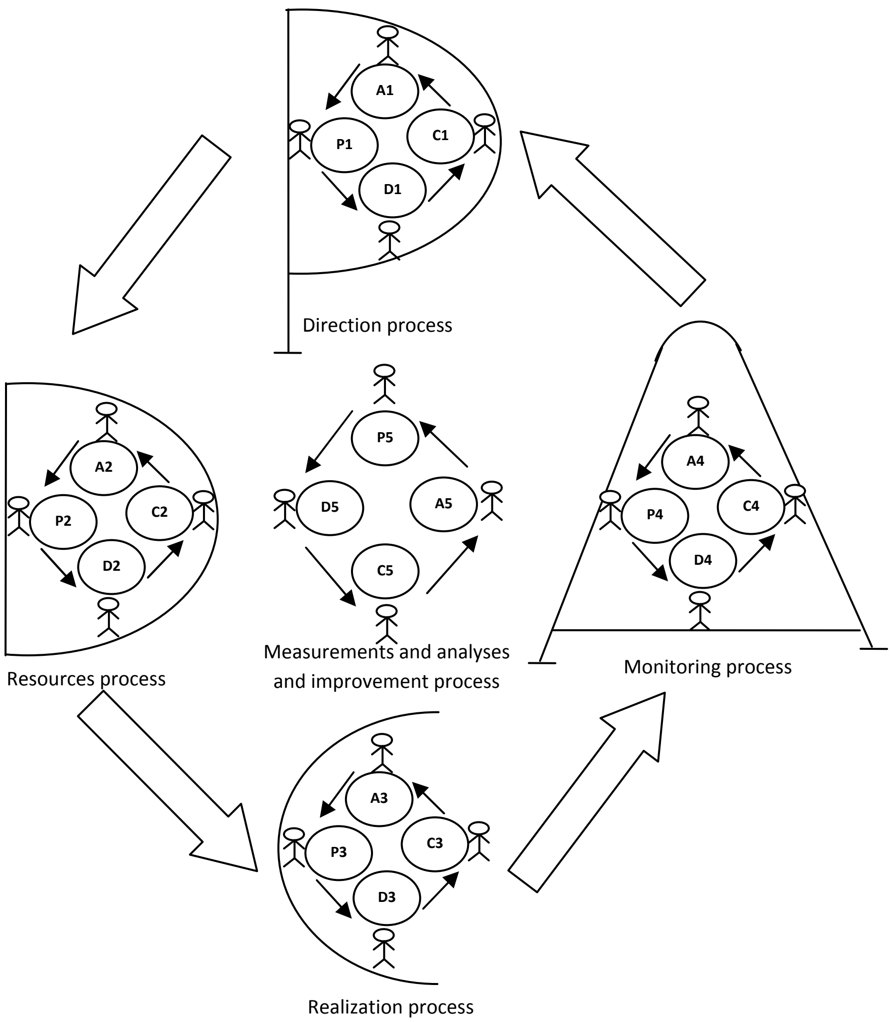

Figure 1. Model QMS-MAS

3. UML Class and Sequence Diagram

The UML models the objects and their links to form diagrams. We distinguish several representations proposed by UML that are objects, class, use case, components and deployment diagrams which correspond to static diagrams; sequence, collaboration, statechart and activity diagrams that correspond to dynamic diagrams.

In this paper, we focus exclusively to the class diagrams (static structure) and to the sequence diagrams (dynamic structure) since this design mode based on the object-oriented programming.

The MAS generic modeling propose the use a micro framework (the agents structure through a dynamic diagram) and macro (the organization structure through a static diagram) for the agents development. Indeed, one directly related to the platform is used for the MAS implementation known as QMS structure represented by the class diagram, and the other, said QMS agents structure represented by the sequence diagram which leading to the MAS generic modeling [17].

3.1. Static structure: Class diagram

The macro analysis stage consists to identify the agents roles within the QMS and associates the communications protocols which make it possible to set up the interactions organization between the various agents.

Therefore, this structure allows handling entities and attributes classes (variables) with methods (functions using attribute). The classes are connected with each other by the simple dependency or hierarchy (the heritage) relations. Basing on standards ISO 9000 [10], ISO 9001 [11] and ISO 9004 [12], we can summarize the different QMS requirements. It should be to model the system structure that can best respond to the efficiency and the customer satisfaction.

Moreover, while basing on the process approach and the DEMING Wheel concept (Plan, Do, Check, Adjust PDCA), we have identified the different processes of QMS and assigned to each process four agents that represent the PDCA cycle. Thus, the direction process is associated with four agents P1, D1, C1 and A1; the resources management process with P2, D2, C2 and A2 agents; the product realization process through P3, D3, C3 and A3 agents; the monitoring process with P4, D4, C4 and A4 agents and the measurements analyses and improvements process of QMS via P5, D5, C5 and A5 agents [13].

Each agent cited above will represent a class; moreover, we will add another class that represents the "Customer" agent. Its role is to propose expectations to agent P1, requirements to agent P3, claims to agent D4, and criteria to agent C4. Thus, this principle has a consequence to add the following objects: "Expectations," "Requirements," "Claim," "Planning surveys." Other objects were implicated in identifying the interaction from one agent to another: "Objects", "Actions," "Resources," "Products", "Audits", "Performance Indicator", "Quality Control" "Surveys", "Non-conformity/Risk", "Defects", "Assessment/Analysis ".

Also, different objects that can store information related to the various objects planning mentioned above such as: "Planning objects", "Planning resource", "Planning product", "Planning audit", "Planning performance indicators", "Planning quality control", "Planning claims" and "Planning assessments". Figure 2 represents the class diagram of QMS.

3.2 Dynamic structure: Sequence diagram

In the micro context, the agent structure will be shown through a dynamic diagram, which is the protocol diagram, also called sequence diagrams in UML. They represent the message exchanges (interactions) between different agents. They thus highlight the system dynamics and in particular the various exchanges or actions between the QMS components.

Numerous researches using the dynamic agents structure from a sequence diagram. Indeed, we can cite a few according to their application type namely:

(a) The UML Agent application to Supply Chain Management [7];

(b) The use of MAS for the definition of safety glass manufactures process to optimize the piloting for this system type [8];

(c) The embedded function implementation and distributed architecture of technical diagnosis for complex systems [14].

Sequence diagrams along activity diagrams and collaboration diagrams are interaction diagrams. They allow specifying the interactions between an objects group in a time framework. This diagram is read from top to bottom, shows the order in which messages are sent between objects [15]. The sequence diagram in Figure 3 illustrates this mechanism.

For the direction process, the agent P1 will create objectives $\boldsymbol{O_i}$ from the expectations $\boldsymbol{Ex_i}$ of customers' agent. These objectives will be treated by the agent D1 and controlled by the agent C1 (consistency, feasibility, planning) to the agent A1. Its role is to correct and adjust and returns the results $\boldsymbol{R_{i1}}$ to agent P1.

Furthermore, the agent D1 will create objectives for the resources process $\boldsymbol{O_{ressi}}$ through agent P2. It will require the planning (recruitment, resources acquisition, training, maintenance, etc.) that will be achieved by the agent D2. This work is supervised by agent C2 which returns the gap to the agent A2 which in turn enhances and improvements $\boldsymbol{R_{i2}}$ through P2.

The realization objectives $\boldsymbol{O_{reali}}$ synthesized by the agent D1 and the requirements $\boldsymbol{R_{eqi}}$ given by the agent customer will be processed by the realization process through the agent P3. Its request the planning (quantities, quality control, the parameters related to realization process, the deadline for product realization, etc…) to agent D3. This agent contributes the realization steps and employs the resources provided by agent D1 that according to the customer requests and the objectives assigned to its process. Its employment results are controlled by the agent C3 and C4. The rectifications to bridge the gap between the request and the realization are treated by A3. The improvement actions, corrective and preventive are handled by A5.

The agent P4 triggers the monitoring process (controls, audits, performance indicators) in planning the frequency, the appropriate methods and the necessary resources (agent, systems and products). As with these provisions, the agent D4 executed and interfaced with the customer agent to collect the claims $\boldsymbol{Cl_i}$ and appreciate its satisfaction. From the results, the agent C4 will correct the initial data in order that the monitoring system is able to detect the gaps. This last could adversely consequences affect on the customer and the effectiveness of other agents. These measures are undertaken by A4.

The agent P5 of improvement process meets all the data on the monitoring results. It will identify the areas for improvement and give priorities as to the objectives defined. The agent D5 will plan the actions (corrective, preventive, improvement) and will convey toward C5 that control and follow their realization. The agent A5 provides their attribution to agents A_i *(i=1, 2, 3, 4, 5)* for continuous improvement is synchronized and not redundant with other agents.

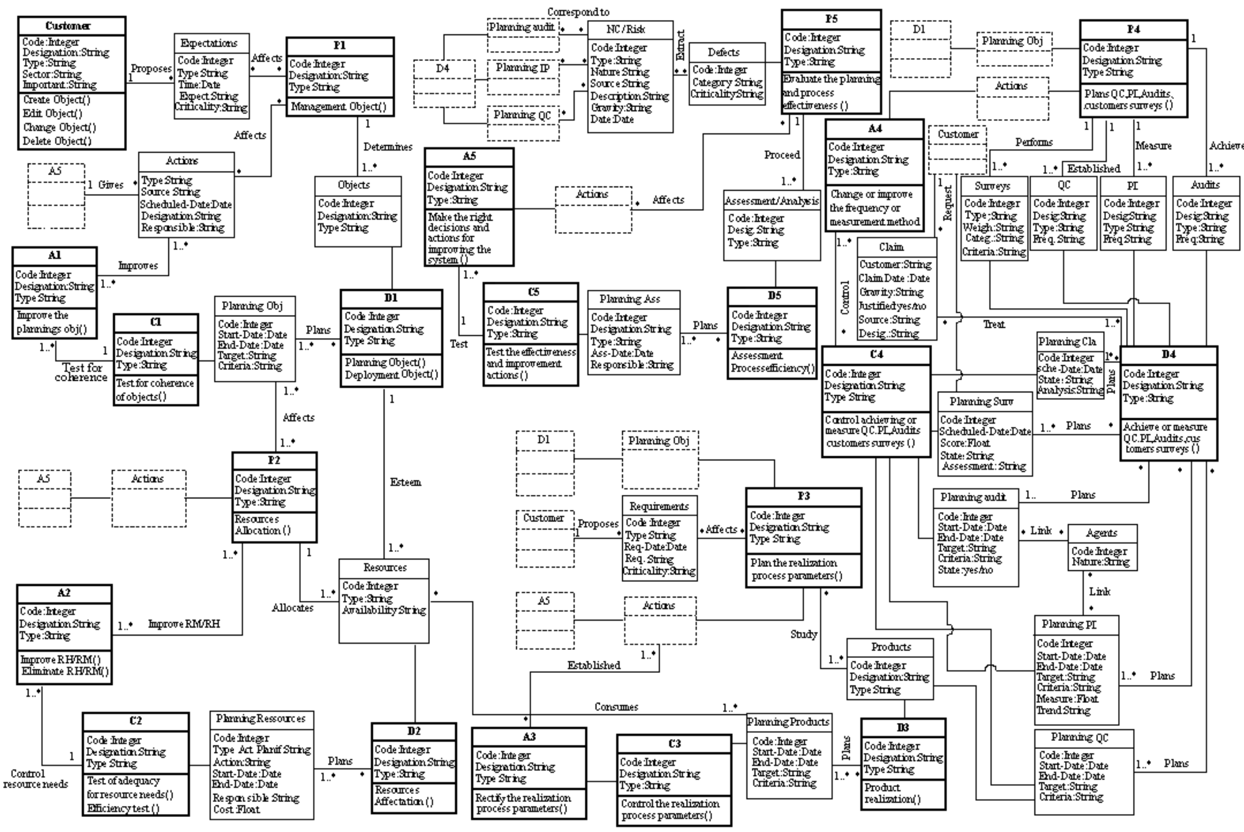

Figure 2. Static agents QMS

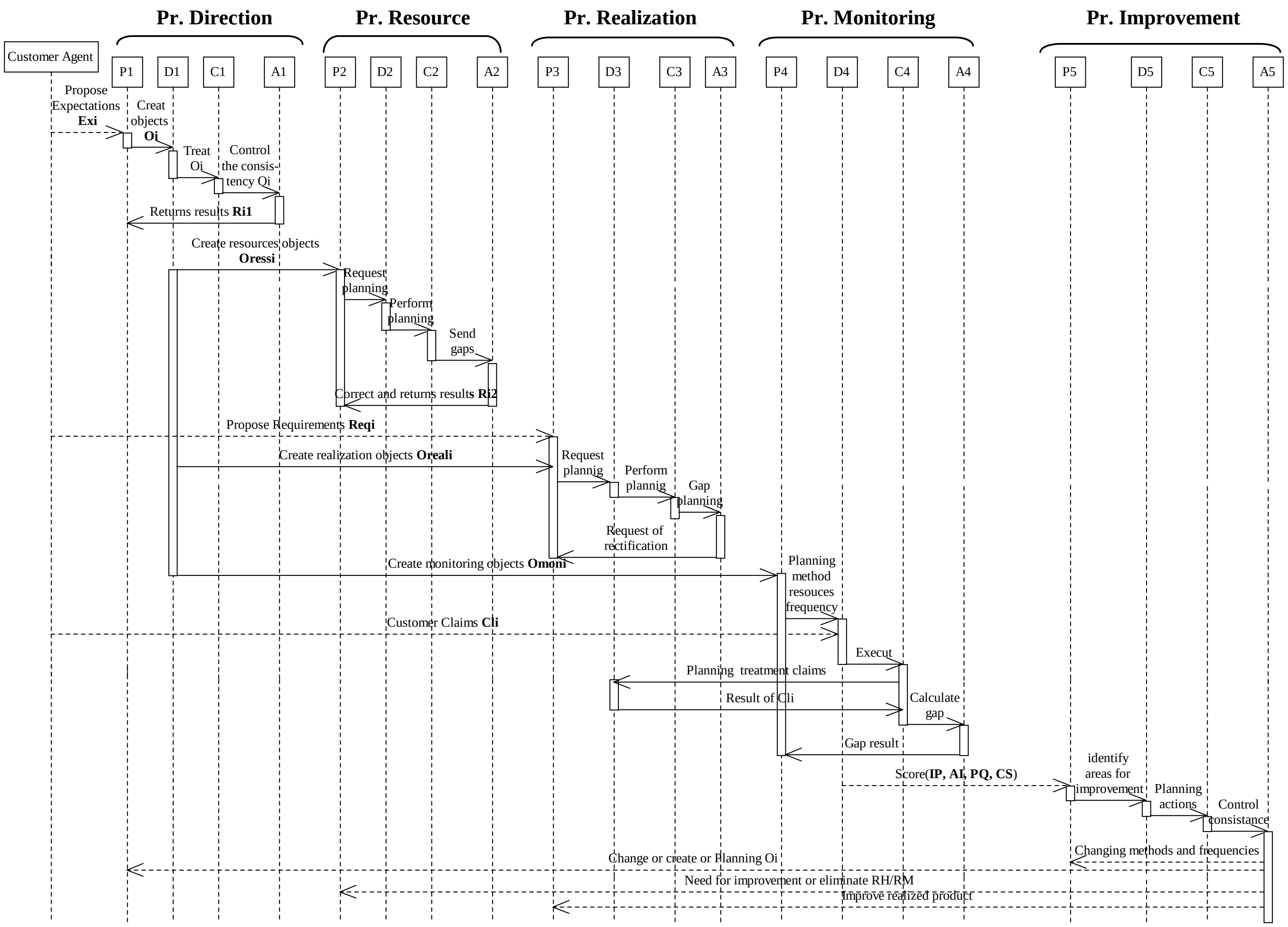

Figure 3. Dynamic agents QMS

4. Presentation a real case for the validation model

Either a Tunisian company operates in the mechanical and electrical sector. Its customers are different types:
(a) Wholesalers that distributed the power strip and dominoes nipples;
(b) Local integrators that integrate lighting;
(c) Foreign integrators that manufacture boiler and that this company produces desks.
With a fleet of injection plastic machines and overmolding and workshops fixtures components, it tries to compose with its resources for satisfy the customer requirements and expectations. So from this example that we were interested to demonstrate the modeling MAS of QMS existing has been certified ISO 9001 Version 2000 since June 2008.

As such, we begin with the "Customer" agent that has issued the following expectations:
(a) Rapid industrialization of new products (Exp1);
(b) Availability and responsiveness to requests and changes of orders (Exp2);
(c) Improving the products quality technical (Exp3).

Given this situation, the agent P1 translated the expectations in the internal objectives. The objectives infer are:
(a) Increasing the availability of injections machines (OBJ1);
(b) Increasing the personnel versatility and the qualifications of the assembly and wiring unit (OBJ2);
(c) The scrap and rework reduction for all products (OBJ3);
(d) Planning improving (OBJ4);
(e) The stocks fractures reduction (OBJ5);
(f) The delivery delays reduction (OBJ6);
(g) The performance monitoring mechanisms (OBJ7);
(h) The objectives achieving and continuous improvement (OBJ8).

All these objectives have been planned by the agent D1 that has defined the performance indicators and appropriate targets given the existing means and resources (PI_i, $Time_i$). The agent D1 also esteemed the additional resources need such as:
(a) The provision of a CAM (RESS1);
(b) The provision of a CMMS (RESS2);
(c) The engineers' recruitment for industrialization (RESS3);
(d) The team assembly training (RESS4);
(e) The acquisition of two other injection machines (RESS5);
(f) Development of dimensional inspection laboratory (RESS6);
(g) A laboratory establishment for metrological qualification instruments of control measures and testing (RESS7).

The agent D1 also defines the objectives deployment in relation to all other agents. Thus, the agents (P2, D2, C2, and A2) will deal the resources management and the objectives OBJ1 and OBJ2.

The agents (P3, D3, C3, and A3) will work on the objectives OBJ3 and OBJ4; OBJ5 and OBJ6.

The agents (P4, D4, C4, and A4) will interest in overall system monitoring through audits, control, customers listening and especially the performance of other agents following the indicators and performance criteria already established by D1. The objective was affected is OBJ7.

The agents (P5, D5, C5, and A5) will be as objective OBJ8.

They analyze the surveillance results and communicate the improvement actions to all other agents. So the objectives are achieved and that the customer agents are satisfied.

If we consider the dynamic aspect model, the realization agents P3, D3, C3, and A3 will be used to tune between agents P1, P2; D1, D2; C1, C2 and A1, A2 and P4, P5; D4, D5; C4, C5 and A4, A5. These combine the most operational objectives. This is logical since these are use and consume resources and deliver consequently the products under duress the customer requirements. The agents P5, D5, C5, and A5, according to the monitoring results ensure the balance between the objectives, the resources and the customer satisfaction. In other words, do not over or under the quality.

So, the agents P2, D2, C2, and A2 will focus on planning, realization and evaluation their management. They focus on training, investment, maintenance and recruitment. In addition, they provide to the agent D3 skilled resources available and able to achieve the objectives and customers requirements.

The agents P4, D4, C4, and A4 will manage the internal and external monitoring. They detect nonconformities, gaps, risks and performance trends of other agents. They are also listening to the customer and collect the claims and indices or satisfaction scores. For this company, the agent P4 wills plan the audits and controls according to the activities importance. The results collected by D4 showed the nonconformities include:
(a) Irregularity in the product quality (NC1);
(b) Persistence of waste for deliveries (NC2).

In analyzing the results, the agent P5 found the following inconsistencies:
(a) No claim customers collected (IC1);
(b) Score audit process was acceptable (IC2);

(c) The performance indicator of the resources process is quite good and stable (IC3).

All gaps are identified by the agents P5, D5, C5, and A5 which are treated to ensure compliance and effectiveness. Thus, the instant action, corrective, preventive and improvement are undertaken. Indeed, the agent A5 has decided to increase the frequency of audits and performance indicators measurements while it concluded that supervision was insufficient. In addition, to the resources process the agent A5 recommended changing the target objectives and deadlines since the means available was really late because the gaps in terms of budgets.

The Figure 4 shows the representation dynamic agents QMS for this case study.

From this example, we have identified for this company many issues, namely:

- How to refine the deployment and the objectives consistency from the expectations and resources available?
- How to ensure the dimensioning of monitoring mechanisms according the objectives and results?
- How to ensure the continuous improvement system capability seen the adjustment frequency objectives and efficiency improvement actions?

To limit these different points, we plan to apply this model on several techniques of artificial intelligence from the MAS which represented the QMS of this company.

5. Conclusion

In this paper, we have proposed a multi-agent approach for QMS piloting. In this context, we started by modeling the various structures which are realized using the UML modeling language.

Indeed, we relied primarily on two different UML diagrams. One is directly related to the static platform used for the MAS implementation represented by the class diagram, and another, called dynamic structure of QMS agents represented by the sequence diagram leading a generic modeling MAS. To validate our new approach feasibility, we translated it to a real industrial case to validate the two proposed models. During this experiment, the approach has been used from direction process to improvement process through the resources, realization and monitoring process.

This approach remains appropriate with the requirements of the ISO9001 standard and provides a modeling framework that will be a fertile ground to implement tools and methodologies to ensure the objectives covered by QMS in particular customer satisfaction and system efficiency.

Thus, the area decision-support improvement actions using the multi-criteria techniques, the algorithms for optimization and planning mechanisms for monitoring, the neural networks, the fuzzy logic, the genetic algorithms, the classification techniques and quality gap treatment are interesting prospects to extend and implement this approach. The combination of quality tools (Pareto, 5M, Balanced Scored Card BSC, Quality Functional Deployment QFD, 8D, etc.) and heuristics techniques are therefore possible.

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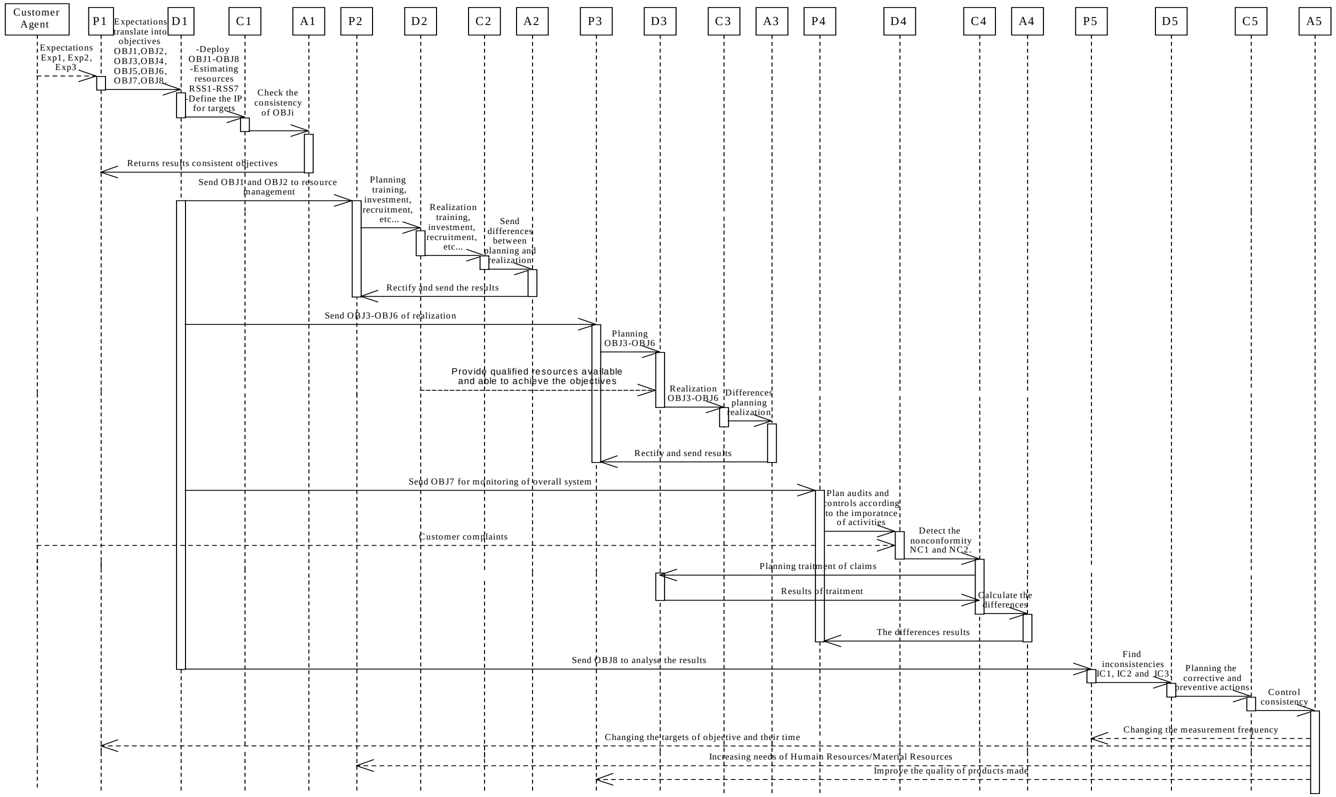

Figure 4. Dynamic agents QMS for case study

Exp1: Rapid industrialization of new products;
Exp2: Availability and responsiveness to requests and changes of orders;
Exp3: Improving the products quality technical;
OBJ1: Increasing the availability of injections machines;
OBJ2: Increasing the personnel versatility and the qualifications of the assembly and wiring unit;
OBJ3: Scrap and rework reduction for all products;
OBJ4: Planning improving;
OBJ5: Stocks fractures reduction;
OBJ6: Delivery delays reduction;
OBJ7: Performance monitoring mechanisms;
OBJ8: The objectives achieving and continuous improvement;
NC1: Irregularity in the product quality;
NC2: Persistence of waste for deliveries;
IC1: No claim customers collected;
IC2: Score audit process was acceptable;
IC3: Performance indicators of the resources process are quite good and stable;
Example: Performance Indicators (PIs) to satisfy OBJ1 are:
PI1: The conformity spare parts rate;
PI2: The qualification of qualified personnel rate;
PI3: The maintenance tools quality rate;
PI4: The supplier service rate;

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