Process modelling and simulation for medication-use process

Johan Royer[1,3], Michelle Chabrol[1], Jean-Luc Paris[2],
[1] LIMOS CNRS UMR 6158, Blaise Pascal University, 63173 Aubière, FRANCE
[2] Institut Pascal/UBP/IFMA CNRS UMR 6602, Campus des Cézeaux, 63171 Aubière Cedex, FRANCE
[3] CHU de Clermont-Ferrand, 58 Rue de Montalembert, 63000 Clermont-Ferrand, France
E-mail : jroyer@chu-clermontferrand.fr, chabrol@isima.fr, paris@ifma.fr

KEYWORDS
LT, Simulation, Modelling methodology, Medication-use process, BPMN

ABSTRACT

University Hospital of Clermont-Ferrand requested decision-making software in order to help the practitioners to choose a strategy and to make choices. First we have to understand and identify the system with accuracy and choose the best tools to develop this software. Therefore, we need to select a language (BPMN) and a methodology (ASDI) able to model the processes of the system following choices and requests of the hospital. In addition to that, we have to choose the tool (SIMIO) to build our simulation model which is the main part of our decision-making software. To illustrate the result of this work, a quick example of application of this tool is presented below.

INTRODUCTION

Because of the increasing number of constraints – especially economic – decision-makers have a lot of difficulties to change their organization, anticipate the future and decide which strategy will be the most efficient. In this context, unfavorable for investment, University Hospital of Clermont-Ferrand, like all French hospitals, has to confront these problems and thus requested a tool able to help them face these ones.
Indeed, when we focus on medication-use process (MUP), we see that all practitioners who have to make strategic or economic decisions to improve their department's efficiency are in a difficult situation which requires having as much information as possible.
The question addressed here is to carry out a methodology and a tool able to give a lot of information on different domains (economic, human resources, capacity of production, etc.) on a specific field, the medication-use process (from the prescription to the administration).
Moreover, University Hospital of Clermont-Ferrand has still a lot of progress to do in its management and production to significantly improve its efficiency. This is another motivation to have a decision-making tool which enables to test and explore new solutions. For example, among this improvement progress, it is possible to list dispensing robot, individual nominative dispensing, drug prescription validation, etc.

So, the following article presents how we arrive at a decision-making software adapted to pharmacists. This article is organized as follows: the first section describes the context of our work and is followed by a section regarding the tools that we use to model the MUP. Before presenting a case of application of our simulation model in the last section, we present this model and the software used to build it. Finally, we conclude on the current situation of our work.

HOSPITAL REQUESTS

In order to have useful decision-making software, the hospital imposes some conditions and options that the software must have. These requests can be classified in two categories: technical and ergonomic.

Technical requests

For the hospital some options must be included in the software, in order to be the most efficient to test new solutions:

- Production for external medical organization: The tool must be able to support the integration of external structures production. Indeed, nowadays a hospital able to supply medications to other medical organizations has a big economical advantage. The only limit imposed by the hospital (with the production capacity) is to avoid a failure in the cold chain. So, the other structures must be at most one hour of transportation away. So for this request we have two main parameters: distance to hospital (in minutes) and number of demands.
- Type of dispensing: Today, in a hospital, it is possible to find different ways to dispense medicines to patients. Indeed, depending on technological solutions, a hospital can use a robot to prepare the patient prescription while in another one this work is done by pharmaceutical assistants.
  Below, we give a short description for each type of dispensing:
  - Individual Nominative Dispensing (IND): computerized prescription and dispensing robot;
  - Global Dispensing: handwritten prescription, shelves and bulk delivery to departments.
  - Computerized Dispensing: computerized prescription, shelves and bulk delivery to departments.

Proceedings 28th European Conference on Modelling and Simulation ©ECMS Flaminio Squazzoni, Fabio Baronio, Claudia Archetti, Marco Castellani (Editors)
ISBN: 978-0-9564944-8-1 / ISBN: 978-0-9564944-9-8 (CD)

These three types are the mains but there are some specific situations such as:

- Automated dispensing cabinets : computerized prescription and unit dose drug dispensing;
- Manual Individual Nominative Dispensing: Contrary to the others, in this situation even if the prescription is computerized, its preparation is entirely manual.

Therefore, we must take in consideration the way to prepare a prescription/order and more precisely how each medicine is supplied.

- Human resources: Of course, one of the requests is the capacity to play on number of pharmaceutical assistants, storekeepers, pharmacists or on their versatility. Therefore we have here the following parameters:
  - The number of workers for each profession;
  - The versatility of each worker.
- Automation: As said previously, the hospital wants to be able to include robots in its production. So, it is necessary to give them the possibility to define the parameters of robots in the decision-making tools. When we look at dispensing robots, we see that the main characteristics are the capacity of production expressed in doses/hour and the stock capacity (in dose). For unit dose packaging robot, which is also an important tool, the main characteristic is, as the dispensing robot, the capacity of production (in doses/hour).
- Financial cost: The last request of the hospital is to know the economic impact of the tested solutions. It is not a parameter needed for simulation but we have to integrate this in the decision-making tool in order to give the most accurate information to decision-makers.

Ergonomic requests

As the tool will be intended to practitioners, namely people with no high skills in informatics, the software must be the simplest to use and the most understandable. Therefore we have here three important criterions:

- Ergonomic interface to enter important data;
- 3D simulation to facilitate the understanding;
- A simple name for each required data.

With these requests, it is now possible to begin the second step of our work in order to build a simulation model: the understanding of the MUP. However, to be able to do this, we have to identify the flows in the system and the involved processes. Indeed, with this work, we will know who are the stakeholders in the MUP, how the activities, the tasks are linked, etc. Finally, we have to build a map of the MUP processes.

HOW TO UNDERSTAND THE MUP ?

In order to study efficiently the MUP, we have to model the processes involved. Nowadays, a lot of languages, methods and methodologies give us the possibility to build such a map. Naturally, each of them has advantages and drawbacks and we must choose one of them.

Even if we can choose a language corresponding to our expectations, we wanted to give to pharmacists the opportunity to help in this work. In addition to that, after some reflections we decide to give to pharmacists not only a decision-making tool, based on a simulation model, but also a background which enables us to have a better comprehension of the MUP possibilities. At this level, doing that implies to explore all MUP configurations and consequently to study many hospitals. Finally, a processes map of University Hospital of Clermont-Ferrand becomes a generic processes map of hospitals, where the maximum of possible configurations for the MUP will be included.
As previously stated, to be able to develop our processes map requires to use a language usable for the pharmacists and for us. To solve this problem we selected five languages: Event-Process Chain, UML, Petri Nets, BPMN and LAESH (Rodier 2010). Each of this language was evaluated by pharmacists and junior pharmacists in order to select the most understandable for them. The result of this evaluation (which is not presented in this article) classed these five languages as follow: 1 – BPMN; 2 – UML; 3 – LAESH; 4 – EPC; 5 – Petri Nets. Therefore we choose to build our processes map with BPMN.

BPMN Model

Using BPMN language enables us to build a model of the MUP from the prescription of medicines to their administration. Therefore, this model incorporates all of the entities interacting with the MUP and maps all involved activities.
It has to be noted that the whole BPMN model is not built with the same granularity (microscopic, mesoscopic, macroscopic). Indeed, some activities are not very important for us and outside of our direct problem. In this case, these activities have a macroscopic representation. Otherwise, the activities that are very important for us and for the understanding of the MUP have a microscopic view.
This BPMN model has been validated by pharmacists.

Figure 1 shows a macroscopic view of pharmacy. This symbolism does not come from BPMN but we developed it in order to simplify the whole map and to understand the main phases in one look.

On Figure 2, a part of the microscopic view of "Phase 1" is presented.

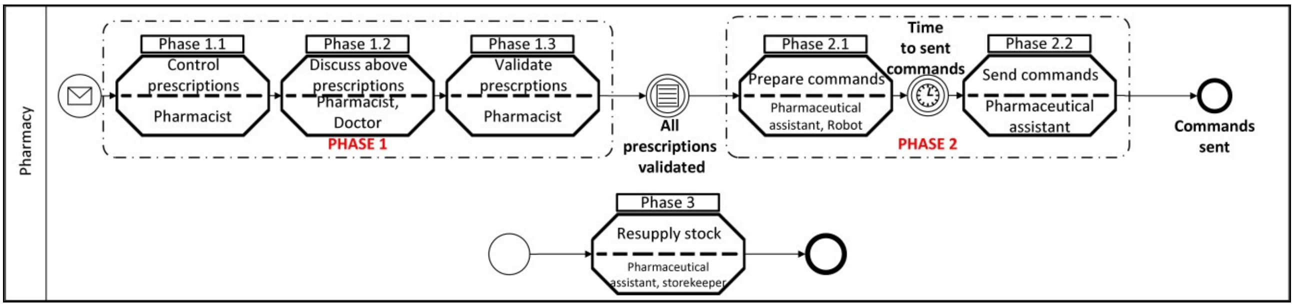

Figure 1 : Macroscopic view of pharmacy

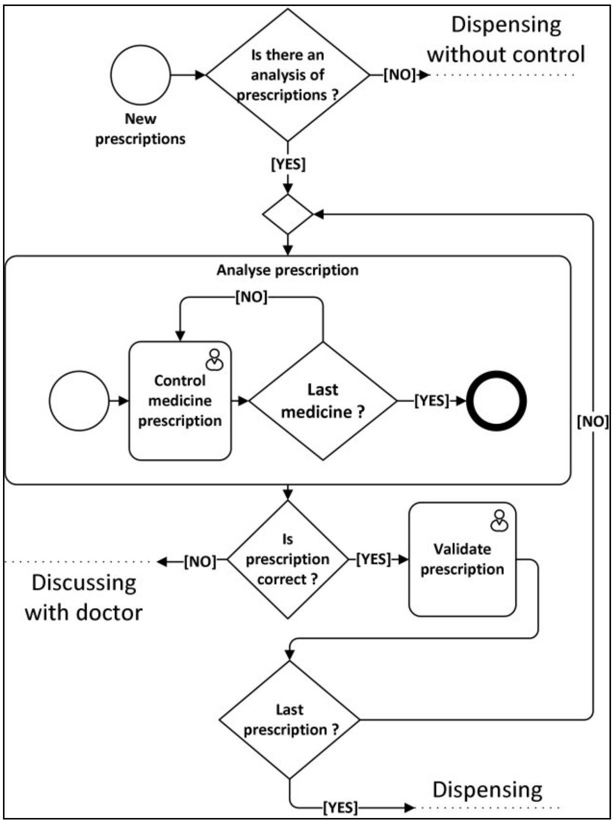

Figure 2 : Part of a microscopic view of "Phase 1"

In our model it is possible to find all actors (human or not) involved in the MUP. These actors are classified in three pools:

- Department: Doctor, nurse, pharmacist and dispensing cabinet;
- Pharmacy software;
- Pharmacy: Pharmacist, Pharmaceutical assistant, storekeeper, robot, mechanical carousel.

As it is impossible to describe the whole model in this article, we will only present a "block description" of this model in order to understand the MUP. Indeed, this model needed 3 months to be developed, including discussion and processes modelling. Furthermore, this processes model has around 150 activities only for standard process and integrate 5 main scenarios (depending on dispensing politic: individual nominative dispensing, etc.) and a total of 132 different scenarios with the various possibilities.

So in this BPMN model we can find for each pool:

- Department: Ordering the prescription and medication reconciliation; Transcribing onto care plan; Checking needed medicines; Ordering needed medicines; Controlling received medicines; Filling and updating pillbox; Administering medicines and treatment updates; Validating the treatment;
- Pharmacy software: Entering prescriptions into computer system; Updating robot production plan; Controlling automated dispensing cabinets;
- Pharmacy: Reviewing prescriptions; Resupplying stocks; Dispensing medicines; Distributing medicines.

ASDI Methodology

Although some languages, as BPMN, are able to specify and analyze the functioning of a complex system, they are not necessarily included in a method or methodology. Conversely, some methods and methodologies are not necessarily supplemented with a language.
Indeed, a modelling methodology provides a general guide and can be defined as follows:

"*A modelling methodology is a set of methods, tools, approaches and concepts for modelling a system*" (Chauvet 2009).

Therefore its role is to combine approaches, languages or methods from different backgrounds in order to integrate them in a logical approach.
This is the reason why we chose ASDI methodology. ASDI stands for Analysis, Specification, Design, and Implementation and it is a methodology developed to enable the design of tools for decision support. In this methodology, these tools are called action models (simulation model, metaheuristic model, analytical model, etc.) (Gourgand et al. 1991; Gourgand et al. 1992). This methodology enables to model a class of systems and produces a "generic knowledge model" of this class. A library of software components is built and is used to generate an action model (equivalent to computer program) (Fig. 3). The conceptual framework of the ASDI methodology is based on a modelling

process separating explicitly the collection of knowledge and its utilization. So, each step requires choosing the most appropriate tools based on system characteristics, objectives, etc.
Finally, systemic view, reflecting ASDI application, consists of a hierarchical decomposition of the system with the object paradigm in three interrelated sub-systems (communicating and complementary). They are logical, physical and decision-making subsystems.

We will stop here regarding methodologies, because ASDI was already used successfully in hospitals (Huet 2011; Rodier 2010) owing to its flexibility and adaptability.
But contrary to (Huet 2011), who focused on final decision-making tools, and (Rodier 2010), who used LAESH language and did not work on the MUP, our work gives to practitioners, and especially pharmacists, an approach to work by themselves with a more common language (BPMN) on the MUP.
With the Figure 3 of ASDI methodology, it is possible to see its main steps. We see that some tools are needed to use ASDI and consequently also for our approach. The first of all is the UML class diagram useful to identify the entities in the system and the links between them. The work of (Huet et al. 2010) and (Rodier 2010) have made possible the construction of our data collection, reusing and completing UML class diagrams previously established.
The second was in original ASDI, a UML activity diagram. Thus, as BPMN is more efficient than UML for our work, we need to replace activity diagram by BPMN model.
As seen previously, the choice of the BPMN language went through an evaluation of several different languages and integrated pharmacists in the development of this first tool.

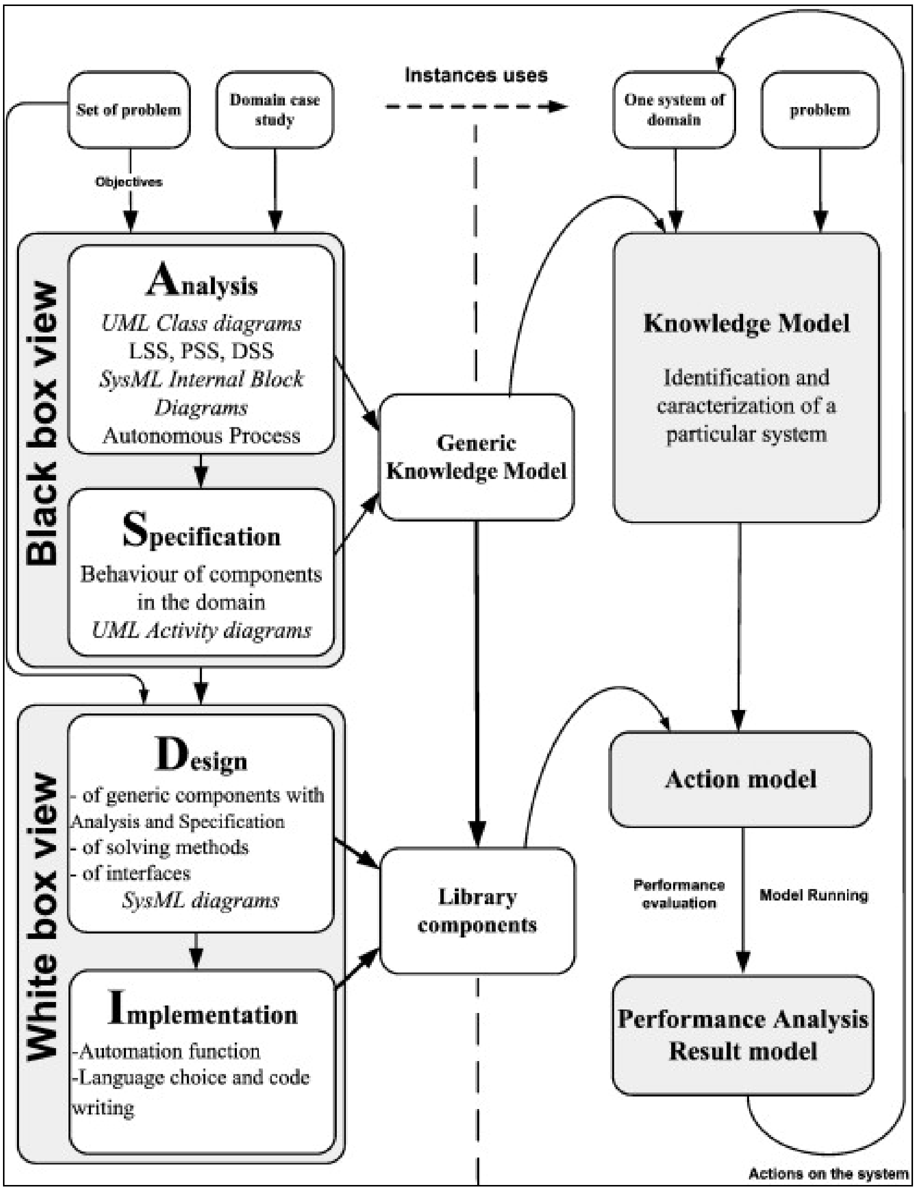

Figure 3 : ASDI methodology

Therefore, their involvement has made possible the development of a strong understandable model to them.
Finally, the use of SIMIO software helped to design a generic simulation model of the MUP that can support any different hospital organization; we will now present those.

SIMIO AND SIMULATION MODEL

The choice of software for performing the simulation model is SIMIO.
This software is a tool to build and run dynamic 3D animated models of a wide range of systems – e.g. factories, supply chains, emergency departments, airports, and service systems. To model a system we model the flow of entities through the system and the resources that constrain that flow. SIMIO uses an object approach to modeling, whereby models are built by combining objects that represent the physical components of the systems such as workstations, conveyors, and forklift trucks in a manufacturing facility, or the gurney in an emergency room of a hospital system. Each object has its own custom behavior as defined by its internal model that responds to events in the system.
Moreover, its graphic interface for constructing 3D models is also an asset, the objective being that this model will be used by practitioners.

The model

During the development of our model (Figure 4), this last changed constantly, and so far, it is not yet the final version. Indeed, each discussion with pharmacist gives new ideas to improve it and as hospital world is in constant evolution, it is difficult to not adapt our model to the reality. So, the following presented model is the most complete for the moment but certainly not the last.

What does our model ?
For the time being, the simulation model – stochastic (number of orders, preparation time, number of products, etc.) – is able to simulate the whole preparation of orders (commands, prescriptions, demands) coming from hospitals departments. So, all the steps from prescription to administration can be found in this model.
We also tried to consider all hospitals configurations in the simulation model, but as we have the constraint to be generic, we cannot consider spatial data (at least not yet).
Before giving an example, we will describe all elements included in this model. Each element is identified on Figure 4 with a number.

Entities and human actors
As said previously, we chose to considerate only orders and not the medicines. Indeed, medicines number is always in the thousands, although it depends on the hospital size. So the orders are our first entity. The second is the medicines coming back from departments. As for medicines in orders we consider a "return list" (No. 2) instead of each product.
At first sight, these choices could seem inappropriate because they do not take the large number of medicine types in consideration. Indeed, some are stored in cold room, while others need special preparation. So to avoid this problem there is a probability for each order to be composed of different types of products. These types are: Manual picking; Automatic picking (dispensing robot); Cold room; Solute/Solution; Carousel picking. So these main types correspond to the different ways to store medicines in pharmacy. Same goes for returned medicines.

In addition to these two entities, human actors are incorporated in our model. Indeed for each activity which needs to be completed by a human, we associate a worker classified in 2 categories: Validator (No. 4) (Junior or Senior Pharmacist); Pharmaceutical assistant (No. 5) (PA).

While validator is needed to control and validate prescription (equivalent to nominative order), pharmaceutical assistant prepares orders with the help of resources that we shall now present.

Resources
The human actors need some resources to work and prepare the orders. Depending on the type of the order, these needs will not be the same. Therefore we have:

- Control area (No.3): where PA edits, controls and validates the orders.
- Validation area (No. 6): where pharmacists work;
- Dispensing robot (No. 7);
- Mechanical carousel (No. 8);
- Shelves: For manual picking (No. 9);
- Cold storage room (No. 10);
- Restock area (No. 11): Fictional stock for returned products.

Processes
The "Processes" are a specificity of SIMIO and are not directly visible for common users. These objects are a sequence of steps that may changes the state of one or more elements in the model to perform some custom logic. This logic can concern seize/release resources, evaluate alternatives, change behavior, etc.
So, we find in our processes:

- Seize/release PA;
- Manage the number of available PA;
- Mobilize PA if needed (with a defined maximum);
- Guide orders in the model;
- Seize/Release/Create Validator;
- Etc.

Options recap
Finally, if we resume all possibilities available in the simulation model, the user can choose:

- The number of each human actor with a schedule for each day (seven slots a day);
- The number of each resource with schedule for some of them (for example dispensing robot);
- The type of each order with parameters (preparation mode, number of product, etc.);
- The global number of orders on the day (12 slots);
- A specific PA for an order;
- Etc.

Data

Collecting data

All data previously needed to run the model can be found on real system and in the Pharma software, used in University Hospital of Clermont-Ferrand. This software was used to retrieve orders delivered during May, 2013.

Representing data

The obtained data were mostly in spreasheets. So, it was necessary to handle these ones to obtain mathematical equations and distributions to model data like arrival time, number of elements, preparation time, etc. When all data were ready, we build new tables which can be imported in SIMIO. For example, we have tables with number of orders per hour, weekly schedule for PA, type and characteristics of orders, departments delivered per day, etc.

Example of process

Before presenting an application for our simulation model, here is an example for a computerized dispensing, meaning computerized order from department and manual preparation. In addition to that, we suppose that this order must be prepared by the PA #1 and it includes solutions, cold and normal medicines. Therefore, the process of this order (black arrows in Figure 4) is in our model:

- Order is generated in Department (No. 1);
- As order does not include IND, it goes directly in No. 3;
- If the PA #1 is available the "Edit and control" step begins. Otherwise, the order waits for this specific PA;
- After that, as order includes cold medicines and solutions, this order is split in three "sub-orders" (**A** in Figure 4). One goes to No. 10, and as the two others have manual preparation, they go to No. 9;
- At this level, there is no priority between each "sub-order". So they are prepared one after another exclusively by PA #1 who is dedicated temporarily to these orders;
- When one "sub-order" is ready, it waits in **B** until others are ready, then the model combines and sends them to the department.

CASE OF APPLICATION

To illustrate the application of our simulation model, we test here a simple situation where the University Hospital of Clermont-Ferrand wants to integrate in its pharmacy a dispensing robot in order to prepare prescriptions. We will focus here only on one day (Monday 13th May 2013) for two motives. The first one is that the influence of the robot on the production is more significant on a busy day, where a lot of orders is placed. The second one is that a robot can improve production on a long period, but not equally on each day. Therefore a hospital will not invest in a robot only for some days of improvement. So, to show the real impact of the robot, we need to study each day of production and in our case a day where a robot could be really useful.

During this day, the pharmacy prepared 130 orders for 60 departments in 9 hours of work (including breaks). For now, 6 departments use computerized prescriptions, so if we complete this with a dispensing robot we are in a situation of individual nominative dispensing. With this new organization on Monday 13th May, the number of orders would decrease of 20 orders (110 left).These orders are replaced by 50 prescriptions for 50 patients among all patients of the 6 computerized departments. The Table 1 resumes the situation:

Table 1 : Number of orders/prescriptions to prepare

	Before IND	With IND
Manually	130	110
With robot	0	50

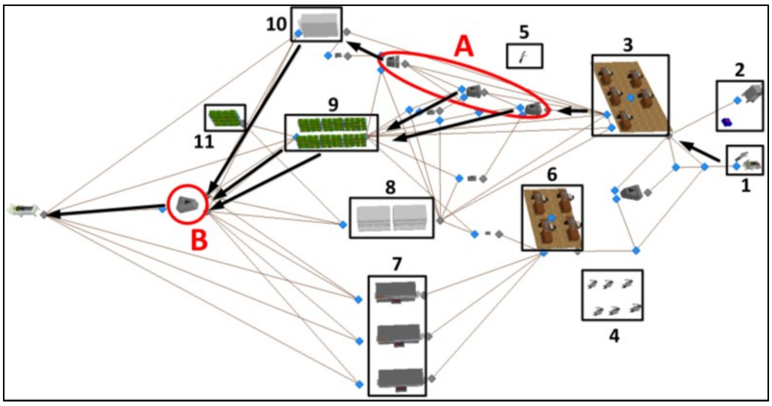

Figure 4 : Graphic view of our simulation model

In addition to that, the robot requires a PA during the peak of production (between 8h and 12h). So the Table 2 gives the number of PA per period on this day:

Table 2 : PA Monday schedule

Period	8h/12h	12h/13h	13h/16h	16h/17h
Before IND	6	1	6	1
With IND	5 + 1 (robot)	1	6	1

We do not focus here on the robot capacity production. Indeed, as we have not a lot of prescriptions to prepare, any robot would be suitable for us. Therefore, when we run our simulation model we obtain the following results:

Table 3 : Number of prepared orders/prescriptions

	At 11h30	At 13h	At 16h	At 17h
Reality	46	80	125	130
Simulation before IND	58	71	116	123
Simulation with IND	51	60	103	109

With the diminution of orders to be prepared with the IND we attain the objective of 110 orders for this day. In addition to that, the PA dedicated to the robot in the morning is not yet totally busy with this task. Indeed we have only 50 prescriptions to prepare, and at this level the robot does not require a lot of PA time. For example the dispensing robot HEMERA by SINTECO is able to prepare doses for around 100 patients by hour. If one prescription is equal to one patient the PA is only busy for less than 30 minutes and up to 1 hour with this production. Therefore we have a margin of time between 2,5 and 3,5 hours a day and consequently between 12,5 and 17,5 hours a week. Finally, as previously stated a dispensing robot has a big impact on pharmacy production.

CONCLUSION

The contribution of this article is to present some tools to help practitioners in taking strategic and organizational decisions. Although they are dedicated especially to pharmacists they are also usable for other decision-makers.

These tools give them the capacity to build model, to explore new solutions and to know their influence. This is notably the role of our simulation model presented here. Indeed, it evaluates possible configurations of MUP and highlights their consequences. This model is able to do so because it includes a lot of parameters, so it is suitable for different hospitals like the University Hospital of Clermont-Ferrand.

The first tests with the simulation model were successful. The results were close to reality for our hospital and both methodology and results have been validated by pharmacists. Now it is possible to test and submit some solutions to this hospital. However, there is still some configurations to test and improve (for example unit dose robot) before having a complete simulation model.

Furthermore, a sensibility analysis will be led on parameters (numbers of workers, robot cycles, etc.) to determinate their influence on the system.

Finally, bringing our simulation model in line with the generic processes model will be our next work. In other words, the aim is to automate the translation of BPMN model into SIMIO model. Moreover, the development of a graphical interface for recording and reading results is imperative to make it easier for many practitioners to use the simulation model.

REFERENCES

Chauvet, J. 2009. *Une méthodologie de modélisation pour les systèmes hospitaliers : application sur le Nouvel Hôpital Estaing*. PhD Thesis. Blaise Pascal University, Clermont-Ferrand, France.

Gourgand, M. and Kellert, P. 1991. “Conception d’un environnement de modélisation des systèmes production”. In *3ème congrès international de génie industriel* (Tour, France).

Gourgand, M. and Kellert, P. 1992. “An object-oriented methodology for manufacturing system modeling”, *Summer Computer Simulation Conference* (Reno, Nevada, USA). 1123–1128.

Huet, J.C., Paris, J.L., Gourgand, M. and Kouiss, K. 2010. ‘Modèle de connaissance générique du circuit du médicament dans un hôpital’. *In MOSIM’10 : 8ième ENIM IFAC International Conference of Modeling and Simulation* (Hammamet, Tunisia).

Huet, J.C. 2011. *Proposition d’une méthodologie de réingénierie pour le contrôle par le produit de systèmes manufacturiers : Application au circuit du médicament d’un hôpital*. PhD Thesis. Blaise Pascal University, Clermont-Ferrand, France.

Rodier, S. 2010. *Une tentative d’unification et de résolution des problèmes de modélisation et d’optimisation dans les systèmes hospitaliers. Application au Nouvel Hôpital Estaing*. PhD Thesis, Blaise Pascal University, Clermont-Ferrand, France.

AUTHOR BIOGRAPHIES

JOHAN ROYER is a PhD student and a hospital engineer in University Hospital of Clermont-Ferrand. He obtained an engineer diploma from IFMA in 2011 specialised in logistics and industrial systems.

JEAN-LUC PARIS is professor at IFMA since 2005. His research areas are modeling, design and optimisation of business process (mainly in healthcare domain) and Knowledge Management.

MICHELLE CHABROL is an associate professor in ISIMA. Her research area is modeling methodology.