The goal of this systematic literature review is to show the application of discrete event simulation in financial models by exemplifying some already existing utilizations and introducing the Coloured Petri Nets into this approach. It was found some effective simulation programs that utilize different approaches and also examples of the applications of CP nets in different kinds of business processes. This article hadn’t defined a new model to be implemented but it had evidenced the efficiency of the Cp nets to develop a new one. Therefore, this work will not only generate information to feed the big data that is growing constantly nowadays but it will also introduce a new effective approach that might boost the 4.0 industry in finance.

Palavras-chave: Coloured Petri Nets, Simulation in Finance, Discrete Event Simulation, Business Analysis in Simulation Programs
1. Introduction

As we all know, the financial aspect of a company is among the most important. The financial aspect provides the means required for a company's operation. To make this aspect the most efficient as possible, the usage of simulation programs to create models that help organize and control finances has been more adopted over the last few years. As demonstrated by Georgakopoulos and Hornick (1995), a company's cost reduction is something that makes the company stand out. The development of adaptable financial approaches is therefore relevant.

This work was developed to enhance the knowledge in the discrete event simulation which is an important Industrial Engineering’s study field. Besides, using the Web of Science’s database in 27/05/2017 at 5pm it was possible to notice that the number of studies developed about discrete event simulation in finance were few throughout the past years, having its peak in 2010 with 3 studies published in that database. However, with the 4.0 industry the usage of software and new sources of information is extremely important as everything composes the big data that is used nowadays to automatize different approaches applications. Therefore, this study was made to explore a new approach used to create scenarios in the finance aspect which might be one of the pieces that collaborate for the boost of the 4.0 industry in finance.

Image 1 – Number of Discrete Event Simulation in Finance’s studies published in the past years

Source: Web of Science database (2017)
That said, as the market for new approaches in financial simulators has a lot of opportunities, this paper aims to show the applicability of Coloured Petri Nets, a discrete event simulation program that uses the Petri Nets programming language. Besides, the goal is also to show that a new financial approach can be more effective with the Cp nets, as each day the business world is becoming more competitive and companies are required to search for optimal structure tools to rely on.

For that, it was used a qualitative approach as some of the features of the Coloured Petri – Nets were compared to the literature aiming to show the feasibility of using it in a financial approach. Therefore, this work will first detail the methodology used, followed by a theoretical review of the basic concepts and its results and analysis’ developments. Lastly, the final considerations and the references will finish this work.

2. Methodology

This work was made using a qualitative approach that consisted in the comparison between some existing literature with the study proposals. Besides, this work was developed in Brussels, Belgium aiming to improve the knowledge of this study field there.

For the development of this work, first of all, searches were conducted on Google Academics, ScienceDirect and Cite Seer X databases. Furthermore, keywords were selected according to the subject that was wanted to be proved. After that, the keywords in these database lead to 16 articles. Between these 16, there was 1 article that included a citation to another relevant article. Besides that, another book and a patent were found with one of the keywords on a website. Thus, this study was based on 17 articles, 1 patent, 1 book and 1 other book that was the basis of the basic knowledge of Cp nets and the keywords used were: Financial Simulation Program, Discrete Event Simulation, Cp nets business simulation, Business analysis in simulation programs and Simulation in Finance.
Almost all of the articles were completely read, excluding articles that were outside the scope of the study. After reading the articles, the most important parts were included in the study, and all was compared and structured.

3. Theoretical Review

The stability of the financial aspect of a company depends on numerous variables, such as the state of the market. Kahl (2007) says that in finance “volatilities must be flexible enough to reflect market behavior” (p. 1). That said, Liston, Byrne, Byrne and Heavey (2007) present the strongest advantage of discrete event simulation, which allows for the analysis of variability by experimenting with ‘what if’ scenarios, relevant to the needs of a financial approach.

Discrete-event simulation can be used not only in finance, but also in other scenarios. Hill, Miller, and McIntyre (2001) give examples of the usage of discrete event simulation even in military analysis models, which show the variability of models that this kind of simulation can produce.

4. Results and Analysis

4.1. Results

Hubalovsky (2015) and Khodyrev and Popova (2014) show the importance of algorithms as a tool in the development of simulations models and even in all practical activities. This will be intrinsic to the understanding of the codes that are used to develop a model to a financial analysis.

Domonkos (2010) says that it is important to choose an appropriate simulation program, which is flexible so as to attend to all of the existing topics and, at the same time, intuitive and easy to manage. He also presents the advantages of utilizing specialized simulations software tools, programs that were created with one goal: simulation modeling. These software tools make it easier in the development of new simulation models and analysis. There, one can find options of input and output data, and even tools used to detect errors. In the simulation
program languages that have the models generated by writing code, the program allows for
greater flexibility even though it takes more time to develop. Graham and Harvey (2001) also
present the importance of a flexible approach as each company manages its finances in
different ways. Coloured Petri Nets is a special program that fulfills all of these requirements.
Katsaros (2009) shows that "Petri Nets modeling languages provide an explicit representation
of both states and events and an easy to understand and intuitively appealing graphical
representation" (p. 238). Even though Petri Nets is a great tool for modeling, it is a simpler
version which requires a lot of places in the modeling. This is why Coloured Petri Nets Basic
Concepts (Jensen, 1997) demonstrates that Cp nets is a higher level modeling language which
compacts all of the information in specified tokens where the data is attached. Each token has
a defined color so it can be distinguished from the others. This program allows one to model a
complete system that can be easily managed.

In the development of a simulation, there are several steps to take into account. It is really
important to know what kind of simulation is the most appropriate for each case, how it is
going to be developed and what are its basic requirements. Hubalovsky (2015) discusses the
importance of first creating a conceptual model of the real process or real study before
developing the computer simulation. In this way, all is clear when one starts the process of
simulating.

Wynn, Rozinat, Fidge, Hofstede, and Aalst (2009) define two types of simulation for business
processes: long-term planning and short-term planning. The latter is more useful for
operational decision support in concrete situations. That said, it may be used in the case of a
financial simulation. Short-term planning leads to less mistakes and more accurate data.
Since the focus of this study is financial simulation, it is necessary that the program has all of
the important tools to develop a consistent financial simulation. First of all, Hubalovsky
(2015) describes the most important objective of the modeling: "finding of adequately
description of the dependency system outputs on its inputs" (p. 2227) and Khodyrev and
Popova (2014) mention the steps of a simulation model, the workflow of model level, process
elements of model level and environment of model level. The workflow of model level allows
for the possibility to identify the time of the occurrence of the event, as its time to the next
program initialization. U.S. Patent No. 6,064,984 (2000) also uses this relation between a financial amount and a time amount for developing a financial planning. As was already introduced, the program Coloured Petri Nets disposes a lot of tools to help with modeling. As its basis is the Petri Nets modeling language, this dependency and this timing of events are intrinsically present in the modeling program.

Liston, Byrne, and Byrne (2007) discuss the development of a model utilizing the eM-Plant, an object-oriented discrete event simulation package that was developed by Tecnomatix. After the authors define some of the existing tools in the simulation package that were used to build the model. Among these tools, there are the possibility of attributing a base cost to each event in a transaction model, the Transport that simulates the transportation of goods between spots and record the charge each time that this function is used, and the indication of the risks related to each scenario by checking it with different and random numbers data. In this simulation model, it also noticed that the program Cp Nets has these properties that help to evaluate a financial approach.

One of the usages of this modeling program is illustrated by Ribas et al. (2015). They introduce the Coloured Petri Nets in the Cloud Services (used nowadays so sellers can offer many purchasing options with interactive tools) presenting an effective approach using this simulation program. They list the elements (colors and functions) used in each step of the framework, which was divided in cost estimate, evaluate benefits and risks and compute cost/cost radio. In a financial simulation, all of these steps are necessary as the basis of a financial system is to estimate the cost and try to have a projection of its consequences. That said, some examples will be given of these elements used in the Cloud Services that can be essential for a new financial simulation program:

Color lc (list of cost elements, with type, name and value), Place Cost Elements Cloud (contains each cost so it can be predictable the total cost), Color lw (to associate a value to a criterion), Color la (to associate a value to the criterion for some alternative), Color qual (pair or numbers that represent a qualitative evaluation) and Place Criteria weights (contains a list of criteria and a value predefined associated to each one).

The evaluation of risks, like said before, is intrinsic to financial approaches. Artzner, Delbaen,
Eber, and Heath (1999) and Longstaff and Schwartz (1995) show the different ways to measure market and non-markets risks and evaluate them, and as we know, the Cp nets have the capacity to attend this requirement. Dailami, Lipkovich, and Dyck (1999) and Mitchell (2009) also present the importance of managing risks when one has a financial approach, and Cp-nets has the tools to manage them.

Another example of the usage of Cp Nets to help with transactions is when Katsaros, Panagiotis, Odontidis, Vasilis and Gousidou-Koutita (2005) use this program to check the Net Bill electronic cash system. In this example, they dispose of plenty of Cp nets tools to validate and guard the important phases of the transaction, where the safety is one of the most important requirements in a financial approach.

Ribas et al. (2015) also describes the usage of Cp nets to "compute the monthly cost of all running instance and the savings by using spot instances" (p. 108) so they can see how spot instances may help with cost reductions. Spot instances provide a dynamic approach of the usage of a service. It takes into account all that the client is willing to pay varying in real time. This was used in a virtual purchasing transaction, showing the possibility of applying it in other frameworks. Besides, it is possible to apply several types of distributions which allows the simulation to be adapted to the current situation. This can be seen in Jansen-Vullers and Reijers (2005) that in the redesign of the processes use the uniform, beta and exponential distribution, which were the most suitable to their study.

Jensen (1997) also emphasizes in his book the fact of the Petri Net having a hierarchical base which allows for several tools for the discrete event simulation. Also Varga (2001) exposes the OMNeT++, that is a discrete event simulation program that utilizes the language C++ for modeling, a program which the hierarchical structure of simulation is present. That said, it is possible to see one more tool that the Cp Nets have compared to other effective simulation programs.

4.2. Analysis

After reading all of these sources, it was possible to see the importance of having a well-structured financial model in a company. This is the foundation upon which the rest of the
company is built. Furthermore, as it was expected, the usage of a simulation modeling can improve the performance of a company when it comes to complex frameworks. In the simulation models, it is always important to take into account the unpredictability and the volatility of the structure. The evaluation of risks, the assumption of different scenarios, is something that is important to put into the spotlight.

All that said, this work lead to the demonstration of different approaches of the usage of the Cp nets, presenting the wide range of opportunities for financial modeling. This discrete event simulation program has the capacity of impacting a financial framework, leading the whole framework to a more simplified and more effective performance. Thereby, the initial expectation was confirmed as the Cp-nets were seen to be the right program to be used with modeling financial approaches.

5. Final Considerations

Therefore, it was possible to see that the Cp-nets has all the support information and tools to develop a financial model as it was expected. Rozinat, Wynn, and van der Aalst (2009) define the main challenge of a business process simulation, which is to represent the real process of interested in the simulation, and is also the main challenge of a financial simulation. Coloured Petri Nets dispose of the most different platforms to make this main challenge happen. Finally, one of the limitations of this work was the few number of studies already developed about this subject. However, with the 4.0 industry’s growth, future writes will be able to avail of a higher amount of information of the discrete event simulation in finance, being able to develop more accurate qualitative comparisons besides developing new quantitative approaches.

REFERÊNCIAS


