A physics-based approach to evaluate crisis impacts on project management

Clara Le Duff
Centre Génie Industriel – IMT Mines Albi
clara.le_duff@mines-albi.fr

Jean-Philippe Gitto
Scalian, Toulouse
jean-philippe.gitto@scalian.com

Julien Jeany
Scalian, Toulouse
julien.jeany@scalian.com

Raphaël Falco
Scalian, Toulouse
raphael.falco@scalian.com

Matthieu Lauras
Scalian, Toulouse
matthieu.lauras@mines-albi.fr

Frederick Benaben
Centre Génie Industriel – IMT Mines Albi
frederick.benaben@mines-albi.fr

ABSTRACT

Project management has become a standard in business. Unfortunately, the projects as well as companies are increasingly subject to major disruptions. In this context, it is of prime importance to have the ability to manage the risks inherent to these projects to best achieve their objectives. The existing approaches of crisis management in the literature no longer seem to be adapted to this new normality. The future of research lies in a more systematic crisis assessment and a better conceptualization of the uncertainty associated with risks. It is necessary to rely on the collection of heterogeneous data in order to maximize the understanding of the project environment and to find a way that best describes and visualizes the influence of crises on the project management processes. This article uses the POD approach and applies it in the context of project management to address these issues.

Keywords

Crisis Management, Project Management, Risk Assessment, Physics of Decision, Simulation

INTRODUCTION

In the current context of globalization and systematization of the world, companies must deal with the instability every day. Most of the current organizations use project management standards to achieve their goals. This type of management has many advantages such as improving the collaboration of people from different departments, increasing the motivation and involvement of the actors, being able to achieve complex objectives, etc. A better understanding and analysis of their organizations will allow them to improve their management, to make them more resilient and therefore more resistant to a crisis. In this paper, we use the following definition for crisis: "a crisis is an event [creating a break in the state of a system] that surprises individuals, restricts their response time and threatens their primary objectives" (Hermann, 1963). The crises that companies undergo are more and more complex and harder to evaluate. In the phase of preparing for a crisis it is important for managers to be able to assess the impacts of the risks they face in order to best define the strategy (Coombs and Laufer 2018). This research paper focuses on the following research question: How to assess the impacts of risks that may led to a crisis on a project seen as a system with specificities and complexities? The proposal of this paper is based on the concept of "Physics of Decision" (POD), a framework developed to support a more efficient decision making (Benaben et al, 2020). This framework has an original approach in the definition of potentialities (risks and opportunities). It models these potentialities as forces that affect the performances of the system. The main objective of this research work is to demonstrate the relevance of this approach in a project environment by proposing this methodology (POD) dedicated to project management, notably in the context of a crisis, and to discuss its feasibility on an illustrative case. The paper is organized as follows. The second section highlights existing research about the assessment of crisis impact, risk management in project context and the related work on risk management field precisely on POD which is used in this paper. The third section presents the proposal of the paper. The fourth section presents the experimentation and the result, while the fourth section is a discussion and a conclusion of the research.

BACKGROUND AND PROBLEM STATEMENT

Crisis Management

Started in the late 70s, "Projectization" has gained popularity among all type of organization for the past decades (Backlund et al, 2014). This trend bears the great challenge to ensure project performance in a large panel of activities (industries services, construction, etc.). To structure successful projects, international standard appeared as PMI (Project Management Institute) which provides knowledge areas applicable to all projects (Project Management Institute 2018). To take care of disruptions or unexpected events, one of those areas focuses on crisis management.

The field of crisis management is divided into 3 parts: Management Phases, Interaction Between Crisis Respondents and Information-Management Enablers. The part that interests us is the crisis management part. The literature agrees that there are 4 step in these part: (i) the mitigation step, which consist of reducing the degree of impacts risks and the vulnerability of our system, (ii) preparedness which correspond to develop the strategy and to prepare our system to face the crisis, (iii) the response phase which is the implementation of the planned actions and finally (iv) the recovery phase which is those actions that repair and restore our system (Lee et al 2017). In the preparation phase, one of the most important things is to analyse the risks as well as possible, especially by evaluating their impact on the system, in order to be able to create the response strategy (Coombs and Laufer 2018).

The field of risk management therefore seems useful and can be a real contribution in the preparation phase of the crisis. The field of risk management has been a very mature research area for decades. Many principles and methods have been established and are still, to this day, a basis for research and practice. Risk management is composed of a set of very standardized processes: Risk identification (identify the risks specific to the system and their factors), risk assessment (assess the impact and probability of these risks), risk mitigation (develop strategies to limit the damage, and control the occurrence of these risks) and finally manage and recover from these crises (Ho, et al. 2015) and (White, 1995). The risk assessment step is a key step in risk management, as a wrong assessment of a risk can be critical for the project and its deliverables. The purpose of risk assessment is to identify, analyze, evaluate and control the risks that may impact our system (BS EN, 2010). There are four types of methods developed in the field of risk assessment: probabilistic methods, interval probabilities, possibilistic measures, and qualitative methods (Flage et al. 2014). Therefore, there is much discussion about the techniques and tools to be provided but still no consensus is made on the best practices to have.

Methods developed such as those using Bayesian networks or even probabilities have proven to be successful when fed with historical data. But in today's environment that contains deep uncertainties, these traditional methods are no longer suitable for expectations to drive their projects (Aven, 2015). It is necessary to better define and characterize the knowledge and lack of knowledge of a system to better assess the risk impact of a situation with uncertainty or instability. In spite of all techniques developed, we notice that it is now necessary to custom the frameworks created to specific situations.

Risk and Crisis assessment method for project

As we know, the common techniques of the risk assessment process no longer solve the current problems due to the complexity of current projects (Marle et al, 2013). We must now try to consider a framework that would take into account a network of interacting risks (Liu et al, 2016). Many techniques have recently been developed in this sense, such as: analytical network process (ANP) (Boateng et al, 2015), the interpretive structural model (ISM) developed in (Dandage et al, 2018), a fuzzy weighted ISM (Tavakolan and Etemadinia, 2017), and the structural equation modelling (SEM) (Liu et al, 2016). Despite this, Taroun (2014) explains that these techniques do not provide a complete understanding of the impact of risks, or their drivers, on project objectives (other than cost, quality, and time).

A Physics-Based Approach

Among all the existing techniques for assessing the consequences of risks and crises, the concept of POD (Physics of Decision) caught our attention because it seems to address the majority of the problems we identified earlier. The Physics-Based Approach POD is a framework created to propose a performance management approach to

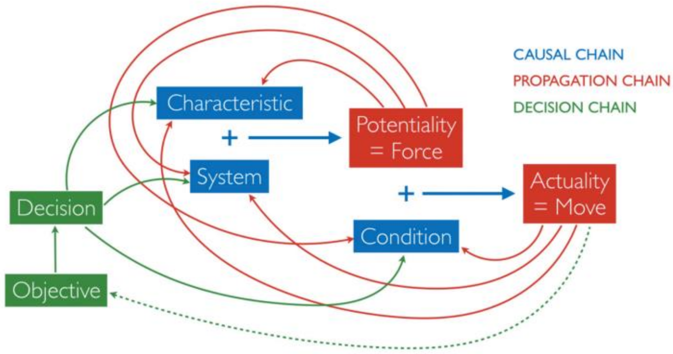

Figure 1. POD generic framework

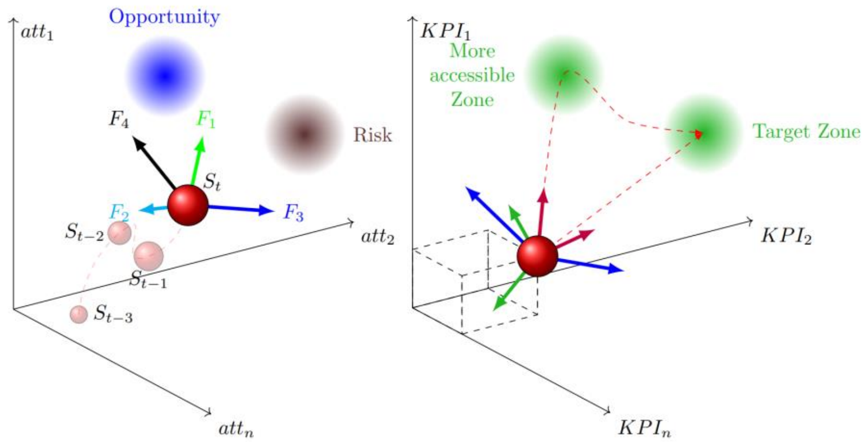

Figure 2. The description and the performance space

decision making (Benaben et al, 2019). The basis of this framework is the causal, propagation, and decision chains.The thought process for creating these chains is explained in (Benaben et al, 2021) and illustrated on Figure 1. A system is defined by these internal and external attributes named characteristics. These characteristics induce potentialities (risks or opportunities) in the scope of the studied system. These potentialities become actualities if these conditions are true. Actualities change the attributes of the system and thus its performance.

The second part of the framework is the modelling of two types of environments for a system: the description space and the performance space (Figure. 2). The first environment takes into account the attributes that define the system at each step time. The second space, the performance space, is sized using the KPI's that we are interested in. Clearly, performance is a reflection of the state of the system in these specific spaces. The POD approach explains that there is a link (even if it is not explicit) between these two spaces. The variation of the attributes of the system will vary the performances of this one. In this approach, the variations of these characteristics are in fact the risks and opportunities that become realities, in the framework and the description space these potentialities are in fact forces. To analyze the variations in the performance space and to be able to evaluate the impact of events, we can define in these specific space target zones to be reached or areas to be avoided, depending on the definition of the system. In summary, risk assessment faces three main issues: taking into account the complexity of the system and the interdependence between risks, then taking into account the uncertainty and finally in project management, which is unique and finite in time, it is not possible to have historical data specific to our subject. For us POD can bring a light on these three steps. Firstly, concerning the complexity and interdependencies of the system, the use of causal chains, propagation and decision allows us to model these dependencies well (with the hypothesis that we know the causes and consequences of each risk). Then for the uncertainties and the need of historical data, we will model our system, and be able to create sensitive analysis on the parameters of our project. We can then model these data in the two POD spaces and analyse these results. With all this, it allows us to better assess the impacts of risks and therefore to bring clarity in the preparation phase of crises in project management domain.

PROPOSAL: A PROJECT MANAGEMENT PHYSICS-BASED APPROACH

Research Assumption

The POD approach offers an original method for decision making through performance management by modelling risks and opportunities as forces that influence the characteristics of a system. The goal of this research is to prove that the POD framework can be used and usefull in the project management field and in particular by bringing an answer to the evaluation of the impact of the risks (that led into crises) which it goes through. POD framework assumes that the link between attribute and performance space exists. This means that each change of attributes (due to a decision or an event) influences the KPIs and therefore the performance of the system. This framework is general, it has been applied in various domains (election, pandemics and supply chain) and has demonstrated its interest in evaluating the consequences of different events (risks and opportunities) on performance. The POD approach seems to be relevant to our problem of evaluating the impacts of a risks in project management, which is one of the missions of risk management. However, is it possible to model a project as a description space? Is it possible to visualize the impact of a disruptive event on its performance?

Research Proposal

In this section, we propose a three-step proposal.

First step, we need to define the project to be studied and the scope. The scope will define the study scale for a project. We can imagine a project according to three different scopes: the operational, the organizational and the strategic area.

The **second step** consists in defining the two specific spaces in a project management context. The first space, called the description space is about the characteristics of the project according to the chosen scope, and each of them corresponds to a dimension of this space. These characteristics must cover a maximum of data that could define the project. The categories of data to be collected are the technical data of the project (duration, available resources, link between tasks, planning...), the data corresponding to the external context of the project (political decisions...) and also the social and human characteristics of the project (conflicts, emotional intelligence...). These data are obtained initially by interviewing all the actors of the project and by reading all the project documents. They can be fed by the analysis of social networks or any means of collecting information. The ideal is to identify the characteristics that can evolve over time and that have an influence on the performance of the project (motivation, expertise...) The second space, called the performance space, which corresponds to the project's performance, is also specific to each project. The macroscopic indicators of time, quality and budget usually provide a general view of the project's progress, and these are often supplemented by more precise or detailed indicators, depending on the needs (delay, customer satisfaction, for example). The target areas defined will be the areas to be reached at the end or at the milestones of the project, they can be static or dynamic.

Then as a **third step**, we propose to formalize the project according to one of the three main simulation modelling groups: Discrete event modeling, system dynamics or multi-agent modelling. The goal is to formalize dynamically the behaviour of the project using all the data collected. The output of the simulation will give us the KPIs variations and so the performance at each period of time. The advantage of this approach is that it does not require to know the general equations of the system to be modelled between the characteristics and the performances nor to bring exact solutions to this system of equations.

Once the understanding of the project is established and simulated, the **fourth step** is to establish crisis tests to be defined. The result of this simulation is the creation of the project performance space. The objective of these simulations is to study the impact on the project performance of different potential events in order to identify those that could lead to a crisis situation. To carry out this analysis we make simulation campaigns. The campaigns run treat a great number of possible crises and allows us to understand the impact of them in our project and to quantify it.

The **fifth step** is to visualize the performance of our system in the face of disruption. Thanks to this we have a clear visualization of what is happening in our system and we have a good understanding of its behavior, so it will be easier to implement strategies.

The figure 3 shows the scheme of the global methodology developed.

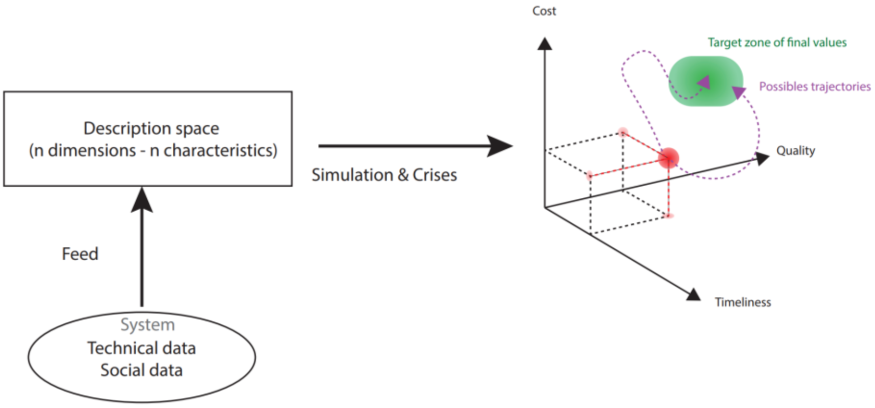

Figure 3. Proposal

EXPERIMENTATION

After formalizing the proposal, we have chosen a case study to test and validate this method in a project management context.

First step: the use-case

Working with a group of researchers, research and development (R&D) project is a good first illustrative case. An R&D project is a scientific project whose goal is to provide answers to a scientific problem by carrying out a literature review and an experiment to prove the contribution of the results found.

Innovative industrial Lab project

R&D project is generally composed of four main steps: the bibliography, the proposal, the experimental work and the report of the research. The bibliography is a critical step because it is essential for the positioning of the research work and the constitution of the proposal. Moreover, this task is done by humans, it requires a lot of reading work and the duration of this task is very time consuming. This is why we have chosen to focus on this sub-project as a first illustration. The specificity of the chosen project is that it is an R&D project in a consulting firm, so there are interns and consultants who work within the bibliography.

Bibliography Process

In our industrial case, the bibliography process is defined as follows: There are three types of stakeholders working on the project: the scientific manager (SM: he coordinates the project, has a great expertise but does not work 100% of his time on the project), the intern (Int: works 100% on the project, starting with an average expertise that increases over time), and the inter-contractors (IC: person working in the company as a consultant and working on R&D projects while waiting for a mission to work on). Inter-contractors are unstable resources. Indeed, they are there as reinforcements of the project and do not work on the project from the beginning to the end. They can have very diverse profiles and therefore very diverse characteristics. The project lasts in our case about 4 months, and an inter-contractor remains on the project about 2 to 4 weeks. These consultants have a capital importance because even if they remain only a few days or weeks on the project, they bring added value and help to the task progress. Each of human resources has its own characteristics, for example a scientific manager will normally be more expert than an inter-contractor, but this manager will work less time on the project whereas the inter-contractor or the trainee will work full time. There are three types of papers people have to read and analyse: PhD theses, conference papers and journal articles. Each paper has its own characteristics, a thesis will be harder and longer to read, but it will bring more quality to the project than a conference paper for example. After analysis, these sources are sorted into two piles, if they are relevant for the project or not. The tasks are shown Figure 4. The assumptions of the process are:

- One paper is read by one and only one human resource;
- Every human resource has to finish his/her document in order to read an another one;
- Human resources improve their expertise as they work on the project.

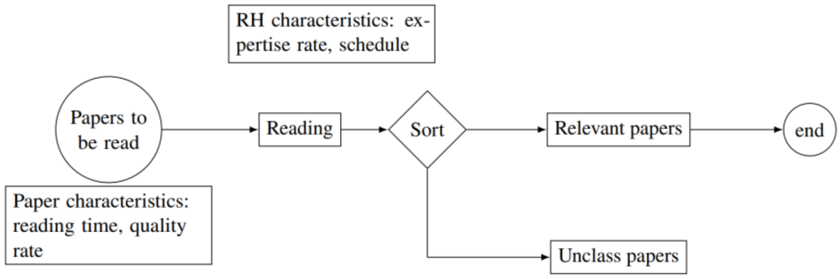

Figure 4. Bibliography Tasks

Table 1. Data of the project

Parameters	Values
Scientific manager (SM)	1
Inter contract (IC)	Flow per week
Intern (Int.)	1
Article arrival rate	Triangular(0.40,0.53,0.48) per day
Paper arrival rate	Triangular(1.4,1.55,1.51) per day
Thesis arrival rate	Triangular(0.4,0.5,0.45) per day
Reading time SM / Article	1.5 hours
Reading time SM / Paper	1 hour
Reading time SM / Thesis	10 hours
Reading time IC / Article	7 hours
Reading time IC / Paper	5 hours
Reading time IC / Thesis	20 hours
Reading time Int. / Article	5 hours
Reading time Int. / Paper	4 hours
Reading time Int. / Thesis	20 hours

Second step: the definition of characteristics and performance indicators

After defining the project system to study, we had to choose the data which better described it. We have chosen the following data:

- a human resource has the following parameters: expertise rate, schedule;

the documents to be read have the following characteristics: reading time, quality rate.

With the help of interview campaigns and discussions with experts we were able to define the values of some groups of characteristics. The "social" group (which take into account a human singularity) are

- the reading time depending on the person;
- the quality that each person brings to the project;
- the modelling of the expertise of resources that increases over time.

For the technical characteristics the identified parameters were:

- the find rate of each document (it corresponds to the arrival of each document on the "to be read" pile);
- the reading time of each document according to the type;
- the quality that brings each type of document read to the project;
- the flow of inter-contract on the project;
- the salaries of each human resources.

Some of these data have been modelled using distribution functions that best correspond to reality (Table 1). For choosing performance indicators, we have picked 3 KPIs specific to bibliography: the overall quality of the bibliography work, the number of relevant documents read and finally the cost generated by this process.

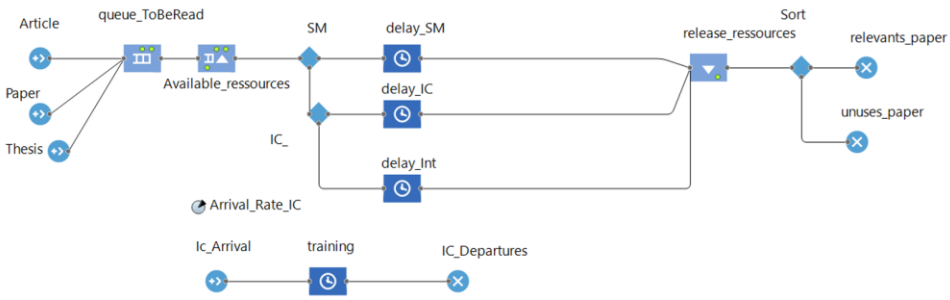

Figure 5. The picture of the model - Anylogic

Third step: simulation of the project

According to our proposal, the first step was to chose the type of modelling for simulation that will fit with this process. Three main simulation modelling paradigms have been considered : agent-based model, system dynamic and discrete event. Discrete event simulation is used to model an operational situation which is driven by events. It also captures individual variation of all parameters (Tako and Robinson, 2012). This is the chosen solution. The simulation was performed with the AnyLogic software. AnyLogic Process Modelling Library supports

discrete-event, or, to be more precise, process-centric modelling paradigm. Using the Process Modeling Library blocks we were able to model the real-world systems in terms of units (transactions, customers, products, parts, vehicles, etc.), processes (sequences of operations typically involving queues, delays, resource utilization), and resources (Anylogic Help). The picture of the model is shown Figure 5. So we ran the simulation to get the data in normal conditions. We defined a target zone that represents the performance values we want to achieve at the end of the project.

Table 2. Value of the target zone

Parameters	Values min	Values max
Quality rate (%)	60	80
Cost of the project (k€)	15	20
Paper read	50	60

Fourth step: definition of crisis scenarios

The goal is then to simulate events leading to a crisis in the project. We have chosen to see the impact of Covid-19 crisis if it had appeared during this bibliography phase. The appearance of this specific crisis would have implied the absence of consultants on the R&D projects. Indeed, they would have been on mission at the client's to help them manage the crisis. This really represents a crisis because it induces a reduction in the amount of work by more than 50%. We have chosen to study the behaviour of the bibliography project over 2 months and this disruptive event occurs after 1 month. The performance values are picked every day.

Results

There are many ways to visualize performance evolution. The first chosen visualization is a global one which represents the progress of the project each day compared to the final objective. The first trajectory generated is the inertia which is the reference trajectory for our study (when all goes well during the project). The result for the inertia trajectory is shown on Figure 6 with the green line. We defined the target zone that represents the final objective of the process as the grey cube on Figure 6 (value in Table 2). The disruption scenario investigated is shown on Figure 6 with the red line. First thing, the two trajectories are at the beginning almost the same (due to the distribution on function present in the simulation), and we see it is at the exact moment when the crisis appears that the curves move away. Also, the second trajectory, by undergoing the crisis without acting, will not reach for the objectives initially fixed. Finally, we notice that the quality indicators are not too much impacted. This can be explained simply by the fact that there were just fewer actors on the project but they were not less competent.

The second visualization is based on a daily comparison of KPI values. The will here is to be able to compare daily performances of the process. The results is shown on Figure 7.

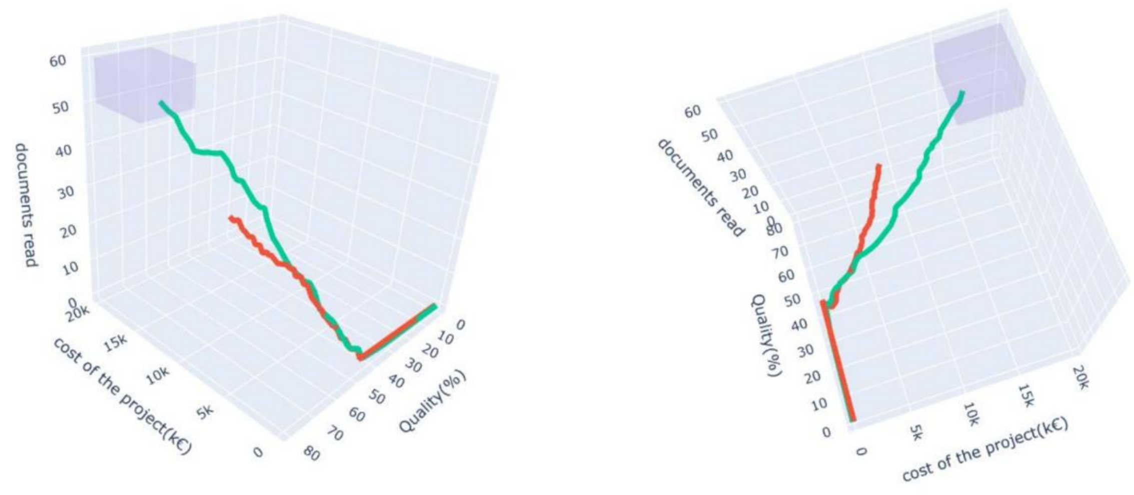

Figure 6. Two point of view of the results for the cumulative performance

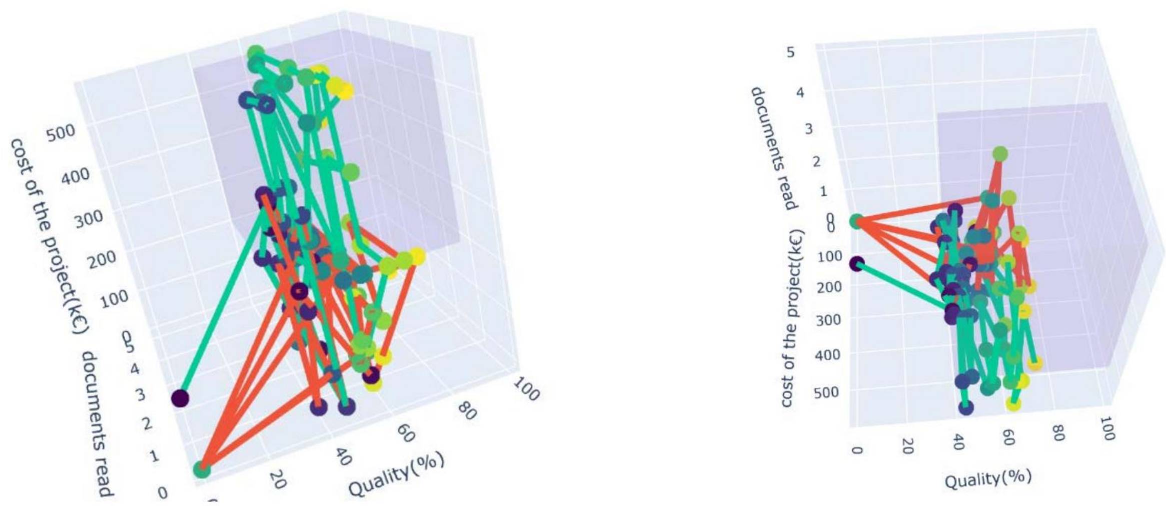

Figure 7. Two point of view for the daily performance

This visualization is a little less easy to read. The green line also represents the nominal situation, the red line represents the crisis scenario and the grey cube represents the target zone. The colours of the markers represent the evolution of time (blue the start of the project, yellow the end). In nominal operation, only 38% of the points are not in the target zone. For the crisis scenario, 63% of the points are not in the target zone. Moreover, thanks to this visualization we also notice an interesting point for the project manager. We notice that the more time goes by, the more the global expertise of the project increases (this is manifested by the translation of the yellow points towards a higher quality). In this visualization mode, however, it seems impossible to compare the two trajectories represented by the lines.

CONCLUSION AND PERSPECTIVE

About the first visualization, we notice a real difference between the two situations, we can evaluate qualitatively or quantitatively the gap between the two trajectories or how far we are from the target. In our case study, we can even see when the project starts to drift by studying the moment when the curve moves significantly away from "the normal". Dividing the performance into three dimensions allows us to see which indicators are going wrong.

About the daily view, the defined target area is a good indicator of the good progress of the project. This view also allows us to notice the evolution of the daily values. For example, we can see that the quality of the daily project is increasing (the colour gradient is moving).

This research is only a preliminary work to show the interest of using POD in project management. We can imagine exploring several avenues for future research. The next step is to vary the parameters of the model using simulation campaign in order to get enough data to "learn" the impact of an event depending on the current situation of it. The analysis of these simulation campaigns using machine learning is clearly an avenue to explore in the future in order to detect and predict a crisis. We can then compare corrective actions and see which one is the most interesting. We can also be interested in identifying deviations in real time, by finding a way to read just the project simulation models using real data. Human behaviour is a significant parameter into projects, so another step can be to include more human behaviour in models and in simulation (for example the social link between the human that influence the project). Maybe the consideration of a nominal zone instead of a nominal trajectory is a good way to improve the results as well.

Having a visualization of the situation rather than a dashboard with several indicators is something that, for us, allows the manager to understand and evaluate the situation of a project more The more complex and precise the model, the closer it will be to reality. We can therefore simulate several types of scenarios and see the impact of these even before they happen.

The result mainly concerns visualization of the performance deviation due to a major disruption. We generated two views about the evolution. The first view may be useful in a global context of global analysis of the project and its objective. The second view is for a daily use and a daily comparison.

REFERENCES

"About Process Modeling Library | AnyLogic Help." n.d. Accessed August 12, 2021. https://anylogic.help/library-reference-guides/process-modeling-library/pml.html#about-process-modeling-library.

Aven, T. 2016. "Risk assessment and risk management: Review of recent advances on their foundation." *European Journal of Operational Research*, 253 (1): 1–13. https://doi.org/10.1016/j.ejor.2015.12.023.

Backlund, F., D. Chronéer, and E. Sundqvist. 2014. "Project Management Maturity Models – A Critical Review: A Case Study within Swedish Engineering and Construction Organizations." *Procedia - Social and Behavioral Sciences*, 119: 837–846. https://doi.org/10.1016/j.sbspro.2014.03.094.

Benaben, F., L. Faugere, B. Montreuil, M. Lauras, N. Moradkhani, T. Cerabona, J. Gou, and W. Mu. 2021. "Instability is the norm! A physics-based theory to navigate among risks and opportunities." *Enterprise Information Systems*, 0 (0): 1–28. Taylor & Francis. https://doi.org/10.1080/17517575.2021.1878391.

Benaben, F., M. Lauras, B. Montreuil, L. Faugère, J. GOU, and W. Mu. 2019. "Physics of Organization Dynamics: An AI Framework for opportunity and risk management." *2019 International Conference on Industrial Engineering and Systems Management (IESM)*, 1–6. https://doi.org/10.1109/IESM45758.2019.8948167.

Benaben, F., B. Montreuil, J. Gou, M. Lauras, L. Faugère, and W. Mu. 2020. "A physics-based theory to navigate across risks and opportunities in the performance space:Application to crisis management." *Proceedings of HICSS 52 - 52nd Hawaii International Conference on System Sciences*, 2187.

Boateng, P., Z. Chen, and S. O. Ogunlana. 2015. "An Analytical Network Process model for risks prioritisation in megaprojects." *International Journal of Project Management*, 33 (8): 1795–1811. https://doi.org/10.1016/j.ijproman.2015.08.007.

"BS EN IEC 31010:2019Risk management - Risk assessment techniques." n.d. Accessed January 2, 2022. https://www.bsigroup.com/en-GB/standards/bs-en-iec-310102019risk-management---risk-assessment-techniques/.

Coombs, W. T., and D. Laufer. 2018. "Global Crisis Management – Current Research and Future Directions." *Journal of International Management*, 24 (3): 199–203. https://doi.org/10.1016/j.intman.2017.12.003.

Crockford, N. 1980. *An introduction to risk management*. Woodhead-Faulkner.

Dandage, R. V., S. S. Mantha, S. B. Rane, and V. Bhoola. 2018. "Analysis of interactions among barriers in project risk management." *J Ind Eng Int*, 14 (1): 153–169. https://doi.org/10.1007/s40092-017-0215-9.

Flage, R., T. Aven, E. Zio, and P. Baraldi. 2014. "Concerns, Challenges, and Directions of Development for the Issue of Representing Uncertainty in Risk Assessment." *Risk Analysis*, 34 (7): 1196–1207. https://doi.org/10.1111/risa.12247.

Hermann, C. F. 1963. "Some Consequences of Crisis Which Limit the Viability of Organizations." *Administrative Science Quarterly*, 8 (1): 61–82. https://doi.org/10.2307/2390887.

Ho, W., T. Zheng, H. Yildiz, and S. Talluri. 2015. "Supply chain risk management: a literature review." *International Journal of Production Research*, 53 (16): 5031–5069. Taylor & Francis. https://doi.org/10.1080/00207543.2015.1030467.

Lee, N.-S., S. Hirschmeier, S. Müller, and L. J. Luz. 2017. "Enablers in Crisis Information Management: A Literature Review."

Liu, J., X. Zhao, and P. Yan. 2016. "Risk Paths in International Construction Projects: Case Study from Chinese Contractors." *Journal of Construction Engineering and Management*, 142 (6): 05016002. American Society of Civil Engineers. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001116.

Marle, F., L.-A. Vidal, and J.-C. Bocquet. 2013. "Interactions-based risk clustering methodologies and algorithms for complex project management." *International Journal of Production Economics*. Elsevier.

Project Management Institute (Ed.). 2013. *The standard for portfolio management*. Newtown Square, PA: Project Management Institute.

Project Management Institute. 2018. *A Guide to the Project Management Body of Knowledge (PMBOK Guide-Sixth)*. Project Management Institute.

Tako, A. A., and S. Robinson. 2012. "The application of discrete event simulation and system dynamics in the logistics and supply chain context." *Decision Support Systems*, 52: 802–815. https://doi.org/10.1016/j.dss.2011.11.015.

Taroun, A. 2014. "Towards a better modelling and assessment of construction risk: Insights from a literature review." *International Journal of Project Management*, 32 (1): 101–115. https://doi.org/10.1016/j.ijproman.2013.03.004.

Tavakolan, M., and H. Etemadinia. 2017. "Fuzzy Weighted Interpretive Structural Modeling: Improved Method for Identification of Risk Interactions in Construction Projects." *Journal of Construction Engineering and Management*, 143 (11): 04017084. American Society of Civil Engineers. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001395.

White, D. 1995. "Application of systems thinking to risk management: a review of the literature." *Management Decision*, 33 (10): 35–45. MCB UP Ltd. https://doi.org/10.1108/EUM0000000003918.