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Toward a Generic Information System for Projects Portfolio management using Physics of Decision (POD)

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Abstract

Project portfolios are complex and unique systems. Projects within the portfolio share the same resources to achieve the set objectives. Monitoring and controlling the progress of these projects requires implementing and understanding techniques such as risk analysis or decision support. In a complex and uncertain world, decision-making is a critical process that can cause uncontrollable and unanticipated disruptions. It is necessary to predict the consequences of and identify the effects of changes within the internal and external environment. However, the uniqueness of project portfolios poses a challenge for prediction because it cannot be based solely on historical data. This research presents a management tool based on decision support techniques and defined rules of behavior that a project portfolio could have. These rules are generic and adaptable and the goal is that managers can use and adapt these. These rules are defined using the Physics of Decision (PoD) vision and the adaptation of this vision using first-order logic. example of its

use. approach allows us to present a solid basis for creating a decision support system by being generic to the field of project management but leaving the possibility of adapting the functioning of this tool.

Keywords: Portfolio Monitoring, Execution Phase, Changes, Decision Support System

1. Introduction

Collaborative situations within organizations have necessitated the development of methods and tools for managing activities (Seymour and Hussein, 2014). As the world becomes increasingly interconnected, companies across all sectors have divided their activities into projects, portfolios, and programs to achieve more strategic objectives (Cooper et al., 1999),(Meskendahl, 2010). Projects within the same portfolio or program are interconnected due to several factors: the same human resources are allocated to multiple projects, the shared raw materials and products are divided among projects, the project essential outputs are needed for the continuity of other projects, budget sharing, the existence of a sub-contracting agreement...

Much theory has been developed, notably to maximize financial benefits by selecting projects and optimizing resources within a portfolio (Arantes et al., 2022), (Markowitz, 1991). However, financial project portfolios are no longer the only ones being studied. Nowadays, a project portfolio can represent a construction portfolio, an IT development portfolio, or even a supply chain management portfolio. Markowitz's robust research mainly focuses on asset and stock management, and therefore, these theories must be broadened and challenged with other problems such as risk management, forecasting,

adaptation to change, and more. However, despite all this research, many portfolios still fail to reach their objectives, follow up their planning, or not trigger cost explosion (Kose et al., 2024) due to failures in the portfolio management process. These failures can be diminished and managed through the implementation of information systems (Pearlson et al., 2024)

Most portfolio management software is merely descriptive or intervenes only in the selection, prioritization, and evaluation phase of projects within a portfolio (el hannach et al., 2019). It is imperative, therefore, not only to implement selection and prioritization techniques but also, once portfolios are initiated, to establish continuous feedback loops and monitoring mechanisms. Indeed, cascade effects are phenomena that greatly influence the evolution of complex systems such as project portfolios, and taking them into account improves the success of predicting the impacts of these changes (Ellinas et al., 2022). Portfolio monitoring is based on several principles: the implementation of governance, tracking the progress of the projects within the portfolio, monitoring strategic alignment, and accounting for changes. (Project Management Institute, 2018). The monitoring phase of a project portfolio is considered the core of the decision-making problem related to that portfolio (Nguyen et al., 2018). The monitoring of a system, and more specifically of a project portfolio, is based on objectives and targets. To this end, key performance indicators (KPIs) are defined. These KPIs are categorized, defined and tracked throughout the monitoring process. The portfolio monitoring should be based on the appropriate KPIs, and decisions should likewise be grounded in these KPIs. Decision-making in this context becomes increasingly complex because there are more and more variables within and linked to the system (Martinsuo

and Gherardi, 2020). In an interconnected network, it is important to model cascading effects at the scale of a portfolio as it is done within a project (Zhang et al., 2023).

The following research question is addressed: **What are the design principles and implementation strategies for developing a generic and modular platform that integrates monitoring, anticipation, and risk management functionalities to enhance the decision-making and management processes of a project portfolio manager?**

Our study aims to propose a generic platform for portfolio management capable of modeling changes and anticipating the impacts of changes on the overall project portfolio execution. This platform will be based on modeling the dynamics of a project portfolio exclusively using a causality model, which facilitates the propagation of cascade effects. This work is structured as follows: section 2 reviews the evolution of portfolio management and the measurement of performance. It also includes current work on decision support systems existing in portfolio management and the work regarding the model of cascading effects. Section 3 Presents the vision used to answer the research question: Physics of Decision (PoD). This section first presents the basic vision of PoD and the assumptions underlying this proposal. Next, the implementation of this vision through a metamodel is introduced. In Section 4, the step-by-step use of this metamodel to create an information system will be explained. Then the formal design of our prototype to monitor a portfolio of projects is presented. Section 5 presents the function developed during the research through a pedagogical example. The last section is a conclusion and the next steps.

2. Related Works

The literature will therefore focus on how the portfolio management domain has evolved, and then on the influence of performance in this management domain. Then the failures to anticipate the evolution of portfolios will be identified such as cascade effect and dependencies, and finally, the limits of today's decision support systems will be highlighted.

2.1. Project Portfolio Management and definitions

Changes in customer habits and the need for companies to be flexible to adapt to their environment have given rise to the "projectization of the world" (Garel, 2013). The first concepts of modern project management were introduced at the beginning of the 19th century. Institutions play a crucial role in the development of standard concepts and processes for project management. The Project Management Institute (PMI) was created to bring together professionals' vision and increase interest and knowledge in this field. To increasingly cooperate with more companies and achieve ambitious objectives, businesses have developed and structured their activities into projects, programs, and portfolios (Cooper et al., 2000). At the beginning of the last decade, 84% of companies worldwide were working on multiple projects simultaneously (Lova and Tormos, 2001).

A portfolio is a collection of projects that continue and follow a life cycle in five phases: initiation, planning, execution, optimization, and monitoring/control. These phases constitute a cycle, and each can be executed or adjusted during the portfolio's life (Project Management Institute, 2018). The goal is to group within the same portfolio the projects contributing to the same strategic

objective defined by the company. Divided activities into portfolios can help define and manage organizational capabilities (Roberts and Hamilton Edwards, 2023). The first research area in managing portfolios focused on selecting the best projects that could constitute the portfolio (Danesh et al., 2018). Then, techniques for prioritization and resource allocation were developed to optimize and improve the decision-making process of selection and prioritization phases (Barbati et al., 2023). Over the years, it has become evident that portfolios are interdependent and that in a highly VUCA (volatile, uncertain, complex, ambiguous) socio-economic world, portfolios face increasingly internal and external changes (Nabati and Ashrafi, 2021) that lead to failure of projects or the whole portfolio (Schmidt, 2023)

Since the 2010s, the study of uncertainty and change has been integrated into portfolio management theory (Hansen and Svejvig, 2022) to face these issues. Studies therefore recommend incorporating adaptability and the ability to quickly absorb change (Hoffmann et al., 2020). In a dynamic environment, agility concepts such as sensing, seizing, and reconfiguring improve drastically portfolio's success (Bechtel et al., 2023).

2.2. Portfolio Management monitoring through performance indicators

At the end of the 1990s, several studies demonstrated a direct relationship between project success and best project management practices (Belassi and Tukel, 1996). One of the best practices of project portfolio management is to assess and control the portfolio using performance measurement (Kock et al., 2020). The field of Project Portfolio Performance (PPP) has two objectives: 1) to evaluate the current performance of the portfolio, and 2) to forecast the performance of the portfolio based on its current status (Zarghami

and Dumrak, 2020). In the development of portfolio theory, performance was initially summed up by financial indicators, which were among the first studied (Bushuyev et al., 2021). Subsequently, time and quality aspects were analyzed, leading to the creation of the project management golden triangle of indicators: The cost, quality, and delay. These indicators have long represented the aspects that the stakeholders aim to achieve in terms of performance (Pollack et al., 2018). For years, this has been the primary measure of success and thus performance (White and Fortune, 2002) (Bryde, 2008), indicating the development of trade-off theory. However, it is clear that these three metrics are no longer sufficient and have therefore evolved (Pollack et al., 2018). This is particularly supported by a study by Pollack, which shows that these concepts are at the core of research but are complemented by other concepts such as Scope and Performance.

Indeed, with current issues, especially concerning the environment, new key performance indicators (KPIs) have emerged: sustainability, robustness, resilience, etc (Aghajani et al., 2023). The choice of KPIs depends on the objectives of the project portfolio under study. The performance depends on several factors, such as the sector of activity or the company's interests. It would be necessary to propose a way to aggregate indicators rather than simply selecting them. The main aggregation techniques are based on Multi-Criteria Decision Making (MCDM) (Taherdoost and Mohebi, 2025). The aim is to assign weights according to the interest and importance of the indicator and to create a score with corresponding mathematical relationships. The final score represents, for example, the relative state of performance (Bumba et al., 2023). Through all these examples, we understand that

decisions are always based on performance objectives. To evaluate possible decisions for a manager, several methods exist. The first is the simulation of the system through scenario creation. These simulations can be based on agent-based systems (Khodabandelu and Park, 2021) or dynamic systems (Yousefi Roodsari, 2022). The second solution is the implementation of optimization models (Skolpadungket et al., 2007). In both cases, several scenarios are tested and compared.

2.3. Cascading effect and interdependencies within portfolios.

Projects primarily fail due to cascading effects caused by unanalyzed dependencies. Generally, an interdependence is defined as "when one project is partially or wholly influenced by another project(s) for its development" (Bathallath et al., 2016). The nature of dependencies can occur at different levels: at the level of tasks, objectives, collaborators, or even at the level of the project itself (Bai et al., 2021). Currently, changes are treated independently (Daood et al., 2024), which interferes with and undermines the management of responses to these changes. To address this problem, (Bilgin et al., 2017) proposes to identify dependencies upstream of the portfolio execution. These dependencies can be various: financial dependencies, resource dependencies, or dependencies at the level of deliverables (where the output of one project or task is, in fact, a component of another project). They also propose quantifying these dependencies using weights provided by experts. Additionally, Ellinas models the propagation of direct or indirect failure effects on an engineering project using interactions (Ellinas et al., 2022). Dependencies can also be visualized in a dependency graph, where nodes and arcs would be proportional to the importance of the projects and the dependencies, respectively (Bilgin

et al., 2017). In any case, it is important to study dependencies and take them into account in the projection and management of the portfolio. Different scales must be considered in the portfolio governance process, particularly the strategic scales in terms of governing authority (Tuominen and Martinsuo, 2024).

2.4. Decision support system to monitor and control portfolio

For decades, this has been the case for projects: information systems are no longer just about planning and resource management but real support for understanding the entire life cycle of the portfolio (Akopov, 2012), (Teubner and Stockinger, 2020). The decision support process is defined as "computer technology solutions that can be used to support complex decision making and problem-solving" (Shim et al., 2002). In the portfolio management process, the decision support process is crucial (Kock and Georg Gemünden, 2016). Studies have shown that their use has a positive influence on portfolio performance (Kock et al., 2020) especially to acquire and process data that can be formalized and taken into account in the situational awareness of a portfolio (Hansen et al., 2020).

In the literature, most Decision Support Systems (DSS) focus on planning and risk analysis (Hazır, 2015). They are becoming increasingly systemic and mature, and for example, we are now seeing DSS with contextual and strategic data (Aloini et al., 2019). EL Hannach developed a Project Portfolio Management System that, during the prioritization and selection phases, connects strategic objectives with operational project management purposes, which is unprecedented (el hannach et al., 2019). However, this remains within the realms of selection, prioritization, and evaluation, at the front end of

portfolio management. The selection phase is the most studied (Micán Rincón et al., 2023). There is thus a need to develop a decision support tool not only for the selection and optimization of projects within a portfolio, but also to assist in managing the system, particularly when faced with uncertainties, complexity, and unforeseen events.

To sum up, the literature shows that there is a lack of tools for monitoring portfolios and tracking or evaluating changes through the performance paradigm. The lack of consideration of cascading effects in the literature is notable. Although various tools exist, they often have different functions, or the software is specific to each company. Some decision support systems (DSS) deal with both planning/resources and risks but operate mainly at the beginning of portfolio management.

3. The Physics of Decision (POD) Framework as a basis for an Information System

This section presents how the POD framework can be the basis of the creation of a DSS used to monitor and anticipate the consequences of a change within the portfolio of projects during the execution phase. This section consequently presents the main principles of this application. First, at the scope level of this application, it is necessary to adhere to the model and apply the method developed below to portfolios consisting of projects, which themselves are made up of tasks. Then we will propose a pedagogical example to illustrate the functions that were implemented.

3.1. *POD framework: the basis*

The POD framework is based on the following analogy: the performance of a system can be modeled as a trajectory and risks and opportunities can be viewed as forces that change the performance of the system by deviating that trajectory (Benaben et al., 2021). Two spaces are defined to analyze our system. The first space is the description space, in which we can define and initiate our system with its attributes as dimensions. These attributes may be the known parameters for the considered system but also its internal or external environment. The second space is the performance space, in which we can position our system according to the values of its performance indicators. The dimension of the performance space is the significant KPI for the system. This performance is an aggregation of attribute values in the description space but will enable us to visualize objectives, trajectories, risks, and opportunities in this space. The question of this aggregation is, of course, specific to each studied system. To design these two spaces and implement them in an information system, it is necessary to know the attributes of the components. These attributes, based on their values, will first instantiate the potential and then the potentiality. This framework was detailed in (Le Duff et al., 2024) and can be described as the class diagram of Figure 1.

The principle is as follows: the bottom model is a class diagram corresponding to the domain under study, here portfolio management. This is where we will store the relevant attributes of the components. The Core model above it must address and translate the entire dynamics of our system, it is the representation of the POD model.

The Physics of Decision (POD) ontology, as outlined in the (Benaben et al.,

2021) reference, employs the concept of "Potentialities". In this framework, a potentiality that poses a threat to the performance of a system is termed a "Risk," while one that enhances performance is termed an "Opportunity". Therefore, using the bottom model, we will be able to create instances of the Core model.

Here are the assumptions corresponding to the model:

- Each evolution is the triggering of a risk or an opportunity in our system (the execution of a task is seen as an opportunity, or the absence of a resource as a risk).
- Each risk or opportunity is a combination of a component and its susceptibility to danger or favorability (the execution of a task is the combination of the task's potential to be executed, i.e. all the resources and inputs are available, and the task's susceptibility to this potential).
- Each danger or favorability (potential) is actually created by a component and notably by formulas on the characteristics of this component (A resource has a *motivational* attribute, and if this attribute falls below a certain threshold, the resource created the danger of *declining the productivity*).
- The susceptibility of a component is also expressed by a formula on characteristics of my system (regarding the danger of a resource's productivity falling, the susceptible components will be those tasks whose *resources needed* attribute contains the human resource that generates the danger).

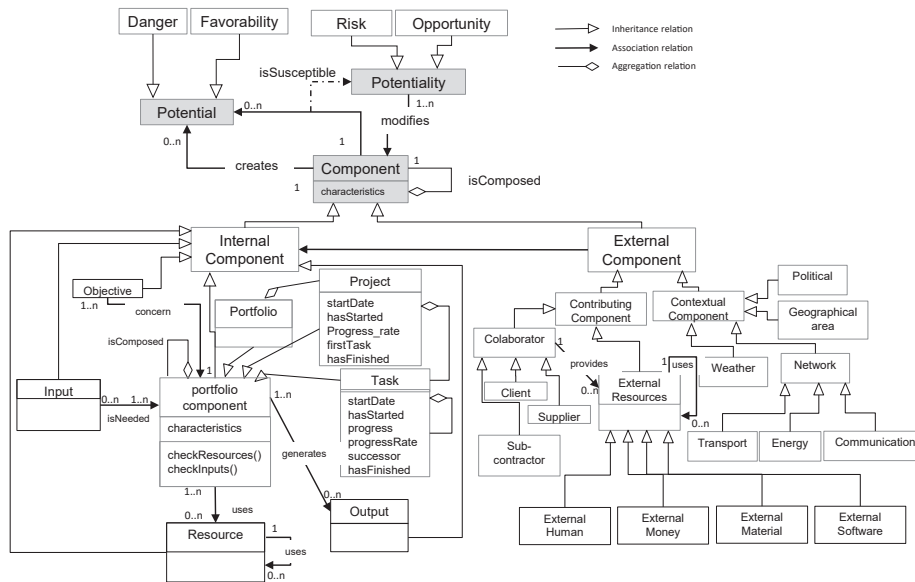


Figure 1: The POD ontology extended to the portfolio project management domain

- The activation of a risk or an opportunity is also done by a formula on characteristics (the condition to trigger the potentiality of declining the productivity is for example another threshold of motivation is reaching and so there is no doubt that the productivity is decreasing).
- The consequences of a risk or opportunity are expressed by a change in one or more system attributes (for example, the decrease in productivity will have the following consequences: the quality of the task’s deliverables is decreasing).

One of the goals of our approach is to model changes within the portfolio and their cascading effects with a maximum generic model. If the consequences of activating potentialities are a change in attributes, the effects induced by this change, if the chains have been defined, will also be propagated. For

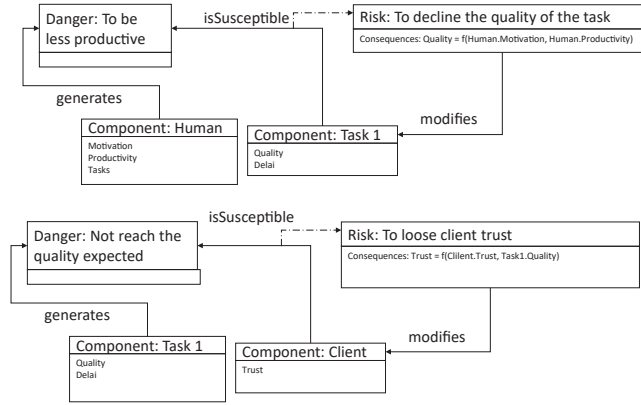


Figure 2: Example of the cascading effect that encompasses the model.

example, we know that the risk of a resource’s motivation decreasing will reduce the quality of the task’s deliverables, but we also know, thanks to experts for example, that a decrease in the quality of the task’s deliverables will reduce customer confidence. This mechanism is illustrated with the corresponding chain in Figure 2.

Therefore, we have chosen to have rules that correspond to the dynamics of the system and are thus associated with risks and opportunities. For each risk or opportunity in our model, it is, therefore, necessary to have at least the information on the triggering formulas of the following associations:

- The condition for the creation of the potential by the component
- The condition for the susceptibility of a component to this potential
- The condition for triggering the potentiality

The aim is, therefore, to define each evolution as the activation of all the conditions of the chains of potentialities, including evolution in daily operation

(defined as *functional behavior*) and evolution regarding the emerging change (defined as *emerging behavior*). In order to distinguish between disruptive behavior and functional behavior, the terms functional behavior (which corresponds to the nominal function of the portfolio) and emerging behavior (which corresponds to emerging potentialities, positive or negative, identified by portfolio managers) are used. Therefore, for the foundation of our DSS, there are two main components: (i) A knowledge base containing all the components of our system, its environment, and their relevant attributes for instantiating the conditions, (ii) a knowledge base corresponding to the risks and opportunities studied, with conditions expressed using the attributes of the components of the system and the environment.

This diagram represents the components identified within our portfolio. The foundation of this model is that a portfolio component (a portfolio, a project, or a task) can be defined as this component "needs" inputs, "uses" resources, and "generates" outputs. These fields are not mandatory, but they help define these components. These inputs, resources, and outputs are components of the system. This model aims to be adaptable (a portfolio manager can add, delete, or link the different components differently). Thanks to this, we can instantiate and organize all the information concerning our project. This information can be internal (about resources, material goods, etc.) or can come from the external environment (clients, suppliers, political environment, etc.).

The primary objectives of this decision support system are as follows: first, enable tracking the progress of the portfolio, then allow for studying scenarios by changing component attributes and analyzing cascading effects,

and finally enable the inclusion of major changes of any type. About the types of portfolio targeted by this vision, we believe that it can be applied in theory to any project portfolio which is made up of several projects and which is managed by performance, indicators, or objectives. The difficulty lies in defining the potential or potentialities corresponding to the system. Here we have therefore chosen to present this vision first with projects divided by WBS and therefore made up of tasks.

3.2. The Physics of Decision for Portfolio Management (PODPM) design

The following section illustrates how to implement decision support systems using the previously presented concepts.

3.2.1. Components and performance definition

At the initialization of the portfolio, following the selection and prioritization of projects, the attributes of projects can be stored in the database. The PODPM simply allows the creation of each component and the creation of its attributes (name, duration, etc.). One of our contributions is that the attributes can be chosen by the user based on the attributes they track for the rules definition. In addition to this definition, to manage the project portfolio in real-time, it is highly recommended to monitor it through performance indicators (Silva et al., 2021). Subsequently, the objectives are defined in the form of performance indicators. These indicators can be defined using the attributes of the system and its environment, and thus, for each Key Performance Indicator (KPI), we would have:

$$kpi_i = f(att_1, att_2, \dots, att_m) \quad (1)$$

For a project portfolio, performance is defined as follows: according to Ojiako, it manifests through two dimensions: effectiveness and efficiency.

Effectiveness refers to the alignment between the specific expectations of various stakeholders and what has been delivered by the portfolio. Efficiency, on the other hand, relates to the quality of the actions implemented to achieve the desired goal. Efficiency depends on four elements: adherence to the planned schedule, budget compliance, quality, and customer satisfaction. Effectiveness is based on future-readiness, the strategic plan, portfolio balance, and collaborative synergies (Ojiako et al., 2023).

Regarding effectiveness, it is essential to define stakeholders' expectations and provide feedback. As for efficiency, it involves classic indicators such as: i) Current progress versus expected progress, ii) Current portfolio costs versus expected costs, iii) Total current planned portfolio costs versus projected portfolio costs.

3.2.2. Knowledge based for potentialities definition

One of our main contributions is the implementation of the POD metamodel into a knowledge base to represent the entire dynamics of a portfolio. The objective is to express the following potentialities (risks and opportunities) with the following attributes, in brackets, the risk of delay on a job due to an unreliable supplier is given as an example. :

- component type generator of the potential, here danger (Supplier)
- generation condition of the potential (The supplier trust is low: $SupplierA.Trust < 80\%$)
- name of the potential (The supplier trust is low)

- component susceptible type (Task)
- component susceptible condition to create the potentiality, here risk (The supplier supply good for the task: $Tasks.listSupplier = SupplierA$)
- potentiality name (There is a risk of not receiving the good for the task)
- condition of triggering the potentiality (The supplier is not sending the goods: $Task.goodReceived = []$)
- consequences event (The task can not continue)

Some attributes will be interesting to store in a database, here the Supplier's trust is an attribute of our Supplier component, and the list of task substitutes is also an attribute to know. Using this data, we will be able to instantiate the risks and opportunities present in the system at any given moment.

3.2.3. The acquisition of data in real time

The goal of this information system is to easily store and update new data coming from both external and internal sources. These data need to be standardized in the form of a value of an attribute of a system component or its environment: "*concept.attribute*". For example, if a factory is closed, it is better to have an attribute representing this situation, such as a boolean with a value of *True* if the factory is open and *False* if the factory is closed ($Factory.isClosed = True$ or $False$).

Also in the world, it is possible to anticipate change that will occur in the future. Therefore there is a database that lists planned actions, but with a date linked to the update. This data can come from the external environment or the knowledge of the portfolio manager. It allows managers to

take this data into account in the evolution of our portfolio generated by the information systems. For example, a human resource will not be available for two days for one week. So in my system, there is a component corresponding to this resource and an attribute called "isAvailable" that is True or False. An event will be created that will change the component's availability attribute from True to False in two days and this same attribute from False to True in two days + one week.

3.2.4. The potential instantiation algorithm

After explaining all the components required to implement the POD-based control framework. This section will present the instantiation logic in the pseudo-code Algorithm 1.

The chosen algorithm follows the following principles:

- Each rule is evaluated at every time step and after every change.
- In priority rules, risks are preferred to be activated first rather than opportunities to avoid having an overly optimistic scenario.
- Direct potentialities are activated first, followed by indirect ones at the end.

4. The implementation of the PODPM information system

Figure 3 presents the architecture of the PODPM information system. This architecture enables portfolio to be tracked by time step, to integrate internal and external changes at the operational, organizational and strategic levels, and to evaluates the portfolio regarding the future. The system

Algorithm 1 Instanciation and Triggering potentialities

List potentiality rules PR

Boolean representing cascade effect DPA

#While there are cascade effects

while There are direct cascade effect **do**

for PotentialityRules in PR **do**

for PotentialityRules n **do**

 GenerationCondition = Check_generation_condition(PotentialityRules)

if GenerationCondition == True **then**

 CreatePotential(PotentialityRules)

 SusceptibleCondition = Check_susceptible_condition(PotentialityRules)

if SusceptibleCondition == True **then**

 CreatePotentiality(PotentialityRules)

 TriggeringCondition = Check_triggering_condition(PotentialityRules)

if TriggeringCondition == True **then**

 Apply Impact in System

end if

end if

end if

end for

end for

end while

Return system at time $t + 1$

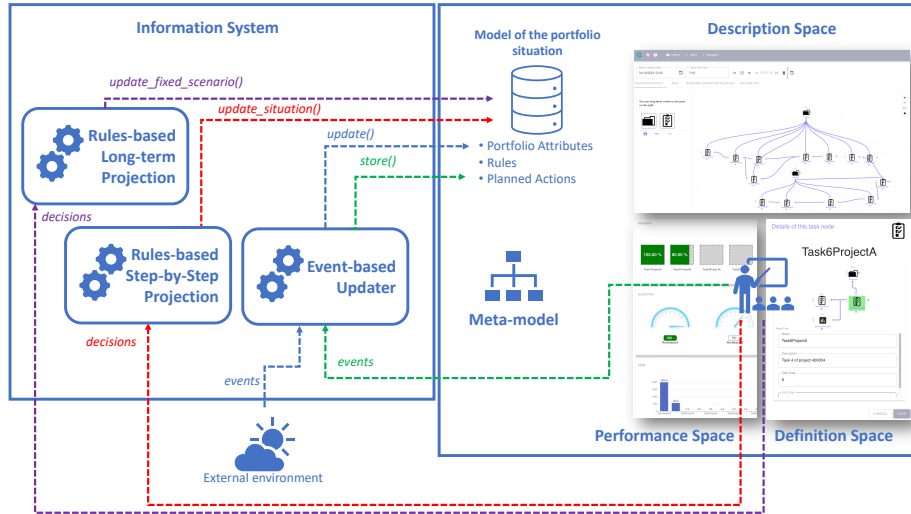


Figure 3: The PODPM Architecture to support Decision Making in a portfolio context

communication is based on REST API exchanges. In terms of architecture, there are 3 main functions and three main databases.

4.1. The rules-based step by step projection function

At any time, with the database up to date, you can see the status of the portfolio, the rules that govern it and the actions planned. The step-by-step projection function breaks down the activation of the rules and the possible cascade effects. The first step is to activate the projection. For each rule, the DSS instantiates those that are active and thus deduces risks and opportunities. For each rule, the DSS will check the activation conditions; if these are verified, the risk or opportunity will occur and the DSS will instantiate the rules again. The function will generate the outputs, i.e. the state of the system at time $t + 1$. This takes into account the cascading effects of the changes by creating a double-check loop of the rules until no changes

are made.

4.2. The event-based uploader function

The update function is used to update the three databases. For portfolio attributes, it can be updated either by the portfolio manager or by sensors that measure external environmental attributes. The rules are also updated by the portfolio managers. The portfolio manager can also rectify and modify the attributes of portfolio components or planned actions in the portfolio description space. Every change is just a change of an attribute of a component, or an attribute of a rule.

4.3. The rules-based long-term projection function

The projection function uses the same mechanisms as the step-by-step function. This projection function is useful if the portfolio manager wants to see how the actions he has planned evolve in the portfolio. The aim is for them to enter all the information they have planned for the projection they want. For example, the receipt of goods or the absence of resources. Then he can project the evolution of the portfolio and see the Kpis. The aim is that he can adjust and see what decisions he can take that would increase or improve his performance. The portfolio manager can: (i) test new rules which may correspond to new policies he wants to implement, (ii) test the impact of a decision (which he has defined in the form of planned actions) over the long term, (iii) test several scenarios he is currently examining or aiming for.

4.4. The three databases

There are three different databases. The first database stores all the components of the system, its environment and all their attributes. The

second database, the one presented in section 3.2.2 represent the rules linked to the potentialities and therefore the dynamics of the system. Finally, the last database is the planned actions, which represent the changes that will occur in our system.

5. Evaluation on a pedagogical example

The following paragraph uses a concrete example to illustrate the functions presented above.

5.1. Usecase Context

The context was created using a project manager, the aim not being to recreate a portfolio, but to create an educational example with the same constraints as the projects they have to manage. The context is as follows: we have a portfolio of a construction company consisting of two house renovation projects: Project A (PA) and Project B (PB). The portfolio manager manages four different resources: *Architect1*, *Architect2*, *Workforce 1* (a group of workers), and *Workforce 2* (a second group of workers). The portfolio is examined over the first 33 days. The defined tasks do not constitute a real portfolio of projects and are fictitious to serve the explanation.

The first assumption is that the project selection and resource allocation stages have been successfully completed so the main part is on focusing on portfolio execution and the management of operational changes. Every project has an objective, and therefore a performance target. Here, the performance of our portfolio is to track planned costs by task and project and to have no delays on tasks or projects. In addition, it is interesting to track the evolution of resource load over time. We can therefore define three KPIs:

Table 1: Capacity of resources

	Architect1	Architect2	Workforce 1	Workforce 2
Work (man.day)	1	0.7	6	6
cost (dollars/man.day)	200	170	200	165

Table 2: Planning and resources allocation

N	Activities	Pred	Resources Allocation	Work	duration
1	PA T1 - Renovation Plans	/	Architect 1	10man.day	10days
2	PB T1 - Renovation Plans	/	Architect 2	7man.day	10days
3	PA M1 - Received Building permit	1	Architect 1	1man.day	1day
4	PB M1 - Received Building permit	2	Architect 2	1man.day	1day
5	PA T3 - Renovation of the roof	3	Architect 1/Workforce 1	5man.day/10man.day	5days
6	PA T4 - Renovation of the garden	3	Architect 2 /Workforce 1	4,9man.day/28man.day	7days
7	PBT3 - Renovation of the roof	4	Architect 2 /Workforce 2	1 man.day/30man.day	5days
8	PAT5 - Renovation of the living room	5 - 6	Workforce 1	30man.day	5days
9	PAT6 - Renovation of the pool	8	Workforce 1	18man.day	3days
10	PBT4 - Renovation of the living room	5	Workforce 2	18man.day	3days
11	PBT5 - Renovation of the living room	10	Workforce 2	12man.day	2days
12	PM2 - End renovation	9 - 11	/	/	1 day
13	PAT7 - Check up and delivery	12	Architect 1	2man.day	2days
14	PBT6 - Check up and delivery	12	Architect 2	1,4man.day	2days

budget performance, delay, and allocation rate. These KPIs are arbitrary, the aim is to say here that any type of kpi can be defined.

The resource capacities per day for the 30 days are presented in Table 1. The resource *Architect 1* has a work of 1man.day and costs 200 dollars/man.day. The *Architect 2* has 0.7 man.day and cost 170 dollars/man.day. The *Workforce 1* has a work of 6man.day and cost 200dollars/man.day. The *Workforce 2* has a work of 6man.day and cost 165 dollars/man.day. The tasks are described in Table 2. Activities starting with *PA* *** (respectively *PB* ***) are relative to Project A (respectively Project B) In order to model portfolio dynamics, it needs to be translated into opportunities or risks. Re-

member that in our hypothesis, all changes are risks or opportunities, so the first need is to define the opportunities in normal operation: the functional behavior (i.e. the progressive progress of the project portfolio, and in that case, it's the progress of the tasks that creates portfolio's dynamic).

Our model is designed to be adaptable, but the Table 3 proposed a set of 5 functional behavior rules that can be used to instantiate the evolution of most portfolios. For example, in order to define the dynamic for starting a project (opportunities n°1 in Table 3), the need is to translate that the opportunity is present if the project CAN start ie, that it has all these inputs and resources available. This is what is translated by the `checkInputs()` method, which is ultimately a check of the "necessary inputs" attributes with their values in the system. For example, if the required input is that the contract has been signed, this will result in: "*Contract.isSigned = 1*" and the method will check the value of the *isSigned* attribute in the *Contract* component. Similarly for resources, if the requirement is for an architect to be 50% available per day, this will be expressed as *Architect1.availableRate/day > 50*. The method will then check whether the architect has an availability rate greater than 50%. For the potential generation condition, it can only exist if the project has not begun and can begin in time. So the *startDate* attribute encompasses this information, which corresponds to whether the project date is greater than or equal to the current date, and the `hasStarted()` method corresponds to a check of the *hasStarted* attribute of the component *project*.

For clarity of reading, the first line of the rule corresponds to the natural language equivalent of the condition (and the last column corresponds to the impact of the corresponding rule) and is therefore a value assignment.

The second line is the mathematical expression for the first-order logic that corresponds to this condition (and the assignment for the impact). The following table explains the attributes and methods of each object that are used to express the rules. As mentioned above, we can get by with attribute values to express these conditions (and impacts). For the moment, emerging risks and opportunities for the use case have not been introduced.

Table 3: Couple Favorability/Opportunity to model the functional behaviour of a portfolio.

generator type	Condition of generation (R1)	susceptible type	Condition of susceptibility (R2)	Condition of triggering (R3)	Impacts
1 Project P_x	A project is not started $P_x, P_x.hasStarted() = No \wedge P_x.startDate \leq now$	Project P_y	The project has inputs and available resources $P_y = P_x \wedge P_y.checkInputs() = 1 \wedge P_y.checkResources() = 1$	Project Manager trigger	The project is activated $P_y.hasStarted() = Yes \wedge P_y.activeTasks = None$
2 Project P_x	Project started, first Task not started $P_x, P_x.hasStarted() = Yes \wedge P_x.activeTasks = None$	Task T_y	The first task has inputs and available resources $P_x.firstTask = T_y \wedge T_y.checkInputs() = 1 \wedge T_y.checkResources() = 1$	Project Manager trigger	The first task is activated $T_y.hasStarted() = Yes \wedge P_x.activeTasks = T_y$
3 Task T_x	Task has started and is not finished $T_x, T_x.hasStarted() = Yes \wedge P_x.progress \leq 1$	Task T_y	The first task has inputs and available resources $T_y = T_x \wedge T_y.checkInputs() = 1 \wedge T_y.checkResources() = 1$	Project Manager trigger	the task progress $T_y.progress = T_y.progress + T_y.progressRate$
4 Task T_x	Task is finished and has successor $T_x.hasStarted() = Yes \wedge P_x.progress \geq 1$	Task T_y	The successor task has inputs and available resources $T_x.successor = T_y \wedge T_y.checkInputs() = 1 \wedge T_y.checkResources() = 1$	Project Manager trigger	the successors of the tasks are activated $T_y.hasStarted() = Yes \wedge T_x.hasFinished() = Yes$
5 Task T_x	The last task is finished $T_x.hasStarted() = Yes \wedge P_x.progress \geq 1 \wedge T_x.successor = end$	Project P_y	The projects can generated outputs $T_x.project = P_y$	Project Manager trigger	the project is finished $P_y.hasFinished() = Yes \wedge T_x.hasFinished() = Yes \wedge P_y.generateOutputs() = Yes$

5.2. PODPM Application

5.2.1. General overview of the Application

When you open the application, you can create or open an existing portfolio.

After defining or opening the monitored portfolio of projects, the PODPM Information System can be used.

5.2.2. The Description Space Menu

The Description Space menu shown in Figure 4 is where the portfolio manager can update the data of the components and its environment attributes database, if necessary, add or delete the various component attributes. The links between the components in the Description Space menu just help to highlight the interdependencies. These interdependencies exist if either: i) a component is composed of components, ii) a component is a resource, an input, or an output of a project component or iii) if project components are predecessors or successors of another project component.

5.2.3. The Risks and Opportunities Rules Menu

The Risk and Opportunity rules menu is where the portfolio manager inserts the functional potentialities (for example the set of five potentialities presented above) and emerging potentialities he has identified them. The five functional potentialities presented above are all defined, see Figure 5. The manager can add, delete or modify rules based on his knowledge of the environment and the system.

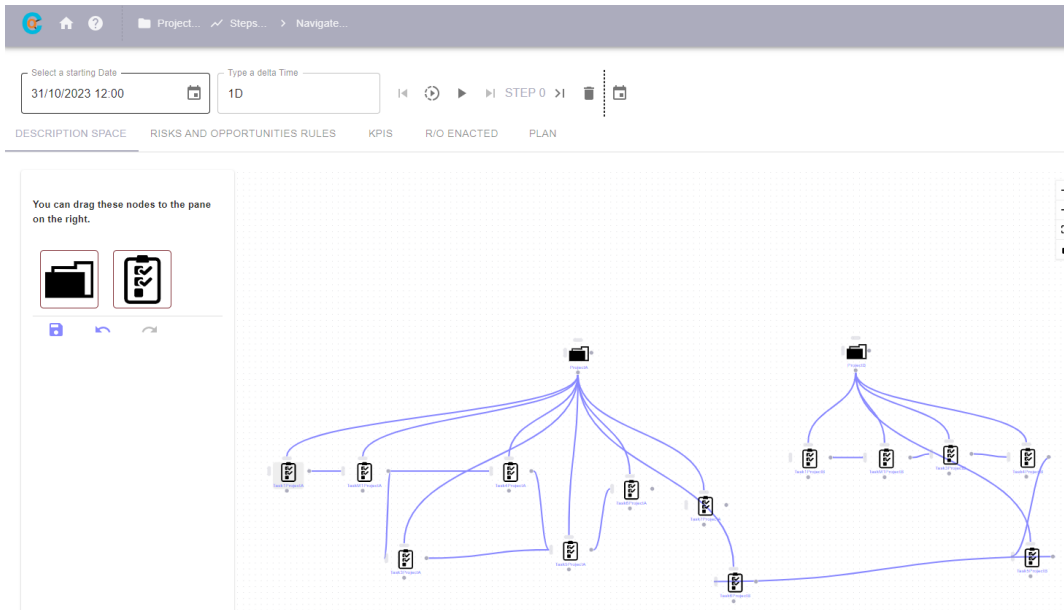


Figure 4: The Description Space menu of the PODPM of the illustrative case of the two Projects A and B

Id	Potential ...	Potential ...	Potential Name	Componen ...	Potential S...	Potentiality Name	Condition Event Name	Condition ...	Type Event	Consequences Nam...
0	<input type="checkbox"/>	<input type="checkbox"/>	The project (component_generator name) has not yet started.	Project	<input type="checkbox"/>	The (component_susceptible name) can start. It has all the inputs needed.	The manager chooses to start the project	<input type="checkbox"/>	direct	The (component_s...
1	<input type="checkbox"/>	<input type="checkbox"/>	The first Task of (component_generator name) can started	Task	<input type="checkbox"/>	The first task of (component_generator name) can start	The manager chooses to start the first task of project	<input type="checkbox"/>	direct	The first task (compon...
2	<input type="checkbox"/>	<input type="checkbox"/>	The Task of (component_generator name) can continue	Task	<input type="checkbox"/>	The tasks (component_generator name) can progress	The manager chooses to continue the task	<input type="checkbox"/>	indirect	The task: (compon...
3	<input type="checkbox"/>	<input type="checkbox"/>	The Task of (component_generator name) is finished, successor has to start	Task	<input type="checkbox"/>	The next task (component_susceptible name) can starts	The manager chooses to start the successors task	<input type="checkbox"/>	direct	The next task (compon...
4	<input type="checkbox"/>	<input type="checkbox"/>	The Task of (component_generator name) is finished, and it is the last task	Project	<input type="checkbox"/>	The last task (component_generator name) is finished, project (component_susceptible name) end	The manager chooses to end the project	<input type="checkbox"/>	indirect	The last task (com...
5	<input type="checkbox"/>	<input type="checkbox"/>	The Task of (component_generator name) can continue	Task	<input type="checkbox"/>	The tasks (component_generator name) can progress	The manager chooses to continue the task	<input type="checkbox"/>	indirect	The task: (compon...

Figure 5: The functional opportunities of the illustrative case of the two Projects A and B

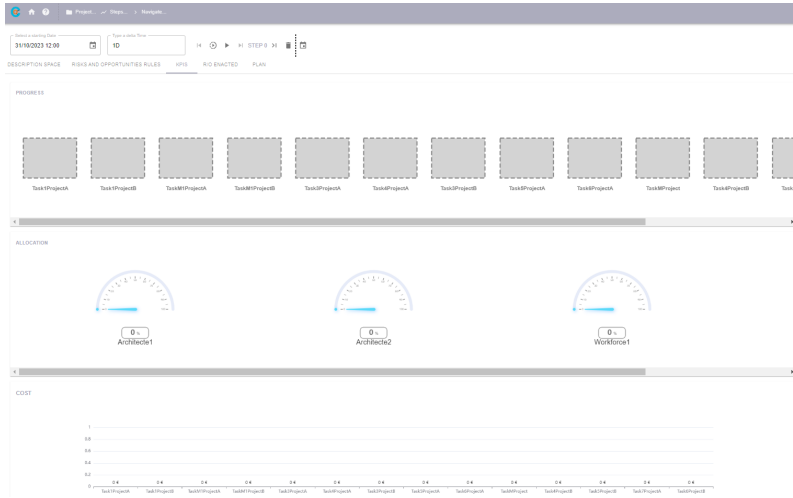


Figure 6: The KPIs menu of the PODPM of the illustrative case of the two Projects A and B

5.2.4. The KPI Menu

The KPI menu is where the KPI are defined and tracked. At the beginning of the portfolio, all the kpis are initiate. Three KPIS are defined: progress, resource allocation and task costs - which are presented in figure 6. The KPI menu represents the data used in the Performance Space defined in POD vision.

5.2.5. Performance Space Menu

Regarding performance, we previously highlighted the importance of having a clear idea of its state and evolution . We have therefore defined a last monitoring menu that shows the current performance in the form of a trajectory, the black line is the objective targeted by this performance and the red line is the current projected performance. At the begging, the current performance is at the same level at the objective performance (see Figure 7).

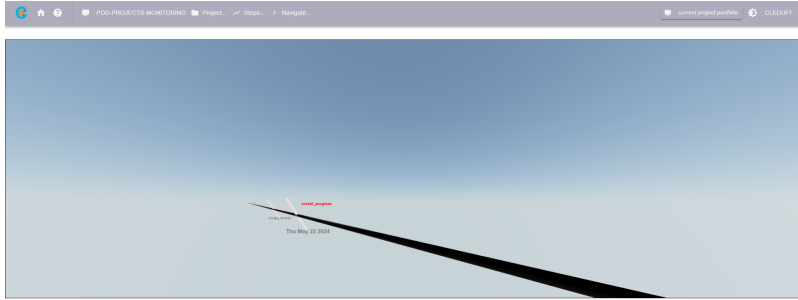


Figure 7: The Performance Monitoring menu of the overall performance of the system at the initial state

5.2.6. Action Planned Menu

Finally, whenever something new is known by the manager, he can add the information (with the standard of $attributs.value = data$ at specific date) on the menu : ActionPlanned (see Figure 8). These actions allow the system to include changes that would not be taken into account by previously defined rules. Induced changes, on the other hand, can trigger a rule. For example, if a resource is absent, it can declare this to the manager, who will enter the information in this menu. Then a rule that can deifnine the pausing of a task if an associated resource is absent can trigger and therefore instantiate these consequences.

Now let's look at a possible scenario, and focus on the potentialities that can appear during the PA - T1 and PA T2. As a reminder, in the case study, tasks have inputs needed and in particular a building permit for the PAT1 and PBT1. So there is no way that the opportunity to start these tasks will be done if the building permits are not received.

So far, we have a classic information system at the start of a portfolio. The update and the step-by-step functions are fairly trivial and update the

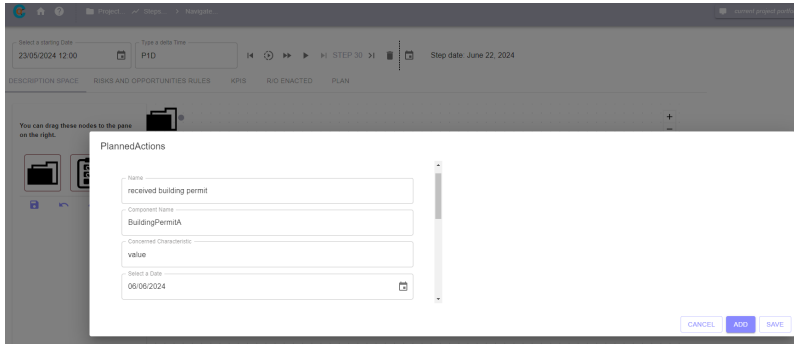


Figure 8: The Actions Planned menu of the PODPM of the illustrative case of the two Projects A and B

data with first-order rules. For example, for task PAM1, we need to receive the building permit for project A. Normally, the action plan is to receive it on day 13. So we'll look at the following scenario: we received the building permit 3 days after the initial date. When using the platform, this simply means that you need to create a Planned Action with a delivery date and have, for example, an *isReceived* attribute that would go from 0 to 1. We then use the projection function to assess the impact of this scenario on the performance of the portfolio and see the results on the trajectory. The result is shown in Figure 9.

5.3. Limits and discussion of this illustration

This illustrative example focuses on the first functions that can be developed with the POD metamodel, and the advantages of implementing it in an information system. This section will discuss more about the implementations, the pros and cons of the proposed framework and the practices to have or to avoid to improve the success of your portfolio using the PoD framework. Regarding the implementation of this tool, it can be done progressively. First,

allows us greater freedom in defining and evolving the characteristics of the portfolio. This way of modeling the dynamics works because it can be modified and improved over time. It can also be easily adapted to various types of project portfolios. Regarding the decision support system itself and particularly the decision support system based on a projection of the states of systems, the main contribution is to have a projection algorithm that loops into the systems states to propagate a cascading effect, and it works during all the execution phase. The main drawback of this approach is: Because it's first-order logic, it can become difficult to encode behavior specific to each component, and the more components have multiple behaviors, the more difficult it is to model them by attributes. The more complex the system is, the more the dynamics can take multiple forms, and it can be difficult to identify the correct developments based on the attributes. For a socio-technical system such as the portfolio, decision support must also take into account human factors and dynamics. In this framework, we can think of implementing potentialities that are more closely linked to social dynamics. There is also work developed by (Bai et al., 2024), where the propagation of risks is seen through the perception of users and this perspective could be developed in this approach by creating cascade effects between chains of different potentialities.

6. Conclusion

Project portfolios are becoming increasingly difficult to manage because of the VUCA world that surrounds us. The interdependencies of systems such as organizations, their environments, the market, etc., facilitate the propagation

of cascading effects that are difficult to anticipate. Information systems must be adaptable and capable of integrating change and dependencies. Most work on portfolio management has focused on describing, designing, and implementing portfolios. But once the portfolio is operational and starts, it is very difficult to reanalyze and modify them. It is also difficult for decision support systems to anticipate and integrate changes in the portfolio's internal or external environment. With this DSS, the first contribution is the fairly generic modeling of portfolios with components and attributes. The second contribution is the modeling of portfolio dynamics in first-order logic rules, which can be modulated and adjusted, thus contributing to the adaptability of the DSS. It is the definition of the algorithm that instantiates the potentialities and activates the dynamics, all while taking into account the cascade effects with the double-check loop and the direct and indirect potentialities. Finally, the last contribution is the projection of a portfolio at any time and with selected information to study the different scenarios imagined by the manager. Regarding the future works on this framework and methodology, one of the suggestions for future research is to add suggestions based on emerging opportunities in the database. Indeed, if a deviation on the performance trajectory occurs, we could consider developing an algorithm that tests possible opportunities (stored in the databases and previously identified) and proposes the best one, or the one that most effectively improves alignment with the defined objectives. We'd also like to be able to aggregate KPIs and visualize a set of multiple indicators using the trajectory of the Physics of Decision. Finally, regarding the mid-term of the tool collaboration can also be set up, so that, for example, several pieces of information can be fed back

by several actors in the portfolio. A multi-partner tool can be developed with tested scenarios by each actor, or multiple trajectories including all the stakeholder's performance can be viewed by everyone to create discussion around compromises or negotiation.

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