An approach to the organizational strategic decision-moment in new product development*

Abstract

Purpose: To explain the strategic decision-moment behaviour from an organizational approach, particularly from the cross-functional integration in new product development processing. Design: The methodology is focused on agent-based simulation, particularly using NetLogo software. Virtual experiments were developed to identify the effect of the agents interactions with each other and with the environment. Results: The presence of prior information and the disposition of the interaction meetings among departments in the cross-functional integration processes have a decreasing impact on the number of steps required to reach an agreement, but the number of necessary decisional interactions is not affected. Limitations: The comprehension of the decision-moment that is made within this research process is focused on the organizational approach to the development of new products. It is interesting to contrast the results with other organizational approaches and with studies on real cases. Originality: Application of agent-based simulation on the functional understanding of the strategic decision-moment in the organizational context.

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Una aproximación al momento de la decisión estratégica organizacional en el desarrollo de nuevos productos

Resumen

Propósito: Explicar el comportamiento del momento de la decisión estratégica desde un enfoque organizacional, en particular desde la integración interfuncional presente en el proceso de desarrollo de nuevos productos. Diseño: La metodología se centra en la simulación basada en agentes, particularmente utilizando el software NetLogo. Se desarrollaron experimentos virtuales para identificar el efecto de las interacciones de los agentes entre sí y con el entorno. Resultados: La presencia de información previa y la disposición de las reuniones de interacción entre departamentos en los procesos de integración interfuncional tienen un impacto decreciente en el número de pasos necesarios para llegar a un acuerdo, pero la cantidad de interacciones decisionales necesarias no se ve afectada. Limitaciones: La comprensión del momento de la decisión que se realiza dentro de este proceso de investigación se concentra en el enfoque organizativo del desarrollo de nuevos productos. Es interesante contrastar los resultados con otros enfoques organizativos y con estudios sobre casos reales. Originalidad: Aplicación de la simulación basada en agentes sobre la comprensión funcional del momento de la decisión estratégica en el contexto organizacional.

Palabras clave:
Decisiones, Diseño, Innovación, NetLogo.

Introduction

The main conception of the decision-moment approached within this research was addressed by Hernández (2020) and Hernández et al. (2015, 2016, 2017, 2019), who made a proposal to comprehend the decision-moment as explained from the strategy formation process, from the existence of cycles between deliberate and emergent strategies and from the emergence of a grieving process that occurs when deliberate strategies are deconstructed to open the way for the emergent ones. The above procedure understands deconstruction as the possibility of considering the dominant characteristics of hierarchies, disorganizing the identity of deliberate processes (Narváez, 2013). In terms of the strategy formation process, deconstruction denotes the absence of an absolute particularity of the deliberate strategies; this makes the strategies unusable due to certain events that require the agents to generate emerging strategies to guarantee their viability within the system in which they are developing (Hernández et al., 2019).

Continuing with the previous contributions, this research proposes to develop an organizational approach to the moment of decision concept, focused on the development of a new product, particularly in cross-functional integration, by granting a bounded and relevant context to create a simulation model adjusted to the reality that helps to clarify the emergence of the decision moment.

This particular feature of organisations is intended to be used as an approach that allows understanding and explanation of the decision-moment functioning, specifically in the process of developing a new product. This approach starts from the conception proposed by Orlikowski and Yates, (2002) that combined the concept of objective time (time on the clock) with the subjective one (time of the event). Then, the notions of the compression of temporal influence in organisations result, focused on the use that members of the organisation give to time in practice and how this has an impact on temporary structures.

In this research, the new product development process is taken as an organizational approach, since it includes a successive pattern of decisions in which strategies that are considered not only deliberate, but also emerging can be visible. In addition, it is an organizational process in which there can be evidence of discontinuity and therefore deconstruction events, as stated by Ghezzi (2013).

There is a very recognised relationship between cross-functional integration and the success of the development of a new product (Ernst et al., 2010; Genç and Di Benedetto 2015; Song and Parry 1997).

The cross-functional integration concept has had various definitions. Other terms have also been used in the study of cross-functional integration in the development of new products, such as 'cooperation', 'interaction', 'communication' and 'coordination' (Ernst et al., 2010).

For Ernst et al. (2010), the cooperation that occurs within the cross-functional integration typical of the process of developing a new product is classified by the need to perform collective activities, and it implies a level of interdependence and restrictions on the interactions between the functional areas of an organisation. Such elements belong to the Resource Dependence Theory (Ruekert and Walker, 1987; Salancik and Pfeffer, 1978).

In other words, interfunctional cooperation contributes positively to the development of a new product, but it is a cooperation that must be associated with precise stages. As indicated by Song et al. (1998), an organisation most likely ensures the success of a new product in a market when it applies cross-functional integration to the specific functions and stages for the development of the particular product and does not apply all functions of the company on all stages (Ernst et al., 2010). In fact, since the generation of knowledge from scientific research useful within organisations, it is requested that there be interdisciplinarity for the execution of projects (Jeffrey, 2003).

For the purposes of this research, cross-functional integration is explicit in the initial ideas proposed by Urban and Hauser (1993) and recently developed by Bardhan and Pattnaik (2017), Genç and Di Benedetto (2015), Kang et al. (2020), Pei et al. (2019), Yongsheng and Jinjie (2019) and Zhao et al. (2011); these authors explain the relationship between research and development, production, finance and marketing departments (see Figure 1). The relationship between the research and development (R&D) and production departments should be marked by the design variables for manufacturing and the needs of the process; between research and development and marketing, by production design and consumer needs; between marketing and production, by the sales forecast and the inventory. Finally, the relationship between finance and the other departments is marked by budget and financing requirements.

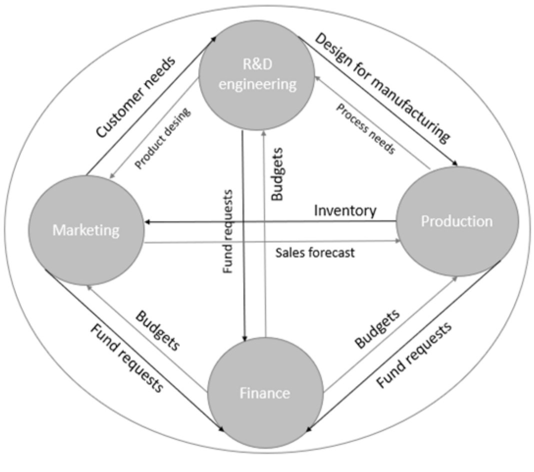


Figure 1. Cross-functional Integration.
Source: Urban and Hauser (1993).

For this reason, this document is intended to contribute to an explanation of the strategic decision-moment from an organizational approach based on the particular situation of new product development processes (Brown and Eisenhardt, 2013; Minguela et al., 2000), using cross-functional integration (Urban and Hauser, 1993) and executed in virtual agent-based simulation experiments through the NetLogo software. Next, the methodology used is explained.

Materials and Methods

This research is based on a quantitative methodological approach. The type of research is explanatory. Inquiring into the causes of certain events that become evident and the interaction between the variables that make up a phenomenon are the interests that underlie explanatory research. Specifically, Hernández et al. (2006, p. 83) define it as research that "goes beyond the description of concepts or phenomena or the establishment of relationships between concepts; that is, it is aimed at answering for the causes of physical or social events and phenomena." This is appropriate for the purpose of this research.

The methodological development of this document has been mainly focused on agent-based models, particularly the NetLogo software which can be used to explain the emergence of the strategic decision-moment from an organizational approach. The starting point is the process of developing a new product through the cross-functional approach, specifically at the stage of selecting the idea.

Agent-Based Modelling is a reality representation technique that combines mathematics and computation, it has several agents that interact with each other with minimal direction (Axelrod, 2005; Moreno et al., 2007). Its purpose is not focused on faithfully representing applications observed from empiricism, but seeks, in a great diversity of applications, to provide understanding of fundamental processes (Axelrod, 2005). In addition, it is very useful for observing the emergence of phenomena (Gilbert and Troitzsch, 2005) and understanding how social structures evolve (Gilbert and Abbott, 2005). This makes it an appropriate technique to simulate the problem proposed in this research.

The situation to be modelled from the organizational approach corresponds to different departments interacting with each other in the *process of developing a new product* in order to seek the emergence of the decision-moment, specifically at the stage of selecting the idea through consensus.

Departments are each represented by a turtle (mobile agent in NetLogo) moving through a space of the organisation (world) with the information of their variables according to the cross-functional integration. For example, in the case of the R&D department, the variables are *product design, manufacturing design and financing requirements*. The departments can be crossed with the *consensus probability information* from other departments when the turtles that represent them are located in some plots containing information (sections of the world in NetLogo). For instance, in the relationship between R&D and marketing, the latter finds the information of the former and verifies that there is a probability that the *consumer needs variable* (marketing variable) and *the product design* variable (R&D variable) coincide. From this information, the departments decide whether or not they have a match with the other department. Calling the meeting will depend on the type of decision of the department having the information.

The two possible types of decisions are *exploitation*, in which the department makes the most of the information, that is, it calls the meeting with the other department; and *exploration*, in which the department is driven to seek more information around the world.

At the meeting, each of the departments' variables will be submitted for evaluation in order to build a joint proposal.

Considering the above, the following scenarios can occur in the meeting:

1. Consensus: Both departments accept the levels of the variables, reaching an immediate agreement on the proposal.

2. Disagreement: Both departments contradict the variables, leading to an immediate rejection of the proposal. In this case, the assembled agents must completely change the parameters of each of the variables and continue moving around the world.

3. Modification: Considering a certain margin of tolerance, understood as the extension of the range in which the departments can reach consensus within the meetings and which is determined by the characteristics of the environment, the departments can modify their values to reach an agreement within the meeting.

According to Sáez Vacas et al. (2003 p. 15), the organizational environment can be stated as a set of three types of basic environments:

- **Stable environments:** They are characterised by being stable, simple, favourable and integrated.
- **Reactive-adaptive environments:** They are relatively stable, somewhat complex and essentially favourable and diverse.
- **Turbulent unstable environments:** They are dynamic, hostile, diverse and complex.

Based on the above and the levels of risk that can be taken depending on the scenarios, the margin of each variable is associated with the environment in which the idea of new product development is being generated (see Table 1).

Table 1. Margin for modification scenarios based on environment types

Type of environment	Margin
Stable	±3
Reactive-Adaptive	±2
Unstable turbulent	±1

Source: compiled by the authors.

The variables that the different departments can take are associated with the cross-functional integration, which will be linked to the direct interaction between pairs of departments (see Table 2). That is, the values described as intervals in the last column of the following table represent the solution alternatives of each of the cross-functional integration variables proposed by Urban and Hauser, (1993).

Table 2. Interaction variables between departments

Interaction	Variables	Measuring unit	Values
R&D-Marketing	-Product design -Consumer needs.	Product design types	[2-10] with variations of 1 [10-50] with variations of 10
R&D-Production	-Manufacturing design. -Process needs.	Manufacturing design types	
Marketing-Production	-Sales forecast -Inventory.	Product units	
Finance-other departments	-Finance Requirement. -Budget.	Monetary units	

Source: compiled by the authors.

On the other hand, there are the types of decisions—exploration and exploitation—in which the probability of the type of decision will depend directly on the type of environment. Tzovara et al. (2012) suggests that exploitation decisions are related to a particular alternative, where known information is exploited. This situation is common in stable environments. In turn, Tzovara et al. (2012) states that exploration is frequent in uncertain environments, which encourages the search for new alternatives. These contributions made it possible to configure these input parameters for simulation development (see Table 3).

Table 3. Types of decision with probabilities according to the environment

Decision	Description	Probability		
		Stable	Reactive–adaptive	Turbulent
Exploitation	It corresponds to the situations where the decision agent exploits the obtained information; generally, it is associated to one of the alternatives (Tzovara et al. 2012).	80%	50%	20%
Exploration	They develop in an uncertain environment. This is why the decision agent is motivated by the need for strictly exploring the alternatives (Tzovara et al. 2012).	20%	50%	80%

Source: compiled by the authors.

Additionally, NetLogo is a software that allows the development of agent-simulation processes based on agents, a computational modelling method in which the researcher has the possibility of developing virtual experiments on agents that interact with each other. Thus, it is possible to observe what happens with fragments of reality establishing certain particular parameters (Altawee, 2015; García-Valdecasas, 2011, 2016).

The following elements were defined for the simulation process based on the concepts provided within the new product development process from the perspective of cross-functional integration:

- **Turtles (mobile agents in NetLogo):** R&D, marketing, production, finance, R&D information, marketing information, production information and finance information
- **Movement:** In the case of the departments' turtles, the movement around the world will be associated with speed and flexibility, which will depend on the characteristics of the department each turtle represents (see Table 4). In the case of the turtles that represent the departments' information, they will not have any movement and they will be distributed around the world in a random way from the initial configuration of the world, just like the turtles that represent departments.
- **Meetings:** They are generated when the turtles are in the same plot.
- **Steps (ticks):** They correspond to the moments of time when interaction through meetings is possible between the different departments.
- **Stop:** The world stops when all turtles have variables with values at tolerable intervals among all. (see Figure 2)

Table 4. Department movements

Department	Speed	Flexibility	Justification
Production	It does not have the capacity (very slow). A step per each tick.	It does not have the capacity (very rigid). A 90° turn possibility.	According to Urban and Hauser (1993), the first stage of the new product development process is the generation and selection of the idea. Besides, the participation of *Production* (at the beginning of the development) is low.
Marketing	It does not have this capacity completely developed but it tends to be positive (fast). Three steps per each tick.	It has a very low development of the capacity (rigid). A 180° turn possibility.	Marketing is subject to the restrictions imposed by the clients (Urban and Hauser, 1993), this is why it is considered rigid but it has to act in a moderately fast way in order to make public the information within the company, efficiently but accurately.

Department	Speed	Flexibility	Justification
Research and Development	It does have a fully developed capacity (very fast).	It does have a fully developed capacity (very flexible). A 360° turn possibility.	R&D must be very fast at sharing the ideas the other departments generate in order to receive feedback. It also has to be flexible in the generation of new proposals. It is one of the departments that most participates in the first stages of the development of new products (Urban and Hauser, 1993).
Finance	It has a very low development of the capacity (slow). Two steps per tick.	It does not have this capacity fully developed but it tends to be positive (flexible). A 270° turn possibility.	Within the whole new products development process, Finance presents a low participation, low but continuous; it mainly participates when required (Urban and Hauser, 1993). This is why it is considered slow, but it must be flexible when required.

Source: compiled by the authors.

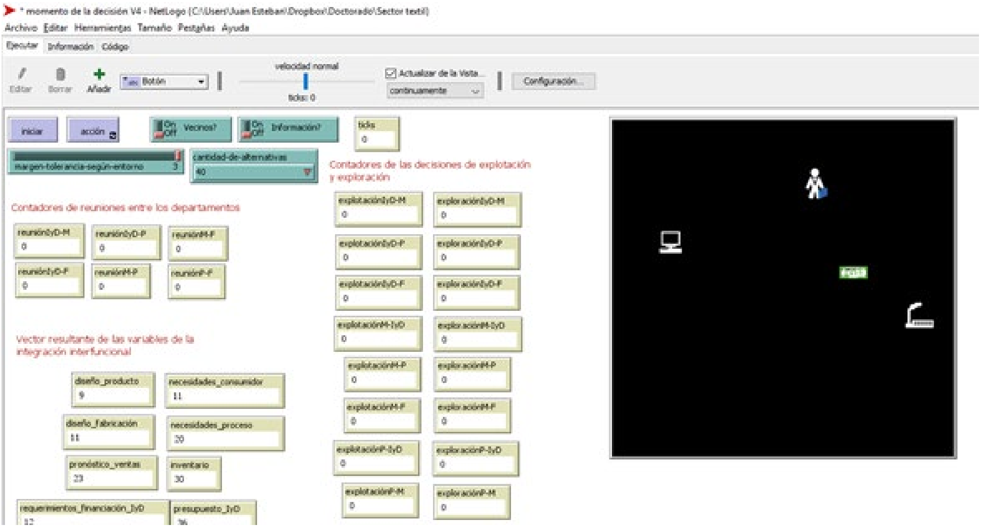


Figure 2. Model screenshot.
Source: NetLogo software.

Finally, the model remains with the following input variables (see Table 5) which will feed the simulation, allowing a demonstration of the agents' behaviours in the virtual experiments with certain variations of these parameters. This behaviour is reflected in the output variables (see Table 6).

Table 5. Model's input variables

Variable	Possible values	Description	Source
Information available on departments within the world, representing the intelligence of agents	On (true): Corresponds to the fact that there is information in the world about departments. Off (false): Corresponds to the fact that there is no information in the world about departments	The presence of information will allow the departments to have the possibility of making exploration or exploitation decisions against the possibility of reaching agreements with other departments on the variables of cross-functional integration	There is a relationship between information processing and the utility function of the chosen solution within a decision-making process (Greenstein, 2015). Paul et al. (2005) state that information is fundamental to the decision-making process. Decisions that suffer from information delays will have implications in terms of quality, since in group decisions it is relevant to acquire information early, in order to have enough time to process it.
Possibility of meeting between departments in neighbouring plots, representing the provision of interaction with the other departments	On (true): Corresponds to the greater willingness of the departments to have meetings with others, opening the possibility of meetings in neighbouring plots. Off (false): Corresponds to the fact that the meeting arrangement is limited to the interaction with other departments in the same plot.	The possibility of having meetings in neighbouring plots will denote greater departments' willingness to meet with others.	In cross-functional integration are supported in the interactions between members of different departments or functional areas, in order to build agreements on decisions in the new product development process (Ernst et al., 2010; Genç and Di Benedetto, 2015; M. Song and Parry, 1997; Urban and Hauser, 1993).

Variable	Possible values	Description	Source
Environment	1: Turbulent Environment 2: Adaptive Environment 3: Stable Environment	The type of environment will influence the interval for the modifications in the meetings (see Table 2) and the probabilities of the exploration and exploitation decisions (see Table 3)	According to Sáez-Vacas et al. (2003, p. 15), organizational environments can be grouped organizational environments can be basically grouped into three types: - Stable environments: they are characterized by being stable, simple, favourable and integrated. - Adaptive environments: they are relatively stable, somewhat complex, practically favourable and diverse. - Turbulent unstable environments: they are dynamic, complex, hostile and diverse, complex, hostile and diverse.
Number of alternatives	2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50.	It determines the range of values that the cross-functional integration variables can take (see Table 2). For example, the selector is at 2, the interval is [0-1] and if the selector is at 20, the interval is [0-19]	With respect to the definition of objectives, the problem-solving process in the decision-making process involves identifying and selecting the desirable and possible beneficial alternatives to solve the problem posed (Berumen and Llamazares, 2007). From this perspective, guidelines for the stakeholders in the decision-making process, can have an influence on the number of alternatives, since they can participate in the delimitation of the problem.

Source: compiled by the authors.

Table 6. Model's output variables

Variable	Description
Number of steps (Ticks)	It represents the number of steps that should have been taken so that all cross-functional integration variables were equal, that is, the number of moments of possible interactions that were needed to reach a consensus on the decision.
Number of meetings (encounters)	It corresponds to the number of interactions represented in meetings between the departments before reaching a consensus on the cross-functional integration variables.
Number of exploration decisions	It corresponds to the number of exploration decisions made by the departments before reaching a consensus when there is presence of information in the world
Number of exploitation decisions	Corresponds to the number of exploitation decisions made by the departments before reaching a consensus when there is presence of information in the world.
Resulting vector of cross-functional integration variables	It corresponds to the final values of the cross-functional integration variables, where the departments reached a consensus.

Source: compiled by the authors.

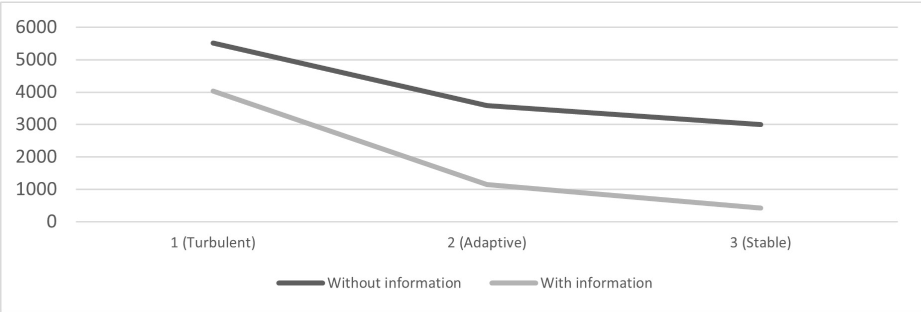
Results

In this section, the results obtained from the virtual experiments will be presented. A total of 15,600 runs were programmed with variations in the presence of previous information (yes or no), *possibility of meeting in neighbouring plots* (yes or no), margin of tolerance according to the environment (1. turbulent, 2. adaptive and 3. stable) and number of alternatives (2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40 and 50), where each of the previous numbers indicates the number of possible solutions on each of the variables of the cross-functional integration relations. Each value combination of these variables was run 100 times.

The descriptive analysis is developed from the combination of the different input variables described in the previous paragraph and the results obtained in the output variables (average of the number of steps required to reach an agreement, average number of meetings required to reach an agreement, average of the number of exploitation decisions and average of the number of exploration decisions). From the result of these output variables, the results will be presented.

Average number of steps (ticks)

When there is the presence of prior and available information so that the different departments decide to have a meeting (encounter) with another department, the behaviour of the average number of steps (ticks, as it is called within NetLogo) denotes a tendency to decrease the average number of steps required to reach an agreement as the environment becomes more stable when information is present (see Graph 1).

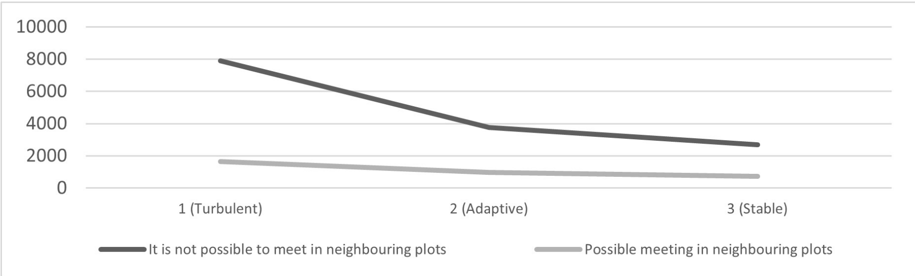


Graph 1. Average number of steps according to the existence of information in different environments.
Source: Hernández (2020).

On the other hand, when there is no prior and available information so that the different departments decide to call a meeting, the agents can reach consensus when they are in the same space and can interact. This case demonstrates a decrease in the number of average steps required to reach an agreement when there is no presence of prior information in the world for the departments.

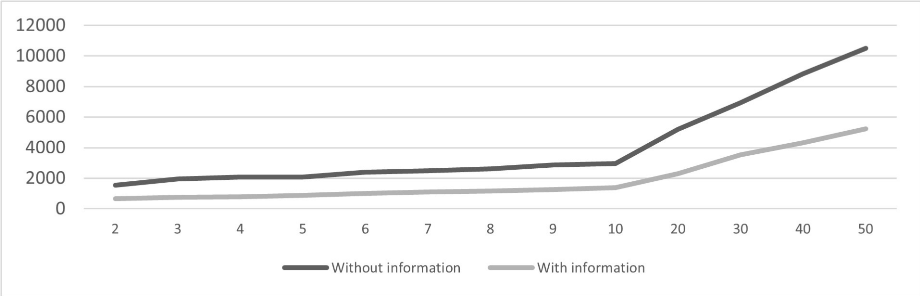
Analysing the results from the perspective of the average behaviour of the time steps from each of the states of the environment with and without information, it is evidenced that on average, the decisions without previous information in turbulent states take 26.8% longer than in the cases in which there is previous information. In the case in which the environment is in an adaptive state, the average time difference between decisions without and with information is 67.9%. Finally, in the case of stable environments, the average difference without and with information prior to decisions is 85.7% in relation to time.

Regarding the possibility of meeting in neighbouring plots evaluated from each type of environment, in general terms, the possibility of encounters with departments that are located in neighbouring plots has a decreasing effect on the average number of steps in the three types of environments. This is more significant in turbulent (see Graph 2).



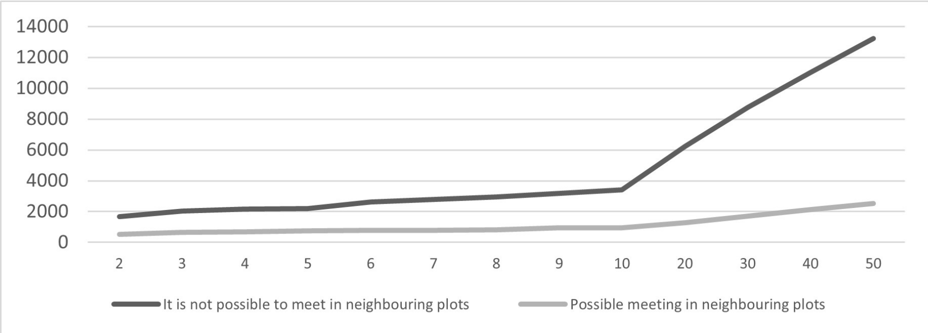
Graph 2. Average steps for the possibility of meeting in neighbouring plots by each type of environment. Source: Hernández (2020).

Regarding the type of information according to the number of alternatives, in general, as the number of value alternatives that the variables can take to reach agreement in the functional departments increases, the average number of steps of each run increases as well and is greater when there is no prior information (see Graph 3).



Graph 3. Average total steps by type of information, according to the number of alternatives.
Source: Hernández (2020).

Regarding the possibility of meeting in neighbouring plots according to the number of alternatives, the average total steps are higher when there is no possibility of meeting the departments in the neighbouring plots (see Graph 4).



Graph 4. Total steps average by neighbours, according to the number of alternatives.
Source: Hernández (2020).

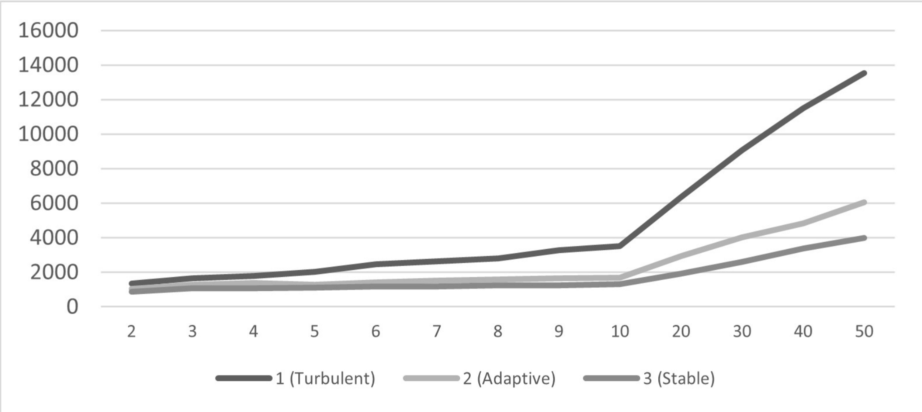
By combining the possibility of having access to information with the possibility of meeting in neighbouring plots, the average number of total steps is presented to a lesser extent at the crossroads of the scenario composed of the possibility of encounters in neighbouring plots with having any previous information. The highest average total steps measure is presented in the scenario formed by the absence of possibility of meeting in neighbouring plots without having access to previous information. The average number of total steps is much more sensitive to the possibility of having meetings in neighbouring plots than to the presence or absence of information (see Table 7).

Table 7. Average total steps by type of information, according to the possibility of meeting in neighbouring plots

	Neighbours?	
Information?	**It is not possible to meet in neighbouring plots**	**Possible meeting in neighbouring plots**
Without information	6,666.2	1,401.9
With information	2,916.9	827.5

Source: Hernández (2020).

The average number of total steps against the types of environments is greater in turbulent environments, followed by the adaptive environments and, finally, by the stable environments. The three types of environments increase the average number of total steps as the number of alternatives increases (see Graph 5).



Graph 5: Average total steps by type of environment, according to the number of alternatives.
Source: compiled by the authors

Average number of meetings (meetings)

The presence or absence of additional information becomes irrelevant as the environment becomes more turbulent in relation to the number of meetings held by the different departments in order to reach a consensus. In general terms, the possibility of meetings with departments that are located in neighbouring plots does not have a significant effect on the number of meetings in the three types of environments.

Regarding the type of information according to the number of alternatives, as the number of value alternatives that the variables can take to reach agreements between the departments in the cross-functional integration increases, the average number of meetings of each run increases as well.

About the possibility of meeting in neighbouring plots according to the number of alternatives, in general, as the number of alternatives increases, the total average of meetings between departments increases, regardless of whether or not it is possible to meet in neighbouring plots. In fact, the behaviour of the two curves (with and without the possibility of meeting in neighbouring plots) is similar on average with a difference of 0.11% more meetings if it is not possible to have meetings in neighbouring plots.

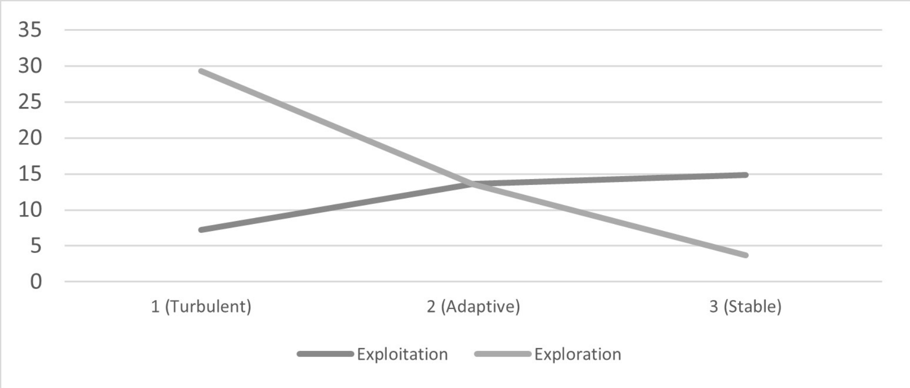
Concerning the type of information according to the average of total meetings between departments to reach a consensus, the scenario without prior information has the fewest number and there is the possibility of meeting in neighbouring plots, with 12.67 meetings.

In general terms, the turbulent state has the highest average number of total meetings to reach an agreement, followed by the adaptive states and, finally, by the stable states.

Exploration and exploitation decisions total average

As for the exploitation decisions seen by the type of environment, they present an increasing behaviour of the average number of meetings to reach an agreement, starting with the turbulent states, followed by the adaptive states with an increase in the number of decisions of 46.7% and ending with an increase of 8.6% in stable states.

On the contrary, exploration decisions show a downward behaviour starting with the turbulent environments, decreasing by 53.8% the number of decisions in the adaptive environment and, finally, decreasing by 72.7% in the stable environment (see Graph 6).



Graph 6. Exploration and exploitation decisions total average by the type of environment.
Source: Hernández (2020).

The average number of exploration decisions regarding the possibility of encounters in neighbouring plots has a decreasing behaviour, from turbulent states to stable states; this same situation occurs when it is not possible to meet in neighbouring plots, but it is evident in the three states that the average number of these types of decisions is greater.

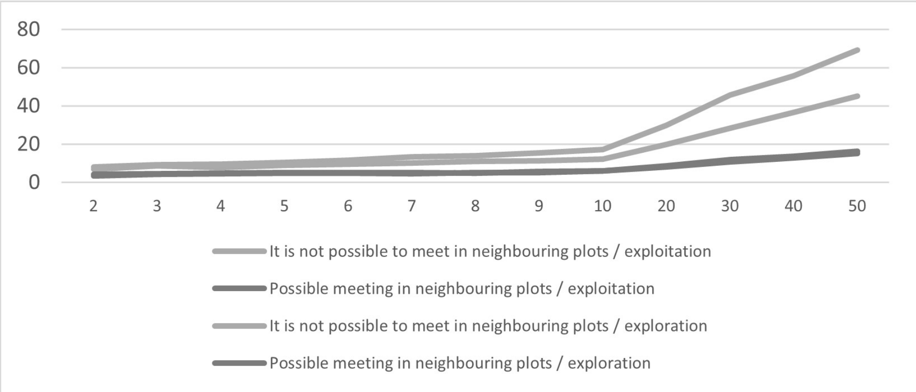
Exploitation decisions with no possibility of meeting in neighbouring plots have an increasing behaviour from the turbulent states towards the adaptive states; in the transition from adaptive to stable states, there is a decrease of 0.7%. In contrast, exploitation decisions with the possibility of encounters in neighbouring plots have an increasing trend from the stable to the turbulent state, but in general it has lower average quantities than when it is not possible to meet in neighbouring plots (see Table 8).

Table 8. Average exploration and exploitation decisions by the type of environment according to the possibility of meeting in neighbouring plots

	Type of environment		
Neighbour? /type of decision?	**1 (Turbulent)**	**2 (Adaptive)**	**3 (Stable)**
false / exploitation	11,71	19,19	19,05
true / exploitation	2,79	8,00	10,71
false / exploration	47,44	19,17	4,75
true / exploration	11,09	7,86	2,63

Source: Hernández (2020).

Regarding the number of alternatives according to the possibility of meeting in neighbouring plots, in general, as the number of alternatives increases, the required number of exploration and exploitation decisions increases, with and without the possibility of meeting in neighbouring plots. Exploration decisions when it is not possible to find neighbouring plots presents the highest average in each of the alternatives, followed by the exploitation decisions when it is not possible to meet in neighbouring plots and, finally, exploration and exploitation decisions are very close when it is possible for encounters in neighbouring plots (see Graph 7).



Graph 7. Average exploration and exploitation decisions by the number of alternatives, according to the possibility of meeting in neighbouring plots.
Source: Hernández (2020).

Discussion

The structure of the results discussion is expressed based on the output variables within the model. The first one is the *steps or ticks* as determined by NetLogo, the second output variable is meetings or encounters and finally, the third output variable is the number of exploration and exploitation decisions.

About the average number of steps

When agents have more information, they will make to some extent much faster decisions; this will depend on the decision-moment-making process that is acquired (when agents are overloaded with information, it may take longer than expected due to processing (Paul et al., 2005). This situation becomes evident when granting agents greater intelligence is intended by giving them information prior to the meetings with other agents within the joint decision-making process of cross-functional integration (Urban and Hauser, 1993) in order to choose between exploring or exploiting alternatives (Lin, 2012).

This is evidenced in the three types of environments. In all three cases, decisions with prior information are much more efficient in terms of the number of steps used to make the decision, understood as the fractions of time taken by the different departments to process the information and then make decisions on whether or not to proceed to encounter the other departments. The difference in the number of steps when there is previous information becomes much more evident in turbulent environments, it decreases in adaptive environments and is almost similar in stable environments.

These results can be explained by the definition of the types of environments. According to Sáez-Vacas et al. (2003), stable environments lack dynamism, are simple, favourable and integrated; this makes the presence of additional information much more effective on the number of steps required to reach an agreement between departments. Adaptive environments show a little more dynamism, complexity and diversity, and the presence of information has a minor effect on the number of steps. Finally, in turbulent environments, which are completely dynamic, diverse and hostile, the presence of prior information is more likely to lose its effect on the number of steps required to reach an agreement.

This is in line with the contributions of Peljhan and Marc (2021), who, from the point of view of enterprise risk management, state that organizations that have new product development processes benefit to some extent from the information provided by enterprise risk management, especially organizations that operate in unstable environments and that explore alternatives to the new product development process.

Therefore, it is possible to state that information, in general, is beneficial in terms of the amount of time in all three types of environments, which allows decisions to be made much faster on average. As with the presence of information, stable environments tend to be faster for decision making. However, in turbulent environments, the exercise of seeking to have complete information delays decisions, as the effect of information to make the decision-making process more efficient in terms of the number of steps to reach agreements in such environments decreases.

On the other hand, regarding the possibility of meetings (encounters) with departments that are located in neighbouring plots, the different environments show a decrease in the time required to reach an agreement when interaction between agents in the neighbourhood is possible, corresponding to the contributions of Ernst et al. (2010) with respect to cooperation in cross-functional integration. Particularly, turbulent environments are more sensitive to decreasing fractions of time in terms of decision. This suggests that for decisions taken jointly, such as cross-functional integration, a greater willingness (understood as the capacity for attention to interact with other departments seeking the emergence of a decision) is desirable.

In turn, compared to the number of decision alternatives that different departments have, when there is information available prior to the meeting, the number of average steps to reach an agreement is less than when there is no information, this is similar to the contributions of Paul et al. (2005), who state that information is fundamental for making joint decisions and that it is essential to have access to it early in order to have time to process it. Concerning the possibility of meeting in neighbouring plots variable, there is a relatively homogeneous behaviour in terms of the proportional difference in the possibility of encounters as the number of alternatives increases. In other words, there is a proportional stability in the difference in the number of steps to reach an agreement according to the possibility of having an encounter in neighbouring plots and the lesser number of alternatives of the departments when the encounter in neighbouring plots is possible.

Finally, the effects of the possibility that departments can gather in neighbouring plots will be much more evidenced when there is no previous information, based on a significant reduction in the average number of steps to reach an agreement. This situation also occurs, but to a lesser extent, when there is prior information. On the other hand, in the case of the possibility of prior information, it tends to have a decrease on the average number of total steps to reach an agreement, either with or without the possibility of meeting in neighbouring plots; this decrease is much more significant when it is not possible to meet in neighbouring plots. This invites us to think that the average number of total steps required to reach a consensus is much more sensitive to the presence or absence of prior information when there is the possibility of meetings in neighbouring plots.

About the average number of meetings

The presence of additional information in stable environments makes agents require fewer meetings to reach agreements contrasted to when agents do not have that additional information, but it should be noted that the difference is minimal. This situation is similar with respect to adaptive or turbulent environments, since the function of the additional information prior to the meetings has no effect on the number of meetings that the departments must have to reach an agreement since they are in an environment that allows them to be more flexible. This means that in general terms, there is no significant difference in the presence of information regarding the average number of meetings to reach an agreement.

Regarding the possibility of meeting in neighbouring plots, it becomes clear that by having greater availability of the departments in stable environments, they will have fewer possibilities of meetings, which have an increase in adaptive and turbulent environments. It should be noted that in general terms, the differences in encounters in the three states are not significant.

In turn, as the number of value alternatives that the cross-functional integration variables can take increases, the greater the number of interactions that departments must have in order for the decision to be taken (either with the presence or absence of information prior to the meeting).

On the other hand, the possibility of meetings in neighbouring plots has an impact on the average number of meetings between departments to reach a consensus. There is an oscillation in values very close to zero of the percentage differences of the average number of meetings that are needed to reach an agreement, implying it has little relevance.

By contrasting the possibility of meeting in neighbouring plots with the possibility of having information prior to the meeting, the highest average number of total meetings is obtained in the scenario formed by the non-possibility of meeting in neighbouring plots and the presence of prior information. The scenario with the lowest average number of total meetings appears when there is prior information and it is not possible to meet in neighbouring plots. The variation in the average number of meetings required to reach an agreement is not very significant in terms of the possibility of meetings in neighbouring plots and the presence of information.

In general terms, turbulent states, being chaotic as indicated by Sáez Vacas et al. (2003), need a higher average number of meetings to reach a consensus and this is strengthened when the number of alternatives is greater, followed by the adaptive states and, finally, the stable ones.

About exploration and exploitation decisions

It should be noted that, in the simulated decisions on the choice of the idea in new product development processes with cross-functional integration, both exploration and exploitation decisions are presented. This is in line with the contributions of Li et al. (2022), who showed simultaneous exploration and exploitation skills in innovation processes, focused on new product development in Chinese pharmaceutical companies, stating that the presence of these two processes is due to the fact that the identification of new opportunities is based on a broad and deep knowledge of the company's current processes and the industry in which it operates.

However, the average number of exploration decisions is much more sensitive to turbulent states, as this state is the one with the greatest number of decisions of this type, which is in line with Tzovara et al. (2012) contributions. At the same time, the highest average number of exploitation decisions occurs in stable states. This implies that the possibility of having a turbulent state will require increasing the exploration of alternatives in order to reach a joint decision. On the other hand, with exploitation decisions, stable states allow the meetings to concentrate on alternatives that have known results.

Regarding the results of the differences in the average number of exploration and exploitation decisions due to the possibility of meeting in neighbouring plots in the different types of environments, in the case of exploration decisions, it is evident that the fact of having the possibility of encounters in neighbouring plots reduces the number of decisions, which are much more forceful in turbulent environments. The same happens with exploitation decisions, in which the most significant decrease in the average number of decisions occurs when there is the possibility of encounters in neighbouring plots.

In turn, the percentage difference between the average number of exploration and exploitation decisions is more significant with quantities of large alternatives and presents an apparent general increasing trend. The difference always presents a greater advantage for exploration decisions over exploitation decisions.

On the other hand, the fact of not having the possibility of meeting in neighbouring plots has a greater incidence in the number of exploration decisions than in the exploitation decisions, presenting an increase in the average number of decisions when it is not possible to meet in neighbouring plots.

In terms of the average quantity, it can also be seen that exploration decisions are predominant in turbulent environments and exploitation decisions in stable environments, in line with Lin (2012). Particularly for adaptive environments, the number of exploration and exploitation decisions does not show much difference. Another element that stands out is that as the number of changes increases in all cases, the average number of decisions increases as well.

Conclusions

From the development of this document, the following elements that explain the moment of the decision can be drawn:

Information has an impact on the decision-moment in terms of the time fractions to reach a joint agreement within the process of developing a new product through cross-functional integration in three types of environments.

This is because information implies a smaller number of steps to arrive at an agreement, particularly in stable environments, possibly due to the conditions that this type of environment provides for the decision with more concrete and precise information. Paradoxically, information is not relevant to the number of meetings required to reach an agreement between departments, since it allows them to have the possibility of knowing from that information how beneficial the interaction with the other department will be and, in this way, decide to have the meeting or not (explode); the number of encounters is similar. One could speak of a minimum number of interactions that must exist between the departments in order for them to reach a consensus. In other words, when there is prior information, decision makers are efficient in terms of the time steps required to make the decision, but they must comply with a minimum number of decision interactions with other agents which is similar if there is no previous information.

This situation is similar to the availability of the departments to interact with others which is reflected in the possibility of meeting in neighbouring plots, obtaining as a result that in all types of environments there is a decrease in the steps required to reach an agreement but without an influence on the number of interactions between departments. In other words, regarding the availability of interaction between agents, they are efficient in terms of the number of time steps required to reach an agreement, but the same number of interactions is required.

Conversely, in terms of exploration and exploitation decisions, virtual experiments allow envisioning that in turbulent states, more effort is required from departments to explore new alternatives; this allows them to reach a joint decision. In stable states, the exploitation of known alternatives is preferable.

Finally, regarding future research, these results obtained in virtual experiments could be contrasted with real models of organisations. On the other hand, this type of virtual experiments should be extended to other organizational approaches in order to compare results.

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