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The governance of platform development processes: A metaphor and a simulation model

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ABSTRACT

Platform market competition has been extensively researched, but the governance of the platform development process prior to market launch has received little attention. We develop a system dynamics simulation model using the avalanche game as a metaphor for platform development. We describe a typical platform development process, and show how this process corresponds to the game. To examine the role of incentives for consensus building in platform development, we extend the original simulation model of the avalanche game using literature on platform development. This provides insights about how platform governance incentives influence the platform development process. Specifically, we find that under high degrees of urgency, consensus is achieved more quickly when a greater number of participants are involved in a standards committee. We explain this counterintuitive notion by making use of the literature on decision-making in networks of interdependencies.

1. Introduction

Platform-based markets have become highly important in several industries, especially in high tech industries, and the number of platforms and firms whose activities revolve around them has grown considerably over the last years (Eisenmann et al., 2011; Gawer & Cusumano, 2013; Zhu & Iansiti, 2012). Platforms are essential to the operation of most technological systems, such as ICT systems, because they enable the interconnection of various technological components and subsystems. The most recent conceptualization of platforms, spans engineering design and economic perspectives and defines platforms as: “evolving organizations or meta-organizations that (i) federate and coordinate constitutive agents who can innovate and compete, (ii) create value by generating and harnessing economies of scope in supply or/and in demand, and (iii) entail a technological architecture that is modular and composed of a core and a periphery” (Gawer, 2014). The increasing importance of platforms calls for deepening knowledge about these platforms (Gawer, 2009; Papachristos & van de Kaa, 2018), and over the years various scholars have focused on platforms in their research.

Scholars that study platforms focus primarily on participant networks that are mediated by these platforms. To study such networks, they mainly use three theoretical perspective: industrial or network economics (Katz & Shapiro, 1986), strategic management (Shapiro & Varian, 1998), and technology management (Wheelwright & Clark, 1992). Network economists primarily analyze network effects, a market mechanism that arises often in platform mediated markets (Farrell & Saloner, 1985; Katz & Shapiro, 1985). Strategic management scholars focus on factors that affect platform market success (Schilling, 1998; Suarez, 2004), and technology management scholars study how platform design influences the generation of network effects (McIntyre & Srinivasan, 2017). What these scholars have in common is that they focus on platform selection, the stage at which platforms are developed and compete in the market. Several scholars have developed frameworks to explain the outcome of platform competition (Schilling, 1998; Suarez, 2004; Van de Kaa et al., 2011). Furthermore, modelling and simulation studies have been conducted to understand market related platform processes (Hagiu & Spulber, 2013; Parker & Van Alstyne, 2005; Rochet & Tirole, 2003; Windrum, 2004; Heinrich, 2013). Future research agendas focus primarily on platform market competition rather than on development (McIntyre & Srinivasan, 2017).

Few scholars focus on platform development processes prior to market launch (Backhouse et al., 2006; Nickerson & Zur Muhlen, 2006). Platform development often takes place in industry-wide standards committees where firms develop a shared set of rules for future technological development (Dokko et al., 2012; Rosenkopf & Nerkar, 2001; Simcoe, 2012), which may become eventually standardized. The combined set of standards form the core technologies that underlie platforms (McIntyre & Srinivasan, 2017). Standardization scholars focus on

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the reasons for firm participation in standards committees (Hawkings, 1999), the influence such firms can have (Dokko & Rosenkopf, 2010), and the reasons for delays in the standardization process (Simcoe, 2012). Such standards committees have increasingly become the preferred arrangement to coordinate technological change and innovation across large numbers of firms (Chiao et al., 2007; Lavie et al., 2007; Farrell & Simcoe, 2012). Their involvement depends on the motives, incentives, and benefits they anticipate at the end of the platform development process (Hawkings, 1999). Few scholars have focused on why firms remain committed to platform development based on the theory of decision-making in networks of interdependencies (Farrell & Simcoe, 2012; Van de Kaa & De Bruijn, 2015).

This paper bridges platform development and decision making in networks of interdependencies. In doing so, we build on a prior study of Van de Kaa and de Bruijn (Van de Kaa & De Bruijn, 2015) who studied the development of WiFi. They proposed five incentives to explain why firms remain committed to a platform while the decision-making process in standards committees is at times cumbersome. These incentives include: (i) the perspective of future gain, (ii) the perspective of enduring gain, (iii) strong voting rules, (iv) a sense of urgency, and (v) an incentive to compromise.

The objective of this paper is to better understand the governance of platform development processes by adapting a simulation model for platform development using the five incentives of Van de Kaa and De Bruijn (Van de Kaa & De Bruijn, 2015). We draw on the avalanche management game for which a simulation model has been developed (Lane, 2008), and use it as a metaphor for platform development processes (Booth-Sweeney & Meadows, 1995). At the core of the metaphor lies the insight that the coordination challenge in the avalanche game *is like* the coordination challenge in a platform development process. We extend the original simulation model to reflect the platform governance context and the incentives proposed by Van de Kaa and De Bruijn (Van de Kaa & De Bruijn, 2015). The effect of the incentives proposed in the literature can be explored through the simulation model. We offer this metaphor to the practitioner community rather than develop a large, unintelligible model that will be put to the side. Small models can have just as much potential impact in multi-stakeholder settings (Ghaffarzadegan et al., 2011).

We contribute to the literature on platforms and standardization by developing a simulation model, which can give us better insights into the decision-making processes in standards committees. The simulation model shows unexpectedly that participants involved in such processes with a high degree of urgency, result in a quicker consensus on platform development. We provide an explanation by borrowing from the theory of decision-making in networks of interdependencies (De Bruijn & Ten Heuvelhof, 2018; Klijn & Koppenjan, 2004).

The rest of the paper is structured as follows. Section 2 provides a literature overview on platform development processes. Section 3 outlines how the original model has been modified and how it is used as a metaphor in a platform development context. Section 4 presents simulation results and Section 5 concludes the paper.

2. Literature review

Platforms have been studied from multiple perspectives: industrial or network economics, strategic management, and technology management (McIntyre & Srinivasan, 2017). There are two stages involved in realizing platforms; development and selection. Selection is the stage after platform development where it may compete with other platforms. Research that has been conducted on both platform development and selection will be presented in this section.

2.1. Platform development stage

The core technologies that underlie platforms are often developed in standards committees, such as IEEE. These are industry-wide organizations, through which engineers from different firms attempt to reach consensus for a shared set of rules for future technological development (Dokko et al., 2012; Rosenkopf & Nerkar, 2001; Simcoe, 2012). A firm's ability to participate and control technological evolution so that its capabilities are sustained or even enhanced may become a crucial determinant of its competitive advantage. Firms have opportunities to shape such change in these committees (Dokko et al., 2012).

Standardization scholars have studied the details and the mechanisms involved in these standards committees in depth. Greenstein (Greenstein, 1992) argues that firms tend to develop common standards in committees in order to solve potential coordination problems. Committees are usually set up when firms realize that they need a technological solution which is not yet available. They can either decide to develop it themselves or in consortia, or they can try to set up a committee at a formal organization. In the latter case, they must ask formally the board of the organization to approve the new committee. If approved, the committee is established, and firm representatives may join and discuss the contents of the protocol through the submission of technical proposals.

Normally, several meetings are needed to agree on the technical specifications that underlie the platform. Participant groups prepare proposals for the technology according to their interests, and try to gain support for them so that they can influence the contents and direction of the platform's specifications. At each meeting, a certain number of voting members participate, and several proposals are discussed and put to vote. Participants can approve, oppose, or abstain from proposals that are put forward. A proposal is accepted if it receives a certain percentage of votes.

Firms are likely to join standards setting organizations (SSOs) that develop specifications contingent on the number of patents that they hold or have applied for (Blind & Thumm, 2004). These patents result in future financial returns if the platform achieves market dominance (Dokko & Rosenkopf, 2010). Often, conflicts may arise during standard setting (Lemstra et al., 2011) which can delay considerably the standardization process (Simcoe, 2012). Then, the question of a firm's commitment to the process arises. Firms can have additional incentives to participate in committees and reach a consensus decision despite the fact that their interests may diverge (Van de Kaa & De Bruijn, 2015).

Van de Kaa and De Bruijn (Van de Kaa & De Bruijn, 2015) offer five incentives for cooperative behavior. First, all participants involved in platform development know that they can benefit from the outcome of the decision-making process in the long-term because one of their proposals may be accepted and some of their patented technologies will generate future revenue. Second, once an agreement about a platform is reached, all participants stand to benefit from the fact that they can now realize complex systems that could not be achieved earlier if the platform had not been available. Third, strong voting rules which reward active participation may keep the decision-making process on track. Fourth, further competing platforms may be in development in other committees or consortia, and actors may feel an urgency to reach consensus first. Fifth, participants may also gradually become more incentivized to compromise because of the competitive threat of other platforms becoming available first.

Several scholars study the reasons why firms participate in committees that develop common platforms (Blind & Mangelsdorf, 2016). Firms tend to develop common platforms in committees in order to solve potential coordination problems (Greenstein, 1992). There are additional reasons why firms may participate and try to influence platform development processes. For example, the likelihood that a firm joins a platform development group depends on the number of patents that it holds or has applied for (Blind & Thumm, 2004), as the patents produce financial returns if the platform achieves market dominance (Dokko et al., 2012). Other scholars study the influence that firms may have in the standardization process. For example, Dokko and Rosenkopf (Dokko & Rosenkopf, 2010) study the influence of job mobility within firms on their overall influence on formal standards setting within standards committees.

2.2. Platform competition stage

Scholars have developed frameworks with factors for platform success to explain the outcome of platform competition (Suarez, 2004; Van de Kaa et al., 2011), such as the classic battle between VHS and Betamax (Cusumano et al., 1992; Wonglimpiyarat, 2005), between Microsoft and Sun Microsystems (Garud et al., 2002), and more recently between Blu-ray and HD DVD (Gallagher, 2012). The frameworks have been applied to cases of platform competition to assess their completeness and relevance (Van de Kaa & De Vries, 2015) and to determine weights for the factors (Van de Kaa et al., 2017; Van de Kaa et al., 2014). The emergence of a dominant technology platform is an outcome of markets that are characterized by network effects (Arthur, 1996) that increase the value of a platform as more people adopt it (Farrell & Saloner, 1985; Katz & Shapiro, 1985). A range of factors are thought to influence network effects and the outcome of platform market competition (Suarez, 2004; Van de Kaa et al., 2011).

For example, early market entry gives firms an advantage that may result in a winner-takes-all outcome (Lieberman & Montgomery, 1988), and enables a quick build-up of installed base (Shapiro & Varian, 1999). Installed base and complementary goods are positively related and both affect platform success positively (Schilling, 1998; Schilling, 2002). Firms can apply strategic resources to pursue certain strategies in order to increase installed base and the availability of complementary goods (Gallagher & Park, 2002). Additional factors include backwards compatibility, financial resources, firm reputation, marketing (e.g., preannouncements) and flexibility. For example, Gallagher and Park (Gallagher & Park, 2002) studied successive generations of video gaming consoles that fought for market acceptance and found that the consoles that offered backwards compatibility[1] were more successful as they could benefit from a previous generation installed base.

Furthermore, financial resources can be used to apply penetration pricing strategies and increase the installed base. Often, game consoles are even priced below cost to increase the installed base. In turn, complementary goods are priced high so that firms can earn profits from these goods. Although backwards compatibility can increase previous installed base, it can also decrease technological superiority and the overall chances of success. This was the case for the battle between MPEG-2 Audio and AC-3 for a multi-channel audio sound solution. MPEG-2 Audio was technologically superior compared to AC-3 because it was backwards compatible with MPEG-1 Audio (Van de Kaa & De Vries, 2015). Various scholars tend to agree on the importance of establishing diverse inter-organizational networks behind the platform with actors that are fully committed to the platform as these increase both the platform's installed base and its availability and variety of complementary goods (Cusumano et al., 1992; Van de Kaa et al., 2015; Van den Ende et al., 2012).

3. Method

The avalanche game is a management task where a group of participants is positioned around a large hoop, or similar object, and each one supports the hoops weight with one finger (Lane, 2008). The group is required to lower a physical object towards a particular height, under certain conditions and rules. To better understand the governance of platform development processes, we apply this game as a *metaphor*.

Organizational literature emphasizes the role of common cognitive schema and frameworks (Spender, 1989; Weick, 1979), metaphor and analogy (Nonaka & Takeuchi, 1995), and stories (Brown & Duguid, 1991) as means to bring together and align diverse individual experiences and understanding. Metaphors cut across different contexts and thus allow imaginative perceptions to be combined with literal levels of cognitive activities (Bateson, 1973). Along with analogies and models, metaphors are part of the process of scientific discovery (Tsoukas, 1991). Metaphors have frequently been used in organization science (Weick, 1979; Buckley, 1968; Cohen et al., 1972; March, 1962; Morgan, 1997). They enable researchers to think by analogy, develop their understanding, and facilitate problem solving (Lakoff & Johnson, 1980; Gick & Holyoak, 1980; Miller & Lin, 2015). Through their use, some part of reality is understood in terms of something else, usually a common base reference.

The use of metaphors implies a way of thinking and a way of seeing that pervades how we understand our world generally. For example, research in a wide variety of fields has demonstrated that metaphors exert a formative influence on science, on our language and on how we think, as well as on how we express ourselves on a day to day basis. Metaphors are used whenever we attempt to understand one element of experience in terms of another. They proceed through implicit or explicit assertions that A is (or is like) B and they highlight certain aspects of what is observed while they leave others in the background.

A metaphor frames understanding in a distinctive yet partial way. This is the case for all metaphors in organization and management studies. For example, stating that an organization is like a machine is a true statement in the sense that an organization reliably produces certain outcomes (Morgan, 1997). At the same time, the metaphor ignores the human aspects of organizations. It follows that it is desirable to use a range of metaphors about organizations and management. The particular advantage to propose the avalanche game as a metaphor for the platform governance context, is that it is possible to use and modify a formal system dynamics model developed to replicate the physical dynamics of the game (Lane, 2008). This allows for much more structured thinking, and the system dynamics diagrams allow for a more evocative metaphor.

In this paper, the avalanche game is viewed as a metaphor to explore the relative importance of cooperative and competitive behavior displayed in the governance of platform development processes. The application of a metaphor along with a simulation model is an appropriate approach to better understand platform governance, because the process of platform development has emergent properties and it can be unstructured (Van de Kaa & De Bruijn, 2015). Furthermore, the participant network around platforms can be seen as a complex system, and the decision-making processes in committees have become more complex due to industry convergence (Van de Kaa et al., 2009). The result is that a wider range of markets can be affected by the launch of new platforms and the outcome of their competition. The challenges of complexity in such a context pose a significant problem for research, which may be addressed through modelling and simulation methods (Davis et al., 2007; Harrison et al., 2007).

We first identify the elements of the metaphor between the avalanche game and the platform development process prior to its market launch. We then use these elements to modify the original system dynamics avalanche game (Lane, 2008) and to develop a new model. Finally, we interpret the results using current theory.

4. Results

4.1. The avalanche game

The avalanche game supports discussion about individual behavior and group goals, and about the role of breaking rules to achieve aims. The game introduces participants to such lessons in a few minutes. It offers a metaphor to explore the relative importance of cooperative and competitive behavior (Lane, 2008). Such behavior can arise when conflicting strategic objectives coexist in organizations, in the prisoners' dilemma, and in integrated bargaining situations. The game may also be relevant to situations that involve competing companies in which the resulting behaviors are mediated by market regulations.

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[1] e.g., PlayStation 2 was backwards compatible with PlayStation 1.

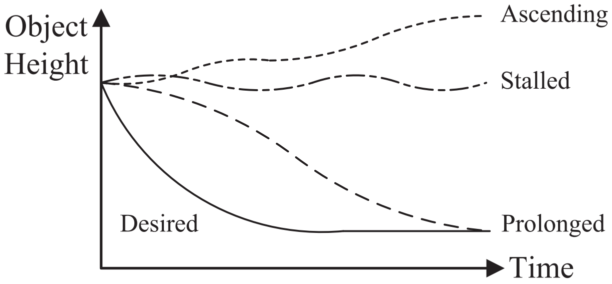

Fig. 1. Modes of behavior (adapted from Lane, 2008).

4.1.1. *Participant tasks*

The group of participants position themselves around the object, and each one supports the object in a horizontal position using one finger. Each participant has two objectives, to lower the object and to maintain contact with the object at all times. Participants move their fingers downwards and lower the object until it reaches its designated height. There is a clear condition: they must lower the object while simultaneously maintain contact with it. Silence is encouraged during the game so that participant coordination is achieved solely through contact with, and movement of the object. Coordination is achieved as each participant sends and receives a signal to other participants through the height and speed of his finger that supports the object. When more participants are involved, the pursuit of these objectives by each one may cause the object to move upwards rather than downwards. If a participant loses contact with the object, (s)he must declare this to the facilitator, who monitors the game. In such a case the task starts again.

4.1.2. *Three outcomes of the game*

The task is easily accomplished with a few participants. For example, when the object used is a hoop, three participants will manage to produce the desired behavior each time (Fig. 1). This is possible, as any object in a three-dimensional space requires at least three support points to stay horizontal. It is impossible for three participants to lose contact while they lower their fingers. However, when the group size increases it is not so easy to complete the task. The interactions between participants that attempt to lower the object and maintain contact may lead to counter-intuitive behavior. Possible outcomes may be divided into four stylized modes (Fig. 1): the desired, the prolonged, the stalled, and the ascending mode. The first is the desired outcome. In the second, the task is accomplished but it takes much longer. In the stalled process, the object may just stay near its initial position height, with some small and apparently random, upward and downward movements. In the ascending mode, the object moves away from its objective.

4.1.3. *Explanation for the dynamics of the game*

All participants share the objective to lower the object to the *Desired_Object_Height* (Fig. 2). The object rests on the fingers of the participants and exerts a certain *Contact_Pressure*. They must lower the object through a constant *Downward_Finger_Movement*, and maintain contact with it, thus they must maintain a *Contact_Pressure* with the object. When one participant reduces his *Finger_Height*, ceteris paribus he reduces the *Contact_Pressure* on his finger. When all the participants move in sync, they reduce the *Object_Height* and thus the *Contact_Pressure* for each one remains the same. If the game is played with three participants then they all are equally involved in maintaining the *Object_Height* due to the geometry of the situation. With more than three, not all of them are required to do so, and either of the two links in Fig. 2 may stop to operate at some time. For example, a participant may move his finger down, but if the remaining participants can support the object and do not move, then his action will not change the *Object_Height*. Instead, he will experience a reduction in *Contact_Pressure*, which may cause him to overreact to maintain contact, lift his finger, and cause neighboring participants to do the same to maintain contact themselves.

Apart from the number of participants and the particular geometry used in the game, a number of additional factors influence the game. These are:

1. The weight of the object: This directly affects the object pressure the participants experience. It is more difficult to lose contact with heavier objects.
2. Errors in the position of fingers: The natural "wobbling" introduced via the participants having to keep their fingers horizontal.
3. The speed of individual finger movement: Participants may move their fingers at slightly different speeds.
4. Degree of response to pressure variation: The degree that participants compensate for deviations from the nominal object pressure they experience.
5. Finger sensitivity to pressure: This is a function of the individual physiology of the participants and introduces an additional level of heterogeneity.

4.2. *The avalanche game as a metaphor for SSO*

In the avalanche game, the outcome for each participant depends on the actions of all the rest as the movement of the object is determined

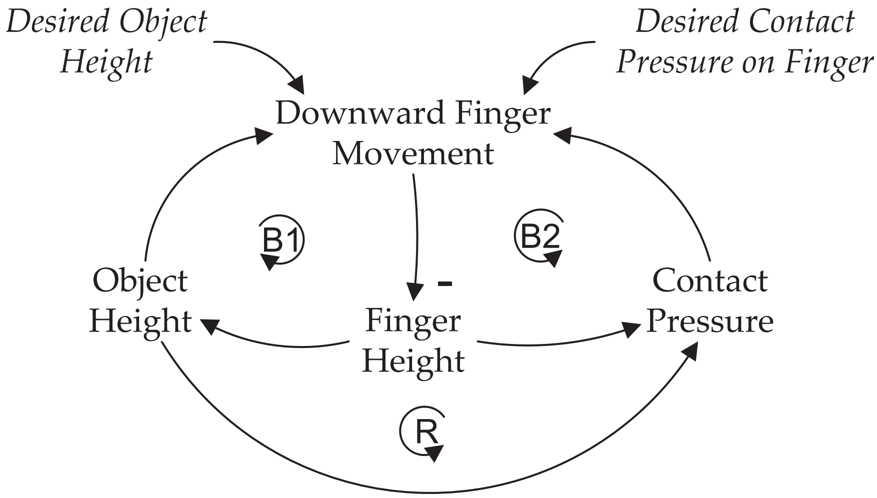

Fig. 2. Causal loop diagram for the avalanche game (adapted from Lane, 2008).

Table 1
Correspondence of crucial factors in the avalanche game and in the platform development process.

Avalanche game	Platform development
The weight of the object	Urgency of platform development
Errors in the positioning of fingers	Errors in technical proposals
The speed of individual action –finger movement	Individual participant actions that influence platform development
Degree of response to pressure variation	Degree of response to development pressure
Finger sensitivity to pressure	Degree of over or under reaction to pressure
Intended finger height	Intended level of platform development

by its geometry and characteristics. A metaphorical link may be drawn with prisoner dilemma situations, bargain situations, situations where cooperative/competitive behavior of participants is conditioned by the underlying context of their interactions, and situations where companies work in alliances on joint research projects (Kapmeier, 2008). The avalanche game also has similarities with situations where individuals or organizations are required to set multiple and conflicting strategic objectives (Roberts et al., 1968; Weil, 2007). Thinking about such situations in metaphorical terms may result in creating insights (Morecroft et al., 1995).

In the avalanche game, participants aim to reach a certain target height together. In platform development processes, participants aim to develop a platform that is supported by everyone. In the avalanche game, the weight of the object the participants support drives the process. In the platform development process, the expected benefits that a common platform provides and the urgency to develop the process and reach a compromise to avoid competition from other platforms drives the process. In both situations participants have equal access to the process in which they participate, but there is natural variation in both cases due to: (i) the weight of the object – urgency of platform development to stem potential competition from rival platforms, e.g. consortia, (ii) errors in the positioning of fingers – errors in participant technical proposals, (iii) the speed at which participants move their fingers – individual participant actions that can have positive or negative influence on platform development, (iv) the degree of response to pressure variation – the degree of response to development pressure, and (v) finger sensitivity to pressure – the degree of over or under reaction to pressure. The correspondence between the two processes is summarized in Table 1.

4.3. Model development, validation and testing

The original model was replicated in Powersim © from the original Vensim © equations and is available upon request from the authors (see Appendix A for equations). In the original game, the group participants try to lower the height of the object. This corresponds to the stock of *Intended_Level_of_Platform_Development* (Table 1). This varies with the rate of *Platform_Development_Process* which corresponds to *Downward_Finger_Movement* rate in the original model.

We made two modifications to the original model (see both model structures in Appendix B). First, we introduced a *Proposal_Diversity* variable as each participant has different interests and wants the platform development process to reflect them. Platforms have many attributes and their development process is multifaceted. Each participant in the platform development process has particular preferences for platform attributes that taken together may support platform development towards a particular direction which may be supported by other participants too, or not. Each participant perceives an *Actual_Platform_Development* that is different from that of other participants because platform development may satisfy more, or less, of his/her preferences and neglect others.

If a participant perceives a high *Actual_Platform_Development* this implies that a lot of his/her preferences are met as some preferred platform attributes are embedded in platform design and development moves forward. Nevertheless, this may also imply that the preferences of other participants are not met, and their platform development proposals may reflect this, and increase the diversity of proposals. The *Proposal_Diversity* variable formulated as the standard deviation of *Actual_Platform_Development* is meant to capture this effect. Greater diversity implies that some platform attributes are getting built into platform design and that platform development moves forward. Other participants may oppose this more or less, and thus the *Proposal_Diversity* variable can accelerate or slow down the rate of *Platform_Development_Process*. For example, unfettered growth and platform complement diversity poses an integration challenge for platform development (Dhanasai & Parkhe, 2006; Boudreau, 2012; Cennamo, 2016).

The second modification, was to introduce *Development_Urgency* in the model, to account for the difference between the avalanche game and platform development (grey in Fig. 3). The diversity effect is mitigated by the platform *Development_Urgency* that participants perceive out of fear of being preempted by other competitors in the market. In the avalanche game, the participants aim to lower the object, but there is no external or time pressure to get it done. However, the situation is different in platform development, because it may face competition in the same market. Thus, platform development participants may be under pressure to develop their platform earlier to achieve first mover advantage (Lieberman & Montgomery, 1988). We expect that the *Effect_of_Diversity_on_Platform_Development* increases with *Development_Urgency*. The diversity effect has a multiplicative effect to *Proposal_Adjustment* and the *Actual_Effect_on_Normal_Development_from_Pressure.*

The model was validated and tested using the procedures presented in Section 3. The sensitivity tests with the constants produce the expected behavior. Next, we test the model to establish confidence in its validity using standard system dynamics tests [(Sterman, 2000), Chapter 21]. We conduct a fundamental validation test to see whether the model as replicated in Powersim © reproduces the four behavior modes of the original model with the same parameters values. We repeat the same test with the modified model and discuss the results in the text with examples. We subject the model to extreme conditions and assign high and low values to the input parameters. After sensitivity analysis on the effect of simulation time step on simulation results, it is set to 0.5 days. The integration method is set to Euler because random number generators are used in the model.

4.4. Interpretation of the results

The model was simulated for four years with time step of 0.5 days. The number of participants involved in the process ranged from 10 to 30 (Fig. 4). The results illustrate some intuitively logical insights when *Development_Urgency* is varied from 4 to 5.8. First, a greater number of participants in such processes tends to produce divergent process outcomes. Just as in the original avalanche game, a greater number of participants tends to raise rather than lower the object. Thus, the platform development process is not likely to be successful or it will take longer to reach consensus. In cases of 10 and 30 participants, it is possible that in some runs participants may diverge so slowly or progress may be so slow that the platform development process may appear stagnant and may eventually “run out of steam”. In such cases, the intended platform is likely to be superseded by developments in the market and will eventually be outcompeted if it ever makes it to the market.

The second insight is that a high degree of *Development_Urgency* always results in a relatively rapid conclusion in every case. Furthermore, the results indicate that given a high degree of urgency (5.6 and 5.8 in Fig. 4), consensus is achieved more quickly when more participants are involved. For example, when development urgency is

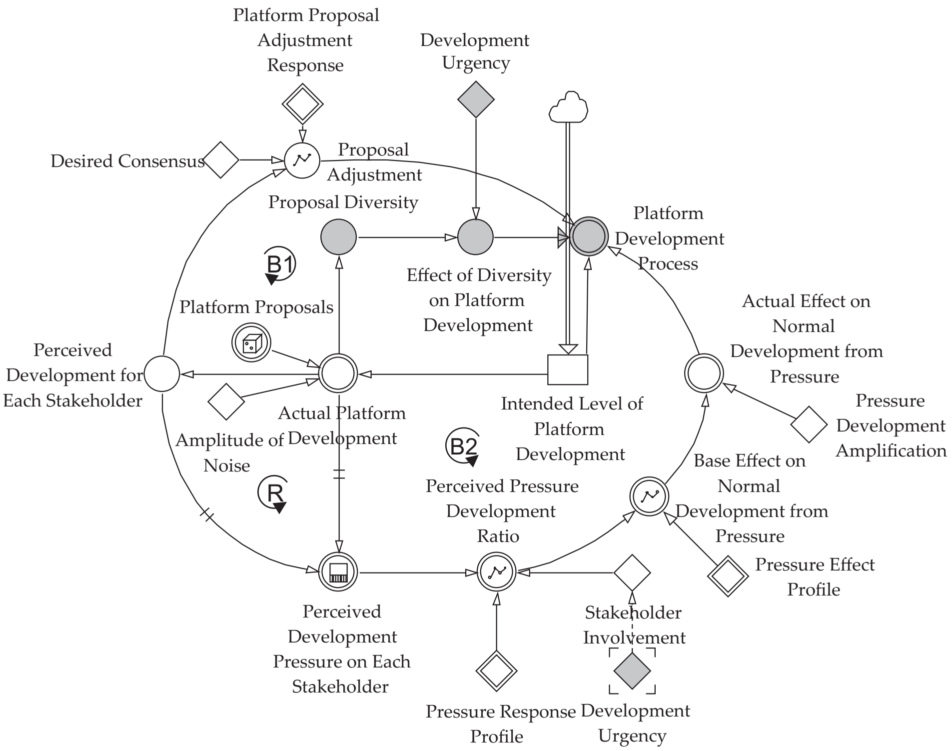

Fig. 3. Stock and flow diagram of the modified avalanche game.

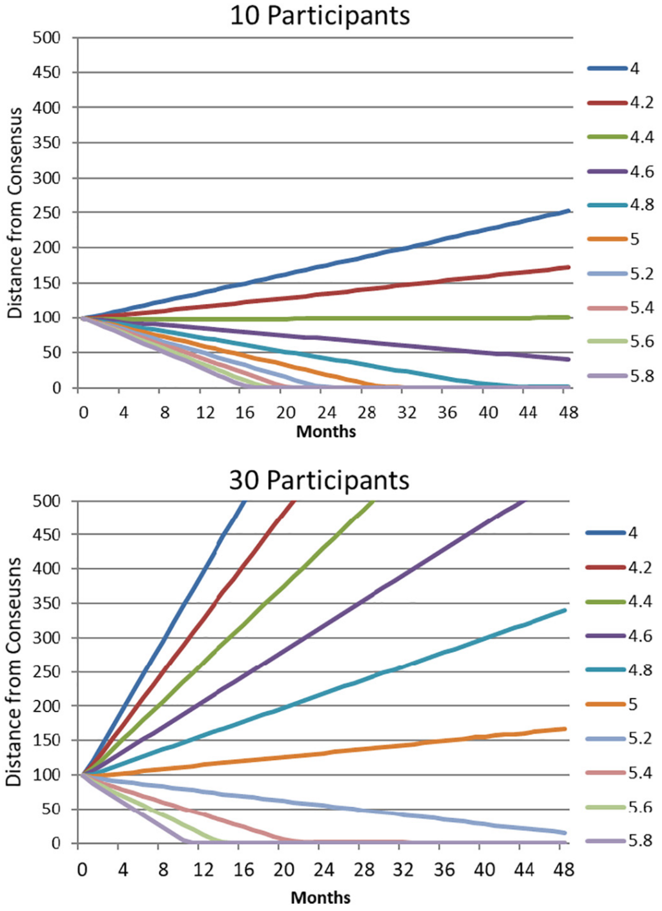

Fig. 4. Simulation results with 10 (top) and 30 participants (bottom) for increasing levels of *Development_Urgency*.

high (5.8), it takes 17 months to reach consensus when 10 participants are involved, whereas it takes approximately 11 months to reach consensus when 30 participants are involved. The difference between the set ups with 10 and 30 participants is generated by the *Platform_Development_Process* flow variable that drives the *Intended_Level_of_Platform_Development*. The former is influenced by the *Proposal_Diversity* and the *Actual_Effect_on_Normal_Development_from_Pressure* (see Fig. 3).

The effect of *Proposal_Diversity* is greater with 30 participants for the same level of *Development_Urgency* because of the greater number of *Actual_Platform_Development* proposals. This variable samples values from the uniform distribution implemented in *Platform_Proposals* (in the original avalanche model, this distribution is implemented inside *the Actual_Finger_Height variable*). The greater the participant number, the greater the number of values sampled from the distribution, and the standard deviation used to represent the *Proposal_Diversity*.

The *Actual_Effect_on_Normal_Development_from_Pressure* is influenced by the *Perceived_ Development_Pressure_on_Each_Stakeholder* which is greater with 30 participants on average, compared to the 10 participants case. This is because the *Perceived_Development_Pressure_on_Each_Stakeholder* is equal to *Perceived_Development_for_Each_Stakeholder* minus the *Actual_Platform_Development* (following the implementation in the avalanche game model, see Appendix A). The reason is that with 30 participants the maximum of the initial values of *Actual Platform Development* is greater than that of 10 participants because of the random, uniform values sampled from *Platform Proposals*.

The *Perceived Development_for_Each_Stakeholder* holds the maximum of those values and this is greater with 30 than with 10 participants because the random, uniform distribution implemented in *Platform_Proposals* and used in *Actual_Platform_Development* is sampled three times more for 30 participants than 10. Thus, it generates a greater range of values. Then, the higher *Perceived_Development_for_Each_Stakeholder* generates greater *Perceived_Development_Pressure_on_Each_Stakeholder*. The greater pressure produces a greater *Actual_Effect_on_Normal_Development_from_Pressure*.

The *Development_Urgency* amplifies this difference between 30 and 10 participants. The 30 participant set up diverges faster than the 10

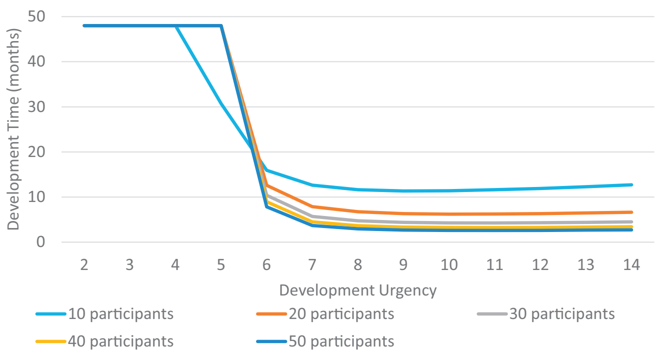

Fig. 5. Development time with development urgency results with 10, 20, 30, 40 and 50 participants.

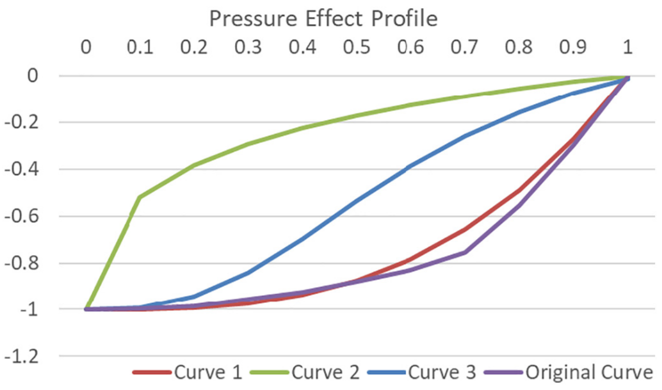

Fig. 6. Range of alternatives pressure effect profiles.

Table 2
Simulation results with alternative pressure effect profile curves.

	Curve 1	Curve 2	Curve 3
Avg. development time	17.35	80.12	106.6
St. dev. development time	0.476488	0.987473	1.241296

participant at low *Development_Urgency* values, and converges faster at high *Development_Urgency* (Fig. 4). This points to the existence of a threshold point between low and high *Development_Urgency* values which is approximately at 4.6. At this value 10 participant converge while 30 participants diverge. This is because the *Actual_Effect_on_Normal_Development_from_Pressure* is positive for 10 participants while it is negative for 30. This then generates convergence in the first case and divergence in the second due to the minus sign in *Platform_Development_Process* (see Appendix A).

These results led us to explore and summarize the effect of development urgency on total platform development time, e.g. the time at which the stock of *Intended_Level_of_Platform_Development* reaches zero. To do this, we ran the model with 10 to 50 participants for a large range of platform *Development_Urgency* values. Each line represents the average of 50 simulation runs (Fig. 5). Four observations can be made based on the results. First, there is a minimum threshold above which urgency has an effect in development time. This level increases with the number of participants involved in platform development. Second, there is a crossover level where greater numbers of participants benefit from the platform development process. Third, there are diminishing returns to increasing number of participants in the process. Fourth, there is a level for development urgency beyond which no further gains can be made in terms of platform development time. This seems to be independent of the number of participants involved.

To explore the effect of “Pressure Effect Profile” in more depth, we approximate the original curve in the avalanche game with an analytic expression (Curve 1) and introduce two alternative response curves 2 and 3 (see Appendix C, Fig. C.1). Results indicate that the original response profile results in the shorter development time. Intuitively this makes sense as curves 2 and 3 represent a situation where increased participant sensitivity to pressure variations can lead to overreactions. The end effect is that platform development takes longer. See Fig. 6 and Table 2.

In summary, the results indicate that a greater number of participants in decision-making processes tends to produce a greater range of diverging process outcomes. This is in line with existing research: the more actors, the more complex the network (Van de Ven, 1976). In fact, it is argued that consensus formation is negatively correlated with group size, since larger groups suffer from problems related to control and coordination (Smith et al., 1994). The same holds true for platform development processes: the more actors involved, the lower the chances consensus is achieved (Rada, 2000; Vercoulen & Van Wegberg, 1998).

However, the results also indicate that a high degree of *Development_Urgency* results in a relatively rapid conclusion in every case. Thus, if urgency is higher than the range tested in Fig. 4 (e.g. due to the existence of an alternative competing platform that is developed in a consortium), the number of participants may be less important. Simulation results show that under an extremely high degree of urgency (5.6–5.8), consensus is achieved more quickly when more participants are involved (Fig. 4). The complexity of the platform development process in terms of the number of interacting participants and their conflicting stances (Kauffman & Levin, 1987; Simon, 1962) is higher, which is apparently conducive to faster decision-making. This is counterintuitive to the common belief that small groups of participants tend to reach a consensus faster than a large group and it is not in line with current research on platform development processes (Rada, 2000; Vercoulen & Van Wegberg, 1998).

The use of the model as a metaphor to conceptualize and think about platform development processes and their potential outcomes, implies that it cannot be used to explain these outcomes or develop theory. To explain these outcomes, it is necessary to do an empirical study or look in current theory. For example, in the theory of decision-making in networks of interdependencies (De Bruijn & Ten Heuvelhof, 2018; Klijn & Koppenjan, 2004), actors have their own resources, interests, and stances. Actor alignment can be very difficult, particularly if there are many actors and if they have conflicting interests and stances. The literature on decision-making in networks of interdependent actors proposes several alignment strategies, or put differently, strategies that create incentives for actors to cooperate, instead of exploiting their conflicting stances (Lowndes & Pratchett, 2011; Torfing et al., 2012; Weible et al., 2011; Grote & Gbikpi, 2002). These strategies are often inspired by game theory that suggests the inclusion of more participants in a negotiation will likely broaden the negotiation agenda with more issues of interest. The broader negotiation agenda can provide more room for maneuvering and thus contribute to consensus building and faster decision-making (De Bruijn & Ten Heuvelhof, 2018; Klijn & Koppenjan, 2004; Greenstein, 1992; Blind & Thumm, 2004).

For example, take a family comprising a father, a mother and three children – an 18-year-old daughter, a 16-year-old daughter and a six-year-old son. They have to decide about a summer holiday. The father proposes an August holiday on the east coast of America. He now needs the support of his family members. Not everyone likes the idea. Someone wants to go to the east coast, but not with the whole family. Another wants to keep her options open and does not adopt a position. The third may be tempted by America, but does not want to go to the east coast and does not want to go with the whole family. The fourth wants to go to Europe.

How can these holiday plans be aligned? One option is for the father to discuss his plans with the family, and if they do not change their position, to put them under pressure. This option will probably not be very successful. Another option is to broaden the negotiation agenda.

This involves: (1) broadening the agenda, e.g., it is not just about the holiday, but about how we as a family can have a quality holiday together; (2) involving the participants, e.g. asking the family members to list their holiday wishes and to prioritize those issues that are most important to them. These could include rules about going out, whether to take the family pet along, whether to go on summer holiday or a skiing holiday, etc. Each of the participants must list issues that are attractive to them. There must be something in it for them – there needs to be a perspective of gain, but the list can also include issues that the participants strongly oppose. So, there is 'gain' and 'pain'.

A broader negotiation agenda provides strong incentives for cooperation. We distinguish four incentives for cooperation (De Bruijn & Ten Heuvelhof, 2018; Lemstra et al., 2011; Blind & Mangelsdorf, 2016; Cusumano et al., 1992; Wonglimpiyarat, 2005). First, the incentive to negotiate. A broader agenda incentivizes parties to participate and negotiate as all parties stand potentially to gain something. The incentive is strong because if one party refuses to take part in the process, the others will benefit and this party will not. This is usually linked to a sense of urgency to negotiate and benefit. Second, the broader agenda creates much more room for maneuver – the negotiation is more flexible. Smart combinations can be made, leading to a more acceptable compromise. The more space and flexibility, the faster the decision-making process can be.

Third, the incentive for cooperative behavior. A broad negotiation agenda can create coalitions that can be different for each agenda issue and thus create dependencies and incentives for cooperation. For example, the father and his daughters disagree about taking the family pet along but agree about going on a skiing holiday. If the daughters want their father's support for the skiing holiday, they know that they will need to collaborate with their father when it comes to deciding about the pet.

Fourth, strong incentives for peer pressure. During a negotiation, actors depend on each other and they have a perspective of gain. Once a critical mass of actors is satisfied with their gain, they might pressure the rest to conclude the discussion. Given the strong interdependencies that have emerged, it might be hard for the minority of remaining participants to resist this pressure. If they leave, they will be left empty-handed and they might also jeopardize their relationships with the other actors, who they are likely to meet again in other processes.

There are three reasons why we think that this is a realistic representation of platform development processes. We use the case of WiFi development as an illustration. First, in platform development committees such as the IEEE 802.11 for WiFi, participation is open to all interested members and committee size is not limited (Van de Kaa & De Bruijn, 2015). This means that there is a multi-actor setting and the more participants there are, the more interactions can emerge. More interactions can result in faster decision-making because there are more options for cooperation in a setting with more participants rather with few.

Second, each participant favors a solution that comprises several technological proposals for the platform specification. During the development of WiFi, participants had different ideas about the method of transmitting radio signals, the used bandwidth frequency, and its capacity (Lemstra et al., 2011). From a game theoretical perspective, these technological proposals can be defined as issues – they can be linked and they make it attractive to work together with other participants. The more issues there are, the more potential connections and the more incentives for cooperation. Indeed, during the development of WiFi, task groups of IEEE 802.11 committee members formed around various issues, and they developed successfully several parts of the WiFi platform (Van den Ende et al., 2012).

Third, there is a more subtle mechanism at work here. Many participants and many issues are involved in the process. For individual participants, it is almost impossible to oversee or embrace this complexity. They do not exactly know who might cooperate with whom. What they do know is that coalitions (task groups) will be formed and that each participant has several options. As a result, there is an incentive for them to speed up. Their perception might even be: first mover takes all – the first participants that manage to form a coalition (or a task group), will gain. If these perceptions emerge, participants might have a strong incentive to cooperate.

Although we did not find indications of this mechanism in the literature, it seems logical to assume that once a consensus emerges within a committee, the process of decision-making can speed up abruptly because the participants have only two options: either they work together with those who are reaching consensus, or they do not work with them and take a big risk that they will end up empty-handed.

5. Discussion and conclusion

In this paper, we developed a simulation model to give more insight into platform development processes. We used the avalanche game (Lane & Lubatkin, 1998) as a metaphor for platform development processes and extended it to reflect the platform governance context and the incentives presented in the literature. We examined the effect of these incentives for consensus building in platform development through the simulation model. We now discuss contributions, implications, limitations and areas for future research.

5.1. Contributions and implications

We contribute to the literature on platforms (Eisenmann et al., 2011; Gawer & Cusumano, 2013; Zhu & Iansiti, 2012) in different ways. We developed a system dynamics simulation model as a metaphor for the process of platform development. The value of this process comes from using the model to explore platform development from a different perspective. We examined an existing model to explain a process, and modified and applied it to a different context, instead of developing a new model. The value in this is that we were forced to explore the contrast and the parallels between the two contexts of model application: the avalanche game and platform development.

The avalanche game offered a particular representation through which to view and reason about the platform development process. The metaphor cast a particular light on the meaning of operational variables and result interpretation. The results suggest that under a relatively high degree of urgency, the more participants involved in the decision-making process, the quicker a consensus is reached. This counterintuitive result was explained through the literature on decision-making in networks of interdependencies. Future research to investigate further cases of platform development could explore whether this explanation holds more broadly.

The insights from this study can benefit practitioners involved in committees for platform development. Decision-making rules are not always available and it is up to the committee chair to establish such rules (Lemstra et al., 2011). The results from this study may be used by such chairs to better understand decision-making processes in committees and possibly to direct the process towards success.

5.2. Limitations and areas for future research

The use of the model as a metaphor to conceptualize and think about platform development processes and their potential outcomes, implies that it cannot be used to explain the counterintuitive simulation results in the paper and develop theory, but it can only motivate further research about them. Still, a practical explanation for the counterintuitive results obtained in this study could be that applying so much pressure to a decision-making process amounts to it being run in a Hobbesian manner where participants are merely present and quickly converge on a common platform, rather than engage in a dialectical process about the merits and weaknesses of each platform proposal. The equivalent case in the original avalanche game is asking the participants to lower a heavy object made of dense metal. In this case, participants can easily maintain contact with the object because they cannot exert enough force to raise the object using their fingers. So, although the decision-making process may be quicker, given a high degree of urgency and a large number of participants involved, the resulting platform might not be technically superior to competing alternatives. Future research could study the outcome of the decision-making process given a high degree of urgency and a large number of participants.

A limitation inherent in our approach is that we only incorporated the five incentives for consensus building in platform development committees that were offered in the literature. However, more factors might be relevant and may be studied in future research. Furthermore, the number of participants varies in real world, platform development cases. More may join the group and bring knowledge, technology, or required capabilities. Others may exit as they become disenchanted or look for better opportunities elsewhere. Second, as people tend to discount the future in general (Kahneman, 2011), the sense of platform development urgency is also likely to vary during a platform development process. Future models of platform development processes should take such issues into account.

Finally, any metaphor frames understanding in a distinctive yet partial way so any metaphor pressed too far can be rendered irrelevant for the inference of any conclusions. For example, in the avalanche game it is realistic to keep the object weight constant. We keep *Development_Urgency* as a constant parameter in our model, too. However, it is a proxy for competition from rival platforms which, in reality, changes with time, and to increase relevance to this context, *Development_Urgency* should be made dynamic. This change involves a tradeoff as it would make our model more relevant to the platform development context, but would also distance it from its source metaphor. Thus, caution is required if the model is to be used to consider temporally dynamic competition.

Appendix A

A.1. Constant parameter values

Parameter name	Type	Unit	Initial value
Intended level of platform development	Level	Meter	100
Desired consensus	Constant	Meter	0
Development urgency	Constant	–	1
Pressure effect profile	Constant	–	{−1, −0.995, −0.985, −0.955, −0.925, −0.88, −0.83, −0.755, −0.555, −0.295, 0}
Platform proposal adjustment response	Constant	–	{−1, −1, −1, −0.8, −0.4, 0, 0.4, 0.8, 1, 1, 1}
Pressure development amplification	Constant	–	1
Pressure response profile	Constant	–	{1, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0}
Stakeholder involvement	Constant	–	‘Development Urgency’
Noise amplitude	Constant	Meter	1
Number of stakeholders	Constant	–	Count(Nofactors)

A.2. Equation listing and documentation

A.2.1. Actual effect on normal development from pressure

Powersim notation: 1 + (1 + ‘Pressure Development Amplification’) ∗ ‘Base Effect on Normal Development from Pressure’

Logic: This variable is equivalent to *Actual Effect on Normal Development from Finger Pressure* in the original model. In this model it represents the pressure on stakeholders to improve the platform and conclude its development.

A.2.2. Actual platform development

Powersim notation: For (i = Nofactors|‘Intended Level of Platform Development’ + ‘Noise Amplitude’ ∗ ‘Platform Proposals’[Index(i)])

Logic: This variable is equivalent to *Actual Finger Height* in the original model. In this model it represents the actual development level of the platform which is the intended level plus a noise effect created by the divergent preferences of stakeholders.

A.2.3. Base effect on normal development from pressure

Powersim notation: For (i = Nofactors|Graph(‘Perceived Pressure Development Ratio’[Index(i)],0,0.1,‘Effect Profile’))

Logic: This variable is equivalent to *Base Effect on Normal Development from Pressure* in the original model. In this model it represents the reaction of each stakeholder to the state of platform development. The same *Effect Profile* is implemented for all stakeholders.

A.2.4. Effect of diversity on platform development

Powersim notation: ‘Proposal Diversity’/‘Development Urgency’ ∗ 1≪m/da≫

Logic: This variable is not included in the original model. *Development Urgency* is placed in the denominator to attenuate the effect of diversity (see *Platform Development Process*). Platform Proposal Diversity is in the numerator because it is assumed that it intensifies any adjustment of proposals from stakeholders.

A.2.5. Perceived development for each stakeholder

ArrMax(‘Actual Platform Development’)

Logic: This variable has the same formulation to Object Height for Player in the original model. In that case it is used to find the maximum finger height. In our model it is used to find the maximum value in Actual Platform Development. The stock of Development starts at a set value and decreases towards zero, just as in the original model, indicating the progress made in the platform development process. Thus, the maximum value of the Actual Platform Development array represents the minimum level of platform development. It is assumed that all stakeholders can agree that platform development has reached this minimum level.

A.2.6. Perceived development pressure on each stakeholder

Powersim notation: For (i = Nofactors|DelayInf(‘Perceived Development for Each Stakeholder’ – ‘Actual Platform Development’[Index(i)], 1≪da≫,1,0≪m≫))

Logic: This variable is equivalent to Pcvd Pressure Indent on Finger in the original avalanche model. It is assumed that pressure develops from the difference between the perceived and actual platform development.

A.2.7. Perceived pressure development ratio

For (i = Nofactors| Graph(‘Perceived Development Pressure on Each Stakeholder’[Index(i)]/‘Stakeholder Involvement’,0,0.1,‘Pressure Response Profile’))

Logic: This variable is equivalent to *Pcvd Pressure Indent on Finger* in the original model. It is assumed that greater stakeholder involvement, increases the sense of control over the process and thus attenuates the *Perceived Development Pressure on Each Stakeholder*.

A.2.8. Platform development process

− ‘Effect of Diversity on Platform Development’ ∗ ‘Proposal Adjustment’ ∗ ‘Actual Effect on Normal Development from pressure’ ∗ min(1,max (0,Number(‘Intended Level of Platform Development’)))

Logic: This variable is equivalent to the Downward Finger Movement in the original model. It is assumed that diversity is beneficial to the development process as diversity facilitates the resolution of platform development problems. The expression is multiplied with the stock variable Intended Level of Platform Development as it is assumed that platform development is more difficult close to its conclusion as more details need to be worked out simultaneously.

A.2.9. Platform proposals

For (i = Nofactors|Random(− 1,1))

Logic: In the original model, the random number generator is implemented in the *Actual Finger Height* variable. In our model it is separate as it is good modelling practice.

A.2.10. Proposal adjustment

Graph(‘Perceived Development for Each Stakeholder’ / ‘Desired Consensus’, 0, 0.2, ‘Platform Proposal Adjustment Response’)

Logic: This variable is the same as the *Height Adjustment Movement Effect* graph variable in the original model. The *Object Height for Player* and *Desired Object Height* variables are renamed into *Perceived Development for Each Stakeholder* and *Desired Consensus*. All stakeholders adjust their proposals. It is assumed that no stakeholder actively tries to sabotage the proposal, just as in the avalanche game no participant sabotages the game. Thus, the *Desired Consensus for Platform Development* which represent the conclusion of the platform development process is common for all stakeholders.

A.2.11. Proposal diversity

Number(ArrStDev(‘Actual Platform Development’))

Logic: This is an additional equation to the original model. It is to represent a measure of diversity of platform proposals and intended development. It is assumed that the proposal diversity arises out of the stakeholder proposals that want to take platform development towards a particular direction and thus can slow or accelerate the process depending on whether they are converging or diverging with the majority view on platform development. In this way diversity is modelled as 1D variable. Realistically it would be modelled as 2, 3 or n dimension variable depending on the specific case.

Appendix B. Model comparison

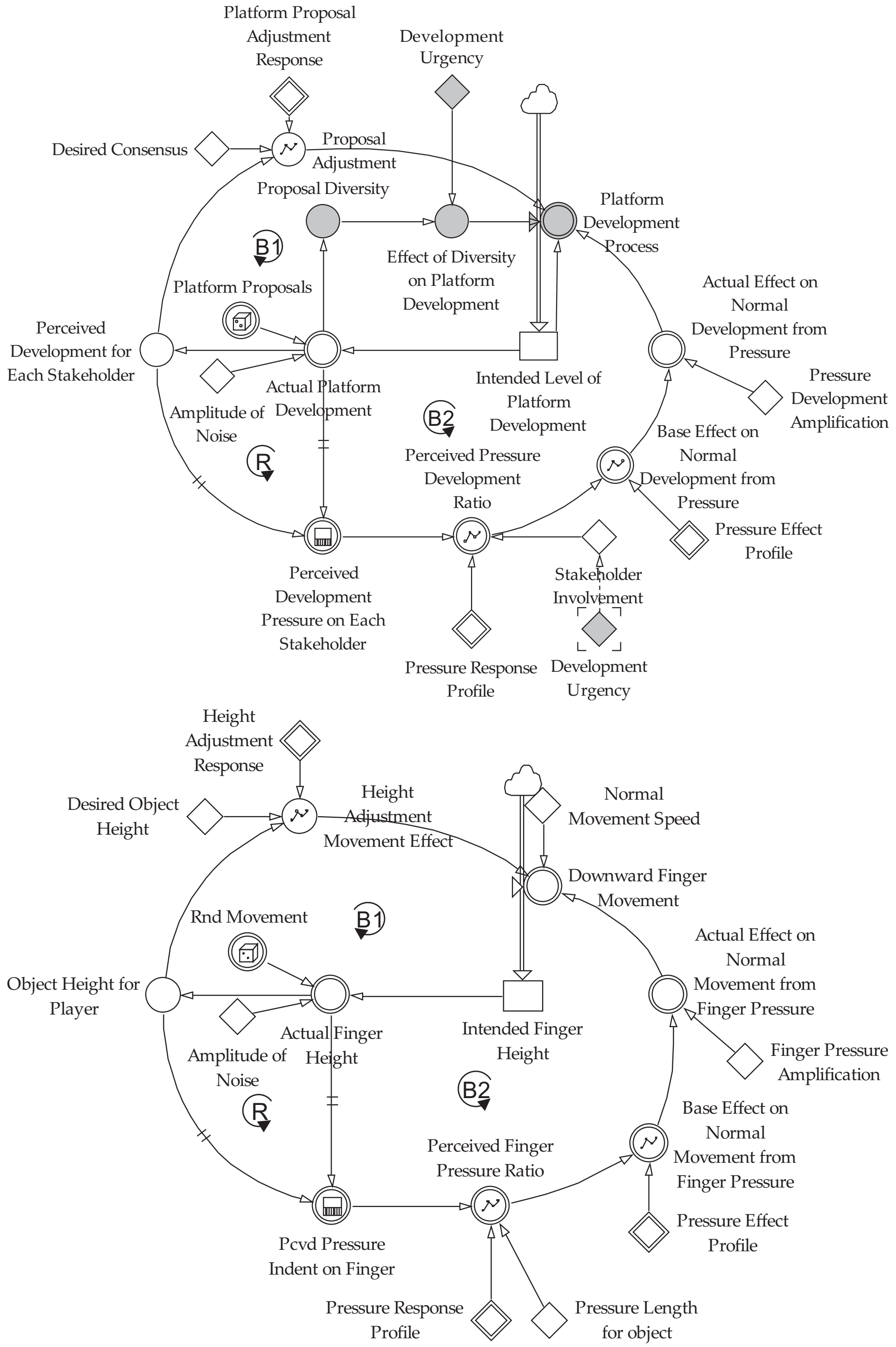

Fig. B.1. Stock and flow structure of the modified model and stock and flow structure of the original avalanche model.

Appendix C. Pressure effect profile sensitivity analysis

The profile used in the original avalanche model does not implement an analytical function for the variable *Base Effect on Normal Development from Pressure*. This profile is approximated with an analytical expression along with two additional ones that are implemented in our model (see Fig. 1).

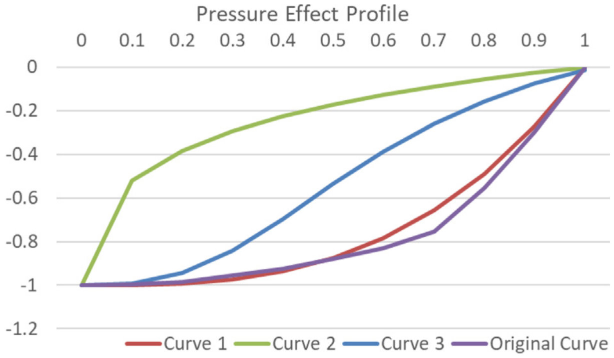

Fig. C.1. Pressure effect profile curves used in the model.

The formal expressions for the variable *Base Effect on Normal Development from Pressure* in the model are:
Curve 1: 1 + ‘Perceived Pressure Development Ratio’ˆ3
Curve 2: 1–2/(1 + sqrt(‘Perceived Pressure Development Ratio’))
Curve 3: −1 + tanh(2 ∗ ‘Perceived Pressure Development Ratio’)ˆ3
∗(1.1ˆ‘Perceived Pressure Development Ratio’)

These do generate different behavior in the model as shown in the results below. Curve 1 performs significantly better compared to the other two curves. This is to be expected as overreaction to pressure amplifies the reactions of game participants and will only lead to slower progress.

	Curve 1	Curve 2	Curve 3
Avg. development time	17.35	80.12	106.6
St. dev. development time	0.476488	0.987473	1.241296

Further sensitivity analysis was done on *Pressure Effect Profile*. Its values are multiplied by a sensitivity factor {0…2}. This increases the differences in the *Perceived Pressure Development Ratio* and thus makes the platform development process take longer, more than 1400 days which is the simulation time (Fig. C.1). The same result is observed when the analysis is repeated for Pressure Development Amplification variable.

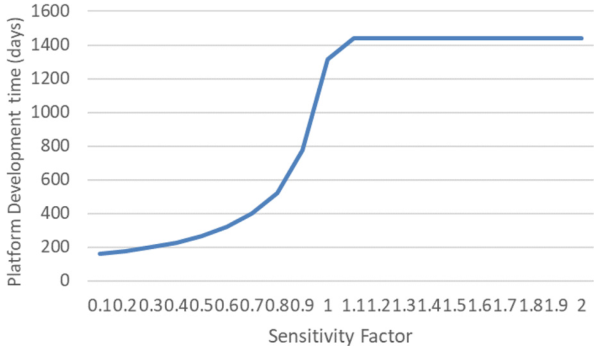

Fig. C.2. Sensitivity analysis results on *Pressure Effect Profile.*

Repeating the sensitivity analysis with *Stakeholder Involvement* gives the result in Fig. C.3. It is the mirror image of Fig. C.2. The interpretation of this is that significant stakeholder involvement is required to achieve substantial reductions in platform development time. The exact values in Fig. C.3 are not important, nor in the original model as the purpose is to illustrate the mechanism at work behind the behavior observed in the avalanche game.

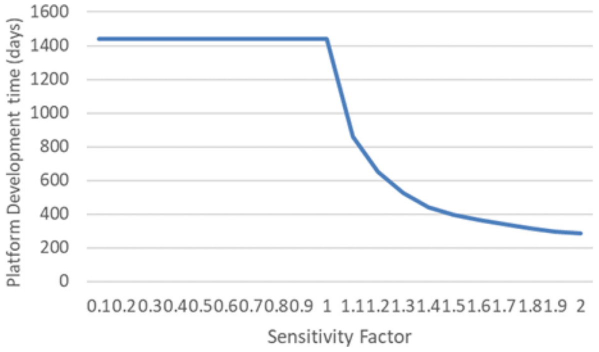

Fig. C.3. Sensitivity analysis results on *Stakeholder Involvement.*

Repeating sensitivity analysis for *Platform Proposal Adjustment Response* gives the result in Fig. C.4. As expected, faster adjustment responses reduce development time.

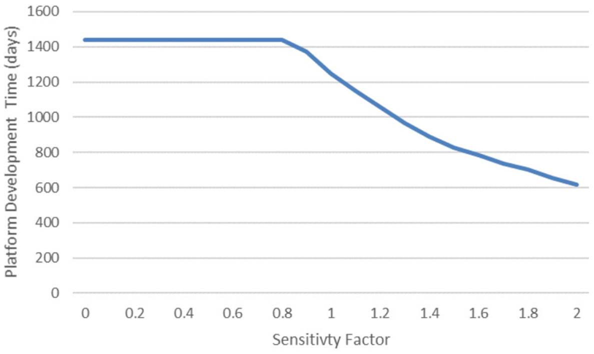

Fig. C.4. Sensitivity analysis results on *Platform Proposal Adjustment Response*.

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