Untangling the origins of Strategic Innovation
A System Dynamics Approach

Support Material
Annex 1. Model equation list

Equation list includes variables description and unit of measures

init Dismissed_innovations = 0
flow Dismissed_innovations = +dt*Dismissing_rate
doc Dismissed_innovations = Innovative projects that are not integrated in the strategy of the firm are dismissed
unit Dismissed_innovations = Innovations

init Failed = 0
flow Failed = +dt*Failure_rate
doc Failed = Technical innovations that are not successfully integrated in the strategy of the firm and enter into the stock "failed"
unit Failed = Innovations

init First_Developed_innovations = 1
flow First_Developed_innovations = -dt*Refusal_rate
-doc First_Developed_innovations = -dt*Approval_rate
+dt*First_Development_rate
doc First_Developed_innovations = Technical innovations presented for the approval
unit First_Developed_innovations = innovations

init Full_developed_innovations = 0
flow Full_developed_innovations = -dt*Dismissing_rate
-doc Full_developed_innovations = -dt*Integration_rate
+dt*Full_development_rate
unit Full_developed_innovations = innovations
init Innovations_approved_for_experimenting = 0
flow Innovations_approved_for_experimenting = -dt*First_Developed_Obsolescence_rate
-doc Innovations_approved_for_experimenting = -dt*Full_development_rate
+dt*Approval_rate
doc Innovations_approved_for_experimenting = Innovation approved to be implemented on a small scale
unit Innovations_approved_for_experimenting = Innovations

init Innovations_Refused = 0
flow Innovations_Refused = +dt*Refusal_rate
doc Innovations_Refused = Innovations refused by top managers. These innovations are abandoned and no more examined to be developed
unit Innovations_Refused = Innovations
init \hspace{1em} \text{Obsolete\_innovative\_projects} = 0
flow \hspace{1em} \text{Obsolete\_innovative\_projects} = +\text{dt}\text{*First\_Developed\_Obsolescence\_rate}
doc \hspace{1em} \text{Obsolete\_innovative\_projects} = \text{Obsolete} \text{innovative projects} \text{ that are definitely abandoned and no more examined}
unit \hspace{1em} \text{Obsolete\_innovative\_projects} = \text{Innovations}

init \hspace{1em} \text{Perceived\_failure\_rate} = \text{Failed}
flow \hspace{1em} \text{Perceived\_failure\_rate} = +\text{dt}\text{*Change\_in\_failure\_rate\_perception}
doc \hspace{1em} \text{Perceived\_failure\_rate} = \text{Strategic} \text{ integrated innovations} \text{ failed} \text{ under competitive pressure and, consequently, abandoned}
unit \hspace{1em} \text{Perceived\_failure\_rate} = \text{Innovations}

init \hspace{1em} \text{Perceived\_integration\_rate} = \text{First\_Developed\_innovations}
flow \hspace{1em} \text{Perceived\_integration\_rate} = +\text{dt}\text{*Change\_in\_integration\_rate\_perception}
doc \hspace{1em} \text{Perceived\_integration\_rate} = \text{The total amount of} \text{ innovations} \text{ integrated in the corporate strategy as percepted by top management}
unit \hspace{1em} \text{Perceived\_integration\_rate} = \text{Innovations}

init \hspace{1em} \text{Resourced\_for\_development} = 0
flow \hspace{1em} \text{Resourced\_for\_development} = -\text{dt}\text{*Resources\_consumption\_rate} \\
+\text{dt}\text{*Resources\_accumulation\_rate}
doc \hspace{1em} \text{Resourced\_for\_development} = \text{The stock of total} \text{ resources} \text{ accumulated to sustain} \text{ the development of} \text{ innovative projects}
unit \hspace{1em} \text{Resourced\_for\_development} = \text{Resources}

init \hspace{1em} \text{Strategic\_integrated} = 0
flow \hspace{1em} \text{Strategic\_integrated} = -\text{dt}\text{*Failure\_rate} \\
+\text{dt}\text{*Integration\_rate}
doc \hspace{1em} \text{Strategic\_integrated} = \text{Technical} \text{ innovations} \text{ integrate} \text{ successfully in the strategy of the firm.}
unit \hspace{1em} \text{Strategic\_integrated} = \text{Innovations}

aux \hspace{1em} \text{Approval\_rate} = \text{IF(First\_Developed\_innovations}<0, \\
0,\text{MIN(First\_Developed\_innovations}, \\
\text{First\_Developed\_innovations}\text{*Fractional\_approval\_rate}))
doc \hspace{1em} \text{Approval\_rate} = \text{Innovation approved} \text{ by top management each month. These innovations will be developed on a small scale to be tested}
unit \hspace{1em} \text{Approval\_rate} = \text{Innovations per month}

aux \hspace{1em} \text{Change\_in\_failure\_rate\_perception} = (\text{Failure\_rate}- \\
\text{Perceived\_failure\_rate})/\text{Time\_to\_perceive\_failure\_rate\_changes}
doc \hspace{1em} \text{Change\_in\_failure\_rate\_perception} = \text{The net} \text{ change in the precepted failure rate. Top managers perceive how many strategic integrated innovations fail under competitive pressure and must be abandoned}
unit \hspace{1em} \text{Change\_in\_failure\_rate\_perception} = \text{Innovations per month}
\[ \text{Change in integration rate perception} = \frac{\text{Integration rate} - \text{Perceived integration rate}}{\text{Time to perceive integration rate change}} \]

The net change in the perceived integration rate. Top managers perceive how many innovations are integrated in the strategy of the firm with a certain delay.

\[ \text{Change in integration rate perception} = \text{Innovations per month} \]

\[ \text{Dismissing rate} = \text{Full developed innovations} \times \text{Reference dismissing rate} \times \text{External competitive pressure} \]

The rate at which fully developed innovative projects are dismissed. After a certain period of time, innovative projects lose their innovative attributes for two reasons, the firm develops new innovations, rivals develop similar or alternative innovations. The rate at which projects are dismissed by top managers depends on the reference fractional dismissal level that represents the willingness of the company to maintain the fresher projects and the effect of the approval pressure that represent the intensity of rivalry.

\[ \text{Dismissing rate} = \text{Innovations per month} \]

\[ \text{Failure rate} = \text{Strategic integrated} \times \text{MIN}(1, \text{Fractional failure rate}) \]

The rate at which innovations integrated fail and accumulate in the stock "failed".

\[ \text{Failure rate} = \text{Innovations per month} \]

\[ \text{First Developed Obsolescence rate} = \text{MIN} (\text{Innovations approved for experimenting}, \text{Innovations approved for experimenting} \times \text{Ref obsolescence rate} \times \text{External competitive pressure}) \]

The rate at which presented innovative projects become obsolete. After a certain period of time, innovative proposal loose their innovative attributes for two reasons, the firm generates new innovations, rivals generate similar or alternative innovations. The rate of obsolescence depend from the reference fractional level of obsolescence that represents the willingness of the company to maintain the fresher projects and the effect of the approval pressure that represent the intensity of rivalry.

\[ \text{First Developed Obsolescence rate} = \text{Innovations per month} \]

\[ \text{First Development rate} = \text{IF}(\text{Time to autonomous initiatives}=0,0, (\text{Time to autonomous initiatives} \times \text{Reference productivity for unit of time})) \]

The number of innovation that are developed to be examined by top management.

\[ \text{First Development rate} = \text{Innovations per month} \]
Full_development_rate = MIN(Innovations_approved_for_experimenting, Resources_consumption_rate/Resource_for_development_per_project, Innovations_approved_for_experimenting - First_Developed_Obsolescence_rate)

Full_development_rate = Innovations that come under complete development each month. These depend from the total resources that are available and from the amount of resources that each innovation requires to be fully developed.

Full_development_rate = Innovations per month

Integration_rate = MIN(Full_developed_innovations, Full_developed_innovations*(Fractional_integration_rate), Full_developed_innovations - Dismissing_rate)

Integration_rate = Innovations per month

Refusal_rate = First_Developed_innovations - Approval_rate

Refusal_rate = Express how many innovations presented by front line management are refused by top managers

Refusal_rate = Innovations per month

Resources_accumulation_rate = Approval_rate*Reference_resources_per_project

Resources_accumulation_rate = The rate at which top managers plan resource accumulation to sustain innovative projects. It is a function of reference resources that each project needs and the approval rate that represents how many innovative projects were approved.

Resources_accumulation_rate = Resources per month

Resources_consumption_rate = Resourced_for_development/Time_to_resource_absorption

Resources_consumption_rate = This represents the rate at which each project absorbs resources to be full developed.

Resources_consumption_rate = Resources per month

Effect_of_implementation_rate_on_resource_for_development = GRAPH(Implementation_rate, 0, 0.2, [2, 1.8, 1.6, 1.4, 1.2, 1.0, 0.8, 0.6, 0.4, 0.2, 0.01] "Min:0;Max:2;Zoom")

Effect_of_implementation_rate_on_resource_for_development = The more will be the implementation rate the more simple the implementation will be and the less will be resources destined to a single project

Effect_of_implementation_rate_on_resource_for_development = Dimensionless
**Effect of relative failure rate on fractional approval rate**

The effect of failure rate is as follow: the more it increases the more prudent will be top managers in approving innovative projects, so the less will be the approval rate.

**Effect of relative failure rate on integration rate**

The more will be the fractional failure rate the less will be the integration rate, because top managers become more prudent and want to spend more time to integrate innovative projects.

**Fractional approval rate**

The percentage of developed innovations that are approved by top managers to be developed on small scale each month.

**Fractional failure rate**

The strategic innovations failure rate depends firstly on the reference fractional failure rate that is influenced by two factors: fractional integration rate and external competitive pressure. The higher the integration rate the less top managers will dedicate attention to innovation integration and the higher the failure rate will be.

**Fractional integration rate**

The fraction of innovative project that are integrated in the strategy of firms and became strategic innovations.

**Fractional time to new initiatives**

The fraction of time that effectively will be allocated to new initiatives.
aux Implementation_rate =
Full_developed_innovations/First_Developed_innovations
doc Implementation_rate = Express the performances in term of ability to implement innovations
unit Implementation_rate = Dimensionless

aux Relative_failure_rate = Perceived_failure_rate/Perceived_integration_rate
doc Relative_failure_rate = Performance in term of failed strategic innovations that are appreciated in relation with integrated innovations
unit Relative_failure_rate = Dimensionless

aux Resource_for_development_per_project =
Effect_of_implementation_rate_on_resource_for_development*Reference_resources_per_project
doc Resource_for_development_per_project = Amount of resource effectively destined to a single innovation project
unit Resource_for_development_per_project = Resources per innovation

aux SIR_Synthetic_innovation_rate = MAX(0.00001, Strategic_integrated/Total_innovations)
aux Time_to_autonomous_initiatives =
Total_time_available*Fractional_time_to_new_initiatives
doc Time_to_autonomous_initiatives = The unit of time available each month for innovative initiatives
unit Time_to_autonomous_initiatives = Unit of time per month

aux Total_innovations = Failed+Strategic_integrated
const External_competitive_pressure = 1
doc External_competitive_pressure = It express the level of competitive turbulence of the industry [D'Aveni, 1997] also called level of rivalry among firms [Porter, 1985]. It can vary from 1 that represents an industry with a low level of rivalry to 2 that is a very turbulent industry.
unit External_competitive_pressure = Dimensionless

const Ref_obsolescence_rate = 0.1
doc Ref_obsolescence_rate = The fractional rate of obsolescence is set as an independent variable and can be interpreted as the willingness of top managers to retain in the stock only a small portion of innovative initiatives
unit Ref_obsolescence_rate = Fraction per month

const Reference_dismissing_rate = 0.001
doc Reference_dismissing_rate = The fractional dismission rate is set as an independent variable and can be interpreted as the willingness of top managers to abandon older technical innovation and retain in the stock only a small and well qualified portion of them.
unit Reference_dismissing_rate = Fraction per month
const Reference_fractional_approval_rate = 0.3

doc Reference_fractional_approval_rate = The percentage of innovations that are normally approved by the firm's top management each month.

unit Reference_fractional_approval_rate = Fraction per month

const Reference_fractional_failure_rate = 0.2

doc Reference_fractional_failure_rate = Reference fractional failure rate

unit Reference_fractional_failure_rate = Fraction per month

const Reference_fractional_integration_rate = 0.30

doc Reference_fractional_integration_rate = This is the reference rate at which top managers want to integrate innovative projects. This is an ideal goal set "a priori" by top managers.

unit Reference_fractional_integration_rate = Fraction per month

const Reference_fractional_time_to_new_initiatives = 0.3

doc Reference_fractional_time_to_new_initiatives = Percentage of total time available that front line managers can allocate to autonomous initiatives

unit Reference_fractional_time_to_new_initiatives = Dimensionless

const Reference_productivity_for_unit_of_time = 1

doc Reference_productivity_for_unit_of_time = Express how many technical innovations can be realized in a unit of time

unit Reference_productivity_for_unit_of_time = Innovations per unit of time

const Reference_resources_per_project = 1

doc Reference_resources_per_project = Reference amount of resources needed to each project to be developed

unit Reference_resources_per_project = Resources per innovation

const Time_to_perceive_failure_rate_changes = 4

doc Time_to_perceive_failure_rate_changes = Time to perceive the change in the failure rate. It is normally set at 4 because the reports are examined on a quarterly basis by top management

unit Time_to_perceive_failure_rate_changes = Months

const Time_to_perceive_integration_rate_change = 4

doc Time_to_perceive_integration_rate_change = Time to perceive the change in the integration rate. It is normally set at 4 because the reports are examined on a quarterly basis by top management

unit Time_to_perceive_integration_rate_change = Months

const Time_to_resource_absorption = 1.5
Time_to_resource_absorption = Time that innovative projects need to absorb resources and become fully developed

Time_to_resource_absorption = Months

Total_time_available = 50

Total_time_available = The amount of time available each month for work. The unit of time is a conventional measurement (it can be days, hours or minutes) and indicates the total time of front line managers to work

Total_time_available = Time unit per month
Annex 2
Characterisation of non-linear effects to represent managers’ mental models

Characterisation of the effect of relative failure rate on approval rate

Aggressive mental models

Conservative mental models
Characterisation of the effect of implementation rate on resources for development of a single project

Aggressive mental models

Conservative mental models
Characterisation of effect of failure rate of the integration rate

Aggressive mental models

Conservative mental models
Annex 3. Selected simulation outputs for validation

Reference fractional time to autonomous initiatives = 0

![Graph of simulation outputs for validation](image-url)
Reference fractional approval rate = 0
Reference fractional integration rate = 0

Time

Relative_failure_rate

Effect_of_relative_failure_rate_on_integration_rate

-1.0
-0.5
0.0
0.5
1.0
1
2
1
2
1
2
Annex 4. Simulation software settings

<table>
<thead>
<tr>
<th>Software</th>
<th>Powersim constructor 2.51</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Integration method</strong></td>
<td>Euler (fixed step)*</td>
</tr>
<tr>
<td><strong>Start time</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>Stop time</strong></td>
<td>180</td>
</tr>
<tr>
<td><strong>Time step</strong></td>
<td>0.625</td>
</tr>
</tbody>
</table>

* We adopted Euler’s integration method. We tested the robustness of our model by running several simulations with the Runge-Kutta method and we did not encounter any significant differences with Euler’s method simulations.