Managing Innovation through Internal Corporate Venturing. A System Dynamics Approach

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1. Introduction

This paper explores the firms' ability to continuously nurture strategic innovation through the promotion of Internal Corporate Venturing programs. Fundamental goal of the research is to investigate the conditions that enable companies to conduct successful corporate venture programs.

During the 70s Corporate Venture Capital - ICV encountered a large diffusion among US diversified companies as a mean to explore new business opportunities in related industries and to generate innovation in products, processes and services [von Hippel, 1977].
Top managers devoted many efforts to design rewards and incentives policies to stimulate the entrepreneurial behaviour of employees and to increase the number of submitted projects [Drucker, 1985].

ICV programs experienced three main problems [von Hipple, 1977; Zahara, 1991 1993].
The rate of new project delivered by engineers was lower that expected. Because of the poor numbers of new projects presented, ICV programs weren't able to provide significant new strategies.
The second problem concerns the discontinuity in project presentation rate. This jeopardized the possibility to generate a stable flow of innovation introducing new products and services (developed in the ICV program) in the normal activity of corporation.
A further problem experienced by ICV programs was the economic disequilibrium between resources invested and benefits. The increase of costs was determined by the introduction of complex mechanisms of incentives and rewards which didn't boost enough the development of new projects.

Despite their partial failure, ICV programs remain one of the most powerful mean to stimulate innovation in large established companies. ICV projects may introduce new strategies or can contribute to modify the general strategy of the company [Burgelman, 1983a, b,c]. A typical ICV project incorporates a new market strategy for the new product or the new service developed. New products and new services may require new production processes.
Top managers, through ICV programs, can integrate in the company's corporate strategy the ideas coming from front line managers which have closer contacts with final customers.
During the 90s ICV programs were introduced also by non diversified companies to revitalize mature business or to increase sales and profitability, through to new products and services [Baden-Fuller and Stopford, 1994].

The problem of the effectiveness, measured by the total number of project presented and by the continuity of the presentation rate, of ICV programs remains partially unsolved. This paper tries to answer to the problem exploring, though a System Dynamics model simulation, the Internal Corporate Venturing process. The analysis is centred on the design of organizational context and in particular on the role played by incentives and rewards.

The paper is structured into six parts. After a brief review of the literature, dedicate to clarify the relation between corporate entrepreneurship and strategic management,

the conceptual model is illustrated. The third part is devoted to the stock and flow model description, the fourth to the model validation. In the fifth part simulation results are presented. In the conclusive section I discuss simulation results and I give address for further researches.

2. Corporate entrepreneurship and strategic management

In the mid 90s inside the strategic management field a debate emerged on the relation between firms' strategy and industry structure. According to strategic management scholars like Abell [1993], Hamel and Prahalad [1995], D'Aveni [1995 e 1999] and Markides [1997, 1998, 1999 and 2000] the industry structure is considered a dynamic environment that could be modified by companies' innovative strategies. Based their work on the model of competitive strategy, they developed an original approach to analyze industry transformation processes.
D'Aveni [1995] studied the effects of strategic innovation in middle sized companies and discovered that high focused and innovative companies can build competitive advantage and become industry leaders.
Markides [1997] has clarified the content of strategic innovation: "*the essence of strategy is to choose one position that the company will claim as its own. A strategic position is simply the sum of the answers that a company gives to the questions: Who should I target as customers? What products or services should I offer them? How should I do this in an efficient way?*" Strategy is all about choosing a distinctive (different from competitors) strategic position, in this perspective strategies are unique and they can be called "innovative". To have a unique strategic position a company must generate constantly strategic options and then has to choose among them. The competitive advantage based on strategic innovation could be sustained only if companies are able to renew the sources of their creativity thereby nurturing internal entrepreneurship.

The power of strategic innovation was recognized also by Henderson and Cockburn [1994, 2000] which demonstrate how new strategies, implemented by pioneer companies, can become dominant and can influence the strategic behaviour of competitors and the industry structure. They relate the ability of the firm to generate new strategy to a distinctive set of resources. Once the new strategy has been implemented and has been imitated by competitors, the original set of resources becomes obsolete and the company must renew it.

These contributions clarified the effect of innovative strategies on industry structure, but didn't bring much light on the process through which companies create new strategies.

A powerful contribution comes from studies on corporate entrepreneurship.
Stopford and Baden Fuller [1994] demonstrated a linkage between the creation of ventures within an existing organization and the Schumpeterian entrepreneurship, which happens when an enterprise changes the rules of competition for its industry in the manner suggested by Schumpeter [1934].
Many authors have underlined corporate entrepreneurship as a process that contributes to firm survival and performance [Covin and Slevin, 1989; Ducker, 1985, Lumpkin and Dess, 1996], they argueed that entrepreneurial attitudes and behaviours are necessary for firms of all sizes to prosper and flourish in competitive environments.

Bower [1991] argues that in large companies the ability to create strategic innovation is related to the bottom-up process of understanding the innovation signals that comes from the front line management.

According to Burgelman's process model of Internal Corporate Venturing [1983a, b and c, 1985], the success of ICV depends on the availability of autonomous entrepreneurial activity on the part of front line management, on the ability of middle level managers to retain at an higher level of the organizational structure the implications of entrepreneurial initiatives and on the capacity of top managers to allow viable entrepreneurial initiatives to influence the corporate strategy.

In a more recent contribution, while presenting an ecological model of strategy creation process, Burgelmann [1991] emphasizes the role of managers in designing the firm's structural context which is constituted by the firm's organisational structure and the administrative systems such as, for example, information, rewards and incentive mechanisms. Administrative mechanisms influence the atmosphere in which the emergent strategic behaviour of front-line managers is shaped.

The above mentioned contributions clarified the relation between ICV and strategy formation process, they also pointed out the role of the firm's structural context, in particular of the organizational structure and the intangible elements of the organizational context, in fostering the emergence of autonomous entrepreneurial initiatives. However remain partially unexplored the theme of effectiveness of ICV programs, defined as the number of project presented and the constant of the presentation rate and the role played on it by administrative mechanism like incentives and rewards.
Capitalising on relevant literature on internal corporate venturing, I propose a System Dynamics model of ICV process to investigate the determinants of effectiveness of ICV programs.

Rooted in control engineering and the theory of servomechanism [Richardson, 1991], System Dynamics (SD) was created at Massachusetts Institute of Technology in the late 50s by Jay Forrester [1961, 1968a, 1968b, 1969, 1973].
Originally conceived to address problems encountered by managers in corporate systems [Forrester, 1961; Roberts, 1978], SD modelling contributed valuable insights in many realms.
SD modelling is based on the assumption that many phenomena can be successfully analysed as elements of a dynamic system. Such a dynamic system is characterised by a particular behaviour over time. A system's behaviour can be studied as the result of the internal structure of feedback loops among variables. A SD model can therefore be considered as a reasonable abstraction of the structure and behaviour of the real system observed [Richardson and Pugh, 1981], and represent a theory of the behaviour of that system.
SD literature contains an impressive collection of examples of how models, built by scholars of this field, have facilitated theory building in different contexts.
For example, Forrester pioneered the SD field by modelling urban growth and decay, and world dynamics [1973]. Meadows [1970] generated a model of the dynamics of commodity production cycles. Mass [1975] modelled economic cycles and Low [1980] used a SD perspective to analyse Solow's model of growth.

Moreover, SD models have provided useful environments to explore theories of business cycles [Sterman, 1985, 1986], to investigate the petroleum life cycle [Davidsen, Sterman and Richardson, 1990], to analyse high-technology market growth-cycles [Morecroft, 1986] and to interpret strategic behaviour of firms [Markides 1999 and 2000; Senge, 1990].

The use of simulation in organization theory and in the strategic management field requires some remarks. The translation of a verbal theory to a mathematical representation results in the loss of richness, however there are two benefits in using the modelling and simulation. First "*The simulations enforces the internal consistency of the theory, thus ensuring that the behaviour it pourpots to explain can in fact be generated by its underlying assumptions"* [Repenning, 2002]. Second, a simulation model is a laboratory where it's possible to discover implications of the theory that are not intuitively obvious: a theory that describes any type of non-linear process can often generate a much wider range of behaviour that its author anticipates.

3. Introducing the conceptual model

The model conceptualization could be started unfolding assumptions made to represent, through causal loop diagrams, the internal corporate venturing process. These assumptions are based on relevant contributions on ICV processes [Burgelman, 1983a,b,c; von Hippel, 1977].

- The ICV Unit is an independent organisational unit inside the Corporation. It can be figured as a "think thank", like the Xerox Park were engineers work eon innovative projects that later are implemented in the Corporation.
- The ICV unit has its economic funds, provided by the Corporation. If the initial stock of funds is entirely consumed, the Corporation will deliver further funds to the ICV unit.
- Engineers work exclusively for the ICV unit, during the conduction of the ICV program they are exempted from other tasks in the Corporation.
- ICV unit engineers submit to ICV committee (formed by top managers and external advisors) projects for new products and/or services. The projects are presented using an appropriate format: a business plan including the technical/industrial analysis and the market potential analysis for the new product/service
- Engineers are responsible for project presentation and for project completion. They are free to choose how to allocate their time. However if the projects presented are higher than projects completed, top managers can act to rebalance the time allocation to project completion.
- Managers review and approve presented projects.
- Once approved, presented projects are completed and are delivered (or implemented) in the Corporation. Projects flow out from the ICV unit and enter in the Corporation. A special force called Delivery force, constituted by high qualified workers, is in charge of projects implementation. Delivery force is part of the ICV unit, but operates in the Corporation.
- Incentives are given to engineers to stimulate the presentation of new projects, independently if they are approved or not.
- Rewards are given to engineers for each project completed.
- The duration of ICV program is of ten years (120 months). The typical duration of such programs may vary from 3 to 10 years, for the simulation was chosen the higher level to verify the existence of cyclical behaviour.

The model presents four critical feedbacks (Figure 3.1). The problem of time allocation plays an important role in each of these feedbacks.

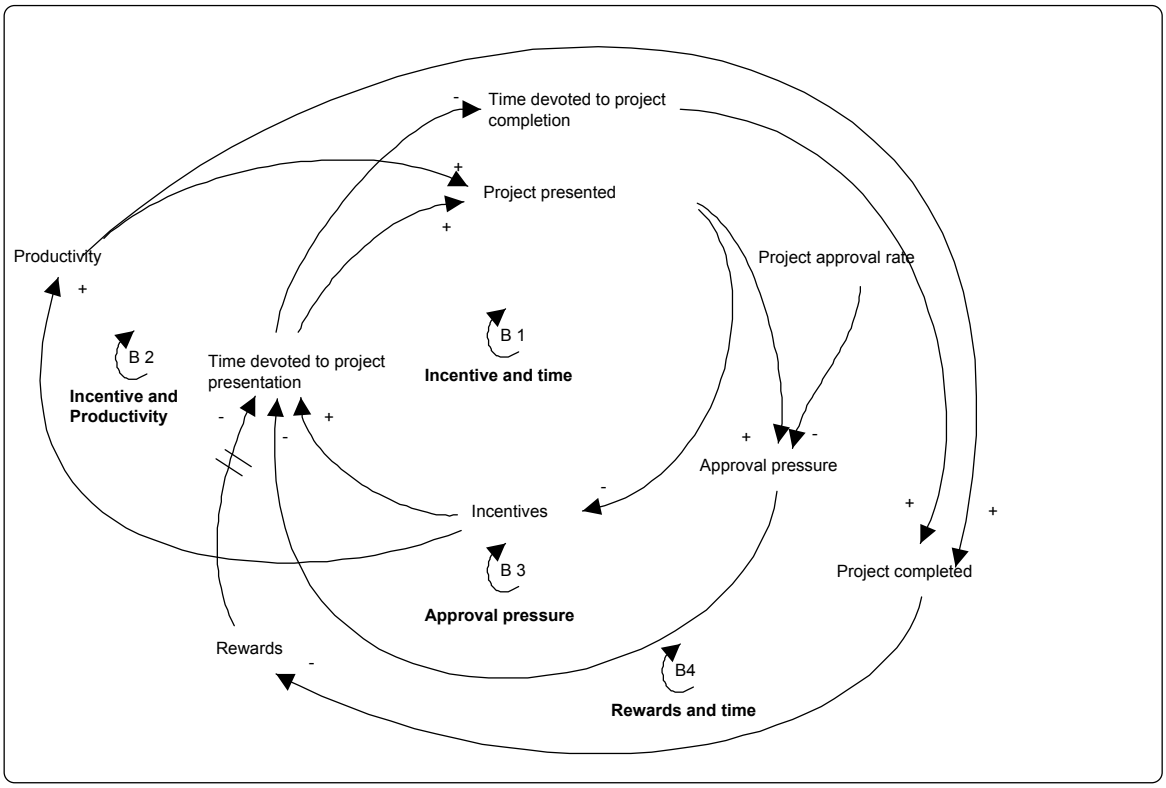
B1 Incentive and time. The more incentives are given to stimulate the project presentation, the more time will be allocated on project presentation activity. The more projects are presented the less incentives are given to stimulate the presentation of projects, because top managers (which govern incentives) are satisfied with the presentation rate.

B2 Incentive and productivity. The more incentives are given for project presentation the more will be engineers productivity in project presentation. This will have a positive influence on the number of projects presented and will stimulate mangers to reduce incentives.

B3 Approval pressure. Top managers work in the Corporation. Every month they devote only a small amount of their time to project examination (they devote the majority of their time to normal tasks). The increasing gap between the project presentation rate (that can vary according to the time dedicated and the productivity of engineers) and the approval rate, forces top managers to intervene on the time schedule of engineers reducing the time for project presentation and increasing the time for project completion. This will reduce the presentation rate and consequently the gap.

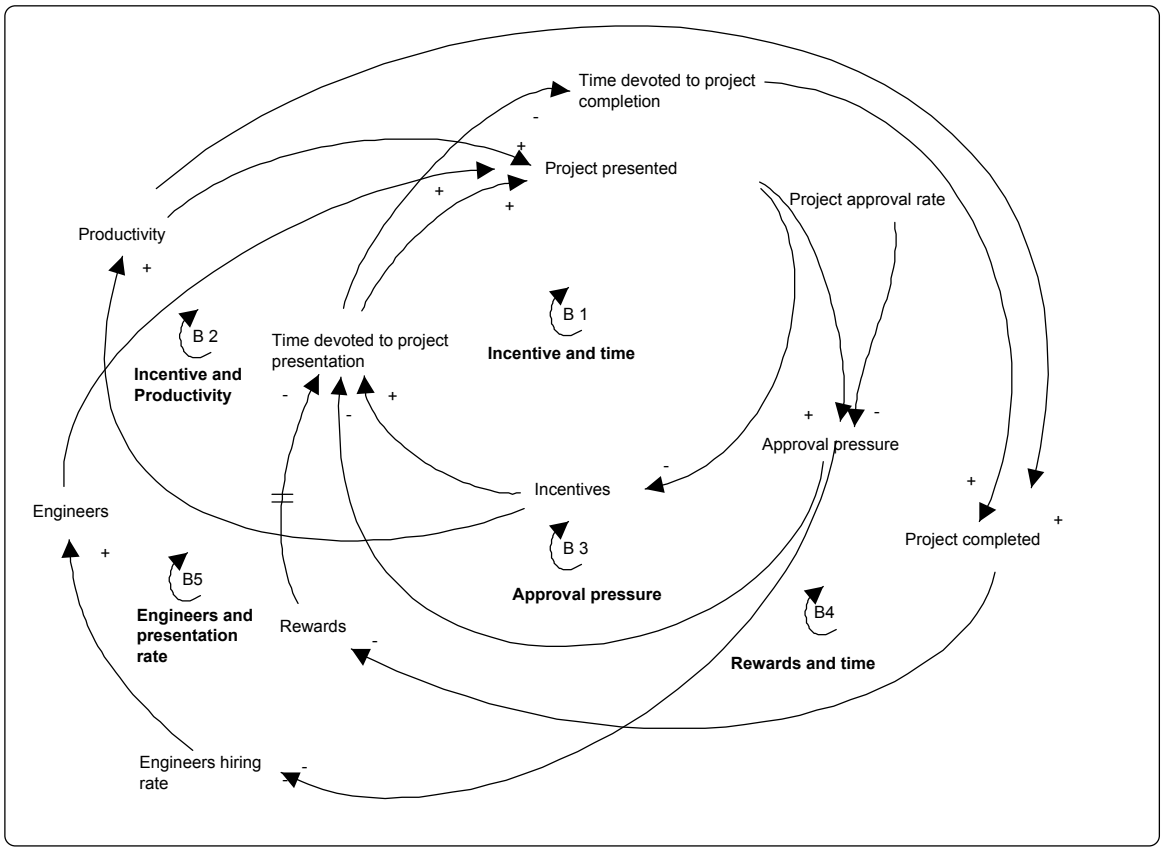
B4 Rewards and time. The introduction of rewards for each project completed reduces the time dedicated by engineers to project presentation and increases the time for projects completion. This will increase the project completion rate and will stimulate top managers to reduce rewards for project completion rate. Engineers have a delay in perceiving rewards because these are paid at the end of the project development process (only when projects are implemented) consequently they will reduce the time devoted to project presentation only when they will perceive rewards.

Figure 3.1 Main feedback loops



The negative feedback, *B5 Engineers and presentation rate,* describes the hiring policy for engineers (Figure 3.2). The increasing of the approval pressure, caused by the gap between the project presentation rate and the project approval rate, will have a negative influence on engineers hiring rate. Top managers will reduce the new engineer hiring rate to reduce dimensions of the ICV unit (assuming the quit rate constant). The reduced number of engineers in the ICV unit will determine a reduction in project presented.

Figure 3.2 Engineers hiring policy

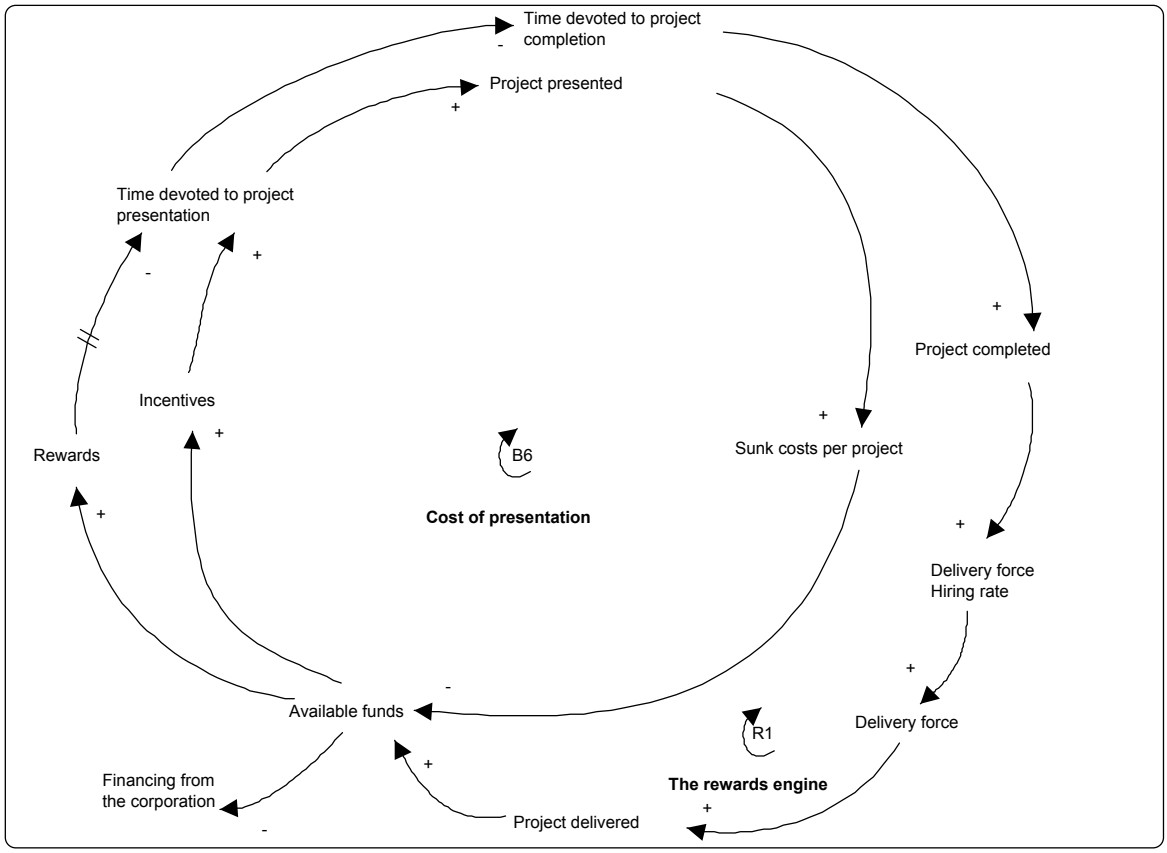


The last two feedback loops are related to economic aspects of the ICV process (Figure 3.3).

B6 Cost of presentation. The presentation of new projects determines expenses related to the R&D activity of engineers. The available funds will decrease stimulating the reduction of incentives which determines a reduction of: time devoted to project presentation, project presented and costs related to project presentation.

R1 The rewards engine positive feedback introduces the role of the delivery force. The increase in project completed will determine an increase in the demand of new delivery force. Projects start to generate revenue only when they are implemented in the Corporation. The increase of delivery force has a positive influence on project delivered and finally on available funds. The availability of funds will stimulate: the increase of rewards, the decrease of time devoted to project presentation and the increase of the time devoted to project completion.

Figure 3.3 Feedbacks describing dynamics of economics



The prevalence on negative feedback in the conceptual model can give some hints on what can be the behaviour of the system. While positive feedbacks generate growth, amplify deviations and reinforce change, the negative loops seeks balance equilibrium and stasis [Sterman, 2000]. Negative feedback loops act to bring the state of the system in line with goal or desired state and during this process they can cause oscillations.

This conceptual model has been translated into formal model based on stock and flow diagrams which is described in the following section.

4. Stock and Flow diagrams

Grounding on the causal loop analysis the model describes the management of the ICV organisational unit. General assumptions are the same made for the causal loop design.
The unavailability in the entrepreneurship literature of recent data on economic aspect of ICV programs was solved adopting conventional values built capitalizing old values.

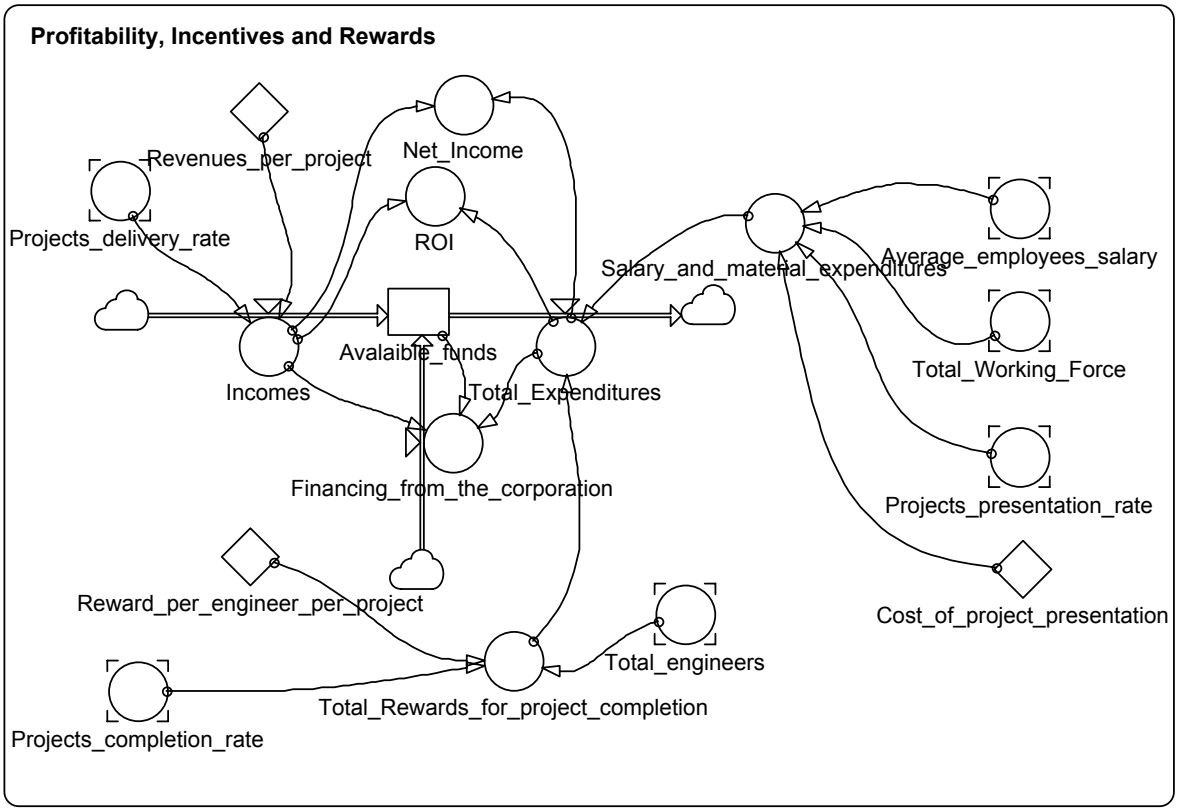
The model is articulated into five parts which describe different aspects of the Internal Corporate Venturing process:

- profitability, incentives and rewards;
- project development;
- employees dynamics;
- salary and incentives for employees;
- productivity of employees.

Profitability, incentives and rewards

The goal of this part is to illustrate the dynamics of main economic aggregates of the ICV division (Figure 4.1).

Figure 4.1 Profitability Incentives and rewards

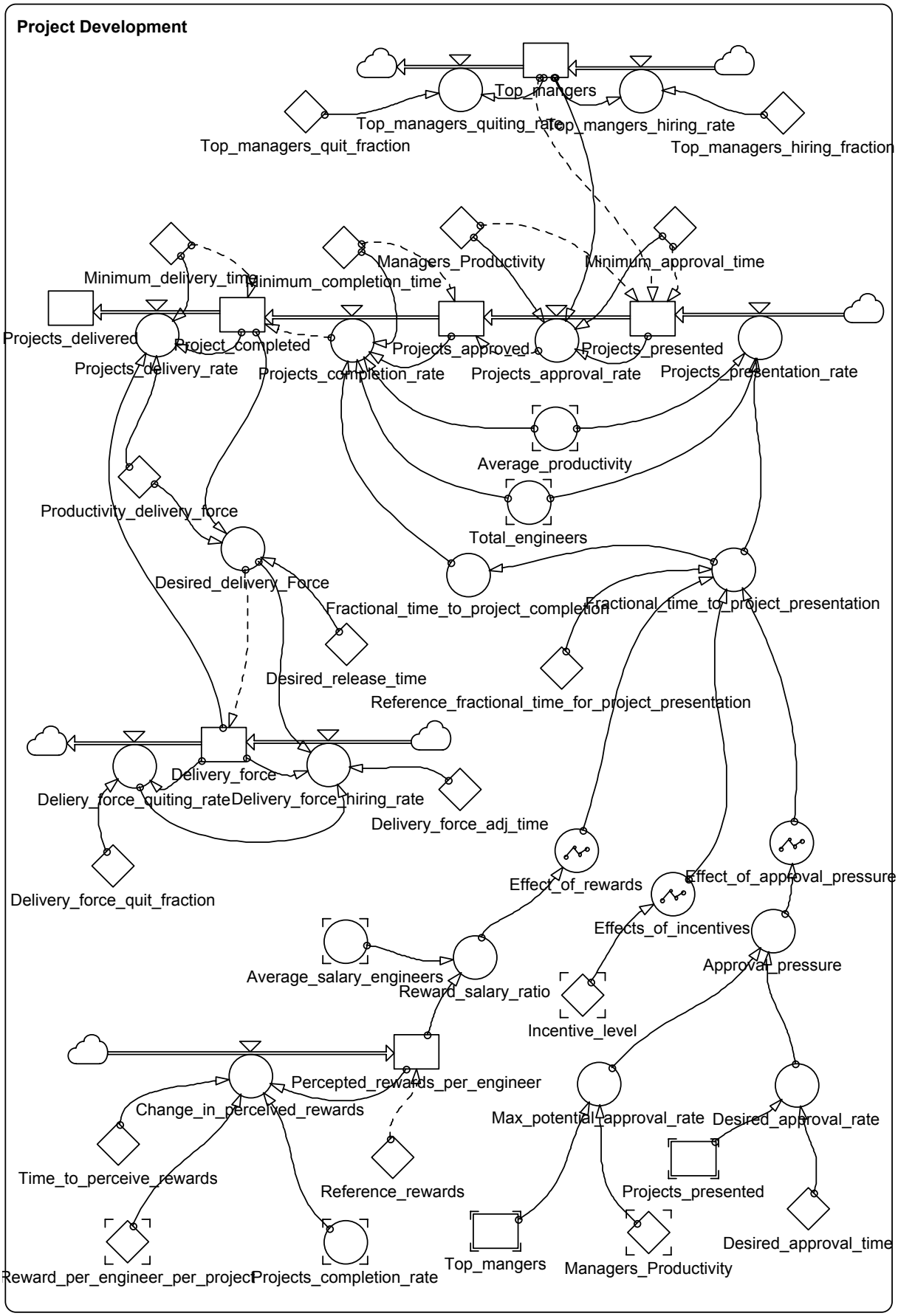


The section of the model is built around the stock *Available Funds.* The stock represents the amount of money destined to the ICV division by the Corporation. The initial amount of funds, for a 10 years ICV program, is of 10 million euros.
Using this amount of money the ICV division finances the development and the implementation of new projects and expenses for the workforce (engineers and

implementation workforce).The stock has two inflows. The first is given by incomes, generated by projects implemented. Once projects are completed in the ICV unit they are implemented in the Corporation which pays an amount of money to the ICV unit.
The second inflow is represented by financing from the corporation which are given only if the available stock falls to 0; this is an emergency financing that enables the ICV division to continue its work in case of financial difficulties.
Total expenditures are determined by the salary of workers and the cost for project presentation. The average salary of workers is calculated as weighted average of the salary for three categories of workers: engineers, working force and delivery force. The cost of project presentation is given by the expenses in R&D sustained by engineers to develop new business ideas. Once the project is approved it has to be completed with more in depth technical analysis and marketing surveys, but it doesn't requires R&D expenses.
The salary includes incentives for project presentation. Incentives are given as a percentage of the salary to stimulate the presentation of new projects; they can vary from 0 to 10% of the salary of engineers.
Rewards are given to each engineer for each project completed, they can range from 0 to 10 euros.
The Return on Investment - *ROI* has been adopted as a conventional measure of profitability of the projects. In the model the ROI has been calculated as the ratio between the net profit generated by the project and the total expenses.

Project Development
This is the core part of the model. There are four main stocks controlled by four rates which represent the flow of projects from the business idea stage to the implementation stage (Figure 4.2). Projects are submitted to top manager by engineers, once approved the projects are completed by engineers and come into the *Project completed* stock. The delivery force implements projects into the Corporation.

Figure 4.2 Project development



The project approval rate has a relative simple structure. The assumption is that the number of top managers is constant. At the beginning of ICV programs the Corporation's CEO choose the team of top managers that have to supervise the ICV program, during the ICV programs some managers can be allocated to new functions and new tasks inside the Corporation, consequently they must leave the ICV committee and are replaced. The participation to ICV Committee is not a full time job, top managers allocate to this activity only a small portion of their working time, generally below the 20% of the monthly working hours, consequently can be assumed that the productivity in projects processing is constant.
The structure of the model was designed to have a stock of project approved which is higher than the other stocks. This is consistent with the literature contribution on ICV processes and internal entrepreneurship [Burgelman, 1983a, 1983b; Bower 1970] for which top managers prefer to have a portfolio of strategic initiatives (as a safety reserve) exceeding the completed projects.

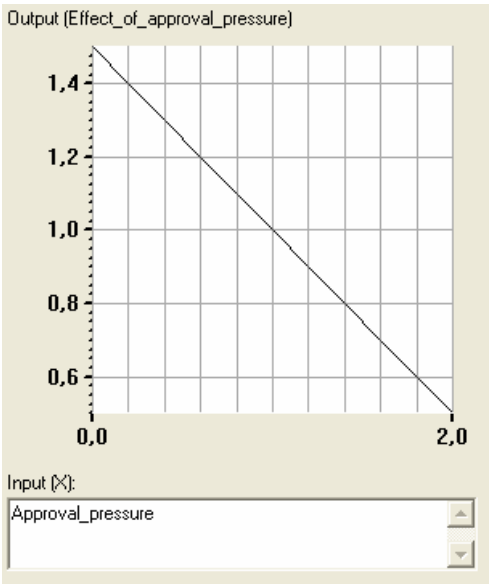
The number of project completed influences the hiring rate of the delivery force. The delivery force is constituted by managers and engineers of Corporation, temporarily allocated into the ICV unit. They do a border line job: they work close with engineers of the ICV unit to implement in the Corporation new projects. During the ICV program they can leave the ICV unit and come back to normal tasks (it's assumed a constant and low monthly quit fraction), in this latter case they are immediately replaced.

The central problem in this part of the model was to determine the time allocation of the engineers between project presentation and project completion. The fraction of time devoted to project presentation determines, as difference, the fraction of time remaining for project completion. The reference fractional time allocated to project presentation is of 50%. The reference time is decided by the top managers which, at the beginning of the ICV program, plan that engineers should have an equal distribution of time between presentation and completion. However is non-realistic to assume that the real fraction of time will be constant during the program, because there are many factors which can influence the behaviour of engineers.
The challenge to determine the fractional time to project presentation was solved introducing the combination of three different effects: *effect of approval pressure, effect of incentives* and *effects of rewards*. The effects represent three different types of pressure which are directed in different directions, to better represent the total pressure deriving from the combination of these forces the effects combine each other through a multiplication.

Effect of approval pressure. This effect was built to represent the behaviour of top managers inside the ICV process and in particular the level of authority they can exercise on engineers. Engineers are responsible for project presentation as well as for project completion. They are free to allocate their time when the approval pressure is equal to 1 (Figure 4.3). The approval pressure is determined by the constant comparison between the *max potential approval rate* (related to the top mangers productivity) and the *desired approval rate* (mainly related to the number of projects presented). When the approval pressure is over 1, means that managers have to process a number of projects exceeding their capacity, consequently they will act to reduce the time that engineers can devote to project presentation. An approval pressure inferior to 1 means that there are few projects presented compared to the top managers processing capacity, consequently top managers will force engineers

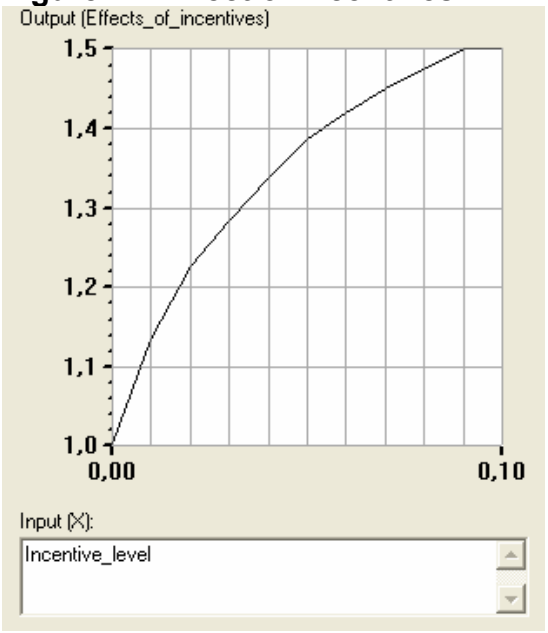
to allocate more time on project presentation. The effect of approval pressure on fractional time to project presentation ranges from -50% to +50%. The managers can only address the behaviour of employees using their authority, but they cannot have the complete control of engineers working time. For instance: as the approval pressure increase two times the effect on fractional time devoted to project presentation will be negative for only 50%.

Figure 4.3 Effect of approval pressure



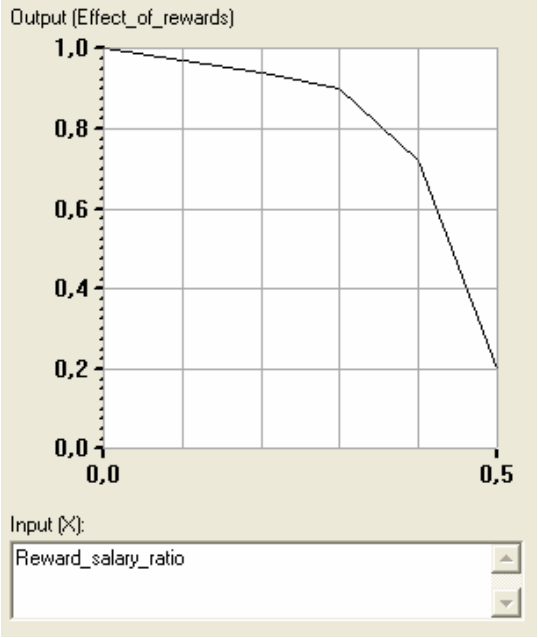
Effect of incentives. Incentive level influences the commitment of engineers in project presentation and stimulates them to spend more time on project presentation (Figure 4.4). Engineers think that the higher will be the project presentation rate the more will be incentives. Incentives can vary from 0 to 10% of the ordinary salary of engineers; when incentives are at 10% the increase of time devoted to project presentation is of 50%.

Figure 4.4 Effect of incentives



Effect of rewards. The introduction of rewards for each project completed to each engineer is a powerful way to influence the time allocation. Engineers will be stimulated by the possibility to obtain rewards for project completed. Consequently they will dedicate less time to project presentation to focus on project completion. The perception of incentives is not immediate. Because incentives are given only at the end of project development process, is realistic to assume the existence of a delay in rewards perception. Engineers will start to switch their time only when they will perceive that the work on project completion is well recognised by top managers, through incentives. The perception of incentives is not absolute: engineers perceive incentives comparing them to their salary through the *Rewards salary ratio.* The increasing of this ratio will determine a negative effect on the time allocated to project presentation which can reach the maximum level of 50% (Figure 4.5).

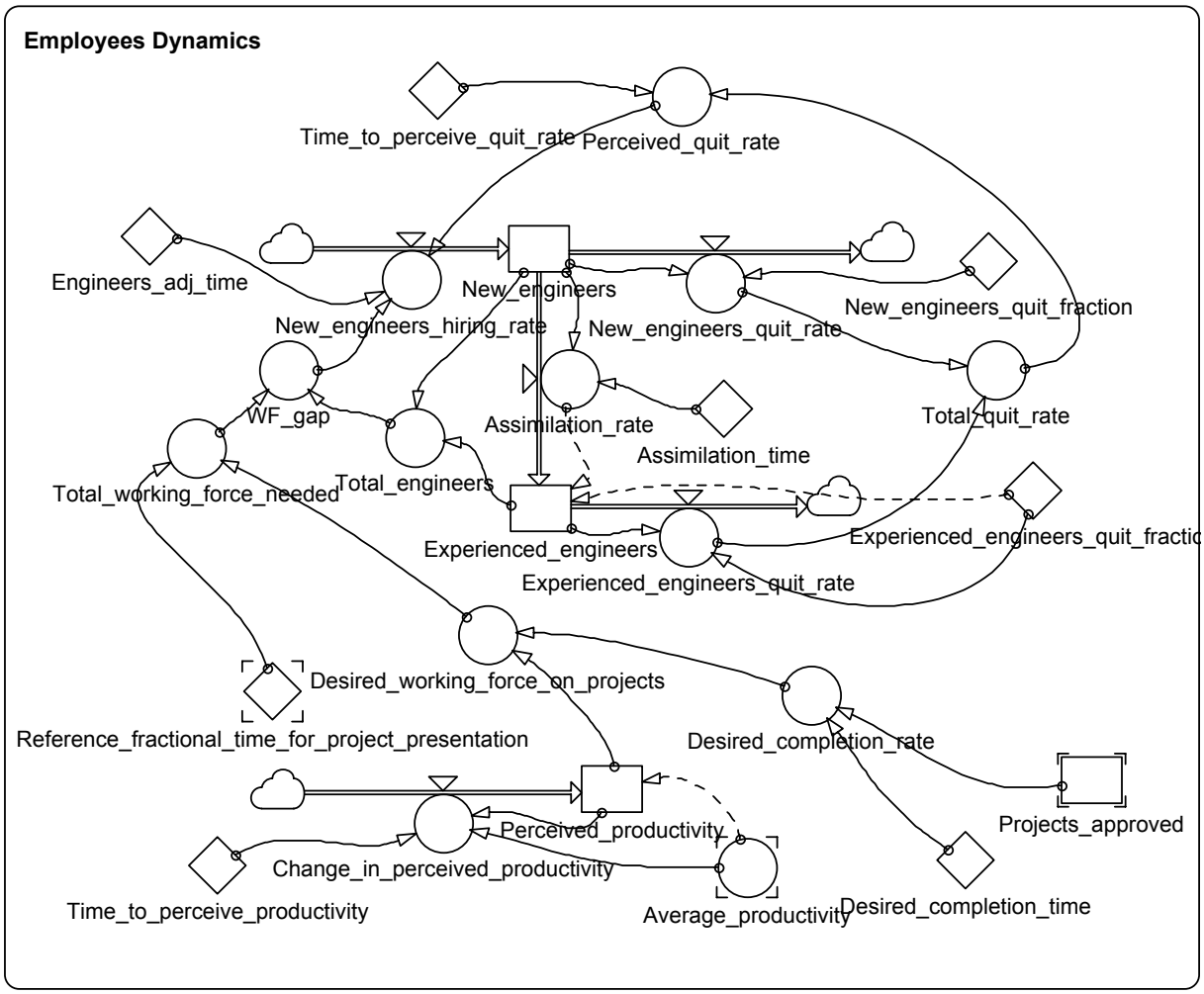
Figure 4.5 Effect of rewards



Employees Dynamics

This part of the model represents the dynamics of engineers. The structure adopted (Sterman 2000) for the stock and flow diagram is built around two stocks: *New engineers* and the *Experienced engineers* (Figure 4.6).

Figure 4.6 Employees dynamics



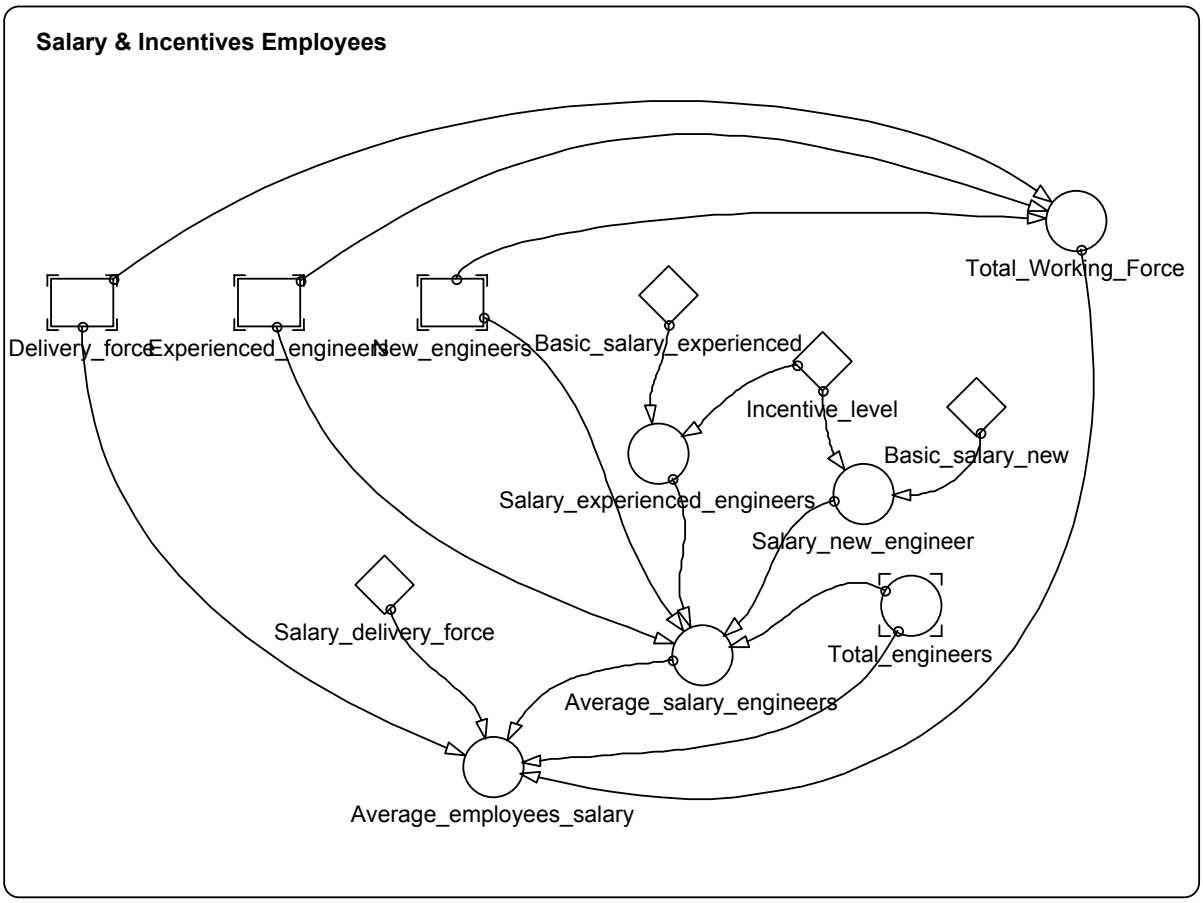
The ICV division is an organizational unit devoted to innovation; the Corporation doesn't hire experienced engineers, but it focuses on new high-talented engineers that can brig fresh ideas. Recruitment is conducted among engineers already employed in the Corporation as well as on external job market. New engineers became experienced in two years (assimilation time). The quit rate is supposed extremely low and it express the number of engineers that leave the ICV unit, they can remain in the Corporation with other tasks or can leave the Corporation. The quit rate is not influenced by top managers; they don't reduce voluntary the number of engineers because this can affect the competences accumulated in the ICV team.

The hiring policy is governed by the *Total working force needed* which is constantly compared to the total engineers available. If the working force needed is less than totals engineers, it influences the hiring rate. The total working force needed is determined by the fractional time for project presentation and the desired working force on projects. This last is determined by top managers that from one side have a perception of engineers' productivity and on the other side have a desired completion rate determined by the number of project approved.

Salary and incentives Employees

The diagram illustrates the calculation of the cost of the total workforce (Figure 4.7). The salary for experienced engineer, according to what normally happens in the labour market, is higher than the salary for young. The incentive level, which is calculated as a percentage of the basic salary, is the same for experienced and new engineers. The delivery force employees have no incentives because they don't have to generate new ideas and complete new projects, but they have only to implement projects already made; besides is possible to hire new delivery force instead of give them incentives to boost productivity.

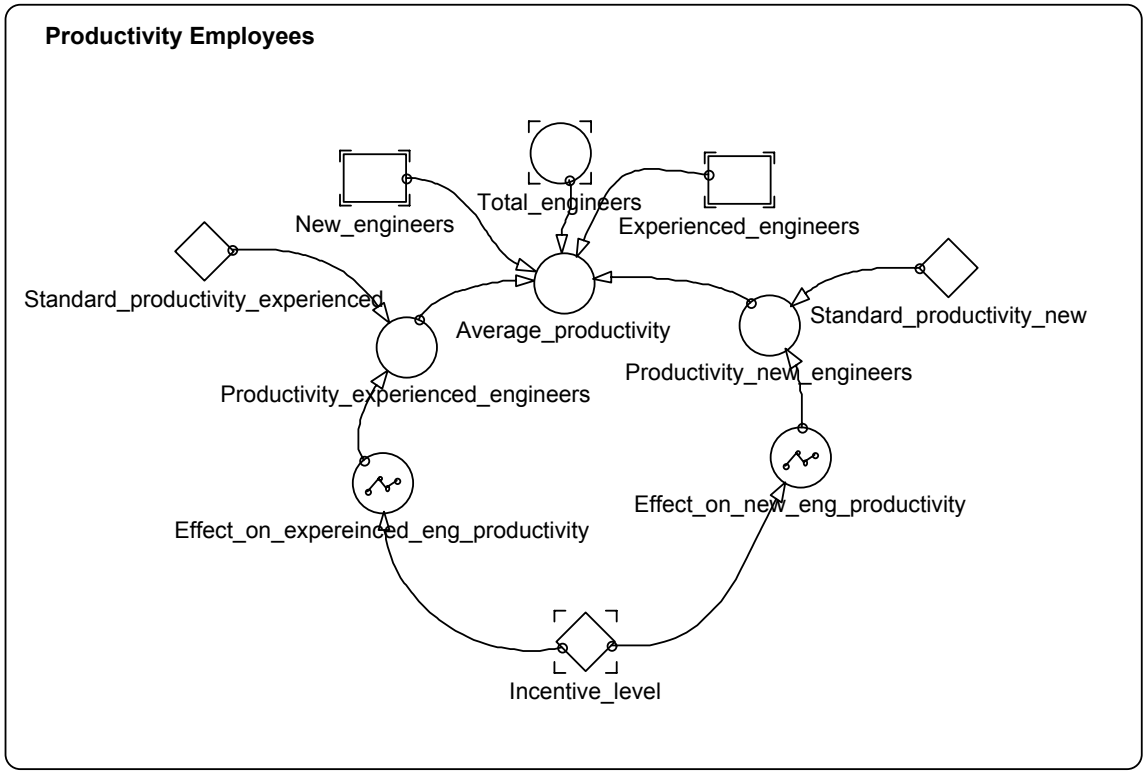
Figure 4.7 Salary and incentives



Productivity Employees

The diagram depicts the productivity of new and experienced engineers (Figure 4.8). The productivity influences the project presentation rate and the project completion rate (according the time devoted to the two activities). The productivity of new engineers is supposed to be inferior to the productivity of experienced ones.

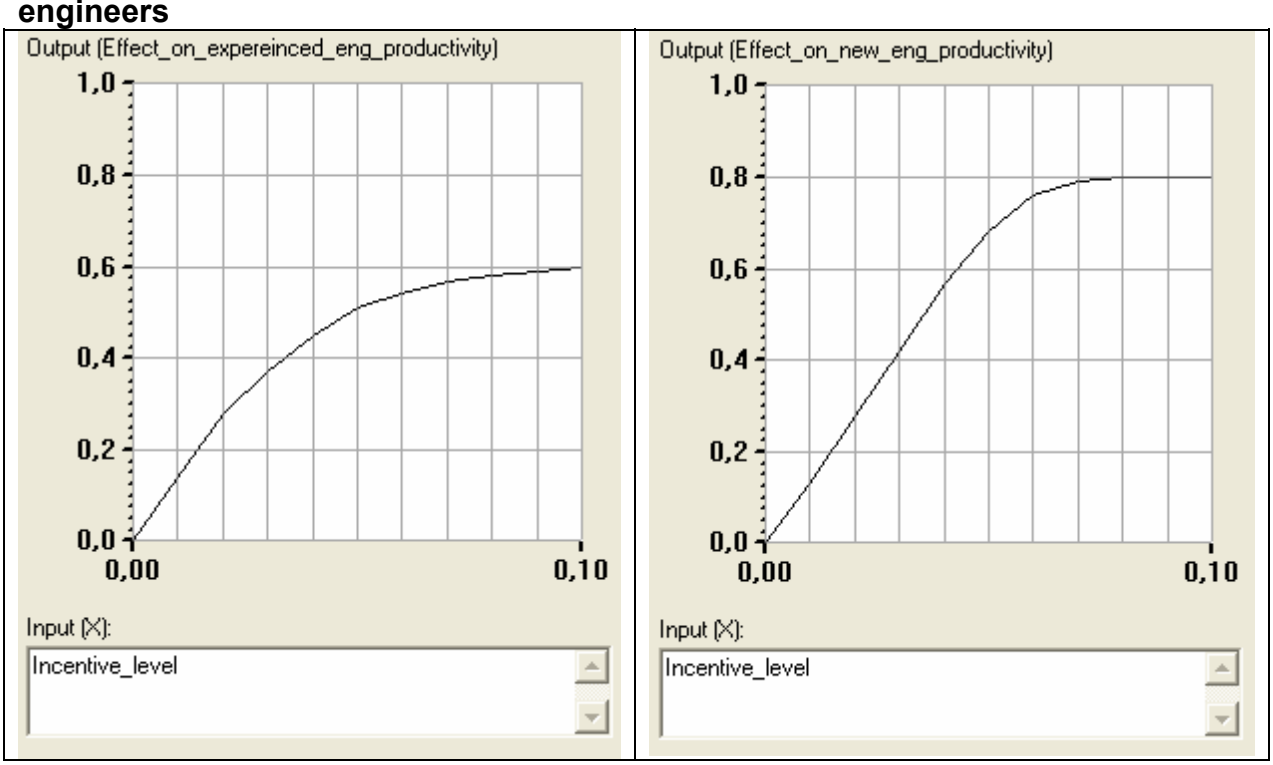
Figure 4.8 Productivity employees



The productivity of engineers can be influenced by the introduction of incentives, however, according to empirical evidence [Hanan, 1976] , effects for the increasing of incentives' level will be different for new and for experienced engineers.

The non linear relations shows that the maximum increase in experienced engineer productivity reach 60% with an incentive level of 10%, after this is not possible to achieve better results (Figure 4.9). Young engineers are more sensible to the increasing of incentives. An incentive level of 8% increases their productivity of the 80%, however, also increasing more the incentive level, is not possible to obtain further improvements.

Figure 4.9 Effect of incentives on productivity of new and experienced engineers



5. Validation

Despite the theoretical nature of the paper, the translation into System Dynamics language of concepts and hypothesis from the literature requires a process of validation of the model, mainly devoted to asses the internal validity of its structure.

In System Dynamics validity is seen as the adequacy of model structure in representing the selected aspects of the reality with respect to its purpose [Barlas, 1989, 1990]. The validity is a concept which relates the model structure with the reality. There are two main type of models: causal and correlational. Causal models are named also descriptive model where are causal statements on how the real systems actually operate. In this case what is essential is the internal validity of the structure creating the behaviour. Correlational models, called also “black box” models, don’t have any claim of causality in their structure. These models are considered to be valid if model output matches real data.
Our model is a causal descriptive model built on theoretical contributions, in this case the validation process must develop through tests for assessing the structural (internal) structural validity of the model (internal validation) like the structure oriented behaviour tests. They asses the validity of the structure indirectly, by applying certain behaviour testes on the model generated behaviour patterns.
Two types of structural validation tests have been performed:

- *extreme conditions tests* to show the behaviour of the model under extreme conditions of main variables;
- *behaviour sensitivity tests* to determine those parameters to which the model is highly sensitive.

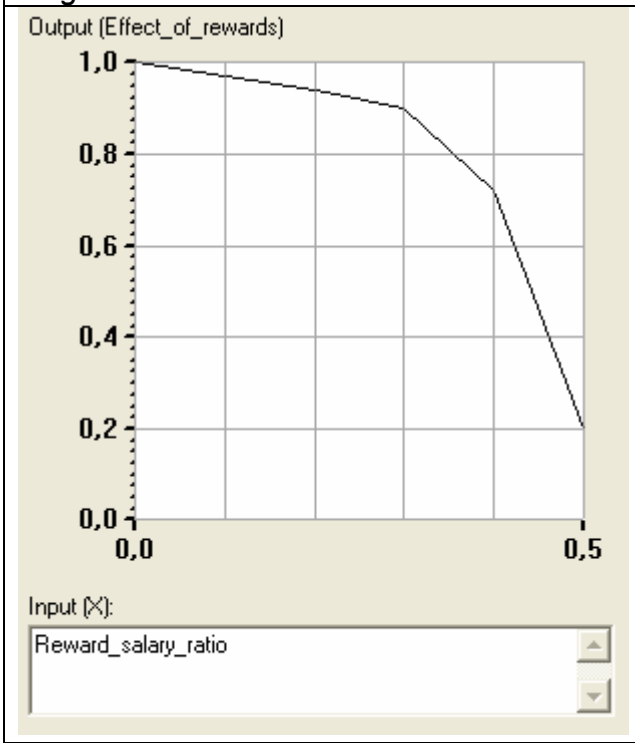
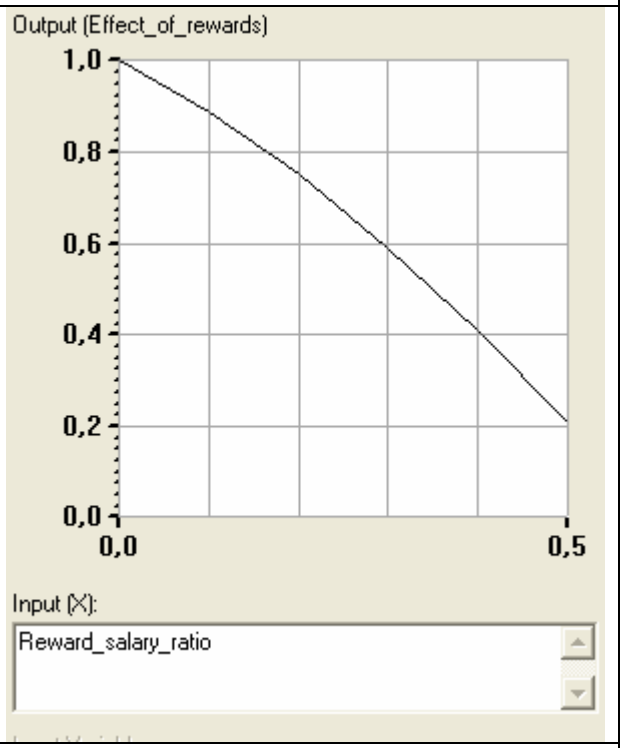
The first extreme condition test was performed assuming that the reference fractional time for project presentation was 0% of the total time of engineers. This means that engineers are completely focused on project completion and they don't work on project presentation. The expected result is that the project presentation rate will be 0. Simulations confirmed expected values. No project is presented and no project is processed. The introduction of incentives and rewards doesn't affect the behaviour of the system because engineers don't take into consideration to allocate any time on project presentation.

Others extreme tests were conducted assuming extreme values for the workforce involved in different stages of the ICV programs: engineers, top managers and delivery force
The second extreme condition test was performed assuming that there are no engineers. The expected result was that no project is presented. Simulation shows that no project was presented.
The third extreme condition test is performed assuming the absence of top managers. The expected result is that project presented are not approved and so they cannot be completed and delivered. Simulation confirmed expected results.
The fourth extreme conditions test was performed assuming the absence of delivery force. The response of this test was as expected: no project was delivered.

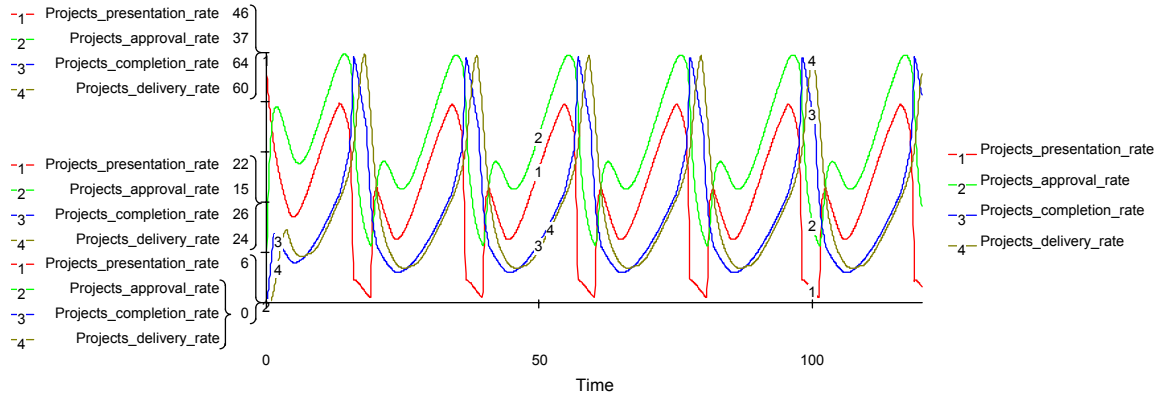
The sensitivity analysis was focused on the three effects which influence the fractional time to project presentation.
In the *effect of rewards* graph the shape of the curve, which relates the rewards/salary ratio and the fractional time devoted to project presentation, was modified to have a reduced effect of rewards on time allocation: engineers will be less sensible to rewards in switching their times from project presentation to project completion (Figure 5.1). The simulation was run introducing the highest level of rewards. It' possible to observe oscillations in the original version of the model. After the modification of the curve's shape, oscillations disappeared. This means that the model his high sensitive to the effect of rewards.

Similar modifications on the curves shape of *effects of incentives* and of *effect of approval pressure* were made, without observing macroscopic changes in the behaviour of the system as in the case of *effect of rewards*.

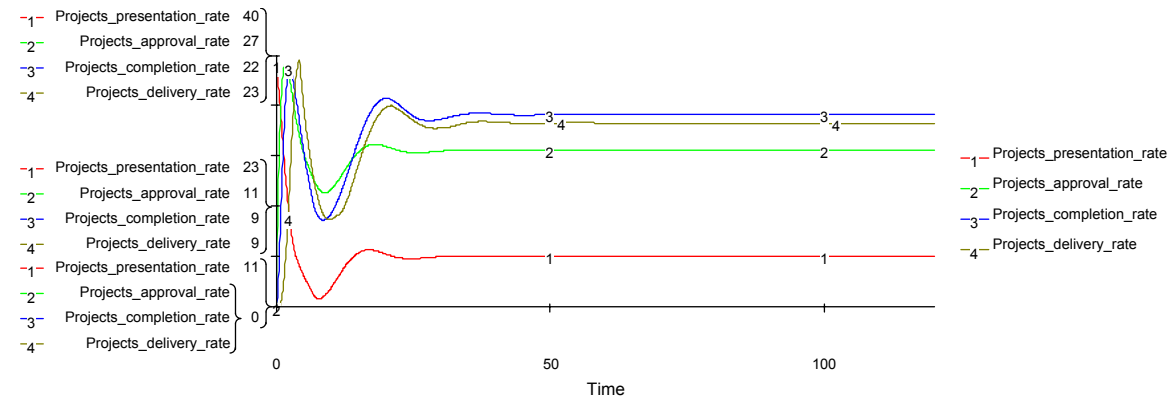
Figure 5.1 Sensitivity analysis on *Effect of rewards*

Original version	Modified version
	

Original version



Modified version



6. Model Simulation

Four simulations were run to analyse the behaviour of the model in the basic version and after the introduction of three different policies for incentives and rewards.

Base run

Incentive level: 0, rewards: 0

In this simulation there are no incentives for project presentation and no rewards for project completion. The goal is to show how the system behaves without policies to stimulate projects presentation.

The economics dynamic shows a linear increase of funds available determined by the constant difference between *Incomes* and *Total expenditures*.

ROI, the measurement of the profitability of the ICV program, is negative at the very beginning of the programs because there are more projects presented and no projects approved and delivered.

Equilibrium is reached after circa 30 months, the ROI stabilizes at 1 which means a 100% of return of investment. Oscillations can be explained by the initial discrepancy between the presentation rate, the approval rate and the completion rate that is reduced thanks to the action of the *approval pressure* on the time devoted to project presentation and project completion.

Figure 6.1 Available fund. Funds stay constant for 15 months then they increase linearly.

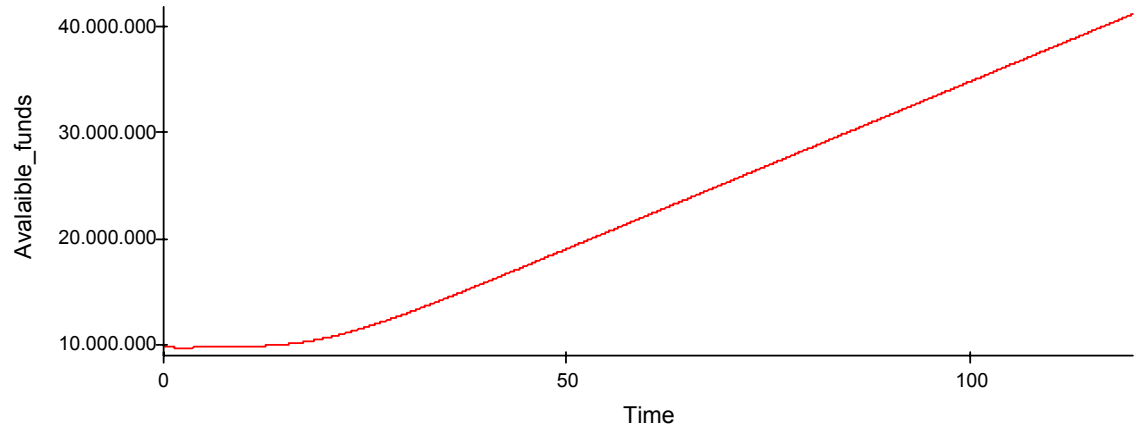


Figure 6.2 ROI. The Return of Investment is negative for a short period of time. The negative pick is related to an increase of projects presented not balanced by an increase of projects approved and delivered.

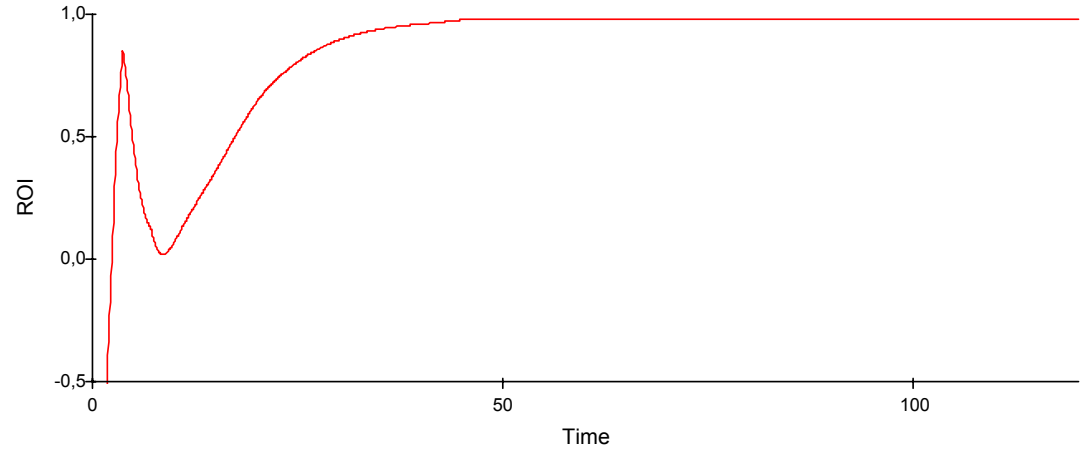


Figure 6.3 Average productivity. The decrease of average productivity is related to the increase of the number of engineers planned by top managers to increase the project presentation rate.

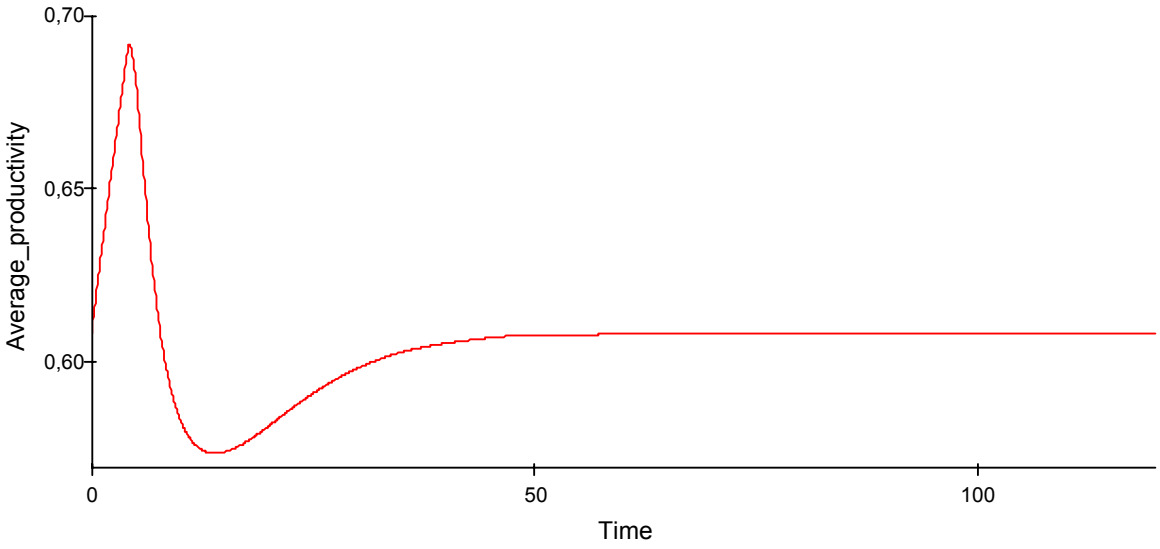


Figure 6.4 Time allocation and approval pressure. While the approval pressure approaches the value 1 the fractional time to project presentation and the fractional time to projects completion converge.

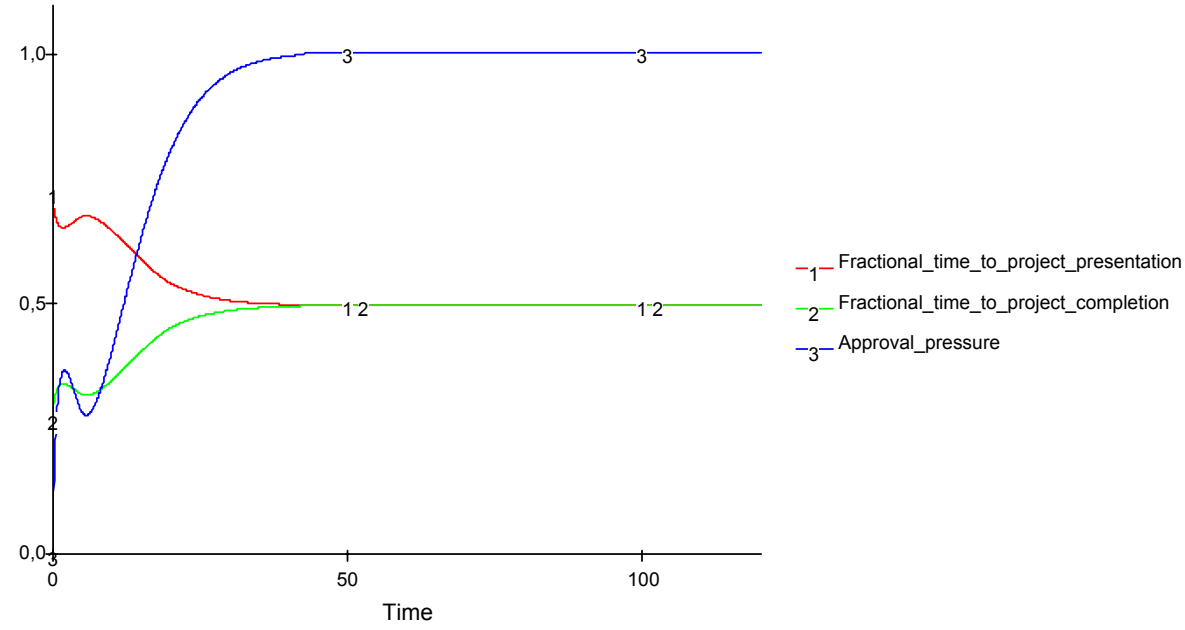


Figure 6.5 Project developments stocks. The number of project delivered reaches 8.300 without incentives and rewards.

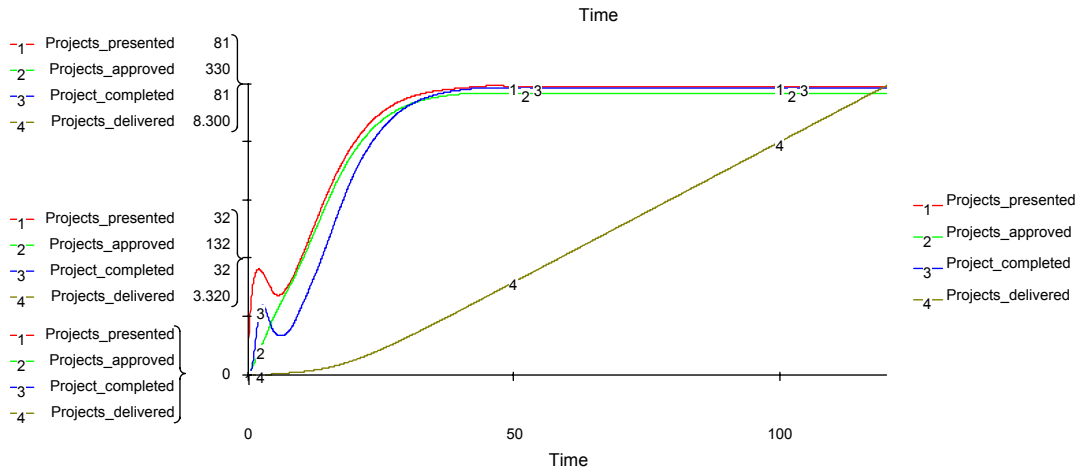
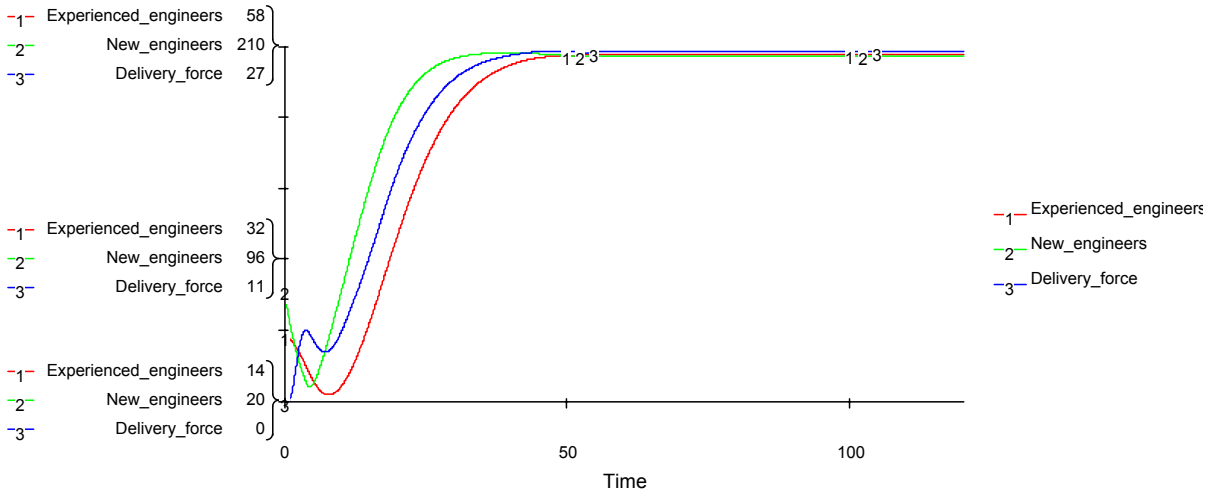


Figure 6.6 Employees dynamics. The dynamic of employees before the stabilization is characterised by a peck of the delivery force determined by the increase of the project presented at the beginning.



Policy 1 – Incentives for project presentation
Incentive level: 0.10 (10% of salary for new and experienced engineers); rewards: 0
The first policy is the introduction of incentives to engineers for project presentation. The simulation shows a substantial increase in ROI. The number of project delivered is the 5% more than the basic model. The most impressive result is the increasing of engineers' productivity of the 80% compared to the previous simulation. The system presents more oscillations (compared to the previous simulation) before reaching the stationary state, this is related to oscillations in the approval pressure.

Figure 6.7 ROI. It's possible to observe a relevant improvement of ROI compared to the previous run.

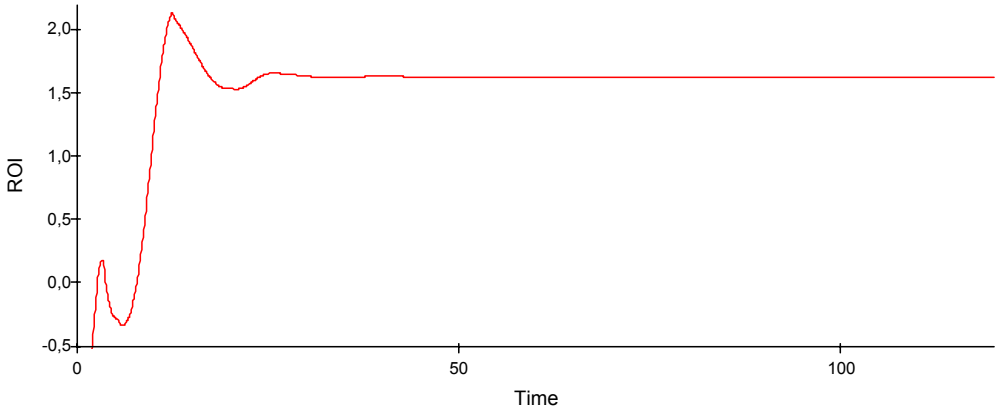


Figure 6.8 Average productivity. Despite more oscillations the average productivity, boosted by incentives, stabilizes at an higher value compared to the previous simulation.

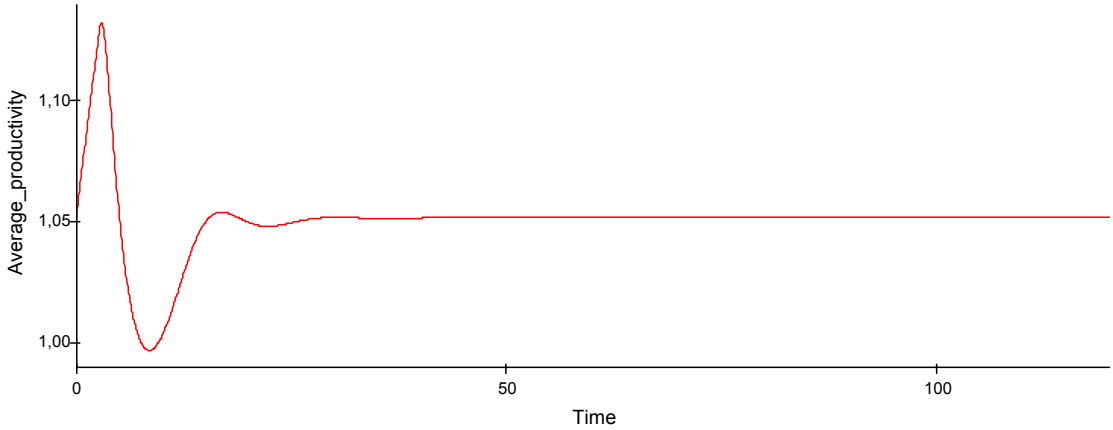


Figure 6.9 Time allocation and approval pressure. Engineers, stimulated by incentives, initially focus on project presentation, the increase of the approval pressure balances (and brings in equilibrium) the time allocation.

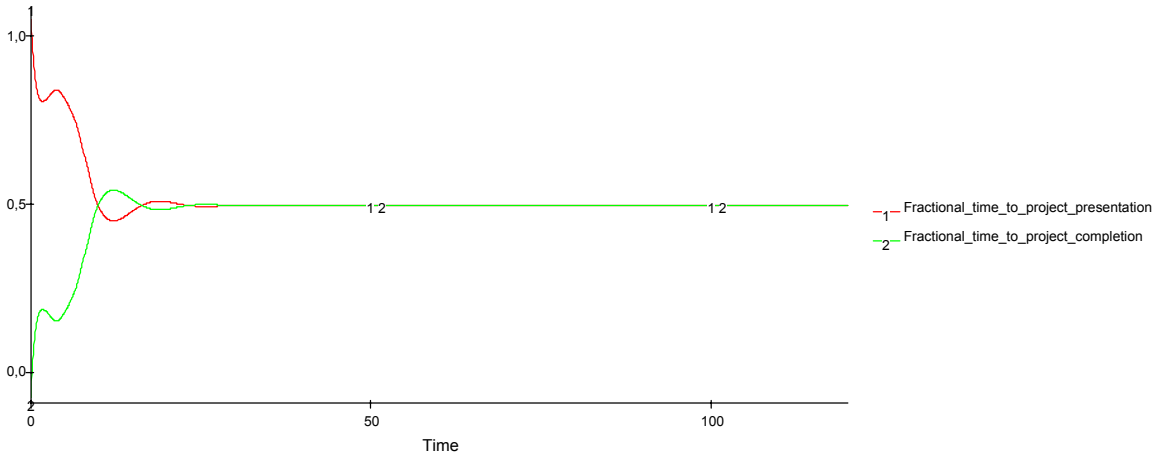


Figure 6.10 Project developments stocks. The total number of projects delivered increases (9,100) compared to the previous simulation.

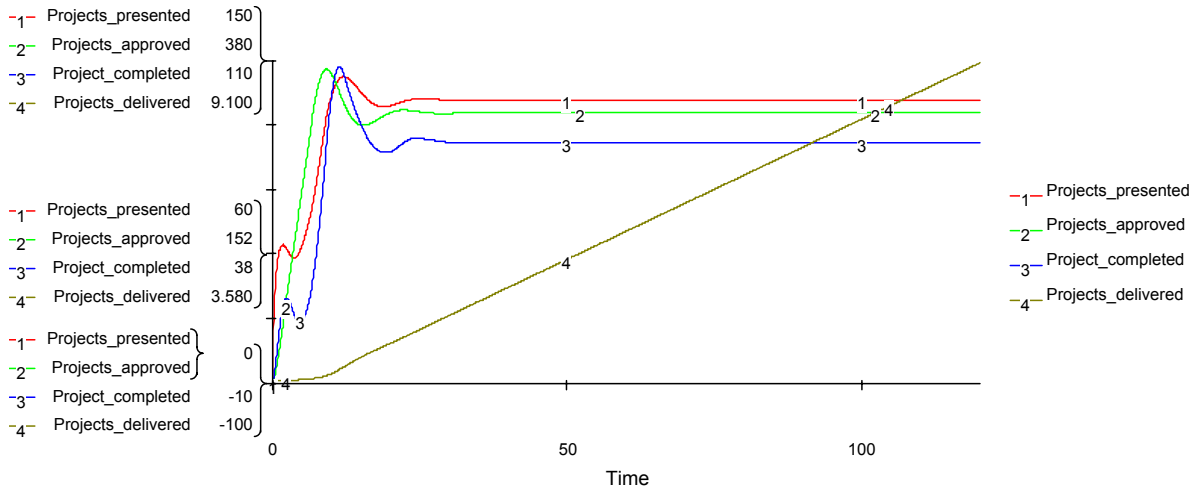
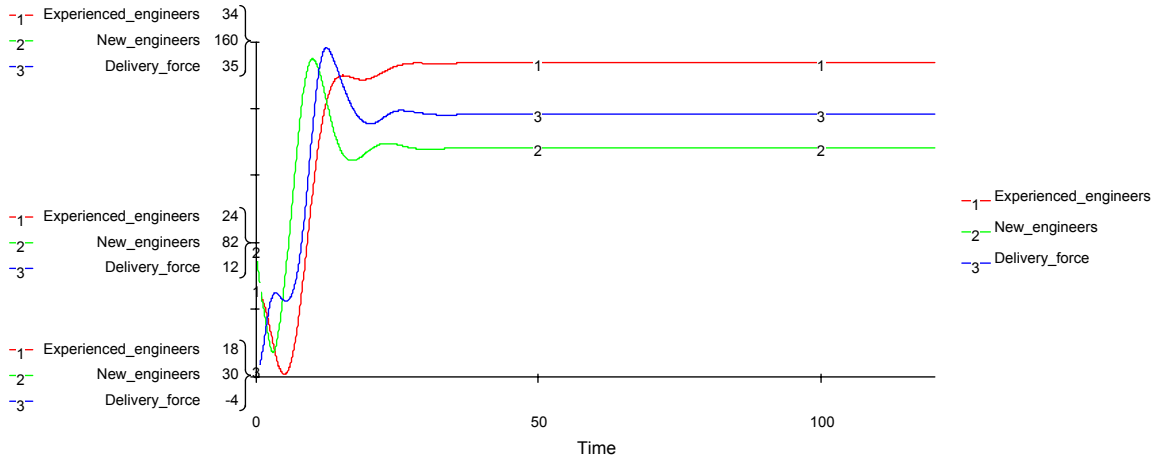


Figure 6.11 Employees dynamics. Due to the increase of productivity and the increase of project presented, top managers will suspend the hiring of new engineer after circa 20 months. The effect is the reduction of new engineers.



Policy 2 – Rewards for project completion

Incentive level: 0; rewards: 10 euros per project per engineer

The introduction of rewards, keeping the level of incentives at 0, causes oscillations. The profitability (measured by ROI) of the ICV unit is oscillating from 0 to 2.5 (for a brief period is below 0). The number of project delivered falls dramatically. The oscillations are generated by the combined effect of rewards and of approval pressure. From one side rewards will push engineers to focus on project completion; on the other side the increase of approval pressure will determine the intervention of top managers that will force engineers to allocate the major part of their time to project presentation.

Figure 6.12 ROI. Despite oscillations, ROI reach periodically a higher value (2.5) compared with the previous simulation.

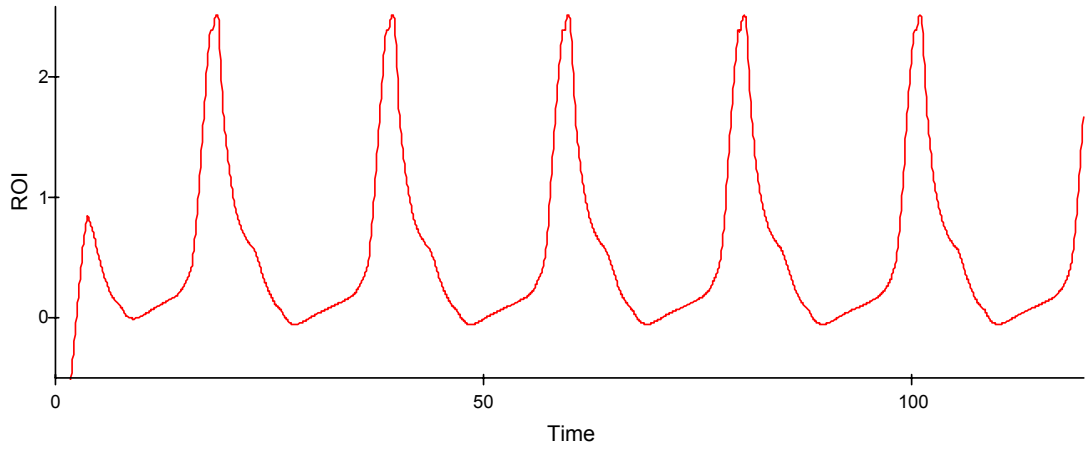


Figure 6.13 Average productivity. The average productivity oscillates because of oscillations of the number of engineers.

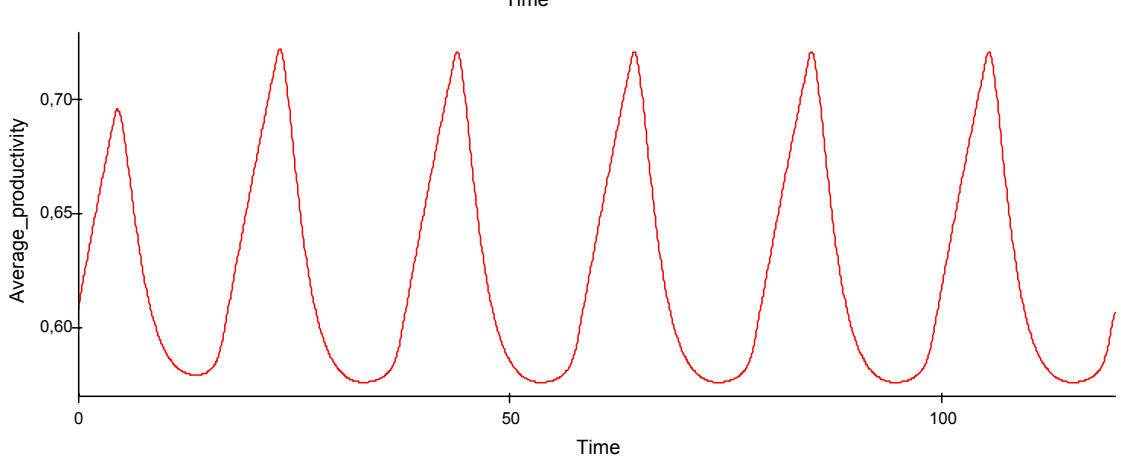


Figure 6.14 Time allocation and approval pressure. Engineers are pushed by two forces: rewards stimulate them to work on the project completion, and contemporarily they are forced by top managers (through the approval pressure) to allocate their time on project presentation.

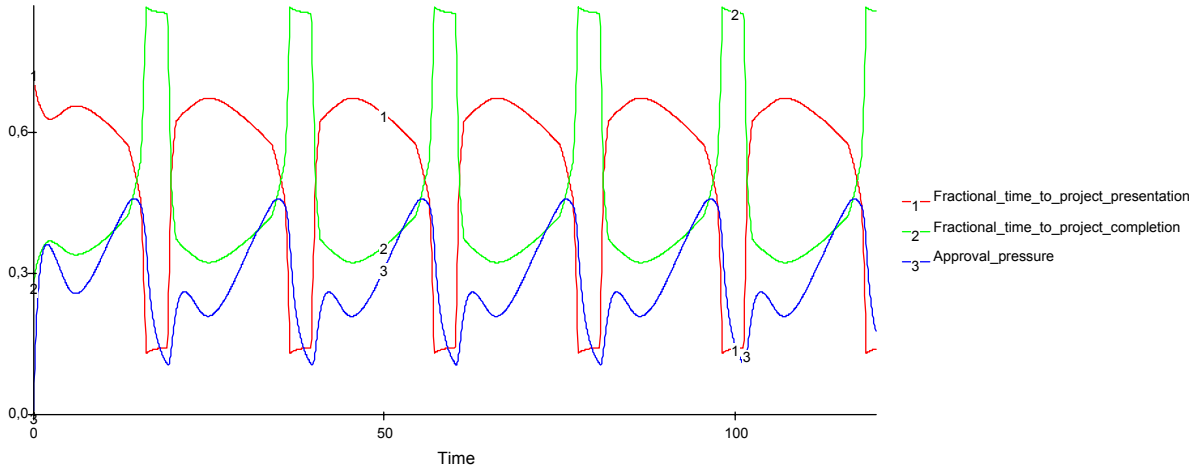


Figure 6.15 Reward/salary ratio. The oscillations of project completion rate causes cyclical reduction and increase of rewards which engineers perceive for projects completed. This causes oscillations in the rewards/salary ratio.

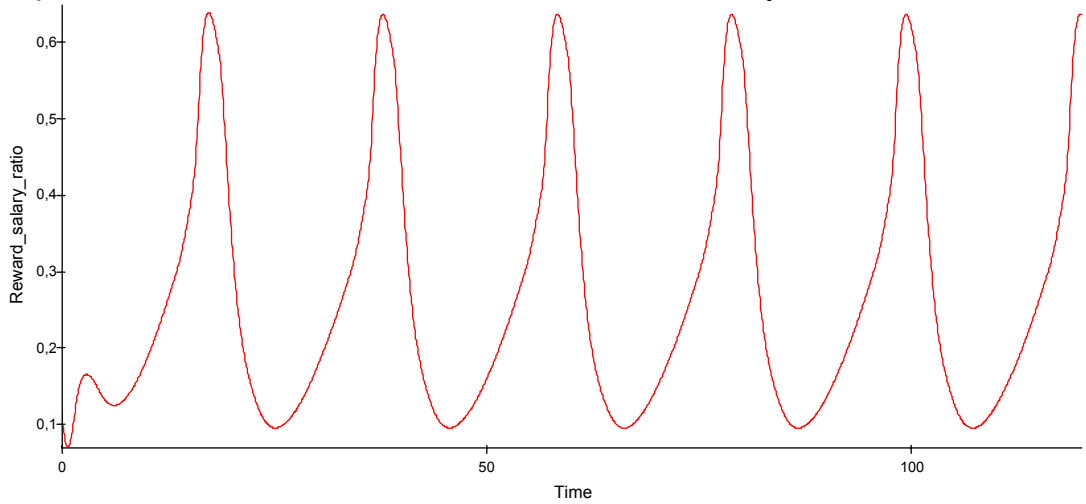
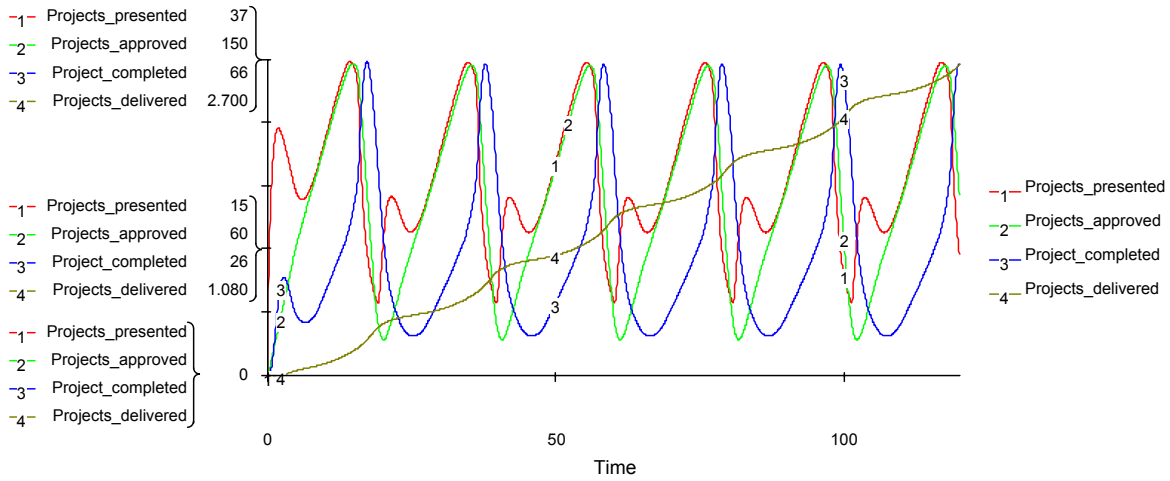


Figure 6.16 Project development stocks. The possibility to adjust quickly the delivery force smoothes the amplitude of oscillation for the project delivered.



Policy 3 – Incentives and Rewards

Incentive level: 0.05 (5% of salary for new and experienced engineers); rewards: 10 euros per project per engineer

With the level of reward at 10, top managers introduce incentives to reduce the time which engineers devote to project completion. This will cause amplification of oscillations compared to the Policy 2, however the number of the project delivered increases and also available funds increases.

Figure 6.17 ROI. Amplified oscillation compared to the Policy 2

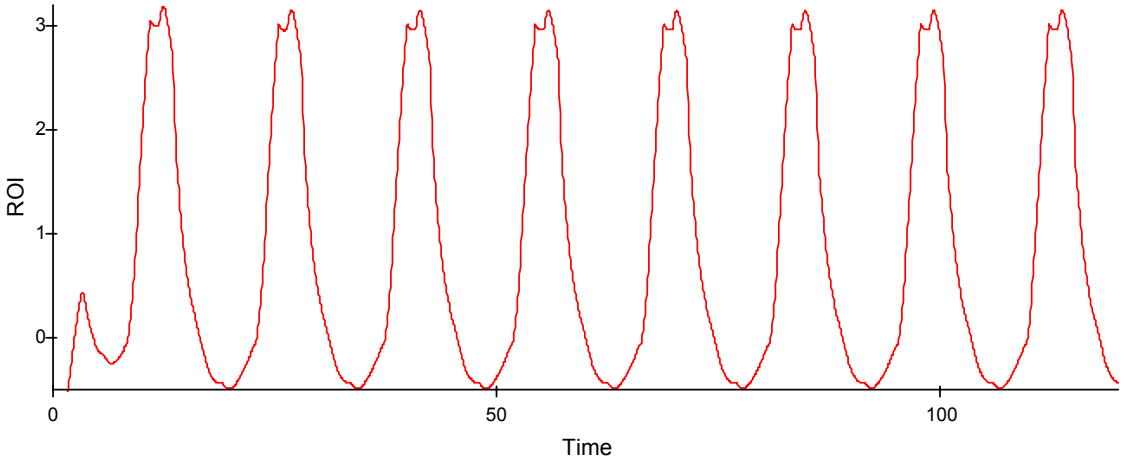


Figure 6.18 Time allocation. The combined effect of approval pressure, rewards and incentives, causes dramatic oscillation in time allocation.

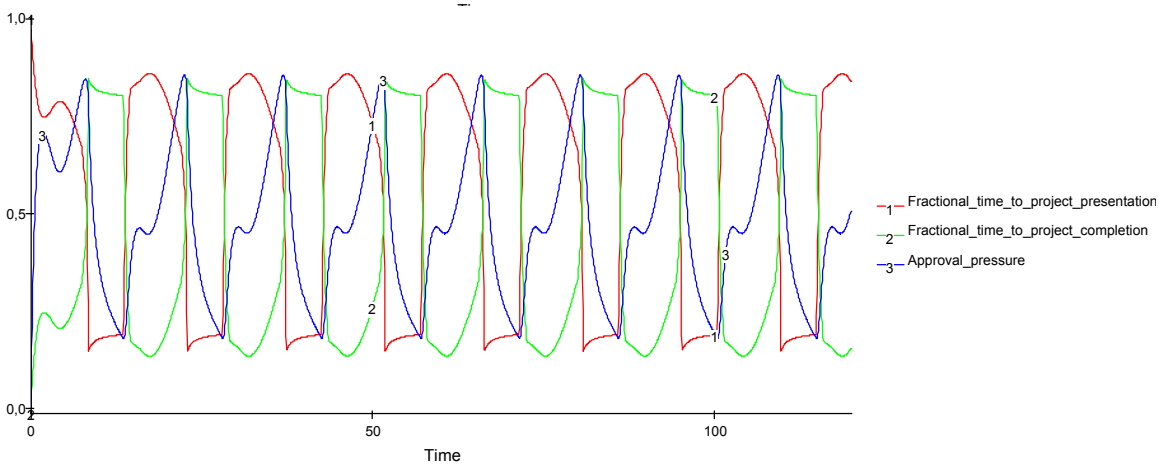
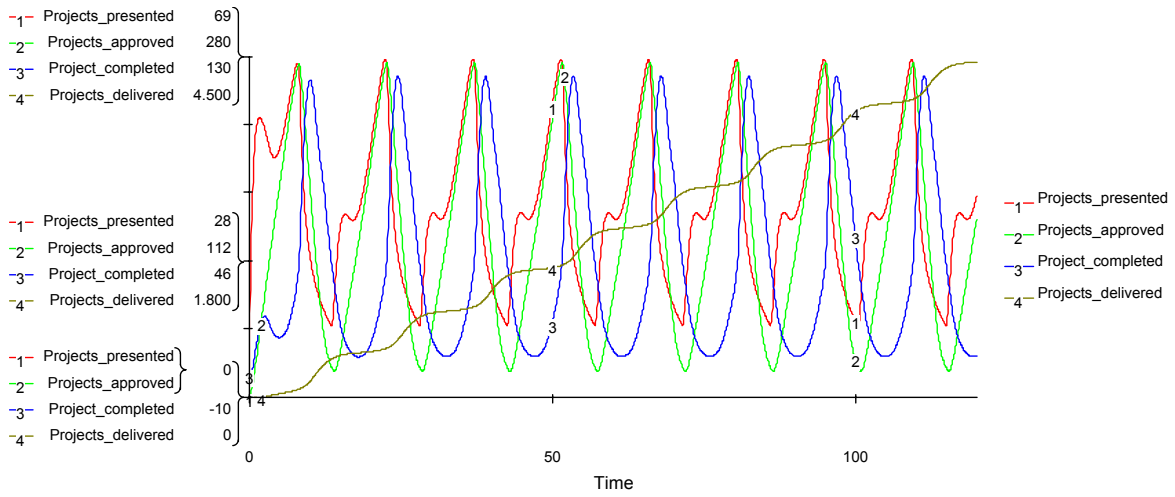


Figure 6.19 Project development stocks. Despite the amplification of oscillations the number of final project delivered increases compared to the Policy 2. This is determined by the effects of incentives on the productivity of engineers and the effect of rewards on the time allocated to project completion.


1 Projects_presented 69
2 Projects_approved 280
3 Project_completed 130
4 Projects_delivered 4.500
1 Projects_presented 28
2 Projects_approved 112
3 Project_completed 46
4 Projects_delivered 1.800
1 Projects_presented 0
2 Projects_approved
3 Project_completed -10
4 Projects_delivered 0
0
50
100
Time
1 Projects_presented
2 Projects_approved
3 Project_completed
4 Projects_delivered

7. Discussion and conclusions

The research findings presented in this paper shed more light on the role played by rewards and incentives, tangible elements of the organization context in internal corporate venturing processes.

Simulations results show that two of the policies, commonly implemented in ICV programs affect seriously the effectiveness of the innovation process.
The introduction of rewards causes oscillation in the project presentation rate. This jeopardises the possibility to generate a stable flow of innovation introducing new projects and services (developed in the ICV program) in the normal activity of corporation. Rewards affect the economic equilibrium lowering the level of available funds.
The discontinuity in the project presentation rate and poor economic performances persist also after the introduction of a combination of rewards and incentives.

The analysis shows that the first best policy to maximize the number of projects implemented is the introduction of incentives. This policy not only influences the effectiveness of the ICV program (the number of project delivered) but also the efficiency: the amount of available funds and the ROI are higher than in the other cases.
The introduction of a combination of rewards and incentives could be considered as a second best. On one side there is an amplification of oscillations which can be considered as a negative aspect because doesn't assure a constant flow of innovation to the Corporation. On the other side, because the effectiveness was defined as the number of project completed within the ICV program, the combination of rewards and incentives improves the total number of project completed with respect to the introduction of rewards.

The model results are consistent with scholars which consider the introduction of incentives as the most powerful way to improve the effectiveness of ICV programs [von Hippel, 1977; Fast 1979; Hanan, 1976].
The same scholars have pointed out how corporations are generally reluctant to introduce incentives, because top managers cannot see the immediate link between money expenditures and results. And also when they introduced incentives they didn't obtain expected results.
The simulation revealed that the introduction of incentives "tout court" doesn't improve the efficacy and the efficiency of the ICV programs if managers don't act constantly to equilibrate the engineers' time allocation. In the model the managerial action is represented by the *approval pressure*, that equilibrate the time that engineers devote to project presentation under the pressure of incentives. The effectiveness of ICV programs depends largely from the structural context in which new strategic initiatives grow and in particular by the administration mechanism that enables top managers to conduct a fine tuning work on the behaviour of the engineers-innovators.

The model has two major limitations mainly related to intrinsic limits of the modelling approach.
The model building requires a series of assumptions made to translate verbal theory into equations. In particular is not completely realistic to assume a standard

productivity of top managers in project approval. For instance: managers' productivity can be influenced by the results of ICV program. If they notice good results in terms of project presented and in terms of economic values they can increase the productivity. Also the assumptions made on the productivity of delivery force should be reconsidered and can be linked to the ICV program performances.

The model has a major limit because it assumes that the ICV unit as completely separated from the Corporation. This is true from a formal point of view, but there are many factors that link the behaviour of the ICV unit to the behaviour of the Corporation. The dynamics of employees, the fund available, the managerial action can be influenced by what is happening in the Corporation. Moreover the performance of ICV unit can modify the behaviour of top managers and the strategy of the Corporation with feedback effects on the internal corporate venturing program.

The major improvement in the model can be achieved extending the boundaries of it; System Dynamics and feedback concept are powerful tools to investigate the dynamic relation between the Corporation and the ICV unit and to identify the "corporate" variables that play a major role in influencing the effectiveness of the ICV processes.

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Appendix 1. Alphabetical equation Listing

Parameters are from the base run of the model (File reference: STRIN4_1.SIM)

init Avalaible_funds = 10000000
flow Avalaible_funds = +dt*Financing_from_the_corporation
+dt*Incomes
-dt*Total_Expenditures
doc Avalaible_funds = The amount of money available to the ICV division to invest in new projects. The initial amount is provided by the Corporation.
init Delivery_force = Desired_delivery_Force
flow Delivery_force = +dt*Delivery_force_hiring_rate
-dt*Deliery_force_quiting_rate
doc Delivery_force = The workers implementing projects in the corporation
init Experienced_engineers =
Assimilation_rate/Experienced_engineers_quit_fraction
flow Experienced_engineers = -dt*Experienced_engineers_quit_rate
+dt*Assimilation_rate
doc Experienced_engineers = The number of experienced engineer doing project presentation and project completion. The new engineers after the assimilation time become experienced
init New_engineers = 80
flow New_engineers = -dt*Assimilation_rate
+dt*New_engineers_hiring_rate
-dt*New_engineers_quit_rate
doc New_engineers = The number of young engineers hired specifically to present and complete projects
init Perceived_productivity = Average_productivity
flow Perceived_productivity = +dt*Change_in_perceived_productivity
doc Perceived_productivity = The perception that top managers have of the productivity
init Percepted_rewards_per_engineer = Reference_rewards
flow Percepted_rewards_per_engineer = +dt*Change_in_perceived_rewards
doc Percepted_rewards_per_engineer = The reward that engineers extimate as suitable for their work
init Project_completed = Projects_completion_rate*Minimum_delivery_time
flow Project_completed = -dt*Projects_delivery_rate
+dt*Projects_completion_rate
doc Project_completed = The project completed by engineers. They can be implemented in the corporation by the delivery force.
init Projects_approved = Projects_approval_rate*Minimum_completion_time
flow Projects_approved = -dt*Projects_completion_rate
+dt*Projects_approval_rate
doc Projects_approved = The number of project presented by enigeers. They must be approved by top managers
init Projects_delivered = 1
flow Projects_delivered = +dt*Projects_delivery_rate
doc Projects_delivered = Project implemented within the corporation. With the delivery they go out from the ICV unit and start to generate revenues and costs for the corporation

init Projects_presented =
Managers_Productivity*Top_mangers*Minimum_approval_time*0
flow Projects_presented = -dt*Projects_approval_rate
+dt*Projects_presentation_rate
doc Projects_presented = The project presented to the top management by engineers. The project are in draft format, they must be approved by top managers and then they are completed by engineers
init Top_mangers = 20
flow Top_mangers = +dt*Top_mangers_hiring_rate
-dt*Top_managers_quiting_rate
doc Top_mangers = The top managers of the coprporation who examin and approve projects
aux Assimilation_rate = New_engineers/Assimilation_time
doc Assimilation_rate = The rate that determines the evolution of new engineers in experienced engineers
aux Change_in_perceived_productivity =
(Average_productivity-Perceived_productivity)/Time_to_perceive_productivity
doc Change_in_perceived_productivity = The rate of change in the perception of productivity
aux Change_in_perceived_rewards =
((Reward_per_engineer_per_project*Projects_completion_rate)-
Percepted_rewards_per_engineer)/Time_to_perceive_rewards
doc Change_in_perceived_rewards = The rate of change in the perception of rewards for engineers
aux Deliery_force_quiting_rate = Delivery_force_quit_fraction*Delivery_force
doc Deliery_force_quiting_rate = The workers implementing projects quit rate
aux Delivery_force_hiring_rate = (Desired_delivery_Force-Delivery_force)/Delivery_force_adj_time+Deliery_force_quiting_rate
doc Delivery_force_hiring_rate = The workers implementing projects hiring rate. This is influenced by the number of project completed and by the quiting rate
aux Experienced_engineers_quit_rate =
Experienced_engineers*Experienced_engineers_quit_fraction
doc Experienced_engineers_quit_rate = The monthly quiting rate for expericned engineers
aux Financing_from_the_corporation =
IF(Avalaible_funds+Incomes-Total_Expenditures<0,Total_Expenditures,0)
doc Financing_from_the_corporation = Funds provided by the Corporation in the case available funds falls to 0
aux Incomes = Projects_delivery_rate*Revenues_per_project
doc Incomes = The incomes derived from projects implemented in the Corporation
aux New_engineers_hiring_rate =
MAX(0,Perceived_quit_rate+WF_gap/Engineers_adj_time)
doc New_engineers_hiring_rate = The hiring rate of new engineers devoted to the ICV program
aux New_engineers_quit_rate = New_engineers*New_engineers_quit_fraction
doc New_engineers_quit_rate = The monthly quit rate for new engineers
aux Projects_approval_rate =
MIN((Top_mangers*Managers_Productivity),Projects_presented/Minimum_approval_time)

doc Projects_approval_rate = The rate at which projects are approved by top managers
aux Projects_completion_rate = MIN(Average_productivity*Fractional_time_to_project_completion*Total_engineers, Projects_approved/Minimum_completion_time)
doc Projects_completion_rate = The rate at which projects are completed by engineers
aux Projects_delivery_rate = MIN((Productivity_delivery_force*Delivery_force),Project_completed/Minimum_delivery_time)
doc Projects_delivery_rate = The rate at which projects are implemented (delivered) into the Corporation
aux Projects_presentation_rate = Average_productivity*Total_engineers*Fractional_time_to_project_presentation
doc Projects_presentation_rate = The number of projects that are presented by engineers each month
aux Top_managers_quiting_rate = Top_managers_quit_fraction*Top_mangers
doc Top_managers_quiting_rate = The quiting rate of the top managers of the corporation
aux Top_mangers_hiring_rate = Top_mangers*Top_managers_hiring_fraction
doc Top_mangers_hiring_rate = The hiring rate of the top mangers in the corporation
aux Total_Expenditures = Total_Rewards_for_project_completion+Salary_and_material_expenditures
doc Total_Expenditures = The expenditure determined by cost of project presentation, salaryes (including incentives), rewards
aux Approval_pressure = Desired_approval_rate/Max_potential_approval_rate
doc Approval_pressure = The approval pressure that top managers feel
aux Average_employees_salary = (Total_engineers/Total_Working_Force*Average_salary_engineers)+(Delivery_force/Total_Working_Force*Salary_delivery_force)
doc Average_employees_salary = The average employees salary considering engineers(new and experienced) and the delivery force. This salary includes engineers incentives.
aux Average_productivity = (Experienced_engineers/Total_engineers*Productivity_experienced_engineers)+(New_engineers/Total_engineers*Productivity_new_engineers)
doc Average_productivity = The weighted average of the productivity of engineers in project presentation and project completion
aux Average_salary_engineers = (Experienced_engineers/Total_engineers*Salary_experienced_engineers)+(New_engineers/Total_engineers)*Salary_new_engineer
doc Average_salary_engineers = The average salry of engineers including incentives
aux Desired_approval_rate = Projects_presented/Desired_approval_time
doc Desired_approval_rate = The number of projects that top managers should process
aux Desired_completion_rate = Projects_approved/Desired_completion_time
doc Desired_completion_rate = The rata at which project should be completed. it is influenced by the projects approved

aux Desired_delivery_Force =
Project_completed/Productivity_delivery_force/Desired_release_time
doc Desired_delivery_Force = The persons required to implement in the corporation the project completed
aux Desired_working_force_on_projects =
Desired_completion_rate/Perceived_productivity
doc Desired_working_force_on_projects = The working force that should work on projects to complete projects approved
aux Effect_of_approval_pressure =
GRAPH(Approval_pressure,0,0.2,[1.5,1.39,1.3,1.2,1.09,1,0.89,0.8,0.69,0.6,0.5"Min:0.5;Max:1.5;Zoom"])
doc Effect_of_approval_pressure = The effect of approval pressure on time allocated to project presentation
aux Effect_of_rewards =
GRAPH(Reward_salary_ratio,0,0.1,[1,0.97,0.94,0.9,0.72,0.2"Min:0;Max:1;Zoom"])
doc Effect_of_rewards = The effect of rewards on time allocated to project presentation
aux Effect_on_expereinced_eng_productivity =
GRAPH(Incentive_level,0,0.01,[0,0.14,0.28,0.37,0.45,0.51,0.54,0.57,0.58,0.59,0.6"Min:0;Max:1;Zoom"])
doc Effect_on_expereinced_eng_productivity = The effect of incentives on the productivity of the experienced engineers
aux Effect_on_new_eng_productivity =

GRAPH(Incentive_level,0,0.01,[0,0.13,0.28,0.42,0.57,0.68,0.76,0.79,0.8,0.8,0.8"Min:0;Max:1;Zoom"])
doc Effect_on_new_eng_productivity = The effect of incentives on the productivity of new engineers
aux Effects_of_incentives =
GRAPH(Incentive_level,0,0.01,[1.004,1.134,1.228,1.283,1.338,1.388,1.419,1.45,1.474,1.5,1.5"Min:1;Max:1.5;Zoom"])
doc Effects_of_incentives = The effect of incentives on time allocated to project presentation
aux Fractional_time_to_project_completion =
1-Fractional_time_to_project_presentation
doc Fractional_time_to_project_completion = The fractional time devoted to project completion by engineers (as residual time of time devoted to project presentation)
aux Fractional_time_to_project_presentation =
Effect_of_approval_pressure*Reference_fractional_time_for_project_presentation*Effects_of_incentives*Effect_of_rewards
doc Fractional_time_to_project_presentation = The time devoted to project presentation by engineers
aux Max_potential_approval_rate = Top_mangers*Managers_Productivity
doc Max_potential_approval_rate = The number of projects that top managers can process
aux Net_Income = Incomes-Total_Expenditures
doc Net_Income = The net incomes generated by ICV activity
aux Perceived_quit_rate = Total_quit_rate/Time_to_perceive_quit_rate
aux Productivity_experienced_engineers =

Standard_productivity_experienced+(Standard_productivity_experienced*Effect_on_expereinced_eng_productivity)
doc Productivity_experienced_engineers = The productivity of experienced engineers in project presentation and completion
aux Productivity_new_engineers = Standard_productivity_new+(Standard_productivity_new*Effect_on_new_eng_productivity)
doc Productivity_new_engineers = The productiity of new engineers in project presentation and completion
aux Reward_salary_ratio = Percepted_rewards_per_engineer/Average_salary_engineers
doc Reward_salary_ratio = The ratio express the relative importance of rewards compared to salary
aux ROI = (Incomes-Total_Expenditures)/(Total_Expenditures)
doc ROI = The measure of the profitability of the projects
aux Salary_and_material_expenditures = Average_employees_salary*Total_Working_Force+Projects_presentation_rate*Cost_of_project_presentation
doc Salary_and_material_expenditures = The cost of projects in terms of salry of employees and fixed costs
aux Salary_experienced_engineers = Basic_salary_experienced+Basic_salary_experienced*Incentive_level
doc Salary_experienced_engineers = The total salary of experienced engineers including incentives
aux Salary_new_engineer = Basic_salary_new+Basic_salary_new*Incentive_level
doc Salary_new_engineer = The total salary of new engineers including incentives
aux Total_engineers = Experienced_engineers+New_engineers
doc Total_engineers = The total number of engineer working on projects presentation and completion
aux Total_quit_rate = Experienced_engineers_quit_rate+New_engineers_quit_rate
aux Total_Rewards_for_project_completion = Total_engineers*Projects_completion_rate*Reward_per_engineer_per_project
doc Total_Rewards_for_project_completion = The amount of money given each month for project completed to each engineer
aux Total_Working_Force = Delivery_force+Experienced_engineers+New_engineers
doc Total_Working_Force = The total working force, not included the top managers who are in the corporation and not in this ICV unit
aux Total_working_force_needed = Desired_working_force_on_projects*(1-Reference_fractional_time_for_project_presentation)
doc Total_working_force_needed = The desired working force on project considering the fractional time devoted to project presentation
aux WF_gap = Total_working_force_needed-Total_engineers
doc WF_gap = The gap between the actual woking force and the desired working force
const Assimilation_time = 24
doc Assimilation_time = The training time (formal training and on the job trining) for new engineers to becaome experienced
const Basic_salary_experienced = 1000
doc Basic_salary_experienced = The basic salary fo experienced engineers

const Basic_salary_new = 800
doc Basic_salary_new = The basic salary fo experienced engineers
const Cost_of_project_presentation = 1000
doc Cost_of_project_presentation = The cost of project presentation, included material consumption, usage of instrumental tools.
const Delivery_force_adj_time = 1
doc Delivery_force_adj_time = Time necessary to adjust the delivery force
const Delivery_force_quit_fraction = 0.05
doc Delivery_force_quit_fraction = Fraction of delivery workforce leaving the ICV unit each month
const Desired_approval_time = 1
doc Desired_approval_time = The desired approval time of a project by top managers
const Desired_completion_time = 1
doc Desired_completion_time = The desired time to complete a project
const Desired_release_time = 1
doc Desired_release_time = The time necessary to implement projects
const Engineers_adj_time = 1
doc Engineers_adj_time = The time takes to complete the hiring process
const Experienced_engineers_quit_fraction = 0.15
doc Experienced_engineers_quit_fraction = The percentage of experienced engineers that quit each month
const Incentive_level = 0.00
doc Incentive_level = The level of incentives given to engineers. Between 0 and 10% on the standard salary
const Managers_Productivity = 4
doc Managers_Productivity = Projects that top managers can process and approve each month
const Minimum_approval_time = 1
doc Minimum_approval_time = The minimum time required to approve a project
const Minimum_completion_time = 1
doc Minimum_completion_time = The minimum time required to complete a project by engineers
const Minimum_delivery_time = 1
doc Minimum_delivery_time = The minimum time required to implement (delivery) projects in the Corporation
const New_engineers_quit_fraction = 0.2
doc New_engineers_quit_fraction = The percentage of new engineers that quit each month
const Productivity_delivery_force = 3
doc Productivity_delivery_force = The projects implemented each month by the delivery force
const Reference_fractional_time_for_project_presentation = 0.50
doc Reference_fractional_time_for_project_presentation = The reference time that engineers have to allocate on project presentation according to top managers desires
const Reference_rewards = 100
doc Reference_rewards = The reference rewards ais the averegare of rewards commonly applied by other companies
const Revenues_per_project = 8000

doc Revenues_per_project = Revenues generated from projects implemented each month in the corporation
const Reward_per_engineer_per_project = 0
doc Reward_per_engineer_per_project = The amount of money gave to engineers for ech project completed. Between 0 and 10. Decision maker: the top managers.
const Salary_delivery_force = 800
doc Salary_delivery_force = The salary of the delivery force.
const Standard_productivity_experienced = 1
doc Standard_productivity_experienced = The basic productivity of experienced engineers (without incentives)
const Standard_productivity_new = 0.5
doc Standard_productivity_new = The basic productivity of new engineers (without incentives)
const Time_to_perceive_productivity = 1
doc Time_to_perceive_productivity = The time required to top managers to perceive the productivity of engineers
const Time_to_perceive_quit_rate = 1
doc Time_to_perceive_quit_rate = The time that top managers need to perceive the quiting rate
const Time_to_perceive_rewards = 1
doc Time_to_perceive_rewards = The time to perceive rewards by engineers
const Top_managers_hiring_fraction = 0.05
doc Top_managers_hiring_fraction = Top managers leaving the ICV programs for others assignment in the Corporation
const Top_managers_quit_fraction = 0.05
doc Top_managers_quit_fraction = Top managers in the Corporation involved in ICV program

Simulation set up for each run
Start time: 0.00
Stop time: 240.00
Method: Euler (fixed step)
Time step: 0.0625

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