A system dynamics investigation of project portfolio management evolution in the energy sector
Case study: an Iranian independent power producer

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Abstract

Purpose – Project portfolio management (PPM) is a commonly used technique to align projects with strategy and to ensure adequate resourcing for projects. In this paper, to gain a better understanding of PPM dynamics, a system dynamics (SD) model was developed. To do so, an Iranian independent power producer was used as a case study in the energy sector; moreover, policy options were derived and generalized for such a developer company.

Design/methodology/approach – To cope with the complexity of business processes in a power producer company and to formulate an optimum policy, causal relations and loops were derived first and then state-flow diagrams were designed to simulate the problem in the system, as it is usual in the SD methodology.

Findings – The proposed model was applied to a real-world case study to rectify managers’ viewpoint about their business dynamics and to formulate new project portfolio strategies to improve the viability of the company. The model proved how a static portfolio analysis can misguide managers in planning their project portfolio strategies, and how effective feedback can improve PPM in developing companies in the energy sector.

Originality/value – Systems approach, especially SD methodology, has been rarely used to analyze PPM problems in the energy sector. This study highlights the implications of feedback and dynamics in PPM and tries to derive optimal value of portfolios.

Keywords System dynamics, Project portfolio management, Feedback structure, Utility company

Paper type Research paper

1. Introduction

Considering the changing environment and increased competition, project-based companies must have the capability to manage and implement various projects simultaneously
through optimum use of their resources to reach their organizational vision and increase value added (Moghadam et al., 2015). As many organizations shift toward “management by projects,” projects are often the main vehicle for delivering the organizational strategy. Project portfolio management (PPM) has gained attention that can provide a holistic decision-making framework to align projects with strategy and to ensure resource sufficiency for the project portfolio (Killen and Hunt, 2009; Moghadam et al., 2015, Michael et al., 2015). In some research studies, a project portfolio is defined as a group of projects that compete for scarce resources and are conducted under the sponsorship or management of a particular organization (Dye and Pennypacker, 1999; Ghasemzadeh and Archer, 2000). PPM is the art and science of applying a set of knowledge, skills, tools and techniques to a collection of projects to meet or exceed the needs and expectations of the organization’s investment strategy (Pennypacker, 2002). Two significant PPM activities are prioritization and selection first, and then the organization and optimized management of the portfolios’ implementation (Levine and Wideman, 2005).

There are different tools and techniques in a vast amount of literature that are applicable for PPM, such as scoring model, mathematical programming model, economic or financial model, metaheuristic algorithms, robust optimization, stochastic programming and decision-analysis technique (Samuelson, 1969; Mulvey and Vladimirou, 1992; Neuneier, 1996; Pinto and Millet, 1999; Cooper et al., 2000; Detemple et al., 2003; Brandt et al., 2005; Banerjee, 2008; Morris and Pinto, 2010; Chen et al., 2013; Lorca and Prina, 2014; Solimanpur et al., 2015; Moghadam et al., 2015; Tavanaa et al., 2015; Nasr-Esfahani et al., 2016; Faezy-Razi and Shariat, 2017; Jafarzadeh et al., 2018; Montajabiha et al., 2017; Nayebpour and Nazem-Bokaei, 2017; Gökgoz and Atmaca, 2017; Costa et al., 2017; Pérez et al., 2018; Odeh et al., 2018).

Nowadays, the combination of dynamic environment and high complexity of projects always leads to increased uncertainty (Daft and Armstrong, 2009; Duncan, 1972; Sterman, 1992; Rodrigues, 1998; Lyneis et al., 2001; Bulbul, 2006). The weakness of the existing approaches in project planning and analysis is the lack of dynamism (Ching-rui, 1984). Major feedback loops are highly vital for successful PPM (Franco, 1994). The analysis of PPM policies in a dynamic environment is one of the most appealing areas for the application of system dynamics (SD) because in the PPM, different kinds of variables are influencing and there are various nonlinear feedback relations among system variables (Franco, 1994; Lyneis and Ford, 2007).

SD methodology differs in many ways from the traditional approaches to project management (Rodrigues, 1994). The key distinctive characteristics of SD approach can be identified as follows: being holistic, considering causal feedbacks, non-linearity, time delays, endogenous modeling and being highly policy-oriented (Rodrigues, 1998; Bianchi and Sedehi, 1995). The primary objective of an SD model is to capture all the relevant feedback processes responsible for the project system behavior (Rodrigues, 1994, 1998). The effectiveness of SD approach in project planning and analysis is not only because of its systematic and dynamic analysis but also because of its value in quantitative analysis and policy analysis (Ching-rui, 1984).

Recently, SD models have been used as a decision support system (DSS) for policy design and decision-making in different fields, such as investment planning in business (Marquez and Blanchar, 2006), public decision support (Skraba and Rozman, 2012), urban planning (Briano et al., 2010), production and manufacturing systems (Rafiei et al., 2014), social issues (Lashgharian-Azad et al., 2010; Saleckpay et al., 2013), energy sector (Hosseini et al., 2012; Hosseini et al., 2014; Salman and Razman, 2014; Hosseini and Shakouri, 2016), agriculture (Bastan et al., 2018) and in various other areas. System thinking and SD modeling
techniques as a DSS in the field of project management dynamics have also been used. Roberts (1964) an industrial dynamic model to explore the basic dynamics and factors influencing outcomes of R&D projects. Allaway and D’Souza (1994) developed a decision support model to illustrate feedback and control in a product portfolio model. Using this model enables managers to make better dynamic decisions. Bianchi and Sedehi (1995) sketched a dynamic model for allocation of financial (i.e. cash flow provided by current sales) and human resources to marketing and R&D policies simultaneously for better management of product portfolio and new product launching in an industrial firm. An SD model was built and simulated by Qingrui and Weiqiang (1993), based on different portfolio incentives and along different stages of the company’s evolution. The authors suggested some new portfolio methods according to the different periods of career development and the company’s evolution. They also offered some recommendations about how to balance the portfolio incentive to improve the value of intellectual capital. Nasirzadeh et al. (2012) developed an SD model to prioritize useful factors in PPM-processes, but no simulation was conducted in this research. Izadin et al. (2015) developed an SD model for project accepting, which examined the effective factors in the decision-making process. The number of staff assigned to the projects as well as the identified delay in project execution took into consideration. Haghighi-Rad and Rowzan (2018) developed a hybrid system dynamic model to analyze the impact of strategic alignment on project portfolio selection. The integration of system dynamics with multi-objective decision-making was applied to address project portfolio selection. The aim was to plan and control the progress of project portfolio while maximizing the strategic adaptation subject to the changes of the human resources. Table I shows some studies related to PPM.

Literature shows that there is a lack of system thinking in the methods and tools by which the dynamics of PPM problems are investigated. In addition, there exists rare literature in applying systems approach, especially SD methodology, to analyze PPM problems in practice. In this research, to show how a static portfolio analysis can misguide managers in selecting their medium- to long-term portfolio strategies, a dynamic and systematic portfolio policy analysis tool is developed through an SD approach in a real case study. The developed SD model is used to investigate the dynamics of portfolio policy design, evaluation and selection in an Iranian independent power producer (IPP). The analysis helps the company to align its investment plan in the medium to long term.

The paper is organized as follows. In Section 2, the problem is clarified, and the model basis is provided. Section 3 describes the research methodology and the process through which the research is conducted. Section 4 describes the proposed SD model by explaining and analyzing the main loops and equations, as well as simulation results of different scenarios. Finally, Section 5 concludes the paper.

2. Statement of the problem
Development dynamics of small and medium enterprises (SMEs) in the energy sector has been considered rigorously in extant literature (Killen et al., 2008; Ostermark, 2005). One of the significant areas of emphasis is investment plan or investment project portfolios (Wan, 2009), which identifies how an SME formulates its investment program through PPM policies that profoundly impact upon the company’s success (Morcos, 2008; Moghadam et al., 2015). Here, the focus is on feedback loops that should be considered in PPM policies. These feedback come from a company’s internal or external environment, which are useful in investment program success.

The initial idea of this research is formed within a strategic planning consulting project in an Iranian private IPP. The main concern was formulating an appropriate portfolio
policy. The company, which had been registered as a private joint stock company, is a pioneer in Iran’s leading build-own-operate (BOO) power plants and provision of management solutions for the electric power generation, distribution and energy sale industry. The company’s mission has been defined as follows:

The company tends to play an effective role as a developer and investor in energy and related sectors in Iran and targeted markets to create and enhance stakeholders’ value within a sustainable development framework.

The company has a portfolio of forthcoming investment projects in four strategic business units (SBUs), namely, conventional power generation (12 projects), cogeneration/utility (3 projects), power and water distribution (4 projects) and renewable energy (1 project). Before conducting the consulting project, the company had already developed its long-term PPM policies based on some static portfolio analysis tools (i.e. GE[1] matrix, BCG[2] matrix) and intuitive knowledge of its managers. Figure 1 is drawn based on a 10-year-old roadmap of the company’s investment projects. Based on the investment policy, management plan and financial requirements of projects, the company’s expected cash flow was going to face a U-shaped dynamic with significant negative values in its minimum point during an unsupportable period of time; that is, in the first forthcoming years of the plan, the company

<table>
<thead>
<tr>
<th>Authors</th>
<th>Brief description</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allaway and D'Souza (1994)</td>
<td>Explaining feedback and control in product portfolio management</td>
<td>Dynamic modeling</td>
</tr>
<tr>
<td>Bianchi and Sedehi (1995)</td>
<td>PPM</td>
<td>Dynamic modeling</td>
</tr>
<tr>
<td>Ghasemzadeh and Archer (2000)</td>
<td>Project portfolio selection (PPS)</td>
<td>DSS</td>
</tr>
<tr>
<td>Killen et al. (2008)</td>
<td>Development of PPM capabilities</td>
<td>Case study</td>
</tr>
<tr>
<td>Nasirzadeh et al. (2012)</td>
<td>PPM</td>
<td>SD</td>
</tr>
<tr>
<td>Chen et al. (2013)</td>
<td>Portfolio selection</td>
<td>Constrained fuzzy analytic hierarchy process and fuzzy technique for order of preference by similarity to ideal solution (TOFSIS)</td>
</tr>
<tr>
<td>Izadin et al. (2015)</td>
<td>Project acceptance policy</td>
<td>Data envelopment analysis (DEA), TOFSIS, and linear integer programming</td>
</tr>
<tr>
<td>Tavammaa et al. (2015)</td>
<td>PPS</td>
<td>SD</td>
</tr>
<tr>
<td>Solimanpur et al. (2015)</td>
<td>Portfolio selection</td>
<td>Genetic algorithm (GA) and AHP</td>
</tr>
<tr>
<td>Nasr-Esfahani et al. (2016)</td>
<td>PPS</td>
<td>Harmony search algorithm and modern portfolio theory</td>
</tr>
<tr>
<td>Arratia et al. (2016)</td>
<td>PPS</td>
<td>Mixed integer linear programming</td>
</tr>
<tr>
<td>Nayebpur and Nazem-Bokaei (2017)</td>
<td>Portfolio selection</td>
<td>GA and fuzzy synthetic evaluation (FSE)</td>
</tr>
<tr>
<td>Faezy-Razi and Shariat (2017)</td>
<td>PPS</td>
<td>Artificial neural network (ANN), decision tree and regression</td>
</tr>
<tr>
<td>Jafarzadeh et al. (2018)</td>
<td>PPS</td>
<td>Fuzzy quality function development (QFD) and DEA</td>
</tr>
<tr>
<td>Montajabigha et al. (2017)</td>
<td>PPS</td>
<td>Robust optimization</td>
</tr>
<tr>
<td>Haghgibi-Rad and Rowzan (2018)</td>
<td>PPS</td>
<td>SD and multi-objective decision-making (MODM)</td>
</tr>
<tr>
<td>Pérez et al. (2018)</td>
<td>PPS</td>
<td>Fuzzy mathematical programming</td>
</tr>
</tbody>
</table>

Table I. Related portfolio management studies
has enough revenue and a positive cash flow. The intensive investment program postpones revenues by construction time and pushes the company’s cash flow to a negative value during an intolerable period. This will result in a bankrupt company. Figure 2 has been derived from the manager’s viewpoint about investment programs and their financial requirements and earnings.

The roadmap was based on the managers’ priorities for different projects in different SBUs. In the SBU, projects were divided into three categories, i.e. small, medium and big, and priorities of these categories were insignificant, very low and very high, respectively. The source of these priorities was nested in the managers’ minds and the fact that in the later years, the company conducted its activities in a relatively desirable environment, in which it could support its investment with special foreign finance. Owing to new sanctions against Iran’s energy sector in the middle of the first year of the roadmap, the company was about to lose international support: financial resources provided by international

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**Figure 1.** Schematic cash flow of the company for the investment management plan

**Figure 2.** Current roadmap of the company’s investment program
institutions and power plant equipment. Moreover, international insurance for projects turned almost impossible. The problem came from the fact that the management team was not successful in changing mind and developing new priorities in line with the new situation and ongoing environmental changes. As the financial capability of the company was not enough to support such an extensive program (Figure 2) and the management team was persistent on their plan, the company was about to go bankrupt shortly (Figure 1).

According to the managers’ opinion, two main decision criteria to formulate portfolio policies were cash flow and installed decapacity. However, the consulting team added two other items by analyzing the dynamics of these variables and considering their effects on other variables. Therefore, the problem was expanded as follows:

- The cash flow should not be negative; otherwise, some negotiated projects are abandoned. This will have a negative effect on the company’s brand. In such circumstances, the company almost ignores this effect. Marketing personnel, who are the most critical agents in the company, are not trained purposefully; hence, sometimes less strategic projects are seriously considered. This will affect the company’s productivity.
- Total installed capacity should be as high as possible as it determines the final power of the company among the rivals in the market.

To make the right decisions in the right time, managers have to keep in mind all the mechanisms and feedback affecting total cash flow and total installed capacity. To help managers better understand the dynamics of portfolio policy formulation in their company about the dynamic environment and to cope with the complexity rising from a trade-off between these two criteria, SD modeling was proposed by the consulting team. SD can be a suitable solution that provides a virtual micro-world and enhances managers’ perception of the dynamics for portfolio priority selection. In this regard, the consulting team started modeling consequences of investment project priority selection. Based on project size, all projects in the SBUs were divided into three categories:

1. small, including distributed generation (DG) and power and water distribution in small industrial parks, combined heat-power (CHP);
2. medium, including cogeneration and wind power plants; and
3. big projects, including combined cycle gas turbine (CCGT) and gas turbines.

Each SBU has a mixture of these types of project. It should be mentioned that these categories are another classification (different from SBU segmentation) of projects; this classification is more suitable for this study. The model entails the following subsystems:

- total cash flow;
- life cycles of all projects;
- company’s brand;
- financing and repayment rate;
- net hiring rate; and
- training and productivity of personnel

The model will contain all variables needed to analyze the mechanisms and dynamics of these subsystems.
3. Research methodology: system dynamics model of project portfolio management

Figure 3 describes the process through which this research was done. As inputs, the company’s mission and goals, as well as SBUs, were extracted. Then, through some meetings with senior managers and staff, the system’s conceptualization completed through drawing a causal loop diagram. After formulating equations using numerical data, system’s information about processes and procedures and expert opinions, the SD model of the company’s project portfolio was completed. In the next step, different scenarios were developed, and the optimal policy was proposed.

3.1 The conceptual model

In this section, the dynamics of the problem described above is evolutionarily illustrated. Figure 4 depicts the dynamics of capacity development in the company. A considerable share of the (positive) cash flow of the company is allocated to investment in projects. Thus, an increase in cash flow causes an increase in the company’s total investment in the given year. Total investment is allocated to three categories of investment projects, which is shown by the index $i (i = 1, 2, 3)$ for small, medium and big projects. Therefore, the increase rises allocated investment in each category. This increase leads to a rise in the investment project construction rate and operating capacity (with a delay of construction period) in each category. The more operating capacity the company possesses, the more income it can gain. The increase, finally, would close the loop and cause a rise in cash flow (loop $R_1$ in Figure 4).

As the operating capacity of the company increases, its brand among competitors in the power industry is enhanced; this increase expands the company’s potential and ability to negotiate for more investment projects in each category and consequently, with a request processing delay, it raises the negotiated projects in each category. This increase guarantees more construction rate and finally closes the loop with more operating capacity. This phenomenon forms the positive feedback loop $R_2$.

Human resource development and the effect of its related costs are depicted in loop $R_3$ in Figure 4. An increase in cash flow increases personnel budget, which leads to an increase in headcount. More headcount, about the share of marketing personnel of total personnel, brings on more marketing man-hour effort in each category of investment projects. Thus, the negotiation rate for investment projects would increase. This finally
increases the operating capacity and income, which results in more cash flow. On the other hand, more headcount means the company has to spend more on more salary and training, which has a negative effect on the cash flow. When the investment increases, indeed, the total development costs increase so that the total cash flow decreases (loop B1 in Figure 4).

More investment project negotiation rate increases negotiation and development costs. Therefore, total cash flow decreases, leading to decline of investment and project construction rate. While the project construction rate decreases, the operating capacity decreases with a delay and then the company’s brand decreases, causing the decline of investment project negotiation. This phenomenon forms the negative feedback loop B2.

When the project construction rate increases, operating capacity, O&M costs and therefore total investment costs increase, leading to a decline in cash flow. When the cash flow decreases, the investment and consequently project construction rate decreases (loop B3 in Figure 4).

As mentioned above, an increase in cash flow increases personnel budget, which leads to an increase in headcount. More headcount leads to more finance man-hour and therefore more finance rate and final investment. This finally increases development costs that result in less cash flow (loop B4 in Figure 4).

Another essential part of the model is related to financial human resources. As is shown in loop B4, like human resource development loop, increase in cash flow would bring on more finance efforts in each category of investment projects. This finally raises investments and operating capacity, which consequently increases cash flow with some delay. On the other hand, with an increase in finances, payment rates also increase.
3.2 Mathematical formulation of the simulation model

In this section, the mathematical formulation of the main relationships of the model is explained. The model has about 110 variables, of which 27 are state variables; 36 are rate variables, and others are auxiliary variables. The simulation period lasted from 2007 to 2025, and simulation time steps were one-fourth of a year. The index $i$ in following equations refers to three categories of investment projects in the company.

As the main variable, the company’s cash flow is calculated through the following formula.

\[
\text{CashFlow}_t = \text{Net income}_{i,t} + \text{Shareholders\ equity}_t - \text{O&M costs}_{i,t} - \text{Final investment}_{i,t}
\]

\[
- \text{Finance payment rate}_{i,t} - \text{Negotiation costs}_{i,t} - \text{Personnels' salary}_{t}
\]

\[
- \text{Training costs}_{t} - \text{Shareholders' profit}_{t}
\]

(1)

Loan payment rates in each category are calculated through the capital recovery factor as follows. In the formula, $j$ is a natural number and refers to the number of loans achieved in each category during the simulation period. $n_i$ is the payment period, and $I_i$ is the interest rate for investment projects in each category, i.e. the payment periods and interest rates are different in different categories.

\[
\text{Payment rate}_{i,t} = \sum_j \left( \frac{I_i \cdot (1 + I_i)^{n_i}}{(1 + I_i)^{n_i} - 1} \right) \times \text{Finance rate}_{i,j,t}
\]

(2)

Following, four formulas represent the model’s structure in its investment sector. In formula (6), participation ratio refers to the ratio of an external source in project financing (i.e. foreign and domestic banks and financial institutes).

\[
\text{Project construction rate}_{i,t} = \frac{\text{Final investment}_{i,t}}{\text{Initial capital cost perMW}_i}
\]

(3)

\[
\text{Final investment}_{i,t} = \text{Allocated investment}_{i,t} + \text{Finance payment}_{i,t}
\]

(4)

\[
\text{Allocated investment}_{i,t} = \text{Investment priority}_i \times \text{Investment share} \times \text{Cash flow}_t
\]

(5)

\[
\text{Finance rate}_{i,t} = \frac{\text{Participation ratio}_i}{1 - \text{Participation ratio}_i} \times \text{Allocated investment}_{i,t}
\]

(6)

As another essential formula, the company’s brand is calculated through a lookup function (Figure 5) in which the total operating capacity and the total given-up capacity are two inputs. Total given-up capacity refers to the investment projects of which licenses are expired because of financial limitation during the simulation period. The lookup function shows that if total developed capacity (equal to total operating capacity minus total given up capacity) reaches 10 GW, then the company’s brand is the most effective among its private sector rivals.
The company’s brand is given by:

\[ K = \sum_i \text{Operating capacity}_{i,t} - \sum_i \text{Given up capacity}_{i,t} \]  

(7)

Explanation of other formulas is passed up because of the long list of detailed and simple equations. Table II shows the main parameters’ values in the base run; the most important parameters are priority 1, priority 2 and priority 3, which are representative of the company’s investment portfolio policy toward small, medium and big projects. These parameters have been derived from the company’s financial documents and managers’ interviews in a steering committee in the company, consisting of members of the board of directors and mid-level managers.

3.3 Model validation

Model validation is an important part of an SD simulation and defined as a process of evaluating the model to find out whether all parts of the model together can make a true result or not. Following, the validity of the model is shown by a series of tests that have been

![Figure 5. Lookup function for the company’s brand](image)

<table>
<thead>
<tr>
<th>Row</th>
<th>Parameter’s name</th>
<th>Parameter’s unit</th>
<th>Parameter’s value in the base run</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Investment priority1</td>
<td>Dmnl</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>Investment priority2</td>
<td>Dmnl</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>Investment priority3</td>
<td>Dmnl</td>
<td>0.85</td>
</tr>
<tr>
<td>4</td>
<td>Personnel’s budget ratio</td>
<td>1/Year</td>
<td>0.01</td>
</tr>
<tr>
<td>5</td>
<td>Marketing personnel ratio</td>
<td>1/Year</td>
<td>0.6</td>
</tr>
<tr>
<td>6</td>
<td>Finance personnel ratio</td>
<td>Dmnl</td>
<td>0.2</td>
</tr>
<tr>
<td>7</td>
<td>n1</td>
<td>Year</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>n2</td>
<td>Year</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>n3</td>
<td>Year</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>I1</td>
<td>1/Year</td>
<td>0.25</td>
</tr>
<tr>
<td>11</td>
<td>I2</td>
<td>1/Year</td>
<td>0.14</td>
</tr>
<tr>
<td>12</td>
<td>I3</td>
<td>1/Year</td>
<td>0.07</td>
</tr>
<tr>
<td>13</td>
<td>Participation ratio1</td>
<td>Dmnl</td>
<td>0.2</td>
</tr>
<tr>
<td>14</td>
<td>Participation ratio2</td>
<td>Dmnl</td>
<td>0.7</td>
</tr>
<tr>
<td>15</td>
<td>Participation ratio3</td>
<td>Dmnl</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Table II. Main parameters of the model
divided into two categories in the literature, namely, tests of model behavior and tests of model structure (Sterman, 2000; Forrester and Senge, 1980; Barlas, 1996).  

3.3.1 Tests of model behavior. Tests of model behavior evaluate the adequacy of the model structure through analysis of behavior generated by the structure (Forrester and Senge, 1980). In this paper, behavior prediction, boundary adequacy, surprise behavior and behavior sensitivity testing are used. The focus of behavior prediction test is on future behavior, and it is needed to check the pattern-prediction and event-prediction of simulated results (Forrester and Senge, 1980). For the pattern-prediction test, simulation results in Figure 6 showed that the model could qualitatively generate the correct pattern of the company’s total cash flow that was considered as the reference mode in Figure 1. Also, for the event-prediction test, the model does not produce any unexpected changes in the behavior of variables. 

The behavior-sensitivity test focuses on the sensitivity of model behavior to changes in parameter values (Forrester and Senge, 1980). As an instance, the sensitivity of the model is examined for changes in the amount of the personal’s salary ranges between ± 25 per cent of its current value (Figure 7). The following results show that the model is appropriately sensitive to changes in parameters. 

In the boundary adequacy test, the model needs to be examined whether the main influencing concepts and structures for addressing the policy matter are endogenous to the model. The model proposed in the paper includes subsystems such as project development process, human resource, finance, the company’s brand dynamics and cash flow management. Also, the boundary adequacy of the model is verified in a steering committee of the consulting project in the company, consisting of members of the board of directors and mid-level managers.

Finally, in a surprise behavior test, it is analyzed whether the model simulates any unobserved or unrecognized behavior or not (Sterman, 2000). Simulation results of all of the variables in the model are consistent with their values in the real world, and there is no surprising behavior.

3.3.2 Tests of model structure. Tests of model structure assess structures and parameters directly. In this paper, extreme condition, structure verification and parameter verification tests are used.
The extreme condition test aims to answer the question of whether each equation makes true sense even when its inputs take on extreme values (Sterman, 2000). As an instance for extreme condition test, as the average income of operating capacity increases by five times from 2015, the results show that the projects that are ready for negotiation increases considerably and total operating capacity increases accordingly by a delay (Table III and Figure 8). Moreover, as the unit capital costs increase by five times, total operating capacity does not increase significantly. These results show that by applying the extreme condition test, the model behaves appropriately.

Structure verification means comparing the structure of the model directly with the structure of the real system that the model represents (Forrester and Senge, 1980). In a steering committee of the consulting project in the company, the structure of the model was verified.

In the parameter verification test, the purpose is to determine whether the parameters correspond conceptually and numerically to real life or not (Forrester and Senge, 1980). The accuracy of the parameters’ values was verified by the company’s experts including members of the board of directors and mid-level managers.

### 4. Simulation results
In the following subsection, simulation results of two scenarios (base run and proposed policy) are presented and discussed.

| Table III. Parameters’ changes in extreme point test |
| --- | --- | --- | --- | --- |
| Row | Parameter’s name | Parameter’s unit | Base run | Extreme point test |
| 1 | Average income of operating capacity_{1,2,3} | Dmnl | 1 | 5 |
| 2 | Unit capital costs_{1,2,3} | Dmnl | 1 | 5 |
4.1 Results of the base run

Figure 9 shows the simulation results for the operating capacities of three categories of investment projects and the total cash flow. Owing to difficulties with foreign finance, operating capacity of big projects does not have any growth in the initial years. However, in the final years, it shows a positive behavior. Small and medium projects have not developed considerably as their priority is not significant. Total operating capacity in the base run reaches 2,480 MW, of which the main development is in the final years.

Although operating capacity develops finally, the behavior of total cash flow is not impressive. It shows two sunken modes in the initial and final years of simulation. The first U-shaped behavior is bearable because the cash flow is still positive. The last one is as well a considerable gap (minimum of cash flow = $ -175mn), and it seems that the company will experience bankruptcy in the final years, given its current portfolio management policy.

Unquestionably, the outcome of a current situation (base run) is not plausible for managers who wish to play a useful role in Iran’s energy sector as their relative share of country’s operating capacity is trivial. Moreover, the viability of the company is about to face up to a challenging encounter given the current situation continues. In the next section, it is attempted to find the proposed portfolio policy to reach a satisfactory outcome of the simulation.

4.2 Proposing an optimum policy

The consulting team believed that the origin of the problem comes from the company’s portfolio policy-making mechanism. Therefore, after the base run simulation, the
consulting team asked managers to propose an alternative portfolio policy to control the consequences of their previous policy. Although at this stage managers had been provided with a dynamic microworld in which effective factors of the problem were interconnected with a feedback structure, they still offered the alternative option statically and unilaterally. This offer includes some changes in investment projects priorities and the share of marketing and financial personnel. Table IV summarizes their alternative policy option.

As is shown in Figure 10, in the alternative policy, the cash flow’s behavior is better, even though the problem remains. In this policy, the cash flow problem is solved via less investment initiation (here the total operating capacity is 1,559 MW, whereas in the base run, the capacity is 2,480 MW).

The consulting team started to design a simple priority adjustment mechanism and test policy alternative offered by managers to evaluate its effectiveness. The mechanism is designed using an SD model; it is tried to consider the consequences of investment portfolio priority adjustments systematically. The logic of the designed mechanism is stated via the following rules:

- If cash flow is negative, do not invest in medium and large projects that require more capital and their construction delay are relatively long.
- If cash flow is not negative but yet small, do not invest in big projects and concentrate on small projects.
- If cash flow is considerable and decreasing, do not invest in big projects. In this situation, small and medium projects have an approximately similar priority.
- If cash flow is considerable and increasing, do not invest in big projects and concentrate on medium projects.

Table IV.

<table>
<thead>
<tr>
<th>Row</th>
<th>Parameter’s name</th>
<th>Parameter’s unit</th>
<th>Base run</th>
<th>Static alternative policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Priority 1 Dmnl</td>
<td>0.05</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Priority 2 Dmnl</td>
<td>0.1</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Priority 3 Dmnl</td>
<td>0.85</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Marketing personnel ratio</td>
<td>1/Year</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>5</td>
<td>Finance personnel ratio</td>
<td>1/Year</td>
<td>0.2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Figure 10.

Simulation results for the base run and the alternative policy.
If cash flow is big enough, do not invest in medium projects (as big projects are more profitable) but do not neglect small projects (as construction delay of big projects is long and the company should provide minimum positive cash flow in the construction period of significant investment projects).

Table V summarizes the above-mentioned rules in a mathematical format. Numbers and reference points of formulations are derived from an above-mentioned expert panel.

Because of its discontinuity, it is suggested that “If Then Else” formulations should not be used frequently (Sterman, 2000). To enter the above-mentioned priority adjustment rules, a sample data of rules is generated, and three smooth mathematical formulations are calculated via “Curve Fitting Toolbox” in MATLAB software. Figure 11 shows surfaces and their polynomial form of the formulation, where $x$ and $y$ present cash flows of the present ($t$) and the previous years ($t-1$), respectively.

Figure 12 shows the simulation results of three scenarios. As is shown, in the proposed scenario, the cash flow problem is solved; moreover, the company exploits its cash flow much better than the second scenario as the company’s cash flow should not be increasing forever, and the company should use it in its investment projects to create more profit. On the other hand, the operating capacity in the proposed policy is near to the base run and higher than the second policy option.

4.3 Concluding remarks

The proposed policy option showed how the company could optimally use its resources to be more successful in the future. Moreover, the role of SD modeling, which provides microworlds for managers to understand the problem and design, evaluate and select an appropriate policy, is of high importance in this consulting project.

Results of scenario planning showed that practitioners in this industry would consider the following points:

- The consequences caused by feedback from project investment financial requirements on the company’s survival should be taken into account when the company plans its investment program. SMEs, which are always eager to grow fast, sometimes fail to consider such apparent feedbacks.
- The effect of project portfolio dynamics should be considered systematically, that is, short-term successes (in the case: increasing big projects construction rate) should not mislead a company so that it disregards its long-term success (in this case: having a reliable cash flow).

<table>
<thead>
<tr>
<th>Row</th>
<th>Condition</th>
<th>Small projects</th>
<th>Medium projects</th>
<th>Large projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>If cash flow$_t &lt; 0$</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>If 0 =&lt; cash flow$_t &lt; 100$</td>
<td>0.8</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>If 100 =&lt; cash flow$_t &lt; 200$ and cash flow$<em>t$ - cash flow$</em>{t-1} &lt; 0$</td>
<td>0.4</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>If 100 =&lt; cash flow$_t &lt; 200$ and cash flow$<em>t$ - cash flow$</em>{t-1} &gt; = 0$</td>
<td>0.2</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>If cash flow$_t &gt; = 200$</td>
<td>0.4</td>
<td>0</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Table V. Formulation of the proposed priority adjustment rules
Figure 11. Curve fitting results for the proposed priority adjustment rules.

Note: \( f(x, y) = p_{00} + p_{10}x + p_{01}y + p_{20}x^2 + p_{11}xy + p_{02}y^2 + p_{21}x^2y \)

Figure 12. Simulation results for the base run, the alternative policy, and the proposed policy.
The investment portfolio prioritization is a dynamic process that may be revised frequently as per different internal and external situations in a company. Managers should sometimes break their mental model and think more effectively about their decisions dynamics.

Balanced allocation of (financial, human and other organizational) resources about its future consequences is one of the most important factors that should be taken into consideration in investment companies.

This study showed how using a simulation tool for managerial decision-making can facilitate the process of understanding and learning the mechanisms that affect a company’s current and future performance. It can provide an interactive virtual world to design, apply and evaluate different policy options so that they could be tested by such a simulation laboratory before performing in the real world. This approach facilitates the company’s sustainable development without imposing trial-and-error costs.

5. Conclusion
In this paper, the project portfolio management of an Iranian IPP was taken into consideration. In the presented loops, there were delays and nonlinearity between most of the variables. This subject turned investment portfolio priority adjustments into a complex decision and needed an approach based on systems thinking and mathematical modeling. Therefore, an SD modeling approach was used to give managers of the IPP a system understanding of influential factors in the mentioned portfolio policy problem. Once the model’s validity was approved, it was used to predict and evaluate the company’s future, given the company’s current situation. Finally, it was used to design, evaluate and select an appropriate policy option for the problem (project portfolio management).

Results are indicative of the fact that systems thinking within a feedback structure could effectively help managers to understand and find useful solutions to their current concerns. Moreover, this research showed how static models of portfolio strategy analysis might misguide managers in selecting their medium- to long-term portfolio policies, and it showed the necessity of using such dynamic approaches in formulating utilities’ portfolio policy.

In this paper, only financial and marketing resources were focused on; a model could be developed to include other factors such as the company’s infrastructure, alliances and joint ventures and different type of finance.

Notes
1. General Electric, GE Matrix, implies multifactor portfolio matrix, that assist a firm in making strategic choices for product lines based on their position in the grid.
2. Boston Consulting Group, BCG Matrix, is a growth share model, representing growth of business and the market share enjoyed by the firm.
3. Projects with construction license in hand.

References


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