


# Optimum Project Portfolio Selection for Developmental Plans Using Goal Programming

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## ABSTRACT

In vision-driven development plans, such as the Kuwait Mid-Range Development Plan 2015/2016–2019/2020, themes and pillars are derived from the plan’s vision, and global indices are assigned by international organizations to accurately measure the performance against the vision’s themes. This allows for comparison with other countries, and it also set targets for progression over time. One or more projects are assigned to the indicators of these global indices. A multi-criteria mathematical programming technique (e.g., goal programming) is used with multiple goals and priorities where an optimal portfolio of projects is found that satisfied the selection criteria.

## KEYWORDS

Evaluation Model, Global Indices, Integer Programming, Kuwait’s Mid-Range Development Plan, Multi-Criteria Programming, National Plan, Project Evaluation Model, Project Management, Vision-Driven Development Plans

## 1. INTRODUCTION

The project portfolio selection problem has been discussed for decades by many researchers in the fields of project management, financial management, risk management, and investment (Jafarzadeh et al., 2015; Pérez et al., 2018). It is a complex decision-making process, partially due to the existence of multiple and often conflicting objectives, and partially due to the high number of projects from which a subset or a portfolio is chosen (Khalili-Damghani et al., 2013).

In countries where national development planning is centralized and administered by the state, and where government entities are asked to suggest projects that would lead to the improvement of the of

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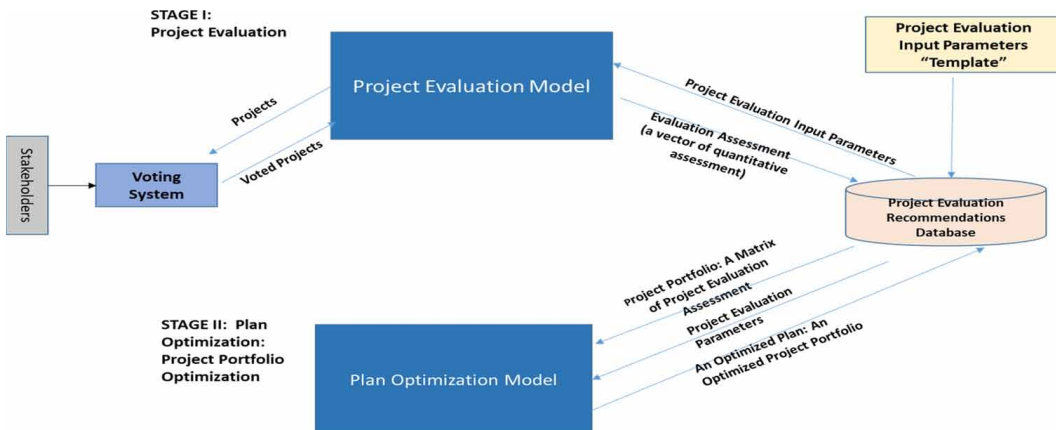
the country’s position in relation to a set of global indices that would also lead to the improvement of the objectives of the national plan’s vision, selecting an optimum portfolio of the suggested projects that would lead to a certain level of improvement in these indices becomes a challenging problem.

In this paper, the project portfolio selection problem is addressed at a national level, within a development planning environment, using Kuwait’s Mid-Range Development Plan 2015/2016–2019/2020 as a case. And when dealing with national projects, two sets of activities are identified. There are those that deal the evaluation of each project in terms of their efficiency; effectiveness; broad developmental impact; and sustainability, including cost and benefits analysis, economic analysis, and risk assessment analysis, (etc.). Second, there are those related to the selection of a portfolio of projects to be included in the developmental plan. Figure 1 is a block diagram representing these two sets of activities as a two-stage interrelated process: a project evaluation stage and a project portfolio selection. The focus of this paper is on Stage II, where the output from Stage I, which is the main input to Stage II, is already specified and estimated.

### 1.1. The Process of Assigning Project to National Plans

In vision-driven development plans, such as the one in Kuwait, themes and pillars are derived from the plan’s vision. Themes represent desired “end states” for Kuwait, and pillars represent the drivers Kuwait’s different institutions (executive, legislative, and judicial) can use to achieve the themes. A matrix of themes by pillars is created, where the intersection of each theme and each pillar (the cell of the matrix) would represent a potential area of improvement. Global indices by international organizations such as the World Bank, the UN, and other international sources are then identified and assigned to each cell of the matrix, that is, the intersection of each theme and pillar, where applicable. These global indices allow for accurately measuring the performance against the vision’s themes, allow for comparison with other countries, and set targets for progression over time.

Figure 1. A block diagram of a two-stage project evaluation and plan’s project portfolio selection



Each global index consists of multiple indicators; each represents a concrete area of improvement. A strategic direction, representing an area of improvement, is specified, and assigned to each indicator, along with a certain targeted position for improvement. Government entities and stakeholders are then asked to use these strategic directions to submit one or more projects for each strategic direction that would address and have an impact on the improvement of the strategic direction. This would consequently lead to the improvement of the indicator to which the strategic direction is assigned. Projects submitted must be directly related to the vision of the development plan.

In the Kuwait's Mid-Ranged Development Plan, 2015/2016–2019/20, five themes are derived from the vision, and there seven pillars supporting these themes: citizen participation and respect of the law, effective and transparent government, prosperous and diversified economy, nurturing and cohesive nation, and globally relevant and influential player. And the supporting pillars are administration, economy, infrastructure, living environment, healthcare, education and human capital, and international position. Table 1 in the Appendix shows the global indices and their sources, reflecting the position of Kuwait vis-à-vis these indices, indicated as a percentile. Table 2 shows the Themes and Pillar Matrix with global indices.

Vision-related projects are classified into three categories that require different levels of monitoring and support. These three categories are defined as follows:

- **Tactical projects**
  - Projects that do not frequently occur in Kuwait and have a high measurable impact
  - Projects that are not part of the current mandate of the entities but need to happen to achieve Kuwait's vision
- **Enabler projects**
  - Projects that do not have a high measurable impact on a standalone basis but are required in order to support the implementation success of other projects
  - Enablers can be infrastructure enablers, which include basic infrastructures such as roads, electricity, water, sewage, and so on, or administrative enablers, such as the improvement of key government processes or the establishment of specialized institutions
- **Operational projects**
  - Projects that occur frequently, or represent a core part of the activities of the government entity that owns the project

According to the above project's classification, The Kuwait's Mid-Ranged Development Plan, 2016/2017–2019/20 includes 17 vision-related tactical projects, 19 enablers, and 88 vision-related operational projects (see Table 3).

To achieve the vision, Kuwait should target to reach a position of at least 30th percentile by 2025 and at least 20th percentile by 2035, globally. These positions would provide Kuwait with a competitive positioning on a regional and international level and would help ensure that Kuwaiti citizens and residents experience a high standard of living.

## 2. REVIEW OF LITERATURE

### 2.1 Project Portfolio Selection

The project portfolio selection (PPS) problem has been discussed by many researchers in the fields of project management, financial management, risk management, and investment for many decades (Baqeri et al., 2019). The project selection is a complex decision-making process, partially due to the existence of multiple and often conflicting objectives, and partially due to the high number of projects from which a subset or a portfolio is chosen.

Tahri (2015) gives the following summary about PPS: "The Project Management Institute (2017) defined the project portfolio as "a set of projects or programs and other operations that are grouped to facilitate effective management of that work in the pursuit of strategic objectives." Thus, the project portfolio is the effective translation of strategic business objectives. Therefore, to successfully manage a project's portfolio, we must choose the projects to be implemented; hence, the projects selection process is so important.

The selection of a project portfolio is a process that involves the evaluation of a set of valid projects that achieve specific strategic objectives (Mantel et al., 2011). This process must be done periodically

to ensure the selected projects satisfy the organization's resources constraints (Ghasemzadeh & Archer, 2000) and external constraints (market regulation, laws, and others). This involves solving the problem of project portfolio selection.

To do this, several techniques exist: numeric and non-numeric methods (Mantel et al., 2011) and linear and nonlinear optimization methods for mono-objective and multi-objective problems. Each company must choose the model that best reflects its maturity level (Hugo and Caballero, 2012).

## 2.2 Linear Optimization

In mathematical optimization, a linear optimization (LO) problem is an optimization problem in which we minimize (or maximize) a linear function on a convex polyhedron. Linear functions can describe the function that we minimize (or maximize) and constraints. LO is the discipline that studies these problems; it is also known as linear programming, a term introduced by George Dantzig in 1947, but this name tends to be avoided because of possible confusion with the concept of computer programming.

## 2.3 Integer Linear Programming

Many problems of operational research can be expressed as LO problems. These problems also appear as subproblems in algorithms designed to solve more complex problems. Some LO problems require variables that take only integer values (so-called integrity constraints) or even the values 0 or 1. Then, we are talking about Integer Linear Programming (ILP). These problems are much more challenging to solve than the LO continuous variables. An ILP problem is not an LO problem in the sense that its admissible domain is not a polyhedron but a discrete set of points. However, it can be described as a problem of OL, which adds the additional constraints that some variables can only take integer values. We distinguish between mixed-ILP with integer and continuous variables and the integer problem with all integer variables.

## 2.4 Goal Programming

Goal Programming (GP) is a branch of combinatorial optimization (Wolsey & Nemhauser, 1999), whose particularity is to try to optimize several objectives simultaneously on the same problem (against a single objective in LO and ILP). The idea for this method was introduced initially by Charnes and Cooper (1961). They presented an approach to solving linear decision problems with multiple objective functions. This method has been extended by Ijiri's (1965) work and Ignizio's (1976) work to solve nonlinear problems. Their method has been used in several theoretical and practical work (Chankong & Hamies, 1983; Martel & Aouni, 1998; Spronk, 1981; Steuer, 1985) based on the following assumptions:

- Pre-assign weights (or priorities) to goals or targets groups
- Set values of positive and negative deviations
- Minimize the weighted sum of these deviations

## 2.5 Integer Goal Programming

In the Integer Goal Programming (IGP) method, the same principle applies, except the solution definition domain; we add the additional constraints that the variables can take only integer values or even the two values 0 or 1, depending on the nature of the problem, in which case it is called 0-1 Goal programming (Tripathy & Biswal, 2007)". This current research paper used this method.

Recently, Mohagheghi et al. (2019) presented a comprehensive review of project portfolio selection and optimization studies focusing on the evaluation criteria, selection approach, solution approach, uncertainty modeling, and applications. This study reviews more than 140 papers on the project portfolio selection research topic to identify the gaps and present and future trends. The

findings show that the financial criteria and social and environmental aspects of project portfolios have been foci for research in project portfolio selection in recent years. Also, meta-heuristics and heuristics approaches to finding the solution of mathematical models have been critical research by scholars. For more references see Parth (2017), Budak and Ustundag (2021), and Olson (2017).

### 3. PROJECT PORTFOLIO SELECTION OPTIMIZATION

#### 3.1. Methodology

A Multi-Criteria Mathematical Programming Technique (e.g., Goal Programming) is used with multiple goals and priorities to find an Optimal Portfolio of Projects. And given the following model input,

an Optimal Portfolio of Projects is found that satisfies the selection criteria stated below and also that would generate the output specified later in this paper.

##### 3.1.1 Model Input

As it was stated earlier, the focus of the paper is on Stage II, the project portfolio selection, and as such, the input to the model would be the output from Stage I. The following parameters are required:

- The project assessments in quantitative values:
- Project is already active or not started yet
- The start and end date for each project
- Project environmental sustainability ranking
- Project financial analysis results (including the annual budget available for each project)
- Project economic analysis results in economic benefits
- Project risk assessment results
- The project type (Tactical project, Enabler project, or Operational project)
- If the project is Enabler, which projects depend on its completion
- The prerequisite projects that are required to be completed before the given project should start
- The contributions of the project to each indicator in term of increasing the percentile of the indicators
- The weight (importance of each index)
- The priority of each index

##### 3.1.2 Selection Criteria

1. All active projects that are vision-related will be included in the portfolio automatically. Still, their contributions to the indicators will be added only if they will be completed before the end of March 2025.
2. All Enabler projects will be added if they are a prerequisite for vision-related Tactical or Operational project(s).
3. Tactical projects should take the highest weights and priorities and select a set of these projects with maximum total contributions to their corresponding indicators. The projects with minimum costs and less completion time can be considered to have less weight and priority.
4. Operational projects should take the lowest weights and priorities and select a set of these projects that have maximum total contributions to their corresponding indicators. The projects with minimum costs and less completion time can be considered to have less weight and priority.
5. The annual portfolio costs should not exceed the available annual budget.

### 3.1.3 The Outputs

1. The Optimal Portfolio of Selected Projects
2. How much did the Optimal Portfolio satisfy the main objective for each of the 19 indices?
3. Which indicators need more future projects and what much room is there for improvement (strategic direction)?

## 3.2 Goal Programming Project Portfolio Selection Formulation

### 3.2.1. The Mathematical Model

In this section, we describe the goal linear programming model that is applied to the portfolio selection of projects submitted with regards to the strategic directions in Kuwait's development plan. An overview of goal linear programming model formulation is given first (see any Operations Research Textbook or Al-Husain et al., 2011; Al-Qaheri & Hasan, 2010; Al-Qaheri et al., 2011; Hasan et al., 2010; Wu et al., 2017), followed by a detailed description of the specific model related to the application in hand, and finally, input data required for this application are presented.

## 3.3 General Goal Linear Programming Model Formulation

A goal is the desired result. It may be underachieved, fully achieved, or overachieved, and relative emphasis applied through managerial action contributes to the degree of goal achievement. Symbolically, 1 unit of effort applied to activity  $x_j$  might contribute an amount  $a_{ij}$  toward the achievement of the  $i^{\text{th}}$  goal.

The target level for the  $i^{\text{th}}$  goal,  $b_i$ , is fully achieved if

$$\sum_{j=1}^n a_{ij}x_j = b_i$$

To allow for underachievement or overachievement, let

$d_i^-$  = negative deviation from the  $i^{\text{th}}$  goal (underachievement)

$d_i^+$  = positive deviation from the  $i^{\text{th}}$  goal (overachievement)

From this, for the  $i^{\text{th}}$  can be stated in general terms as

$$\sum_{j=1}^n a_{ij}x_j + d_i^- - d_i^+ = b_i = 1, 2, \dots, m$$

It is required that one or both of the deviational variables ( $d_i^-, d_i^+$ ) be zero in the solution since both underachievement and overachievement can't occur at the same time.

The goal programming model must be able to incorporate goal attendants with both ranking and weighting as appropriate. Let

$P_k$  = Ranking coefficient for all deviations having  $k^{\text{th}}$  priority of being avoided

$w_{ik}^-$  = Relative weight of the  $d_i^-$  in the  $k^{\text{th}}$  rank

$w_{ik}^+$  = Relative weight of the  $d_i^+$  in the  $k^{\text{th}}$  rank

With  $m$  goals, the goal linear programming model may be formulated mathematically as requiring the minimization of the linear weighted ranking function

$$\sum_{i=1}^m \sum_k P_k (w_{ik}^- d_i^- + w_{ik}^+ d_i^+)$$

Subject to the linear constraints

$$\sum_{j=1}^n a_{ij} x_j + d_i^- - d_i^+ = b_i \quad i = 1, 2, \dots, m$$

$$x_j, d_i^-, d_i^+ \geq 0 \quad i = 1, 2, \dots, m, j = 1, 2, \dots, n$$

Goal programming seeks a satisfactory level of goal attainment that represents the best possible overall outcome. This aim can be realized if several goals are stated and formulated mathematically to permit appropriate consideration in the goal programming model. Therefore, the decision-maker must determine which goals are the most important and assign an ordinal value (priority),  $P_k$ , to each goal or group of goals. Further, within a given goal, there may be sub-goals of unequal importance that must be given different weights,  $w_{ik}^-$ ,  $w_{ik}^+$ .

Solving any goal programming model involves achieving the highest priority goal, first, before any of the lower priority goals are considered. Once the highest priority goal is attained to the fullest extent possible, the goal programming model proceeds to find a satisfactory level to the next highest priority goal, and so on. However, it is not always possible to achieve every goal to the extent desired by the decision-maker. But the advantage of goal linear programming over ordinary linear programming is that it seeks, within the given set of constraints, to minimize the deviation from the established goal's targets. In contrast, ordinary linear programming seeks to minimize or maximize certain goals directly.

### 3.3.1 Notations

$c$  : The project category: Enabler ( $E$ ), Tactical ( $T$ ) or Operational ( $O$ ) project

$C$  : The set of all project categories  $C = \{E, T, O\}$  i.e.  $c \in C$ .

$j_c$  : Index for project  $j$  in category  $c$

$J_c$  : The set of all project available to be selected in the portfolio in category  $c$  i.e.  $j_c \in J_c$

$J$  : The set of all project available to be selected in the portfolio i.e.  $J_c \in J$

$R_{j_E}$  : The set of all projects where the Enabler project  $j_E$  is a prerequisite for them

$i$  : Index for goal  $i$  that should test for achievement

$I$  : The set of all goals that should test for achievements i.e.  $i \in I$

The starting period in month of project  $j_c$ ,  $t_{j_c} = 1, 2, \dots, f_{j_c}$ , where  $f_{j_c}$  is the end period in month of the project  $j_c$  that does not exceed March 31, 2025

$F_{j_c}$  : The set of all  $f_{j_c}$

$AL$  : The set of all active projects that their  $f_{j_c}$  does not exceed March 31, 2025

$NAL$  : The total number of AL projects

$AG$  : The set of all active projects that their  $f_{j_c}$  exceeds March 31, 2025

$NAG$  : The total number of AG projects

$z_{j_c}$  : Global Plan Index for project  $j_c$

$Z$  : The set of all  $z_{j_c}$   $Z_{j_c}$  to

$ycost_{j_c,y}$  : The cost of project  $j_c$  for year  $y = 1, 2, \dots, 5$

$budget_y$  : The total annual budget available for year  $y = 1, 2, \dots, 5$

$y_{z_{j_c}}$  : Index of project indicator  $y$  that belong to project index  $z_{j_c}$

$Y_{z_{j_c}}$  : The set of all  $y_{z_{j_c}}$

$b_{y_{z_{j_c}}}$  : The contributions for the project  $j_c$  to each indicator  $y_{z_{j_c}}$  : in terms of increasing the percentile of the indicators

$d_i^-$  = Negative deviation from the  $i^{th}$  goal (underachievement)

$d_i^+$  = Positive deviation from the  $i^{th}$  goal (overachievement)

$k$  = Index for priority

$P_k$  = Ranking coefficient for all deviations having  $k^{th}$  priority of being avoided

$w_{ik}^-$  = Relative weight of the  $d_i^-$  in the  $k^{th}$  rank

$w_{ik}^+$  = Relative weight of the  $d_i^+$  in the  $k^{th}$  rank

The decision variables:

$X_{j_c,y_{z_{j_c}},t_{j_c}} = 1$  If project  $j$  of category  $c$  that have indicator  $y_{z_j}$  and start at time  $t_j$  is selected to be in the portfolio

$X_{j_c,y_{z_{j_c}},t_{j_c}} = 0$  Otherwise

### 3.3.2. Goal 1

All active projects that are vision-related will be included in the portfolio automatically. Still, their contributions to the indicators will be added only if they will be completed before the end of March 2025. This has a priority ,

$$X_{j_c,y_{z_{j_c}},t_{j_c}} + d_1^- - d_1^+ = 1 \forall j_c \in ALandc \in C \quad (1)$$

and the objective is to minimize both of  $d_1^-$  and  $d_1^+$  .

### 3.3.3. Goal 2

All Enabler projects will be added in the portfolio if they are a prerequisite for vision-related Tactical or Operational project(s). This has a priority  $P_1$  ,

$$X_{j_E,y_{z_{j_E}},t_{j_E}} + d_2^- - d_2^+ = 1 \forall j_E \text{ where } R_{j_E} \neq \emptyset . \quad (2)$$

d the objective is to minimize both of  $d_2^-$  and  $d_2^+$  .



### 3.3.4. Goal 3

Tactical projects should take the highest weights and priorities and select a set of these projects with maximum total contributions to their corresponding indicators. This has a priority  $P_2$ ,

$$\Sigma c \in Tb_{yz_{jc}} X_{jcyz_{jc}} + d_3^- - d_3^+ = M_1 \quad (3)$$

where  $M_1$  should exceed the maximum total contributions of tactical projects to their corresponding indicators, and the objective is to minimize  $d_3^-$  with  $w_{32}^-$  taking the highest weight.

### 3.3.5. Goal 4

Tactical projects with minimum costs for these projects can be considered to have less weight and priority. This has a priority  $P_3$

$$\Sigma yEc \in T^{ycost} jcyX_{jcyz_{jc}} + d_4^- - d_4^+ = M_2 \quad (4)$$

where  $M_2$  should not exceed the maximum total costs of tactical projects, and the objective is to minimize  $d_4^+$  with  $w_{43}^+ < w_{32}^-$ .

### 3.3.6. Goal 5

Tactical projects with less completion time for these projects can be considered to have less weight and priority. This has a priority  $P_4$ ,

$$\Sigma c \in Tf_{jc} X_{jcyz_{jc}} + d_5^- - d_5^+ = M_3 \quad (5)$$

where  $M_3$  should not exceed the maximum total completion times of tactical projects, and the objective is to minimize  $d_5^+$  with  $w_{54}^+ < w_{43}^+$ .

### 3.3.7. Goal 6

Operational projects should take the highest weight and priority and select a set of these projects that have maximum total contributions to their corresponding indicators. This has a priority  $P_5$ ,

$$\Sigma c \in ob_{yz_{jc}} X_{jcyz_{jc}} + d_6^- - d_6^+ = M_4 \quad (6)$$

where  $M_4$  should exceed the maximum total contributions of operational projects to their corresponding indicators, and the objective is to minimize  $d_6^-$  with  $w_{65}^- < w_{54}^+$  taking the highest weight.

### 3.3.8. Goal 7

Operational projects with minimum costs for these projects can be considered to have less weight and priority. This has a priority  $P_6$ ,

$$\sum y \sum c \in o^{y \cos t_{jcy}} X_{jcyz^{j_c}} + d_7^- - d_7^+ = M_5 \quad (7)$$

where  $M_5$  should not exceed the maximum total costs of operational projects, and the objective is to minimize  $d_7^+$  with  $w_{76}^+ < w_{65}^-$ .

### 3.3.9. Goal 8

Operational projects with less completion time for these projects can be considered to have less weight and priority. This has a priority  $P_7$ ,

$$\sum_{c \in T} f_{j_c} X_{j_c y z_{j_c} t_{j_c}} + d_8^- - d_8^+ = M_6 \quad (8)$$

where  $M_6$  should not exceed the maximum total completion times of operational projects, and the objective is to minimize  $d_8^+$  with  $w_{87}^+ < w_{76}^+$ .

### 3.3.10. Goal 9

The annual portfolio costs should not exceed the total annual available budget for each year. This has a priority  $P_8$ , and the objective is to minimize  $d_{8+y}^+$ .

$$\sum_{j_c} (y \text{cost}_{j_c y} - \text{budget}_y) X_{j_c y z_{j_c} t_{j_c}} - d_{8+y}^+ = 0 \text{ for } y = 1, 2, 3, 4, 5 \quad (9)$$

### 3.3.11. Goal 10

The selected projects portfolio should reduce the average of the Global Indices to 30 by the end of year 2020.

$$\frac{\sum z_{j_c} \in z \sum y z_{j_c} \in z_{j_c} \text{ by } z_{j_c} X_{j_c y z_{j_c} t_{j_c}}}{|z|} + d_{14}^- - d_{14}^+ = 30 \quad (10)$$

This has a priority  $P_9$  and the objective is to minimize  $d_{14}^+$ .

### 3.3.12. The Goal Programming (GP) Model

$$\text{Minimize } P_1(d_1^- + d_1^+ + d_2^- + d_2^+) + P_2 w_{32}^- d_3^- + P_3 w_{43}^+ d_4^+ + P_4 w_{54}^+ d_5^+ + P_5 w_{65}^- d_6^- + P_6 w_{76}^+ d_7^+ + P_7 w_{87}^+ d_8^+ + P_8 \sum_{y=1}^{y=5} d_{8+y}^+$$

+  $P_9 d_{14}^+$   
 subject to :

$$X_{j_c y z_{j_c} t_{j_c}} + d_1^- - d_1^+ = 1 \forall j_c \in AL \text{ and } c \in C$$

$$X_{j_E y z_{j_E} t_{j_E}} + d_2^- - d_2^+ = 1 \forall j_E \text{ where } R_{j_E} \neq \emptyset$$

$$\sum_{c \in T} b_{y_{z_j c}} X_{j_c y_{z_j c} t_{j_c}} + d_3^- - d_3^+ = M_1$$

$$\sum_y \sum_{c \in T} y_{c \text{ cost}} X_{j_c y_{z_j c} t_{j_c}} + d_4^- - d_4^+ = M_2$$

$$\sum_{c \in T} f_{j_c} X_{j_c y_{z_j c} t_{j_c}} + d_5^- - d_5^+ = M_3$$

$$\sum_{c \in O} b_{y_{z_j c}} X_{j_c y_{z_j c} t_{j_c}} + d_6^- - d_6^+ = M_4$$

$$\sum_y \sum_{c \in O} y_{c \text{ cost}} X_{j_c y_{z_j c} t_{j_c}} + d_7^- - d_7^+ = M_5$$

$$\sum_{c \in T} f_{j_c} X_{j_c y_{z_j c} t_{j_c}} + d_8^- - d_8^+ = M_6$$

$$\sum_{j_c} (y_{c \text{ cost}} - \text{budget}_y) X_{j_c y_{z_j c} t_{j_c}} - d_{8+y}^+ = 0 \text{ for } y = 1, 2, 3, 4, 5$$

$$\frac{\sum_{z_{j_c} \in Z} \sum_{y_{z_j c} \in z_{j_c}} b_{y_{z_j c}} X_{j_c y_{z_j c} t_{j_c}}}{|Z|} + d_{14}^- - d_{14}^+ = 30$$

$$X_{j_c y_{z_j c} t_{j_c}} = \begin{cases} 1 \\ 0 \end{cases} \forall j_c$$

$$d_i^-, d_i^+ \geq 0 \text{ for } i = 1, 2, \dots, 14$$

#### 4. INPUT DATA AND MODEL DEVELOPMENT

An Excel file was developed from all data input included in the Kuwait Mid-Range Development Plan 2015/2016–2019/2020. And to test the previous Binary Mixed Goal Programming Model (BMGPM), we assumed values for all the model requirements. We ran the model in two ways. First, the model was run using an Excel built-in Frontline Solver, which requires an Excel datasheet. Then we developed another representation of the model using Frontline RASON, a high-level, declarative modeling language embedded in JSON (JavaScript Object Notation), the popular structured format widely used in Web and mobile applications. This representation does not require input from an Excel datasheet but inputs data from any source, such as a text data file, data from a database, and data from an Excel datasheet.

#### 5. MODEL RESULTS AND ANALYSIS

Factitious data were used to validate the model to understand that when real data are available the model should provide valid results. Both model representations, the Excel-based and the RASON formulation mentioned above, and their solvers, generated identical results. And the generated results satisfied all the goals of the model and produced an optimum portfolio of projects.

Table 3 in the Appendix shows all the projects and key information represented as columns in the table. For example, a value of 1 in the Project Selection column indicates that the project is selected in

the portfolio, and 0 means the project is not selected. The table shows that the best portfolio includes the following projects:

- a) **Tactical projects:** 9 projects (projects IDs T3, T4, T6, T8, T9-T12, and T15) are selected out of a total of 17 Tactical projects.
- b) **Enabler projects:** All the 19 Enabler projects are selected.
- c) **Operational projects:** 64 projects (O1-O64) are selected out of a total of 88 Operational projects.

The total project portfolio contributions (decrease percentile) is 6.42.

Table 4 in the Appendix shows that Goal 1 and Goal 2 are satisfied for selected projects where all  $d_1^-, d_1^+$  and  $d_2^-, d_2^+$  are equal to zeros, as we want them to be minimized, and their priority  $P_1$  is satisfied in Table 7.

Table 5 shows Goals 3 to 8 are satisfied, as they stated in the model description where the level is the value of the left-hand side (LHS) of the goal (the part before the negative and/or positive deviations). The Project Goal is the right-hand side (RHS) of the goal. All the positive or negative deviations that should be minimized are equal to zero, and the values of the weights for the goals are  $w_{32}^- = 100$ ,  $w_{43}^+ = 80$ ,  $w_{54}^- = 70$ ,  $w_{65}^- = 60$ ,  $w_{76}^- = 50$ , and  $w_{87}^+ = 40$ , which satisfied the conditions:  $w_{32}^-$  take highest weight for goal 3,  $w_{43}^+ < w_{32}^-$  for goal 4,  $w_{54}^- < w_{43}^+$  for goal 5,  $w_{65}^- < w_{54}^-$  for goal 6,  $w_{76}^- < w_{65}^-$  for goal 7, and  $w_{87}^+ < w_{76}^-$  for goal 8. The priority  $P_2 - P_7$  is for Goals 3 through 8 are satisfied in Table 7.

Table 6 in the Appendix shows that Goal 9 for years 1–5 are all satisfied where the positive deviations (amount over) are all zeros. It is to be noted that level = 0, in year 1, means that the total cost equals to the total budget for this year (which is true) and their priority  $P_8$  is satisfied in Table 7.

Table 6 also shows the result of Goal 10 and their priority  $P_9$  is not satisfied and have a value of 2.1 (as shown in Table 7) percentile as over deviation  $d_{14}^+$  that should be zero in the objective function.

Table 9 shows the average of the Global Indices is 51.39 and the average of the contribution to index improvement is 32.1 excluding indices 4 and 18 as no projects were assigned to these two indices.

It must also be emphasized that this index improvement is for 2020 and not for 2025 as the situation for the next 5-year plan (2021-2025) would be different in terms of assigning projects to the Global Indices.

Table 7 shows that all priorities  $P_1 - P_8$  are satisfied with the total value of the objective function is equal to zero for  $P_9$  ( $P_9 = 2.1$  which means that this goal is not satisfied as mentioned above).

Table 8 in the Appendix shows each index, the projects assigned to it, project code, project selection status (1 selected, 0 not selected), and the improvement (project percentile improvement). The totals for each index are also shown. For example, for Index 1 there are 4 projects, 3 projects, and the total improvement to the index percentile is 15. It should be clarified, as it was indicated at the beginning of the paper, that each index consists of multiple indicators and projects are assigned to one or more indicators of the index. So, in reality, the percentile improvement of each project is an improvement of the indicator's percentile. The average improved percentile of all indicators of the index becomes the improved percentile of the index.

Table 9 summarizes and provides extra information as follows:

1. The Contribution to Index Improvement means the total project portfolio contribution to the index.

2. The Percentage of Improvement is the Contribution to Index Improvement divided by the Index Percentile.
3. The New Percentile is generated by subtracting the Contribution to Index Improvement from the Index Percentile.
4. The improvement Required per Plan is generated by dividing 20 by 4. The 20 refers to the percentage needed to improve the global indices by 2035 (the end of the 4<sup>th</sup> development plan), and the 4 refers to the number of plans (during the period 2015 to 2035). And the average for the 4 plans during this period is 5 percent.
5. The Average Per Plan is generated by dividing improvement Required per Plan by the Index Percentile.
6. Over/Under Achievement is computed by subtracting the Avg Per Plan from the Percentage of Improvement.

So, for example, Index 1's percentile is 40, 4 projects were assigned to this index, and only 3 were selected. The total improvement of the selected projects is 15, a 38% improvement, which leads to a new index percentile of 25, an improvement of 15 points, which is 10 points improvement over the required 5 points. The objective is to improve this index by 5, however, for the selected project portfolio does not include projects for two of the indices, 4 and 18, as projects were not assigned to these.

Table 10 shows the fictitious cost and budget available data for goals 4, 6, 7, and 9.

## 6. CONCLUSION AND FUTURE RESEARCH

In vision-driven development plans, such as the Kuwait Mid-Range Development Plan 2015/2016–2019/2020, themes and pillars are derived from the plan's vision, and global indices by international organizations are assigned by international organizations to accurately measure the performance against the vision's themes. This allows for comparison with other countries and also set targets for progression over time. One or more projects are assigned to the indicators of these global indices. A Multi-Criteria Mathematical Programming Technique (e.g., Goal Programming) is used, with multiple goals and priorities, where an Optimal Portfolio of Projects is found that satisfied the selection criteria. Two models were developed using an Excel built-in Frontline Solver and Frontline RASON, a high-level, declarative modeling language. The models were tested using fictitious data. Both models generated identical optimum projects portfolios that lead to the significant improvement of the global indices the projects were assigned to.

As a complementary project to this paper, future research would be to implement Stage I (as shown in Figure 1 above) and create a system that integrates Stage I and II. And another future research project would be to create a Decision Support System (DSS), encoding Frontline RASON code for testing and validating different scenarios using real data. Another future research is to create a Plan Simulator to explore the impact of the selected projects on the Global Indices of the 5-year plan before the plan approval and its actual implementation.

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## APPENDIX

Table 1. Global indices

#	Index	Current Percentile	Source
1	Ethical government index *	40	World Economic Forum "Global Competitiveness Report", 2014–15
2	Effective policymaking index*	61	World Economic Forum "Global Competitiveness Report", 2014–15
3	Ease of doing business index	51	World Bank, 2014
4	Government spending index*	55	World Bank, 2011–2013 Business Monitor International, 2011–2014 Economic and social commission for Western Asia "National accounts studies of the Arab region" report, 2013
5	Business sophistication index	53	World Economic Forum "Global Competitiveness Report", 2014–15
6	Labor market performance index*	40	World Economic Forum "Global Competitiveness Report", 2014–15 United Nations Development Program, 2013
7	Exports of goods & services index*	49	United Nations conference on Trade and Development (UNCTAD), 2013–14
8	Government ICT usage index*	67	World Economic Forum "Global Information Technology Report", 2014
9	Logistics performance index	38	World Bank "Logistics Performance Index report", 2014
10	Quality of transport infrastructure*	53	World Economic Forum "Global Competitiveness Report", 2014–15
11	Cross-border traffic flow index	49	World Bank, 2013–14
12	Resource & energy use index*	78	World oil and gas review, 2014; World Bank, 2010–13; International Energy statistics, 2012
13	Average time to obtain public housing	20 years	Public Authority for Housing Welfare, to be internally calculated
14	Environment performance index	43	Environment Performance Index, 2014 (Yale Center for Environmental Law & Policy)
15	Healthcare quality index*	54	International Diabetes Federation, Atlas 6th edition (2014 update) World Economic Forum "Global Competitiveness Report", 2014–15 World Health Organization "Globocan Report", 2012
16	Workforce readiness index*	65	World Economic Forum "Global Competitiveness Report", 2014–15 World Economic Forum "Human Capital Report", 2014–15
17	Education quality index*	69	World Economic Forum "Global Competitiveness Report", 2014–15
18	Global peace index	17	Institute for Economics and Peace, 2014
19	Net inflows of FDI's*	36	World Bank, 2013
20	International relations index*	59	Henley & Partners, 2014 Bloom Consulting "Country Brand Ranking Report", 2014–15

\*Composite indices calculated as a composition of various indicators based on international sources.



Table 2. The themes and pillars matrix and the global indices

Themes	Citizen participation & respect of the law	Effective & transparent govt	Prosperous & diversified economy	Nurturing & cohesive society	Globally relevant & influential player
<b>1 Administration</b>	1 Ethical government index	2 Effective policy making index 4 Government spending index	3 Ease of doing business index		
<b>2 Economy</b>			5 Business sophistication index	6 Labour market performance index	7 Exports of goods & services index
<b>3 Infrastructure</b>		8 Government ICT usage index	9 Logistics Performance Index	10 Quality of infrastructure (air/port/rail/roads)	11 Cross-border traffic flow index
<b>4 Living environment</b>		12 Resource & energy use index	13 Average time to obtain public housing	14 Environment performance index	
<b>5 Healthcare</b>				15 Healthcare quality index	
<b>6 Education &amp; Human capital</b>			16 Workforce readiness index	17 Education quality index	
<b>7 International positioning</b>	18 Global peace index		19 Net inflows of FDI's		20 International relations index

Source: Kuwait Mid-Range Development Plan –2015/2016–2019/2020 Working Draft, [https://www.scpd.gov.kw/archive/20150708%20Revamped%20KDP\\_PDF%20version\\_EN.pdf](https://www.scpd.gov.kw/archive/20150708%20Revamped%20KDP_PDF%20version_EN.pdf)

Table 3. The projects selection

Project	Project Code	Name	Project Type	Project Selection	Total Project Contributions	Portfolio Contributions
			(E, T, O)			
1	T1	Revamp of coop societies system	T	0	1	0
2	T2	Create an incubator for small and medium enterprises	T	0	5	0
3	T3	Develop Boubyan Island and Silk City (consultancy study only)	T	1	5	5
4	T4	Expansion in the creation and development of free zones in Kuwait	T	1	2	2
5	T5	Unions cities project - 6 cities	T	0	6	0
6	T6	Public warehouses and border crossings company (Abdali)	T	1	3	3
7	T7	Design and implement the e-Kuwait project	T	1	10	10
8	T8	Railway project	T	1	4	4
9	T9	Metro project	T	1	2	2
10	T10	Mubarak Al-Kabeer port	T	1	8	8
11	T11	Enriching local fisheries through information management and developing techniques	T	1	6	6
12	T12	Hospitals health insurance company	T	1	8	8
13	T13	Develop and implement a training program for Kuwaiti professionals	T	1	15	15
14	T14	Establishment of the national employment development center	T	0	5	0
15	T15	Sabah Al-Salem University project	T	1	2	2
16	T16	Determine the work of disciplines offered by private universities and colleges market needs	T	0	8	0
17	T17	Improve standards for learning in Kuwait for teachers, curricula, and management	T	1	7	7
18	E1	Reform of the financial management of the state	E	1	4	4
19	E2	Strategy preparation of a national integrity, transparency, and anti-corruption strategy	E	1	6	6
20	E3	Activating and developing legislative frameworks and institutional mechanisms in line with international conventions	E	1	9	9
21	E4	North Zour station - phase ii	E	1	8	8
22	E5	Al-Khairan power station and water distillation plant - phase i	E	1	5	5
23	E6	Establishment and operation power generation plants (Abdaliyah)	E	1	3	3
24	E7	Establish mechanisms to maintain the rights of migrant workers	E	1	3	3
25	E8	Create organization communications and information technology commission	E	1	7	7
26	E9	Create transport regulatory authority	E	1	5	5
27	E10	Improve roads infrastructure	E	1	4	4
28	E11	Implementation of the master plan of the state	E	1	6	6

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Table 3. Continued

Project	Project Code	Name	Project Type	Project Selection	Total Project Contributions	Portfolio Contributions
			(E, T, O)			
29	E12	Healthy cities initiative	E	1	6	6
30	E13	Health promotion	E	1	4	4
31	E14	Measuring patient satisfaction and dealing with the health services	E	1	1	1
32	E15	Change concepts and values of work in the private sector	E	1	6	6
33	E16	Study "mesa advantage" to measure and evaluate the education system	E	1	5	5
34	E17	Linking embassies to issue a visa from abroad	E	1	6	6
35	E18	Enforce legislative requirements of vision and development plan	E	1	1	1
36	E19	Building integrated legislative framework for environmental management	E	1	1	1
37	O1	Adoption and implementation of sound corporate governance standards by the units of the banking and financial system, which would contribute to the consolidation of the basic ingredients for the durability of the financial centers of these units and to improve the efficiency of their performance and achieve financial stability	O	1	5	5
38	O2	Establish authority of manpower project management office	O	1	3	3
39	O3	Develop capabilities	O	1	6	6
40	O4	Zour refinery project	O	1	9	9
41	O5	Industrial Strategy for the State of Kuwait in 2035 draft	O	1	7	7
42	O6	Design and construction of the city's technical research and services, petroleum and petrochemical technology	O	1	13	13
43	O7	The establishment of the Petroleum Research Center continued KPC	O	1	11	11
44	O8	Automating licenses commercial services	O	1	1	1
45	O9	Reconstruction of the 5 centers of commercial licenses (Mansuriya - Around Me - Khaitan - Back - Jahra)	O	1	6	6
46	O10	Support cooperation between the research and development, production, and service sectors of the private sector and state institutions	O	1	4	4
47	O11	The contribution of scientific research and development institutions in support of plans and programs of technological development in Kuwaiti private sector	O	1	2	2
48	O12	Technological Center for Intellectual Property	O	1	10	10
49	O13	Empowerment of women in community development	O	1	5	5
50	O14	Training center, studies, and Research on Women	O	1	8	8
51	O15	Craft skills and economic development for Kuwaiti women	O	1	4	4

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Table 3. Continued

Project	Project Code	Name	Project Type	Project Selection	Total Project Contributions	Portfolio Contributions
			(E, T, O)			
52	O16	Building new reservoirs North LNG Mina Al-Ahmadi refinery	O	1	4	4
53	O17	Project olefins and aromatics second third is integrated with Al-Zour refinery	O	1	8	8
54	O18	Enhance the export capacity of industrial plants exportable cooperation with international organizations	O	1	5	5
55	O19	The creation, delivery, and operation and maintenance of the infrastructure of the industrial zone Shedadiya	O	1	2	2
56	O20	And implementation of the national plan for business continuity and disaster management mode	O	1	6	6
57	O21	Automation of procedures in the management of public services	O	1	9	9
58	O22	Project update databases and information systems and the development of statistical information system of civil services	O	1	6	6
59	O23	The geographical spread of the card delivery devices and devices version and prompt delivery of the card through a subsidiary body of the centers in all provinces	O	1	4	4
60	O24	To facilitate customs procedures Aljmarkih- mall study	O	1	7	7
61	O25	Deepening the waterway between the Earth and the head of the island of Failaka and deepen the port of transportation on the island	O	1	4	4
62	O26	Build liquefied gas tankers to load 58 tons meters per inhabitant carrier (VLGC)	O	1	10	10
63	O27	Reload systems and infrastructure for ports, Kuwait	O	1	12	12
64	O28	The development of the eastern runway airport and the establishment of the third runway	O	1	5	5
65	O29	The development of the eastern runway at the international airport	O	1	8	8
66	O30	The new air traffic control tower	O	1	7	7
67	O31	Kuwait Airport expansion project Terminal (2)	O	1	5	5
68	O32	Determine the overall strategies of the Kuwaiti ports and ports of Business Development	O	1	8	8
69	O33	Increase the depth and width of the navigation channel of the port of Shuwaikh	O	1	6	6
70	O34	Supply, installation, and maintenance of electricity and water meter system with electronic automatic meter reading and data collection system	O	1	9	9
71	O35	Supply, installation, and operation of photovoltaic panels on the roofs of government buildings	O	1	7	7
72	O36	Al-Khairan city project	O	1	5	5
73	O37	Al-Matla city project - design	O	1	3	3
74	O38	Low-cost-housing company	O	1	7	7

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Table 3. Continued

Project	Project Code	Name	Project Type	Project Selection	Total Project Contributions	Portfolio Contributions
			(E, T, O)			
75	O39	Provide housing units (4 projects)	O	1	6	6
76	O40	Environmental control system	O	1	8	8
77	O41	Design and construction of the power plant from renewable sources facilities (with a capacity of 75–100 MW)	O	1	9	9
78	O42	Electric power generation from renewable sources station (with a capacity of 75–100 MW)	O	1	8	8
79	O43	Study and evaluation of the implementation of pilot specialized research station to develop advanced technology for water desalination and renewable energy	O	1	3	3
80	O44	Study and evaluation of the typical specialized research station to develop advanced technology for water desalination and renewable energy	O	1	2	2
81	O45	Environmental fuel project	O	1	4	4
82	O46	Development of health services for school project	O	1	6	6
83	O47	Prevention and response to chronic non-communicable diseases	O	1	5	5
84	O48	Project activating the role of health information	O	1	4	4
85	O49	Support the role of the private sector in the field of health project	O	1	8	8
86	O50	The development of occupational health services	O	1	7	7
87	O51	The development of primary health care services project	O	1	9	9
88	O52	Build public sports centers / facilities (4 projects)	O	1	5	5
89	O53	Encourage and motivate the practice of sport in society	O	1	2	2
90	O54	Sport support schools, colleges, and universities	O	1	1	1
91	O55	Ambulance Center's main hospital building in Jahra	O	1	6	6
92	O56	Children's Hospital building in Mubarak Al-Kabeer	O	1	3	3
93	O57	Improve quality of health services in Kuwait (2 projects)	O	1	4	4
94	O58	New building Adan Hospital	O	1	8	8
95	O59	New building Amiri Hospital	O	1	7	7
6	O60	New building Ibn Sina Hospital	O	1	5	5
97	O61	New building Razi Hospital	O	1	2	2
98	O62	New buildings Farwaniya Hospital	O	1	4	4
99	O63	New Morning Hospital	O	1	6	6
100	O64	Project to ensure the safety of patients	O	1	9	9
101	O65	The development of the blood bank services	O	1	7	7
102	O66	Jaber Al-Ahmad Hospital - South Surra	O	1	5	5
103	O67	Police Hospital	O	0	4	0

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Table 3. Continued

Project	Project Code	Name	Project Type	Project Selection	Total Project Contributions	Portfolio Contributions
			(E, T, O)			
104	O68	Build rehabilitation center with home-care services	O	0	6	0
105	O69	Take advantage of the training and continuing education capabilities of private universities	O	1	6	6
106	O70	Develop and implement a training program for Kuwaiti professionals	O	0	5	0
107	O71	Training centers, school districts	O	0	8	0
108	O72	Identify and syndicate vocational training needs	O	1	9	9
109	O73	Curriculum Development	O	1	5	5
110	O74	The development of educational and school departments and achieve professional development of leaders and workers in general education and all other types of education	O	1	8	8
111	O75	Support research and development activity in the private universities	O	0	9	0
112	O76	Expansion and development of the Faculty of Dentistry Clinics	O	0	5	0
113	O77	Promotion and development of infrastructure for scientific research at Kuwait University	O	1	4	4
114	O78	Introduce an electronic learning system across educational institutions in Kuwait (5 projects)	O	1	21	21
115	O79	National tests for university admission	O	1	7	7
116	O80	Ensure quality control academic and professional accreditation Authority	O	0	2	0
117	O81	Establishment of vocational skills center	O	1	4	4
118	O82	Kuwait competitive in the international promotion of indicators	O	1	6	6
119	O83	Activating the role of economic diplomacy	O	0	6	0
120	O84	Strengthening the role and efforts of the State of Kuwait in the field of human rights	O	0	5	0
121	O85	Enhance the image of Kuwait internationally through the use of public relations firms	O	1	9	9
122	O86	Exhibitions of Islamic art inside and outside the State of Kuwait	O	0	8	0
123	O87	Cultural and artistic exchange project inside and outside Kuwait	O	1	10	10
124	O88	Publish and distribute Kuwaiti creations outside Kuwait	O	0	2	0
			Sum =	<b>108</b>	<b>730</b>	<b>645</b>

Table 4. Satisfaction of Goals 1 and 2

Project #	Project Type	Project Selection	Level	Relation	Project Goal	Deviations	
						Over	Under
3	T3	1	1	=	1	0	0
4	T4	1	1	=	1	0	0
6	T6	1	1	=	1	0	0
8	T8	1	1	=	1	0	0
9	T9	1	1	=	1	0	0
10	T10	1	1	=	1	0	0
11	T11	1	1	=	1	0	0
12	T12	1	1	=	1	0	0
15	T15	1	1	=	1	0	0
18	E1	1	1	=	1	0	0
19	E2	1	1	=	1	0	0
20	E3	1	1	=	1	0	0
21	E4	1	1	=	1	0	0
22	E5	1	1	=	1	0	0
23	E6	1	1	=	1	0	0
24	E7	1	1	=	1	0	0
25	E8	1	1	=	1	0	0
26	E9	1	1	=	1	0	0
27	E10	1	1	=	1	0	0
28	E11	1	1	=	1	0	0
29	E12	1	1	=	1	0	0
30	E13	1	1	=	1	0	0
31	E14	1	1	=	1	0	0
32	E15	1	1	=	1	0	0
33	E16	1	1	=	1	0	0
34	E17	1	1	=	1	0	0
35	E18	1	1	=	1	0	0
36	E19	1	1	=	1	0	0
37	O1	1	1	=	1	0	0
38	O2	1	1	=	1	0	0
39	O3	1	1	=	1	0	0
40	O4	1	1	=	1	0	0
41	O5	1	1	=	1	0	0
42	O6	1	1	=	1	0	0
43	O7	1	1	=	1	0	0

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Table 4. Continued

Project #	Project Type	Project Selection	Level	Relation	Project Goal	Deviations	
						Amount Over	Amount Under
44	O8	1	1	=	1	0	0
45	O9	1	1	=	1	0	0
46	O10	1	1	=	1	0	0
47	O11	1	1	=	1	0	0
48	O12	1	1	=	1	0	0
49	O13	1	1	=	1	0	0
50	O14	1	1	=	1	0	0
51	O15	1	1	=	1	0	0
52	O16	1	1	=	1	0	0
53	O17	1	1	=	1	0	0
54	O18	1	1	=	1	0	0
55	O19	1	1	=	1	0	0
56	O20	1	1	=	1	0	0
57	O21	1	1	=	1	0	0
58	O22	1	1	=	1	0	0
59	O23	1	1	=	1	0	0
60	O24	1	1	=	1	0	0
61	O25	1	1	=	1	0	0
62	O26	1	1	=	1	0	0
63	O27	1	1	=	1	0	0
64	O28	1	1	=	1	0	0
65	O29	1	1	=	1	0	0
66	O30	1	1	=	1	0	0
67	O31	1	1	=	1	0	0
68	O32	1	1	=	1	0	0
69	O33	1	1	=	1	0	0
70	O34	1	1	=	1	0	0
71	O35	1	1	=	1	0	0
72	O36	1	1	=	1	0	0
73	O37	1	1	=	1	0	0
74	O38	1	1	=	1	0	0
75	O39	1	1	=	1	0	0
76	O40	1	1	=	1	0	0
77	O41	1	1	=	1	0	0
78	O42	1	1	=	1	0	0

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Table 4. Continued

						Deviations	
						Amount	Amount
Project #	Project Type	Project Selection	Level	Relation	Project Goal	Over	Under
79	O43	1	1	=	1	0	0
80	O44	1	1	=	1	0	0
81	O45	1	1	=	1	0	0
82	O46	1	1	=	1	0	0
83	O47	1	1	=	1	0	0
84	O48	1	1	=	1	0	0
85	O49	1	1	=	1	0	0
86	O50	1	1	=	1	0	0
87	O51	1	1	=	1	0	0
88	O52	1	1	=	1	0	0
89	O53	1	1	=	1	0	0
90	O54	1	1	=	1	0	0
91	O55	1	1	=	1	0	0
92	O56	1	1	=	1	0	0
93	O57	1	1	=	1	0	0
94	O58	1	1	=	1	0	0
95	O59	1	1	=	1	0	0
96	O60	1	1	=	1	0	0
97	O61	1	1	=	1	0	0
98	O62	1	1	=	1	0	0
99	O63	1	1	=	1	0	0
100	O64	1	1	=	1	0	0
101	O65	1	1	=	1	0	0
102	O66	1	1	=	1	0	0

Table 5. Satisfaction of Goals 3–8

		M1=	30	Deviations	
<b>Goal 3</b>		<b>100</b>		<b>Amount</b>	<b>Amount</b>
	<b>Level</b>	<b>Relation</b>	<b>Project Goal</b>	<b>Over</b>	<b>Under</b>
	32	>=	30	2	0
		M2=	12,000,000	Deviations	
<b>Goal 4</b>		<b>80</b>		<b>Amount</b>	<b>Amount</b>
	<b>Level</b>	<b>Relation</b>	<b>Project Goal</b>	<b>Over</b>	<b>Under</b>
	11,250,000	<=	12,000,000	0	750,000
		M3=	60	Deviations	
<b>Goal 5</b>		<b>70</b>		<b>Amount</b>	<b>Amount</b>
	<b>Level</b>	<b>Relation</b>	<b>Project Goal</b>	<b>Over</b>	<b>Under</b>
	30	<=	60	0	30
		M4=	83	Deviations	
<b>Goal 6</b>		<b>60</b>		<b>Amount</b>	<b>Amount</b>
	<b>Level</b>	<b>Relation</b>	<b>Project Goal</b>	<b>Over</b>	<b>Under</b>
	89	>=	83	6	0
		M5=	70,000,000.00	Deviations	
<b>Goal 7</b>		<b>50</b>		<b>Amount</b>	<b>Amount</b>
	<b>Level</b>	<b>Relation</b>	<b>Project Goal</b>	<b>Over</b>	<b>Under</b>
	67,250,000.00	<=	70,000,000.00	0	2750000
		M6=	170	Deviations	
<b>Goal 8</b>		<b>40</b>		<b>Amount</b>	<b>Amount</b>
	<b>Level</b>	<b>Relation</b>	<b>Project Goal</b>	<b>Over</b>	<b>Under</b>
	111	<=	170	0	59

Table 6. Satisfaction of Goal 9 for years 1–5 and Goal 10

				Deviations	
Goal 9-Year1				Amount	Amount
	Level	Relation	Project Goal	Over	Under
	0	<=	0	0	0
				Deviations	
Goal 9-Year2				Amount	Amount
	Level	Relation	Project Goal	Over	Under
	-330000	<=	0	0	330000
				Deviations	
Goal 9-Year3				Amount	Amount
	Level	Relation	Project Goal	Over	Under
	-50000	<=	0	0	50000
				Deviations	
Goal 9-Year4				Amount	Amount
	Level	Relation	Project Goal	Over	Under
	-10000	<=	0	0	10000
				Deviations	
Goal 9-Year5				Amount	Amount
	Level	Relation	Project Goal	Over	Under
	-1440000	<=	0	0	1440000
		51.39			Deviations
Goal 10				Amount	Amount
	Level	relation	Project Goal	Over	Under
	32.10	<=	30	2.1	0

Table 7. The objective function for priorities  $P_1 - P_9$

<b>P1</b>	<b>0</b>
<b>P2</b>	<b>0</b>
<b>P3</b>	<b>0</b>
<b>P4</b>	<b>0</b>
<b>P5</b>	<b>0</b>
<b>P6</b>	<b>0</b>
<b>P7</b>	<b>0</b>
<b>P8</b>	<b>0</b>
<b>P9</b>	<b>2.1</b>

Table 8. Project portfolio for each global index

Global Index	Project Code	Project Selection Status	Project Contribution*	Improvement
<b>1</b>				
	<b>T1</b>	<b>0</b>	<b>1</b>	<b>0</b>
	<b>E1</b>	<b>1</b>	<b>4</b>	<b>4</b>
	<b>E2</b>	<b>1</b>	<b>6</b>	<b>6</b>
	<b>O1</b>	<b>1</b>	<b>5</b>	<b>5</b>
	<b>Total</b>	<b>3</b>	<b>16</b>	<b>15</b>
<b>2</b>				
	<b>E3</b>	<b>1</b>	<b>9</b>	<b>9</b>
	<b>O2</b>	<b>1</b>	<b>3</b>	<b>3</b>
	<b>O3</b>	<b>1</b>	<b>6</b>	<b>6</b>
	<b>Total</b>	<b>3</b>	<b>18</b>	<b>18</b>
<b>3</b>				
	<b>E4</b>	<b>1</b>	<b>8</b>	<b>8</b>
	<b>E5</b>	<b>1</b>	<b>5</b>	<b>5</b>
	<b>E6</b>	<b>1</b>	<b>3</b>	<b>3</b>
	<b>Total</b>	<b>3</b>	<b>16</b>	<b>16</b>
<b>4</b>				
	<b>Total</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>5</b>				
	<b>T2</b>	<b>0</b>	<b>5</b>	<b>0</b>
	<b>T3</b>	<b>1</b>	<b>5</b>	<b>5</b>
	<b>T4</b>	<b>1</b>	<b>2</b>	<b>2</b>
	<b>T5</b>	<b>0</b>	<b>6</b>	<b>0</b>
	<b>Total</b>	<b>2</b>	<b>18</b>	<b>7</b>
<b>6</b>				
	<b>E7</b>	<b>1</b>	<b>3</b>	<b>3</b>
	<b>O13</b>	<b>1</b>	<b>5</b>	<b>5</b>
	<b>O14</b>	<b>1</b>	<b>8</b>	<b>8</b>
	<b>O15</b>	<b>1</b>	<b>4</b>	<b>4</b>
	<b>Total</b>	<b>4</b>	<b>20</b>	<b>20</b>
<b>7</b>				
	<b>T6</b>	<b>1</b>	<b>3</b>	<b>3</b>
	<b>O16</b>	<b>1</b>	<b>4</b>	<b>4</b>
	<b>O17</b>	<b>1</b>	<b>8</b>	<b>8</b>
	<b>O18</b>	<b>1</b>	<b>5</b>	<b>5</b>
	<b>O19</b>	<b>1</b>	<b>2</b>	<b>2</b>
	<b>Total</b>	<b>5</b>	<b>22</b>	<b>22</b>

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Table 8. Continued

Global Index	Project Code	Project Selection Status	Project Contribution*	Improvement
8	T7	1	10	10
	T8	1	4	4
	E8	1	7	7
	O20	1	6	6
	O21	1	9	9
	O22	1	6	6
	O23	1	4	4
	Total	7	46	46
	9	E9	1	5
O24		1	7	7
O25		1	4	4
Total		3	16	16
10	T9	1	2	2
	T10	1	8	8
	E10	1	4	4
	O26	1	10	10
	O27	1	12	12
	O28	1	5	5
	O29	1	8	8
	O30	1	7	7
	Total	8	56	56
11	O31	1	5	5
	O32	1	8	8
	O33	1	6	6
	Total	3	19	19
12	O34	1	9	9
	O35	1	7	7
	Total	2	16	16
13	E11	1	6	6

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Table 8. Continued

Global Index	Project Code	Project Selection Status	Project Contribution*	Improvement
	O36	1	5	5
	O37	1	3	3
	O38	1	7	7
	O39	1	6	6
	<b>Total</b>	<b>5</b>	<b>27</b>	<b>27</b>
<b>14</b>				
	T11	1	6	6
	O40	1	8	8
	O41	1	9	9
	O42	1	8	8
	O43	1	3	3
	O44	1	2	2
	O45	1	4	4
	<b>Total</b>	<b>7</b>	<b>40</b>	<b>40</b>
<b>15</b>				
	T12	1	8	8
	E12	1	6	6
	E13	1	4	4
	O46	1	6	6
	O47	1	5	5
	O48	1	4	4
	O49	1	8	8
	O50	1	7	7
	O51	1	9	9
	O52	1	5	5
	O53	1	2	2
	O54	1	1	1
	O55	1	6	6
	O56	1	3	3
	O57	1	4	4
	O58	1	8	8
	O59	1	7	7
	O60	1	5	5
	O61	1	2	2
	O62	1	4	4
	O63	1	6	6

continued on following page

Table 8. Continued

Global Index	Project Code	Project Selection Status	Project Contribution*	Improvement
	O64	1	9	9
	O65	1	7	7
	O66	1	5	5
	O67	0	4	0
	O68	0	6	0
	<b>Total</b>	<b>24</b>	<b>141</b>	<b>131</b>
<b>16</b>				
	T13	1	15	15
	T14	0	5	0
	E14	1	1	1
	E15	1	1	1
	O69	1	6	6
	O70	0	6	0
	O71	0	8	0
	O72	1	9	9
	<b>Total</b>	<b>5</b>	<b>51</b>	<b>32</b>
<b>17</b>				
	T15	1	2	2
	T16	0	0.08	0
	T17	1	7	7
	E16	1	5	5
	O73	1	5	5
	O74	1	8	8
	O75	0	9	0
	O76	0	5	0
	O77	1	4	4
	O78	1	21	21
	O79	1	7	7
	O80	0	2	0
	O81	1	4	4
	<b>Total</b>	<b>9</b>	<b>79.08</b>	<b>63</b>
<b>18</b>				
	<b>Total</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>19</b>				
	O82	1	6	6
	<b>Total</b>	<b>1</b>	<b>6</b>	<b>6</b>
<b>20</b>				
	E17	1	6	6

continued on following page



Table 8. Continued

Global Index	Project Code	Project Selection Status	Project Contribution*	Improvement
	E18	1	1	1
	E19	1	1	1
	O83	0	6	0
	O84	0	5	0
	O85	1	9	9
	O86	0	8	0
	O87	1	10	10
	O88	0	2	0
	<b>Total</b>	<b>5</b>	<b>48</b>	<b>27</b>

\* Project Contribution is fictitious data

Table 9. The projects that are assigned to each index and their contribution to index improvement

Global Index	Percentile	No of Projects	No of Projects Selected	Contribution to Index improvement	Percentage of Improvement	New Percentile	Improvement Required Per Plan	Over /Under Achievement
1	40	4	3	15	38%	25	5	10
2	61	3	3	18	30%	43	10.25	7.75
3	51	3	3	16	31%	35	7.75	8.25
4	55	0	0	0	0%	55	8.75	-8.75
5	53	4	2	7	13%	46	8.25	-1.25
6	40	4	4	20	50%	20	5	15
7	49	5	5	22	45%	27	7.25	14.75
8	67	7	7	46	69%	21	11.75	34.25
9	38	3	3	16	42%	22	4.5	11.5
10	53	8	8	56	106%	-3	8.25	47.75
11	49	3	3	19	39%	30	7.25	11.75
12	78	2	2	16	21%	62	14.5	1.5
13	20	5	5	27	135%	-7	0	27
14	43	7	7	40	93%	3	5.75	34.25
15	54	26	24	131	243%	-77	8.5	122.5
16	65	8	5	32	49%	33	11.25	20.75
17	69	13	9	63	91%	6	12.25	50.75
18	17	0	0	0	0%	17	-0.75	0.75
19	36	1	1	6	17%	30	4	2
20	59	9	5	27	46%	32	9.75	17.25
<b>Average=</b>	<b>51.39</b>		<b>Average=</b>	<b>32.1</b>				

Table 10: fictitious cost and budget available data for goals 4, 6, 7, and 9

Project	Cost for year 2015-2016	Cost for year 2016-2017	Cost for year 2017-2018	Cost for year 2018-2019	Cost for year 2019-2020	budget available for year 2015-2016	budget available for year 2016-2017	budget available for year 2017-2018	budget available for year 2018-2019	budget available for year 2019-2020
T1	250000	250000	250000	250000	250000	260000	240000	230000	300000	300000
T2	1000000	1000000	1000000	1000000	1000000	900000	1200000	800000	1000000	1000000
T5	1250000	1250000	1250000	1250000	1000000	1270000	1280000	1290000	1200000	1200000
T7	500000	500000	500000	500000	500000	450000	550000	490000	500000	500000
T13	1500000	1500000	1500000	1500000	1500000	1520000	1530000	1490000	1500000	1500000
T14	2250000	2250000	2250000	2250000	2250000	2260000	2280000	2230000	2250000	2250000
T16	1750000	1750000	1750000	1750000	1750000	1720000	1730000	1750000	1720000	1720000
T17	250000	250000	250000	250000	250000	260000	270000	250000	240000	240000
O67	250000	250000	250000	250000	250000	260000	240000	230000	300000	300000
O68	1000000	1000000	1000000	1000000	1000000	900000	1200000	800000	1000000	1000000
O69	1250000	1250000	1250000	1250000	1250000	1270000	1280000	1290000	1200000	1200000
O70	500000	500000	500000	500000	500000	450000	550000	490000	500000	500000
O71	1500000	1500000	1500000	1500000	1500000	1520000	1530000	1490000	1500000	1500000
O72	2250000	2250000	2250000	2250000	2000000	2260000	2280000	2230000	2250000	2250000
O73	1750000	1750000	1750000	1750000	1750000	1720000	1730000	1750000	1720000	1720000
O74	250000	250000	250000	250000	250000	260000	270000	250000	240000	240000
O75	250000	250000	250000	250000	250000	260000	240000	230000	300000	300000
O76	1000000	1000000	1000000	1000000	1000000	900000	1200000	800000	1000000	1000000
O77	1250000	1250000	1250000	1250000	1250000	1270000	1280000	1290000	1200000	1200000
O78	500000	500000	500000	500000	500000	450000	550000	490000	500000	500000
O79	1500000	1500000	1500000	1500000	1500000	1520000	1530000	1490000	1500000	1500000
O80	2250000	2250000	2250000	2250000	2250000	2260000	2280000	2230000	2250000	2250000
O81	1750000	1750000	1750000	1750000	1750000	1720000	1730000	1750000	1720000	1720000
O82	250000	250000	250000	250000	250000	260000	270000	250000	240000	240000
O83	250000	250000	250000	250000	250000	260000	240000	230000	300000	300000
O84	1000000	1000000	1000000	1000000	1000000	900000	1200000	800000	1000000	1000000
O85	1250000	1250000	1250000	1250000	1250000	1270000	1280000	1290000	1200000	1200000
O86	500000	500000	500000	500000	500000	450000	550000	490000	500000	500000
O87	1500000	1500000	1500000	1500000	1500000	1520000	1530000	1490000	1500000	1500000
O88	2250000	2250000	2250000	2250000	2250000	2260000	2280000	2230000	2250000	2250000

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