Draft

USER'S MANUAL

Product Planning/Enterprise Integration Demonstration Facility

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Version 1

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1. Introduction

The Product Planning/Enterprise Integration Demonstration Facility (PP/EI DF) User's Manual (UM) has been developed for a number of reasons. First, the UM will provide users with a background that is sufficient to successfully understand and operate this software tool. Second, the UM imparts the significant technical and research contributions that are implicit within the PP/EI DF. Finally, the UM discusses the main reasons that organizations should attempt to integrate, and thus, centrally plan resource allocations.

Because the PP/EI DF software has been programmed in Borland C++ for Windows, the resulting program is readily understandable and easy to use. Further, because of its graphic capabilities, the program is able to accomplish its purpose of imparting understanding of product portfolio concepts. It is suggested, however, that users who are unfamiliar with basic Windows functions, should consult their Windows manuals prior to attempting to use this program. An understanding of Windows will better ensure that users are fully able to utilize the PP/EI DF software.

2. Background and Purpose

2.1. Goal and Objectives

The PP/EI DF resulted from the sponsored research project entitled *Life-Cycle Engineering Research for Product Portfolio Development*. This research project was made possible from funding provided by Northern Telecom The goal of the project was to establish a baseline so that work done in the past may be used as a means for increasing the efficiency and effectiveness of product planning and product continuation activities.

The main objective of the PP/EI DF is to extend knowledge in the areas of product planning and enterprise integration. Subsidiary objectives of the PP/EI DF project are:

> 1) To develop a demonstration facility which aids product portfolio, i.e., product planning[1], and enterprise integration[2] in organizations which have product managers.

> 2) To ensure that the PP/EI DF methodology will serve as a basis for enterprise integration.

> 3) To provide research experience for qualified undergraduate and graduate students.

2.1 Research Focus

The focus of this first version of the PP/EI DF is the development of a facility that can be easily expanded and that explores and demonstrates approaches that may be used to achieve the most efficient mix of products. The essence of the PP/EI DF is derived from generally accepted techniques found in capital budgeting, finance, and product planning literature. Emphasis in the later stages of the PP/EI DF will be to incorporate concepts made explicit in research previously conducted for Northern Telecom by Virginia Tech. Thus, later stages may include the integration of product design, development, and production areas into the PP/EI DF.

2.3. PP/EI DF Method

The concepts of PP/EI are made clear to interested persons through the PP/EI DF computer program. The demonstration facility has been developed in C++ and C. This demonstration facility is intended to result in the simplification of the

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[1]Product planning activities center around decisions made to determine what products should be initiated and produced.

[2]Enterprise integration refers to attempts to acquire all needed information from within the firm to make product planning decisions.

disclosure of key concepts. Thus, while the program will not solve real world problems, it establishes some of the key requirements for programs that will.

The PP/EI DF categorizes data as: (1) external, (2) corporate wide, and (3) product specific. In addition, the PP/EI DF follows a gating structure to discriminate between product life-cycle phases. The objective of the PP/EI DF is to select the optimal product portfolio from among all possible product portfolios[3]. Further, the PP/EI DF is dynamic in that it will find the optimal product portfolio as it changes in subsequent fiscal periods.

2.4. The PP/EI DF Program

The PP/EI DF software consists of three modules. These are the: (1) I/O Module, (2) Preprocessor Module, and (3) Optimization Module. The I/O Module has been developed in Microsoft C++ for Windows, and provides a combination of textual and graphical interfaces to enable the input of corporate, external, and product specific data. The I/O module is the only module with which the user may have direct contact. The Preprocessor Module is called when the user chooses either the *Optimize a Portfolio* or *Display Ranked Portfolios* options. When these options are chosen, this PP/EI DF module performs several operations. Some of these are to determine: (1) the future worth of each product, (2) the end-of-period constraint coefficients and product requirements, and (3) the horizon point. The Optimization Module is based on a fast enumeration method, and serves to: (1) eliminate from consideration portfolios that violate constraints, (2) determine the portfolio with the highest future worth, and (3) sort feasible portfolios in descending order according to future worth. Output from the Optimization Module is then passed back to the I/O Module for display.

2.5. Project Personnel

Personnel for the PP/EI DF project consisted of two faculty members, two graduate students, four undergraduate students, and one consulting

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[3] Product portfolio is a unique set of products which can be provided. All product portfolios for an organization can be determined by making explicit every possible set of products. Therefore, if a company may produce k products, then there will exist 2^k product portfolios.

programmer. Faculty consisted of Dr. Wolter J. Fabrycky, Lawrence Professor of Industrial and Systems Engineering and Dr. Scott F. Midkiff, Associate Professor of Electrical Engineering. Two graduate students (Rhett Hudson, Electrical Engineering and William Hoehn, Industrial and Systems Engineering) both worked as research assistants. Brennan Bowen (ISE), Mani Homayoun (MSE), and Andy Thompson (ISE), all undergraduates, performed work in the Fall of 1992 to model the product development process. Shawn Looney, an undergraduate in Aerospace Engineering, performed work in the Spring of 1993. Dr. Chunming Duan worked as a consulting programmer to develop the Optimization Module in C++.

3. Systems Supported

3.1. Hardware Requirements

All IBM PC's or compatibles with a 386SX or higher CPU and a hard disk drive may be used to run the PP/EI DF software. However, all 386SX, 386DX, and 486SX based machines must have a math co-processor installed. Further, to achieve adequate performance in terms of speed, it is recommended that the PC have a minimum of 4 megabytes of RAM memory installed.

3.2. Software Requirements

Since the PP/EI DF software is Windows based, Windows 3.1 or higher must be installed. Further, it is recommended that DOS 5.0 or higher be used on the system.

4. Overview

4.1 Scope

The objective of the PP/EI DF software is to show that multiple products, all which compete for some finite organizational resources, can be simultaneously considered for funding with respect to their entire life-cycles. The PP/EI DF software works by determining the group of products (i.e., the product portfolio) that yields the highest future worth, while also meeting the constraints imposed by scarce organizational resources.

Scarce organizational resources (constraints) and product specific requirements are represented in the software by continuous functions. The program supports a large number (2,160) of these organizational constraints, and an unlimited number of functions may be created and combined to define them. Further, an unlimited number of product specific demands are supported. A maximum of 60 fiscal periods may be considered at one time. Fiscal periods may be defined in the software to be years, quarters, and months.

4.2. Copying files to a Hard Disk

The PP/EI DF comes supplied on a single 3.5" 1.44 MB high density diskette. However, the program will not run from the floppy drive. Thus, it is necessary that the files on the program diskette be copied to the user's hard drive.

As a first step, a directory should be made on the user's hard drive. This is done by entering the DOS command "md <directory name>". The program diskette should now be inserted into the user's floppy drive. Assuming that the floppy drive is the DOS a: drive, that the hard drive is the DOS c: drive, and that the directory has been named **vtools**, the PP/EI DF files can now be copied by entering the DOS command, "xcopy /s a: c:\vtools".

4.3. Starting the PP/EI DF

The PP/EI DF must be run under Windows 3.1 or higher. The PP/EI DF may be run in one of two ways. The first is to run PP/EI DF by first starting Windows, and then selecting the **File** option from the within the Window's Program Manager. The user should then select the **Run** option from within the **File** menu. This action will result in the Run window being opened. At this point, the user should type "c:\vtools\df11.exe" into the **Command Line** box in the Run window. After this line has been entered, the user should click the mouse once on the **OK** box. Selecting **OK** will result in the PP/EI DF main window opening.

The second way to run PP/EI DF is to set the program up as an application. If the user intends to use PP/EI DF on a regular basis, this method is recommended over the first. To add PP/EI DF as an application, the user should start Windows and then double click the mouse on the **Windows Setup** Icon in the **Main** Window. At this point, the Windows Setup Window will be opened. The user should now select **Options** within this window. From here, select **Set**

Up Applications.... This will result in the **Applications Setup** window opening. At this point, the user should select the option "ask you to specify an application" and then click the mouse once on the **OK** box. This action will result in the **Setup Application** window being opened. The user should now type "c:\vtools\df11.exe" into the **Application Path and Filename** box and then click the mouse once on the **OK** box. Selecting **OK** will result in the PP/EI DF being added to the application window. The user can now always start PP/EI DF by starting Windows, double clicking the mouse on the **Application Icon**, and then double clicking the mouse on the **PP/EI DF Icon**.

4.4. Selecting the Product Set

A product set is the entire group of products that the PP/EI DF will consider for funding. Thus, if five products (prod0, prod1, prod2, prod3, and prod4) are to be simultaneously considered for funding, then the product set contains these five products. The user must define a product set before any other actions can be taken in the PP/EI DF.

The PP/EI DF contains a facility to define multiple product sets. In some cases, the organization employing a computer-based tool of this type may choose to exclude some products from the product set. In this case, a new product set is formed. Further, an organization may desire to determine what will happen to the optimal portfolio if the resource consumption and revenue profiles for a product are not as were stated. This type of comparison is termed sensitivity analysis, and may be conducted by creating a separate product set[4].

4.5. Organization Pull-Down Menu

The organization menu contains information that is specific to the organization, and that is not directly linked to a specific product. This menu option enables the user to define the fiscal period length, minimum attractive rate of return (MARR), the available resources, and the minimum expected revenues.

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[4] It should be noted that the user could also define two products in the same set, that are mutually exclusive. However, this type of action would not readily facilitate multiple product sensitivity analysis.

4.6. Product Pull-Down Menu

The product menu contains information concerning individual products, and the interrelationships that exist between products. This option allows the user to define new products, edit existing products, and define mutual exclusivities and contingencies.

4.7. Portfolio Pull-Down Menu

The portfolio menu enable the determination of the optimal portfolio and ranked feasible portfolios. The optimal portfolio is the portfolio of products (i.e., subset of the product set) that has the maximum future worth and also meets all organization constraints. A second option allows the user to display a list of portfolios that meet all organization constraints and are ranked by their future worth's.

The portfolio menu also allows the user to enter a new fiscal period. To do this, the user must first select the portfolio from the ranked list of portfolios that they wish to fund. The PP/EI DF will then advance the organization constraints and the funded products one fiscal period in time. All products that were not funded will remain in the product set but will not have advanced in time[5].

4.8. Function Types Supported

The PP/EI DF enables the user to define: (1) product specific resource consumption and revenue profiles, and (2) organization constraints. Constraints, resource consumption, and revenue are defined as continuous functions, and appear within the PP/EI DF as profiles.

The PP/EI DF enables the user to define profiles using five types of continuous functions. These are: (1) constant, (2) ramp, (3) growth, (4) exponential, and (5)

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[5] It is important to note here that the product set is actually a new product set which was created when the enter new fiscal period option was selected. For example, if the original product set was named correct.1, then the new product set will be named correct.2. Because of this, the user can always re-open correct.1 by selecting it from the open product set option. However, the user cannot change the outcome of the enter new fiscal period option once it has been enacted.

decay. A constraint, resource consumption, or revenue profile may be any combination of the five types of the functions supported by the PP/EI DF.

5. Entering Organization Data and Constraints

5.1 Fiscal Period Length

A maximum of 60 fiscal periods can be considered by this program. Fiscal period length may be set by the user to be one year, one quarter (i.e., 3 months), or one month. Thus, depending upon the user's choice in setting the fiscal period length, the PP/EI DF considers a maximum of 60 years, 15 years, and 5 years respectively.

Fiscal period length is set by selecting **Organization** from the main window. The user should then select the **Fiscal Period** option within this window. At this point, the user may select the fiscal period length (one year, one quarter, or one month) they desire by clicking the mouse on the appropriate box. After the fiscal period length is set, clicking the mouse on the **OK** box in the bottom right corner of the **Fiscal Period** window will return the user to the main window. As an alternative, if no change is desired, then clicking the mouse on the **cancel** box will enable this.

5.2 The Minimum Attractive Rate of Return (MARR)

The minimum attractive rate of return (MARR) may be set as low as zero and as high as 100 percent. Note that the MARR is entered in terms of a percentage. Thus, a user desiring a MARR = 0.15 should enter 15 in the appropriate window and field.

The MARR is set by selecting **Organization** from the main window. The user should then select the **MARR** option within this window. At this point, the user may enter the MARR in terms of percentage in the MARR entry field. After the MARR is set, clicking the mouse on the **OK** box in the bottom right corner of the **MARR** window will return the user to the main window. As an alternative, if no change is desired, then clicking the mouse on the **cancel** box will enable this.

5.3 Organization Constraints

Organization constraints exist to set the maximum amount of five types of resources that the portfolio may consume in any one gate and period, and also to set the minimum revenue that the portfolio must generate in each gate and period. Thus, if there are 5 periods, and 6 gates, then up to 180 constraints can be defined.

All constraints types must be defined for each gate and may continue over 60 periods. Constraints are entered as continuous functions. The PP/EI DF enables the definition of five continuous function types. The user may define as many of these functions as they desire in a single or multiple fiscal periods. This enables the development of customized resource consumption and revenue generation profiles.

An Organization Constraint may be set by selecting **Organization** from the main window. The user should then select either the **Budget**, **Minimum Revenue**, **Staffing**, **Storage Space**, **Production Resources**, or **Design Support** option within this window. This action will result in the opening of a side window containing gate information. At this point, the user must select the gate they want to work on. This is done by clicking the mouse once on the appropriate gate. This action will result in the opening of a constraint window. At this point, the user may enter constraints as continuous functions. This is done by first single clicking the mouse on as many adjacent periods as the function to be defined will extend over. Next, the **Function** should be single clicked. A menu of functions containing **Constant**, **Growth**, **Decay**, **Exponential**, **and Ramp** will be displayed. The user should select the function type needed by single clicking the mouse of the appropriate entry. After the constraint is set, double clicking the mouse on the box in the upper left corner of the window will return the user to the main window.

Note that minimum revenues in a specific gate and period will default to zero if no minimum revenue functions are defined. This means that for each gate and period that no minimum revenue is defined, it is acceptable for the product portfolio to return no revenue. Note also that cost, staffing, storage space, design support, and production resources will default to infinite in a specific gate and period if no functions are defined in the period and gate. This means that

for each gate and period that one of these constraint types is not defined, the product portfolio may consume infinite resources of that constraint type.

6. Entering Product Data

6.1 New Product

A new product may be added to the product set by first selecting the **Products** option from the main menu. Next, the user should select the **New Product...** option from the Products menu. This action will result in a **New Product** window being opened. At this point the user is required to enter the new product's name, life length in fiscal periods, the fiscal period of the product's life that the product is currently in[6], and whether the product is hardware or software.

The user will then be required to enter the fiscal period in which the new product passes through each of its six gates. Since by definition, no work can occur on the product before it passes through gate zero, setting gate zero greater than one will result in product inception later than period one. In other words, no resource consumption and revenue functions can be defined to occur prior to the fiscal period in which the product passes through gate zero. It should also be noted that each successive gate must occur at least one fiscal period beyond the prior gate. Because of this gate requirement, no product may have a life length less than six fiscal periods.

During the entry of gate information, the user is also required to input risk adjusted discount rates (RADR) as a multiple of the MARR. The RADR for products is included here because it is recognized that some products may have much greater risk than other products. Also, the riskyness of products in earlier gates may be much greater than in later gates. Thus, the inclusion of RADR's provides a means to discriminate between products based on each product's inherent riskyness and on each gates inherent riskyness. The user may choose

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[6] The current period of the product's life-cycle will usually be set at one because most products entered into the PP/EI DF will have just began their life cycle's. However, in some cases, products entered into the PP/EI DF for the first time may have been funded in the past (e.g., when an existing organization first attempts to use PP/EI DF type software). In this case, the current period may be greater than one.

not to include RADR's by simply setting each RADR field equal to one (1). All calculations will then simply involve the MARR.

Product specific resource consumption in the form of cost, staffing requirements, storage requirements, production space, and design support, and expected revenues can be input by selecting the appropriate box in the lower portion of the Product Window. Resource consumption and revenue profiles for the product can be defined by first selecting the periods over which the function will extend. This can be done by selecting adjacent fiscal periods with the mouse. Selected fiscal periods will be highlighted in blue. Note that in no case may a function start in one gate and finish in another. That is, all fiscal periods that a function covers must lie within the same gate. Gates are shown on the bottom of the entry window. After the fiscal periods have been selected, the user can select the **Function** option to define a function. Functions can then be defined in the same way as organizational constraints.

6.2 Open Product

A product that has been previously defined can be modified. Modifications can be made by first double clicking the mouse of the product's name in the main window. This will open the **Edit Product** window. Changes to the product can now be made in the same fashion as new products are defined.

6.3 Delete Product

A product may be deleted by first selecting the product in the main window by clicking on it once with the mouse. This will result in the selected product being highlighted. After the name has been highlighted, the user should select the **Products** option from the main menu. This action will result in the products menu being displayed. At this point the user should select the **Delete Product** option. A window will now be displayed asking whether the user truly wishes to delete the product. Selecting **Yes** will result in the product being deleted. Selecting **No** will return the user to the main menu.

6.4 Product Interaction

6.4.1 Must Fund

The must fund option allows the user to specify the condition that any feasible portfolio must contain the product set as a must fund. Thus, any portfolio that does not contain the product set as a must fund would be infeasible.

To set a product as a must fund, the user should first select the **Products** option from the main menu. Next, the **Must Fund** option should be selected from the **Products** window. This action will result in the must fund window being opened. The user should now select all products that are to be set as must funds. This is done by clicking the mouse once on the appropriate products in the lower portion of the must fund window. When a product's name is highlighted in the lower portion of the must fund window, then it has been set as a must fund. After all products have been selected, the must fund window can be closed by selecting the **OK** box in the lower right hand corner.

6.4.2 Do Not Fund

The do not fund option allows the user to specify the condition that any feasible portfolio cannot contain the product set as a do not fund. Thus, any portfolio that contains the product set as a do not fund would be infeasible.

To set a product as a do not fund, the user should first select the **Products** option from the main menu. Next, the **Do Not Fund** option should be selected from the **Products** window. This action will result in the do not fund window being opened. The user should now select all products that are to be set as do not funds. This is done by clicking the mouse once on the appropriate products in the lower portion of the do not fund window. When a product's name is highlighted in the lower portion of the do not fund window, then it has been set as a do not fund. After all products have been selected, the do not fund window can be closed by selecting the **OK** box in the lower right hand corner.

6.4.3 Mutually Exclusive

The mutually exclusive option enables the user to define two products that cannot both exist in a feasible portfolio. Hence, all portfolios that contain the two products will be infeasible.

A product may be set mutually exclusive of another product by first selecting either of the two products in the main window by clicking on it once with the mouse. This will result in the selected product being highlighted. After selecting either product, the user should select the **Products** option from the main menu. Next, the **Mutually Exclusive** option should be selected from the **Products** window. This action will result in the mutually exclusive window being opened. The user should now select all products that the previously selected product is to be mutually exclusive of. This is done by clicking the mouse once on the appropriate products in the lower portion of the mutually exclusive window. If a product's name is highlighted in the lower portion of the mutually exclusive window, then it has been set mutually exclusive of the previously selected product. After all products have been selected, the mutually exclusive window can be closed by selecting the **OK** box in the lower right hand corner.

6.4.4 Contingent

The contingent option enables the user to define the case where one product (e.g., prod1) must exist in the portfolio before another product (e.g., prod2) can also exist. That is, prod2 is contingent upon the acceptance of the prod1. Hence, all portfolios that contain the prod2 but not prod1 will be infeasible. However, it is acceptable for a portfolio to only contain prod1 and not prod2.

A product may be set contingent upon another product by first selecting the product that is to be contingent upon the other product in the main window by clicking on it once with the mouse. This will result in the selected product being highlighted. After selecting the contingent product, the user should select the **Products** option from the main menu. Next, the **Contingent** option should be selected from the **Products** window. This action will result in the contingent window being opened. The user should now select all products that the previously selected product is to be contingent upon. This is done by clicking the mouse on the appropriate products in the lower blackened out portion of the

mutually exclusive window. If a product's name is highlighted in the lower portion of the contingent window, then the previously selected product is contingent upon it. After all products have been selected, the contingent window can be closed by selecting the **OK** box in the lower right hand corner.

7. Portfolio

7.1 Display Optimal Portfolio

The optimal portfolio for the product set under consideration can be determined by first selecting the **Portfolio** option from the main menu. The user should next select the **Display Optimal Portfolio** option within the Portfolio menu. This will result in the opening of a window that contains the products within the optimal product portfolio. In addition, the future worth of this portfolio will be displayed at the top of the window. Selecting the **OK** box at the bottom right hand corner will close the optimal portfolio box. Note that if no feasible portfolios exist, a window displaying this message will be opened. This window can be closed in the normal fashion.

7.2 Display Ranked Portfolios

A ranked list of feasible portfolios for the product set under consideration can be displayed by first selecting the **Portfolio** option from the main menu. The user should next select the **Display Ranked Portfolios** option within the Portfolio menu. This will result in the opening of a window that contains a ranked list of the future worth's of the feasible product portfolios. Double clicking the mouse on any of these future worth's will result in a new window being opened. This window displays the products in the ranked portfolio selected and its future worth. Selecting the **OK** box at the bottom right hand corner will close this new window. Next, the user can return to the main menu by selecting the **OK** box at the bottom right hand corner of the ranked portfolio window. Note that, as before, if no feasible portfolios exist, a window displaying this message will be opened. This window can be closed in the normal fashion.

7.3 Enter New Fiscal Period

After the user has determined the optimal portfolio and also viewed the ranked portfolios, they may choose to enter a new fiscal period. Entry into a new fiscal period requires that the user first select the **Portfolio** option from the main menu. The user should next select the **Enter New Fiscal Period** option within the Portfolio menu. This will result in the opening of a window that contains a ranked list of the future worth's of the feasible product portfolios. The user must then double click the mouse on the portfolio they wish to fund. This action will result in a window containing the products to be funded being opened. If the user wishes to fund these products, they should click the mouse once on the **OK** box in the lower right hand corner. If the user does not wish to fund these products, they should click the mouse once on the **cancel** box.

If the **OK** box was selected, the PP/EI DF will then advance the organization constraints and the funded products one fiscal period in time. All products that were not funded will remain in the product set but will not have advanced in time.

It is important to note here that the product set just mentioned is actually a new product set that was created when the **Enter New Fiscal Period** option was selected. For example, if the original product set was named correct.1, then the new product set will be named correct.2. Because of this, the user can always re-open and view the contents of correct.1 by selecting it from the open product set option. However, the user cannot change the outcome of the **Enter New Fiscal Period** option once it has been enacted.

Appendix A - Glossary of Terms

Product Set - A product set is the entire group of products that the PP/EI DF will consider for funding. Thus, if five products (prod0, prod1, prod2, prod3, and prod4) are to be simultaneously considered for funding, then the product set contains these five products. The user must define a product set before any other actions can be taken in the PP/EI DF. Further, the PP/EI DF allows users to define and work with multiple product sets.

Product Portfolio - A subset of the product set. There exist 2^n product portfolios where n is the number of products in the product set. Thus, if $n = 5$ products are to be simultaneously considered for funding, then there exist $2^5 = 32$ portfolios. That is, there are 32 possible combinations of the five products.

Fiscal Period - The length of time that elapses before the organization reconsiders product portfolio. Fiscal periods can be defined to be one year, 3 months, or one month.

Gate - A point in time in which a product enters its next life cycle phase. The PP/EI DF divides product life-cycles by requiring that all products pass through six gates. A product must pass through gate zero before it can consume resources and return revenues. Further, a product can no longer consume resources or return revenues after it has passed through gate five.

Horizon - The point at which the longest-lived product is completely phased out.

Must Fund - The must fund option allows the user to specify the condition that any feasible portfolio must contain the product set as a must fund. Thus, any portfolio that does not contain the product set as a must fund would be infeasible.

Contingent - The contingent option enables the user to define the case where one product (e.g., prod1) must exist in the portfolio before another product (e.g., prod2) can also exist. That is, prod2 is contingent upon the acceptance of the prod1. Hence, all portfolios that contain the prod2 but not prod1 will be infeasible. However, it is acceptable for a portfolio to only contain prod1 and not prod2.

Mutually Exclusive - Two or more products that cannot exist simultaneously in a feasible portfolio. Hence, all portfolios that contain the two products will be infeasible.

Product Requirement - The amount of resources of one of five types required by a product in a specific period and gate.

Organizational Constraint - The maximum resources of a certain type in a period and gate that are available for consumption by portfolios of products.

Minimum Attractive Rate of Return - The lowest acceptable return on investment that the organization will accept. The minimum acceptable rate of return (MARR) includes components to account for inflation and the lowest acceptable rate of return.

Risk Adjusted Discount Rate - Risk adjusted discount rates (RADR) are an extension of the MARR in that they also include a component for product specific risk. Thus, RADR $\geq$ MARR.

Future Worth - A means of comparing alternatives on an equivalent basis, the future worth is the sum of revenues less costs adjusted for time using the product specific risk adjusted discount rates.

Feasible Product Portfolio - A product portfolio that meets all organizational and product interaction constraints.

Optimal Portfolio - A feasible portfolio that also has the highest worth of all feasible portfolios.

Appendix B - General Future Worth Formulation

This appendix contains the formulas used to calculate the future worth of continuous money flows at the end of a fiscal period. Functions may end within a gate or at the end of a gate where the end of a gate is period N. However, while a function may extend over numerous fiscal periods, in no case may a function extend over more than one gate. The future worth functions presented in this section assume that the function starts at fiscal period zero.

Annual (Uniform)

$$F_t = \overline{A}$$

$$F_N = \int_0^N \overline{A}\, e^{rt} dt = \frac{\overline{A}}{r}\left[e^{rN} - 1\right]$$

Gradient

$$F_t = Gt$$

$$F_N = \int_0^N Gt e^{rt} dt = \frac{G e^{rN}}{r}\left[N - \frac{1}{r} + \frac{1}{r e^{rN}}\right]$$

Decay

$$F_t = c e^{-jt}$$

$$F_N = \int_0^N c e^{-jt} e^{rt} dt = \frac{c}{r-j}\left[e^{N(r-j)} - 1\right]$$

Exponential

$$F_t = c e^{jt}$$

$$F_N = \int_0^N c e^{jt} e^{rt} dt = \frac{c}{j+r}\left[e^{N(j+r)} - 1\right]$$

Growth

$$F_t = c(1 - e^{-jt})$$

$$F_N = \int_0^N c(1 - e^{-jt}) e^{rt} dt = \frac{c}{r}\left[e^{rN} - 1\right] - \frac{c}{r-j}\left[e^{N(r-j)} - 1\right]$$

Note that r is the risk adjusted discount rate, j is some sloping parameter, c is some constant, and N is the gate horizon (in this case, the latest period the function extends into).

The FW_{N2} of a discrete value (i.e., the future worth at N_2 of the future worth of a continuous function FW_1) is given by:

$$FW_{N_2} = FW_1 e^{(r2N2/K)}$$

where FW_1 is the value of the continuous function, N_2 is the number of periods the discrete calculation extends over (i.e., $N_2 = end_2 - begin_2 + 1$), and K is the number of compounding periods per year.

Thus, the future worth of a continuous function M_N at the horizon point is given by

$$FW_{\bar{N}l} = FW(M_N)\prod_{i=2}^{u}e^{(r_iN_i/K)} \qquad \forall\, l \in 1,2,3,4,5$$

where

$$FW(M_N) = \begin{cases} \dfrac{\overline{A}}{r}\left[e^{r_lN_l} - 1\right] \text{ if } l=1 \\[2mm] \dfrac{Ge^{r_lN_l}}{r_l}\left[N_l - \dfrac{1}{r_l} + \dfrac{1}{r_le^{r_lN_l}}\right] \text{ if } l=2 \\[2mm] \dfrac{c}{r_l - j}\left[e^{N_l(r-j)} - 1\right] \text{ if } l=3 \\[2mm] \dfrac{c}{j+r_l}\left[e^{N_l(j+r_l)} - 1\right] \text{ if } l=4 \\[2mm] \dfrac{c}{r_l}\left[e^{r_lN_l} - 1\right] - \dfrac{c}{r_l - j}\left[e^{N_l(r_l-j)} - 1\right] \text{ if } l=5 \end{cases}$$

and where

r_i = *The RADR or MARR in the gate under evaluation*

$N_1 = N_{1e} - N_{1b} + 1$

$N_i = N_{ie} - N_{ib} + 1$

$\overline{N}$ = *the horizon point.*

Appendix C - Product Specific Resource Demands/Returns

For a single fiscal period *n* and a single function *m* the following formulas are used to calculate end of fiscal period product specific resource demands or returns:

Uniform:

$$F_t = \overline{A}$$

$$EOP_n = \int_{n-1}^{n} \overline{A}\ dt = \overline{A} \quad \forall\ n = 1, 2, ..., N$$

Gradient:

$$F_t = Gt$$

$$EOP_n = \int_{n-1}^{n} Gt\ dt = G(n - \frac{1}{2}) \quad \forall\ n = 1, 2, ..., N$$

Decay:

$$F_t = ce^{-jt}$$

$$EOP_n = \int_{n-1}^{n} ce^{-jt}\ dt = \frac{c}{je^{jn}}\left[e^j - 1\right] \quad \forall\ n = 1, 2, ..., N$$

Exponential:

$$F_t = ce^{jt}$$

$$EOP_n = \int_{n-1}^{n} ce^{jt}\ dt = \frac{ce^{jn}}{j}\left[1 - \frac{1}{e^j}\right] \quad \forall\ n = 1, 2, ..., N$$

Growth:

$$F_t = c(1 - e^{-jt})$$

$$EOP_n = \int_{n-1}^{n} c(1 - e^{-jt})\ dt = \frac{c}{je^{jn}}\left[je^{jn} - e^j + 1\right] \quad \forall\ n = 1, 2, ..., N$$

Since it is possible to have more than one demand or return function m defined in a single period n (i.e., $m > 1$), all EOP_n formulas for all functions M_n defined in a fiscal period n must be summed. Formulation for n periods with M_n defined functions is given by:

$$Y_n = \sum_{m=1}^{M_n} EOP_{mn}$$
$$\forall\ n = 1, 2, ..., N;\ m = 1, 2, ..., M_n$$

Since there exist 6 constraints[7] types per fiscal period, a subscript l may be added to describe the constraint type. Hence, the previous formulation is extended to:

$$Y_{nl} = \sum_{m=1}^{M_n} EOP_{lmn}$$
$$\forall\ n = 1, 2, ..., N;\ l = 1, 2, ..., 6;\ m = 1, 2, ..., M_n$$

where Y_{nl} describes the sum of all EOP_n in a specific fiscal period and of a specific type.

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[7] Resource types are segregated into availability/demand or return/minimum expected return. Therefore, a specific constraint only refers to availability or to expected return; not both simultaneously. Further, there exist 6 constraints. Five of these are of the demand/available resource type while only one (expected revenue) is of the return/minimum expected return type.

Appendix D - Available Resources/Minimum Returns

For a single fiscal period n and a single function m the following formulas are used to calculate end of year resource availability or minimum expected returns:

Uniform:

$$F_t = \overline{A}$$

$$EOP_n = \int_{n-1}^{n} \overline{A}\ dt = \overline{A} \quad \forall\ n = 1, 2, ..., N$$

Gradient:

$$F_t = Gt$$

$$EOP_n = \int_{n-1}^{n} Gt\ dt = G(n - \frac{1}{2}) \quad \forall\ n = 1, 2, ..., N$$

Decay:

$$F_t = ce^{-jt}$$

$$EOP_n = \int_{n-1}^{n} ce^{-jt}\ dt = \frac{c}{je^{jn}}\left[e^{j} - 1\right] \quad \forall\ n = 1, 2, ..., N$$

Exponential:

$$F_t = ce^{jt}$$

$$EOP_n = \int_{n-1}^{n} ce^{jt}\ dt = \frac{ce^{jn}}{j}\left[1 - \frac{1}{e^{j}}\right] \quad \forall\ n = 1, 2, ..., N$$

Growth:

$$F_t = c(1 - e^{-jt})$$

$$EOP_n = \int_{n-1}^{n} c(1 - e^{-jt})\ dt = \frac{c}{je^{jn}}\left[je^{jn} - e^{j} + 1\right] \quad \forall\ n = 1, 2, ..., N$$

Since it is possible to have more than one available resource or expected return function m defined in a single fiscal period n (i.e., $m > 1$), all EOP_n formulas for all M_n functions defined in a fiscal period n must be summed. Formulation for n periods with M_n defined functions is given by:

$$X_n = \sum_{m=1}^{M_n} EOP_{mn}$$

$$\forall\ n = 1, 2, ..., N;\ m = 1, 2, ..., M_n$$

Since there exist 6 constraints per fiscal period, a subscript l may be added to describe the constraint type. Hence, the previous formulation is extended to:

$$X_{nl} = \sum_{m=1}^{M_n} EOP_{lmn}$$

$$\forall\ n = 1, 2, ..., N;\ l = 1, 2, ..., 6;\ m = 1, 2, ..., M_n$$

where X_{nl} describes the sum of all available resources or expected returns of type l in a specific fiscal period n.

Appendix E - Special Case Future Worth Formulation

When r = 0, and/or j = 0, the formulas presented in Appendix B may fail to provide the correct results. Because of this, special case formulas of the future worth functions have been developed and incorporated into the PP/EI DF software to ensure that all instances of r and j values yield valid answers. These special case formulas are presented below.

1 Annual (r = 0)

$$F_N = \int_0^N \overline{A}\, dt = \overline{A}N$$

2 Gradient (r = 0)

$$F_N = \int_0^N Gt\, dt = G(N - \tfrac{1}{2})$$

3 Decay (r = 0; j > 0)

$$F_N = \int_0^N ce^{-jt}\, dt = \frac{c}{je^{jn}}[e^j - 1]$$

4 Decay (r > 0; j = 0)

$$F_N = \int_0^N ce^{rt}\, dt = \frac{ce^{rt}}{r}\left[1 - \frac{1}{e^r}\right]$$

5 Decay (r = j) Assume that r = j = k

$$F_N = \int_0^N ce^{-kt}e^{kt}\, dt = \int_0^N ce^{t(k-k)}\, dt = cN$$

6 Exponential (r = 0; j > 0)

$$F_N = \int_0^N ce^{jt}\, dt = \frac{ce^{jN}}{j}\left[1 - \frac{1}{e^j}\right]$$

7 Exponential (r > 0; j = 0)

$$F_N = \int_0^N ce^{rt}\, dt = \frac{ce^{rN}}{r}\left[1 - \frac{1}{e^r}\right]$$

8 Exponential (r = j > 0)   Assume that r = j = k

$$F_N = \int_0^N ce^{kt}e^{kt}\, dt = \int_0^N ce^{2kt}\, dt = \frac{c}{2k}\left[e^{2Nk} - 1\right]$$

9 Exponential (r = j = 0)

$$F_N = \int_0^N c\, dt = cN$$

10 Growth (r = 0; j > 0)

$$F_N = \int_0^N c(1 - e^{-jt})\, dt = \frac{c}{je^{jN}}\left[je^{jn} - e^j + 1\right]$$

11 Growth (r > 0; J = 0)

$$F_N = \int_0^N c(1 - e^0)e^{rt}dt = 0$$

12 Growth (r = j > 0)   Assume that r = j = k

$$F_N = \int_0^N c(1 - e^{-kt})e^{kt}dt = \int_0^N ce^{kt} - ce^o dt = \frac{ce^{kn}}{k} - cN - \frac{c}{k} + c$$

13 Growth (r = j = 0)

$$F_N = \int_0^N c(1 - e^{0t})e^{0t}\, dt = 0$$

Appendix F - Special Case Resource Consumption/Availability

When r = 0, and/or j = 0, the formulas presented in Appendices C and D may fail to provide the correct results. Because of this, special case formulas of the en-of-period resource consumption and resource availability functions have been developed and incorporated into the PP/EI DF software to ensure that all instances of r and j values yield valid answers. These special case formulas are presented below.

1 Decay (j = 0)

$$EOP_n = \int_0^n ce^{0t}\, dt = \int_0^n c\, dt = cn$$

2 Exponential (j = 0)

$$EOP_n = \int_0^n ce^{0t}\, dt = \int_0^n c\, dt = cn$$

3 Growth (j = 0)

$$EOP_n = \int_0^n c(1 - e^{ot})\, dt = 0$$