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The Fast Resource Evaluation Grid[1]

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Abstract

The success of product design, development and delivery in a technological enterprise crucially depends on the optimal integration of enterprise resources. The Fast Resource Evaluation Grid permits the comprehension of the strengths and importances of these resources as a rational basis for the allocation of effort to close resource gaps.

A Common Ground: This paper addresses issues related to integration in "design" that must necessarily proceed from a statement of shared interests and objectives. There is general agreement on the need for design research aimed at better theoretical understanding of design, and increased engineering productivity in industrial practice. These aims naturally cause us, as a community, to occasionally stop and wonder about the impact of our research on design theory and practice. Furthermore, we would also like to make sense of each others' research results, see how these results fit together, and measure the applicability and value of technical contributions with respect to our own technical objectives.

Motivation: Theory, model, and tool development in "design" has produced many results - but the results appear to be fragmented, with insufficient connectivity among the fragments, and insufficient connectivity from the fragments to the context of their potential use. Attempts to conceptually integrate these results and take stock of the results in the context of our research community are important in order to focus further efforts. This will potentially enable the research to have significant impact on industrial practice - one of the reasons for doing design research in the first place.

Needs: In order to properly understand how design research results fit together and impact practice, it is necessary to stand back, review and comprehend product design, development, and delivery within the context of a technological enterprise. As a step in this direction, what is required is a simple generic model that is capable of capturing the essence and richness of product design, development, and delivery in real enterprises.

Objectives: From the aforementioned standpoint, the paper has the following specific objectives:

1) Distill the key elements of product design, development and delivery (PD^3).

2) Attempt to structure PD^3 into a simple model that enables a technological enterprise to be viewed in an integrated manner.

3) Show how this structure can be used at the highest level to quickly evaluate the state of the enterprise with respect to the resources that determine the "success" of the enterprise.

4) Show how the structure can be used at "lower" more quantitative levels to estimate the value of the resources to the goals of the enterprise, and then to allocate/reallocate investment to improve product design, development and delivery (PD^3).

The *central idea* of the paper is that a value-centered view of product design, development and delivery can be simply represented as a two dimensional *grid*, each dimension of the grid containing a group of related elements that are *invariant* with respect to the specific nature of the enterprise. This grid forms the basis for resource evaluation and resource allocation in the enterprise. Another use of the grid, only partially explored in this paper, is to place and assess research results explicitly within the context of PD^3, and with respect to the ultimate aims of design research.

Paper Format: In order to enable quick reading and assimilation, this paper is deliberately presented in a sequence of interconnected frames with a central diagram and sufficient but limited explanatory text. The text (on most pages) is in two parts: a "story line" in italics that enables a quick "reading" of the diagram, and text explanations and elaborations in bulletized form.

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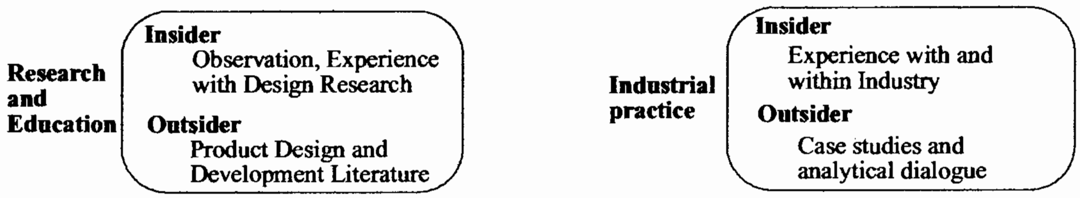
[1] Author names are in alphabetical order.

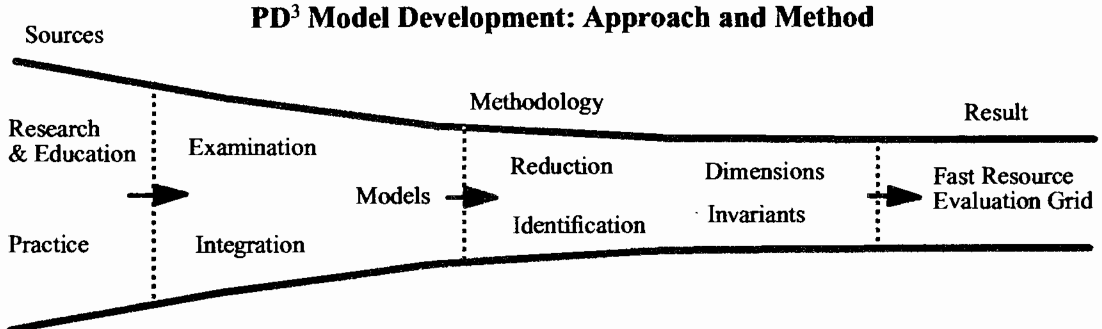
Product Design, Development and Delivery (PD^3): Sources of Knowledge



Development of an integrated view of PD^3 requires examination of a wide variety of sources of knowledge falling into two broad categories: research and education, and industrial practice.

- In order to develop an integrated view of product design, development, and delivery, that is rich and comprehensive, it is necessary to examine a wide variety of knowledge sources. These sources can be broadly categorized as *research and education*, and *industrial practice*.
- Research and education provides both an "insider" view through direct observation and experience with design research, and an "outsider" view of the work of others through published literature and personal communications. Similarly, experience within and with industry, and case studies and analytical dialogue of product programs provide, respectively, "insider" and "outsider" views of design practice.
- These sources of knowledge represent complementary regions of dominant concern. While research and education seek technical insights and advances, industrial practice seek productivity and profit in the broader context of successful product programs.

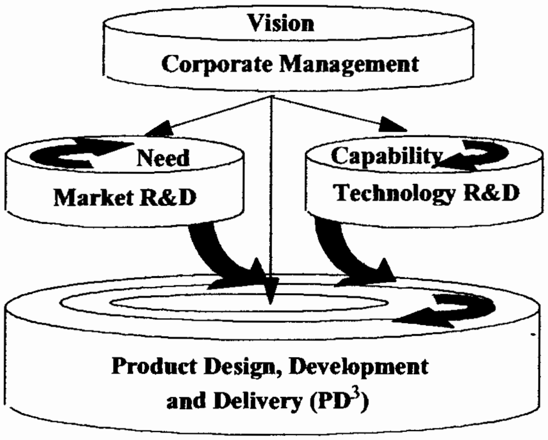
PD^3 Model Development: Approach and Method



Based on examination and integration of a variety of sources of knowledge, our methodology has led to a value-centered model of PD^3: The Fast Resource Evaluation Grid

- The success of a technological enterprise crucially depends on the manner in which product design, development, and delivery (PD^3) is realized. The first step therefore is to show the place of PD^3 in a simple abstract model of the enterprise.
- Based on a careful examination and subsequent reduction of PD^3, two fundamental dimensions, *function* and *process,* can be identified.
- In each dimension there are elements that are always present regardless of the type, size, and maturity of the technological enterprise. These elements are the *invariants* of the dimension. We identified the key function and process invariants and combined them to yield a *grid* of *resources* of PD^3.
- The Fast Resource Evaluation Grid provides an integrated view of PD^3 and enables a rational, *value-centered* assessment of the state of an enterprise.
- To elucidate the meaning and usefulness of the grid, we use (a) three PD^3 case studies, each documented from a different perspective, and (b) two typical advanced texts that address different aspects of PD^3 while being grounded in practice.

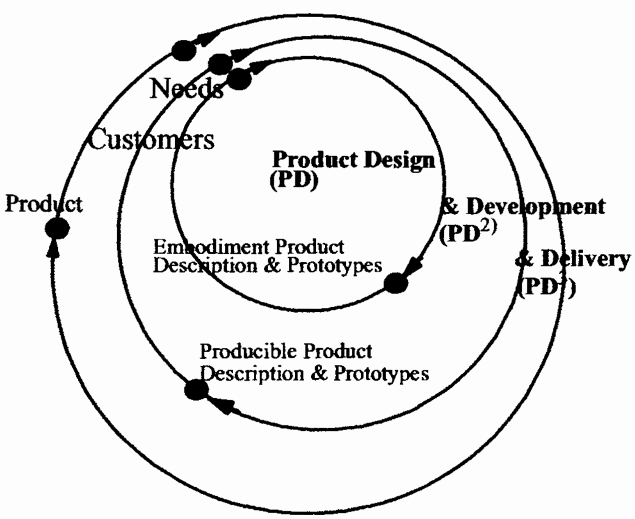
Setting the Context: The Enterprise



PD³ is positioned in an enterprise that includes corporate management, market research and development, and technology research and development. Cycles of activity in Market R&D and Technology R&D feed into PD³.

- It is important to first establish the context of PD³ within the overall enterprise wherein current and anticipated market needs are satisfied by delivery of engineered products.
- For our purposes, the overall enterprise is decomposed into four major functional components: corporate management (CM), market research and development (MR&D), technology research and development (TR&D), and, of course, PD³.
- CM provides the overall driving force by setting direction and vision for the future of an enterprise based on an assessment of internal strengths and potential, and external factors of markets and competition. It also directs and allocates resources to the other functions (thin arrows in figure).
- MR&D is the driving force that essentially determines, assesses, and influences customer needs within the context of the marketplace, and then translates these needs into a market opportunity for the enterprise.
- TR&D is the driving force that develops new or improved technological capabilities to potentially meet market opportunity.
- Both MR&D and TR&D are cycles of interactive, concurrent activities (shaded arrows in figures) that feed their results into PD³ at the appropriate point in time.

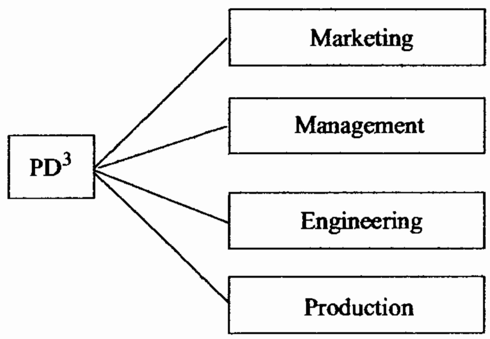
Setting the Context: PD³



Three embedded cycles of activity or work flow in an enterprise characterize the product design, development and delivery of products to markets.

- PD³ can be conveniently described as three cycles of activity or work flow embedded one inside the other: Product Design, Product Design and Development, and Product Design, Development and Delivery.
  - Product Design, Development and Delivery (PD³): The outermost cycle transforms market needs to a product delivered to the market.
  - Product Design and Development (PD²): The middle cycle is embedded in PD³ and transforms market needs to producible product descriptions and producible prototypes.
  - Product Design (PD): The innermost cycle is embedded in PD² and transforms market needs to embodiment descriptions (detailed descriptions of an artifact) and prototypes.
- We note that the "Customers" and their "Needs" in each cycle may not be identical.
- Only within the entire PD³ context, which includes all the resources of PD and PD², can one identify function and process invariants, and rationally evaluate the resources that determine the success of the enterprise. (These resources include, of course, the results of design research.)

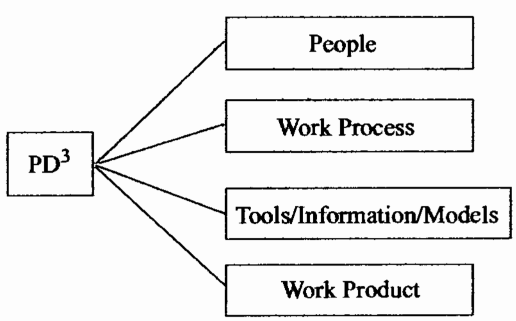
Invariants in the Function Dimension



The function invariants constitute the essential elements of a functional decomposition of PD³.

- Function invariants are the essential elements that are always present in a standard and natural functional decomposition of PD³ in every technological enterprise.
- Each of the function invariants correspond to well defined missions of the enterprise, and involve several professional disciplines.
- The function invariants are as follows:
  - Management: organize and supervise PD³ with the objective of making a profit. This function includes finance, legal, human resources, and other administrative functions.
  - Marketing: continuously monitor market needs and demands, and ultimately sell the product to customers. This includes advertising, sales, customer support and service.
  - Engineering: design and develop the product from need definition to producible prototypes. This includes design engineering, prototyping, and manufacturing engineering.
  - Production: planning, executing and controlling the process of creating products on a large scale from producible prototypes. This includes inventory control, plant engineering, operations planning and control, inspection and quality management, and packaging.

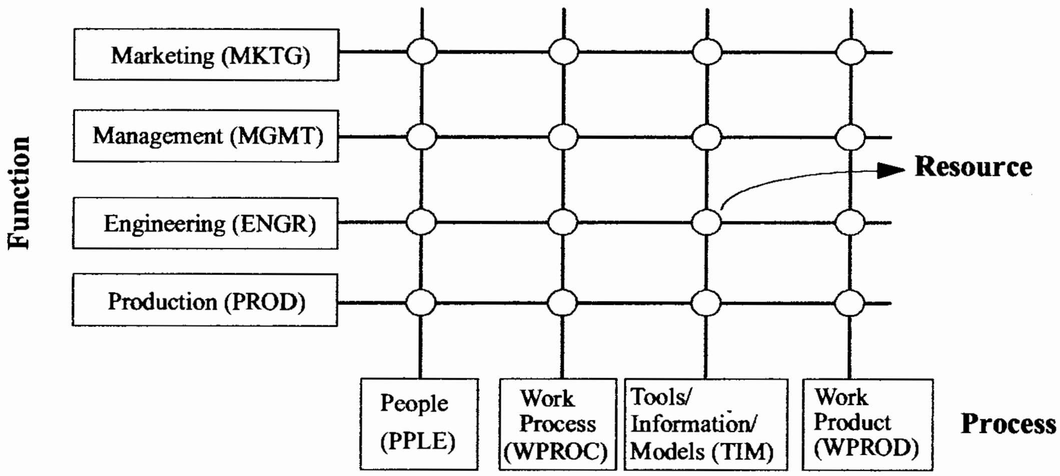
Invariants in the Process Dimension



The process invariants can be regarded as participants in the following flow: people engage in a work process using tools, information and models to create a work product.

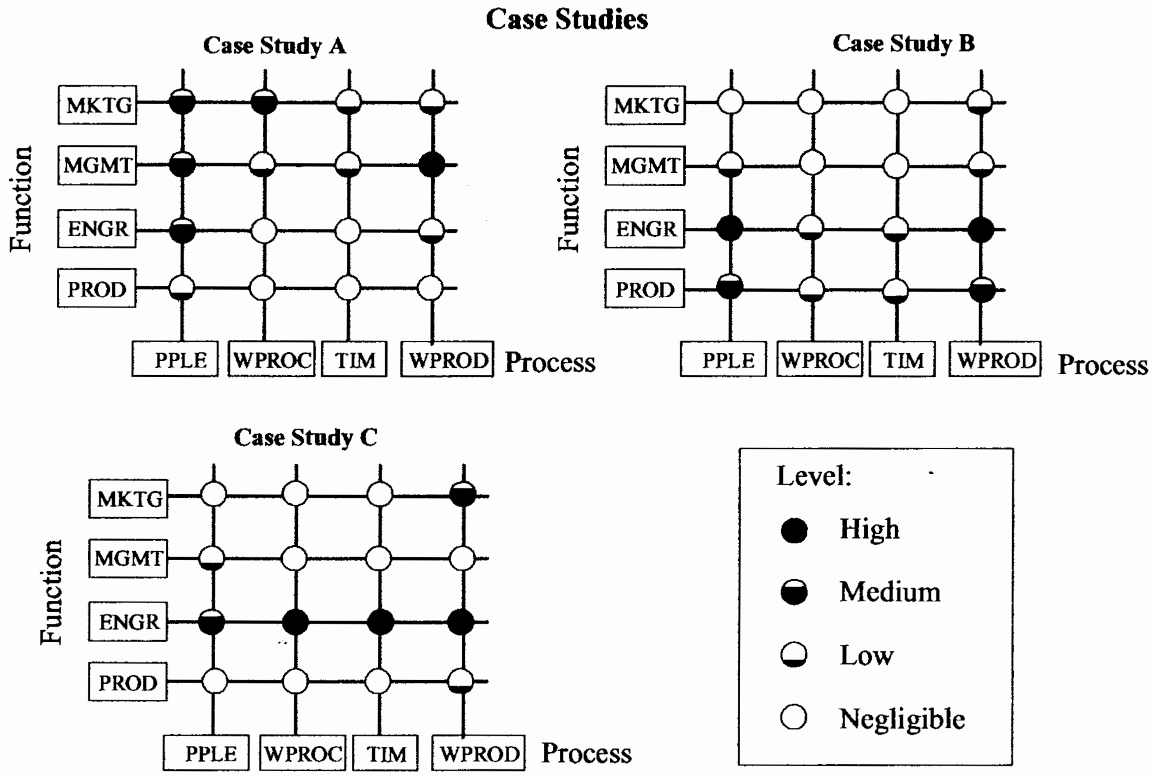
- Process invariants are the essential elements that are always present in a flow decomposition of PD³ in every technological enterprise.
- The process invariants can be regarded as participants in the following flow: people engage in a work process using tools, information and models to create a work product. The process invariants are as follows:
  - People: education, personality, experience, work style, etc., that individuals bring to the enterprise.
  - Work process: task and job content, information flows, task dependencies, etc., that describe the actual activities involved in realization of the work product.
  - Tools/Information/Models: Hardware, firmware, software and knowledge that are part of the infrastructure that facilitates the work process.
  - Work product: Models, plans, and prototypes that are outputs of the flow, and that span a spectrum of representations from abstract to concrete.
- The flow referred to above is usually cyclic in nature - occurring in multiple instances and at several levels of resolution. For example, the work product in one cycle could become a tool in the next cycle.

PD^3 Resource Grid



Function invariants and Process invariants of the PD^3 can be combined to create a grid containing 16 resources.

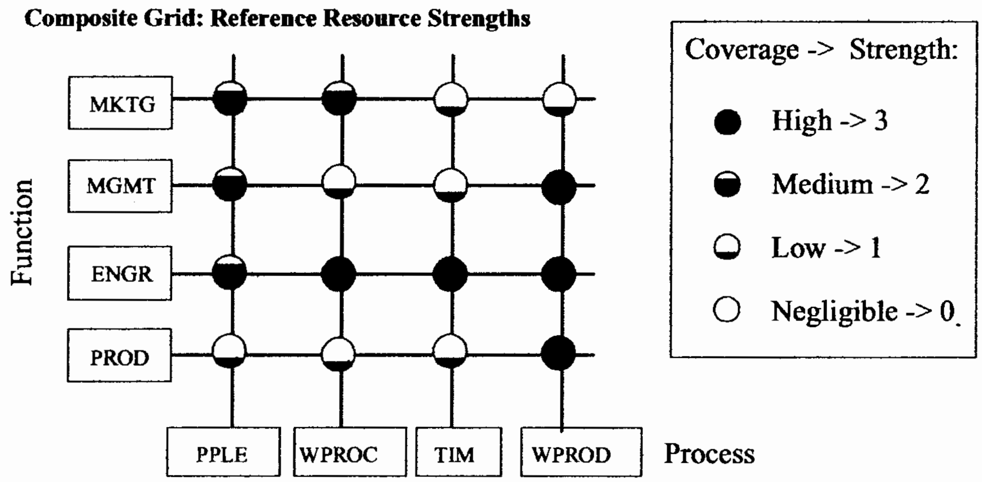
- Each of the function invariants (management, marketing, engineering, and production) requires process invariants (people, process, information, models, tools, and work product) to support that function.
- The pairing of a function invariant i and a process invariant j will be called a *resource*. The resources can be regarded as the assets of the enterprise that collectively provide the means to achieve the goals of PD^3.
- We can refer to a resource by the pair (i,j). For example, the "People" process invariant combined with the "Production" function invariant will be referred to as (Production, People).
- All possible resources, obtained by pairing of function and process invariants, are conveniently represented by a two-dimensional *grid* that provides a basis for an integrated view of all the resources that underlie PD^3.
- When the function invariants and process invariants are combined, the resulting resources have distinct characteristics. Examples of such characteristics for different resources are as follows:
  - People in different function invariants are distinguished by their training, expertise, experience etc. in those specific functions.
  - Work processes are specialized according to function (as well as by other dimensions). For example, work processes of production involve acquisition of materials, material handling and processes, inspection and quality control. In contrast, work processes in engineering involve specification development, design of product and manufacturing process, and prototyping.
  - Tools, information and models are distinguished by the type of function they support. For example, management tools including scheduling and work flow tools; marketing tools include customer surveys and focus group interviews; engineering tools include geometric modeling and finite element tools; production tools including machining centers and plant equipment.
  - Work products for management functions include resource allocation, plans, product strategy, and team development. In contrast, for marketing, work products are customer needs and preferences, market analyses, etc. Engineering work products are product embodiment and manufacturing process plans and prototypes. Production work products are products that are deliverable to markets.
- *Strength* and *importance* are two useful attributes of a resource. To see this more clearly, consider the following simplified example. In the heyday of the mainframe computer industry, the strength of the resource R necessary to produce these machines was aligned with the high importance of R to profitability. Hence, R was of high value to an enterprise within the industry. With the advent of workstations, while R was still strong, its importance diminished significantly resulting in a lower value of R to the enterprise and subsequent losses. A complementary observation can be made about the growth of the desktop computer industry.



Most case studies provide only partial coverage of the grid. Case study A, B, C (see Appendix A) show different areas of focus within the grid.

- A carefully constructed resource grid can be used to form a quick and early assessment of the state of the enterprise. This is a necessary prerequisite to more detailed evaluation based on valuation functions.
- As a simple example of construction and use of the resource grid in practical contexts we use case studies of actual PD^3, and quantify the strengths of each resource from the degree of coverage and emphasis of description of each resource in the case study.
- While each case study probably does not reveal the full reality of the enterprise under investigation, the documentation of the case study is probably a reasonable reflection of the state of the enterprise from the investigator's viewpoint.
- Three case studies (A, B, and C) were mapped on to the resource grid with results shown above. Four levels, from "Negligible" to "High", were used to denote the coverage and emphasis of description of each resource in the enterprise.
- If one examines the resulting grids, one can readily infer that Case Study A (Bowen at al) is from a business perspective, Case Study B (Fuchs and Steidel) is from an engineering (design) practice perspective, and Case Study C (Hawkes and Abinett) is from an engineering design (and development) process perspective. A closer examination of the references cited for each case study shows that these inferences are indeed true. While this is hardly surprising, the important point is that, if we denote each case study as an enterprise, then we can draw useful conclusions about the strengths of the enterprise. Furthermore, as we will shortly demonstrate, when the strength of each resource is appropriately combined with its importance to the enterprise, one can assess the value of that resource to the enterprise. A *resource gap* will be defined, which can then lead to simple guidelines for allocation/reallocation of effort to close the gap.
- First, however, we need to establish the relative strength of each resource in an enterprise, and then create a reference resource-strength grid that is used for assessment of resource gaps.

Case Study Resource Coverage as Reference Resource Strength

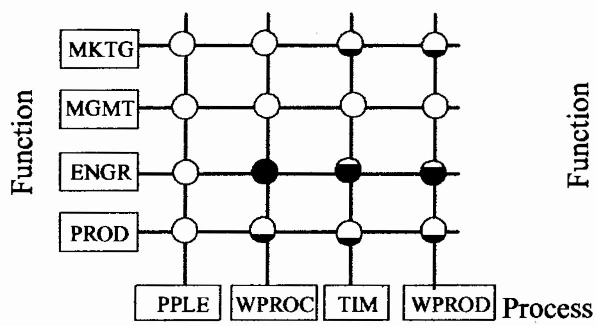


The grids corresponding to Case Study A, B, and C are combined to yield the Reference Resource Strength grid. For our present purposes, the coverage is now directly mapped to a "Strength" that signifies the size and quality of the corresponding resource.

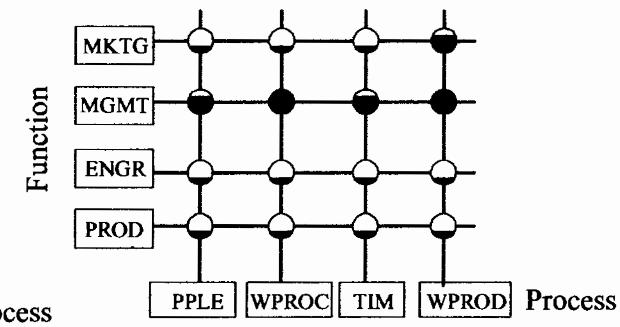
- For a given enterprise, it is possible to assess the *strength* of resource (i,j) as a measure of the size/quality of resource (i,j) relative to the size/quality of the same resource for other enterprises.
- We now intend to use the case studies to demonstrate the use of the grid for resource evaluation and resource allocation in a PD^3 enterprise. Toward this end we first create a composite grid for a hypothetical "well balanced" enterprise formed by combining the grids corresponding to Case Studies A, B, and C.
- This composite grid is "well balanced" because it normalizes the different coverages that result from the varied perspectives of the case studies. Next, as mentioned earlier, imagine that the "Coverage" for a resource in a case study directly corresponds to the "Strength" of that resource in the actual enterprise.
- For example, the "Medium" coverage for the "People" process invariant of the "Marketing" function in Case Study A would reflect a "Strength" of 2 using the mapping shown above. (The strength of this resource depends on size, skills, and organizational structure etc.)
- The strength of each resource of the composite grid is defined as the maximum of the coverages of the corresponding resource of each Case Study A, B, and C. Note that the pattern exhibited by the composite grid is better balanced than the grids corresponding the individual case studies.
- The strength of each resource in the composite grid can be viewed as the **reference strength** of that resource for a "well balanced" enterprise. In order to demonstrate mechanisms for resource evaluation and resource allocation, the composite grid will be used for purposes of comparison with actual strengths of enterprise resources.
- The strength for a resource (i,j) corresponding to the i^{th} function invariant, and the j^{th} process invariant is $S_{i,j}$.

Text Resource Coverage as Resource Importance

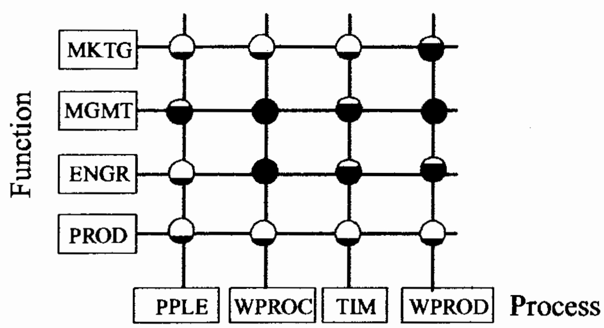
Engineering Design Process
as covered in (Pahl and Beitz)

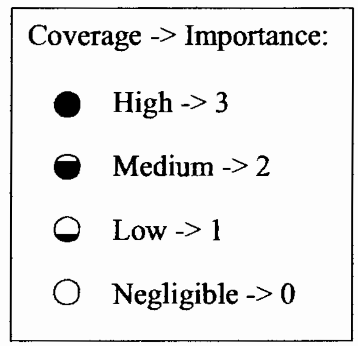


Product Development Management
as covered in (Clark and Wheelwright)



Composite Grid: Reference Resource Importance

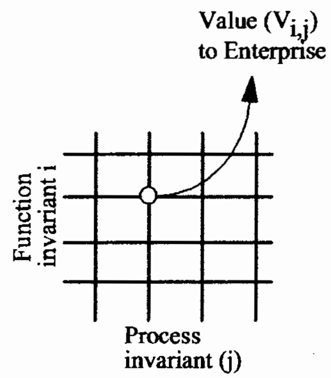




Texts dealing with aspects of PD³ can also mapped on to the grid. They also show different regions of focus within the grid. These grids for texts are combined to create a composite map of the "Importance" each resource.

- For a given enterprise, it is possible to assess the *importance* of each resource (to the success of the enterprise) relative to the importance of other resources of the same enterprise.
- We now intend to use two established texts grounded in product development practice to create a plausible reference model that defines and quantifies the "Importance" of each resource in the grid to the PD^3 enterprise.
- Toward this end we first map the coverage of an engineering design process text (Pahl and Beitz) and a product development management text (Clark and Wheelwright) to the grid. Next, we create a balanced reference grid in a manner analogous to the creation of the reference strength grid. Finally, the coverage levels of each resource in the composite grid is interpreted here as the level of "Importance" of that resource to the PD^3 enterprise.
- The magnitude of the "Importance" level of each resource in the composite grid can be viewed as a measure of how critical that resource is to the success of the enterprise. The strength and the importance of each resource will next be used to determine a useful measure of the "Value" of the resource to the enterprise.
- The Importance for a resource (i,j) corresponding to the i^{th} function invariant, and the j^{th} process invariant is $I_{i,j}$.

Fast Resource Evaluation Grid: Theory



Procedure for resource evaluation:

1) Create an actual resource strength ($S_{i,j}$ for each i and j) grid for the enterprise.

2) Create a importance ($I_{i,j}$ for each i and j) grid for the enterprise.

3) Develop a Valuation function, f, that maps resource strengths and resource importances to Value ($V_{i,j}$).

4) Resource Evaluation: Use the Valuation function to compute the Value ($V_{i,j}$) of each resource (i,j).

$$V_{i,j} = f_{i,j}(S_{k,l}, I_{k,l}, \text{forall} k,l)$$

These Values characterize the actual state of the enterprise.

The actual resource strengths and resource importance are used to quickly estimate the Value of each resource to the goals of the enterprise.

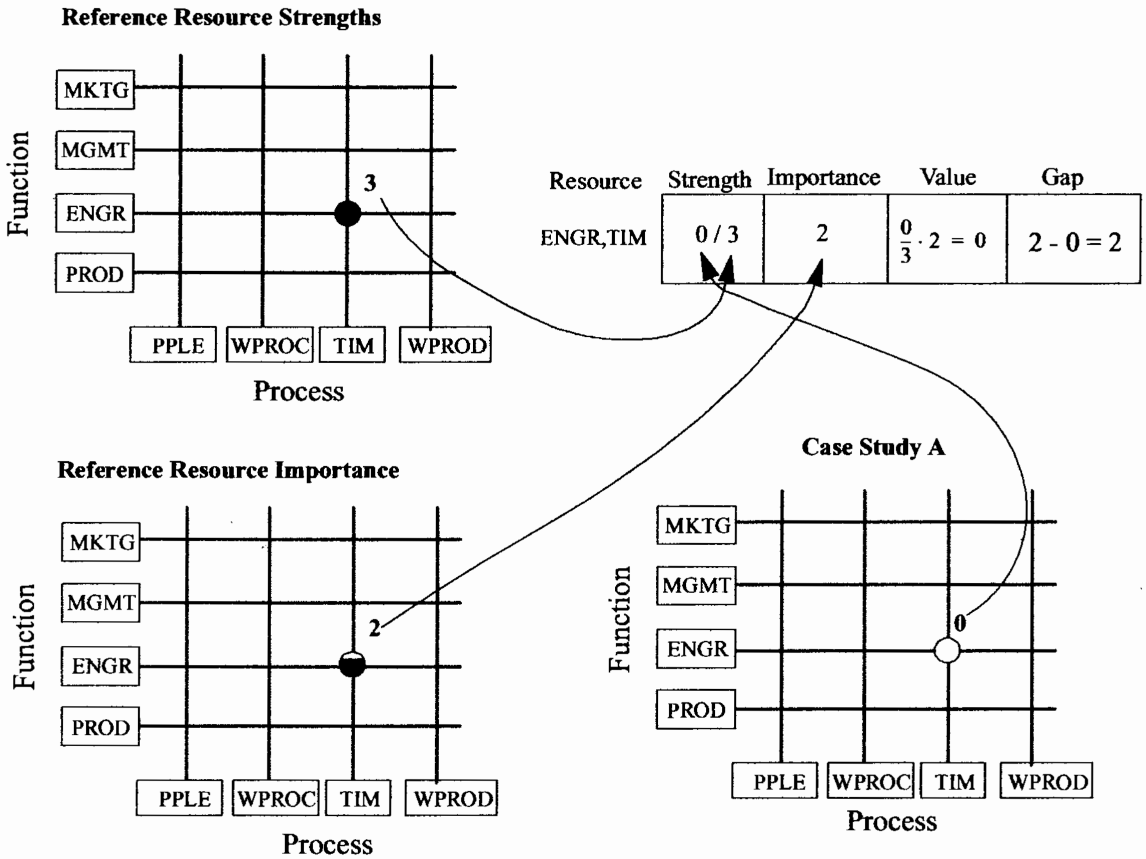
- We will next use the association of strength and importance to each resource to assess the *value* of a resource to the success of the enterprise.
- Value can be evaluated in layers of contexts. For example, the Value of a resource (say "People" process invariant of "Engineering" function invariant) can be determined by its contributions to the context of the process dimension, to the context of the function dimension, or to the context of the entire PD^3 enterprise.
- The Value of a resource depends on the strength of the resource, and the importance of the resource to the goals defined in a certain context. In the context of the PD^3 enterprise, the Value ($V_{i,j}$) of a resource (i,j) depends on the strength of the resource and the importance of the resource to the ultimate success of the enterprise.
- An important issue that arises is to be able to quickly estimate the actual value of each resource of the enterprise so as to assess the state of the enterprise. This assessment would form a rational basis for making decisions regarding allocating additional investments to the resources in order to maximize the aggregated value of the investments to the enterprise. By associating suitable valuation functions with the resources in the grid we create the Resource Evaluation Grid that provides a fast and convenient framework for estimating value based on the strength and importance of resources. A procedure to estimate Value is shown above.
- As a first step to maximizing the aggregate Value of the resources, one can compute the resource "Gap" ($G_{i,j}$) for each resource (i,j) based on a Gap evaluation function $g_{i,j}$:

$$_{i,j} = g_{i,j}(V_{i,j}, I_{i,j})$$

The Gaps provide guidance on allocation and rellocation of investments to resources.

- This procedure for fast resource evaluation for the enterprise are illustrated next using simple and specific functions for computing Value and Gap applied to the relevant grids developed earlier in this paper.

Fast Resource Evaluation Grid: Computation



The value of resources of an enterprise (represented here by Case Study A) can be computed with respect to reference models for the strength and importance of each resource.

- For the purpose of gaining insight into the application of the grid for resource evaluation, imagine an enterprise whose actual resource strengths correspond to the grid developed earlier for Case Study A. The procedure for computing Value and Gap described previously is then applicable to this enterprise using the reference resource strength grid and reference resource importance grid that were shown earlier in this paper.
- Compute the "Value" and "Gap" corresponding to each resource as follows:

$$V_{i,j} \equiv \frac{(S_{i,j})_{act}}{(S_{i,j})_{ref}} \cdot I_{i,j}$$

$$G_{i,j} \equiv \frac{(S_{i,j})_{ref} - (S_{i,j})_{act}}{(S_{i,j})_{ref}} \cdot I_{i,j} = I_{i,j} - V_{i,j}$$

- The computation of "Value" and "Gap" for the (ENGR,TIM) resource using the above equations is depicted schematically in the figure.

Fast Resource Evaluation Grid: Application

		Strength	Importance	Value	Gap
MKTG	PPLE	2/2	1	1	0
	WPROC	2/2	1	1	0
	TIM	1/1	1	1	0
	WPROD	1/1	2	2	0
MGMT	PPLE	2/2	2	2	0
	WPROC	1/1	2	2	0
	TIM	1/1	2	2	0
	WPROD	3/3	2	2	0
ENGR	PPLE	2/2	1	1	0
	WPROC	0/3	3	0	3
	TIM	0/3	2	0	2
	WPROD	1/3	2	2/3	4/3
PROD	PPLE	1/1	1	1	0
	WPROC	0/1	1	0	1
	TIM	0/1	1	0	1
	WPROD	0/3	1	0	1

A concrete application of the fast resource evaluation grid yields insight into the resource values, resource gaps, and new resource allocation for the enterprise.

- The Fast Resource Evaluation Grid applied to Case Study A with respect to the reference resource strength and reference resource importance grids produces the Values and Gaps for each resource as shown above.
- Examination of the evaluation results for the enterprise simulated by Case Study A shows several characteristics:

  1) Since the enterprise emphasized the marketing and management functions (as readily apparent from the actual strength grid for Case Study A), the resource Gap for all the process invariants for those functions are 0.

  2) On the other hand, the difference between the actual and reference strengths of the engineering function, coupled with the higher importance for these functions as indicated by the reference importance grid, results in a larger resource gap for these resources. (The high resource Gaps for some of the production functions is probably due to a somewhat lesser emphasis placed on production functions in both the case studies and texts that we examined.)

  3) A reading of the results provides the useful insight that the critical resource Gaps are in the engineering work process (Gap = 3) and the concomitant tools, information and models (Gap = 2) and proper representation of the engineering work product (Gap = 4/3).
- Furthermore, the Gaps clearly indicate the relative proportions in which any additional investment in resources should be allocated in order to maximum the Value of the resources to the goals of the enterprise.

Related Work

(Hubka and Eder) develop an abstract model of technical systems recognizing the interaction of human systems with technical systems, information systems and management systems. But the top level model almost immediately focuses on technical issues of design theory. (Taylor and Henderson) provide a three dimensional (cube) range representation with elaboration of the abstraction and complexity of the engineering work product. (Tomiyama et al) describe a richer three dimensional (cube) representation of the product model, design process, and design activity somewhat paralleling the elaborations of the engineering work process and product of our model. We have integrated these components into a broader framework that includes the people, marketing and production components of PD^3. This permits a more comprehensive and integrated assessment of the value of all the resources constituting PD^3, thereby providing a rational basis for resource allocation to potentially improve the productivity of the enterprise.

Concluding Remarks

We presented a preliminary model (Fast Resource Evaluation Grid) of an integrated value centered view of PD^3 - the overall context where the research results of the design theory and methodology community realize their value. The model represented function invariants and process invariants of PD^3 in a two dimensional resource grid containing 16 vital resources. By associating strength and importance to each resource of the grid, and defining a suitable valuation function, a value can be assigned to each resource. The computation of value for each resource of a specific enterprise with respect to reference grids enables estimation of resource gaps. The quantification of resource gaps in turn provides guidelines for corrective action in resource allocation/reallocation. We have demonstrated the construction of this model, as well as the procedure for determining value and gap using case studies of real enterprises.

We are now further testing and refining the framework of this research through active engagement with actual enterprises. In addition, we are attempting to place technical contributions (theories, models, and tools from research) within this framework to enable a conceptual integration of results within the context of the enterprise. This will then allow an assessment of where research contributions can potentially aid in closing the resource gaps perceived in the enterprise.

As more resolution is incorporated into the grid, it will be possible not only to see where and how a tool or method fits into the overall scheme of PD^3 but also to clearly understand it value in that scheme. The detailed elaboration of the grid should also provide a rational basis for attempting to resolve typical trade-off conflicts that arise in allocating resources in actual product design, development, and delivery practice. For example, "Should capital be invested in a rapid prototyping capability or a sophisticated solid modeling package?" (We could equally well pose analogous questions regarding our own research.) We welcome feedback on the availability of other case studies, and suggestions for modification of the model, specializations of model, or instantiations of the model with self-assessments of past technical contributions in our community.

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Appendix A: Case Study Summaries

Our choice of the HP Desk Jet, Schlage Lock Co. and DIY Concrete Mixer case studies was based on the availability of simple yet comprehensive case studies that are well documented and span several perspectives on design and product development. However, there are several other perspectives that are required to complete the picture - such as production and marketing cases studies.

Case Study A: HP Desk Jet [Bowen et al]

The HP DeskJet is a thermal ink-jet printer made by Hewlett-Packard (Vancouver Division). The management goal ("guiding vision" (Bowen et al)) for the project was to recapture (market) share of the printer market. This was transformed into the engineering/production goal of design, development and delivery of an ink-jet printer with laser-quality output for less than $1000. The evolution of the project is described mainly from a management perspective (Bowen et al). The following are the our observations from examination of the case study:

> 1) The project was well integrated at the people level. Manufacturing and Marketing moved into the "Laboratory" with Engineering R&D - these 3 functions were "equal" with R&D in the lead. Manufacturing and Production were brought into the process as soon as the first prototypes were built and thus the product was designed for manufacture.
>
> 2) To focus the development team on cost, part of the engineering R&D budget was used to bring materials engineers and manufacturing (early tooling, early test units) into the process early on. The popular DFM maxim "Minimize the number of parts" caused a lot of trouble and expense.

While the case study emphasized how the success of the project was due to "integration", this seems to refer mainly to the organizational level and very little information is given about how well work process and tools were integrated. The case study is presented from a management/business perspective and seems focused on the project from this perspective.

Case Study B: Schlage Lock Co. [Fuchs and Steidel]

In this case study the driving force for product development was the recognition of a new market. In this case, the new market was locks for "pre-hung" doors for pre-fabricated housing. The Schlage Lock Company, a leader in its field, perceived that a need (profit-making opportunity) existed for a new strike plate that could be easily installed in "pre-hung" doors. Thus, the market (need) drove an organization, in this case Schlage, to create an artifact. (The word drive could equally be replaced by "creates an opportunity for".) The management of Schlage then contracted its "Research Division", which comprised 13 engineers, to design a new strike-plate. Our observations from this case study are:

> 1) For the case of the strike-plate, the design process involved the complete range of engineering tasks from investigation of existing patents, conceptual design, modelling determination of "rebound" forces/stresses in the strike plate, material selection, tolerance design, manufacturing process planning, impact and wear testing, and aesthetics.
>
> 2) The design process resulted in several concept variants culminating in a circular strike-plate that was successfully manufactured and tested. However, to develop even "such an apparently simple piece of bent metal", there were "delays, misunderstandings, failures, obstacles, frustrations and the duplication of effort in other departments". This might seem to suggest the value in systematizing the design process in order to improve efficiency/profit.
>
> 3) Finally, the circular strike plate and its cognates were successfully introduced into the market, thus closing the loop from "needs" to "product" delivery.

Case Study C: The DIY Concrete Mixer [Hawkes and Abinett]

This case study concerns the design of a new market segment for a low-priced concrete mixer aimed at the DIY (Do It Yourself) market. Our observations form this case study are as follows:

> 1) The following aspects of the design are comprehensively and systematically documented in the case study: product specification, project scheduling, delegation of design work, synthesis, comparison, evaluation and selection of the frame, tilt-handle and drive of the mixer. The case study also includes details of the sizing and selection of components of the mixer, cost analysis and redesign to reduce cost, and prototyping.
>
> 2) In particular the case study documents the details of the engineering calculations that governed the synthesis, sizing, evaluation and selection of the important components of the product. The case study does not document the production or marketing of the product.