

VARIETY AND INDUSTRIAL PRODUCTION:

THE CASE OF HOUSING

by

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ABSTRACT

Industrial processes have addressed with various degrees of success the question of housing production. If assembly-line methods have proven their efficiency in the production and distribution of low-cost housing, they have been less successful in achieving product diversification, and now suffer from a negative image resulting from this weakness. On the other hand, open and closed systems, based on component kits of parts allowing various assemblies, show a greater potential for variety generation; but their implementation has to face resistances arising from the production systems themselves and from their implications in terms of product conception.

Considering variety as an essential value in the richness of our environment, and regarding individual differences as a variety generator, the purpose of this work is to understand the match between people and industrial systems involved in housing production and to explore the capacity of industrial processes in satisfying individual requirements.

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A ma famille, pour leur affection toujours presente
A Craig, pour les couleurs dans la neige
et autres legendes a inventer

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INTRODUCTION

- 1 The unquestioned efficiency of repetition
- 2 A controversial strategy
- 3 Accept the diversity of the market
- 4 Variety as a solution

INTRODUCTION

1 THE UNQUESTIONED EFFICIENCY OF REPETITION

The prevailing theory in the application of technology to building component manufacture asserts the principles of standardization and mass-production as a panacea. From the architectural theory of the pioneers of Modern Architecture to the commercial practice of developers a whole system rests on these principles. Although lowering the cost of buildings is perhaps not only and directly linked to repetition, this idea of the efficiency of long series is now a cultural fact which is hardly questioned anymore.

Based on successful examples from other industries, like automobile manufacturing, it is inferred that through mechanization and factory production of a limited number of standard parts, the building industry can output a larger volume at a lower cost. This idea is based on an over-simplified conception of production engineering and in spite of serious efforts undertaken for the last 30 years to apply this strategy to component production, the building industry is still lagging behind, compared to other sectors; moreover, there is no overwhelming proof that these efforts have met with any significant success.

Provided it can rely on a continuous demand, mass-production is a particularly efficient, though capital intensive method. Attempts have thus been made to constrain construction markets in order to provide the conditions required for the efficiency of mass-production; but the failure of repetition as a principle to industrialization is based on resistances that neither the declarations of progressists architects nor governmental intentions have been able to modify.

2 A CONTROVERSIAL STRATEGY

The market of housing (and building in general) is diverse. It is segmented geographically, legislatively, and economically. To make large markets possible, the needs for various types of buildings have to be aggregated, which conflicts with the diversity of demand.

Theories and practices of industrialization as applied to housing were initially concerned with variety reduction rather than variety generation. Primarily cost oriented, their preoccupation was "how to repeat the same object as many times as possible". Here can be mentioned the work of the architects of the Modern Movement, like Le Corbusier or the Japanese Metabolists, who considered housing as a consumption good, a "machine to live in" to be produced in large series. Their goal was to search for the ideal cell, which, taking into account the maximum of technical and sociological "norms", could be repeated as many times as possible and assembled in structures of superior order, and then on to the level of optimized city-size organizations.

Standardization and mass-production are often advocated on technical and economical grounds as the only means to answer situations such as massive shelter programs, post-war reconstruction etc.. Indeed the concepts of order and series they convey are not ideologically neutral and often controversial when based on social utopies, as in Le Corbusier's theory asserting: "All men have the same organism, the same functions. All men have the same needs. The social contract which has evolved through the ages fixes standardized classes, functions and needs producing standardized products" or later "Standardization is imposed by the law of selection and is an economic and social necessity".

3 ACCEPT THE DIVERSITY OF THE MARKET

Diversity conflicts with mass-production logic and questions its principles, but as the needs for products are diverse, demand forces the manufacturers to use techniques allowing a certain diversity level. Two forces are changing the context of housing design and production. First, new materials and technologies are emerging which enable other strategies of production. Second, there is a growing consciousness about individual differences; the mass-production concept does not meet the people's requirements and increasingly people want to participate in the decisions that shape their environment, their education, and their consumption. Considering these changes in market and production conditions, the question of industrialization must be formulated in an opposite manner: "How to realize industrially different objects? Are industrial processes compatible with architectural variety?". The industrialization of housing stresses variety production as a technical problem.

4 VARIETY AS A SOLUTION

Resistance of the public is often viewed as a major obstacle to the expansion of industrialized housing. People reject industrialized houses, only accepting them if imposed by economical necessity, and often criticize the monotony and loss in quality of environments they constitute, while idealizing vernacular and other forms of Architecture of the past.

New architectural trends, opposed to the dogmas of Modern Architecture, now advocate variety as an essential quality. But the variety of a project does not solve the problem of monotony at the urban scale or any other aggregated level. This is exemplified in many suburban areas which share the

same undifferentiated aspect, which results from a lack of hierarchy, a lack of intermediate clustering between the formal simplicism of the fabric and the fragmented regularity of individual houses.

Indeed, the problem is not to generate variety for its own sake at the level of each unit. Such a solution, if implemented, would lead to environments as monotonous as those generated by the repetition of a single form: too much variety is visually "noisy" and as disturbing as none.

Regarding variety as a fundamental value in the richness of our housing and environment, it is clear that only the ensemble of differences among social groups and individuals can warrant an architecture satisfying the project of variety. Variety is both the problem and the solution. Since it is no longer automatically generated by the production system (as it was in traditional forms of architecture), variety has to become consciously and intentionally designed-in this system.

The purpose here is not to mourn the lost paradise of craft production but to understand the factors that make us criticize today's fully factory built housing or composed of standard components as less successful in achieving the kind of quality we recognize in traditional forms of architecture.

The hypothesis sustaining this work is that this "lack of good fit" can be attributed to the insufficient capacities of industrial systems for adapting to and satisfying the variety demanded by consumers. We will thus intend to gain a better understanding of the match between people and production systems involved in the production of housing.

The study is composed of four parts and a conclusion:

-I VARIETY WHY:

The first chapter exposes arguments which support the need for variety in housing based on the different requirements of people at an aggregate (segmenting the mass-market) and at an individual level (diversity of individual's needs).

-II WHAT VARIETY?

The second chapter, after a brief presentation of the ways of generating architectural variety, analyses traditional modes of production compared to industrial ones, based on the combination of standard elements in order to understand their implication in terms of product conception, quality, and variety.

-III VARIETY HOW?

In the third chapter tools and methods are presented which may allow us to better understand the kind of variety people want and the production logic used to accomodate it.

-IV STRATEGIES IN COMPONENT PRODUCTION

The fourth chapter encompasses some considerations on the definition of components and an analysis of the strategies used for their production today.

-CONCLUSION

In the conclusion, tools and methods are introduced announcing new possibilities in the variety produced by industrial systems.

I VARIETY WHY?

1 Human needs and wants

1.1 Definitions

1.2 Difficulty in the definition of needs and wants

1.3 Needs in housing

2 Difference of needs

2.1 Demographic and life-style changes challenge the mass-market concept

2.2 Diversity of consumers' characteristics

- Cultural characteristics**
- Social characteristics**
- Personal characteristics**
- Psychological characteristics**

I VARIETY WHY?

1 HUMAN NEEDS AND WANTS

1.1 DEFINITIONS

Mankind needs food, air, water and shelter to survive. Beyond this, people have a strong desire for recreation, education and other services. A useful distinction can be drawn between needs, wants, and intentions, although these words are used interchangeably in common speech:

-A need is a state of felt deprivation in some generic satisfaction arising out of the human condition. People actually need very little. Needs are not created by Society; they exist in the very nature of the human biology and condition. People require food, clothing, belonging, esteem, and a few other things for survival.

-Wants are desires for specific satisfiers of these ultimate needs. A person needs food and wants a hamburger, needs clothing and wants designers' outfits, needs esteem and buys a Jaguar. While people's needs are few, their wants are many. Human wants are always shaped and reshaped by social forces and institutions such as family, peers, corporations.

-Intentions are decisions to acquire specific satisfiers under given terms and conditions. Many people want a Jaguar, only a few will actually buy it at today's price.

1.2 DIFFICULTY IN THE DEFINITION OF NEEDS AND WANTS

Kotler's distinction between needs and wants, although satisfying by its clarity, is difficult to establish in practice (31). When tackling those notions, one encounters a real difficulty in differentiating expressions of the human nature as such from culturally induced requirements. In the case of housing this results in an ambiguous classification. Thus the satisfaction of a cultural requirement for green space, is defined by some as an answer to a physiological need for oxygen.

1.3 NEEDS IN HOUSING

Although it is possible for specialists to define certain thresholds for very specific variables (level of carbon monoxide, etc...), the number of variables is such in the case of housing that it is not possible to isolate them in an adequate manner. Some norms of tolerance can however be established to avoid or reduce the harmfulness of certain solutions. Within those norms one can search for comfort optima, but those are linked to the age, sex, social role, state, professional experience, past life of people. Optima are therefore too difficult to establish and nothing proves that different optima can be compatible as to combine in a global optimum.

1.4 BEYOND BASIC NEEDS

Space has both a practical and a symbolical dimension. Space cannot be reduced as to be a solution to elementary needs; it is loaded with significations that man "produces" while living in an environment. Consequently, a research on space in general, and housing in particular, has to include two approaches:

-one, based on laboratory experiments, studying psychological and physiological reactions to variations in the characteristics of space.

-another, based on observation and experimentation in real conditions, testing the interaction between life-style and space.

An evaluation of the influence of the existing built-form on demand is also of importance in understanding what guides and biases choices.

Having presented the notions of needs and wants, we will now state certain factors and facts, which either at an aggregate or individual level support the necessity of diversity in housing.

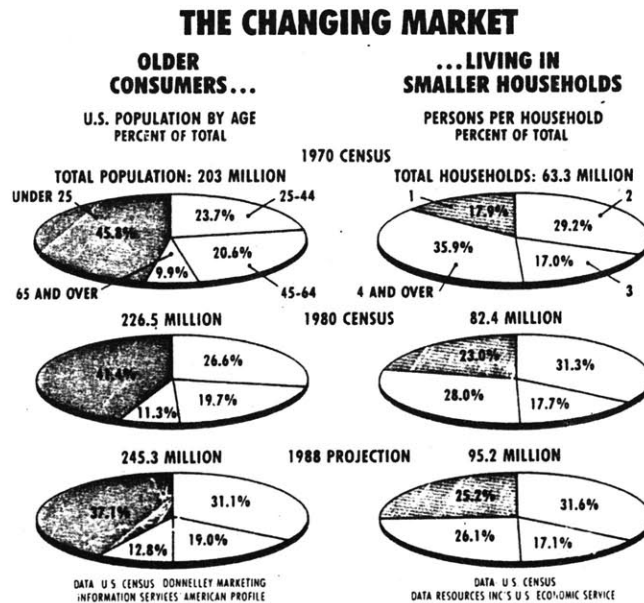
2 DIFFERENCE OF NEEDS

2.1 DEMOGRAPHIC AND LIFE-STYLE CHANGES CHALLENGE THE MASS-MARKET CONCEPT

In the past years, the typical American family consisted of a working father, a homemaker mother and two children. The 1980 census revealed that only 7% of the 82 millions households, then surveyed, fit that description:

- of the families that reported children of 17, 54% of the mother worked full or part-time.
- smaller households now predominate, as more than 50% of all households comprise 1 or 2 persons and singles constitute a fast growing segment.
- 20% of households include persons of 65 or older.

The above chart, from the U.S Census data service, shows the population to be more evenly spread across several household types in 1990 than in 1970; no one arrangement will be typical.



Young adults born during the baby boom will continue in their pattern of low cohort fertility. By 1990, almost two-thirds of the projected number of households will have no children living home or no children at all. Strong trends

are forecasted in delayed marriages, smaller family sizes, and independent living arrangements. Most people will have a variety of experiences in their life-time as they will be more mobile in their type of household and way of life.

As a result of those demographic and life-style changes, the mass-market concept is clearly questioned. Many consumer groups emerge, each, with special needs and interests, demanding for a wide range of different kinds of housing, goods and public or private services. This fragmentation of the market is likely to increase in the near future, as expected by market analyst Laurel Cutler who foresees every market breaking "into smaller and smaller units, with unique products aiming at defined segments".

A further analysis of the diversity of requirements has to be carried out at the level of individual consumers. In order to understand their motivations, we have to study their cultural, social, personal, and psychological characteristics.

2.2 THE DIVERSITY OF CONSUMERS' CHARACTERISTICS

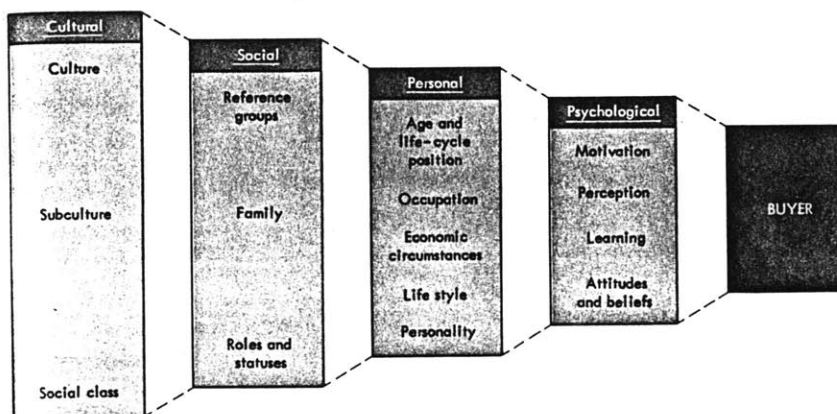


FIGURE 6-3
Buyer Characteristics Influencing Consumer Buying Behavior

- CULTURAL CHARACTERISTICS

As human behaviour is largely learned, culture is an essential determinant of a person's wants. Values, perceptions, preferences and behaviours will be acquired in

a process of socialization involving the family and other institutions. MrX's conception of the house will be influenced by the fact he was raised in a modern society and thus expects certain levels of comfort he has been used to.

- Subcultures

Smaller groups, providing more specific identification to their members, can be isolated; they will be based on:

-nationality (ethnic differences).

-religion (specific taboos or rituals).

-races (distinct way of life).

-geographical location (different life-styles).

MrX's may attach a special meaning to certain types of houses that allow their cultural identification.

- Social class

Social stratification of a society, based on occupation, income, wealth, education, and so on, distinguish classes presenting a certain homogeneity in values, interests and behaviours. Social classes show various product-form preferences. MrX, coming from an upper-middle-class background and successful in his job, is likely to strongly refuse the products of the mobile-home industry.

- SOCIAL CHARACTERISTICS

These factors concern those people in the consumer's life that can influence his behaviour:

-Reference groups

Those groups have an impact on a person's attitudes, opinions, and values. They can be further distinguished into:

-primary group, such as family, friends, neighbours, fellow workers.

-secondary groups, such as associations, professional and other groups.

-aspirational groups, such as sport heroes and movie stars.

Reference groups have various kinds of impact. First they expose the person to various life-styles, then they influence his self-concept and choices because of a desire to "fit-in" and conform to the group. Not all product choice is affected by those influences: depending on the nature of the product, its ostensible character, depending on the person and the cohesive forces in the group they belong to, they will be more effective in inducing behaviour.

- PERSONAL CHARACTERISTICS

The consumer's age, life-cycle, occupation, economic circumstances, life-style and personality are also influential in his choices.

-Age and life cycle

Goods people buy change over their life-time. The concept of family life cycle can help us identify what the wants and values of people will be as they get older.

Seven possible stages are proposed:

- the bachelor stage.
- newly married couple, young with no children.
- full nest 1, young married couple, no children under six.
- full nest 2, young married couple, no children over six.
- full nest 3, older married couple with dependant children.
- empty nest, older married couple with no children home.
- solitary survivors, older single people.

Each age-cycle group has certain specific requirements and interests. This classification, concerning profiles of traditional family, is certainly useful, but, as mentioned before, it does not apply anymore to most of the American population. Another distinction, more recently developed, can be based upon psychological life stages.

-Occupation

Certain needs and wants for goods and services can be induced by a person's profession; in the case of housing

there can be strong connection between specific professional groups and specific models; like in rural vernacular architecture for instance, where house may incorporate work spaces. Today resulting from an increased separation of activities, housing models are rarely linked to particular professions.

-Economic circumstances

This factor is of great importance in people's decisions. Choices will be adjusted according to the income (level, stability, and time pattern), savings and assets, borrowing power and attitude towards spending versus saving of people. In a changing economic climate, income sensitive goods require to be rematched (in price, design) to the solvability of potential buyers.

-Life-style

People with identical subculture and social class can choose to have rather different life-styles. A person selects products in accordance with his or her life-style. Marketers often use the consumer's product choice as a key indicator to develop a "consumer profile" and then design new products consistent with this profile.

-Personality

The personality of an individual includes his character traits, habit and mode of thinking. Each individual exhibits different level of extroversion / introversion, impulsiveness / deliberateness, creativity, conventionality, activeness, etc. Segmentation by personality traits have been implemented with success in certain product areas (cars, beers), by defining product image appealing, through identification, to certain consumer groups.

Another related characteristic of influence in product decision is that of people's self concept. The self-concept is the image an individual has or think people have of

himself. People will choose a product in accordance to these images. The idea is however risky as people may choose according to either their actual or ideal self-concept.

- PSYCHOLOGICAL CHARACTERISTICS

Psychological processes of motivation, perception, learning, beliefs and attitudes operate on the process of choice. In Maslow's theory of motivation, the needs can be ranked in decreasing order of importance as follows:

-PHYSICAL

-physiological: basic survival needs (hunger, thirst).

-safety: self-protection and defense.

-SOCIAL

-belongingness and love: acceptance by a group.

-esteem and status: recognition by a group.

-SELF

-self actualization: development of a value-system.

The basic principle of Freud's theory of motivation is that people are not conscious of the motives inducing their behaviour. Consequently, when choosing products, consumers are assumed to have unconscious psychological as well as conscious functional motives. The unconscious buying motives of people can be studied by using projective techniques and motivational research.

We can now evaluate how complex the interaction between cultural, social, personal, psychological factors influencing consumers' choice must be, and consequently deduce the necessity of a variety of solutions to satisfy consumer's needs and wants.

II WHAT VARIETY? THE QUESTION OF QUALITY

A WAYS OF PRODUCING VARIETY

1 Aleatory

2 Variation on a theme

3 Combinatory

A WAYS OF PRODUCING VARIETY

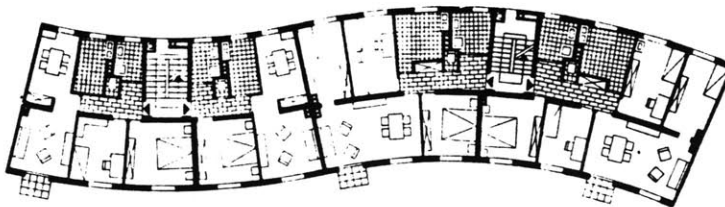
Mechanisms to produce variety in architectural production are:

- Variation: modification of a detail on a type.
- Combination: arrangement, operation and selection of elements within finite sets and configurations.
- Aleatory: random selection of elements in a set.

After a brief discussion on aleatory processes, their interest and limitations, we will focus on variation on a theme and combinatorial processes of diversity, more relevant to us for the purpose of architectural applications.

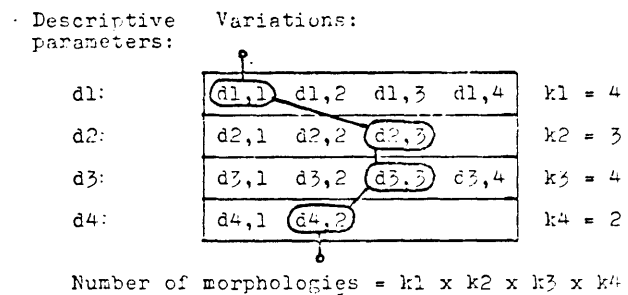
1 ALEATORY

The interest of aleatory mechanisms rely in their capacity to generate new possibles and thus enlarge our potential for variety while not being decipherable or predictable as the other two mechanisms; however, they still have to be governed by intentions and goals, as there cannot be such a thing as a random house. Indeed, total random variety generation based upon all the parameters we can select from, when designing a house, would rapidly lead to such a number of alternatives that they could not be checked by a human even assisted by a computer.



Les Courtilleres. E.Aillaud

To avoid this pitfall, some have intended to introduce a partial or localized randomness in their compositions; like E.Aillaud who, in the Courtilleres, let the masons arrange the windows in the facade panels according to their own will. The consequence of such a process is that, theoretically, all the windows are located differently; on that point of view, the objective variety is very important. But to be perceived, it would require the existence of a structure. Certain searching methods, based upon "controlled" aleatory, can however be helpful in generating variety. We will here mention the use of Zwicky boxes, generating "morphologies" by selection of variables given to various parameters (24); but the application of such a method, can be fruitful only when the number of variables is limited.

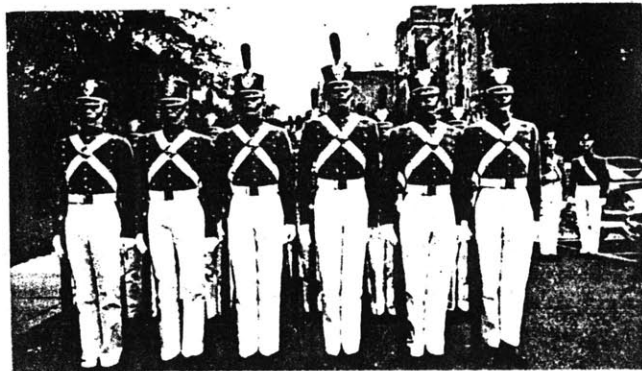


Furthermore, aleatory, like combinatory, is only relying on the values a variable can take. Even if it multiplies those values effectively, the system remains nevertheless unaltered: no new variable can appear.

2 VARIATION ON A THEME

Variation on a theme is the basic principle ruling the production of vernacular artefacts: architecture, tools, furniture. Traditionally, architectural diversity, in craftsman construction, was produced by variation in the interpretation of a cultural model of reference whether a certain type of housing or a certain style of molding. This type of diversity is the one of nature: the diversity of all beings within a same specie is established by variation on

an always identical theme. This variation is global: no cell, no detail, is the same between two faces but the type is always respected. John Harkness describes it as the method "whereby nature has produced a wide variety of patterns and designs which are constantly modifying themselves to be more adaptable to changing conditions;



... its working can be seen, for instance in the variety and strict order of native costumes all over the world as opposed to the monotony of uniforms which were always the products of dictate and formula".

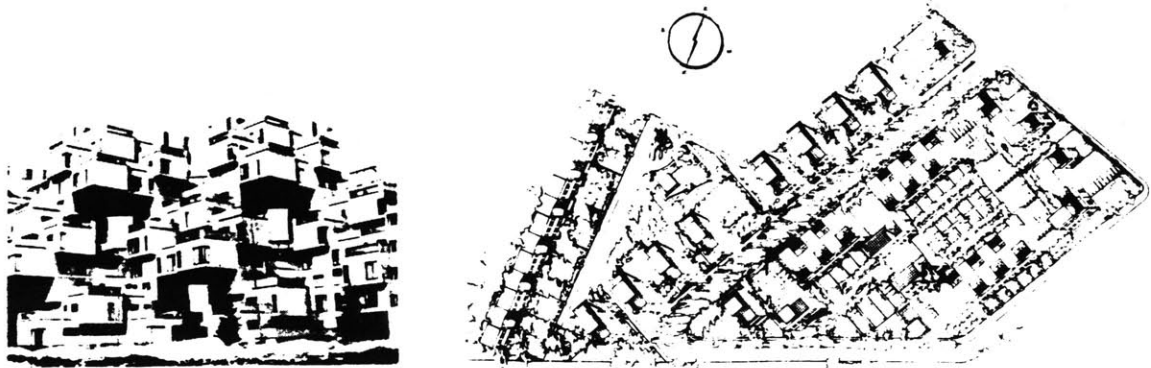


Doors in Amsterdam: although no detail is repeated, the whole, globally perceived, belongs to the same family.

3 COMBINATION

Combinatorial processes are used in many industrial productions based upon the assembly of standard parts; they are the base in construction of open and closed systems. The process consists of getting various configurations by different assemblies of similar objects. Gropius thought of combination as a way to generate diversity starting from identical elements (25). Encouraged by Gropius,

combinatorial processes have been effectively applied by modern architects, either in facade (assemblies of panels), in volume (complex pilings of identical cells) or at the site plan level (combinations of housing types).



Moshe Safdie, Habitat 67

Le Corbusier, Pessac

"there is no limit on diversity in the world. By combinatories on a few primitive elements, unbounded variety can be created;... a familiar example is the proteins, their multitudinous variety arising from arrangements of only twenty different amino acids. Similarly the ninety-odd elements provide all the kinds of building blocks needed for an infinite variety of molecules" says H.Simon (47); Based upon a limited number of elements, initially given, variety is obtained by combination of those elements, from which develops the whole. Consequently, in the case of housing, the potential for variety will depend on the number of building blocks and their flexibility of connection.

The use of combinatorial processes is an interesting solution to willingly diversify. But, if the set of initial elements is too limited or their assembly rule too rigid, the mechanism of variety will be decipherable and predictable, which can affect our perception of the variety of the objects thus produced.

B PRODUCTION MODES AND VARIETY

Introduction: the rules of the game

1 Traditional production

1.1 The whole before the parts

1.2 Type of variety: diversity in unity

1.3 Unity an appropriate goal

2 Production by combination of standard elements

2.1 The whole from the parts

2.3 Type of variety: the marginal difference

3 From "diversity in unity" to "difference in uniformity"

B PRODUCTION MODES AND VARIETY

INTRODUCTION: THE RULES OF THE GAME

The mechanisms of variety production presented before are tied to different systems of architectural conception and production. Before discussing specific industrial strategies as applied to housing manufacturing (chapter IV), we will study the mode of conception of industrial products generated by combination of standard components, as compared to traditionally produced ones, based on the organization of non standard pieces. This understanding will be structured in two parts: after a presentation of these two modes of composition, we will point out some consequences in terms of potential quality of their output and more specifically in terms of kind and level of variety generated.

When analyzing the mode of production of traditionally made or jobbed objects as opposed to modern objects made out of standard pieces, we can notice a major difference in their mode of composition. This difference can be summarized by opposing "the whole before the parts", production principle of the traditionally made objects, to "the whole from the parts" ruling the conception of objects made of selected standard components.

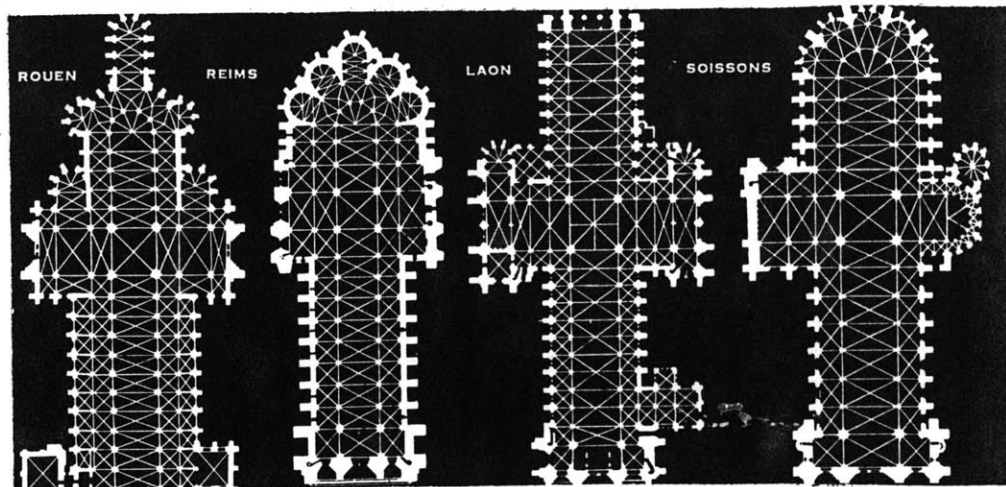
1 TRADITIONAL PRODUCTION

1.1 THE WHOLE BEFORE THE PARTS

We often refer to products made according to traditional methods as examples of good-fit: "the surprising thing to us is that the beautifully organized complexity of the farm wagon, the rowing boat, the violin, and the axe, should be achieved without help of trained designers and also without managers, salesman, production engineers and the many others

specialists upon whom modern industry depends" says Christopher Jones (29). Further studying craftman production, with the example of the farm wagon, he underlines some interesting factors contributing to the adequacy of traditional designs: "each part of the wagon is shaped not by one reason but by many, and there is a delicate adjustment throughout the whole to get the best out of each bit". Alexander qualifies the objects "which display certain kind of behaviour which can only be understood as a product of interaction among parts within the objects" of "systems as a whole" (3). The coherence of shape, material, and function of the craftsman production can be considered as resulting from the organization of parts in such a holistic system: it is "the traditional way of dealing with complexity is to operate, at any one time only upon a single conception of the whole" (29).

1.2 TYPE OF VARIETY: DIVERSITY IN UNITY



French Gothic Cathedrals

Analyzing the mode of production of artefacts of the past, it appears that their unity of form results from a repetitive "trial and error" process "searching for the invisible lines of a good design" and reaching the adequate

fit of the product (29). In terms of variety generated, it is noticeable that within the strong unity ruling their production, traditionally made objects allow for an infinite number of variations. They achieve "diversity in unity", the principle advocated by Gropius as "fabric of democracy", the ultimate societal goal: expressing the individual's richness within a common framework (25).



Thus the conventional measures used in vernacular architecture are the result of a consensus and functions as a support modifiable, adaptable according to the context. As selection is done among a limited range of possibles and as the singularity of the facade remains a secondary concern, the carpenter, possessing a repertory of technical and formal solutions, concentrates his skills on organizing spaces, assembling, fitting or detailing the pieces.

The building process is occurring on the construction site, it can adjust itself to the diversity of demand and to local unpredictabilities. Based on the use of material locally produced and not meant to be diffused on a large market base, the dimensional precision of the constructive elements is not a strong requirement: semi-products allowing for on site adjustments are employed.

1.3 UNITY, AN APPROPRIATE GOAL?

If we often glamorize vernacular products and the richness of details and subtle differences they offer, it is probably that we have not been able till now to define models of such an adequacy that could serve as reference for the contemporaneous production of "diversity within unity";

John Harkness believes the definition of such models "to hold the greatest promise that the architect of the future may achieve harmony without monotony order without regimentation as long as there is a common objective" (25).



The agreement on a form, in traditional construction, is induced by practices, by economical and geographical conditions, by a tendency to make use of the know-how already mastered and by the conformity imposed by the cultural system. All factors which have to be remembered when considering the validity of transfers from craftsmanship experiences to industrial systems.

Today, we may be in the process of trial and error leading to new reference models for housing production or, rejecting their imposition, we cannot find a sufficient social consensus to ensure their coherent definition.

2 PRODUCTION BY COMBINATION OF STANDARD ELEMENTS

2.1 THE WHOLE FROM THE PARTS

When conceiving a product out of a standard range of components, the coherence achieved at the level of the whole is weakened by the nature of the process. To "the whole before the part", principle of traditional production, succeeds the "whole from the parts", by aggregation of standard components. Obviously, the larger the number of parts we can choose from, the lesser consequences or constraints on the conception of the whole. But combinatorial systems, and specially open ones, encounter there a paradoxical situation.

Open systems are built upon conflicting goals: they seek to enlarge the range of possible application of each individual components while performing at the level of aggregated products. Chris Abel expresses perfectly the contradiction of these goals "It is one of the principle of manufacture that if a product is to be designed for maximum efficiency, then its constituent parts must be integrated together in the manner that most closely approximates the desired performance specification of the whole" (1). He also quotes Jean Prouve on the nature of industrial products "Machines are seldom built with parts selected form various sources, they are aggregately designed" (43). The research of a wide interchangeability of the parts is opposed to the technical optimization of possible end products.

2.2 DISCRETE DIMENSIONING AND THE PROCESS OF DESIGN

As changes in the economics of housing production lead to the manufacturing of standard construction elements that can be used in various buildings, heuristical and appoximate measures, based on choice in a continuous range of possible dimensions, are progressively replaced by nominal measures, as a determined number of fixed dimensions is admitted before conception.

When vernacular architecture uses conventional measures adapted to building practices and material employed, those agreed-upon dimensions are used as a reference support which does not exclude singularity: during construction, they can be modified and adapted by the craftsman according to the context. In construction from standardized parts, dimensions are normative: the dimensions of catalogue components escape the decision realm of the designer to be determined by the manufacturers or norm makers. Using a catalogue component will thus imply for the design the introduction of a discrete dimensioning system.

The standardization of parts and the resulting discontinuity in dimensions it implies are not inconsequential on the process of design; if they do not signify uniformity of output or suppression of creative possibilities, they certainly have strong implications: the lesser dimensions offered in component sizes, the more conception will be constrained to go from the parts to the whole. This is obvious in light frame wood construction, where, in order to minimize labor cost and maximize the use of material, houses are often built on a 4' grid which corresponds to the size of plywood sheets, plaster boards...

2.3 TYPE OF VARIETY THE MARGINAL DIFFERENCE

The demand for personalization, submitted to the technological consistency of the object is satisfied in industrial production (and specially mass-production) in differences qualified by Riesman as inessential, marginal (45). Thus, the seriality of the industrial object is compensated by an abundance of choice in colors, accessories or details. To personalize a car, a manufacturer uses serially produced frames and motors, modifies features, adds certain accessories, but the object in nature remains the same; indeed, it is rather the illusion of a personal distinction that is provided, as those "specific" differences are themselves serially produced.

Galbraith thinks that we remedy to the simplicity and uniformity of industrial products by the use of compensatory features and illustrates this idea with the example of a toaster: "it is a toaster of standard performance, the pop-up-kind except that it etches on the surface of the toast, in darker carbon, one of the selection of standard messages or design. For the elegant, an attractive monogram would be available or a coat of arms; for the devout at breakfast, there would be an appropriate devotional message from the Reverend Billy Graham; for the patriotic or worried, there would be an aphorism urging vigilance from the late J. Edgar Hoover; for modern painters and economists, there would be a purely abstract design. A restaurant version would sell advertising" (21). The marginal personalization is used as a value added to promote consumption.

3 FROM "DIVERSITY IN UNITY" TO "DIFFERENCE IN UNIFORMITY"

The transformation of models into series, of series into marginal differences and combinatorial variations has been analyzed by Baudrillard, who opposes the "diversity in unity" of traditionally produced objects to the "differences in uniformity" of industrially produced ones (69). When traditional or jobbed objects are introduced as models in industrial production, their "holistic property", resulting from a coherence between shape, material and function, is weakened and often lost by the use of fac-simile materials, by the optional, by their reduction to stereotypical aspects. This is exemplified in the revival of vernacular and historical styles offered to housing buyers as possible "toppings" of the same model: "The Brittany offers choice of elevations including French colonial, colonial, Tudor and provincial" (60).



Individuality is achieved by exterior treatments and configurations of the same generic box. Restricted by to production constraints, the variety of industrial objects is based on a finite number of combinations of fixed elements and a redundancy of secondary features and accessories, changing with fashion, to compensate that limitation, whereas the variation on a theme used by the hand-made or craftman product is infinite.

Not left anymore to the hazards of individual demand and implementation, the variety of industrial objects becomes systematized in the production process. It is difficult to evaluate quantitatively the level of variety generated by

craftsman verses industrial production, but we are here more concerned with the notion of qualitative difference in the variety produced by those two systems. The "failure" of industrialized housing systems (and in particular those of mass-production) might be nested in their inability to offer a kind of variety more fundamental to the customer than the marginal difference previously described and in the difficulty to achieve the "good-fit" out of an assembly of standard parts.

The issue thus raised is whether it is possible to produce personalized objects offering a more meaningful variety to the buyer, while still respecting the constraints of industrial systems. But how can manufacturers know about the "meaningfulness" of certain varieties to the buyer? And how can they check the technical and economical feasibility of those varieties from a production viewpoint? Such are the questions we address in the next chapters.

**III VARIETY HOW? TOOLS IN CONTROL MANAGEMENT AND MARKETING
A UNDERSTANDING THE DEMAND**

1 Introduction

2 Definitions

2.1 Utility

2.2 Product attributes

2.3 Attribute salience

2.4 Attribute determinance

3 Methods for evaluating consumer's value system

3.1 Observation and experimentation

- Observation

- Experimentation

3.2 Direct questioning

- Dual questioning

- Perceptual mapping

3.3 Indirect questioning

- Covariate analysis

Expectancy value model

Determinant attribute model

- Conjoint analysis

Trade-off analysis

Concept evaluation

A UNDERSTANDING THE DEMAND

1 INTRODUCTION

In our free enterprise economic system, consumer wants and desires are a basic determinant of the nature and quantity of goods and services produced. When developing a new product a company must consider two basic problems. First it must know its market; second, it must understand the nature of the product. Both problems are hard to solve, especially when the product has several qualities each of which appeals to consumers with different interests. But how do we evaluate those wants? and how can we know which of the product features are the most important to the consumer?

In order to understand consumer behavior, we will analyze the nature of those wants as well as the process used by the consumer to evaluate their satisfaction.

There are many judgemental processes, depending on people and situations, and no simple algorithm could encompass them all; but recent researches on behavior, carried on in mathematical psychology or psychometrics, and applied to marketing, have led to various models of the evaluation process. For any product, brand, pattern, style, or other individual offering to the public, there are at least two "levels" of evaluation by consumers:

- Overall attitude toward the item, in term of suitability.
- Attitudes toward each of the item's component features, which presumably combine to produce an overall attitude.

This chapter is primarily concerned with the latter type: what are the important features of an item and how they combine to affect both our overall evaluation and our actual purchasing decision? Most of those models presented view the consumer as judging largely in a conscious and rational manner, and are qualified of cognitively oriented models.

2.2 PRODUCT ATTRIBUTES:

In marketing wording, we perceive products as "bundles of attributes" (31). When evaluating and choosing products, we do not consider the characteristics of the alternatives along one single dimension; indeed, we position them with respect to a set of attributes relevant to the product class. P.Kotler mentions some typical attributes we use in current product categories evaluation:

-Cameras: picture sharpness, speed, close-up distance, size, ruggedness, price.

-Air travel: departure time, speed, aircraft, preflight and onflight service, price.

By extension in the case of housing we can assume some of those reference attributes to be: comfort, design, functionality, price ... to name but a few.

Those lists are by no means exhaustive and each person reference framework will probably differ as to the relevance of a particular attribute. Attributes are used to segment the market according to their influence on different consumers; this influence is reflected in their salience and their importance (determinance).

2.3 ATTRIBUTE SALIENCE

Salient attributes are those that come to the consumer's mind when asked what product attributes are the most important to him, or what are his ideal levels of various product attributes. But it cannot be concluded that the attributes mentioned are necessarily determinant in the decision process. The consumer may have been influenced by commercials biasing his choice or may be unwilling or unable to state his decision base (see direct questioning). In their paper "Determinant buying attitudes: Meaning and Measurement" (38), Myers and Alpert illustrate how misleading can direct questioning be with the example of car attributes.

2 DEFINITIONS

Before presenting some of those models it seems useful to define certain terms and concepts they refer to.

2.1 UTILITY

To understand how a given consumer shares his income among various commodities, economists have designed a model of consumer behavior based on the assumption of a rational process of choice. When purchasing an amount of a certain commodity, the consumer behavior is determined by at least three parameters:

- preference
- income
- cost of the commodity (and opportunity cost).

It is assumed that preference can be expressed by a certain utility factor. It is important to distinguish between total and marginal utility. W.Baumol (7) and E.Mansfield (34) define these concepts as follows:

- The total utility of a quantity to a consumer (measured in money terms) is the maximum amount of money he or she is willing to give or exchange for it (7).
- A utility is a number that represents the level of satisfaction that the consumer derives from a particular market basket (34).
- The marginal utility of a commodity to a consumer (in money terms) is the maximum amount of money he or she is willing to pay for one more unit of it (7).
- The marginal utility measures the additional satisfaction derived from an additional unit of a commodity (34).

In modern economics theory, the consumer is supposed to rationally allocate his income as to maximize his utility: "The rational consumer will choose a market basket where the utility of the last dollar spent on all commodities purchased is the same" (34).

"In proprietary studies asking consumers to evaluate such automobile attributes such as power, comfort, economy appearance and safety, consumers often rank safety as the first in importance. However, these same consumers do not see various makes of cars as differing widely with respect to safety; therefore, safety is not a determinant attitude or feature in the actual purchase decision. At any given time, all the various brands may have the same level of perceived possession of an attribute, and thus it will not be as important for the present as some attribute for which differences are the basis for current brand preferences."

We should therefore be more concerned with the attributes that are really determinant in the decision process and by their relative importance weight to the consumer.

2.4 ATTRIBUTE DETERMINANCE

In the wide spectrum of features of a product there are some that really induce consumer's preference and eventual purchase decision. Those features are called determinant attributes. We can assume that products with high levels as possible of each positive determinant attributes will be preferred by the consumer.

3 METHODS FOR EVALUATING CONSUMERS' VALUE SYSTEM

Since no manufacturer can afford to sell an infinitely convenient product for an infinitely low price it is essential to understand the consumer valuing process and his trade-off between various attribute level combinations.

According to Myers and Alpert (38) there are three types of approaches to understand consumer behavior:

- 1. Observation and experimentation (including unobstrusive measures).
- 2 Direct questioning.
- 3. Indirect questioning, including covariate analysis and conjoint analysis.

3.1 OBSERVATION AND EXPERIMENTATION

- OBSERVATION

Description and limitation: One of the techniques for attempting to identify consumers' preferences is that of direct observation of consumers in purchasing situations. If it can be easily applied in recording consumers' behavior in a supermarket it seems much more difficult to implement in the study of housing.

- EXPERIMENTATION

Description: The experimental approach may be viewed as an extension of the observational method. It makes an attempt to isolate the role of one or more specific features of a product by holding all others constant, varying the factor in question, and then measuring the impact upon some performance criterion such as buying choice.

Application and limitation: This method has the advantage of indicating causality by isolating factors that motivate behavior. Like the observation method it does not rely on respondents' answers. However when many factors must be observed, it turns out to be very costly if not impossible.

3.2 DIRECT QUESTIONING

In those approaches the respondent is asked directly what factors he considers important in his evaluation and for what reasons he prefers one product or brand to another. He may also be asked to rate his "ideal brand" for a given product category in term of several product attributes, so that an ideal product profile may be constructed.

These methods have the appeal of seeming to get directly to the issue of "why do you buy?". However, they rest upon two very questionable assumptions, namely: that the respondent knows why he buys or prefers one product to another, and that he is willing to tell what these reasons are. But consumers often do not understand their own reasons for purchasing something, and even when they do, they are unwilling to admit what may make them look foolish or irrational.

- DUAL QUESTIONING

Description: This approach involves asking two questions concerning each product attribute which might be determinant. Consumers are first asked what factor they consider important in a purchasing decision, and then they are asked how they perceive these factors as differing among the various products or brands. Their preference is supposed to be function of the importance weights they assign to each attribute times their perceived level of attribute per product. Some items may rank high in rated importance but may not be thought to differ much among products and conversely.

-EXPECTANCY-VALUE MODEL

To illustrate, suppose Mr X considers only three attributes are important in buying a house: style and functionality and quality of construction. Furthermore, he feels functionality and style are twice important as style.

The following chart presents estimates of his preference level based on his grading of 5 houses.

House	Style	Function	Quality	Pref I
1	20	20	50	26
2	40	20	20	26
3	20	20	10	18
4	10	20	10	14
5	10	20	10	16
Importance	.40	.40	.20	

Mr X would consider houses 1 or 2 as the most attractive. Note that 1 and 2 have the same grading by compensation of their attributes (based on P.Kotler exemple on cars).

-DETERMINANT ATTRIBUTE MODEL

Attributes stated as important by the consumers do not always function when they actually choose products because they may not be perceived as substancially differing among various products (see attribute salience). Interesting is the fact that competitors generally match on important attributes, neglecting less important attributes that might indeed be determinant.

The model is based not only on the importance of each factors but also on their variability (using standard deviation) among products; they combine in a determinance level which is equal to the importance times the variability of a attribute.

House	Style	Function	Quality	Pref.I
1	20	20	50	263.5
2	40	20	20	230.5
3	20	20	10	132.6
4	10	20	10	83.6
5	10	20	10	118.2
Importance	.40	.40	.20	
Variability	12.25	0.00	17.32	
Determinance	4.9	0.00	3.46	

Using importance weights, we would predict Mr X to choose either house 1 or 2; using derterminance, we think he will prefer house 1.

The expectancy-value model, using weighted importance estimated by the consumer, does not separate the preference among different products as the determinant attribute model does: functionality, though estimated important, is a non determinant attribute and has no influence on the choice. The determinant attribute model eliminates this factor to sort out really influential ones.

"IDEAL" ATTRIBUTES: PERCEPTUAL MAPPING

Description: A direct questioning approach consist of asking the respondent to describe the characteristics of the "ideal" brand or company in the product or service category being studied. An ideal product represents the ideal combination of attributes for the consumer.

By also asking for ratings on existing products in term of the characteristics initially mentioned by the consumer, one hopes to find out where "gaps" exist between consumer's product image and optimal product image.

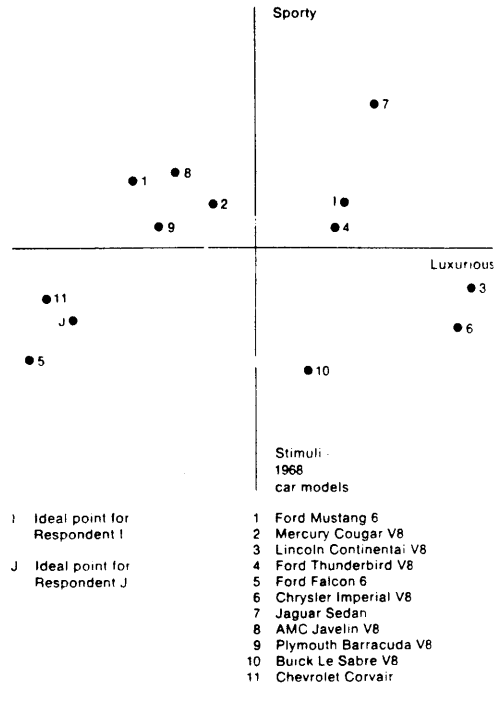
Assumption: A major assumption of this technique is that consumers choose goods according to their self-image and their goals. If the consumer's goal in buying a car is luxury and sportiness of the model, then the consumer will care about characteristics such as design, handiness, speed level, etc..This goal may be sustained by a consumer's self-image such as being a dynamic and sophisticated person.

Application and limitation: Based upon data from large consumer sample, this technique can be applied to determine clusters of preference used to segment the market and support the definition of targeted products.

Unfortunately, this approach shares the problems of traditional questioning, as it assumes that the consumer to has an image of the ideal product he wants and is willing and able to define it explicitly.

Example: P.Green and Y.Wind present a perceptual mapping of consumers' evaluation of the relative similarity of 11 cars and two consumers preference orderings (23).

Perceptual mapping of respondents' judgments of the relative similarity of 11 cars and two respondents' preference orderings



An example of perceptual mapping. The closer a point is to a customer's ideal point the more attractive it will be considered. Thus according to the above perceptual map respondent I prefers Ford Thunderbird while J likes better Chevrolet-Corvair.

3.3 INDIRECT QUESTIONING

Any interviewing approach that does not directly ask the consumers for the motivations of their choice falls into that category.

- COVARIATE ANALYSIS

Description: This method provide a more systematic way of understanding consumer's motivations and behavior. An approach is to use regression analysis, to develop relationships between component attributes and consumer's behavior. The respondent is asked to rate a product on several aspects and on an overall base. Multiple regression is then used to solve for the "importance weights" (regression coefficients) wich assigned to each attribute would maximize the correlation between overall value and a linear combination of the attributes ratings.

Application and limitation: It is always possible that a factor might be totally unacceptable to the respondents, and that its very low rating might cause the rejection of products otherwise acceptable.

This points out a major limitation of covariate analysis; namely, it does not indicate the absolute level of acceptance of the various product characteristics, and thus cannot be relied upon to give the complete story. Therefore, correlation analysis applies mainly throughout the "sensitive range" of a product feature desirability.

Covariate models have in common the relating of product or service component ratings with some criterion, be it product purchase, brand preference, or some overall evaluation of the product or service. Many types of models are possible, all suffering from the weakness of any covariate model: the relationship they establish does not indicate causality.

- CONJOINT ANALYSIS

These models, recently developed in the study of people's perception and preference, are largely based on the same principles and computation tools than covariate analysis; consequently, they share some of their draw-backs (no precision on causality, challengeable assumption of independence of the variables).

Like covariate analysis they assume that, although consumers cannot express in a reliable manner their evaluation and selection process, it can be inferred by studying their choice among products, the characteristics of which are systematically varied. However, they strongly differ in their method of data gathering.

Unless covariate analysis, those models assume that we can measure relative values of things considered jointly which might be unmeasurable if taken one at a time; whence their name "conjoint".

1-TRADE-OFF ANALYSIS (pairwise)

Description: Consumers are presented with matrices showing two attributes at a time, with different level of each attribute, and asked to rank the trade-offs between each cell's combination in order of preference. A computational method (Kendall's tau or phi) converts this rank order into estimated utilities.

Assumption: The model assumes the independence of the attributes studied or in other terms that the extent to which a respondent prefers wood-siding will be unrelated to the model style or size. It may well be that wood-siding is preferred to brick for a Ranch style house but not for a Tudor style one. It also assumes that the degree of "liking" for a certain combination can be computed by multiplying together consumer's utilities for the relevant attribute levels.

A two-at-a-time factor evaluation procedure for cars (23).

For each of the six questions below, please write in the numbers from 1 to 9 to show your order of preference for your next new car.

Miles per gallon				Miles per gallon				Miles per gallon			
Price of car	22	18	14	Maximum speed	22	18	14	Length	22	18	14
\$3,000				80 mph				12 feet			
\$3,200				70 mph				14 feet			
\$3,400				60 mph				16 feet			
Miles per gallon				Miles per gallon				Price of car			
Roominess	22	18	14	Made in	22	18	14	Made in	\$3,000	\$3,200	\$3,400
6 passenger				Germany				Germany			
5 passenger				U.S.				U.S.			
4 passenger				Japan				Japan			

A respondent's utilities in "condominium design and pricing" (20)

Attribute: Level	Utility	Attribute: Level	Utility
Floor: 28th	.315	Price: \$52,000	.738
20th	.311	\$59,000	.217
12th	.271	\$66,000	.035
4th	.103	\$74,000	.010
River View	.769	Unit: Plan B	.471
No View	.231	Plan C	.403
		Plan D	.125
		Plan E	.001

$$\tau = \frac{441 - 3}{444} = \frac{438}{444} = .986$$

2-CONCEPT EVALUATION (Global)

Description: In the concept evaluation technique, consumers are asked to rank product concepts varying simultaneously with respect to all attributes. The data are then analyzed to reconstruct the implicit utility function for the separate attributes.

Example: P.Green and Y.Wind describe how the concept evaluation method works in a glamorous case: the design of a new spot remover for carpet (23). Five attributes, expected to influence consumer behavior, are studied: package design, brand name, price, Good Housekeeping seal of endorsement and a money back guarantee. Three package designs, three brand names, three prices are under consideration (three level factors) as well as the presence or not of the two last factors (two level factors). The cost and difficulty of testing $3*3*3*2*2=108$ alternatives is avoided by selecting a few test combinations, using an experimental design method (orthogonal array) which balances the contribution of the five factors.

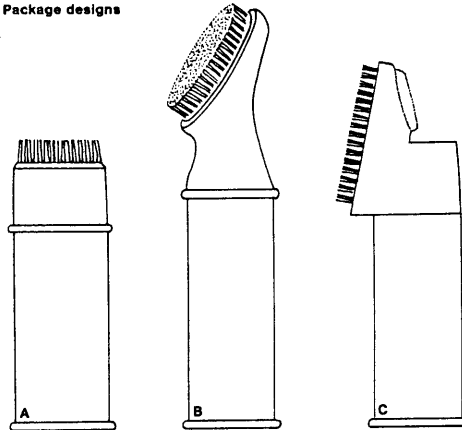
Orthogonal array

	Package design	Brand name	Price	Good Housekeeping seal?	Money-back guarantee?	Respondent's evaluation (rank number)
1	A	K2R	\$1.19	No	No	13
2	A	Glory	1.39	No	Yes	11
3	A	Bissell	1.59	Yes	No	17
4	B	K2R	1.39	Yes	Yes	2
5	B	Glory	1.59	No	No	14
6	B	Bissell	1.19	No	No	3
7	C	K2R	1.59	No	Yes	12
8	C	Glory	1.19	Yes	No	7
9	C	Bissell	1.39	No	No	9
10	A	K2R	1.59	Yes	No	18
11	A	Glory	1.19	No	Yes	8
12	A	Bissell	1.39	No	No	15
13	B	K2R	1.19	No	No	4
14	B	Glory	1.39	Yes	No	6
15	B	Bissell	1.59	No	Yes	5
16	C	K2R	1.39	No	No	10
17	C	Glory	1.59	No	No	16
18	C	Bissell	1.19	Yes	Yes	1*

*Highest ranked

Experimental design for evaluation of a carpet cleaner

Package designs

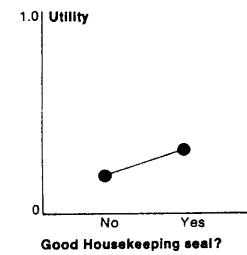
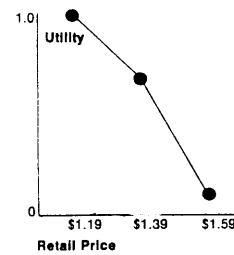
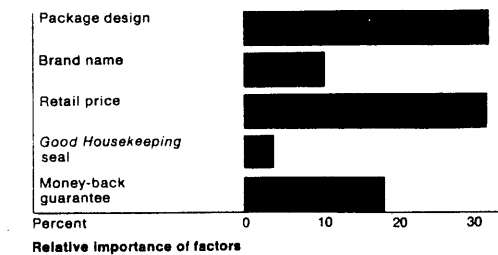
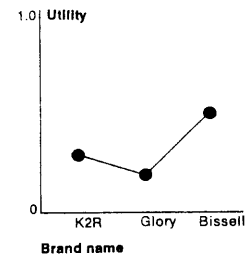
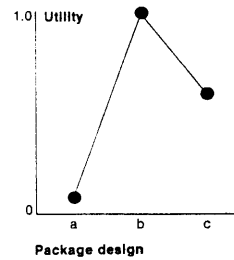
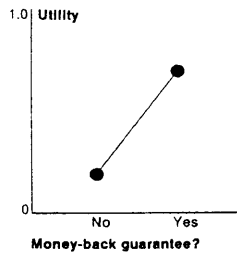


Example of concept evaluation by conjoint measurement

The above exhibit presents an orthogonal array involving 18 of the 108 initial combinations. The respondents are asked to rank in order of preference (or likelihood of purchase) 18 cards, on which figure a design package (A, B, or C) and precisions regarding the four other factors. Simple ranked data needs to be obtained and only 18 out of 108 alternatives can be evaluated.

Computation of the utility scale of each attribute, representing their determinance in consumer's evaluation, is realized by computer programs. From the ranked data of a respondent, the computer extracts a set of scale values for each attribute used in the design process.

As in the previous approach, those scale values are chosen so that they add together in a total utility which matches the original ranking.



The above exhibit presents the utility of each factors. For the preferred combination of the first exhibit, number 18, the package design has a utility of $U(A)=0.6$, the brand name a $U(K2R)=0.5$, the price a $U(\$1.19)=1.0$, the seal a $U(G.H.S)=0.3$, and the guarantee a $U(M.B.G)=0.7$; which sums in a total utility of 3.1. We could get the highest possible utility by using package B instead of C and keeping the same combination of other factors.

We can have an idea of the relative importance of each factor by comparing their utility range (see lower portion of the exhibit). But this relative importance depends largely on the level allowed for each factor during design: if the price had ranged from \$1 to \$2, its relative importance would have certainly increased.

-Application and limitation of conjoint analysis methods
 Concept evaluation techniques are more realistic than trade-off analysis as they involve respondents in choices among global product concepts rather than pairs of attributes. However they are more difficult to apply when many attributes, varying at the same time, have to be considered, while the pairwise approach can easily provide

trade-offs among pairs of attributes. The number of attributes this latter approach can handle is only limited by constraints of test length and respondent's resistance; it is in general restricted to no more than eight attributes.

An advantage of conjoint measurement procedures is their capacity to generate accurate data from simple rankings. Another of their qualities stems from the wide range of application: not only can they evaluate quantified attributes but also sensory (color, texture, shape) and subjectively perceived ones (beauty, satisfaction).

But the greatest benefit of those models is that they do not require the actual testing of all the alternatives. Ten attributes, varied on two levels each, generate 1024 alternative concepts; their exploration in traditional testing would be impossible, whereas conjoint measurement models can predict their validity based on a limited consumer testing.

However, we must be cautious in the application of such models: some product may involve utility functions that are not graspable by a conjoint measurement approach. The challengeable assumption of independence of the factors used by simple additive models, can be suppressed by using more complex interactive ones (polynomial); but those models become rapidly cumbersome due to the number of computations they require. Moreover, the nature of certain products may not make allowance for their reduction into alternative features.

While these limitations are not negligible, conjoint measurement still provides an interesting tool to understand consumers' trade-offs among product alternatives, especially when applied to sensitive attribute ranges.

-Determining product characteristics

Estimated utilities can be applied to modify current products or design new ones for selected public. Once utilities and complementary data (demographic, product consumption, media exposure informations on each respondent) have been gathered for an appropriate sample of consumers, several possible versions of a product, assumed feasible both in price and manufacturing, can be tested. By computing individual's overall liking, it is possible to determine how a product concept stands relative to competitors' offerings and what its market share and target are.

Other methods of direct questioning, not detailed in this study, are Motivation research (53) and Inference of "ideal" attributes (14).

CONCLUSION

-VALIDITY OF MODELS

For those models to have some validity, attention must be paid to the design of the test. This requires the selection of a representative sample both, in terms of size and composition. The length of the test is also a critical point: consumers may be unwilling to participate a 4 hour test and their answers may be affected by tiredness and boredom. Consumer researches are often based on 45-60 minutes interviews on sample of a 100 motivated respondents. But certain consumers are not willing to spend their time on tests for any monetary or other reward.

Careful trade-offs must be worked out by the reseacher in terms of number and appropriateness of the attributes tested. The assumptions underlying the test have to be stated and the attributes listed must refer to the evaluative dimensions used by consumers. Moreover the type of scaling should reflect the kind of attribute being

tested: perceptual measures should not be mixed with physical cues and psychological scaling should not be applied for subjective measures (like quality).

Each of the methods presented in this chapter has some limitations. In particular any of the methods which are not used in a situation involving actual choice and purchase of a product must rely upon what the respondent says, which might be different from what he actually does or thinks in a real situation. Therefore an investigator, interested in identifying the attributes which are determinant in choosing among products, should always ask for the absolute level of attribute acceptance for the product evaluated and check the ratings of different competing products. It can be noted that the dual questioning method is a possible short-cut to regression analysis, as it directly asks the respondent what attributes are important and how they are thought to differ among various products.

When more resources are available for research, certain methods can be profitably combined in the same study. It is particularly interesting to use perceptual mapping to measure consumers' perceptions of certain commodities while applying conjoint measurement to precise consumers' trade-offs. This type of combination can emphasize various aspects of product decision based on the same input data.

However, an investigator does not know whether a given level of importance or difference is of major consequence without some set of external standards. Results from direct and indirect questioning should be subjected to experimental validation for a greater assurance about the existence of causal relationships between the attributes identified as determinant and actual choices, decisions or actions.

B VARIETY AND PRODUCTION STRATEGIES

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B VARIETY AND PRODUCTION STRATEGIES

INTRODUCTION

Various production strategies can be used to produce buildings and their component parts. We here try to understand those different conceptions of production and their consequences, particularly at the level of end product variety. Within a firm, strategical decisions aiming at the improvement of the production system will depend on the goals and objectives of the organization, on the management's "view of the business". Before presenting various manufacturing strategies, the question of objectives of the firm will be briefly treated.

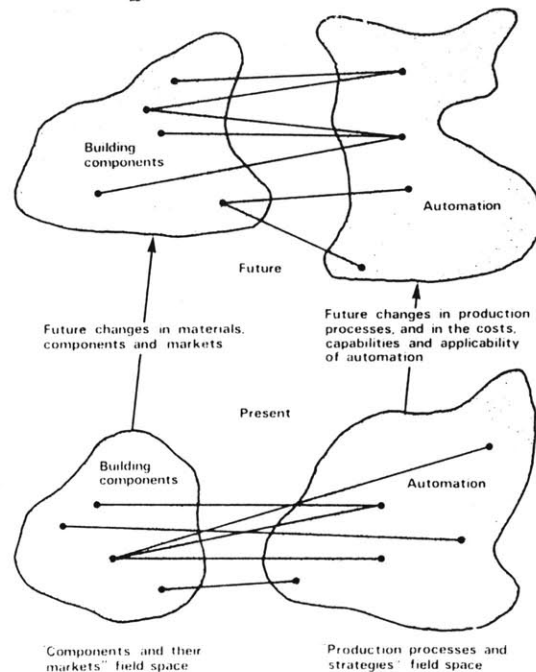
1 THE QUESTION OF OBJECTIVES

The objectives of individuals or companies are numerous, complex and conflicting. For instance, the case of a firm manufacturing components, the objectives of the production manager will be to reduce the production cost per item, which might be achieved through more difficult labor conditions, a lower quality and variety level, consequences negatively viewed by workers, sellers, and customers.

The various external objectives of a firm, amongst which we can mention increase in market share, short and long term profits, sale revenue or rate of growth, are often reduced from a classical economy point of view in the global motivation of "profit maximization". Another definition, which more broadly encompasses the diversity of motivations of modern firms in today's markets is "to create and deliver value satisfactions at a profit". Assuming external objectives have been defined and accepted, internal objectives allowing to meet them have to be established.

They can cover various aspects of production: planning and scheduling, target costs of tooling and handling, etc.. Those relationships between internal and external criterias are usually based upon financial tools quantifying objectives in terms of: current assets, liabilities, liquidity, sales, stocks and profit. Those internal objectives can be further decomposed into departemental targets and so forth.

Decisions in terms of production systems and strategies depend on the various internal and external objectives of the firm and will thus result in a wide range of solutions. As an example, a diversity of approaches to design (engineering, architectural, marketing) can be observed in the various systems proposed to meet the same housing program, like in Operation Breakthrough.



M.A.Malet thinks: "there will not be a "one to one" but a "many to many" relationship between a particular component or class of components and its method of manufacture (similarly, there is a many to many relationship between particular requirement of a component and its design)". He illustrates this "diversity of response" by a model relating the technical variables describing components in their market environment and in their production process (33).

2 PRODUCTION STRATEGIES

2.1 PRODUCTION ENGINEERING CLASSIFICATION

Industrial organizations exhibit a wide range of production strategies. From a production engineering viewpoint, going from one of a kind intermitently produced items towards quantity manufacturing of more standardized and rationalized products, three types of production systems can be distinguished : jobbing, batch, and mass-production.

1-Jobbing or unit production.

It consists of the manufacturing of "one-of-a-kind" products, designed to meet customer's individual requirements. Firms in this category may be further subdivided according to the level of technicality (simple / complex) and the size of the products (requiring more or less production stages). Jobbing is the traditional method of producing building components.

2-Batch production.

Today, it is estimated that 75 % of the products manufactured through industrial methods are processed through small batches, and indeed, most of the components used in construction originate in this production method.

3-Mass production.

Those techniques can refer according to Malet to:

- quantity production, through large labor input, to satisfy mass demand.
- flow production, through processing (chemicals, refinery).
- flow production through assembly line or discrete item machining.

Firms involved in batch and mass categories will produce standardized items; they can be differentiated whether their production is continuous or more or less frequently interrupted and according to their level of flexibility in

accommodating the production of diverse items. Another differentiation can be drawn between firms making "integral" products (or manufacturing industries) and those making "dimensional" products, evaluated in weight, capacity or volume (process industry).

2.2 WOODWARD CLASSIFICATION

In the mid 50's, Joan Woodward undertook the study of various firms in South Essex (England), in order to understand the relationship between technical systems and structures of industrial organizations (54)(55).

Woodward felt production engineers division into jobbing, batch and mass-production was too broad to distinguish between the various manufacturing methods. She thus ordered the firm's production systems into eleven categories, further aggregated into three overlapping groups -unit and small batch, mass and large batch, process production- and a class combining those groups. Here follows her classification:

-UNIT AND SMALL BATCH PRODUCTION

- Production of units to customer's requirements
- Production of prototypes
- Fabrication of large equipments in stages
- Production of small batches to customers' order

-MASS AND LARGE BATCH PRODUCTION

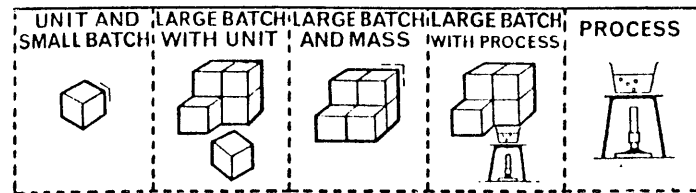
- Production of large batches
- Production of large batches on assembly lines
- Mass production

-PROCESS PRODUCTION

- Intermittent production of chemicals in multiprocess plant
- Continuous flow production of liquids, gases and crystalline substances

-COMBINED SYSTEMS

- Production of standardized components in large batches subsequently assembled diversely
- Process production of crystalline substances subsequently prepared for sale by standardized production methods



As an illustration of this classification in the field of building, we can associate:

- a special concrete casting to unit production.
- a serie of pretensioned beams to batch production.
- a standard concrete block to mass production.
- a regular concrete mix to process production.

2.3 APPROPRIATENESS OF EACH SYSTEM

Each system of production is best suited to achieve certain objectives. Continuous flow processes, initially employed in chemical plants, are increasingly used in the manufacturing of "solid shapes" like steel, mill-board, paper. Unit production, the oldest form of manufacture, more relevant for products satisfying individual requirements, when market aggregation is not feasible or desirable or for rapidly evolving fields which make standardization impossible.

3 VARIETY AND RELATED CONCEPTS

In 1962, Brewer, a production engineer, developed a scale relating firms classified, according to Woodward's system of categories, and their rate of production. Firms in the batch class proved to cover a large part of the scale and sometimes were closer to continuous flow or unit production firms than to each other. Moreover, firms with similar production hardware showed important variation in their rate of production. Woodward's way of identifying the technical variables of firms seemed unsatisfactory to precise if the differences observed between firms were caused by technologies, control systems, strategies or all of them.

In order to further understand those differences between industrial organizations, members of Woodward's research team, Combey and Rackham, insisted on the necessity of solving the problem of measurement of technical variables (55). They thus defined various methods to measure aspects related to technologies and production strategies, but found no comprehensive measure on which comparative studies could be based. Instead, they came up with a concept underlying their measures: the concept of variety in the system of production. While the idea of variety emerged the research carried on by Woodward and her team, it was the first concern of Easterfield (18). In order to define a "policy for finding optimum variety", he also stressed the necessity of techniques to measure the degree of variety produced by a firm. Before presenting some of those methods of measurement, it is important to precise the idea of variety from a production viewpoint as well as related concepts of variety reduction and standardization.

3.1 WHAT IS VARIETY?

Although we could, in simple terms, say that a firm making many products generates a lot of variety, while one manufacturing one or two generates little variety, we need

to refine this concept in order to distinguish among all the cases it can cover. As examples of variety taken from the industry in general:

-A firm, involved in the manufacture of spaceship components, will produce a large number of different components, in order to optimize the technical performance while minimizing the weight penalty of the pieces.

-An electronic manufacturer can produce various circuits requiring much the same processes, machines and components.

-In a manufacture of clothing, variety will be produced within a line by dimensional changes, and extended by qualitative changes in the fabric, color and pattern used.

-A washing powder producer can sell goods identical in nature except for the label and the packaging.

-A railroad-track producer will offer a unique railway model.

All those varieties are difficult to appreciate. If the production of unlimited variety is theoretically possible, it is obviously not the most effective strategy in terms of cost. In the search for economy of production, a firm will try to simplify the number of varieties of a given product. This process of variety reduction is achieved by concentrating the production around certain components or products designed to be used with other elements in various ways. This implies a clear definition of those components and products through standards.

3.2 STANDARDS

Defined by Movshin as "Agreed-upon description of composition, quality, performance, dimensional relationships, methods of manufacturing, procedures or testing" (37), standards are used for identification, information and production purposes. As "specifications having recurring use", standards serve a function of:

-Communication, by defining their subject of application.

-Evaluation, by precisising the conditions to be fulfilled by

the subject they refer to and their criterias of assesment.

3.3 STANDARDIZATION

Standardization, in our case, will be defined as a process that consists of selecting properties of objects or components and assigning values to them. "The properties can be uni-dimensional in terms of say, length, or thickness, or section, or color or can be multi-dimensional by virtue of the material, model or performance specified" (33). It involves three sets of variables -structural ranking, operational level and aspects- whence the term of "standardization space", used by Ciribini (13).

3.4 VARIETY REDUCTION

The reduction of the number of varieties of an item, is achieved by selecting certain of properties for the product corresponding to significant range of applications. This simplification contributes to reduce the cost per item by allowing for longer runs of production for the selected standards: a lumber mill instead of cutting up a gigantic variety of sections will limit its product range to a few sections and lengthes, each serving a range of purposes (Ex: joists with sections allowing certain maximum loads and spans). As a result, standardization is often assimilated to the process of variety reduction.

The consequences of standardization and variety reduction are complex; as mentioned by Easterfield both were "equally advocated as something that would save the British industry, and, equally attacked as something that would ruin it" (18). The problem for a firm is then to establish the preferential balance or "optimum level of variety" it should produce. We will attempt to identify the elements in a firm, that will be affected by changes in the variety of products made. These factors will have to be taken into account when defining the firm's objectives in terms of kind and level of variety it should aim at.

4 MEASUREMENT OF VARIETY

For the purpose of understanding the differences between industrial organizations and their production strategies, it is desirable to have some measure of the degree of variety generated by a firm. In view of the range of type of production, such a measure might be difficult to establish. This chapter presents various attempts of measuring variety from a production viewpoint.

4.1 PERCENTAGE MEASURE OF STANDARDIZATION

Smith-Gavine proposes a measuring tool based in the following premises:

- A firm making one product should be considered as a 100% standardized.
- The more products a firm makes, the lower its standardization measure should be.
- A firm the production of which is concentrated in a few products should be graded higher.
- The more common components enter a range of products in the same proportion, the more the measure should increase.

$$\frac{\sum c_i^2}{(\sum c_i)^2}$$

The formula he suggests uses the cost data usually available from the firm. In the simple case where the firm produces items with no common components, if the total cost of making the nth product is C_n , the standardization measure will be:

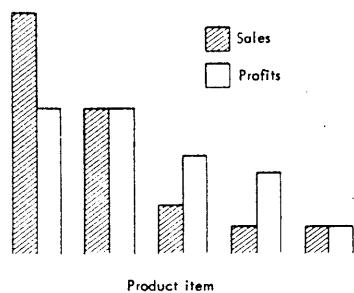
For a detailed description of this formula and its application we refer to the studies of S.A.N. Smith-Gavine mentioned in the bibliography (48)(49).

4.2 LORENTZ CURVE

Easterfield suggests another way of evaluating the variety produced by a firm based on the use of a Lorentz curve (18). Products are plotted in decreasing order of contribution to the total cost of sales of the firm, a graph is then drawn with (percentage of total number of products)

as abscissa and (percentage of contribution to production accounted for by the product) as ordinate. As a result of this ordering, a curve, wholly concave to the right, is produced. The further this curve departs from the diagonal (0,0) (100,100), the more the production is concentrated in a few products. It is also interesting to plot the participation of products to total profit rather than to total production.

Percentage contribution to sales and profits



Product item contributions to a product line's total sales. Both contribution to production or profit measures can give us insight on products of little participation to the firm's output. However, there are cases where these measures do not prove to be effective: as an example, firms with large differences in their total number of products may exhibit very similar curves.

The tools presented by Easterfield -Smith-Gavine "percentage measure of standardization" and Lorentz curve method- are not fully satisfactory in evaluating the technical variables of firms. Although they can give us some insight on the differences among production systems, they do not take into account many factors of importance in those variations. Particularly, they fail to incorporate the factor time in the variation of product range and make little distinction in the nature of products and their components parts. Two searchers, Combey and Rackham, have tackled some of those aspects.

4.3 VARIATION IN THE PRODUCT RANGE

On the initial base of Woodward scaling, they suggested the idea that an important factor underlying the variation of firm's characteristics was the extent to which a firm's product range varied over time.

In this scope, while unit production can be expected, by nature, to show the greatest changes in design and fabrication of items, process production will offer a limited range of products with little change over a number of years. Batch size production, between those extremes, will vary depending on the production strategy of the firm. Other things being equal, a firm making more changes in its product specifications will probably manufacture smaller batches. A measure of those variations can thus offer a tool to differentiate between firms of the batch category and to understand their production strategy.

Here follows a description of the measuring process: "The method adopted was to obtain figures for the number of different products made in 1963 and 1964. The number of different products common to the two years expressed as a proportion of the combined total of different products, was taken as an indicator of the degree of similarity in the product range from year to year. The complement was taken as the indicator of the degree of variation."

We here present a summary of the result of this study to better understand the procedure and its interest. Two firms of the batch category were analyzed and compared.

Madingley, an electronic equipment firm, had a complex production system, enabling it to constantly change its output by different assemblies of various components. Assurance about continuous markets was rare, owing to the continued development in the field of electronics.

Table I. *Variation in product range in Madingley*

<i>Product Division</i>	<i>Different products made in both 1963 and 1964 A</i>	<i>Different products made in 1963 and/or 1964 B</i>	$\frac{A}{B}$	$1 - \frac{A}{B}$
1	40	118	0.34	0.66
2	6	19	0.32	0.68
3	16	56	0.24	0.76
5	7	34	0.21	0.79
7	18	78	0.23	0.77
8	5	38	0.13	0.87
<i>All</i>	92	343	0.27	0.73

Table II. *Variation in product range in Pizzicato Ltd.*

<i>Brass</i>	86	128	0.67	0.33
<i>Reed</i>	24	33	0.73	0.27
<i>Both</i>	110	161	0.68	0.32

As a result, batches were rather small in size, rarely reaching 200 units, and often repeated, up to 6 times a year. If the production were the same in year 63 and 64, 1-A/B would be equal to 0. If the production were entirely different, so that variation was maximum, 1-A/B would be equal to 1. Thus, Madingley, with a result of 0.7 showed a great variation in product range; while another firm, Pizzicato Ltd., producing musical instruments, had a smaller variation index of 0.3, reflecting little changes in production.

These two firms, belonging, according to Woodward scaling, to the batch production category, had both a number of feeder shops producing components, that were then put together in sub-assembly and assembly shops. But unlike Madingley, Pizzicato had not modified its products and production methods in a century. This difference, of course, was largely imputable to the nature of the products of these two firms: Madingley manufacturing special order items in a rapidly developing field, and Pizzicato making small batches of "unchanging" products for a market too limited to justify low-cost manufacturing methods.

After measuring the variation in the product range, Combey and Rackham studied its logical relation to the organizational problems encountered by the firms. Not surprisingly the first firm, to sustain a high variety level, had major imperatives of coordination between sales, design and production, as well as planning and control of manufacture, while the second firm's essential problem was to optimize its provisioning process.

This brief overview gives us an idea of the use of product range variation in differentiating firms of the batch production type and in gaining insight on their specific organizational problems. However, there are limitations in the applicability of this tool, as no distinction is done between the kind of variety produced (marginal/essential).

4.4 NUMBER OF PRODUCTION STAGES

The complexity of products being made, which can roughly be estimated by the number of assembly and transformations during the manufacturing process is also a salient factor in comparing production systems and their outputs. Beyond consequences on stock and inventories, this complexity will have repercussions on the production structure of the firm and the variety it can produce. The bigger the basic element or aggregate to be processed, the lesser variety can be incorporated at the level of the final product: given a similar amount of material with different levels of processing and assembly, the number of houses of a different type that can be generated will dramatically decrease as the level of aggregation increases (studs, panels, boxes). Another factor relevant to the study of production strategies is the level of standardization of the components.

4.5 STANDARDIZATION OF THE COMPONENTS

Standardization is not only a matter of variation in product range over time but also of interchangeability of components between products. Combey and Rackham intended to measure

this degree of interchangeability. After recording what component was used on what product, their method was to compare the actual number of components application to a theoretical number of application, defined as the number of products times the number of components: "The ratio of actual to theoretical application was taken as a measure of components interchangeability. If all components were used on more than one product, it would give a figure approaching 0, and the figure would be nearer to 0, the larger the number of both products and components" (55).

In this framework, mass-production and large batch production can be expected to have high level of interchangeability between products, when it should not be the case in unit production. But this is too simplistic; indeed, we must introduce another notion that further complicates our initial categories. Some firms manufacture highly varied products out of mass-produced components diversely assembled and can also offer a high range of variation over time. Unlike a lot of firms in the unit or small batch production categories, they exhibit a high level of component interchangeability, their different products being based on the combinations of a limited set of standard components. This was the case for the firm of electronic equipment studied before.

4.6 DIFFICULTY OF MEASURING VARIETY

Other researchers, like Perrow (42) and Emery (19), have suggested that the nature of the material being processed is an important source of variety in the production systems: "Techniques are performed upon raw materials. The state of the art of analysing the characteristics of the raw materials is likely to determine what kind of technology will be used...The other relevant characteristics of the raw material, besides the understandability of its nature, are its stability and variability; that is whether the material can be treated in a standardized fashion or whether

continual adjustment to it is necessary" said Perrow. Their studies, however, focused on socio-technical aspects of man-machine systems and were not primarily interested in measuring or understanding the variety of production systems or of their output as such.

Firms, particularly in the batch production category, present too complex technical, structural and behavioral differences to be classified under a single heading. Woodward's classification is indeed too simple to give an understanding of their diversity for comparison purposes. In fact, such an understanding has to be based on the study of many variables that may be independent of each other and cannot be grasped in a simple classification. The measuring techniques presented in this section can be useful in gaining insight on some of the variables defining the level of variety generated by firms and in comprehending their production strategies.

5 THE COST OF VARIETY

5.1 CONSEQUENCES FOR THE MANUFACTURER

Easterfield (18) and, later, J.Movshin (37) have mentioned several factors encouraging standardization from a manufacturer standpoint:

- Diminution of capital requirements, invested in raw material, finished inventory, machines, dies, jigs, templates, floor space and repair parts.
- Manufacturing gains, throughout reduced product development and set-up costs, specialized machines and larger production runs (or batch size).
- Increased labor efficiency, through a learning process resulting from the familiarity of employees with tasks and products.
- Reduction of stock-holding, depreciation and obsolescence.
- Simplification in sorting and packing of products (larger orders, diminished risks of errors).
- Simplification of organizational aspects, improvement of communication in production and distribution processes.

But there are also draw-backs to variety reduction:

- Loss of flexibility in the production process.
- Increased difficulty in adopting technical or design changes.
- Increased inability to satisfy diverse consumer requirements.
- Increased level of boredom or absenteeism due to the repetitiveness of tasks.
- Cost of over-provision.

In the following paragraphs, we will concentrate on analyzing the factors related to the "inner" environment of the firm -namely its production system and organization- on which it can act upon when deciding the level of variety it should produce (47).

5.2 ECONOMICAL ASPECTS

How can we predict the changes in cost resulting from a change in variety production? We can logically expect a number of costs to increase with a rise in the range of items a firm produces, and this, independently of quantities manufactured. Each new item brings more organizational complexity and causes development, set-up, tooling, and inventory costs to the firm. There is little information on the extent to which these overheads rise in relation to the number of products made. It has been suggested by B.D.Tait that these costs would rise more than proportionally to the number of item produced, in a relation to the 1.3 power of the number; but no evidence was offered to support this hypothesis (18). At a certain stage of complexity, computer based systems of sorting, classification and production-scheduling are worthwhile investing, as will be mentioned later in this study.

- BATCH-SIZE

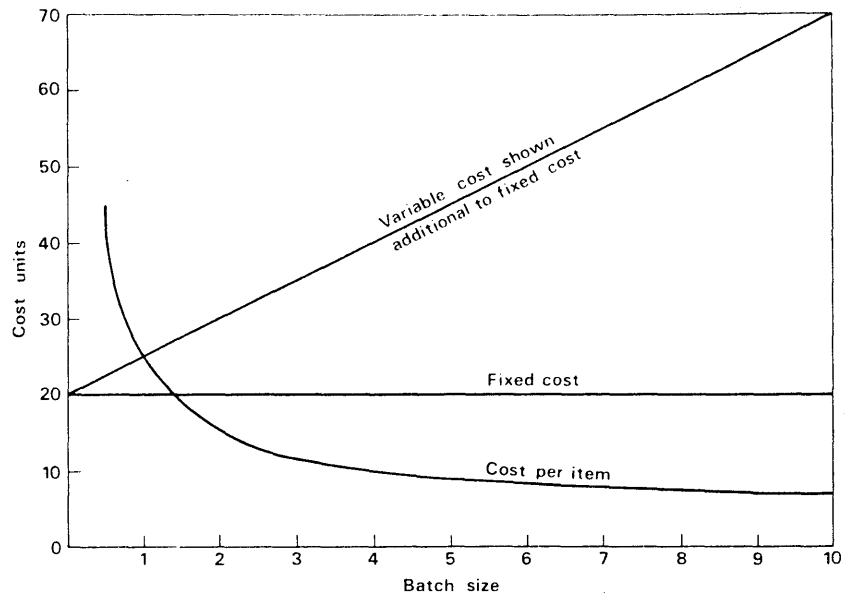
The most important cost resulting from a change in the degree of variety produced by a firm can be imputed to changes in batch size. A reduction in variety, assuming minimal changes in total sales, leads to bigger batch sizes. If in the case of products with a steady demand, this reduction is beneficial, its interest is less obvious in the case of products more unpredictable in demand. For these, the cost of set-up as well as average stock held will determine the opportunity of a bigger batch size. Increases in batch size lead to three major cost effects:

- Spreading of overheads.
- Economies in technical processes.
- Experience effect.

1- Spreading of overhead

In the short run, the cost of a certain output can be dissociated into fixed cost, which remains constant independently of the level of production, and variable

costs, which vary directly with the production level. When deriving a short run cost per unit curve we obtain a down sloping curve showing the cost per unit fall as the level of output increases (33).



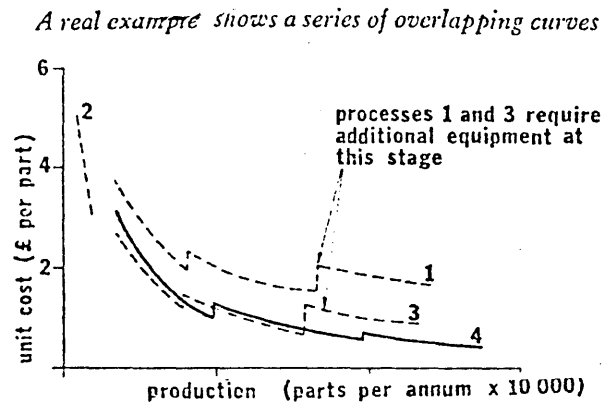
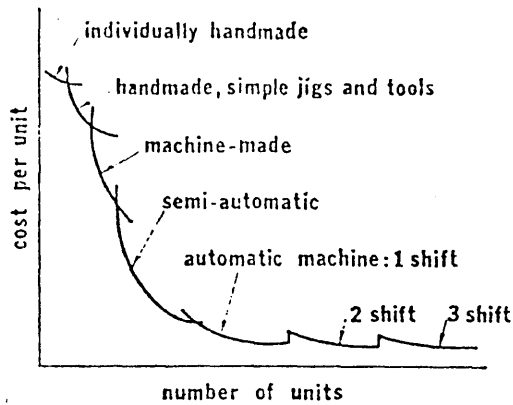
Unit cost against batch size

In practice, the derivation of cost per unit previously described will not be used for pricing purposes. Each batch or order for a product incurs some specific set-up cost that must be absorbed. Globally recorded as "overhead", these fixed costs will be distributed to a certain pro-rata in order to reach an overall equilibrium, which does not reflect accurately the real cost caused by a specific order. Manufacturers will frequently subsidize certain batches with high overhead by charging more for their regular lines. Variety is thus rarely sold at its real cost.

Indeed, it seems more fair to determine cost centers expected to increase proportionally to the number of batches made and to include in the price of an item an amount derived from this batch number divided by the total number of pieces produced. In certain cases, important costs result from the variability in the distribution of batch size; these can be reduced by applying queuing theory in order to seek the optimum number of items to be produced per batch.

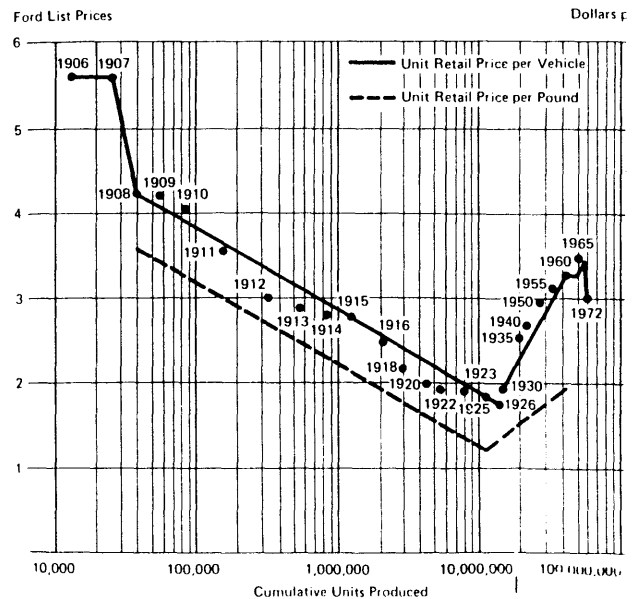
2- Economies in technical processes

As batch size increases, specialized machines, with higher cost, become more economical and new technological ranges may be accessed, resulting in economies in technical processes. Thus, what we can more realistically expect as a cost per unit is a series of overlapping curves, as confirmed in the case of a concrete block manufacturer (46).



3- Experience effect

It was first noticed during WWII that the number of man-hours needed to build an aircraft was diminishing in a regular way by 20%, each time the production to date doubled. The same phenomenon was observed in other industries requiring complex assembly processes and team work (car, airplanes, cameras) with range of 5% to 20% in the fall of price (2).



The Ford experience curve

This relation between volume growth and cost reduction has been expressed in two related concepts:

-The learning curve concept is that "product costs decline systematically by a common percentage each time volume doubles."

-The experience curve concept traces "decline in the total costs of a product line over extended period of time as volume grows". It includes a wider range of costs expected to decrease than the learning curve. Both can become a strategical planning tool for firms wishing to gain a cost advantage over competitors. After a certain time though, this process slows down and the experience curve tails off to an asymptotical direction.

The formula for the experience curve is

$$C_q = C_n \left(\frac{q}{n} \right)^{-b}$$

q = the experience (cumulative production) to date,
n = the experience (cumulative production) earlier
C_q = the cost of unit q (adjusted for inflation),
C_n = the cost of unit n (adjusted for inflation), and
b = a constant that depends on the learning rate;

EXPERIENCE CURVE	b
100%	0.000
95	.074
90	.152
85	.235
80	.322
75	.415

The experience curve results from a combination of:

-Product standardization.

-Scale effect, for capacity costs increase less rapidly than capacity.

-Substitution in the product, cheaper materials or less expensive processes are incorporated in the product line.

-Increase in labor efficiency, based on a learning process, experienced at the level of individuals and cumulating in a group effect.

-Improvements in the production system, in terms of process and techniques.

The benefits resulting from the experience effect should be taken into account when calculating the optimal batch sizes. But if batch production undergoes an experience effect, we do not really know how this process works in the case of sequential production as compared to continuous production where it was initially discovered. We can assume however, that:

-Each new batch does not start its experience process from scratch and benefits from previous experiences.

-The rate of production reached at the end of an old batch is unlikely to be reached at the beginning of a new one.

- STOCK HOLDING

Variation in the number of different products manufactured affects the mean and peak stocks in two ways. As previously mentioned -assuming the same level of production is maintained- the more variety, the smaller the batches will be; T.E.Easterfield estimates that "if the number of varieties is n , the production of any variety will tend, roughly, to be proportional to $1/n$, the batch sizes, roughly to $n-1/2$, and the maximum and average stocks held roughly to $n1/2$. Secondly, the total safety stock held will tend to rise with the number of varieties" (18). Some slow-moving varieties, rarely asked for, can make the situation worse by creating substantial increases in the amount of stocks held and by rising the risks of obsolescence.

- THE QUESTION OF OVER-PROVISION

A standard unit cannot be optimally employed in each of the situations it is used for. It will in certain cases be over-dimensioned, redundant for the task it is asked to perform. When defining a range of standard elements, the difficulty lies in "balancing the cost savings through variety in production, with the wasted cost of overprovision, when the smaller unit in the scale is just not quite big enough for the duty, and the next unit up is somewhat too big".

Methods of operation research can be applied to establish those ranges, based on the frequency of demand of certain elements and the cost of material.

5.3 DEVELOPMENTAL ASPECTS

- FLEXIBILITY

Single minded variety reduction, as a mean to increase productivity and decrease costs, is not always the most desirable strategy. There are several factors favorable to variety, a lot of which are, unfortunately, more difficult to appreciate than mere costs. Flexibility is one of them. A firm cannot pursue, at the same time, a cost reduction strategy and a product innovation or improvement strategy. Constant improvements brought to the production process through mechanization and integration or investment in plant and equipment, affect the firm's capacity to change its products and therefore its capacity to adapt the market. A firm, ideally manufacturing one product at a constant rate, could select its machinery and production process in an optimal manner and benefit from the experience process mentioned above.

However, in a real situation, changes in the prices of material, price of product, volume of demand and technologies are to be expected, which challenge the validity of a punctual optimization. A firm perfectly suited to a certain context will be very affected by any variation from its optimum conditions, whereas a more flexible system will adapt and maintain a better average efficiency (47).

Techniques of linear programming applied to decision making under uncertainty can allow to choose among various type of installations and corresponding levels of variety production.

- ABILITY TO INCORPORATE CHANGE IN PRODUCT OR TECHNOLOGY

The technological possibility to produce new items is closely linked to flexibility. As operations reach a higher level of

elaboration and systemization product and process develop stronger connections; those relationships increase the company's inertia to change, as a modification would require the simultaneous transformation of many elements with high cost implications. Thus, the nature of innovation progressively changes and its intensity diminishes as further steps are taken in the development of product and process towards standardization and cost reduction.

Major innovations occur first, while the firm has not invested too much in tools and development, thus not building its reluctance to incur the costs required by a technical modification or a new product introduction (investments, capital costs of development and product launching). After this stage of product transformation, innovation centers on refining the efficiency of the process by rationalization; a further step can be reached, through backward integration and transfer of process technology (the Ford T development, based on a cost minimization strategy, provides a perfect illustration of this gradual decline in innovation).

Progressively, innovation is reduced to the introduction of new features rather than new products, marginal changes and accessories requiring little alteration of the production process. A lot of this kind of variety is introduced in the production by modifications on existing products asked for by customers. Those modifications are, more than often, costly and contradictory with technical progress but can be justified on other grounds (satisfaction of market requirements).

5.4 THE "OPTIMAL LEVEL OF VARIETY"

- Steps to research the "optimal level of variety"

T.E. Easterfield defines a method to establish the level of variety a firm should produce. We here mention the analytical steps he suggests for this purpose at the level

of the inner environment of the firm:

-Listing of the firm's products, preferably including intermediate components, if those are used in several final products, in order to determine the level of standardization of the firm.

-Analysis of sales records and of the relative importance of the various products in those sales.

-Analysis of the costs of manufacturing at various levels, including overheads outside the factory per se (in stores, drawing office etc..); this may involve studies on the cost accounting system, statistical records and work measures of the firm and evidence of the existence of a learning process should be searched.

-Consideration of implications in terms of technological progress of the firm.

For a company manufacturing varied or complex products, such a study is justified by the improvements brought to its definition of a policy towards variety and insight given about its functioning.

- Appropriateness of variety reduction

Standardization or variety reduction is researched by the firm to answer some problem by finding a limited number of solutions, given available organizational or physical resources, in cases where neither a universal economical solution nor a large number of individual solutions can be designed and accommodated.

Standardization is profitable, from an organizational viewpoint, by the simplifications it brings to sales, stockholding and specifications. Although the same operations could be handled by a computer for a very large number of items at a minimal cost, once initial set-up is guaranteed. But its major advantage stems from the reduction in cost achieved by repetitive production of identical pieces. These advantages, however, have to be weighted

against the lack of technical flexibility and adaptability it implies for the production system and other draw-backs at in terms of product: lower level of customer's satisfaction as compared to purpose-made products and over-provision required by larger range of application.

6 MIXED STRATEGIES

6.1 EVOLUTION OF PRODUCTION SYSTEMS

In Woodward's opinion technical changes in a production system occur by moving towards more advanced and complex forms of manufacture: "from unit and small batch to large batch and mass production, and from large batch and mass-production to continuous-flow and process production"(54). But she does not foresee the disappearance of any of these systems nor the emergence of new ones.

That technical changes occur towards more continuity in the production process does not irremediably imply homogeneization and standardization of the product. If Woodward did not expect the disappearance of any of the production systems mentioned in her classification, she did not foresee new technologies and organization systems that might offer new possibilities in the evolution of firms, blurring the distinction between unit, batch and mass-production.

6.2 STANDARDIZATION AND INDIVIDUAL DEMANDS: A CONTRADICTION?

Industrial theorists have often rejected individual requirements as contradictory with the logic of economic production. In 1943 Urwick said "to allow individual idiosyncrasies of a wide range of customers to drive administration away from the principles on which it can manufacture most economically is suicidal, the kind of good intention with which the road to hell or bankruptcy is paved".

If standardization and rationalization, basics of modern production methods, have made possible increases in our standard of living, it is also likely that those increases will lead to greater demands for customerized goods. Firms making small quantities of special products to customer's individual requirements should then see their number and importance rise in the near future.

6.3 COMBINING STANDARDIZATION AND UNIT PRODUCTION

At what point can we qualify a product of special rather than standard? According to the definition used in the study on South Essex firms, a "special product" may have "a standard content that might amount to as much as 80% or 90% , measured by the criteria of material or labor cost" (55).

A firm can generate different products out of the same standardized parts; but the variety thus produced has to be further analyzed. A lot of firms do not really change their products as such, but create "variety" by the introduction of marginal modifications.

Perfect examples of these practices can be found in the consumer goods industry: a soap manufacturer will "rejuvenate" his products by changing their names and packaging. Indeed, this might not be very different from a mobile-home producer rebaptizing his standard unit "ranch-style" when covering it with a new textured wood siding. The question of marginal variety, already discussed, will not be commented at that stage, but it is suggested that a meaningful variety can be generated out of a set of standard components carefully designed rather than subsequently provided by a large quantity of accessories.

The methods of standardization, and rationalization that were thought to be inadapted to unit production are increasingly included in this process. After re-thinking the manufacturing operations and analyzing the unit products into individual component parts that can be standardized, it is often possible to combine the best of two production methods: produce more economically while answering customers requirements.

IV STRATEGIES IN COMPONENT PRODUCTION

1 Closed systems

1.1 Definition

1.2 Closed systems and variety

2 From closed to open-systems

3 Open-systems

3.1 Definition

3.2 Open systems and variety

4 Resistance to the development of open-systems

4.1 Technical factors

- Dimensional coordination
- Normalization of joints

4.2 Factors inherent to the production strategies

- Market strategies
- Innovation strategy

5 Defining components: central problem of industrialization

5.1 Standardization: where and how should it applied?

- Standardization the whole or the parts

5.2 Aggregate components

- The concept of aggregation
- Size of the building blocks
- The cut-out of aggregates
- Product definition
- The example of automobiles

IV STRATEGIES IN COMPONENT PRODUCTION

If mass production methods have proven their efficiency in terms of quantity output/machine and labor used, they depend on a continuous demand for standardized products which is difficult to achieve in many situations. In the case of housing a lot of efforts have been directed towards the establishment of more continuity in the market, implying a reduction in the variety demanded to adjust production requirements.

However, according to M.A.Malet: "the case against the overall suitability of mass-production strategy for buildings and for all their component parts is considerable: theoretically in terms of mismatch between components and their markets on the one hand and the requirements of mass-production on the other, practically in terms of the history of industrialized building production" (33). Componentized systems, particularly open ones, based on batch production of identical pieces, have thus been advocated as a more appropriate solution to satisfy the diversity.

1 CLOSED SYSTEMS

1.1 DEFINITION

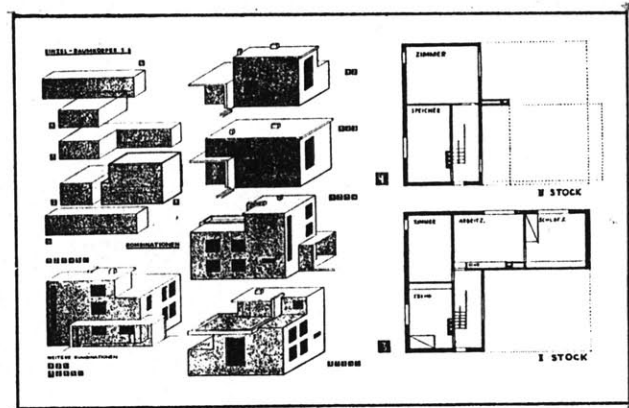
A close-system is a construction kit of parts providing a limited number of possible assembly. The components of such systems are compatible within themselves, but not necessarily with open-systems ones. The conception of a closed system, in which the firm defines freely all the major parts of its components, does not bear any additional constraint than other industrial productions. The economics of the process have to be viable, which means its market has to be such as to reach series generating a competitive

pricing. In the case of industrialized systems for housing this situation is difficult to achieve. Firms generally seek a State contract on public markets, to develop their system, hoping to reach a feasibility threshold.

1.2 CLOSED SYSTEMS AND VARIETY

Theoretically close systems can allow diversity within a project. Close-systems diversity is based on two factors:

- The variants: limited number of different types for elements of a similar nature (dimensional variants for instance).
- Combination of elements: different shapes realized by various arrangements of similar elements.



Closed kit of parts. W.Gropius 1925.

In practice, those theoretical possibilities of variety are rarely implemented by close-systems developers, as diversity is always considered as an extra cost. Those systems generally designed once for good for a specific targeted building type are not aiming at diversity. This restriction results in a lack of variety and a certain inability to satisfy customers' requirements. Overprovision can prevent this problem, but is rapidly contradictory with cost efficiency. Certain variations in dimensions may be available without additional cost within a certain range, joints are less likely to incur any change as they are determinant and proprietary to the system.

2 FROM CLOSED TO OPEN SYSTEMS

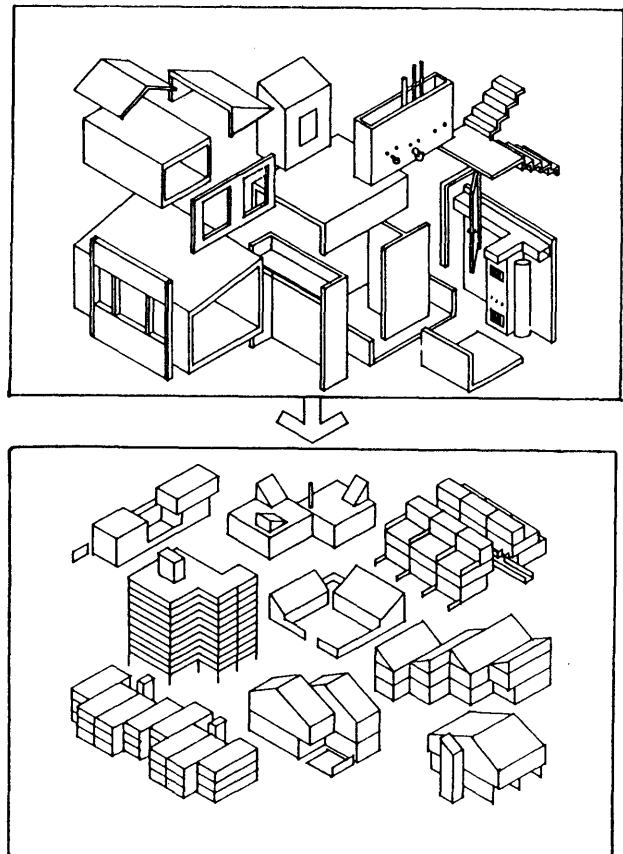
Till now, open-system have not sufficiently developed to cover the feasibility of all buidings. However, tendencies can be observed in their development, resulting from the evolution of closed-systems and particularly those concerned with individual house production. Once the production of components required for their own production has been secured, closed system producers may have to produce additional components to optimize the use of their plant. The excess elements thus produced will be offered on the market place beside their proprietary system. This imply the existence of a market and therefore the compatibility of such components or the adaptability of their production method to purpose-made orders.

But the coordination requirement preliminary to the development of open-systems is limited by strategies and product definition of individual manufacturers and the shift from a closed to open system is difficult to achieve. As an example, Lustron Homes intended to market bathtubs issued from its closed system, but failed because of the specificity of those products. Internal coordination developed in closed systems often prohibits the sale of excess components on an open base as gains in efficiency obtained in closed systems by specific design and tools are contradictory with the coordination and normalization of interface or joints required by open-systems.

3 OPEN SYSTEMS

3.1 DEFINITION

Ideally open-systems combine a large range of components supplied by many different manufacturers observing certain rules of compatibility. A building designer can choose within a component catalogue. Each function within a building can be performed by a family of products of different brands, compatible with the elements it must be connected to. The choice of a brand for a specific function is independant of other selections.



An advantage of open systems is their appropriateness for large batches. Intensive industrialization can be implemented much more easily with open-systems than with close ones: as they assume a large range of applications, the potential market of each components is augmented and sufficient production runs can be reached which justify

those methods. The initial investment, spread on a larger output, is smaller per unit than for the complete sets of elements of closed systems, generally manufactured in smaller batches.

3.2 OPEN SYSTEMS AND VARIETY

The ability of open-systems to generate diversity results from the compatibility of their components, which is a condition for their economic viability. For an open system component manufacturer, the possibility of applying his products to the largest number of different operations is essential. Open-systems will adopt the mechanisms of diversity as they have to target a market much more large and unpredictable than closed ones; providing a wider choice and flexibility to the user, they can lead to more varied architectural solutions, while benefiting from the advantages of large scale production.

Based on economical factors and on advantages brought in terms of quality, speed, improved working conditions, potential adaptability and variety, there is an undubitable tendency in the evolution of housing production towards open systems of industrialization; but this development is however slowed down by several factors presented in the following section.

4 RESISTANCE TO THE DEVELOPMENT OF OPEN-SYSTEMS

In order to be compatible, separately manufactured elements require two types of conventions between producers: on dimensions and on joints.

4.1 TECHNICAL FACTORS

- DIMENSIONAL COORDINATION

Dimensional coordination has been the subject matter of numerous studies, more than often focusing on the research of modules. This orientation is clearly rooted in the ideology of Modern Architecture. Beside the work done on the subject by many international and national congresses, the studies of E.Neufert, E.D.Ehrenkrantz, P.Schofield, influenced by R.Wittkower's principles and of Le Corbusier, with his Modulor, can be mentioned. Those efforts have already been concretized by some dimensional building norms, we could therefore expect this constraint of open-systems to be overcome.

- NORMALIZATION OF JOINTS

The second constraint, on joints coordination, is much more serious. The technical importance of this problem is such that, if solved, we could consider open industrialization to be a reality. Most of the components in today's buildings are serially produced by industrial methods: tubes, connectors, plumbing accessories, heaters, woodworks But those components still require in a lot of cases traditional on site assembly. For its effective implementation, open industrialization entails the serial production of joints either integrated to the components or as separate entities.

The problem thus raised is of a technical order: open systems require a "method of making other people's range of standard components compatibles with each other". The complexity of a prefabricated system of construction lies in its joints, which are its characteristic part.

The fact is corroborated by regular practise in building design, where most of the time spent on construction drawings does not concern the nature of the architectural elements but their interface.

Thus, to allow the interchangeability of components, joints would have to satisfy major requirements of simplicity, versatility and perennality, conditions which seem to conflict with advanced technologies. The "universal" joint, researched to accomplish compatibility between elements, has not yet be found, and it is unlikely that a simple and economical solution could fulfil a wide range of duties.

From those technical problems arise some decisional ones:

-difficulty of concertation among producers to set up coordinated joints ensuring the compatibility of their components.

-contradiction between open-systems and manufacturers' strategies of innovation, marketing and production.

4.2 FACTORS INHERENT TO THE PRODUCTION STRATEGIES

- MARKET STRATEGY

We have covered the consequences of standardization from an internal viewpoint, and will be here more concerned with the way it affects the firm's relation vis-a-vis competition. As expressed by Spillenkothen and Renner "there are built-in features of a competitive market and industry which impede rapide progress towards industrialization and standardization" (50).

If we assume that component producers work in a pure competition system, it means that, subject to inelasticity of demand, they have no choice in the price level of a given product, but have to sell at market price. A producer in this situation intends to retrieve some freedom in price setting, which means tries to achieve a greater elasticity in the demand of his products by lowering competition.

For this reason, open systems do not constitute an interesting strategy to gain a competitive advantage. As the success of individual producers depends on the specificity of their products, their resistance to products compatibility and open systems is not likely to transform easily. Open-systems for the firm result in harder competition: once the joint that was warranting the proprietariness of his systems becomes standard, the manufacturer does not sell any more a set of components the quality of which has to be globally evaluated, but components that can be individually compared to competitors offerings.

A manufacturer will rather design a closed system differentiated by its quality, cost or technology from competitors offers. In doing so, he can fully control his proprietary system in terms of design change and can keep his market "captive" for options, or construction. Another strategy consists of developing a "parasitic" system of components, purposefully designed to be compatible with succesful systems. This tactic is often used in computers, where small companies specialize in "niches" under-exploited by large manufacturers, while adopting their standards of compatibilty.

-INNOVATION STRATEGY

Agreements on the compatibility and standardization of components can heavily constrain the opportunity of technological changes and components modification, as those cannot occur independently from a synchronized modification of related components in the industry. This inertia brought by the commitment to an initial range of standards would slow down innovation and adaptation to consumer demand.

5 DEFINING COMPONENTS : CENTRAL PROBLEM OF INDUSTRIALIZATION

5.1 STANDARDIZATION: WHERE AND HOW SHOULD IT BE APPLIED?

- STANDARDIZE THE WHOLE OR THE PARTS?

For certain items and material the advantages of standardization are unquestioned, since the variety reduction it implies is not resented as constraining the conception and ultimately the diversity of end products. This is the case with technical or structural components of the housing unit, which are in general of minor importance in the level of variety perceived by the user. The consumer is not interested in a specific thickness of floor or beams or in the particular diameter of an electric wire a such. Indeed those elements are not supports of appropriation and hence do not require customerization. Nails, ducts, or semi-products like studs joists, though standardized, exist in a sufficient variety to allow for unlimited combinations and do not seem to require further diversification. If the existing range of standards sub-components is satisfactory, their aggregation in components of a higher level that has to be discussed.

Where and at what level standardization of the building components should be applied beneficially, while still allowing design flexibility to satisfy individual requirements? in other words "are we to standardize the whole product or many of its parts?"(37).

5.2 AGGREGATE COMPONENTS

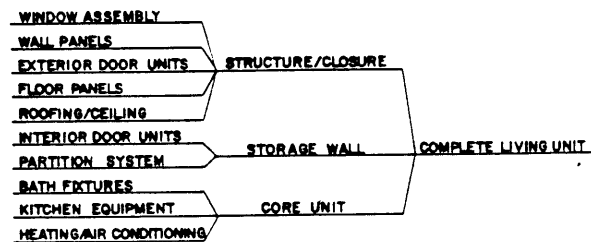
- THE CONCEPT OF AGGREGATION

To minimize the number of on site interventions, the tasks generally performed by various trade should be combined in the manufacturing process. Three concepts can help us define this procedure:

-aggregation is the integration of many tasks into factory made elements.

-aggregates are ensemble of factory assembled primary components which transported on site as finished parts can then be combined to form the whole building.

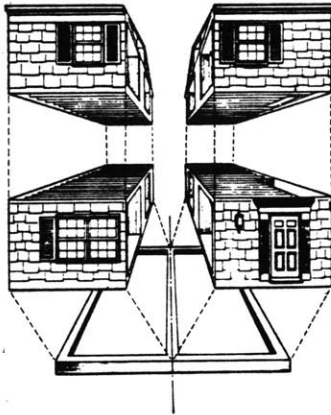
-primary elements, based upon functional and morphological concerns, are objects the dissociation of which into parts is not advantageous or logical.



Maximization of aggregation is researched so that each element includes the largest number of necessary components and does not require addition on site. This tendency to increase the level of aggregation can be observed in the development of bathroom or kitchen unit and also in light-weight prefabrication where panels are often manufactured with windows, doors and lighting fixtures.

- SIZE OF THE BUILDING BLOCKS

Increasing the complexity and size of the aggregates, standardization can be applied at the level of the entire house, thus limiting the number of building blocks composing a house to one: this is the case of fully factory-made units. The production of independant cells has been suggested by Archigram with their "plug-in city" as a solution to closed industrialization. A derived application of this solution can be found with the mobile home industry. But, if the success of mobile homes is unquestionable in terms of cost efficiency, the mass or large batch production of integral or important parts of houses as elementary building blocks is much more controversial in terms of potential richness of the environment they can constitute.



Town-houses built by factory-line methods. At the other extreme, the brick size element, allowing multiple combinations, is not a realistic solution as it requires too much assembly on site and cannot integrate various technical functions like plumbing, heating, lighting etc..

To allow combinatorial possibilities between elements, those have to be interchangeable and of limited dimension with regard to the end product. Among other considerations defining the size of the elements, transport and assembly should be taken into account as they also imply certain dimensional limits; those dimensional thresholds are based on the different methods of handling components.

- THE CUT-OUT OF AGGREGATES

A traditional housing unit could be "cut out" according to a three dimensional modular grid. This would lead to specific parts or aggregates each requiring special assembly. A research of maximal aggregation by this technique would be of limited interest as:

- joints cannot be located without any technical concern.
- the bigger the aggregate, the lesser the possibilities of variety and adaptation of the end product.
- the more specific the aggregate, the shorter the production runs.

Indeed, the composition of aggregates should rather aim at the definition of a limited number of elements as polyfunctional as possible. The question is then to determine what primary elements they should provide:

The search for identical and polyfunctional elements would lead to very costly and redundant solutions if strictly observed. Indeed an aggregate should be conceived as to potentially include a large number of components, all of which do not require to be present in each final ensemble. Thus, a wall can contain the following elements: structural part, phonic insulation, thermal insulation, waste water pipe, hot and cold water pipe, electrical wires, switches, plugs, lighting fixtures, doors, windows. Many variations can be generated by the presence or not of the above components (of course the structural part will be present in each) but also by their location and size.

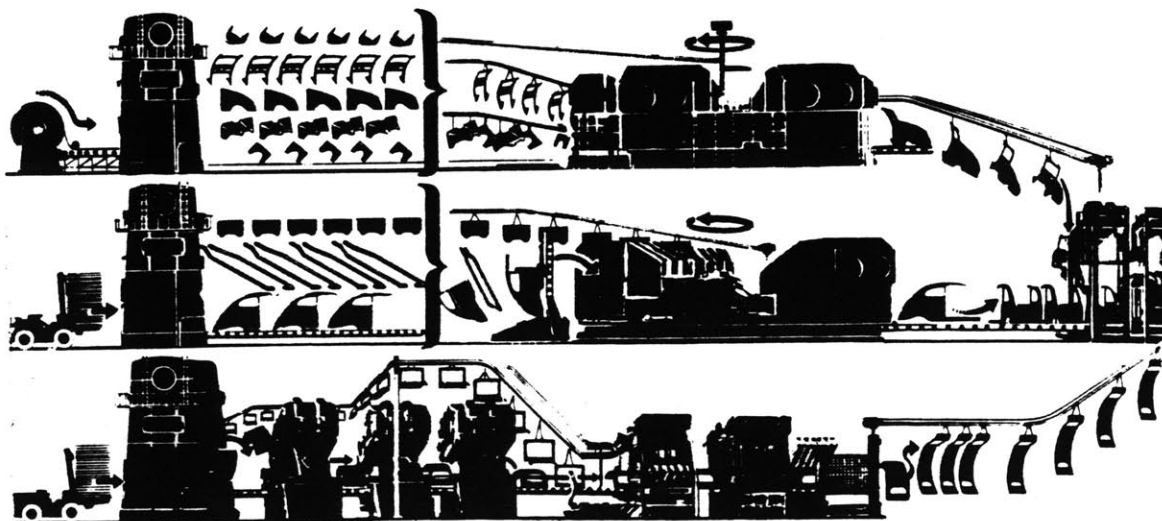
- PRODUCT DEFINITION

If we specify, by a number of parameters, the essential characteristics of the components or aggregates a firm can manufacture (in terms of type, size, presence or not of sub-components, finish), the resulting ensemble constitutes a space of possible products. In this space, given a sufficient knowledge of consumers' needs and wants, we can define areas of individual suitability, which can be clustered according to their density. This provides a useful information to the firm in the definition of preferential areas of standardization. In areas of low density, the special requirements of customers will or will not be satisfied by the firm depending on its policy and on the flexibility of the tools and products concerned.

- THE EXAMPLE OF AUTOMOBILES

The automobile industry can provide us an interesting example on the question. Within a single line, variety is generated by the combination of different body style,

engine, accessories, and colors. Each of the "different" automobiles thus produced will be particularly satisfactory to certain people, although composed out of the same set of interchangeable components. This process, based on the standardization of the elements to be combined, allows the possibility of individual selection among them (44).



Special requirements are covered to a certain extent by the system and may be satisfied in other cases by combination with custom made items. Custom body and accessories shops thus develop beside the automobile industry as complementary to standardized products. The integration of standards and special components provides unique combinations. We will not here discuss the validity of similar processes as applied to housing, but consider this strategy as a possible direction.

CONCLUSION

1 New tools

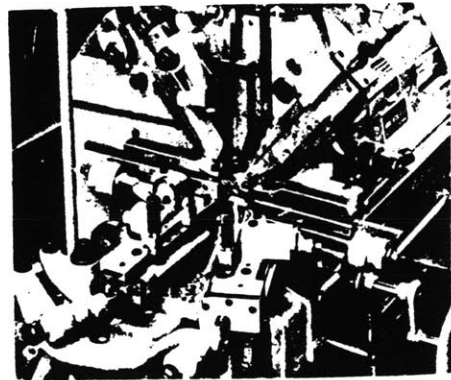
2 Cybernetics

3 Universal machines for specialized markets

CONCLUSION: BEYOND STANDARDIZATION, OTHER POSSIBLES

The diffusion of automation and cybernetics are signs of the emergence of a post industrial society. The mass-production process, due to the important investments and pre-planning it requires, heavily lacks of flexibility in terms of product variation. Galbraith's views on the rigidity of this type of industrialization and its implications in terms of seriality and standardization may be challenged by new production and organization systems.

1 NEW TOOLS

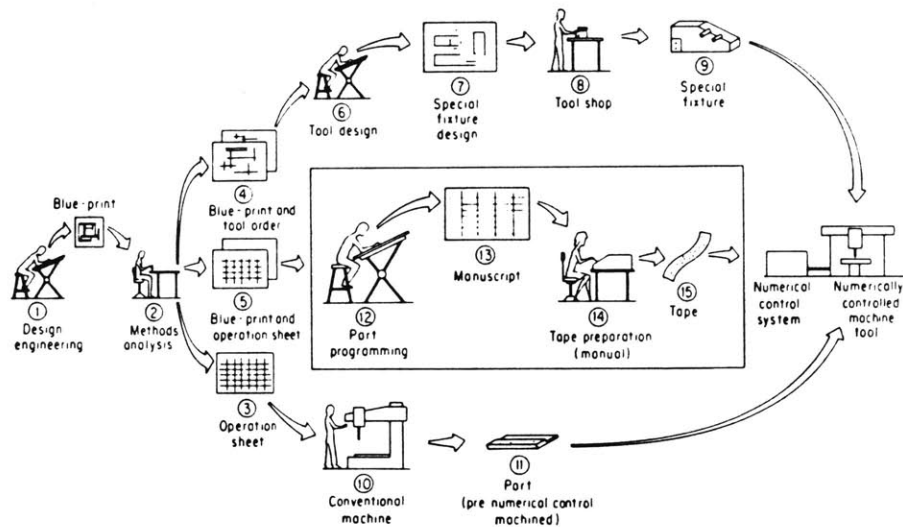


Automatically regulated precision tool (52). New production tools, able to automatically integrate variety are rapidly developing. The range of application of these tools is variable: a machine can realize various tasks on the same product or one and more operations on very different products.

Though at a higher cost, machines of greater accuracy and reduced setting time are now on the market. This is the case of robots, also called "universal transfer device", now equipped with mechanical arms and hands which perform a wide range of operations and thanks to memory systems can be reprogrammed and thus adapted to other tasks when necessary.

Beyond punctual applications for specific tasks, the real improvement, linked to robots, will result from new methods of controlling flexible tools in an "integrated and continuously variable " production process. Machine tool industry has now devised numerically controlled machines (NC) which allow variable production through automatic processes : " all machine tools operate in terms of numerical information derived from the dimensions of the work piece itself and this can be fed back to control the machine's movements, which include automatic tool changing for different operations" (1).

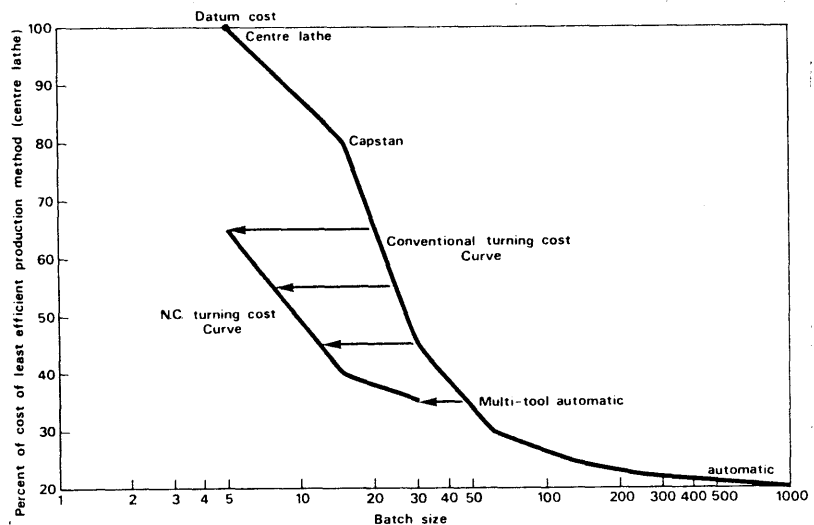
Computer tapes are used to store the information, then sent to the machine. At a higher hierarchical level their programs can be designed by a general computer.



Selection of parts for numerical control machining

By their versatility and their capacity to perform various operations on complex components at a high speed, numerically controlled machines constitute a highly flexible tool. Their potential can be better applied by organizing "machining complexes" grouping various machines each used for certain operation ranges: "Connected by an automated transfer line and controlled by an on line computer, the combination achieves, in effect, a flexible, automatic transfer line" (33).

Integrated complexes of numerically controlled machines can thus output a wide range of different components while still achieving production volumes comparable to mass-production. Machines can be selected and organized to reach certain production levels while balancing their time in use and the kind of task performed according to their sophistication. The "system 24 complex", for instance, can output 2000 to 20.000 components per day varying in size and shape out of a six machine factory (1). The overall production scheduling is also handled by a computer deriving the best production flow from orders of components collected for a small period.



Turning cost against batch size for various methods (33)

The advantages of NC machines are that the cost of tooling and the economic batch size are reduced. Their draw-backs arise from the additional capital and set-up costs they require. The preparation of the control tape, included in set-up costs, can however be simplified with systems possessing record/playback capacities, where operations, first guided manually, are then commanded by tape to the rest of the batch. Aside from the decrease in production times and an increase in the quality of components in terms of accuracy, (NC) machines allow savings in capital locked-up in work in progress as well as in inventories. Moreover, the enlarged product variety they can output widens potential markets, thus reducing the effects of irregularities in demand.

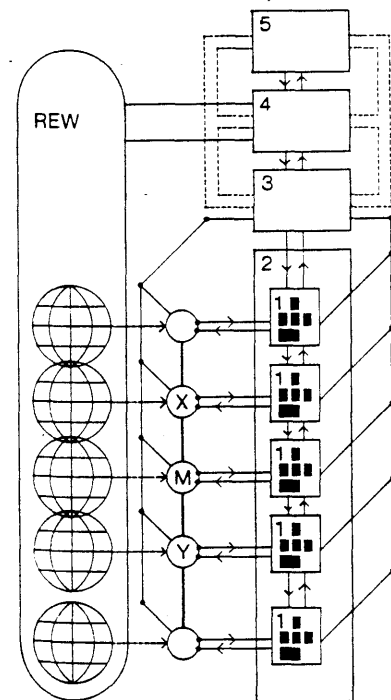
In recent applications to the field of panelized house manufacturing, corners and intersections of components are coded which allow for a rapid "take-off" of a list of features from architectural drawings. This list is fed to a mini-computer which, after checking the size of the pieces, produces the tape for NC machines, the bill of quantities and, if required, assembly details. Numerical control by mini-computer is used in lumber-mills, where a cutting saw minimizes scrap in the cutting of random stock lengths based on an optimal cutting pattern, estimated by computer, between lengths required and lengths in stock. In the case of truss manufacturing, standard data are fed into the computer which produces a finished specification take-off and can be connected to an automatic assembly machine, self-adjusting for production. Assembly machine for corners, trimmers etc.. and sheathing machine for panels (Automation in Housing).



These new tools do not suppress the use for human operators. Automation remains uneconomical for many assembly processes. This is the case in small and medium batch size production, where new approaches of "team assembly" opposing the flow-line production repetitiveness of task rely on small teams of one to ten workers entirely responsible for the manual assembly of complete products; these approaches tend to change the role given to workers by recognizing their specific qualities and result in improved rate and quality of output.

2 CYBERNETICS

The application of control theory to the whole factory has been studied by the cybernetician Stafford Beer (5). Beer views today's industrial organization as "dinosaurs", which, as analyzed by Galbraith in the "New industrial state"(21), try to reduce the world's variety to which they can not adapt. But Beer, more optimistic than Galbraith, thinks cybernetics can enable us to reach a post-industrial era where the firm will behave as an adaptive organism, controlled by a board room or "nervous system" regulating automatically the firm's production and its organization (5). He describes the structure of the "cybernetic factory" as in a five level hierarchical system that he compares to the human nervous system, while viewing company's divisions as the body's major organs:



-The first stage consists of simple relays and position control devices, used to measure such parameters as temperature, pressure or position, which, checked against determined values, can cause possible corrective actions to be taken (vertebral segments).

-The second stage uses techniques like proportional control to keep the process in a steady state, but still require manual interventions and supervision (spinal cord).

-The third stage includes monitoring and coordination of the functions and is based on cost-effectiveness models (autonomic nervous system including sympathetic and parasympathetic trunks)

-The fourth stage determines the optimal operating conditions for the process and uses models of marketing and finance.

-The fifth stage serve the firm's board of directors to decide on the long term future based on operation research models (cortex cerebral).

Thanks to the mathematical formalization of the control function of the firm, problems can be automatically solved by a computer using operation research methods. The mechanism thus designed constitutes a perfect decision support system for managerial choices in terms of the firm's behaviour. Beer expects the role played by managers to be similar to the role of workers in team assembly processes, to require more generalist's skills in order to appreciate more globally conceived problems through cybernetics.

3 UNIVERSAL MACHINES FOR SPECIALIZED MARKETS

Mass-production implies limitation of variety and standardization in order to achieve quantity production. But according to Alison and Peter Smithson "Today, no intellectual case for standardization as such can be made (...). For machine processes can now make to the profile and the degree of smoothness or hardness that use requires, rather than needing to match production processes". New machines (NC), computers, cybernetic methods enable firms to satisfy to a larger extent the diversity of a market, while being more efficient than batch production.

This potential for variable production and responsivity of the firm to its environment through cybernetics are the cornerstone of post-industrial production: "rather than the universal standard and the one-product machine aimed at a tame general market, we have the universal machine, and by "machine" we now include the factory as a whole, capable of adjusting to the vagaries of specialized markets" (1).

If new tools and organizational techniques mentioned above modify the framework of application of standardization it would be naive to think they will entirely erase its necessity: "Instead of tuning the consumer to the machine, we can now tune the machine to the consumer", says Chris Abel. But this credo announcing the best of possible worlds sounds to manicheist too be true.

Variety production cannot be as economical as standardization. It requires more sophisticated and expensive tooling, higher development, set-up, stockholding (not in the case of NC machines), and distribution costs. Those draw-backs, however, can be balanced by gains achieved from a best-fit of the product itself (less material, better satisfaction of customer requirements), by benefits from technical improvements and by access to larger markets.

Though feasible and even worthwhile in certain cases (prototypes, special items), complete variety cannot be considered realistic from a resources viewpoint (material, labor and capital). Hence, the problem is, in the building arena, to determine how variety should be allocated.

The degree of variety and standardization will be different according to the type of component or process of production considered. Some components like windows, ready-cut glass, roof trusses are already offered in a wide variety range and can even be supplied to customers' requirement at short notice. Their production methods incorporate new control

tools that make standardization less rigid and prove its capacity to accommodate controlled variety. A collaboration between product and production process designers can generate a better allocation of the degrees of freedom in products. Hopefully the potential for variety should be provided where it is most likely to be used or valued, while standardization should be focused in those aspects which are of less significance to the user.

Laury Anderson in her vision of a technological society, "United States", which could be applied to many other countries points out the visual poverty and the absurdity of suburban landscapes: "my house is the yellow one with a porch and a pool"; those signs, supposed to be characteristic, do not obviously constitute any serious reference in such a maze-like surrounding. In a society worshipping the individual as a source of richness, certain environments have reached an homogeneous variety almost equal to no variety at all. Galbraith's similar views on the machiavelism of the industrial state, trimming social diversity to serve its own purpose can be challenged by the possibilities of post-industrial systems of production more responsive to their environment and benefiting the social system, instead of adapting it to industrial constraints.

" "Would you tell me, please, where I ought to go from here?" "That depends a great deal on where you want to get" said the Cat" ".(Alice and the Cheshire Cat, from Lewis Carroll's "Alice in Wonderland").

In this work some tools and methods were presented to better understand people and industrial systems involved in the production of housing; the purpose here was neither to fall into the desperation of dead-end prophecies, nor to advance technological changes as solutions for the ideal society, but to increase our awareness of the actual possibilities of producing a richer environment.

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