

The Ecosystem Complex*

A New Approach In Specifying the Man-Environment Relationship

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ABSTRACT

A three-dimensional paradigm is suggested for defining the relationships between an organism and its environment. Called *The Ecosystem Complex*, its constituents fall into three main classes: 1) *Physical* factors which are used to define the physical environment include sound, light, area-volume, radiation, inspired gas, atmospheric pressure, force field, air movement, and temperature and relative humidity; 2) *Organismic* factors which are used to define the organism within the physical environment include age, sex, rhythmicity, psyche, drive, body-type, sensory processes, and genetics; and 3) *Reciprocatve* factors which enable the organism to adapt to the physical environment include diet, clothing, exposure time, social variables, incentive, and activity. Together, these variables and their dynamic interactions must be defined or otherwise specified when determining the effects of the environment on health (physiology), behavior, or affectivity. The potential of the paradigm for use by life-scientists, engineers, planners, and architects is discussed.

Introduction

In 1935, the British botanist Tansley coined the term *ecosystem* to describe the environment of plants in terms of the climate, the soils, and its living organisms. Since that time, study of the ecosystem has taken two distinct trends—one, concerned with energy production and exchange

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between the animal and its physical environment; the second, that of describing the apparent unlimited constituents of the ecosystem itself.

In discussing the latter trend, Egler posts several warnings. "The very subject matter is not organizable, analyzable, nor researchable by the orderly, precise, quantitative methods which are so very much the substance of scientific life today, from the proposal for a research grant, to the published paper . . ."1 He then goes on to say that "the study of the ecosystem is the study of wholes first and parts later."

The purpose of this paper, in part, is to dispute this statement by presenting a concept which identifies the parts of the ecosystem so it can be examined systematically.

This concept is called the *ecosystem complex* and while it was developed primarily for environmental research, it may be used also by designers, planning specialists, engineers, and architects for specifying the design criteria for specific environments. As shown in Figure 1, the ecosystem complex is comprised of three major classes of variables—*physical factors* which include those factors usually considered when we think of the physical environment; *organismic factors* which are those factors used to describe man or other living organisms; and *reciprocal factors* which are the factors that interact between the organism and its physical environment and may be considered as factors that enable the

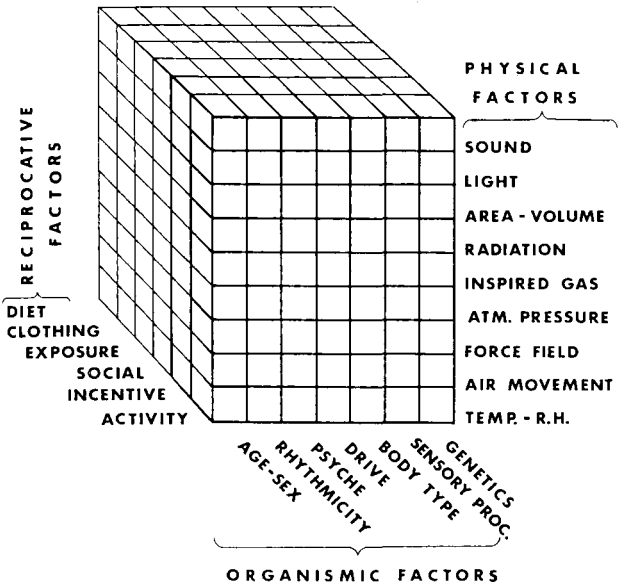


Figure 1. Schematic Representation of the Ecosystem Complex.

organism to adapt to its environment. Depicting these factors as constituents of a three-dimensional solid not only emphasizes the wholeness of the ecosystem, but treats it as a dynamic complex which now can be studied by many disciplines, methods, and approaches. Each of these variables will be discussed separately.

The Physical Factors

1. *Sound.* Noise is popularly grouped with air and water as one of the major sources of pollution. Traditionally, however, sound as well as noise, is defined in terms of intensity (decibels), frequency or pitch, and timbre (overtones). For the designer, the source, whether internal (machinery-typewriters) or external (air conditioning equipment or sonic booms), must be specified as well as the dampening required.

2. *Light.* In contrast, light is more complex. Helson² lists 15 additional dimensions beyond the classical descriptions of hue (color), saturation (richness of hue), and brightness, and includes such factors as warmth (green and blue being cool colors—red and yellow are warm), volume (light shades convey the feeling of large spaces—dark shades restrict the size), glare, and affective tone.

Research in biological clocks is responsible for additional dimensions of light. These include the length of the photoperiod or light-dark (day-night) cycle, the shift in the phase angle (the fact that New York City and Naples, Italy, have the same light-dark cycle, but are 6 hours out of phase with one another). Travelers experience these phase shifts when going from one time zone to another and thus the rate and direction of shift also must be specified.³

3. *Area-Volume.* The size as well as the shape of the space under consideration is relevant to problems of population density, but is equally germane to the Apollo astronauts or the caller in a telephone booth.

4. *Radiation.* Both ionizing and non-ionizing radiation must be defined in terms of the dose-rate relationship. When listing the design criteria for nuclear power plants, the radiation levels downstream from the reactors at various depths in the river must be specified as well as shielding requirements.

5. *Inspired gas.* Normally, little attention has to be given to the gas we breath if we are considering air whose chemical composition is 78% nitrogen and 21% oxygen with the remaining 1% composed of trace elements. However, in order to survive, the oceanauts in the deep-diving submersible need a gaseous environment of heliox, a mixture of 98% helium

and 2% oxygen. Hydrocarbons, ozone, fly-ash as well as household dust and other particulates also come under this category. Odor, an area we surprisingly know little about, is important in defining the gaseous environment especially if we are designing an animal laboratory or rendering facility. Implicit in this area is the use of filters, masking odors, and the use of fresh or recirculated air.

6. *Atmospheric Pressure.* Most of us live in an environment where the atmospheric pressure is close to sea level, or 14.7 pounds per square inch. Since going down in the sea or up into space alters this pressure, protection is needed for man to survive in these environments.

7. *Force Field.* If you are seated at home or at your desk while reading this article, you are in a 1G force field. That is to say, that you are experiencing a gravitation pull of one G. This is also true when you are seated in your automobile at a stop-light. But when the light turns green and you accelerate, you experience increased *positive* G; conversely, increased *negative* G's are experienced when you stop suddenly. Usually defined in terms of frequency and amplitude (buffeting or vibration), and duration and direction, force field is of little concern in routine design problems. However, when we consider the weightlessness of orbital flight or the starting and stopping of such high-speed surface vehicles as the Tokyo-Osaka Railroad, force field enters as a major factor in design.

8. *Air Movement.* Air movement is described in terms of its velocity, direction, and temperature. If the air velocity is exceedingly high, it becomes fatiguing and impairs vision and in turn performance. In addition, it is a source of noise when high-speed exhaust fans are involved. Anecdotal evidence of reactions to automobile air conditioners shows that the fatigue and discomfort associated with these high-velocity blasts of cold air cause people to reduce the speed of the blowers and in turn the resultant cooling in order to avoid the fan noise and wind. Similar findings are also evidenced in forced-air heating systems and "spot" or "local" heaters.

9. *Temperature-Relative Humidity.* Man is a homeotherm, which means that his thermal environment must be fairly uniform—between 74° and 82°F is he is to survive. Current research shows the conditions for optimal comfort to be at 78°F at 50 per cent relative humidity for sedentary man.⁴ Of course, this is less for more active conditions and for various clothing levels.

The Organismic Factors

Seven factors are needed to define the organism, either man or animal, that is located in the physical environment.

1. *Age-Sex.* Age is usually defined in terms of time from birth, however, the age of fetuses can also be specified.

2. *Rhythmicity.* This variable is used to describe such biological rhythms as the respiration cycle, heart rhythm, body temperature rhythm, and menstrual cycle. Each of these is specified in terms of frequency and amplitude.

3. *Psyche.* The psyche represents the psychological makeup of the individual. It includes all of the personality attributes—introvert-extrovert, dominance-submissive, self-reliance, personal worth, withdrawal tendencies, nervousness, anti-social tendencies, relations with others, etc.

It also includes the myriad of aptitudes including numerical, mechanical, language, spatial relations, manipulative and perceptual motor. Intelligence is related to mental age, a value which when multiplied by 100 and divided by the chronological age yields the intelligence quotient or IQ. Perhaps one of the most elusive of the personality traits to measure is attitude since it includes such factors as attitude toward the job, attitude towards the school, the church, peer groups, supervision, etc. The two remaining variables are interests and values and are equally difficult to assess.

4. *Drive.* All organisms have basic biological drives. These are hunger, thirst, and air or oxygen. In addition, there are sex, avoidance of pain, the elimination of biologic wastes of urine and feces, and sleep. Because man is a homeotherm he must maintain his thermal environment within a fairly narrow range; hence, both the maintenance of “comfortable” temperature and atmospheric pressure are considered as basic drives that govern motivation.

5. *Body Type.* Ordinarily we think of three types of builds or body types: the short, chubby individual or endomorph; the normal, well-proportioned person or mesomorph, and the tall slender individual or ectomorph. Body type and size are related to the basal metabolic rate of the individual.

6. *Sensory Processes.* Normal individuals usually are said to possess six senses: the visual sense which includes visual acuity as well as color perception; the auditory sense or hearing; the sense of smell or olfactory modality; the chemical sense of taste; the skin senses of touch, warmth, cold, and pain; and the vestibular sense which controls our balance or ability to walk upright. The sensory processes are usually taken for granted. However, the blind, the deaf, and other sensory-handicapped persons also must be considered in the dimension.

7. *Genetics.* The last way to describe the subject in the physical environment is in terms of his genetics. This is particularly important when

describing pure bred strains of animals. However, the race of the human subject is also implied in this category as well as his country of origin.

Reciprocatve or Adaptive Factors

The last group of factors which interact between man and his physical environment enable him to withstand the environmental extremes and aid in his adaptation. As such, they are called *reciprocatve* or adaptive factors, and there are six in number.

1. *Diet.* Diet is defined as any substance that is taken into the digestive system. Obviously, food immediately comes to mind, and is readily defined in terms of proteins, fats, carbohydrates, vitamins, and minerals. It is also specified in quantity by the number of calories. Water is defined in terms of amount and composition—that is to say, “Rocky Mountain Spring Water,” distilled water, or tap water. Drugs, chemicals, herbicides, and pesticides also come under this category.

2. *Clothing.* Aside from style and fashions, clothing is quantified by its *clo* or insulative value. A “clo” unit of thermal insulation is “the clothing required to keep a resting subject in a comfortable state when the subject is seated in an atmosphere of 70°F with relative humidity less than 50 per cent and air movement at 20 ft./min.”⁵

3. *Exposure.* The frequency and duration of exposure are what enables an individual to adapt to such physical factors as cold, heat, and high altitudes; however, we also talk about dark adaptation which requires about 20 minutes. And people who reside in the stockyards have adapted to the odors which are extremely offensive to the transient visitor. Also included in this variable is the time of day as well as the time of year.

4. *Social.* The social factor involves the group size, national origin, and socio-economic background. The general makeup of the group—prisoners, athletes, retired persons, married, single, divorced, also come under the social description.

5. *Incentive.* The amount an individual is paid in a large part offsets his willingness to accept a hostile environment. For example, the coal miner who works in polluted air, the steel workers who earn their livings in front of the open-hearth furnaces, or their “opposites,” the roughnecks on the drilling rigs of the North Slopes of Alaska withstand those environments because of the pay.

6. *Activity.* Sleeping, working, studying, eating, playing, walking, sitting, running, and swimming are some of the terms we use to describe activity.

In addition, we specify the length of time or duration the organism spends at each activity.

Criteria

All of the factors noted above are known as *independent* variables. As such, they are under the control of the engineer, the architect, the designer, or the researcher. The adequacy of the design, or the effects of exposure to these factors is measured in terms of three *dependent* variables. The first is *health* and involves safety and fatigue. Implied in this criterion are all the physiological parameters of growth, heart action, respiration, body temperature, and metabolism. The second criterion against which the independent variables can be assessed is *behavior*. These include innate or unlearned behavior such as reproduction, migration, maternal behavior, nest building, and aggression, but also include learned behavior or performance. The third criterion is *affectivity* or the way in which people feel whether it be comfortable or uncomfortable—pleasant or unpleasant or hot or cold.

Summary

Fragmentation of the ecosystem in this manner immediately points up its complexity. While it is true, the ecosystem complex involves a large number of variables, it is often not necessary to employ all of these variables in designing a particular space or in conducting a research problem. Yet, they at least have to be considered or held constant when making judgements as to which factors to employ in the design, engineering, or research. Some variables require detailed analysis; others may be irrelevant. But regardless, none can be overlooked when working on any problems of the environment. But more important, understanding of the ecosystem complex requires the contributions of technologists and scientists many disciplines. In this way, the planner, the architect, the engineer, as well as the physiologist, botanist, psychologist, economist, and sociologist, to mention only a few, can make his contribution as an interdisciplinary team whose goal is the understanding and preservation of man and the lower animals.

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