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# On socio-technical ecology and the study of innovations

## *INTRODUCTION*

THE PURPOSE OF THE FOLLOWING ESSAY is to present the general mode of thinking developed in an on-going research project dealing with the interaction between population, technology and settlement[1]. One aspect of the project, among several others under work, has to do with the adoption of innovations and the subsequent effects of their integration. It is this special problem area which will be discussed here. No empirical results will be reported, however. Such will be made available later in a forthcoming study by T. Carlstein, together with a more exhaustive theoretical treatment (cf 1970). In the present context the emphasis is laid upon how empirical information must be organized in order to be capable of being used in connexion with the theoretical frame which is advocated. Particularly in historical work, where so many critical variables cannot be taken as intuitively known, there is a need for a large amount of fresh empirical data or reinterpretation of existing ones before the desirable synoptic picture will be attainable. In the opinion of the present author a great deal of effort must be made in order to make our present piecemal knowledge of society truly additive. But this can be accomplished only if researchers agree about a common and consistent view of the world. Our research project as a whole is trying to work out a proposal for a frame of thinking which we hope will become both widely applicable and internally consistent. Innovation is embraced as one component.

A great number of disciplines have approached the problem of innovation and change out from their specific vantage points and therefore we have now several research traditions which form a parti-coloured mosaic of pieces of knowledge rather than a conceptually well-knitted whole. It seems, however, as if the research traditions could be broadly classified into two groups.

On the one side we find investigations of cases which are described as fully as possible with respect to their situational contexts. The bulk of this material concerns historical cases in western societies or present-day cases in non-western ones. The rendering of data and the analysis is only to a small degree formalized. The aim is to arrive at an understanding in verbal terms of the chosen cases per se, much in the same way as literary works dramatize fictitious situations. Generalizations beyond the historic and geographic contexts are ventured only hesitantly and with strong reservations.

On the other side we find a less long-established variety of studies which aims at a formalized general theory. Generalizations are frequently made in terms of models, intentionally simplified and stripped of most of the particular situational circumstances. Standardized concepts and quantitative information are considered to be essential bases for progress in this tradition.

Beyond this division of approach there is of course much common ground. So, for example, it is probably true to say that all researchers on innovation agree that a new artifact or practice has to pass through a series of rather clear-cut

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stages on its way from idea to established routine: invention, prime innovation, diffusion, saturation. It is rather characteristic that the bulk of empirical investigations made along the quantifying and generalizing line of thinking has so far concentrated mainly on the stage of diffusion, that is on how information about innovations is transferred through a socio-technical system and on how the imitating adopter differs in individual characteristics from the non-adopter or laggard. A considerable amount of knowledge and quite a number of generalizations concerning these aspects have accumulated (Rogers and Shoemaker 1971).

This concentration on diffusion is no accident. As soon as an innovation enters the stage of diffusion, a certain kind of event, the adoption, becomes recurrent throughout the system and by that amenable to statistical treatment. The stages lying before are, taken case by case, at least seemingly unique. The creativity of individuals and small groups in highly particular settings are involved. Afterwards it is hard to interpret in causal terms why things happened as they did. And it is still harder to foresee ahead in time what is going to happen afterwards as all forecasters of technical and social change know so well. Inventions and primary innovations are not within reach of statistical investigations until again a reasonably large number of sufficiently similar case-studies have been assembled and then only if data are so standardized that useful classifications become possible.

For a more full and coherent understanding of the place of innovation in the development of human society it seems now essential to try to see the whole process under one perspective. It is important to begin to understand innovation and change in general terms not only for scientific reasons but also for practical and political ones. In large areas of the world there is far too little of constructive change for life to be endurable. And in the most industrialized countries we seem to need a slowdown or at least a more selective guidance. We need to know more about what circumstances convert inventions step by step into innovations which then start to diffuse. And we need to know more about how one innovation by its diffusion opens the way for other innovations. This can only be achieved if we first of all try to close the gap between detailed story-telling and simplified statistical modelbuilding. Each side has to give up some of its present ambitions. The historian and anthropologist must admit that theory requires simplification. The quantifier must admit that where human actors are involved causal explanations and predictions are possible only within limits. But still further adjustments are needed. In order to locate the full picture of an innovational process in the broader context of pre-requisite conditions and of following consequences we need a way of mapping the whole chess-board on which the game takes place. We must be able to view the situation before the innovation finds its place in the fabric, we must be able to follow how the environment is affected while it is diffusing and we must be able to state how the new end-situation differs from the initial one. To see this process as predominantly a question of communication and mental adaption to new ideas represents a rather restricted perspective. Innovations are in most cases more than just ideas. It is true that rejection of an innovation might be only a mental process. But adoption is not. Events have to be set in motion in some orderly fashion. Conflicting events may have to be counteracted. Institutions may have to be organized in order to shield the innovation from an eroding environment. In other words, innovations must get some sort of real shape in the real world before one can say that they have become adopted. In order to understand what that means we will have to take our investigations much closer to things and events than we have normally been doing.

## *ELEMENTS OF A SOCIO-TECHNICAL ECOLOGY*

It is tempting to compare an innovation which enters a socio-technical system with a new species which enters a biological ecosystem. The latter requires a "niche" in order to establish itself and survive over time. The occupation or carving out of a niche may well entail destruction of other, less competitive species. Correspondingly, an innovation needs a "slot" (Frybourg 1973) to go into. Again a slot could be conceived of as some unexploited opportunity or it may only come about at the expense of some pre-existing thing and procedure which is forced to dissappear. The horse pushed out the bullock from its place before the waggon, eventually to become replaced by the internal combustion engine. But that is not the full story. The whole choreography of moving by vehicle underwent drastic changes by each innovation. People and things became hooked up in new configurations. Space and time became utilized in new patterns. So for example, at the second step oil-fields took over from pasture-land the task of providing energy. A change of this sort indicates that the occupation of one slot sometimes leads to the creation of a new one (here the pasture-land), free for use in the next round.

The concept of a "slot" as a pre-requisite for an innovation takes us beyond summary measures expressed as simple frequences or as prices and profits rendered in monetary units. It requires us to develop a socio-technical ecology, formulated in real terms. We must be able to state how innovations bind up people and things, information and energy in specific spatial and temporal configurations. It may be argued that this is what one is often trying to do in historical and anthropological case-studies. This is certainly true, but what is still missing is a set of concepts, applicable to every conceivable case and powerful enough to reveal many-sided interactions and to admit deductive conclusions beyond what is immediately observable. We need methods for describing and analyzing *situations* in more fundamental ways than we have so far been able to do. Of particular importance is that we can move freely up and down between micro- and macrosituations since we know well that important connexions exist between these two levels, connexions of a kind which get washed out from the picture as soon as we apply conventional statistical aggregation of data.

At the present moment there is no generally accepted language, complete enough to deal with the complex task of developing a socio-technical ecology.

But I believe that one can pick up elements from various fields of research and try to put these together in a fashion which indicates in what direction it would be feasible to proceed. As I see the problem it should be defined as a search for improved ways of describing in general terms complex activities located in their "natural" (= historically given) settings. Let us see how one could go about to create a general language of situations.

Every actor who wants to reach some goal in the near or more distant future must arrange a set of events to happen in suitable order. For this purpose he must have access to needed resources — be they other people, tools, materials, premises, or pieces of information — at the right moments and at the right locations. Let us agree to call the whole sequence of events leading up to a goal *a project*. Defined in this way a project can be of any scale, from preparing a meal over building a house up to sending a rocket to the moon. Assume now that we want to describe a project in more precise ways than we can do by mere verbal explication. A first method would be to use monetary costs and benefits as a wholesale descriptor. A second possibility would be to state the physical magnitude of all elements going in to and out from the project, that is to say to describe its aggregated input-output structure. A third picture would come out if we projected the traces of the project on a map, thereby emphasizing space-use and movements. A forth kind of representation, finally, would be to produce a time-table for the steps to be taken from beginning to end, approximately in the way one is doing it in network planning.

All methods of description just mentioned bring out various dimensions of one and the same process. But they also have in common a very serious shortcoming. They do not clearly demonstrate how real-world magnitudes in one dimension are functionally related to other magnitudes in other dimensions. And therefore one cannot easily see or calculate how a change in one dimension nessecitates adjustments in the other ones.

The central problem to solve is to overcome the conceptual split between our traditional descriptive dimensions. What is suggested here is to start with the unification of the space- and time-dimensions — the map and the time-table — and make them into one single space-time entity. This first step gives us a four-dimensional frame into which we can project observations. In principle four co-ordinate measures are needed for locating an event. But for a graphical demonstration of relations as far as human activities are concerned it is as a rule sufficient to deal with a three- or even only a two-dimensional space-time. This simplification has the heuristic advantage that one can clearly see how processes correspond to geometrical shapes and how the accomodation of competing projects is like a problem of fitting irregular configurations into a space-time puzzle. This view is central and must be explained in more detail.

Elementary operations. Let us first look for building-blocks by which to build up a space-time picture of activity from the micro-scalar end. Then three kinds of elementary operations stand out as quite fundamental: *decomposition, moulding* and *composition.* The first operation means that fractions are cut out from some set of input or raw material. The second operation gives materials suitable shape. The third operation brings pieces together to form a new constellation. Equipment, predominantly containers and tools, is as a rule a necessary ingredient in all kinds of operations. Just to demonstrate, we may think of simple things like cutting a slice of bread from a loaf and taking a pat of butter (decomposition) in order to make a sandwich (composition). We may think of pressing a piece of iron into a nail (moulding). Or we may think of more space-demanding operations like harvesting a fodder crop (decomposition) and making it into ensilage by adding chemicals (composition). It exists an endless collection of specific instances to observe. Every time, however, we will note that three conditions must be fullfilled if an operation is to take place. Even the simplest operation — material and equipment included — consumes some space and some time. Movement is also an inevitable ingredient. Even highly intellectual undertakings, like writing a poem or playing a piece of music, show these basic characteristics. They need also space and time and require movement.

Thus, for operations to be carried out smoothly and undisturbed, access to sufficiently large space-time regions, sufficiently shielded from the surrounding, is a first necessary condition. Secondly, actors, materials and equipment must also be within handy reach. They must be able to form *activity bundles* in a tangible physical sence. Such a region which is suitably furnished for a specific set of activities may be said to form a *pocket of local order* or a *pocket of operations.* By the first term we refer to the fact that the right kinds and amounts of resources must be concentrated in a small region of space-time before operations can start at all. The order is given by nature (history) or has to be arranged. The second term stresses activities per se in the same region.

Researchers who are interested in pursuing work studies must pay close attention to elementary operations in all their manyfold variations. When the aim as here is to give conceptual structure to such a vast field as a socio-technical ecology it would be an overwhelming task to deal with individual operations more than occasionally. One must of course be able to go down to details when required, but — since it is important not to lose contact with wider issues — one must also have stepping-stones for aggregation and simplification.

Pockets of operations. Let us now look away from the details of operations and instead as our leading basic concept choose the pockets of operations in which they are contained. When doing this we must first define the space-time volumes which represent such pockets. This is to a certain extent an arbitrary affair just as all kinds of regionalizations. The principles to be applied will have to depend upon the nature of the empirical question at hand. For the moment we simply assume that we have managed to carry out our delimitation in correspondence with the level of generalization needed for a particular study. We need then only to pay attention to what is passing in and out through the walls of the pockets, disregarding the details of what is going on inside them. This shift of viewpoint leads us to the next step in the development of a unified conceptual structure. We are prepared to apply ideas from input-output analysis, but reinterpreted in a space-time perspective. It is then easy to see (figure 1) that inputs

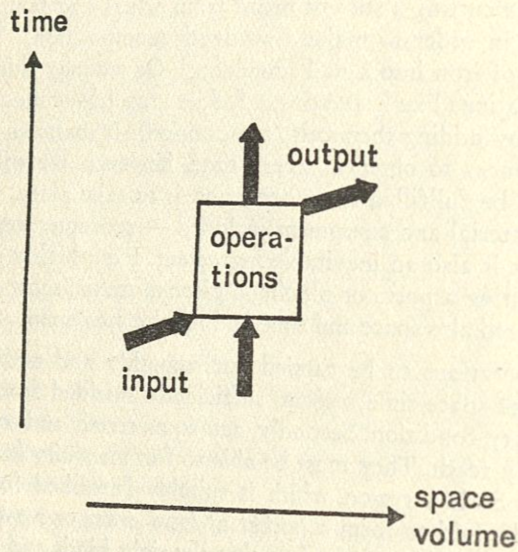



Figure 1. Symbolic representation of the space-time appearance of a pocket of operations. The width of the box represents the needed space (volume) and the height the needed time (duration) for a set of operations to be carried out. Arrows indicate the different directions and the time-relations of inputs and outputs. Rearrangements of inputs are hidden in the box.

to a pocket can come from two directions. They can either come from below (only movement between points in time is involved but not between points in space) or from the side (movement between points in space is involved, something which cannot avoid also to take up time). Outputs have to pass out through the walls of the pocket in a corresponding manner but always later in time. It is clear that the vertical input-output relation corresponds to that we conventionally call *storage* and the almost horizontal to *transport*. It should be noted, however, that in a space-time model nothing can remain at a standsstill. Therefore, the concepts of stocks and flows are not useful here. By definition everything is continuously moving.

Let us now consider some examples of pockets of operations and their respective input-output structure. Farming provides an endless variety of cases to choose among. Figure 1 shows in a simplified fashion harvesting (as it was performed before mechanization) after the moment when the crop has been cut and the sheaves are still spread out on the ground. The operation depicted in figure 2 I is the collecting of the sheaves into shocks for drying. In its finest practical details this operation amounts to the transport of each individual sheave over a short distance. But in this context we prefer to remain at the next scale interval and interpret the procedure as the production (composition) of shocks. If so the "vertical" input to the pocket (in other words pre-existing on the spot) is made up of the scattered sheaves and the "vertical" output (in other words left afterwards on the spot) of the finished shock. The horizontal input and output are two workmen who have to move up to the spot before work begins and leave it for the next when it is ended. The box represents the pocket of the single operation. It has a width corresponding to the area which is needed for providing sheaves for one shock and a height corresponding to the time it takes for two men to do the job. Clearly, going over a whole field amounts to a repetition of the same kind of operation until all sheaves have been collected. If we need to aggregate a step further we may say that the whole cluster of repeated operations takes place at the same *station* which in this case is the field.

The subsequent operations are assumed to take place a few days later. They include loading out in the field, transportation home to the farm, storing in the barn and movement back to the field for the next load. This elementary round of course also has to be repeated until the field is empty.

Clearly, the whole sequence of operations taken together is part of one single project as defined before, that of producing a certain amount of corn. In order to make an exhaustive description we would have to follow events over the whole farming year. But here we are not in the first place interested in the subject matter per se but in certain principles and so the sub-project we have before us in figure 2 must suffice.

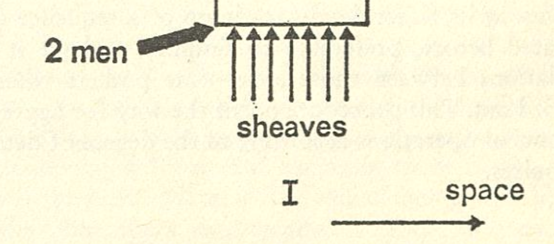
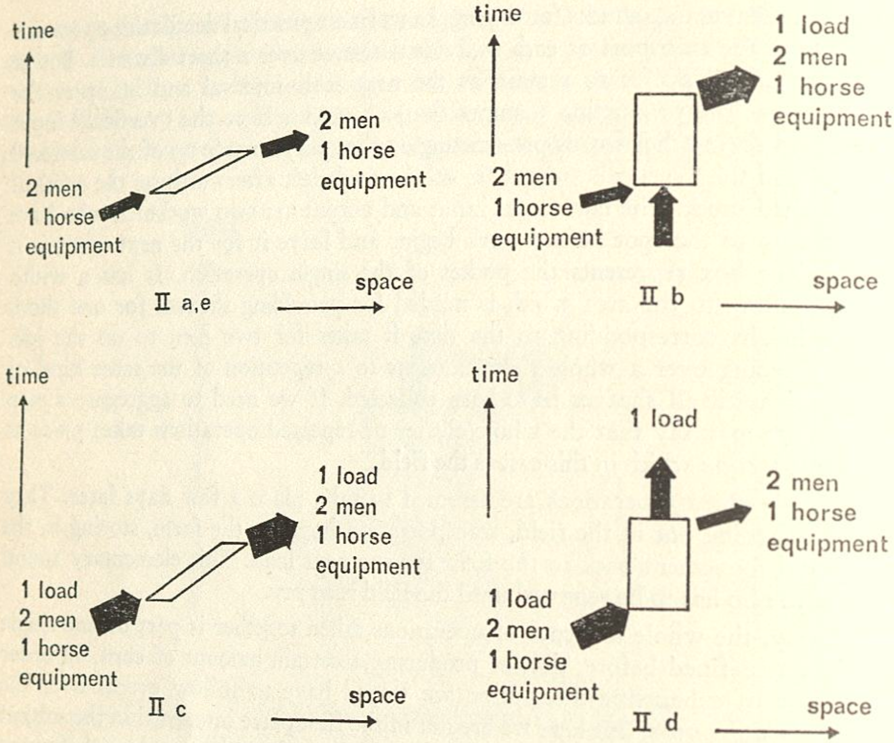



Figure 2. Symbolic representation of a series of farming operations at the end of harvest. I. Assembling of a number of scattered sheaves into one shock, a work carried out by two men without equipment. The basic operation has to be repeated until the whole field is worked over




II. Moving equipment etc. out to the field. II a. Loading the sheaves. This operation has to take place where the shocks are located (shocks are therefore represented as vertical input). II b. Transportation of load to barn. II c. Unloading at barn. Sheaves remain in the barn (therefore represented as vertical output). II d. Movement back to the field for next round. Operations have a fixed order inside the larger project to which they belong. Inputs and outputs must be fitted together in due order. Here the flow of sheaves is the smallest possible common input-output element. Workmen, draught-animal and equipment need not be identical all through the project. A characteristic of small-scale farming is that individuals and entities of other sorts have to follow through projects in all their faces. The more projects become industrialized the more operations are divided up between specialized actors and tools. But this division on the other hand usually means that administrative operations have to be added.

A project is thus in its finest details made up of a sequence of operations. But it is here, as stated before, preferable to simplify and see it as a network of input-output relations between those space-time pockets where the actual operations are carried out. This procedure opens the way for aggregation and allows us to define pockets of operations according to the degree of detail which a special investigation requires.

Input-output elements. The first thing to remember is now that inputs and outputs must be brought to hang together, in order to make up a project. The output from one pocket must serve as input to the next. Frequently several combinations are possible as long as the basic logical order is maintained. In our present case the smallest common denominator is the material which has to be processed. Operations I and II b are also bound to take place in the same piece of space (the corn-field). What the other inputs and outputs are concerned there exists degrees of freedom, at least as long as we view the matter apart from the circumstances of a given situation. On a farm conditions make it most likely that the identical entities, be they people or equipment, take part in the various phases of a project from beginning to end. Modern industry, on the other hand, has used available degrees of freedom to a very large extent for taking advantage of specialization among humans and equipments. Whatever the case may be some strong constraints are always present acting upon how input-output entities can become engaged in a successive series of pockets of operations. Among constraints we will concentrate attention to those which are most closely related to the thinking in space-time terms.

Let us for the sake of simplification make a distinction between only four kinds of elements:

1. individuals
2. units of equipment } indivisibles

3. energy, materials
4. information } divisibles

Of prime importance are the human beings themselves. Nevertheless we must leave out from the discussion important matters such as problems related to man as a creator of projects and organizer of environments. Only certain consequences of his biophysical existence will be noted.

Since the human being is indivisible, his consecutive locations in space-time forms an unbroken trajectory or a *life-line*. A whole human population which continuously regroups itself into cooperating clusters of variable size comes out as a web of intertwinned life-lines with the specification that every line, like a textile fiber, retains its identity from the beginning (the point of birth) to the end (the point of death). The indivisibility imposes strong limitations on how people can allocate themselves between activities, places and times as life proceeds. The physiological needs of each individual person regulates also quite strongly the purpose and timing of many of those events which were earlier classified as decomposition, moulding, composition, storage and transport of both living and non-living entities. But naturally there is also a great number of other determinants at work. All in all the web of human life-lines is inseparably coupled to all the other inputs and outputs of things, information and energy to and from pockets of operations.

It is further important to keep in mind that many other flow elements are made up of indivisible quanta with limited time of existence. Together also these make up sets of more or less mobile populations with characteristic age-distributions. Such populations are for example tools, containers and many kinds of intermediate industrial products. Even these move through space-time along unbroken trajectories. The similarity is admittedly only formal. But it is essential to keep it in mind because if we do not we will misunderstand the logic that governs the relations between pockets of operations and projects and in particular the relations between people and things. (An organist, for example, cannot take home his instrument over night as a violonist can. The same mutual relations hold for an operator of a computer and a clerk with a desk-calculator).

Energy and shape-less materials (air, water, sand, grain) behave differently, at least when seen within the scale limits we are considering here. They can all be divided and united into almost arbitrarily varied quantities. But still, a point to observe is that the quantities available as inputs to any chosen pocket of operation is as well entirely place- und time-dependent. One cannot suddenly bring in a wanted quantity just from empty space. What actually is available is completely determined by how transportation and storage have come to distribute potential inputs beforehand up to the critical moment when a need is felt in some pocket of operation.

Information as an input-output quantity is a more complicated matter to deal with in space-time terms because it exists very few investigations with results that can be applied to the way of thinking advocated here. Only a few general comments are possible. First of all it seems reasonable in this context to divide information into two types. One type is made up of technical know-how, that is to say knowledge of how operations are carried out in principle and of how projects are built up. It is this kind of information which must be carried over from actor to actor when an innovation is under its diffusion stage. The second type of information is of a topographical nature. It deals with the environment of the actor and represents so to speak a catalogue of resources and barriers which must be taken into account when he is planning his operations and projects and is trying to guess what other actors have in mind.

It is selfevident that much information is picked up and carried forward as internalized resources by the individuals themselves. Other kinds of information require physical carriers of some sort, paper, tape, electrons and so on. They are therefore, as far as space-time behaviour is concerned, dependent upon the transport, storage and duplication characteristics of the carriers. Operations on information per se on the other hand obey very peculiar rules. For example, information is not spended when it is distributed. The source still owns it intact. Anyhow, on the whole information is no more than the other input-output entities right away available just outside any pocket of operation. It is flowing along sharply delimited space-time channels and stored very unevenly. So, one of the most problematic aspects of any project is to get access to suitable information exactly when and where it is needed (cf. Pred 1973).

After these short comments on the nature of flows we are ready to go back to where we started, to the concept of a project. Considered as a pure plan of action a project can be designed or analysed quite apart from a real space-time situation. But it cannot be carried through in practice unless actual inputs and pockets of operations can be made available in acceptable (not necessarily the most wanted) locations and sequences and within the time-limits which perhaps are enforced by superior projects or by natural conditions. In farming the seasons are a source of such deadlines, to remind of an important case.

What interests us here is not in the first place the design of more or less efficient plans for projects. Just in passing shall only be noted that the formation of a hypothetical plan is probably a critical part of the mental adoption of an innovation. But the central problem to tackle in our context belongs to the next step: what conditions circumscribe the actual implementation of a project?

THE SPACE-TIME AQUARIUM. At this point it is first of all in order to remind of the fact that space and time are not only formal dimensions which help us to represent the location of events in a symbolic language. The concepts represent also very real resources and as such at least in some respects strictly limited ones. A given region of space has a limited capacity to accomodate pockets of operations with the concomitant storage and transport requirements of inputs and outputs. Time as a purely physical dimension might well be considered infinite. But in the present context this is irrelevant. A human life-time is a limited and unique experience. The number of activities an individual can get involved in per unit of time is limited. A population is made up of a certain number of individuals. Therefore also a whole population has a limited capacity for varied action. In the shorter perspective of the day, week and year it is of most interest to note that the individual can on the whole engage himself in only one pocket of operations at a time. In addition his low mobility makes the field of action around the base-point rather limited. Similar constraints are valid for other indivisible items. Seen together the limited holding capacity of space and time gives rize to rather severe constraints on the freedom to fit in parts of projects. When the space and time limitations work in unification they give rise to a kind of competition between projects which has a much more complex nature than one tends to believe when one is only looking at input-output relations between pockets of operations in unlocalized quantity terms. We have before us a budgeting process which requires not only an allocation of amounts of resources to various purposes. Hidden behind this purely quantitative problem lies the budgeting of sequentially and spatially ordered patterns of pockets of operations over inert entities imprisoned in a space-time vessel (figure 3).

It has been suggested to call our model "the space-time aquarium". This is in fact a suggestive way of describing the viewpoint which is advocated.

This is not the place for a lengthy discussion of the aquarium model in all its consequences. Nevertheless, a selected number of issues must be treated in some

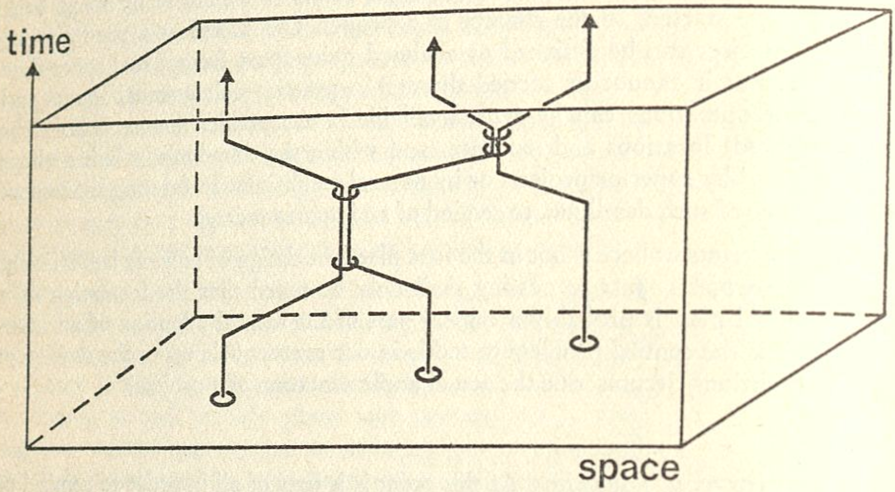



Figure 3. The space-time "aquarium" in which entities generate trajectories, moving ahead inside and between stations. The graph extracts the space-time behaviour of three individuals over a certain period, for example a day.

detail before we are ready to draw conclusions concerning the possible application to innovation research. A basic consideration is the behavioral consequences of the indivisibility of the individual. Let us first view the matter in the daily perspective which helps us to focus upon certain critical details (figure 4).

When a person has entered a pocket of operations for taking part in what is going on there we may say that he is occupied by a *task*. We define a task so that it can be made up of a series of repeated operations as long as they take place at the same station. A task has space-time location and duration. Selfevidently an individual cannot engage in two tasks, separated in space, unless the end of one and the beginning of the next are enough separated in time so that movement between the two locations are permitted. To overcome separation in space always involves spending of time. A further constraint is the necessity of having base-points for meals and rest. The individual cannot engage in tasks situated out in the environment unless they have endpoints so located in space-time that he is able to reach the base-points on agreed times.

As soon as several individuals, starting from different points, have to engage in some common task, the assortment or other tasks which have to be tended to, and the relative location of these, rather strictly define the set of individuals in the area who are free to cooperate.

Analogous conditions are with some modifications valid also for longer periods, the week, the month, the year and so on. The difference is that movements then take the form of migration (more permanent change of base-points) or perhaps of long-distance travel (temporary change of base-points). But the constraints

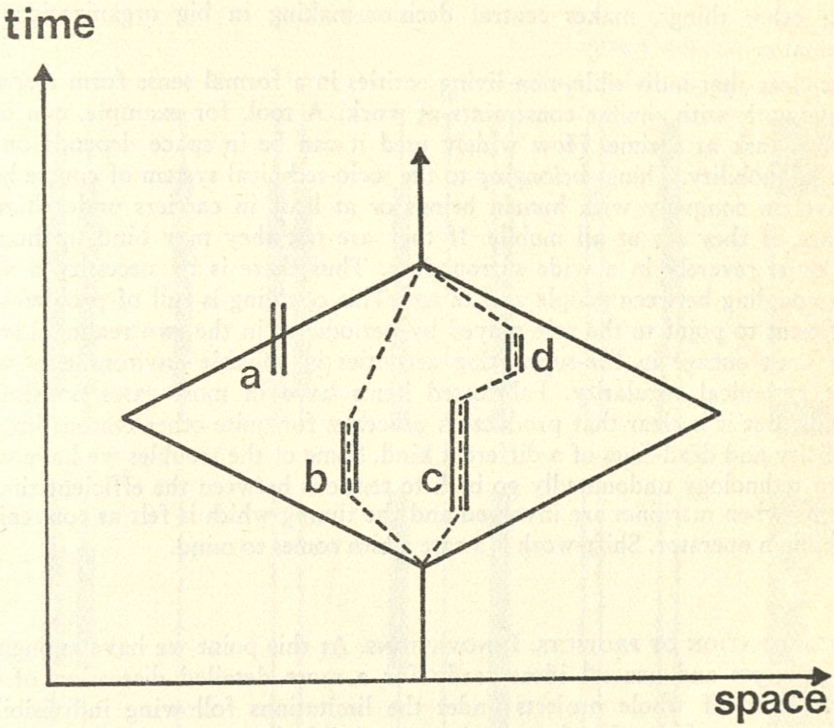



Figure 4. Some fundamental constraints determining the possible trajectories of indivisible entities, for example human individuals. Given 1. a base-point (say the dwelling) which the individual cannot leave before a certain time and which he has to return to before a certain later time; 2. a maximum speed by which he can move out from the base-point and back again. These conditions determine the outer limits of the space-time "prism" available for visits. If we now assume that a, b, c and d represent tasks which have a predetermined location and duration then the individual will not be free to participate in arbitrary combinations although the tasks all start inside the prism. a must be excluded because of its duration. If b is chosen, c and d get beyond reach. If c is chosen, b gets beyond reach. c and d can be combined. Obviously, only d can be chosen whereby both b and c given up. Clearly, the choices finally made affect the trajectories of other entities sharing the same space-time region.

on the grouping of individuals who can cooperate directly fundamentally remain of a similar nature.

The indivisibility has not only consequences for how a selected individual can order the sequence of his own tasks. Much human activity concerns direct personal communication between individuals who are not freely interchangeable because of special competence or earlier commitments. So, as soon as somebody has disappeared into a task of a certain duration he will not be available as a resource for other people until the task is performed. Those who want to see him and have no substitute have to wait. It is safe to say that no social organization is possible without that sort of waiting times and tensions caused by them. This, among other things, makes central decision-making in big organizations so problematic.

It is clear that indivisible, non-living entities in a formal sense form a space-time network with similar constraints at work. A tool, for example, can only have one task at a time. How widely used it can be in space depends on its degree of mobility. Things belonging to the socio-technical system of course have to travel in company with human beings or at least in carriers under human guidance, if they are at all mobile. If they are not they may bind up human paths quite severely in a wide surrounding. Thus there is by necessity a very strong coupling between people and things. This coupling is full of problems. It is sufficient to point to the role played by periodicity in the two realms. Living beings must engage in life-supporting activities in suitable environments with almost rythmical regularity. Fabricated items have in most cases no similar demands. But it is clear that production processes for quite other reasons impose periodicity and dead-lines of a different kind. Some of the troubles we have with modern technology undoubtedly go back to tensions between the efficient timing of events when machines are involved and the timing which is felt as convenient for a human operator. Shift-work is a case which comes to mind.

Accomodation of projects. Innovations. At this point we have enough of basic concepts and general ideas ready for a more detailed discussion of the accomodation of whole projects under the limitations following indivisibility and the nature of the closed space-time vessel. Ideally we would first need to identify the whole universe of entities from which competing projects are going to engross time and room. If, for example, we are interested in activities on a farm we ought to make a complete list of all individuals, animals, pieces of equipment, materials, fields, roads and shelters which the farmer has at his disposal within his domain. After having made that we would know if the various tasks included in a planned project could be allocated inside the farm or if extra inputs had to be brought in from the outside.

For the purpose at hand we must be less ambitious and consider only those inputs which are defined by operations to be hooked together in the selected project. Further, in order to get a more tractable graphical representation than the full aquarium model affords we permit ourselves to transform movement between points in space into time-use imposed upon the moving entity. A final simplification is to cut up space, in the meaning of room, into such "quanta" which are of actual concern for the project. We loose certain aspects of the accomodation of tasks in space (particularly possible conflicts between neighbouring pockets of operations) but we gain in clarity what the timing of events is concerned.

Figure 5 is a visualization, simplified as just suggested, of a feasible solution to the harvesting project discussed before. We get a rather full synoptic view of how the various tasks defined by operations come to give tasks to resources as

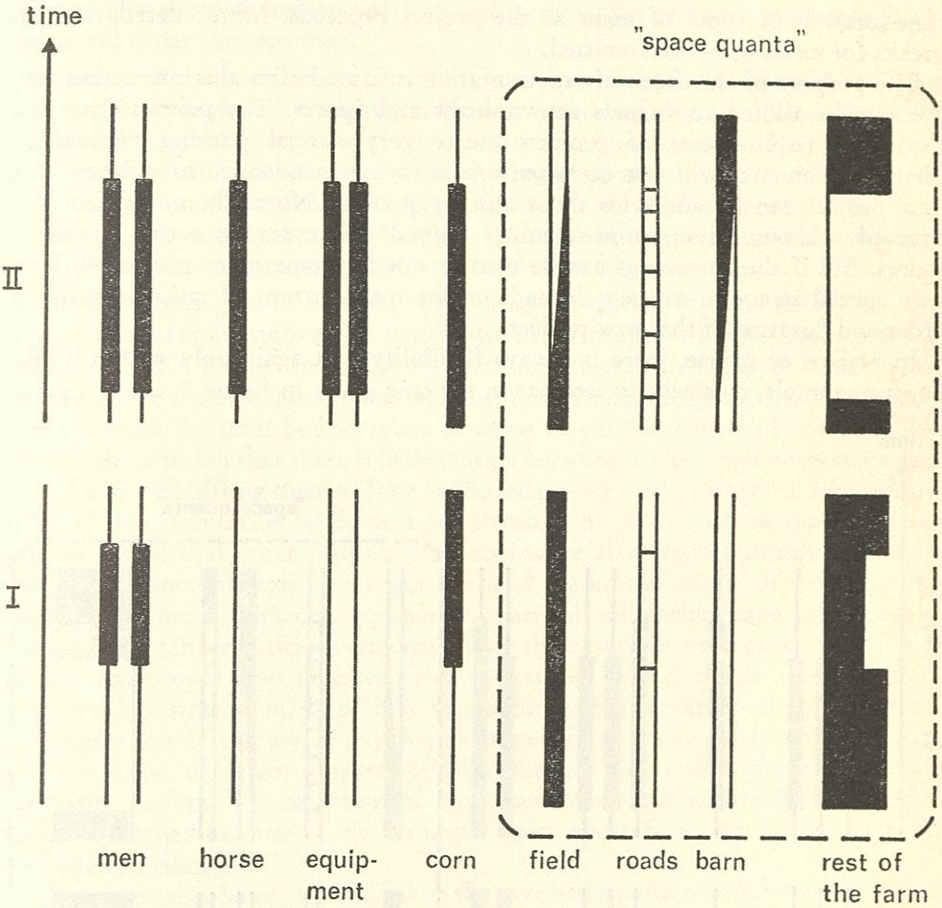



Figure 5. A possible score of the harvesting project described in figure 2. Here, in order to get a firmer grasp of the budgeting aspects, space has been cut up into functional "quanta" and the movement of entities between points in space has been transformed into time-use. The bars mark when the various entities are involved in tasks (= series of operations) belonging to the project under investigation. Thereby is also shown when they are free to enter into tasks belonging to other projects, transportation to and from these other tasks included. Shadings mark when spaces are involved in the project. I. Assembling sheaves into shocks. II. Loading, transporting and storing sheaves. Between I and II lies the drying period.

time proceeds. For convenience it is suggested to call this kind of representation the *score* of a project. On the left side we find the actors, their equipment and the material acted upon. On the right side are the special space-quanta needed and in addition the unspecified parts of the "rest of the farm" where actors and equipment are to be found when they do not appear in the project. The various bars and shadings placed over entities and spaces represent the duration and time-location of types of tasks as the project proceeds. Minor details such as breaks for meals have been omitted.

The purpose of this form of representation is to underline the interaction between tasks alloted to various actors, items and spaces. The point is that the sequential requirements of projects create very special packing difficulties. Simple arithmetics will not do when one is trying in advance to estimate if a new project can be added to those already present. Normally no project can proceed without leaving time-openings unused either among actors, items or spaces. But if these openings can be used or not for some other project with its own special structure entirely depends on the total pattern of tasks in terms of order and duration of that new project.

In reality, of course, there is always flexibility, but again only within limits. So, for example, it is easy to see that in the case given in figure 5 sets of opera-

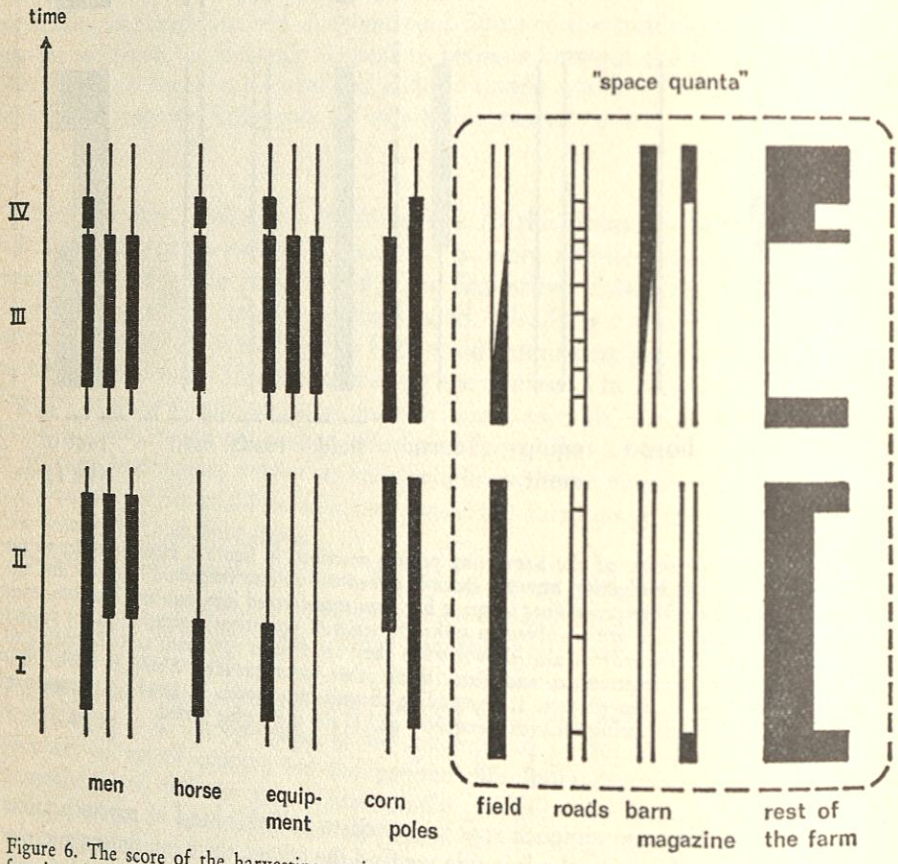



Figure 6. The score of the harvesting project, carried out by a slightly different technique for forming shocks. In this case the time-openings between tasks become more complicated which of course again affect the ways in which other projects can be allocated among entities and spaces. For lack of fully adequate empirial data the scores given in figures 5 and 6 should be seen only as demonstrations of principles but not as entirely correct empirial descriptions. Such descriptions largely remain to be made in a sufficiently exhaustive way.

tions can be divided and pushed forward in time. But one cannot rearrange the sequential order between them.

Let us now assume that the farmer learns that his corn would reach a higher quality if he employed a slightly different method of drying. The score of the harvesting project in its new shape is represented in figure 6. We omit a full description of the separate operations. A first observation is that a larger input of resources would be needed. A second difference is found in the new space-time pattern of operations: there are in all more operations to perform in the sequence and a somewhat more complicated pattern of time-windows.

The two cases give us now an opportunity to discuss in some detail the concept of a slot for an innovation. Assume that the first, more simple case, represents just one sample project in a larger system of projects on the farm which taken together have found a convenient equilibrium. (An equilibrium would be a situation in which the total budget-space in terms of entities, time and room is filled out is such a fashion that there is little tension between projects and no obvious gain to make by reshuffling them as long as the recipes for doing things are left unchanged.) If this assumption holds then an alteration of the procedure applied to one project means that other projects will have to be affected. Adjustments must be made in the total allocation of tasks. If case 2 is adopted instead of a pre-existing case 1, both more workmen, equipment, material and shelter have to be mobilized. With the information given concerning the two cases we cannot know if this means that people must be hired from the outside (and if this is at all possible) and new investments made or if it would be enough to carry out some internal reorganization of the use of existing resources. But we can safely conclude that the allocation of other projects will become affected either inside or outside the farm or both. The adoption of case 2 as an innovation would meet a frictional resistance because of the situation quite apart from the farmer's mental attitude to a change.

If, on the other hand, we had taken the reversed situation as our starting point, that is to say assumed case 2 to represent the initial situation and case 1 the innovation, then our conclusion would have been somewhat different. Case 1 needs the smaller amount of resources. A clear slot exists in the sense that the project can be put in place without changes in the allocation of surrounding projects. This, however, does not mean that a resource-saving innovation can go in without internal or external economic problems. One possibility is that redundant resources become free for new use. A secondary slot is created by these resources in which other projects could expand if they can take on the suitable shape. But it is equally possible that no such solution can be found and that redundancy remains.

## *CONCLUSION*

OUR EXAMPLES SHOW THAT IT IS DIFFICULT TO UNDERSTAND the pre-requisites and consequences of a specific innovation unless one is able to build up a much more global picture of the total situation than isolated cases of the above kind can provide. One needs to know the full score at work in a unit of adoption, covering a rather long period of time — for farming a year and preferably more than so — at least in its major outline. This is a goal which requires a large amount of empirical work. How could that be done?

In historical investigations it is clearly impossible to restore the full score of all projects contained in any named organization, be it a farm, a village, a factory or an institution, unless somebody happens to come across quite unique records. It is still more improbable that one could find data covering a whole community of interacting organizations. But it is probably not necessary to aim at that degree of precision in order to proceed further along the lines suggested here. It would be enough illuminating if we were able to construct models of *types of cases*, representative of their kind, time and area. If we only knew the building-blocks people had to handle at the level of operations and projects we would be able to play around with these in combination in our aquarium. The problem of fitting things together under known constraints would help us to understand what kind of conflicts people used to meet in their every-day world, why they reacted as they did and why certain types of innovations initiated long trains of change.

In order to put us in this position we would have to appreciate that every artifact left over in a museum or described in records embodies a kind of choreography. It was once produced and used (if only stored) in some systematic fashion by human beings. Thus it carved out some share from the limited supply of fibers and spaces in the fabric of its period and place. Even immaterial untertakings in social life, arts and religion laid claim on resources in the shape of localized chains of behaviour. To each case corresponded a score.

As a research undertaking it would not be an impossible task to reconstruct the scores of projects long by-gone. If records and narratives fail one could rely on present-day experiments, something which has already been tried. But in order to be useful in a wider context, in order to be truly additive, the partial studies must be rendered in a conceptual language which includes all fundamental budget dimensions discussed earlier and pay close attention to the proper rendering of sequences and magnitudes.

## REFERENCES


CARLSTEIN, T.
Införandet av skolgång i ett agrart bysamhälle. Geografiska institutionen, Lund 1970.

FRYBOURG, M.
The Impact of Innovation on the Supply of Passenger Transport, Having Regard to Conventional and New Techniques. 5th Int. Symp. on Theory and Practice in Transport Economics, Athens, Oct. 1973.

HÄGERSTRAND, T.
The Domain of Human Geography. In: *Directions in Geography*, ed. by R. J. Chorley. London 1973.

PRED, A.
Urban Growth and the Circulation of Information: The United States System of Cities 1790—1840. Cambridge/USA 1973.

ROGERS, E. M. and SHOEMAKER, F. F.
Communication of Innovations. A Cross-Cultural Approach. New York 1971.