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EVOLUTION OF SOCIAL TECHNOLOGY TO THE INDUSTRIAL REVOLUTION

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Abstract

Our object is to attempt a rigorous application of the conceptual frame of Labour Process to the study of Evolution of Social Technology. The area covered is from the dawn of human evolution to the Industrial Revolution. Some of the major issues such as the emergence of Machine-Process, the emergence of Forces of Nature are taken up for discussion. Later a brief review of some of the view points on Industrial Revolution is attempted and the emergent structure is touched upon.

Part of the material presented here is taken from the paper, "Towards a Conceptual Frame of Labour Process, and of Social Technology and Its Evolution on that Basis" prepared for a Workshop on "Economic Theory" organised by the Indian Statistical Institute, Calcutta, August 18-20, 1979.

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Part I: Introduction and Outline

Introduction

In an earlier paper[1] we attempted at developing the concept of Labour Process (LP) from where Marx had left it. Such an attempt, it was mentioned, was only a first step or the 'foundation' in the development of a whole subject of study termed "social production at the material level". Our concern in this paper is to erect this subject of study on the foundation of LP. In other words, our concern here is at studying the evolution of Social Technology from the viewpoint of LP. As conceived above the subject of study is a vast area in which we may not be able to focus on more than a few issues. Let us carve out these issues and set clear limits for our study.

We begin with the endpoint. Industrial Revolution (IR) is a definite endpoint for our study. IR as viewed from the angle of LP is the substitution of operation, i.e. the unity of operative mechanism and motive-force, rooted in the human body unit, with the unity of objective mechanism and forces of nature. The culmination of this substitution may be seen in the emergence of the unity of Machine Process (MP) and Steam Engine (SE). It is this unity which defines the endpoint of our study in this paper.

Having marked the endpoint the issues may properly be carved out. As is clear our first task would be the viewing of IR from the angle of LP. Once that is done we can go into the tracing of the emergence of the unity of MP and SE. This immediately raises the question of the starting point itself. As to the starting point, it obviously has to be the dawn of human evolution. Thus, in a sense, our study here is a continuation of what we have opened up in the last section of the earlier paper. There in attempting to 'root' the unities of LP in the physiological body unit we had, in fact, gone into primate evolution. This clearly is the starting point of our study in this part.

As delienated above the issues are bounded by IR. on the one end and human evolution on the other. The study needs to begin with a view of IR where the emergence of the unit of MP and SE in all its essential aspects is touched upon. This opens out the issues which are gone into in the subsequent discussion. The first component of the unity, viz. MP, is taken up in some detail starting from the 'primitive'tools of operation. In this discussion, already, issues regarding emergence of forces of nature as motive force are touched upon which are taken up on their own in tracing the emergence of SE. As is obvious, control more specifically, evolution of tools of control is totally left out. In terms of the constituents of LP this means our focus is on the evolution of 'tools' of operation and locomotion till the IR.

Having carved out the issues in the broad area of study let us touch upon our approach. Already in the earlier paper the tool - technique-LP identity has been gone into in some detail. There it was shown that the study of evolution of techniques is the study of evolution of tools, for the only concrete 'base' of techniques are the tools. Thus our study of evolution of techniques is the study of evolution of tools or more specifically <u>tools of labour</u>.

In the earlier paper the evolution of human body unit was viewed as the 'making' of the body unit and its 'using' in definite processes. Thus the two processes associated with the tools - a process 'behind', i.e. making and a process 'beyond', i.e. using - together map out the evolution of tools. In the earlier paper we briefly sketched the evolution of the corporeal body unit whereas now we concern ourselves with the evolution of the extracorporeal limbs.

Further, this approach takes into account the social dimension of techniques. Both the 'making' and 'using' are governed by social tradition and all tools are made and used socially.[2] Even in the case, say, of the simplest iron tools a large number of labourers from the miners who dug the ore to the labourer who gave the final touches to it have participated in its 'making'. Each of these labourers have learnt from their parents, teachers and masters how to perform his part in its 'making'. Same is the case with 'using'. We do not have to discover how to 'use' a screw-driver or a brace. It is taught by our parents, school fellows or the one who sold it to us. Thus what we study here is the evolution of social Technology.

Outline

This paper consists of four parts. In part II an attempt is made at viewing IR from the angle of LP. This opens out two major areas of study: Emergence of MP and Emergence of Forces of Nature which are taken up for discussion in part III and IV respectively. Part V attempts to give a brief sketch of some of the dominant views on IR and exposes the onesidedness of these views in the light of our discussion. Important areas such as changes in the 'content of labour' consequent upon technical change and the material domain opened out for man-nature interaction owing to changes in techniques are touched upon in Part II but are not pursued later on.

Part II: Industrial Revolution

1. Introduction

As is well-known Industrial Revolution (IR) is a historical epoch in the evolution of Western Society. As it is a historical epoch in the evolution of a society it may be viewed from different angles. We may cite the first great writers on IR: Arnold Toynbee, who, it is popularly believed coined the term IR, thought that the essence of IR, "is the substitution of competition for the medieval regulation which had controlled the production and distribution of wealth".[1] Long before Toynbee Marx who had taken up a systematic description of what he called 'die industrielle Revolution' sought its essence in the "machinery revolution". One of the distinguished historians of the early twentieth century sought the characteristic feature of IR in the factory system. Thus it is clear that various writers had viewed it from various angles and sought its essence in various aspects. But what needs to be noted is the fact that none missed to accord a pride of place to the changes taking place in the system of production in that epoch. This has variously been called the emergence of the factory system, modern industry and large-scale industry. As mentioned at the very outset our concern is the study of social technology and as such we confine ourselves to the developments in the technical sphere of IR or the modern industry. We do not propose to go in any detail into the socio-economic development of the epoch. But as and when necessary we draw from within the socio-economic fabric specific developments pertaining to social institutions, relations....etc., the focus all along being on the study of evolution of techniques.

2. Emergence of the Unity of Machine-Process and Forces of Nature

As mentioned above our focus is on the technical aspect of IR and our viewpoint is that of LP. Now the technical aspect of IR viewed from the angle of LP is simply the emergence of the unity of machine process (MP) and forces of nature substituting the unity of operative-machanism and motive-force rooted in the human body unit. In as much as this unity has two components its emergence needs to be traced as the emergence of MP on the one hand and the substitution of the motive-force rooted in the human muscles by forces of nature. Now the emergence of forcesof nature substituting human muscles needs to be viewed in its totality. We have seen earlier that force on its own is at the very base of locomotion whereas in the context of operation it is viewed with reference to a system, viz. operative-mechanism. Thus any study of the emergence of forces of nature substituting human muscles needs to go into both these areas. Thus one is led to the discussion of the emergence of MP on the one hand and the emergence of forces of nature in operation and locomotion on the other. Let us begin by illustrating the emergence of the objective unity mentioned above.

It goes to the credit of William Lee who invented the knitting frame in 1598 of marking the beginning of the new era. Later on Hargreaves invented the spinning jenny, Crompton the Mule and Cartwright the loom. These inventions replaced the respective operative mechanisms. However the motive-force was still supplied by the human muscles. The first effort at substituting the unity was made by Thomas Lombe. His silk-throwing machine was moved by the water-wheel. This was an initial beginning. The real beginning are to be seen in the cotton industry. The invention by John Wyatt and Lewis Paul of the spinning machine and their use of donkeys to move the machine marked the initial attempts of factory system in the cotton industry. However the significant development was Arkwright's water-frame which put the unity of MP and water-power on a sound footing. It was in the 1780s that efforts were made at using the steam-engines, which were till then used for pumping water, as the source of motive force for machines. In 1780 James Pickard patented a mechanism which had application of both crank and flywheel. Though it was originally Watt's idea, having been 'Stolen' by a workman, Richard Cartwrihgt, instead of contesting it, Watt came up with substitutes for the crank which he patented in 1781. From 1783 onwards rotative engines began appearing and spreading in different industries. The thrust of the rotative engines may be gauged from the following:

> The total number of engines built during the Boulton and Watt partnership* was roughly 500, of which 38 per cent were pumping and 62 per cent rotative (mostly for the textile industry)....[2]

As is clear what has been illustrated so far is the emergence of forces of nature: animals, Water and steam-power as motive-force for machine-processes. All these forces had by then emerged as sources of power for locomotion in one way or the other. Special mention needs to be made of the importance of steam-engine as a pumping engine. The emergence of the unity of MP and SE marked a

* the partnership lasted for about 25 years coming to a close in 1800.

turning point not only in the evolution of techniques but also the emergence of a new economic order.

The emergence of the objective-unity, i.e. the 'unity of MP and forces of nature marked the 'placing' of the unity in operation on the plane of nature. The unity rooted in the human body unit now emerges as a process ('rooted') in nature. Consequent upon its 'placing' in nature, i.e. among the 'sum' of objects outside man, it is subject to all the rules which other objects are subject to. So much regarding the 'placing' of the unity. Now let us move on to the 'development' marked by it and its implication to man-nature interactions and man's doings in this interaction.

3. General issues around the emergence of Objective Unity

In as much as the emergence of the objective unity is a replacing of elements rooted in the human body unity by elements of labour. Here let us recall our starting point for the discussion of LP. LP was simply conceived as 'man's doings in man-nature interaction'. The emergence of the objective unity has, obviously, taken away a definite subunity of LP from man's doings thereby altering the content of labour. At the same time as it is a development in tools it marks an improvement in the accuracy of determinate motions and makes for a vast leap on the force front. These improvements have important implications. With every development in tools the 'area' opened out for man's interaction becomes larger. Closely related to this opening out is the emergence of 'materials' needed for the making of tools which are amenable to the more accurate determinate motions and which can withstand the larger magnitude and intensity of force application. These improvements on the determinate motion and force front have further important implications to labour. The exacting requirements thrown up by machines and forces of nature call for discipline and intensity of application on the part of the labour. These, then, are the general issues that need be gone into in the discussion of evolution of social Technology. Let us take up these issues in the specific context of IR.

4. Change in the 'Content' of Labour

We begin with the question of change in the content of man's doings in LP owing to the emergence of the objective unity. Let us recall that LP was conceived as unities at different levels. At one level it was viewed as the conception - execution unity and then at successive levels it was viewed as action-control unity and the unity of operative-mechanism, motive-force and control. With the emergence of the unity of objective-mechanism and forces of nature the elements at the 'base' of the actions are 'placed' outside the body unit and consequently man's role in these actions gets eliminated. With this man's doings in LP get confined to control. Further man has to start and stop these 'objects' which have taken his place, feed the material and take delivery of it. Note here that these actions are defined with reference to these 'objects'. With this, in LP 'objects' occupy a key place man becomes a tendor of these objects.

This changed role of man has an important implication to the question of skill. Skill is rooted in the frame of operative-mechanisms and as such the replacing of operative-mechanism by an objective mechanisms eliminates the very basics of skill of labour. The change in the content of labour and the elimination of skill gets reflected in the initial period of the emergence of factory system. The skilled-craftsmen considered the labour in the factories devoid of skill as mean and degrading. Many of them refused to go to the factories for work. So much regarding the change in the content of labour. Now let us go on to the questions of 'improvements' in tools.

5. Improvements in Determinate-Motions and Magnitude and Intensity of Forces

The emergence of the objective unity is a great step in human development. First of all the emergence of MP by replacing the operative-mechanism rooted in the human body unit made for more accurate determinate motions. Let us illustrate it. The lathes which emerged from the 16th century onwards are clear illustrations of it. The boring machine of John Wilkinson was one of the revolutionary products of the IR-era. With it the accuracy of the bore was vastly improved. It evolved during his work of boring cannon in the production of ordanance:

> The gun was cast solid, and instead of making the boring rod revolve, as had been the previous practice, Wilkinson caused the casting to rotate about a fixed bar along which travelled a sliding cutter. By this method a more uniform bore was obtained than had hitherto been possible. (emph. mine)[3]

Thus the emergence of objective-mechanisms in the place of operative-mechanism rooted in the body unit made for far more accurate determinate motions.

Closely associated with the question of accurate determinate motions owing to the emergence of the objective-mechanisms is the question of forces of nature. It is only with the emergence of objective-mechanisms in the place of operative-mechanisms that the application of outside forces, i.e. forces of nature, as motive-force of operation is made possible. The application of forces of nature vastly increased the magnitude and intensity of forces. For example compare the magnitude of force applied by cattle, horse or water with that of man. According to R.J.Forbes[4] the flour-mills of ancient Rome were driven either by two men or a donkey and the horse when used as a pack-animal could carry four times as much as a man. The early efforts with forces of nature did not make much of a difference to intensity. But the water and windmills and to top it all the steam-engine improved the intensity enormonsly. It is mainly owing to this increased intensity that the lifting of water from the mines at very high rates was made possible. The vast improvement in 'productivity' is also related to this question of intensity.

6. Implications to Man-Nature Interaction

Having touched upon the 'improvement' owing to the emergence of the objective unity, let us go on to touch upon the implications to the external of labour, i.e. nature, in man-nature interactions. The more accurate determinate motions and the vastly improved magnitude and intensity of the forces applied opened a vast material domain for man-nature interaction. The materials which till then could not be worked upon could then on be worked upon with the emergent tools. The working on iron which was made possible by John Wilkinson is a case in point. It is owing to this invention that one of the chief difficulties of Watt in procuring a cylinder sufficiently accurate in bore to prevent the leakage of steam could be solved. Similar was the effect of the increased magnitude and intensity of force that could be applied owing to the development of forces of nature. A case in point is the changes brought about in the iron industry in the later half of 18th century. The power of the water-bellows was vastly increased with the use of the water-wheel and the steam-hammer built by Watt for John Wilkinson "weighed a hundred and twenty pounds and could strike a hundred and fifty blows a minute".[4] They not only made possible the full use of coal in blast furnaces but also speeded up production enormously. The above, i.e. improvements in tools opening out vast material domains for man-nature interaction, may be called the forward linkage. At the same time it is possible to visualise a backward linkage as well.

7. Material Base of Tools

The backward linkage refers to the question of the 'material base'' of the improved tools. With the more accurate motions and vastly increased magnitude and intensity of force such materials are required for the making of these tools which could withstand the increased force and which are amenable to the accurate determinate motions. The increasing replacement of wood by metals, especially iron, in the 18th century and after is a clear illustration of it. This ends our discussion of the development of tools marking IR and its implications to man-nature interaction.

8. Implication of Improvement in Tools to Labour

Now let us go back to the question of labour. Here what one is interested in is in viewing the implication of the vast increase in magnitude and intensity of force to labour. At the first glance itself it is clear that the regularity and continuity which are 'basic' to these objects imposes a certain discipline on the labour. Take for instance the labour of feeding the material and taking delivery of the product. There is a certain rate at which the motion is repeated and the labourer is simply subjected to this rate. He cannot start and stop the 'work' whenever he feels like doing it, he has to follow the rhythm of the machine, so to say.

This completes our discussion of IR. The above discussion has not only opened out a certain theme as to the developments in tools but also opened out two related fields: the change in the content of labour consequent upon the developments in the tools and the 'area' for interaction opened out consequent upon the developments. From now on our focus shall mainly be on the evolution of techniques, i.e. the developments in the tools wherein we shall touch upon the consequences of these developments to the content of labour on the 'area' of interaction in the passing.

Part III: Emergence of Machine-Process

1. Introduction

As introduced earlier the task before us is to trace the emergence of the unity of Machine-Process and Steam-Engine. In terms of the concepts introduced so far these developments that constitute the emergence of the unity can broadly be set under two heads. Under the first head falls the emergence of forces of nature as motive-force culminating in the emergence of steam-engine. Under the second head falls the emergence of Machine-Process. Obviously the discussion of the second proceeds taking the source of motive-force as man. To put it differently the two broad areas correspond to the tracing of developments in the 'tools' of operation and 'tools' of locomotion taking man as the source of motive-force and to the tracing of the emergence of forces of nature as sources of motive-force.

We propose to begin with the task of tracing the emergence of MP in this part. It is clear that in this task the "area" we need to cover is that lying "behind" the MP. To get a grasp of this area we begin with MP and then go 'backwards'. First of all, MP is defined with reference to operations in LP as the operation where the operative-mechanism which is rooted in the human body unit is replaced by an objective mechanism. Thus the area lying behind MP corresponds to the evolution of tools of operation culminating in the objective-mechanism substituting operative-mechanism.

As developed in the structure of Labour-Process operations is viewed as a unity of operative-mechanism and motive-force where the unity is rooted in the human body unit. In the context of such a unity the emergence of objective-mechanism in the place of operative-mechanism is essentially the <u>separation</u> of operative-mechanism from the unity that is 'rooted' in the body unit. Thus the emergence of MP is the separation of the operative-mechanism from the unity retaining the source of motive-force as the body unit of man. This question of separation is raised owing to the fact that operation is a unity of operative-mechanism and motive-force. In the case of locomotion since it is conceived as an interaction of forces the basic element is force and the question of separation does not arise. Instead here the changes is in the direction of facilitating the small human force to deal with larger forces of nature. The evolution of tools of locomotion, thus, is in facilitating forces of man.

In the light of the discussion on IR, it is clear that the evolution of tools of operation make for the emergence of forces of nature on source of motive-force, i.e. every move merit towards separation opens a vast area for the elimination of forces of man whereas the evolution of tools of locomotion simply facilitate the application of forces of man. Our discussion in the following sections is an attempt at developing these two themes in some detail.

Our starting point for the discussion is the dawn of human evolution. Our concern, thus, is the extra corporeal not so much the corporeal body unit. The starting point is the 'object' picked by man and used in carrying out actions. This is the primitive tool or an 'extended limb'.

2. Evolution of Tools of Locomotion

As elaborated above operation, i.e. determinate motion is conceived in the broad area of interaction of forces by introducing the notion of a system. Thus it is necessary for us to begin our discussion of the emergence of Machine-Process by viewing the broad area of interaction of forces.

As already mentioned what is basic to locomotion is interaction of forces and what it determines is either the introduction of locational changes or prevention of such changes. The human role in locomotion is the opposing of natural forces by human muscular forces and 'tools' of locomotion are a medium for transmitting these forces. The central problem in locomotion is that of dealing with the forces of nature of different magnitudes and intensity by the limited human force. This sets the direction of evolution of the tools of locomotion. In tracing this evolution let us begin with the primitive acts of locomotion.

The primitive acts of locomotion are carrying and pulling. Let us briefly go over some of the basic principles underlying these actions. Carrying necessarily requires equilibrium of the man-load combine. With any increase in the magnitude of the load definite problems are posed in keeping the man load combine in equilibrium. This puts a clear limit on the magnitude on the load that can be carried. In pulling the man-load combine is separated and the question of equilibrium can be considered separately. This immediately raises the load that can be pulled. But there are clear limits for this too owing to the smallness of the force that man can apply.

The evolution of tools of locomotion are basically an attempt at dealing with loads of increasing magnitudes with the limited human force. The first and foremost tool that man comes up with is the lever. The primitive lever is a pair consisting of a rod and a support. The rod of the primitive man is an object picked at the flux of the action and the support is the ground below. Now the object itself gets modified in the course of the action and gets a proper geometric form. The working of the lever is governed by the displacement principle: a small force by moving a large distance displaces a large force by a small distance. Here the small force is that of the human muscles and the large one is the load. In due course other mechanisms working under the same principle come to play definite roles in moving loads of increasing magnitudes. Wheel, pulley, screw and the wedge are instances. With these mechanical instruments dead weights (gravity) comes to substitute human forces in moving or at least preventing the motion of bodies. [A lively discussion of these instruments may be found in Galileo. An attempt is made at summarising it in the appendix]. But note that all these instruments have human force at the very base and the essence of these mechanisms in locomotion is only in facilitating the moving of large loads by the limited human forces.

The concept of 'work', so to say, emerges as a consequence of the understanding of the displacement principle. With the understanding of the principle of lever and the role of human forces in displacing large loads there comes to be an objective basis for the measurement of workdone in locomotion. Here the workdone by human force is in moving loads, which is obtained by the product of the load and its displacement. It is obvious that the same formula cannot meaningfully applied in obtaining the 'workdone' in the case of operation.

Before going any further, let us clarify the notion of mechanisms or mechanical instruments as they are called. The first thing that we observe in all these instruments. i.e. lever frulley, wheel...et is that they are all, so to say, systems having more than one element. Lever consists of the rod and the support, wheel consists of the wheel and axle....etc. Thus they are systems of material bodies having definite geometrical axes. The motion in these systems is of certain elements about these axes. The lever moves about the perpendicular drawn at the support, the wheel about the axis running through its centre and so on. Thus what we have called mechanical instruments are systems of material bodies with definite geometric axes and motions about those axes. The purpose they serve in locomotion is in facilitating the application of human forces.

Here it may be pertinent to point out the historical dimensions attached to this group of instruments. It is with reference to this group that Hero of Alexandria said:

> the simple mechanics by which one may move a given weight by a given force are five in number.

More or less the same group reappears in Galileo. All along the notion of machinery was inextricably tied up with these <u>objects</u> since the time of Hero. Those <u>objects</u> were thought to be the primary basis of all machinery. As may be clear our own effort is at viewing these objects not as mere objects but as <u>objects</u> in process. It is essential such a view which allows us to call <u>mechanisms in operation as maching</u>

process to distinguish them from all others.

Having discussed the evolution of tools of locomotion and having clarified the notion of machine-process further the stage is set for the tracing of the emergence of machine-process.

3. The Emergence of Machine-Process

i. The Initial Separation: As introduced above the evolution of tools of operation needs to be studied as the separation of tools of operation from the tools of locomotion. The starting point for the study is the dawn of human evolution and the primitive tool is the object picked by man at the flux of the action. The initial steps of separation may be seen in the separation of the working edge from the gripping edge in the general purpose tools. Note that no such separation can be observed in the tools of locomotion such as lever pulley, wheel....etc. The class of general purpose tools are called the same because there is nothing in the shape of their working edge to express the motion they enter into in the actions. They are still at a general level and they are, predominantly, tools of force application. The distinction in motion is basically owing to the motion of the bodily limbs. Observe the primitive general purpose tools. The definiteness of the hitting, grinding, hammering and so on are not reflected in the 'tool' as such, but only in the motion of the hand. These, in a sense, characterise the boundary of locomotion and operation.

The separation of the working-edge from the gripping edge already gives us three pairs: limb-tool pair in the 'grip'; tool-workpiece pair in the 'work'; and the workpiece-limb pair in the 'hold'. Within the 'grip' and the 'hold' there do not exist any relative motion which in fact make for the required motion in the tool-workpiece pair.

The constrainment of motion in the 'grip' and 'hold' are achieved by muscular forces.

As already mentioned the general purpose tools do not 'concretise' the determinate motion. This concretisation comes about only with the movement from the general purpose tools to specific tools, i.e. the emergence of specific geometric forms at the working end. With this o can talk about determinate motions - the separation of determinate motions from locomotions has begun. It needs to be noted that this movement is not a once for all movement, this is a process of differentiation and refinement.'

With these differentiations and refinement at the working-edge there necessarily goes a different process at the other end. Since operation is a unity of operative-mechanisms and motive-force the initial separation of operative-mechanism with the differentiation of working-edge make way for changes in the force application. This may be seen in the separation of the force-applying piece from the working piece in the tool. Take the case of the hammer and chisel or the rope and the drill. A parallel development is the composite tool where the working-tool is a different piece from the gripping piece and these two are combined together to make the composite-tool.

So far we have touched upon the general purpose tools, specialised tools and composite tools. And through them we have traced the separation of operations in the broader area of locomotions. But all along the unity of operative-mechanism and motive-force as such is 'rooted' in the human body unit. Now we shall attempt tracing the emergence of the operative-mechanism outside the body-unity which in other words is the emergence of machine-process. As is clear this marks the breaking up of the unity rooted in the human body unit.

ii. Emergence within the operation: The emergence of MP can be viewed from two directions: 1. from within the operation; 2. as a movement from outside the operation, i.e. as a movement of the objective-mechanisms from the area of locomotion. We begin with the first. Let us take an example. Consider the fire-drill. It consists of a wooden platform with a hole and a pointed rod. The human hands hold the drill vertically and give partial rotary motion to the drill. The hands by pressing the drill down and by holding it properly eliminate all upward and horizontal disturbing motions. The same hands which constrain motion also introduce motion in the system. In that sense both of these are rooted in the same human body unit.

Now consider the case where one man eliminates the disturbing motions by holding the drill from the top and pressing it down. Another man introduces motion in the pair by means of a rope. The two aspects 'constrainment' and 'introduction' of motion' are clearly separated. It is essentially such a separation which sets the stage for the emergence of MP. All that needs to be done is to arrange material bodies so as to replace the first person who presses the drill down. This is done by erecting a frame which connects the platform with the drill leaving a circular hole so that the drill is placed vertically. This is the objective-mechanism which replaces the first person. Note that the motive-force is still supplied by the other man.

In the case of the fire-drill the separation is clear cut mainly because the motion in the pair: drill-plank is rotary whereas the human limbs, because of the structure of radius and ulna can at best give semi-rotary motion /Details may be found in Gordon Childe[1]/. Owing to this, from early times attempts were made at converting the to-and-fro motion generated by the hand into rotary motion in the drill. The transmitting objects such as the rope and the bow with a string are all concrete expressions of this effort.

iii. Movement from Outside: To clarify the second, let us consider the grinding wheel. The wheel with its abrasive edge or surface is mounted on supports. The workpiece to be ground is held in the hand and is brought into contact with the abrasive surface. Here the wheel mounted on supports is the common wheel talked about in locomotion. The only additions are the abrasive edge as the 'tool' of operation and the hand holding the workpiece. The latter is eliminate once a 'holder' is fixed on to the frame of the wheel. Thus, here the wheel-on-supports is the objective mechanism which has moved from the sphere of locomotion to the sphere of operation, with the tool of operation and the workpiece fitted on to it substituting the operative-mechanism. This marks the emergence of machine-process.

MP, thus, is defined by the advent of objective-mechanisms, in the operations. The objective-mechanism simply substitutes the operative-mechanism of L.P. In other words the determinate motion within the tool-workpiece pair is now obtained by an objective-mechanism and not by the operative-mechanism of LP rooted in the human body unit. But the role of 'motive-force' and 'tools' do not change. Not only the motive-force but also the tools of operation stand in the same relation to both. Given the operation, LP gets expressed through its operative-mechanism and its tools utilising the necessary force both from human body unit and nature. In exactly the same fashion a machine-process gets expressed through the objective-mechanism with its tools, utilising force from various sources. Within the domain of operations, the substitution of LP by MP is thus logically complete.

Note that both the routes of the advent of objective-mechanism have their prior bases in human actions. Consequently, we may say that these 'tools' have evolved in human actions. In one case it evolves in the operation whereas in another it evolves in locomotion and then moves on to the operation. Hence what lies 'behind' these tools is the human actions and the knowledge coincident with them or practical knowledge. Since or outside knowledge does not play any role in their evolution.

4. <u>Change in the Content of Labour</u>: Now let us move on to the content of labour after the evolution of MP. Though in terms of the aspects, i.e. motive-force and operative-mechanism, the relationship remains the same, machine process brings about a change in the content of labour. It breaks the essential unity of labour in operation thereby setting the stage for the utilisation of forces of nature in the place of forces of man.

Let us consider an example say the type-writer, to bring out some of these aspects. Firstly, the combination of motions in writing an alphabet is eliminated by the 'type' where the operation boils down simply to stamping, say with a rubber stamp. In the next stage, there is an explicit objective-mechanism, viz. the typewriter, which holds the type and the paper. Here labour provides only the motive-force.

Here it may be pertinent to take up a point about 'holding' the tool and the workpiece. The fixity of the workpiece or the tool is not a logical requirement for determinate motion within the pair. Take the case of the type-writer. In the modern type-writers the paper is fixed on the rollers and the type strikes at the paper. When the type-writer first made its appearance, the type used to be fixed and a hammer used to strike the paper on to the type. It is clear from the above example that distinctions such as what labour is working on and what labour is working with in the sense of 'fixed' and 'moving' positions, do not take us very far in distinguishing one as the material and the other as the tool...

5. Objective-Mechanism in Process

We conclude this section by constrasting the role of objective-mechanisms in locomotion and in operation. Since locomotion has only force as its structural element the role of objective-mechanisms in locomotion, as mentioned above, is basically as a transmitter of force facilitating the application of force. The determinate motion in the mechanisms as such is not the essence of loconotion, it only facilitat man in dealing with loads of increasing magnitudes with the limited human muscular force. In operation these objective-mechanisms play a different role, they substitute human operative-mechanisms and thus come to occupy the very base of determinate-motions. The essence of t objective-mechanisms is constrainment of motion and the same is the essential element in operation. Thus objective-mechanism comes to its own in operation. Whereas it is only a medium for the transmission of forces in locomotion. To put it differently, in operation constrainme of motion is the 'end' whereas in locomotion it is only a 'means' for the action of forces. The machine process as we have conceived, refers only to operations with an objective-mechanism. Becuase the operation must necessarily have prior basis in LP the objective-mechanism necessarily substitutes the operative-mechanism of LP. In the context of locomotion, on the other hand, the idea is essentially of using a medium to facilitate the application of force. One is essentially the notion of substitution whereas the other is a notion of improvement. With this, notions like the objective-mechanism in locomotion as 'simple machine' cannot have a logical basis in our discussions. It puts the whole idea of machine squarely within the area of operation.

6. <u>Overview of Ideas on Machinery</u>: This section tries to provide an overview of the dominant ideas on machinery of scientists and historians. Already in an earlier section we have touched upon the views of philosophers and scientists on "simple machines". It has been pointed out that our conception of machine-process 'places' the machine in the area of operation. Here the two key ideas seem to be

(i) the tool-machinery distinction.

(ii) the structure of machineries.

In traditional writings, the treatment of tool and machinery is full of statements like: 'tool is a simple machine' and 'machine is a complex tool' which clarify neither the nature of tool nor the nature of machine. By adopting an explicit process view of production from the very beginning we avoid all problems of a prioristic object classification which seem to lie at the root of those kinds of confusions.

In the discussion of structures, similarly there is a deep rooted confusion of the different aspects of the mechanism with the mechanism itself. This, as seen above, gets expressed in the indiscriminate use of the term 'machinery' whether in the context of 'operation' or 'determinate-motion' and 'locomotion'. It is only in the context of operations that the full logical sense of labour-machine substitution is obtained, and our concepts pay full heed to this idea.

With this general view of the traditional writings on machinery let us take up Marx. Marx was critical of the kind of tool-machinery distinction quoted above. Logically, his basic concept appears to be 'machinofacture' which plays the same role as our machine-process. This is only implicitly defined by Marx when he says,

> Thus the working machine is a mechanism which through the instrumentality of the tools attached to it carries out the very same operations which the manual worker of the former days carried out with the tools of a like kind (p.394, Capital).

The "working-machine" of Marx is comparable to our objective-mechanism in operation. But it needs to be noted that in Marx this "working-machine" is only a component of the "fully developed machinery" as he conceived it. Unfortunately, this conception appears to be subject to the same kind of confusions we have talked about:

> All fully developed machinery consists of three essentially distinct parts, the motor machine, the transmitting mechanism, and the mechanised tool or the working machine. (p.393).

Taking the motor machine as the source of motive-force and the working-machine as our objective-mechanism Marx's fully developed machinery covers the whole of operation as opposed to an element of it. Also, given the operative-mechanism and the motive-force as two elements of operation it does not appear possible to segregate transmitting mechanism as an independent element, distinct from the working-machine. Depending upon the specific source of power and the nature of operations one may be able to locate some mechanism as a transmitting mechanism in particular cases, not in general.

Further, Marx does not make any distinction between operation and locomotion (p.396). This vitiates his account of the working-machine. This has its roots basically in the weak structure of LP in Marx. Hence the frame, as it is in Marx, appears rather inadequate for understanding the nature of problems he takes up in the evolution of technology.

In sum, we have attempted at viewing two key issues, viz. the evolution of tools of locomotion and evolution of tools of operation, in the broader area of Social Technology from the angle of LP. This has facilitated our throwing somelight on the notion of Machine-Process thereby placing it in some logical order. Obviously, no historical explanations are attempted.

Part IV: Emergence of Forces of Nature as Motive-Force
OR
The Role of Science in the Evolution of Social Technology

1. Introduction

The subject matter for discussion in this part is the emergence of forces of nature as motive-force in general and the emergence of Steam-Engine as a prime-mover in particular. As in the study of the emergence of MP, so in the study of emergence of forces of nature the concrete 'objects' at our disposal are the tools. It is only through these tools that we can trace the emergence of forces of nature. In the case of MP, though we did touch upon the processes 'behind' tools, i.e. the 'making' of tools, our discussion was mostly confined to the processes 'beyond' tools, i.e. the 'using' of tools. Here in our discussion of the emergence of forces of nature we essentially deal with the processes 'behind' tools, in other words, the tool is viewed as a product and the elements that go into its 'making' are gone into.

Our starting point here is a class of products and our concern is with the processes 'behind' them. What lies 'behind' the product is the material transformation corresponding to a definite LP and LP itself is an expression of a component of social tradition, viz. technique, which was viewed as a unity of knowledge and action. Thus the tracing of the emergence of forces of nature as motive-force boils down to the tracing of these products which in turn is the tracing of the evolution of knowledge and action in LP. Action is nothing but tool 'using' and the study which has been taken up in detail in the discussion of the emergence of MP corresponds essentially to the evolution of action. What is left out is knowledge as a component of technique lying 'behind' the tool. Our discussion, here, then, is to a large extent an attempt at tracing the evolution of knowledge of forces of nature as expressed in the tools.

In the discussion of the Structure of Labour Process a distinction was introduced between practical and scientific knowledge. Knowledge is after all that of material transmation or'change' in nature and as developed in the earlier discussion those changes or transformations. May be classified into two types depending upon the role of man's doings in the transformations. In the case of the transformation which are determined (determining role of human actions) by human actions the knowledge of the transformation is that coincident with the actions. This knowledge may be called practical knowledge. 'I do it so I know it type'. In the case of all other transformations the knowledge is basically that of nature irrespective of or independent of actions. Such knowledge may be called scientific. Thus our concern of tracing the emergence of forces of nature turns out to be a study tracing the role of science or scientific knowledge in the evolution of products which come to occupy a definite place in LP as tools, to be exact 'tools' of force supply.

2. Scientific knowledge in the Emergence of Forces of Nature

The starting point for the study of evolution of tools has already been defined in our discussion of tools in the structure of Labour process. There we began with tools not only as organs of labour but also as products of labour. In fact, the human body unit itself was viewed as a product of labour. Further on, in the discussion of

MP it was mentioned that the evolution of 'extended limbs' have only human activity 'behind' them, i.e. tools evolved in the action. The emergence of MP shows very clearly that the evolution touched upon there has a prior basis in human actions, viz. operations and locomotions. Once such a view is taken the so-called science-technique relation boils down to the evolution of tools outside the activity in LP. As already mentioned what lies behind the tool, which is a product, is the activity in LP and the knowledge, and to say that the product has evolved outside the action in LP is to say that the knowledge lying behind it is not practical knowledge but scientific knowledge. To be more exact the activity-tool circle, i.e. evolution of the tool in the activity and evolution of the activity as evolution of the tool, discussed earlier is cut. With this the prior basis of the tool is no more the human bodily limbs in action but knowledge of nature and our focus needs to be directed to this area. So much for the logical account.

Now, let us begin with scientific knowledge. As elaborated in the structure of Labour Process the 'sum' of objects outside man, i.e. nature forms the material conditions of life. Since these 'objec are essential for the sustenance of life, man needs to view nature through these material conditions of life. Thus from the dawn of human evolution man begins to observe and speculate on the nature of objects outside him such as Sun, Moon, Stars, air and water in different processes. In a sense, these mark the beginnings of scientific knowledge. In the course of such speculations man comes to identify definite forces of nature. The flowing waters, the blowing winds and the moving animals are some of the forces identified.

These were the first forces of nature to emerge as motive-forces in locomotion. To move man and objects needed by him water and wind were used from the very early times by a variety of crafts and sails. Animals which in the beginning were killed for the meat were kept alive and used as carriers of burdens. These mark the beginnings of the emergence of forces of nature as motive-forces.

The forces of nature mentioned above, viz. animals, flowing waters and blowing winds have a long history as motive forces starting with the primitive beginnings in locomotions. The first appearance of forces of animal and water as motive force in operation are to be seen in the grinding of corn. Let us briefly go over the emergence of these forces of nature.

3. Forces of Animal

We begin with animals. It is not necessary here to go into the questions of domestication. All that is necessary for our purpose is to go into the tools which evolved in order to exploit the forces of animals. These tools can broadly be placed under three heads: (i) 'tools' which transmit the power from the animals: tools such as yokes and collars belong here; (ii) 'tools' of control: tools such as nose rings and bits belong here; (iii) 'tools' of protection of the animal: tools such as sandals and shoes belong here. The earliest animals exploited for power were the oxen. In their case yoke and the nose strings were adequate. But the exploitation of horse raised innumerable problems. Firstly, the yoke could not be used. It is the inadequacy of the yoke which necessitated the movement along breast-strap to the padded collar. Similarly the inadequacy of the nose ring necessitated the movement along bits of various types. Further the horse raised another problem. In wet areas it hooves decayed quite fast and they needed proper protection from th environment. It is in this context that sandals and shoes became necessary. These developments led to the use of horse as a better source of motive-force as compared to all other animals.

4. Forces of Wind and Water

As to the forces of wind after the initial beginning in sails one sees it emerging as a definite source of motive-force only in the windmills in the late 12th century in Northern Europe. Though efforts have been made at tracing this development through the Tibetan revolving prayer cylinders and Chinese book-cases not much success has been achieved. But it needs to be noted that during the Industrial Revolution wind was one of the important sources of power in West Europe.

The emergence of tools for exploiting the forces of water seems to be more widespread. The first appearance of the tool is in the form of the horizontal Norse wheel composed of scoops moved by a running stream. These were very slow and did not generate much power. The later vertical wheels owe their name to a Roman Engineer. These wheels are of three types: the undershot wheel, the breast wheel and the ouvershot wheel. Till about the tenth century their main use was in grinding corn. It is after that date that they were increasingly used to supply motive-force for the different Machine-Processes. In fact, from then on till late 18th and early 19th century the water mills of different types spread all over Europe. In fact during the IR when the steam engine emerged as a source of motive-force it had to face competition from wind and water-mills.

5. <u>'Link' Mechanisms</u>

The emergence of these forces of nature as motive-forces in operation called forth developments in two related areas. Firstly, the type of motion in which these forces get expressed may not be the same as the type of determinate motion in the operation. This called for the development of 'tools' of conversion. This is an area to which attention was drawn earlier in the context of fire-drill in the discussion of Machine-Process. In the case of the drill there emerged the strings and the bow....etc; in the case of these later forces of nature cranks, bit and brace, compound cranks....etc emerged in medieval Europe.

Secondly, it was necessary to ensure the continuity and regularity of the supply of force. This was achieved through flywheels and such other mechanical governors. So much regarding animals, wind and water as sources of motive-force. Now let us go on to trace the emergence of steam-engine.

6. <u>Emergence of Steam-Engine</u>

The beginnings of Steam-Engine can be traced back to the streams of thought around two material domains: expansive powers of water and vapour owing to fire, and the atmospheric pressure. The basic 'objects' for this starting point were air, water and fire. Many events were observed around them by primitive man and many relations were imagined. The corporeality of air and the motion of air and water were perceived.

Man became aware of facts such as, (a) that if an inverted vessel or tube is to be kept immersed in water much force need be applied; (b) that if it is vacuous water flows upwards. Similarly he came to know a good deal about the relation of water with fire. The violent motion of water and the sound produced when water is boiled were well-known.

These percepts and ideas seem to be at the base of many products. The suction-pump seems to have existed in ancient Egypt the two notions basic to it are that of vaccum and atmospheric pressu. Later, in the Greek era, Hero of Alexandria invented the Aeolopile, automatic door-openers, dancing statues....etc making use of some of these properties. In all these, the materials and mechanisms consist of water and air in their relation to fire. Either steam-pressure is directly utilised or vacuum is created and atmospheric pressure is utilised.

About 2000 years after Hero's experiments with steam-pressure in medieval Europe it comes up for serious consideration again. Salomon De Cans Seems to be the first to hit upon the idea of applying steam-pressure for pumping water. Edward, second Marquis of Worcester toiled with the same idea. Denis Papin under the Royal Society took up a more systematic study of steam and came up with the "Digester". In his paper on "A New Method of Obtaining very great moving powers at small cost" he observed:

> I felt confident that machines might be constructed wherein water, by means of no very intense heat and at small cost might produce that perfect vacuum which had failed to be obtained by means of gunpowder.

But the question, how was the idea to be realised in a practicable working machine was not solved till Savery came up with his pump. Savery's pump consisted of a cylinder which was alternatively filled with steam from an adjoining boiler and with the cold water from the well. The cylinder had two valves, one opening into the tank, and the other opening out. When the cylinder was filled with steam from the boiler and suddenly cooled by cold water, a vacuum was created. The valve opens in and water gushes into the cylinder by atmospheric pressure. When the cylinder was nearly full steam was let into the cylinder; the valve opens out because of steam-pressure and water was forced to move up through the pipe. In Savery's pump steam was used to create a vacuum in the cylinder as also steam-pressure was used to force the water up from the cylinder.

Next in line was Newcomen's separation of the engine from the pump by introducing pistons. A piston was fitted into the suction and force pump. Another piston was fitted into the cylinder. The two were connected by a beam with a counter weight on the piston rod of the pump. Steam was forced into the cylinder from below, the cylinder was cooled and vacuum was created. The piston was forced down by atmospheric pressure. The upward motion was due to the counter weight at the end of the beam. Newcomen's engine worked entirely by the pressure of atmosphere; steam being used only as the most efficient method of producing vacuum.

James Watt combined the ideas of Savery and Newcomen. By using the piston he separated the engine from the pump. Also he was very particular about the separate boiler at a sufficient distance from the vessel and piston, so that the boiler could be kept hot through out. Secondly, he eliminated the role of atmospheric pressure in the engine. Both the upward and the downward motion of the piston was facilitated by steam-pressure. Thirdly, by introducing the sun and planet wheels the to-and-fro motion of the piston was converted into rotary motion. The third in particular converted the steam-engine into a general purpose prime-mover.

We may contrast the emergence of the Steam-Engine with that of the emergence of Machine-Process. Emergence of MP was viewed as a certain culmination of the tools-in-action whereas the evolution of the Steam-Engine is viewed basically outside the action domain. Emergence of steam engine is the story of the knowledge and use of atmospheric pressure and steam pressure in very many ways. The matter for contemplation for the inventors were notions such as atmospheric pressure and the numerous properties of steam pressure which are clearly knowledge of the 'outside' and not of the material objects in action. This is the basic distinction between the evolution of Machine-Process and Steam-Engine.

The above account of the emergence of forces of nature is only a partial account as it confines itself to the evolution of notions regarding 'events' in nature and the conception of products which can be used in definite LPs as tools. The actual or concrete emergence of the products, i.e. the realisation of the idea in a practicable object is very much conditioned by the 'tools' existing as of that time a connected account of the evolution of which was not gone into here. The above account was basically concerned with the role of science in the conception of products. As the realisation, i.e. the movement from ideas to products, is conditioned by the state of the 'tools' in action, so also the movement from products to their use as tools is conditioned by the socio-economic background. This again is left open.

With this the discussion of evolution of techniques to the IR is complete. Both the processes, viz. the process 'beyond' and the process 'behind' the tools, are gone into. The so-called science-technique relation has sufficiently been clarified.

Part V: Views on Industrial Revolution

What has been attempted in the last four parts of this paper is a certain view of the evolution of Social Technology to the IR from the angle of LP as developed in The Structure of Labour-Process. Having completed that task in this part we attempt a brief review of some of the views of two dominant schools of thought on IR. There is no claim to a comprehensive coverage of each of these schools.

1. Science-based Technology View

One of the schools of thought sees the steam-engine as the very essence of"IR and its concommitant Modern Industry". In a nutshell, the running theme is that the steam-engine is the "very central case" of a general science based technology. The lines along which the science-technology link is established is given below.

The revival of science in the fifteenth and sixteenth centuries was established on a firm basis by the works of Galileo and Fleming Stevinus. Theoretical knowledge was further advanced by the contributions of Newton, Hooke, Boyle, Guericke Black, Denis Pin, Savery and many others. It is their work which made available knowledge of the physical world and deeper secrets of nature. These discoveries pointed out many new sources of power and possible ways of exploiting these sources. Thus by about late seventeenth century rudimentary knowledge of heat and pressure were made available which are at the very base of steam-engine. The noteworthy names in this specific context are those of Denis Papin and Savery.

The discovery of new sources of power and the principles around it were only the starting points. It took almost one hundred years to come up with a workable steam-engine. Technical difficulties came in the way. It is here that the other aspect of science comes to the fore. The progress of science depended on accurate observations. The awareness that unaided human senses are inadequate to explore the deeper secrets of nature led to the invention of many scientific instruments. The fusion of scarce technical skills necessitated for the making of these instruments removed many technical hindrances that stood in the way of the emergence of steam-engine. The important name to be mentioned in this specific context is that of James Watt, 'Mathematical Instrument Maker' to Glasgow University. Also, the emergence of new power sources brought with them increased level of accuracy paving the way for advances in science and technology.

The gist of the argument is brought out very sharply in Hicks:

> The impact of science, stimulating the technicians, developing new sources of power, using power to create more than human accuracy, reducing the cost of machines until they were available for a multitude of purposes; this surely is the essential novelty, the essential revolution,.....(p.148, Economic History).

It is clear that the above view identifies the IR with the emergence of the new source of power, viz. steam-engine. This view of IR revolves around the developments in the forces of nature ignoring the emergence of machine process altogether. This has at its base a certain view of production and man's doings current in West Europe from the 16th - 17th centuries. Eventhough these days one does not find such systematic discussions on production and man's doings the roots can clearly be traced (see appendix 2). In a nutshell the total view boils down to the following: Nature supplies the matter, i.e. objects; man merely moulds them. In this moulding what he can do is to move things towards one another or away from one another. Rest is all done by nature. In moving things man applies muscular strength; consequently evolution of techniques is the discovering of sources of power in nature and using them as a substitute for muscular strength. As is clear from our own discussion of Labour Process, this is a partial view of man's doings. Consequently the view of evolution of techniques is also partial.

2. The Machinery-Revolution View

Now let us take up the other dominant school of thought. At the centre of the other school of thought is Marx. He traces the emergence of steam-engine as a derivative of the machinery system and not as the basis. His interpretation of the case rests on a larger view of production as man-nature interaction and technology as man's mode of dealing with nature. This view enables him to capture the essence of IR in machino-factory. The essence of this revolution is the displacement of division of labour by machinery as the primary basis of technical changes and hence the focus of innovations. This comes out sharply in:

> In manufacture, the revolution in the mode of production begins with labour-power in large-scale industry it begins with the instruments of labour (p.391, Capital I Everyman).

In manu-factory the revolution is in the detailed division of labour and its skill-efflorescence. In machino-factory the revolution is in the emergence of machinery as a system engulfing larger and larger domain of the activities of labour. This transition is made possible by the availability of skilled mechanical workmen in the manufacturing period. The immediate foundation of machino-factory, thus, is manu-factory:

> But the discoveries and inventions of Vaucanson, Arkwright, Watt, and others, were only possible because these inventors found ready to hand a number of skilled mechanics who were placed at their disposal, thanks to the manufacturing period (p.404, Everyman).

Thus manufactory produced machinery. With machinery organised as a system the instruments of labour strikes down the labourer. The unsteady hand of the labourer comes to be replaced by a piece of iron. The human force fails to comply with the standards of machinery system. This makes it imperative for the forces of nature to takeover. The invention of steam-engine requires to be viewed in this context:

> The steam-engine itself,...... did not in those days give rise to any industrial revolution. It was the creation of mechanised tools which made a revolution in the form of steam-engine necessary (p.396, Everyman).

Thus Marx traces the essence of IR in the advent of machine-factory. Steam-engine emerges as a general prime-mover to exploit the possibilities of large-scale opened up by the primary fact that is the machinery system, it is only a derivative not the basis.

As is clear the whole emphasis here is on the machine-process and steam-engine or other forces of nature are seen (merely) as a derivative of the machinery system. As developed in our discussion of MP it is clear that machine-process provides the basis for the 'use' of forces of nature as motive-forces in operation. But that in itself does not explain the processes behind the emergence of these forces of nature in the first instance. And this is what is lacking in Marx's discussion of the subject.

In the light of these two dominant viewpoints let us look at our own approach. The view from the angle of LP has facilitated our identifying certain unities and subunits. Consequently our view of IR is also in terms of these unities, the particular unity being that of operative-mechanism and motive-force. This view, in a sense, accommodates both the above viewpoints of IR and provides a certain 'structure'.

References

Part I

1. D.Narayana, The Structure of Labour Process, CDS Working Paper No.131, 1981.

2. V.Gordon Childe, What is History? Henry Schuman Inc., N.Y., 1953.

Part II

1. p.24. Arnold Toynbee, Lectures on the Industrial Revolution of the eighteenth century in England..... Longmans, London, 1928.

2. p.88, H.W.Dickinson, A Short History of the Steam-Engine, University Press, Cambridge, 1939.

3. p.63, T.S.Ashton, Iron and Steel in the Industrial Revolution, Ed.4, Reprints of Economics Classics, University of Manchester, 1970.

4. p.305, Paul Mantoux, The Industrial Revolution in the Eighteenth Century, (eight impression), Jonathan Cape., London 1947.

Part III

1. V.G.Childe, Rotary Motion in A History of Technology, Vol.I (reprint), (ed) Singer et.al. At the Clarendon Press, Oxford, 1975.

2. Karl Marx, Capital, Vol.I, Everyman.

General References

a. Reuleaux Franz, The Kinematics of Machinery, Dover, N.Y., 1963.

b. Usher A.P., A History of Mechanical Inventions, (rev.ed.), Harvard University Press, Cambridge, Mass., 1954.

Part IV

General References

a. Lynn White, Medieval Technology and Social Change, Oxford.

b. G.Von Tunzelmann, Steam Power and British Industrialisation to 1860, Clarendon Press, Oxford, 1978.

c. V.G.Childe, Wheeled Vehicles in A History of Technology Vol.I (reprint), (ed) Singer et.al, At the Clarendon Press, Oxford, 1975.

d. R.J.Forbes, Power in A History of Technology, Vol.II, (reprint) (ed) Singer et.al, At the Clarendon Press, Oxford, 1972.

Part V

1. J.Hicks, A Theory of Economic History, Oxford,Paperbacks, 1973.

2. Karl Marx, Capital, Vol.I, Everyman.

The Works and Writings of Galileo Galilei from the standpoint of the Study of Social Technology

1. Background

The context of our interest in the works of Galileo is a clear understanding of social technology. Social Technology in its essence is what gets expressed in concrete labour-processes. Now any understanding of social technology is incomplete without some attempt at coming to grips with the machinery question. This is also basic to a clear understanding of such processes related to social technology as training, skill-formation, substitution and elimination of particular aspects of labour-processes. It is essentially from this standpoint that we view Galileo's works and writings. Our exposition of the basic concepts draw their strength and vitality from Galileo's conclusions, direct and indirect, in our own field of interest (social technology). However an appreciation of these conclusions necessitates some familiarity with Galileo's works in the field of other sciences as well. In the following pages we propose to bring into sharp focus his works which are relevant for a clear understanding of social technology on the basis of an overall conceptualisation of his general works.

Let us now give a brief summary of Galileo's contribution. The subject matter of Galileo's contemplations extended from the Sun, Moon, and the planetary bodies on the one hand to light, heat, sound, air, water and solid bodies on the other. He had very definite ideas on all these matters, though his major works were in Astronomy and the science of Mechanics.

Galileo conducted experiments to ascertain the truth about all these matters. When Gilbert's book on magnetism appeared, he conducted experiments to ascertain the truth of Gilbert's assertions. He was aware of the fact that sound travels more slowly than light. To test the propagation of light he conducted an experiment with two experimenters, each with a lantern standing opposite to each other at a distance of a few miles, admitting and shutting light and seeing whether time is required for the propagation. Because of the short distances involved Galileo could not come to any definite conclusions. These reflections on light, sound, heat.....and the like are sprinkled over the length and breadth of his major works on Astronomy and Mechanics.

2. Astronomy

It is commonly said that the new star of 1604 changed the course of Galileo's life. The importance of this statement lies in the fact that probably before 1604 Galileo's position was not very different from the then current Aristotelians. In fact, for several years he taught the Ptolemaic system in the University. Aristotelians made a clear distinction between celestial and terrestrial bodies. They maintained that Earth is immovable.

In accordance with these doctrines comets and novae were thought to be of sublunary character. About comets Galileo did not have much of a doubt; but with the appearance of the new star in 1604 he thought that there is sufficient reason to disagree with the Aristotelians. He waited for an opportune moment to expound his convictions. The telescope which he made in 1609 came in handy for this purpose. He went on accumulating "irrefutable and tangible proof".

With the backing of these observations he came up to attack the Aristotelians and Ptolemy and to uphold the Copernican system. His first efforts were directed at destroying the celestial - terrestr distinction maintained by the Aristotelians and the theologians. Once this distinction was done away with, "all things were equally physical, and all equally divine". The moment all these bodies were brought to the same level he could apply the laws of mechanics discovered by him to these very celestial bodies.

Thus the structure of the Galilean theory of celestial bodies has laws of mechanics at its base, the rest containing really of the application of these laws to the elements concerned. This logical structure of the theory was obviously not compatible with Kepler's laws, and this is probably what made him ignore the latter. In the light of his own observations and the logical structure of his theory, he could draw very definite conclusions from a comparison of two system the Copernican and that of ptolemy.

3. <u>Mechanics</u>

Galileo's greatest contribution to the science of mechanics lies in bringing about a reconciliation between the two traditions, the <u>Archimedean</u> and the <u>Aristolelian</u>. His predecessors in the Archimedean tradition, viz Guido, Stevin and others, rejected the dynamic approach altogether. They had imaginary logical obstacles to the unification of statics and dynamics. On the other hand Aristotle took motion to be the principle of nature and was concerned with the relations of movers and things moved. Galileo agreed with Aristotle on this point. He swept the static approach aside when he wrote:

> "And since to make the weight B descend any minimal heaviness added to it is sufficient we shall leave out of account this insensible quantity and shall not distinguish between the power of one <u>weight</u> to sustain another and its power to move it"
> (p.156, On Mechanics)

Thus what seemed to his predecessors in the Archimedean tradition an imaginary logical obstacle became for Galileo a unifying link between statics and dynamics.

To get an idea about his contributions we should see what his "Two New Sciences" are: The importance of this work could be grasped by the following passage to be found in the book, "A History of the Theory of Elasticity And of the Strength of Materials" by K.Pearson and I. Todhunter:

"....... This dialogue both from its contents and form is of great historical interest. It not only gave the impulse but determined the direction of all the inquiries concerning the rupture and strength of beams, with which the physicists and mathematicians, for the next century principally busied themselves.....'.

The first of the sciences deals with the size, structure, and strength or resistance of matter. Galileo puts the question very succintly in the opening pages of his "Two New Sciences":

"....... still the mere fact that it is matter makes the larger machine, built of the same material and in the same proportion as the smaller, correspond with exactness to the smaller in every respect except that it will not be so strong or so resistant as against violent treatment, the larger the machine, the greater its weakness".

What he does in the next few pages is:

"demonstrate by geometry that the larger machine is not proportionately stronger than the smaller.... For every machine and structure, whether artificial or natural, there is a necessary limit beyond which neither art nor nature can pass; it is here understood, of course, that the material is the same and the proportion preserved". (p.3, Two New Sciences).

"From what has already been demonstrated, you can plainly see the impossibility of increasing the size of structures to vast dimensions either in art or in nature, likewise the impossibility of building ships, palaces, or temples of enormous size in such a way that their oars, yards, beams, iron-bolts, and in short, all their other parts will hold together; nor can nature produce trees of extra-ordinary size, because the branches would break down under their own weight......' (p.130, Two New Sciences).

From the above two passages we get an idea about Galileo's treatment of the size-structure-strength relation in matter in all its complexity. He showed that with any given structure the strength or resistance of the material decreases with increasing size.

It will be noted that in the demonstration given, comparability requires the structure to be held fixed and size to be varied. Thus for analytical purposes it is often necessary to hold structure constant while varying size. There are, however, clearly defined limits to this analytical device, i.e., size may be raised holding structure filed only within more or less well defined bounds. The important point here is that there does not exist any general size-structure invariance. What the limits are depends upon the particular matter considered, and it is clearly possible that in many cases the limits may collapse into a single size structure unity.

Another significant point that emerges in Galileo's mechanics is the unification of natural and artificial matter. Again Galileo was very clear about the purpose of such a study. The purpose of his demonstrating the laws of nature was to clear up very many false notions currently held by artisans and students of mechanics. Galileo expected these demonstrations to be of very definite help in the construction of machines. In one of his letters he wrote;

> And just recently I have completed the discovery of all the conclusions, with proofs, pertaining to the strengths and resistances of wooden beams of various lengths, sizes and shapes;......a sicnece most necessary in the construction of machines and of all sorts of buildings,.......' (February 1609, to Antonio de' Medici quoted in On Mechanics', p.136).

The other science in the "Two New Sciences" deals exclusively with motion. Galileo called it an entirely 'new science', in which he demonstrated the remarkable laws which exist in both "natural" and "violent" movement. Here Galileo discussed the properties of uniform motion, of motion naturally accelerated along planes of all inclinations, and of a motion which is compounded of a uniform and horizontal motion, another which is vertical and naturally accelerated. Here he advanced much farther than the static weight consideration to the general force consideration, though some say he failed to get over the animistic intonations of this "force" concept.

4. Mechanical instruments*

In Galileo's study of mechanical instruments, he treated the nature of the lever, the wheel, the pulley, and the screw. We shall only be concerned with the "mechanism" part of these instruments and not the general nature as such. The whole argument under this head is built around lever.

(i) Lever: In the study of the lever Galileo's first endeavour seems to be to clear up the false notions that were in vogue at that time. He says:

> It should be noted that the utility which is drawn from this instrument is not that of which common mechanics persuade themselves; that is that nature comes to be overpowered and in a sense cheated, some very great resistance being conquered, with a small force by the intervention of the lever".

Galileo clearly demonstrated the impossibility of such an assertion. He showed that in moving a great resistance a small distance, a small force has to cover a great distance. The advantage acquired from the lever was nothing but the ability to move all at once that great resistance which could have been conducted only in pieces by the same force, during the same time, and an equal motion without the benefit of the lever.

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* All references are to On Motion and On Mechanics.

(ii) Wheel: Coming to the mechanics of the wheel he took two examples, the windlass and the capstan which he considered as belonging to the broad class of wheels. His first demonstration was:

> "the two instruments......depend directly upon the lever, and indeed are nothing but a perpetual lever".

After this unification, he went on to bring out the role of force very clearly:

> "Thus when the force is exerted on the wheel by a heavy and inanimate body which has no other impetus than to go downward, it is necessary for this to be suspended by the line tangent to the wheel and not cutting it. But if on the same circumference the force were to be exerted by an animate force which had moment to make impetus in all directions then the effect might be made at any point on the circumference.....'.

He also concluded that the same might also be done with an inanimate force, provided a way were found to have its moment give an impetus along the tangent at some point on the circumference. His talk about animate and inanimate forces the heavy weights and the flow of rivers on the inanimate side and the animal and human force on the animate side - reflects his awareness of the common element, viz. force, and of the basic structure of its source, viz. animate-inanimate.

(iii) Pulley: Coming to the pulley, Galileo claimed that its basis and principle could again be reduced to that of the lever. For this purpose, he theorised about another method of using the lever viz., the lever with the support placed at one of its extremities. Here again he claimed that the advantage drawn from a pulley has nothing to do with the diminution of work. He did not stop here; he proceeded further and explained why it is convenient to use a pulley in lifting water from a well:

> "For when we draw anything downward, the weight of our own arms and other members aids us, where as when we must draw the same weight upwards by means only of the vigour of our members and muscles or, to use the common expression, "by elbow grease", we must raise in addition to the external weight the weight of our own arms, which requires more work.....'.

He further concluded that by properly arranging the pulleys the force could be increased to any desired degree.

(iv) Hammer: In the end Galileo discusses the peculiar phenomenon which we so often observe in day to day affairs. The question posed was this:

> To fix a nail on very hardwood, just to keep a heavy hammer on it does not suffice: but a small motion of the hammer and a hard hit suffices; why?

This again is explained by the principle of the lever. He turned the argument of the lever around:

> "Where will be the marvel if that power which would move a small resistance through a large interval should drive one hundred times greater through one hundredth of the said interval? No wonder, certainly; and for things to be otherwise would be not only absurd, but impossible".

Thus at every turn, he came heavily on the false notions of the mechanicians and artisans and expounded the laws of nature.

(v) Concluding remarks: Galileo's achievement in his study of mechanical instruments is in showing that the lever is at the very base of all other instruments and that their mode of working can be explained by the single principle of the lever. He puts it very simply that in every instrument considered by him viz. the wheel, the pulley and the screw, the lever is used in a "different" way. The other point is that he succeeded in showing that with the use of mechanical instruments thereby is no diminution of work.

Coming to the specific advantage derived from mechanic instruments, we find two points: The first advantage discussed by Galileo was that derived in moving a great weight all at once by means of a given force. This did not mean a diminution of work, as already discussed. The second advantage derived from mechanical instruments was the facility of using some particular instruments for particular purposes. For e.g. where the bucket could not "keep the hold dry of even a small quantity of water", the pump could.

5. Force, and Cost (A review of Galileo's contribution from the standpoint of labour-process)

Galileo clearly distinguished between movers. The flow of the river, he called inanimate force as against the animate force supplied by animals and human beings. His greatness lies in the recognition of something common in all these - the abstract conception of force. He called it motive-force, because it moved mechanical instruments. With the awareness of these movers in nature, there arose the necessity of finding a criterion on the basis of which one could choose the one or the other. Galileo was again clear about this aspect of the problem;

'......the fall of a river costs little or nothing, while the maintenance of a horse or similar animal whose power exceeds that of eight or more men is far less expensive than it would be to sustain and maintain so many men'.

It is obvious that the social forces which are at the back of making the choice need such a criterion and it is supplied by the expense of maintaining such a motive force.

In sum, an exposition of Galileo's writings ranging from theoretical aspects of Astronomy and Mechanics to the economic criterion of cost in choosing forces of nature as motive-force are highly relevant for an understanding of Social Technology. Especially two key areas touched upon by Galileo are directly related to our own discussion of the evolution of Technology. His discussion of the size-structure-strength in matter is related to our discussion of the 'material base' of tools (Part II above). Secondly, his discussion of the mechanical instruments is highly relevant for our discussion of the evolution of tools of locomotion. Our discussion draws much of its flesh and blood from Galileo's expositions. In a sense, Galileo's discussion covers the area of tools of locomotion with forces of man as the source of motive-force and opens out into the area of forces of nature.

Refs:

1. Laura Fermi and Gilberto Bernardini, Galileo and the scientific Revolution, Basic Books Inc. N.Y. 1962.

2. Galileo, Two New Sciences, Dover Publications, 1914.

3. Galileo, On Motion and On Mechanics, tr. by I.E. Drabkin and Stillman Drake, The University of Wisconsin Press Madison 1960.

4. Galileo, Dialogues on the Great World Systems Salusbury translation, The University of Chicago Press, 1953.

- A Mechanistic View of Production & Technology

The different views on technology, to be specific history of technology may broadly be arranged under two heads. The views falling under the first head make a clear distinction between a material plane and a human action plane and then view the history of technology as a history of substitution of 'powers' of nature for 'powers' of man/1/ These views we shall call structural. Under the second head no such distinction is attempted. History of technology is simply viewed as a history of the conquest of materials /2/. Our objective here is to attempt a brief overview of one of the streams of thought falling under the structural head.

The current expression of, the stream of thought which forms our subject matter, may be seen in their interpretation of Industrial Revolution. This interpretation is the contemporary counter-position to the Marxist position and its clearest expression may be seen in Hicks:

> The impact of science, stimulating the technicians, developing new sources of power, using power to create more than human accuracy, reducing the cost of machines until they were available for a multitude of purposes; this surely is the essential novelty, the essential revolution....../3/

So much regarding the current position, what we propose to attempt here is to go back, tracing this view through history. This stream of thought on technology has at its base a certain view of production and man's participation in production. Thus our overview attempts a connected account of their views on production and man's participation

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1. (a) 'It is fair to say, however, that except for a considerable number of isolated examples, the industrial revolution upto the present has displaced man and the beast as a source of power, without making any great impression on other human functions' - Norbert Weiner.
   (b) 'The object of improved machinery is to diminish manual labour, to provide for the performance of a process or the completion of a link in a manufacture by the aid of an iron instead of the human apparatus' - Marx.
   (c) .... When the time came at which the labour and sufferings of slaves were thought worth economising, the greater part of this bodily exertion was rendered unnecessary, by contriving that the upper stone be made to revolve upon the lower, not by human strength, but by the force of wind or falling water - J.S.Mill.

2. The history of technology and engineering is, in the first place, the story of the conquest of materials - R.J.Forbes.

as well. A word of clarification is needed before taking up the task. The standpoint from which the overview is attempted is that of economic theory and as such mainly economists are chosen.

Naturally the question arises as to how far back do we go in tracing this stream of thought. The answer simply is that we go back upto Francis Bacon for we find a convenient starting point in him. Bacon had dealt in detail with production, man's participation in production and the role of science in the evolution of technology etc. This, in a sense, defines the 'area' we have to cover, viz. that lying between Francis Bacon and the present day writers. Let us begin with Francis Bacon.

Francis Bacon believed that man held a central position in the universe and all the things are at man's service. The only way man can survive is by using nature for his own ends. This moulding of nature for human use is what he called production, to be exact the production of things <u>artificial</u>. But things artificial, according to him, are no different from things natural in <u>form</u> or <u>essence</u>. They differ from natural "only in their efficient: for man has no power over nature in anything but motion, whereby he either puts bodies together, or separates them" /4/. The human participation in production is thus reduced to motion, to be exact locomotion. So much regarding Bacon's view on man's participation in production.

Now let us take up the role of science in the progress of arts as dealt by Bacon. Bacon, while commenting on the progress of arts and science of his age observed that they were mainly derived from the Greeks. The Roman and Arabic epochs, according to him, were not conducive for discovering and deriving experiments; they took to the inverse method of discovering experiments first and then building philosophical systems upon them. The right method according to him was to discover and derive experiments from philosophy and the knowledge of causes. This clarifies his view of the role of science in the progress of arts: <u>the arts need to be based on science.</u>

Having touched upon a general writer like Bacon let us take up economists who have written on production, man's participation, science and technology, Let us begin with James Mill and then pass on to J.S.Mill, Jevons and Marshall.

James Mill conceived production as a unity of processes in nature and man's action. The human participation is reduced to that of producing motions: "All that man can do is to place the objects of nature in a certain position". Nature does the rest. The essence of man's participation is sought in his capacity to move things. This aspect is further clarified in the following:

> He (man) <u>moves</u> ignited iron to a portion of gunpowder, and an explosion takes place. He <u>moves</u> the seed to the ground and vegetation commences (emph. mine) /5/

This, as we can see, is nothing but Bacon in its essentials. Now let us go on to Jevons.

Jevons again follows Bacon to a large extent. He reduces all change in nature to motion. Once all change in nature is reduced to motion all that labour can do is to move bodies. Here he quotes Bacon approvingly:

> As Francis Bacon so well said "Man can himself do nothing else than move natural bodies to and from each other; nature working within accomplishes the rest". /6/

Thus the human participation in production is reduced to just the directing of muscular energy of his body. Men could do nothing but "pull, push, lift, press, carry, or otherwise mechanically force things into new forms or new places."

Once the human physical labour is reduced to that of a mere beast of burden What science can do is also limited. Science, "makes muscular energy the key to the vast stores of material energy existing in the things around us". The role of science is in enabling man to enlist the powers of nature. With this technological advances are based upon scientific developments.

Before passing on to J.S.Mill let us mention one other name, viz. Marshall. He fully agrees with Jevons on the human participation in production as well as the role of science in the development of technology.

J.S.Mill is no different from the others in this tradition. J.S.Mill like his father does not say much on the nature of changes in Nature. According to him the requisites of production are labour and natural objects. Nature supplies matter and active energies. Man has "no other means of acting on matter than by moving it". The muscles of man are constructed for it. They could introduce motion or prevent it. The powers of nature or properties of matter do all the work. Man can only move "one thing to or from another". He moves a seed into the ground:

> and the natural forces of vegetation produce in succession a root, a stem, leaves, flowers and fruits. He moves an axe through a tree, and it falls by the natural forces of gravitation. /7/

Thus labour in the physical world is "solely employed in putting objects in motion". The skill and ingenuity of human being are chiefly exercised in discovering movements which are practicable by their powers of bringing about effects in matter.

In Mill's view the savant or the speculative thinker is also a part of production. Many inventions of practical arts are "the direct consequences of theoretic discoveries". Every extension of knowledge of the powers of nature bring about fruitful applications for the benefit of mankind. With man's command over these powers they could be used as a substitute for labour. As already mentioned physical labour is nothing but muscular exertion and naturally the substitution is on the force plane. Forces of nature are substituted for human muscular power. Mill gives an instance of such a substitution:

> In the early ages people converted their corn into flour by pounding it between two stones; they next hit on a contrivance which enabled them, by turning a handle, to make one of the stones revolve upon the other......the greater part of the bodily exertion was rendered unnecessary, by contriving that the upper stone be made to revolve upon the lower not by human strength, but by the forces of the wind or falling water. /7/

In conclusion, it may be said that what was a seed in Bacon has grown into a tree in our own time. In Bacon we see someone propounding the virtues of directed science i.e. science as the basis for "deriving" arts. It was not posed as a reality by him. In the writings of James Mill and Jevons we see it posed as reality. This is what goes by the name of science-based technology. Further owing to the view that all man can do in production is to move things, advances in technology are seen basically as development of new sources of power substituting human muscular power. It is this unified view which get a powerful expression in the writings of the contemporary economists. Simon Kuznet's view of "modern science as the basis of an advancing technology" and Hicks' view of "the impact of science, stimulating technicians, developing new sources of power. .... this surely is the essential novelty, the essential revolution" and such views by others have their roots in the writings of Bacon, Mill and Jevons.

References

1. (a) Norbert Weiner, The Human use of Human Beings
   (b) Karl Marx, Capital, Vol.I.
   (c) J.S.Mill, Principles of Political Economy

2. R.J.Forbes, Man the Maker
3. p.148 John Hicks, A Theory of Economic History, Oxford Paperbacks, Oxford University Press, 1973.
4. pp.46-47 Francis Bacon, Advancement of Learning and Novum Organum, The Colonial Press, N.Y. 1899.
5. p.5 James Mill, Element of Political Economy (third ed.1844) Augustus M.Kelley, N.Y. 1963.
6. p.68 W.S.Jevons, The Principles of Economics, Augustus M.Kelley, N.Y. 1965.
7. p.118 J.S.Mill, Principles of Political Economy, Master Works of Economics, Vol.2, MaGraw Hill, 1973.