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Short Review Paper

Radiation technology a health care innovation: a socio-technical perspective of x-ray to CT scan transition

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Abstract

Technologies do not fulfil societal functions on their own. They themselves have no power and do nothing. They are never applied in a vacuity, but invariably in an application area. They are composed of various artefacts, organizations, scientists, legislations, norms, and values scattered over time, place, crossing over several boundaries. They are structured to help and full fill its functions. They are emerged not just from an individual, firm, but from a wide network of system of actors (Universities, research institutes, government programs, R&D departments in firms)[1]. This paper evaluates the technology, radiation from a socio-technical system analysis perspective. The study identifies the niches, regimes and landscape accounts for the transition of X-ray to a Computed Tomography (CT) scan technology. Through a multi-level perspective analysis, the study finds that the technology X-ray encompasses all five regimes: technological- industrial, science- laboratories and scientists and universities, user/market- industrial, medical services, airport, aerospace and so on, policy-Indian government, and socio-cultural- patients, women's etcetera. It inhibits all dimensions of the socio-technical system. The landscape created before the arrival of the radiation technology-X-ray, supported several novelties like; König tube, Gilbert's electron, Torricelli's barometer, Faraday's anode and cathode, Eugen Golstein's cathode ray, accumulated and resulted in the discovery X-ray and later to a CT scan technology- creating a seamless web with various regimes before its use in medical care management.

Keywords: Socio-technical system, X-ray, radiation, Computed Tomography, niches, regimes, landscape.

Introduction

Technical innovations have emerged not just from an individual, firm, but from a wide network of system of actors (Universities, research institutes, government programs, R&D departments in firms) and to achieve functionalities it involves a 'seamless web'[1-2].

Under medical field, innovations occurs in the field of medications, diagnostic modalities and procedures[3] and the technologies include; drugs, devices, medical and surgical procedures, and organizational and supportive systems within which such care is provided[4]. This paper evaluates one such medical technology called radiation technology from a socio-technical system perspective. The period selected for this study is from 1896 to 2005.

All the data gathered are through secondary source; literature review. The objective is to identify how this radiation technology is being evolved and how its transition took place from X-ray to a CT scan technology by evaluating it from socio-technical system analysis. During this study also identifies the factors responsible for its transition; niches, regimes, landscapes, and actors involved in this system innovation.

Brief on theoretical framework and its suitability

Artefacts fulfill societal functions only when they are linked to human activity, social structures and governing bodies and not exclusively[1]. Artefacts meaning is influenced by the sociocultural and political situation of a social group, their norms and values[5]. There are a range of elements (social groups) linked together with a particular technology through a seamless web to achieve functionality and these clusters of elements are called socio-technical system. Shifting from "one socio-technical system to another is called System Innovation"[1]. Technology emerges from a wide network of systems of actors. These actors and their network are controlled by regulative, normative or cognitive rules referred as 'rule regime'. These regimes are interdependent and are called 'socio-technical regimes'. Nevertheless, during the tension between rules, the natural action of different social groups goes in different ways, causing weakening of linkages and simultaneously producing an opportunity for radical novelties to take home. If rules are shared in social groups or communities, the activities go in the same way-a stable socio-technical systems. To understand this Geels proposed a multi-level perspective (MLP) to distinguish technological niches, technological regimes and socio-technical landscape[1].

There are multiple regimes embedded in a single landscape (Figure-1) and multiple niches in a single regime. Novelties are niches level often generated to the problems of the existing regimes. However, their boundaries cannot be clearly defined and it overlaps.

There are five regimes linked in a socio-technical system: i. technological, ii. science, iii. user/market, iv. policy and v. socio-cultural (Figure-2). In a stable regimes, these trajectories incline to go in a particular direction. Each small arrow represents a move with some tangible effect on the elements of socio -technical systems[1].

In a multi-level perspective, although different regimes are associated and co-evolve, they too have internal dynamics (Figure-3). If these internal developments diverges, then a conflict of thought occurs (shown with shorter diverging arrows). This situation sometimes results in 'loosening up' of linkages, making a window for radical innovations to develop out of their niches.

At the landscape level, changes like; cultural, demographic movements, political and alike may put pressure on the regime. Due to this the actors in a niche level may go in dissimilar ways. There may be a multiple niches. These niches may compete, but gradually link up and reinforce one another.

"A system innovation occurs when the new innovation conquers wide market shares and links up with ongoing processes in the regime. This is accompanied by wider adjustments in the socio-technical regime. System innovations thus involve not only technology and market shares, but also changes in wider dimensions such as regulation, infrastructure, symbolic meaning and industrial networks"[1].

In a stable socio-technical regime (Figure-4), radical novelties have little opportunity to through. In such circumstances, product champions and niche advocates may have high expectations and promise a glorious future for their novelties. But it is very possible, and even likely, that the problems will be solved with incremental innovations within the regime and that niches will fail.

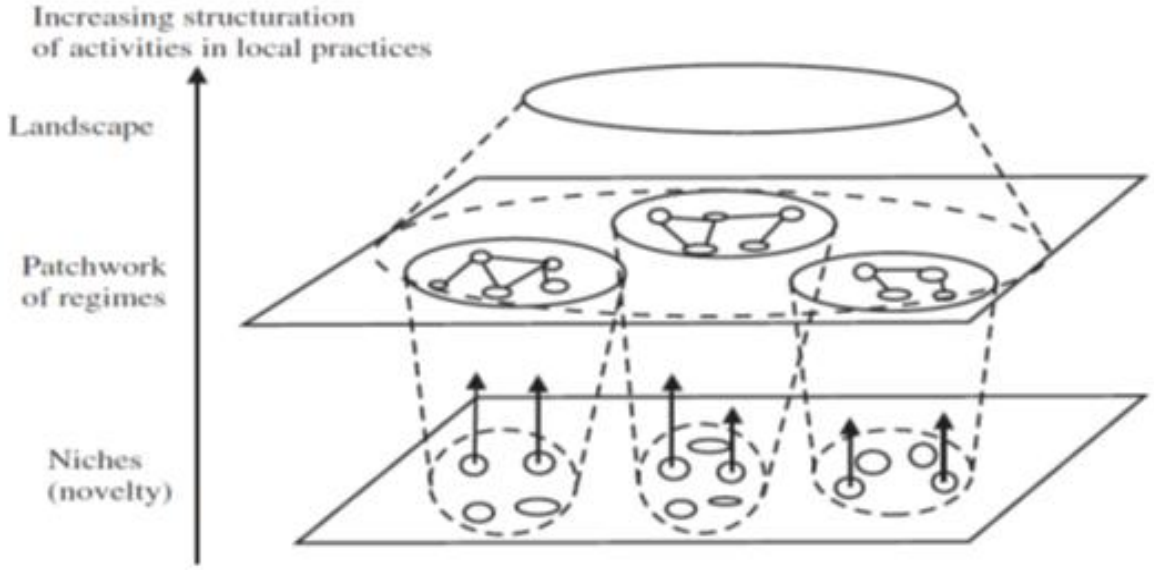

Figure-1: Multiple levels as a nested hierarchy[1].

Figure-2: Alignment of ongoing processes in a socio-technical regime[1].

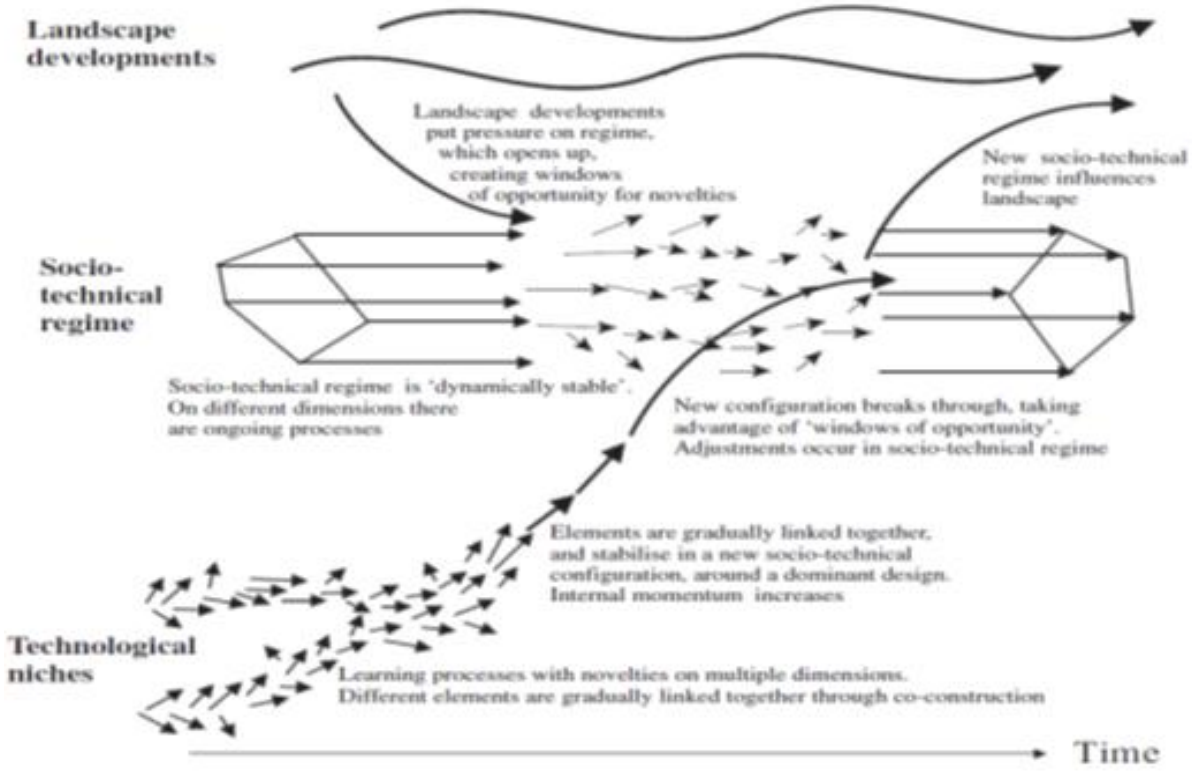

Figure-3: A dynamic multi-level perspective on system innovation[1].

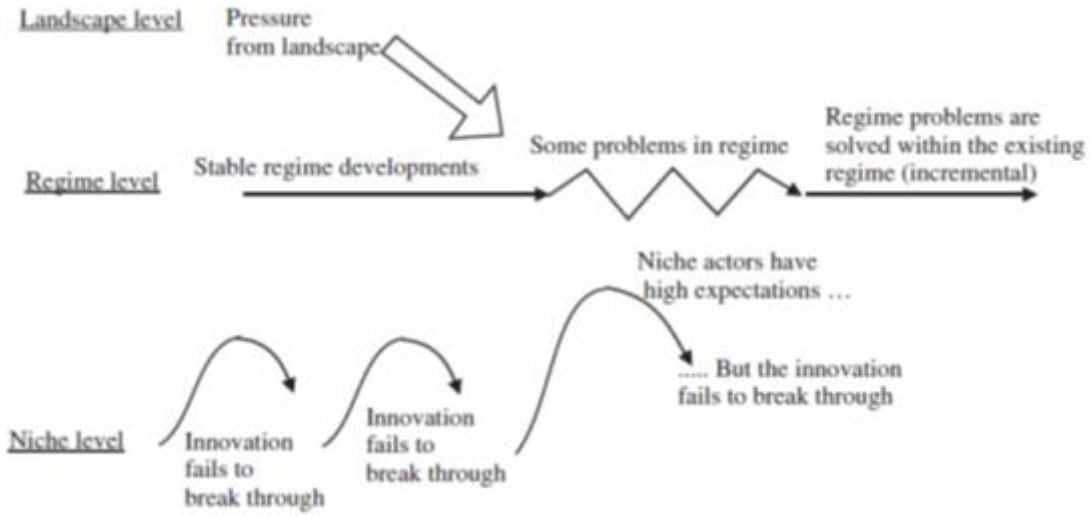

Figure-4: Failures of niche innovations[1].

Phases in System Innovations: The first phase encompasses the emergence of novelty; a new technology is born as a novelty- a solution looking for existing problems. The second phase takes place in small market niches like; the social network that supports novelty may develop a dedicated community to improve new technology, user preferences, legislation and so on. The third phase is about technological diffusion and its competition. Here, the new technology enters a competitive relationship with the established regime due to the internal technical problems which cannot be met apparently by the available technology. For this Rosenberg[6] coined the term 'bottlenecks' and Huges[2] talks of persistent 'reverse salient's'. During fourth phase the new technology gradually replaces the old technology due to improved cost/performance ratio done through incremental innovations. The old and new technologies may co-exist for a substantial period, before the old technology is entirely replaced.

Overview of sector, area, research problem

The first recorded case of medical diagnosis is found in the writings of Imhotep (2630-2611 BC) in ancient Egypt (the Edwin Smith Papyrus). The landscape for patient's diagnosis brought into existence with the Hippocratic Oath. Medical doctors started obeying normative and cognitive rules. A regime of diagnosis under which clinician determines the condition of a patient or a disease by collecting information from various sources and putting them together to make a diagnosis opinion. It provides several possible explanations which can be equated and differentiated. Further decisions on treatment were made based on these pattern studies. This was further drilled down and concluded, based on the data gathered from tests and analysis.

Before 1895 the only method for major diagnosis was through clinical, laboratory and differential diagnosis only. It was only in 1895, when a radical innovation took place by the discovery of X-ray by physicist Wilhelm Conrad Rontgen in Germany. Although, many people had observed the effects of X-ray beams before, but Roentgen was the first one to study them systematically[6]. He discovers X-rays- making the invisible visible[8]. I will categorize it as a niche since it would not have been possible if there is not an assimilation of niches during this period. During 16th Century Gilbert gave the term electron, to describe the properties of attraction which arose from friction. He was the first to create a device which could detect an electrical occurrence. During early 17 century, Torricelli invented the instrument barometer a permanent vacuum ever made. Faraday described the process of electromagnetic and induction of electric current and invented dynamo. He also proposed ions as carriers of electricity along with the terms anode and cathode. In 1876, Eugen Golstein gave the concept of cathode rays. It was due to these niches actively constructed by the incubators or product champions, assimilated together and made a revolutionary innovation, discovery of X-ray, a start of a novel socio-technological system.

Rontgen initiated a fresh era of investigating inside body pictures, without editing and opening the body. He called it X-rays because of its unknown nature. In 1896, with an image of the hand of anatomist Albert von Köliker, this news with the help of worldwide telegraphic and newspaper regimes, sensationally spread with the speed of lightening[9]. This discovery produced a big impact on the society from industries to private wellness. The X-ray workers and images successfully shaped the radiology and physicians within the present medical context[10] and today it has become an important diagnostic tool in health maintenance.

The competitive game between the various regimes begun and created a fresh opportunity for the technology to enter in various regimes. The diffusion of this technology was so fast that within a short time of its discovery, several medical radiographs were made in Europe and in United States. Just after 6 months, this technology was used by the doctors during the Balkan War for detecting the bullets, and broken bones in injured soldiers[7]. Doctors soon picked up this technology to diagnose health complaints. By 1896, this technology was practiced in clinical conditions, surgical operations and in dentistry. But there was a 'reverse salients' in the technology. First was the exposure time, which was about 25 minutes and the second was the heating of the cathode tube. This created a quad for the extensive diffusion of Novelties. König invented a new anticathode tube made up of platinum disc with reduced exposure time up to 5 minutes with minimal heating.

A new landscape level changed created due to cultural change by "Dr. C. Edmund Kells, a dentist in deep south hired first female dental assistant and the one of first to expose a dental radiograph in the United States" at his clinic[11]. The technology even entered the university regime, when "in 1897, Professor Béclère set up his first laboratory of radiology at Tenon Hospital" in France. It moved beyond the conventional photograph when daily X-ray entertainment sessions started organizing in the USA and Europe[8]. By 1896, it was identified that X-rays also affects the living functions like; loss of hair, skin burns etcetera. Antoine Beclere introduced novelties 'safety equipment', lead aprons and lead rubber gloves for the first time.

Just after the X-rays discovery, in 1896, Henri Becquerel in France discovered a natural radioactive ray. Within two years Curies discovered one more radioactive element called *Radium.* These radical innovations took their own separate trajectory of socio-technical system. The new X-ray technology took its trajectory so fast that soon it was gone off to heal cancer patients[7]. A new novelty was introduced in 1904 by John Ambrose Fleming when he put in a vacuum tube consisting hot cathode to flow an electric current in a vacuum creating a new regime called "Coolidge tubes". This new technology replaced all cold cathode tube completely by 1920.

The initial cold cathode X-ray tubes were not capable enough to handle voltages up to 1,00,000 volts. The new Coolidge tubes with high volt X-ray generators up to 10,000,000 Volts started to use in industries– X-rays use beyond medical care. This co-evolution of multiple technologies resulted in new developments likes; use of computers in radiographic inspections, astrophysics[12], X-Ray microscope (Generating images of microscopic objects by using radiation)[13], mammograms, barium enema, computerized axial tomography (CAT) scans, computed tomography (CT) scans and thus along. There are certain imagine test where doctors insert a tiny camera called scope inside the body, to see inside a particular organ like; heart, lungs, or colon[14].

This representational power of digital organizations to generate visual or pictorial images of the physical structure, providing clues of clinical disorders, person's health or ill-health, not only empowers citizens to adopt decisions on their health but also

demonstrates that technologies encompasses the construction of societal relationships. The printout of initial results generated through X-ray, CT scans etcetera, not only allows patients to receive their own assumptions about it, but also provides a proof of their real specific conditions[16].

In India, 7 years after its discovery, the first X-ray machine was imported in 1902. In 1923, a chair in radiology was established at Lady Hardinge Medical College and Hospital in Delhi. After World War I, the radiology practice was initiated in both government and private clinics[17].

Since, X-ray technology has both medical and non-medical use, in India, Central government provided the landscape by enacting Atomic Energy Act, 1962, and under this for medical purpose Radiation Protection Rules 1971. For implementing appropriate regulatory measures aimed at ensuring radiation safety an Atomic Energy Regulatory Board (AERB) was founded in 1989[18]. The sketch of the main social group involved in X-ray technology is shown in Figure-5.

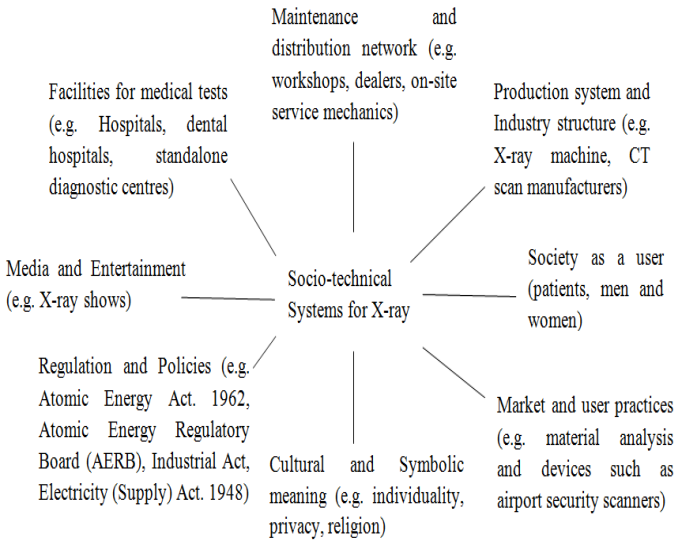

Figure-5: Socio-technical system for X-ray.

The cross-disciplinary collaborations, among engineers, cardiologists, radiologists, and pathologists have contributed remarkable advances and improved devices and techniques. Today in catheterization laboratories any obstructions in the heart and circulation can successfully be opened and abnormal openings can successfully be closed[15] through these radiation technologies.

X-ray technology has created a seamless web with various regimes like airports; security scanners, laboratories; material analysis, animal CT scan, hospitals; diagnostic tests, Industry; to inspect welds, castings, radiographically inspect airbags and canned food products, metallurgical material identification, petrochemical, safety equipment's against radiations, aerospace and so on.

Conclusion

X-ray technology is a socio-technical system and involves all the five regimes linked; Science- laboratories and scientists regimes, universities regime, Technology-Industrial regime, Market and user-Industrial regime, Medical service Regime, Airport Regime, Aerospace regime and so on, Policy- Indian government regime, and socio-cultural-Patients, Women's. The landscape created before the arrival of X-ray technology supported various novelties like König tube, Gilbert's electron, Torricelli's barometer, Faraday's anode and cathode, Eugen Golstein's cathode ray. Accumulated and resulted in the discovery of X-ray. There was landscape level change was created by the dentist Dr. C. Edmund Kells, to take a first female dental radiograph. Other niches created by introduction of safety equipment's by Antoine Beclere-lead aprons and lead rubber gloves, high vacuum X-ray tubes 'Coolidge' made the regime to transform from one level to another explains the understanding of X-ray as socio-technical system.

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