ADOPTION OF HEALTH TECHNOLOGY IN HEALTHCARE FACILITIES: A CASE STUDY

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ABSTRACT

Understanding the process through which new ideas propagate through a population of potential adopters has been the focus of many research efforts. Of all the approaches and theories, the diffusion theory described by E.M. Rogers is widely used in application to many domains including Healthcare.

Viewing adoption from a System Dynamics perspective has also been studied extensively. A simple model of diffusion of new ideas along the model introduced by F.M. Bass has extensively been used in System Dynamics literature. In terms of Health Technology adoption J.B. Homer developed a comprehensive model consisting of 150 endogenous equations and 90 exogenous constants.

The problem with using the Bass model for analysis of adoption of Health Technology is that it is simply not possible to analyse enough of the dynamic parameters in the process. The Homer model, on the other hand is far too detailed to allow for investigative analysis of an adoption case, or to compare a dynamic parameter across a number of cases. This study therefore develops and describes a System Dynamics model as part of the exploratory research method employed which is more specific than the former but less onerous to configure than the latter.

In developing the model, a specific case of adoption of a novel full body x-ray scanner is analysed and used to elucidate the various sub-process and influences within the model. This paper shows how data gathered from the case study is used to systematically construct the dynamic processes which define the innovation-decision process as describe by Rogers. In using the specific case of an innovation which involves a device that is used multiple times (fixed equipment), the model addresses a new dynamic environment. Previous studies have all focused on single-use devices in the health care environment, implants or pharmaceutical product where there is a direct relationship between sale and use of the product. In the case of fixed equipment in this environment, the operational cost associated with each additional use/event is small in comparison with the initial cost of acquiring and installing the device. Furthermore, with fixed equipment the sale of the

unit in no way describes the extent of use. This dynamic, in the main constitutes the contribution of this paper to the understanding of the innovation adoption domain.

Key words: Adoption, Diffusion of Innovation, Health Technology, Innovation-decision process, System Dynamics, Fixed Equipment

INTRODUCTION

Many authors have studied the way in which new ideas or products propagate into a society or market but probably the most universally recognised is the Diffusion of Innovation theory (Rogers 2003). This model, developed and refined over many decades was used by E.M. Rogers to study the progression of innovative farming methods in the corn-growing region of Iowa in the USA in the 1950's. Rogers' definition of diffusion is simply described as follows:

"Diffusion is the process by which an innovation is communicated through certain channels, over time amongst the members of a social system".

Diffusion Studies in the Public Health and Medical Sociology have a long history and include topics like adoption of new drug or medical ideas by doctors, family planning methods, HIV/AIDS prevention as well as other health innovations where the adopters are patients or members of the public (Rogers 2003:64).

The Diffusion of Innovation model is essentially a qualitative description of the process with details regarding the mechanism and forces involved. Describing diffusion in quantitative terms requires a different approach(Van der Watt et al. 2014). Very basic models exist, the most famous of which is the so call "Bass Model" which mathematically consist of a single differential equation (Sterman 2001). In System Dynamics or Systems Thinking terms the model consists of 2 feedback loops as shown in Figure I.

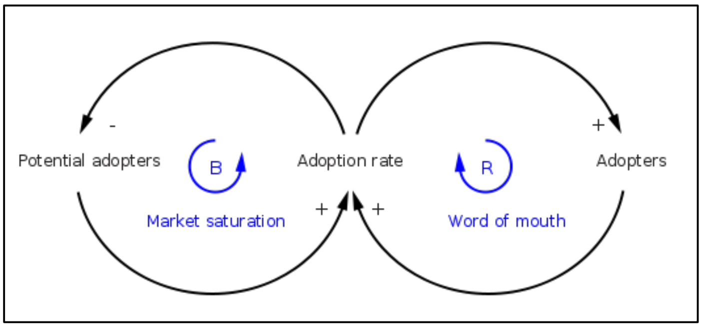

Figure I: Bass Diffusion Model

The loop on the right, labelled "R", represent positive reinforcement loop indicating that the more people have already adopted the new product, the stronger the word-of-mouth impact would be. The second feedback loop on the left labelled "B" represents a negative feedback loop or "balancing" loop. This indicates that as more people adopt fewer remain as potential adopters resulting in the balancing phenomena. The result of this model generates the well know S-shaped adoption curve (Van der Watt et al. 2014).

Homer (1987) developed a very comprehensive model describing the diffusion of emerging medical technologies. The System Dynamics model developed by him consists of more than 150 endogenous equations and 90 exogenous constants or look-up functions. This seminal work has contributed significantly towards the System Dynamics application as well as the understadning of diffusion of innovation (Van der Watt et al. 2014). It does have a number of limitations though. Homer specifically excludes the use of the model for diagnostic technology, procedures unassociated with a product and technology associated with fixed equipment (Homer 1983:560). Homer's model was further developed by Knoll (1995) through the addition of a "payer activity" module, however the limitation discussed above remains. Current research has found no further significant development using System Dynamics to address these limitations.

THE INNOVATION-DECISION PROCESS

One of the key components of the Diffusion of Innovation model is the process describing how the innovation decision unfolds. In some way, it is a summary of the entire model, depicting many of the key parameters of the model in relation to each other. Figure II, illustrates the process:

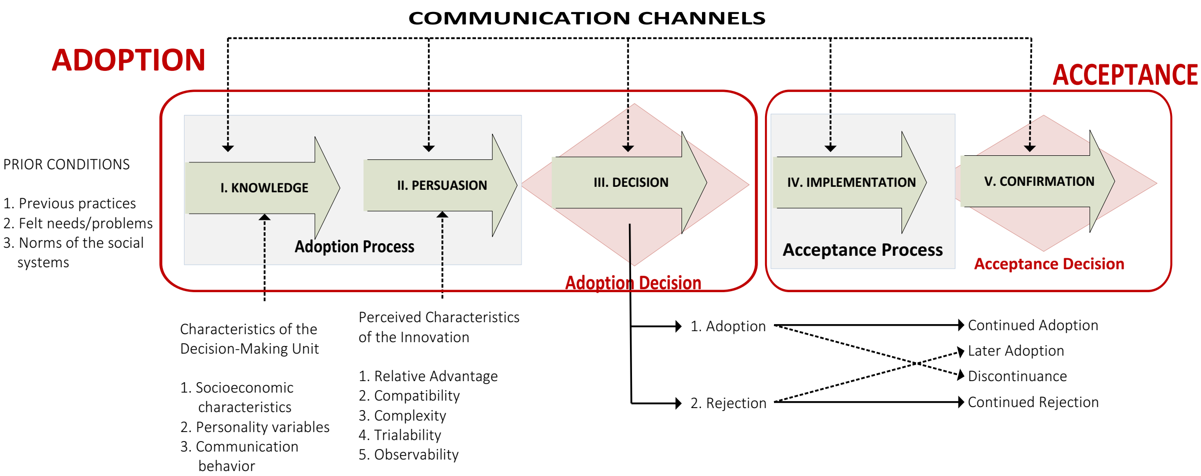

Figure I: Five Stage Innovation-Decision Process (adapted from Rogers 2003:170)

The enhancements from the original diagram shown in Figure II are shown in red and are limited to the following:

i. separation of the process into two parts; Adoption including stage I to III and Acceptance including stages IV and V
ii. highlighting stage III as the "adoption decision" and stage V as the "acceptance decision"

Rather than giving a complete analysis of the innovation-decision process, the next section will be highlighting just some of the concepts for later application in the Case Study analysis:

Prior condition

Prior condition describes some the conditions present in the adopting unit prior to becoming aware of the innovation but which have a bearing on the dynamics of the diffusion, if indeed it does take place. It is further broken down into elements:

i. Previous Practice

This refers to previous practices, consider as standard within the community or participants in the activity. It has a strong relation to other attributes which in turn impacts on the later stages of the diffusion process notably: compatibility and complexity

ii. Felt Needs or problems

This refers to the actual driving force behind someone dissatisfaction or frustration with the *status quo* (Rogers 2003:172). This element is strongly related to relative advantage.

iii. Norms of the social system

Norms are the established behaviour pattern for member of a social system and defines a range of tolerable behaviour (Rogers 2003:26). Although not the same as “previous practice” it also has a bearing on compatibility.

Perceived Characteristics of the Innovation

Perceived characteristics of the innovation includes 5 attributes: relative advantage, compatibility, complexity, trialability and observability. They describe the key parameters that influence both the rate and extent of diffusion. Although the 5 attributes are interrelated imperially, they are conceptually distinct (Rogers 2003:223). For the purpose of the Case Study analysis, on the the first 2 attributes will be discussed:

i. Relative advantage

Relative advantage is the degree to which an innovation is perceived as being better than the idea it supersedes. The nature of the innovation has an impact on the specific type of the advantage whether economic, prestige, efficiency, etc. (Rogers 2003:229).

Diffusion scholars have found relative advantage to be one of the strongest predictors of an innovation’s rate of adoption (Rogers 2003:233).

ii. Compatibility

Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experience, and need of potential adopters. Compatibility is directly related to all three of the “prior conditions”. An idea could be compatible or incompatible in terms of *previous practices*, the *need* or the *norms* of the adopting entity (Rogers 2003:240).

Conceptual System Dynamics model of the innovation-decision process

In an attempt to develop a System Dynamics model which, utilise the constructs of the Diffusion of Innovation model, a series of focus group discussion where held. The groups consisted of 4 experts in the field of technology management, all members of the Graduate School of Technology Management (GSTM) at the University of Pretoria, South Africa.

The result of these discussions is depicted in Figure III below. The conceptual Causal Loop Diagram describes the innovation-decision process with the 2 sub-process corresponding with the separation in Figure II above: Adoption is shown in “blue” and Acceptance in “red”.

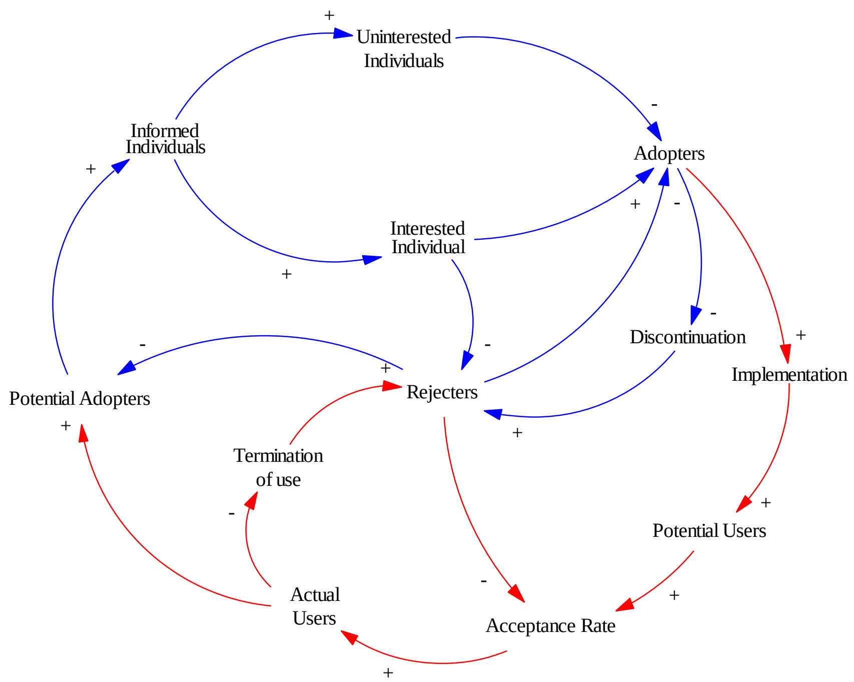

Figure II: Conceptual Causal Loop Diagram for the Innovation-Decision process

With the conceptual causal loop(CLD) diagram as the departing point, the corresponding stock-flow diagram(SFD) shown in Figure IV was developed, describing the key parameters of the Innovation-decision process.

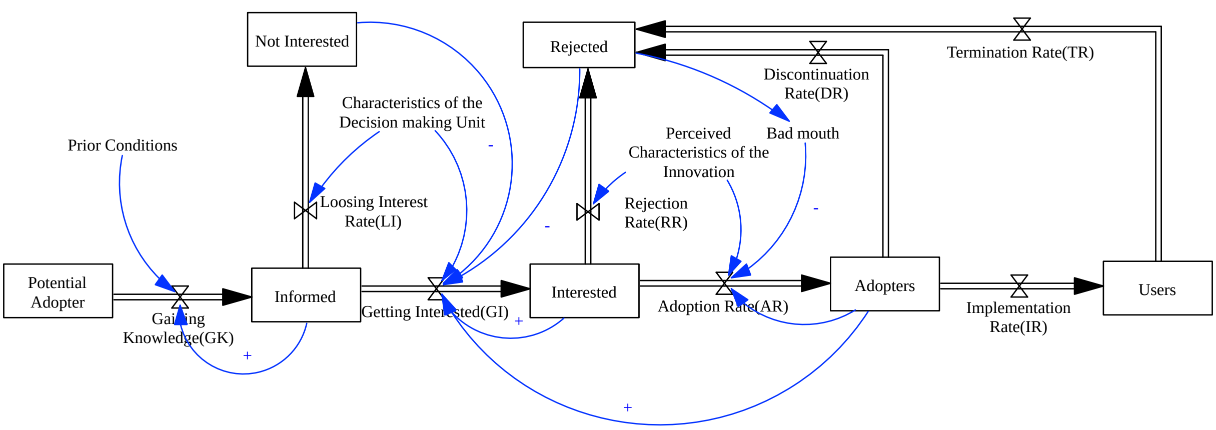

Figure III: SFD of the Innovation-Decision Process

To show the link between the two diagrams for example, the first part of the process is discussed:
In the CLD (Figure III) potential adopter, become informed individuals who in turn can either become interested or uninterested individuals. In the SFD (Figure IV) the stock of Potential Adopters flow into the stock of Informed individuals, through the rate of Gaining Knowledge. This rate is influenced by Prior Conditions. Informed individuals can flow into to the stock of Interested individuals at a rate of Getting Interested. This rate is positively influenced by the Characteristics of the Adopting Unit, the Stock of adopters and the stock of Interested individuals, but it is negatively influenced by the stock of Not Interested and the stock of Rejected individuals.

CASE STUDY: FULL BODY X-RAY MACHINE

Background

The developed of the conceptual model above, was done from literature, combining the knowledge and experience of the focus group. In order to aid in the further development and evaluation of the model, a specific example of diffusion of innovation is evaluated as a case study.

The full body X-ray machine is a unique device produced by the company Lodox (Pty) Ltd (Sandton, South Africa). The specific model is call Xmplar-dr (previously Statscan) and is a diagnostic radiographic Unit (see Figure V), able to produce a single digital full body X-ray of an adult patient – 180cm x 70cm, using a slot scanning technique. It was originally designed to be used in early assessment of trauma patients with multiple injuries, giving attending physician a quick overview of the most important injuries. This allows the team to plan the most appropriate treatment option.(Boffard et al. 2006)

Figure IV: Lodox Xmplar-dr radiographic unit (with permission from Lodox (Pty) Ltd)

The first units were sold in 2004 and to date more than 70 has been sold all around the globe. Although the original application was in Trauma, since 2007 the device has also found application in Forensic Pathology where it is used to scan the body or sometimes human remains retrieved prior to commencement of the autopsy. Since then more than 28 units have been sold for this application, mostly in the USA and South Africa where Medical Examiners and Forensic Pathologist are increasingly relying on the valuable information gained from the X-rays especially tracking and recording foreign bodies like bullets (Knobel et al. 2006).

Interview

An interview was conducted using semi-structured questions related to the application of the innovation-decision process. The participants from Lodox (Pty) Ltd were the Chief Executive Officer (P1), Marketing Manager (P2) and Development Manager (P3). The 120-minute interview was recorded and transcribed. The transcription was analysed using Atlas.ti software. *(Referencing in this article to direct quotation form the interview is inserted in footnotes. The abbreviations shown above is used to indicate the respective interview participant. The researcher's comments and questions are indicated by "R")*

One of the immediate observations from the interview is that the answers to the various diffusion-decision process questions varied depending on each of the applications (trauma or forensics) and each of the markets (public or private in South Africa or in USA). This resulted in the analysis being framed within these market application parameters. For the purpose of this analysis, the contrast between the Forensic Pathology application (here after "Forensic") and the Trauma application (here after "Trauma" segment was selected.

Analysis

Four elements of the innovation-decision process are selected and discussed in terms of its relation to the Lodox case study. In each case the impact of the element on the specific market segment is summarised:

i. Previous Practice

From the perspective of the **Forensic** applications, the Lodox scanner has little to contend with. The application of X-rays in forensic pathology is limited to the occasional use of conventional mobile X-Rays (mobile Radiography) or C-arms (mobile Fluoroscopic Radiography) (Knobel et al. 2006) which has limitation in terms of image quality, it is cumbersome to operate and poses scatter radiation risk to staff[1].

Summary: Absence of well developed previous practice in terms of x-ray imaging means that this element has limited impact. Either neutral or slightly positive towards diffusion.

From the **Trauma** view, previous practice is very relevant and has a significant impact. The standard practice is to use conventional x-ray, normally using an overhead gantry to produce the various dedicated views. Follow-up studies normally involve Computed Tomography Units (CT). This is only done once the patient is stable and a radiographer can "enter the scene" to facility the image acquisition. Lodox turns the entire patient flow

[1] ***P1***: Some of them have C-arms, but it is very finicky. And they do not have peoples that is well trained, ***R***: But a C-arm is not an easy thing to operate.... ***P2***.: I am chasing a bullet that entered here,… ***P1***: and they don't have radiographers. They don't know anything about positioning, ……, and a C-arm is a finicky thing.

around as the Lodox image is obtained while the patient is still unstable and being resuscitated[2].

Summary: Well developed previous practice is strongly opposed to Lodox methodology. The impact is negative towards diffusion.

ii. Felt Need

In the **Forensic** applications, the use of X-rays has been limited. The need for using another modality of acquiring images was not specifically expressed. However, as a result of the Lodox being used in a neighbouring public trauma facility, pathologists were aware of the existence of the technology. When they encountered a specific problem during an autopsy with locating a bullet, the forensic team took the body to the trauma unit and immediately located the object (Knobel et al. 2006). This example seems to be the first documented application of the Lodox scanner in forensics.

Summary: No strongly felt need for a solution but once the knowledge of the solution was obtained, the need became more pronounce. The impact is neutral.

From the **Trauma** viewpoint, the need for rapid assessment of a multi-trauma patient is undoubtedly present. Obtaining a 180cm x 70cm full body x-ray within a minute of the patient arriving in the resuscitation area is invaluable (Deyle et al. 2009).

Summary: Strongly felt need for a rapid method of obtaining an all-in-one picture of multi-trauma patient. The impact on diffusion is positive.

iii. Relative Advantage

For the **Forensic** segment the relative advantage is undisputed (Knobel et al. 2006). The advantages reported include:

- A rapid full body images can be obtained revealing all foreign bodies, even if they were not suspected
- The low radiation means there is no exposure risk for staff
- The unit was found to be easy to use
- The speed at which the procedure is completed means that efficient flow through the department is enhanced

Summary: The relative advantage is clear. The impact on diffusion is positive.

From the **Trauma** perspective, relative advantage is not that easy to determine[3]. Although the obvious advantages described in ii) above, there are some unintended consequences. The private radiology practitioner already owns a conventional x-ray unit as well as a Computed Tomography Unit (CT). Lodox procedures don’t have a uniformly accepted

[2] ***P1***: ..and 2 years later it was found that they never used the machine, …. because they didn't consider changing methodology

[3] ***P2:***….Let first talk Trauma. If I think about the Radiologist and Trauma doctors, the answer is not the same. That is where we got stuck in the beginning. There was no relative advantage clearly shown to the Radiologist. Definitely to a Traumatologist but not to a Radiologist.

fee code[4], so revenue collection is cumbersome. Further more, Lodox use might reduce the need for certain CT procedures which would further erode revenue (Evangelopoulos et al. 2011).

Summary: There is no clear advantage. The impact on diffusion is negative.

iv. Compatibility

The innovation can be described as compatible with the **Forensic** segment. As far as previous practice and norms are concerned, the Lodox scanner is compatible with the adopting unit. The solution also adequately meets the needs of the segment.

Summary: The innovation is compatible with the adopting system. The impact on diffusion is positive.

As for the **Trauma** segment, the innovation can be described as incompatible with previous practice as the workflow or treatment methodology needs to change in order to ensure complete adoption. The solution meets the needs of the segment in that the value of fast, high quality x-rays during trauma assessment, is undisputed. In terms of norms of the adopting unit, the use of Lodox is incompatible with respect to radiologist in private practice, but compatible with traumatologist. This divergence means that to adequately understand the impact of this element, further disaggregation of the applications and market segment would be needed in a future study.

Summary: Compatibility could not be clearly shown. For the purpose of this study, the impact on diffusion is determined to be neutral.

RESULT

The impact of the four elements from the Innovation-Decision Process is summarised in Figure VI below:

		Impact on Diffusion	
Category	Sub-Category	Forensic	Trauma
Prior Condition	Previous Practice	1	-1
	Felt Need/problem	0	1
Perceived Characteristics of the Innovation	Relative Advanatge	1	-1
	Compatability	1	0
	Total	**3**	**-1**

Legend

Positive impact on Diffusion	**1**
Neutral impact on Diffusion	**0**
Negative impact on Diffusion	-1

Figure V: Summary of results

4 ***R:* .. ** Now back to the Radiologist. What do they get for that one scan? What do they get in terms of revenue? ***P2***: That's not been properly defined that they feel comfortable, and are making the same amount of money that they would have….

Although the innovation studied in the two market segments are the same, some significant difference has been show to exist between them. One of the the limitations of this study is that no theoretical basis for the allocation of numeric values towards the scoring system applied in Figure VI is given. The aim however, was to simply show the difference between the two applications with respect to the four elements discussed. The result of “3” for Forensics and “-1” for Trauma indicates that the former is more likely to diffuse than the latter, based on the limited number of elements form the innovation-decision process studied.

Further research would be needed to cover all the element of the innovation-decision process. The result form such a more complete study could then be used to define the parameter values in order to run simulations using the SD model in Figure IV above.

CONCLUSION

The two applications of the Lodox scanner studied, Trauma Vs Forensic services, display significantly different characteristics with reference to the four elements of the innovation-decision process considered in this study. Using the differences extracted through a similar process followed here could assist in unlocking the dynamic processes at play for the entire process.

Extending the study to including all the elements of the the innovation-decision process could provide the data through which configuration of the proposed System Dynamics model, may be completed.

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