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► **To cite this version:**

Sayantana Khanra, Rojers P. Joseph. Orchestration of an e-Government Network: Capturing the Dynamics of e-Government Service Delivery Through Theoretical Analysis and Mathematical Forecasting. International Working Conference on Transfer and Diffusion of IT (TDIT), Dec 2020, Tiruchirappalli, India. pp.219-229, 10.1007/978-3-030-64861-9_20 . hal-03744802

HAL Id: hal-03744802

<https://inria.hal.science/hal-03744802v1>

Submitted on 3 Aug 2022

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Orchestration of an e-Government Network: Capturing the Dynamics of e-Government Service Delivery through Theoretical Analysis and Mathematical Forecasting

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Abstract. Despite the recent growth in e-Government services, there is a paucity of research dedicated to explaining the dynamism of an e-Government network in the extant literature. The process of an e-Government service delivery is vulnerable to changes in the degree of benefits delivered to the public through the e-Government network. Therefore, we developed a theoretical model which is grounded on the actor-network theory, and formulated a mathematical model following the Bass diffusion model to explain the dynamics of various actors within an e-Government network. We also conducted a meta-ethnography study on e-Government maturity models to understand the key benefits of a mature e-Government network. Furthermore, we proposed a technique based on system dynamics modeling, which could aid appropriate authorities in forecasting network stability and monitoring performance of an e-Government network. The study may also aid future researchers, policymakers, and practitioners in conceptualizing the dynamic processes involved in e-Government service delivery.

Keywords: Actor-network theory, Bass diffusion model, e-government service delivery, meta-ethnography, network performance monitoring, system dynamics modeling.

1 Introduction

The United Nations is extensively promoting the use of innovative technologies as effective tools to deliver public services more efficiently and promote social inclusion through participatory decision-making [1-2]. The relationship between technology and society in the context of socio-technical transformations in organizations are explained by two schools of thought [3]. One school of thought focuses on technological determinism, which suggests that technology follows its logic to bring changes in society [4]. Alternatively, the view based on social constructionism argues that society develops the requirement of a technology and determines its role [5]. However, researchers in the field nowadays acknowledge that there is a mid-point between these two schools of thought, which reflects the truer picture, that is, the ability of technology to both enable and restrict transformation in the case of service networks [6-7]. The Actor-Network theory is suitable to explain the dynamics involved in such contexts [6-7]. The theory proposes that mobilization of resources is the key to sustaining the commitment towards a network, and the actors in the network help do so by enrolling allies [8].

Surveys conducted by the United Nations indicate that the efforts by governments to utilize advanced electronic services are increasing in almost every part of the world [1]. The strategic use of innovative technologies to transform government services are called ‘Electronic Government services’ (abbreviated as ‘e- Government services’) and involves the relationships among an arm of government, the citizens it serves, the businesses related to it, and other arms of government [2,9]. The major advantages of adopting e-Government services over the traditional means are redistribution of power from governments at different levels to the citizens, enhancement of the mechanisms for efficient coordination in policy-making and faster information exchange among various stakeholders, promotion and co-production of public services between government and citizens with real-time data, and measurement of collective sentiments of the citizens for the persuasion of appropriate action [9-10].

Arguably, the inherent processes involved in e-Government services are most appropriately represented through a network that helps define and improve the crucial connection between a citizen and the Government [7]. However, the conceptualization of interactions among relevant factors of an e-Government network is scarce in the extant literature. The present study addresses this research gap by developing a theoretical model. Based on the extant literature, the actor-network theory is found to be appropriate for providing a conceptual foundation to meet this objective [7]. We base this argument on the premise that for an e-Government network, enrollment rate among the potential users would depend on the perceived benefits of e-Government services by an actual user of the service [10].

We developed a conceptual model with the help of the actor-network theory, to report the interaction

among relevant factors of an e-Government network. To complete the model, the key benefits of e-Government services are identified following a meta-ethnography approach proposed by Noblit and Hare [11]. This approach is widely adopted when it is required to translate a concept from one study to its counterpart in another based on the interpretation of findings from multiple studies [3]. Furthermore, a mathematical model is formulated to forecast the dynamism of important factors in the conceptual model with the help of the Bass diffusion model [12], which is widely followed in the literature related to technology forecasting to understand the interaction between the current and potential adopters of a new technology [7]. This model classifies adopters into innovators and imitators based on their timing of adoption and their degree of innovativeness [12-13].

The rest of the paper is organized as follows. The second section of this paper provides a concise background of the actor-network theory and its application to an e-Government network. A meta-ethnography study of the e-Government maturity models is presented in the third section. Section four is dedicated to discoursing the formulation of a mathematical model that forecasts the dynamism of important factors in an e-Government network. The operating principle of the mathematical model and the possibility to apply the system dynamics modelling technique are discussed in the fifth section. The sixth section presents a brief discussion on the theoretical and practical implications of the study. Finally, the paper is concluded in the seventh section with the suggestions for future research in the domain.

2 Theoretical Background

The actor-network theory conceptualizes that the process of building and changing networks depends on the actors who spread positive or negative words about solutions among their peers [8]. A network of actors observes two phases, namely translation and transformation (see Figure 1) [14]. Actors in the translation phase translate to actors outside the network the benefits of being inside the network, or otherwise [15]. In other words, actors within a network try to enroll more allies to it and eventually, the more the number of allies enrolled to the network, the more durable and irreversible the network would become [15]. On the other hand, the transformation phase captures the dynamic behavior of a network through stocks and flows [14, 16]. The stocks present the pool of certain resources at a particular time, while flows from one stock to the next one in the network determine the changes in those stocks [16].

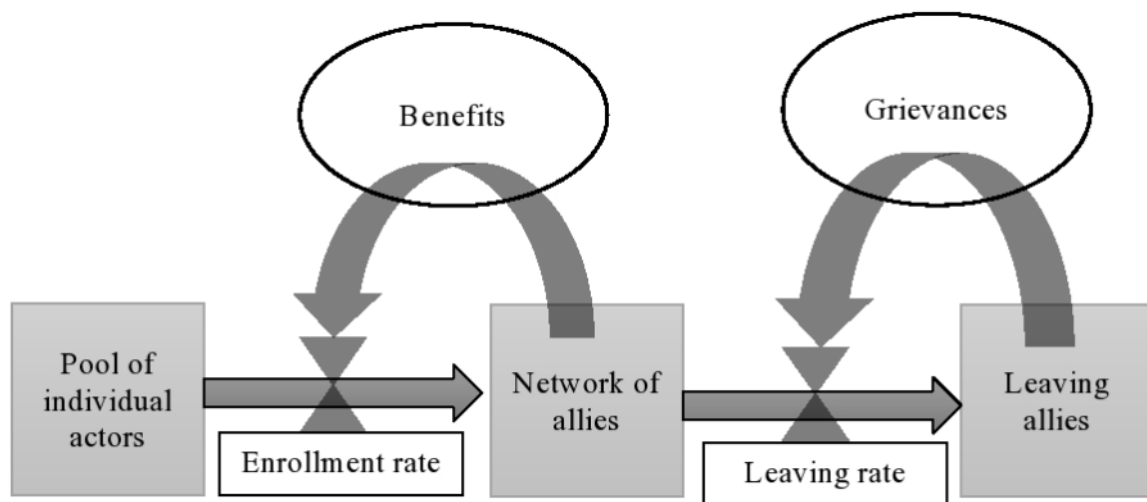


Figure 1: An Illustration of an Actor-network

E-Government networks are reportedly dynamic and vulnerable to changes following the entry or leaving of an actor and subsequently, some networks turn out to be more stabilized than the others [15]. Here, we have two stocks that represent the potential users and the actual users and the flow from the first stock (potential users) to the second stock (actual users) is controlled by the enrollment rate. The benefits of e-Government perceived by an actual user, who may either stay in the network or leave the same, potentially influence his/her peers' decision to join the network.

Following Kirkwood [17], the enrollment process is conceptualized in Figure 2. The other part of the network is developed from the service providers' perspective and contains the stocks of offline Government services and e-Government services. The flow from the first stock (offline) to the second stock (e-Government) is controlled by the implementation rate. The implementation process is also presented in Figure 2. Thus, the benefits of e-Government have impact on both the flows in the network, that is, the enrollment rate and the implementation rate. This warrants further investigation to study the benefits of an e-Government network and identify the key components of the same.

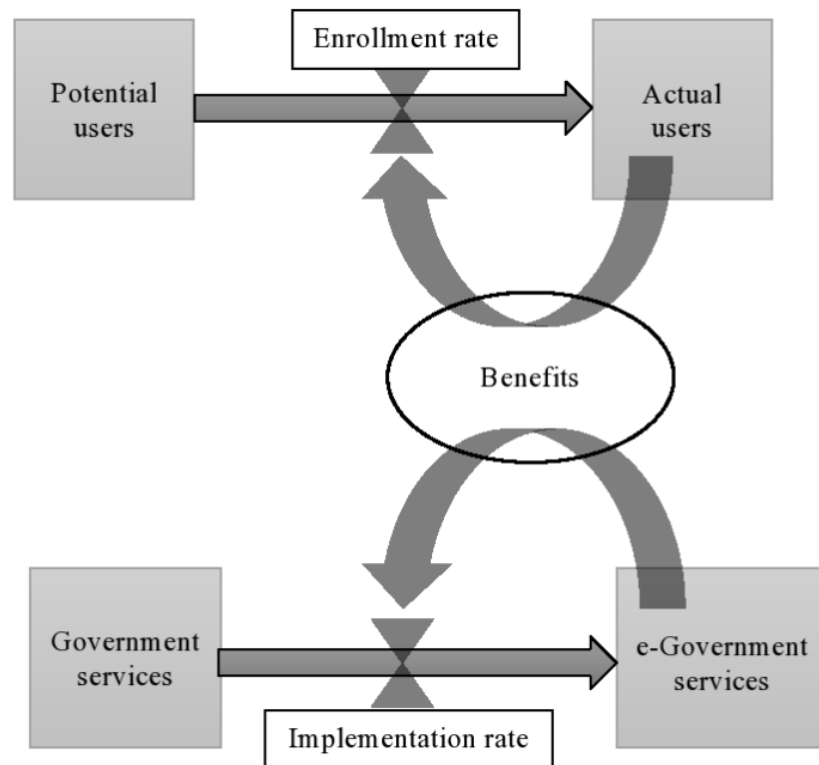


Figure 2: An e-Government Network

3 Meta-ethnography Study

A maturity model provides a structured guide to the development of capabilities in a domain to achieve the required objectives of an organization [3]. The maturity models for e-Government services are scattered among various outlets such as academic journals, annual reports, books, and conference proceedings. To fill this gap, we conducted a meta-ethnography study on the available maturity models for e-Government services to identify the key benefits of a mature e-Government network. Meta-ethnography is a thorough qualitative synthesis method to select, analyze, and interpret studies from the literature related to a focused research objective in order to deliver new insights that complement the extant literature [11, 18].

The rigorous method followed by Khanra et al. [19-20] in identifying resources is adopted here. A total of 27 maturity models were selected and analyzed in the study. Following this, the key focus areas or constructs in different stages of the maturity models under analysis were interpreted. Then, the constructs of one maturity model are translated into that of another, and vice versa, based on the interpretation of the explanation provided for each of the constructs. From the meta-ethnographic analysis and interpretation, the constructs were assigned to five distinct clusters, as reported in Table 1. It may be noted that the synthesisation process prioritizes the knowledge offered by the constructs over the difference in opinion among the researchers about their appearance. Therefore, different constructs appearing in different stages of different maturity models may belong to the same cluster.

To concisely report our findings, we noted down the definition(s) and explanation(s) provided for each

construct within a cluster. Constructs belonging to the same cluster provide similar, if not identical, information about their meaning. Thus, we refined the information by eliminating repetitive points within each cluster. Then, we summarized the filtered information such that it defines or explains the constructs of the five clusters as presented in Table 1.

Table 1. Benefits of e-Government services

Feature	Details
Cluster 1: Online Presence	Static information about Government policies and services is available. The information should be updated regularly and organized efficiently. Downloadable forms may be available for certain e-Government services.
Cluster 2: Facilitating Interaction	A two-way communication channel is established via e-mails and online chat rooms to exchange information between the users and the Government agencies. Advanced services like personalisation options, search options, push notifications, email alerts and uploading documents may be available. The users may provide feedbacks and comments on issues related to a service as well as various rules and regulations concerning the service.
Cluster 3: Integrated Ecosystem	Vertical integration process involves integration of systems at various levels within a department or jurisdiction. Horizontal integration process refers to inter-departmental data sharing. Full integration yields a portal for all e-Government services or a 'one-stop-shop' for joined-up services. Multichannel integration i.e. a blend of online and offline services is also desirable.
Cluster 4: Online Payments	Users should be able to perform complete transactions online which often includes a requirement for payment. Online payment gateways are to be included in the e-Government services so that the users can easily perform financial transactions as per the requirements of those services. There may be a possibility of accepting electronic payments by the users, particularly in the case of e-procurement by the Government.
Cluster 5: Participatory e-Democracy	The users may participate in online discussion within forums that are openly accessible to all. They may take part in anonymous opinion surveys to provide input for policy and legislation proposals. Eligible citizens may cast their votes online.

The clusters are named as 'Online Presence' [B_1], 'Facilitating Interaction' [B_2], 'Integrated Ecosystem' [B_3], 'Online Payments' [B_4], and 'Participatory e-Democracy' [B_5] based on the benefits they offer. Therefore, the benefits of e-Government [B] at a particular time [t] may be expressed as the sum total of five dimensions, as shown in equation 1. The dimensional benefits [B_i] of an e-Government network are normalized with respect to a reference time when the network was launched [$t=0$]. Therefore, B_t actually measures the improvements in the benefits provided by an e-Government network over time t .

$$B_t = \sum_{i=1}^5 B_{it}; \text{ where } B_{it} = (B_{it} - B_{i0}) / B_{i0} \text{ and } B_{i0} > 0 \quad (1)$$

Upon updating Figure 2 with the findings from the meta-ethnography study, we get the theoretical model to understand an e-Government network, as exhibited in Figure 3.

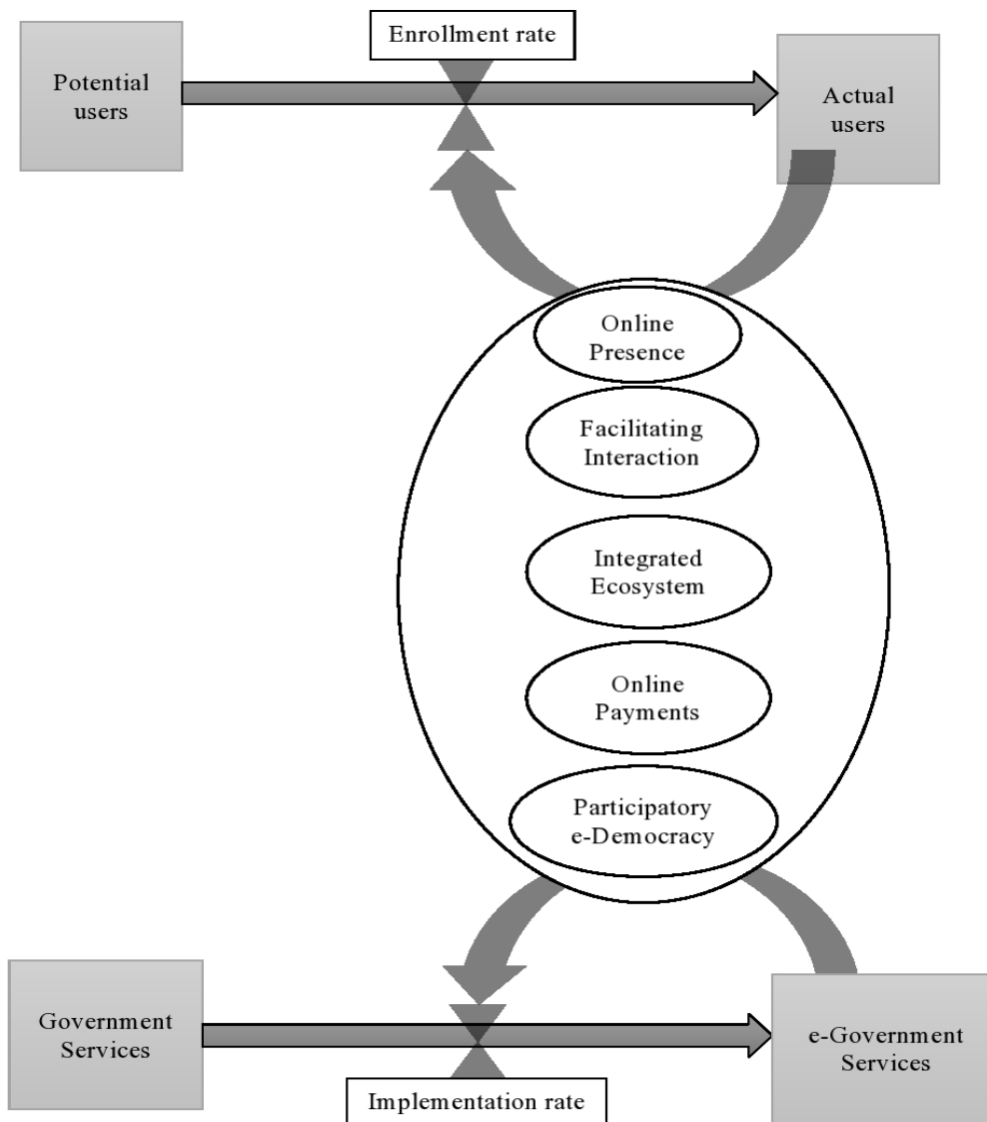


Figure 3: The Theoretical Model

4 Mathematical Model Development

An essential property of a dynamic model is that the conditional probability of technology adoption at a certain point [time = T] depends on the cumulative adoption at time T [12-13]. The Bass diffusion model resonates with the property of actor-network theory by incorporating knowledge about the actors' behavioral process in a dynamic model's parameters [7]. Therefore, the proposed theoretical model may be best complemented by a mathematical model based on the Bass diffusion model [12], where the model parameters include the knowledge about the dynamism of an e-Government network. The Bass diffusion model is defined by a function, $F(T)$, for the total number of adoptors at time T from a likelihood function, $f(t)$, as shown in equation 2 [12]. The likelihood of adoption at time T is partly driven by the innovators and partly by the imitators, where p and q (generally $q > p$; $p, q > 0$) are the coefficients of innovators and imitators, respectively. Equation 3 defines the rate of change in $F(T)$. The solution to this non-linear differential equation is presented in equation 4. Thus, we arrive at the function of $f(T)$ in equation 5, from which the maximum value of $f(T)$ can be determined, as reported in equation 6.

$$F(T) = \int_0^T f(T); \text{ where } f(T) = [p + qF(T)][1 - F(T)] \text{ and } F(0) = 0 \quad (2)$$

$$\frac{dF(T)}{dT} = p + (q - p)F(T) - q[F(T)]^2 \quad (3)$$

$$F(T) = \frac{1 - e^{-(p+q)*T}}{1 + \frac{q}{p} e^{-(p+q)*T}} \quad (4)$$

$$f(T) = \frac{(p+q)^2}{p} e^{-(p+q)T} \left[1 + \frac{q}{p} e^{-(p+q)T} \right]^2 \quad (5)$$

$$f_{max}(T^*) = \frac{(p+q)^2}{4q}; \quad T^* = \frac{1}{(p+q) \ln \left(\frac{q}{p} \right)} \quad (6)$$

Considering the case of user enrollment, p_{1T} gives the co-efficient of users who join an e-Government network without the influence of others (see equation 7) and q_{1T} represents the co-efficient of users who join the network after the actual users translate the benefits of e-Government to them (see equation 8), where G_{uT} denotes the historical growth in enrollment and ε_1 denotes the effectiveness of translation phase. Following equation 3, the enrollment rate is expressed in equation 9. Further, the stock of actual users and the likelihood of enrollment are forecasted in equations 10 and 11, respectively.

$$p_{1T} = G_{uT} * U(T) \quad (7)$$

$$q_{1T} = \varepsilon_1 * B_T * U(T) \quad (8)$$

$$\frac{dU(T)}{dT} = p_{1T} + (q_{1T} - p_{1T})U(T) - q_{1T}[U(T)]^2 \quad (9)$$

$$\hat{U}(t) = \frac{1 - e^{-(p_{1T}+q_{1T})*t}}{1 + \frac{q_{1T}}{p_{1T}} e^{-(p_{1T}+q_{1T})t}} \quad (10)$$

$$\hat{u}(t) = \frac{(p_{1T} + q_{1T})^2}{p_{1T}} e^{-(p_{1T}+q_{1T})t} \left[1 + \frac{q_{1T}}{p_{1T}} e^{-(p_{1T}+q_{1T})t} \right]^2 \quad (11)$$

A similar exercise is carried out for the service implementation part of our theoretical network. The stock of e-Government services and the likelihood of implementation may be forecasted following equations 12 and 13, respectively.

$$\hat{S}(t) = \frac{1 - e^{-(p_{2T}+q_{2T})t}}{1 + \frac{q_{2T}}{p_{2T}} e^{-(p_{2T}+q_{2T})t}} \quad (12)$$

$$\hat{s}(t) = \frac{(p_{2T} + q_{2T})^2}{p_{2T}} e^{-(p_{2T}+q_{2T})t} \left[1 + \frac{q_{2T}}{p_{2T}} e^{-(p_{2T}+q_{2T})t} \right]^2 \quad (13)$$

5 Implementation of Mathematical Model

The equations expressing the enrollment rate and the implementation rate provide an important insight with regard to the growth of stocks. The respective equations indicate that the enrollment rate and the implementation rate slow down as $U(T)$ and $S(T)$ grow. These phenomena may be understood with the help of the system dynamics modeling technique, which primarily refers to the principle of accumulation (Shin, 2007). With the help of this technique, a causal loop diagram consisting of two feedback loops is conceptualized to explain the dynamism of the enrollment rate (Figure 4). Similarly, the feedback loops for the implementation rate is presented in Figure 5. The feedback loops contributing to the net positive and net negative effects are known as reinforcing loop (R1 and R2) and balancing loop (B1 and B2), respectively [17]. These two loops stabilize the rate of change, as they interact by exerting opposite effects of the desired intensity in order to achieve equilibrium in a network [17].

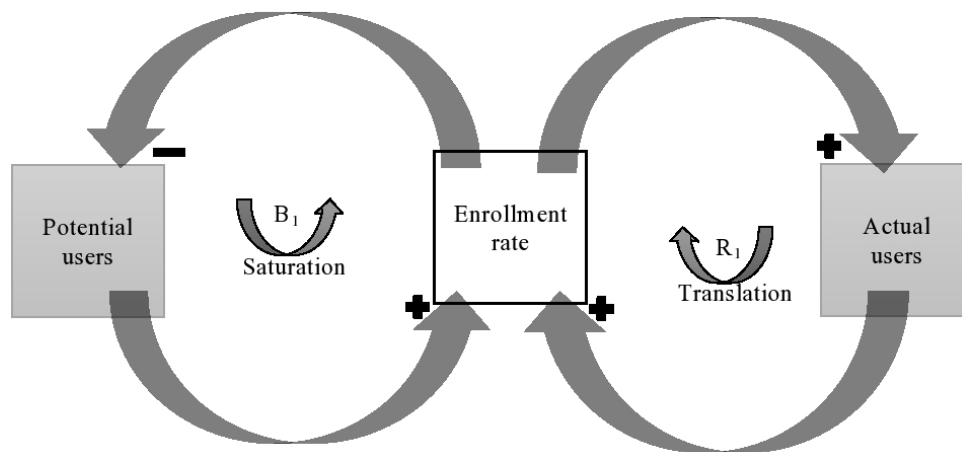


Figure 4. Causal Loop of User Enrolment Process

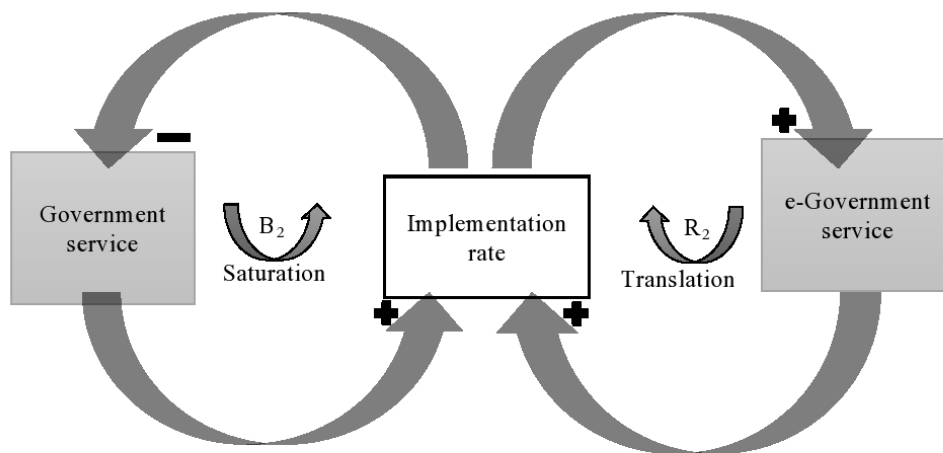


Figure 5. Causal Loop of Service Implementation Process

6 Discussion and Implications

The objective of this paper is to model the dynamics of an e-Government network, which is fulfilled through theoretical and mathematical models. These models are among the earliest ones to analyze and forecast the dynamics of an e-Government network, and hence, this paper yields important theoretical implications on three aspects. First, the theoretical model may contribute towards a better understanding of the dynamism of an e-Government network. Second, the theoretical model is complemented with mathematical equations to forecast the dynamism of important factors in the network. Third, in the process of developing the theoretical and the mathematical models, a meta-ethnography study is conducted, which identified five key dimensions to analyze the benefits provided by a mature e-Government network.

This study extensively discusses how the important attributes of an e-Government network could be forecasted. Since the mathematical model is easy to use once calibrated, this study may appeal to the policymakers and service developers interested in forecasting the important factors in an e-Government network. Thus, the models developed by this study may help the government organizations continue delivering more efficient services and improve the positive social impact of e-Government by better utilization of the network in the long run. Moreover, the provision to use system dynamics modelling technique may make the operation of the mathematical model easier. Hence, continuous assessment of an e-Government network using system dynamics may help the government agencies sustain their operations over time.

7 Conclusion and Future Scope

On critically evaluating the study findings and obtaining expert opinions on the same, four limitations of this study are identified, and consequently, the future scope of this research is suggested. First, the paper only modelled the users' and service providers' perspectives. A future study may incorporate the service developers' perspectives in the theoretical and mathematical models. Second, in our models, we did not classify the pool of users based on different demographic attributes. Also, the purpose of using e-Government may vary among different clusters such as students, entrepreneurs, and senior citizens. Third, we did not differentiate government services based on their nature and scope. Future studies may consider examining specific clusters of services such as health services, educational services, business services, and so on, to address this limitation. Fourth, we considered the estimation of the coefficients of effectiveness beyond the scope of this paper. Interested researchers may explore the latent variables that influence these coefficients using methods such as experimental design and longitudinal study. Despite the aforementioned limitations, this study assumes importance in modelling the dynamics of an e-Government network by using theoretical analysis and mathematical forecasting, thereby making significant contributions to the literature on e-Government services.

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