A Simulation Modelling-Based Investigation of the Impact of IT Infrastructure on Business Process Reengineering

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The literature on business process reengineering (BPR) has promoted business process reengineering as an essential element in helping organizations to achieve their goals. The literature has further claimed that Information Technology (IT) is a major enabler of business process reengineering. Despite all these claims, there has been hardly any effort to demonstrate the interrelationship between business process and information technology infrastructure, and which modeling technique can be used to demonstrate the relationship. This paper investigates how simulation modeling can demonstrate the impact of IT infrastructure on business process. The dynamic synthesis methodology is used with data collected from five commercial banks. The same collected data is used to validate the model. The results indicate that network infrastructure and data integration were significantly related to the process improvement thrust, such that network infrastructure is critical in improving business processes and enhancing customer service.

Categories and Subject Description: H [Information systems], H.1 Models and Principles, H.1.1 Systems and Information Theory – General system theory; I [Computing methodologies], I.6 Simulation and modeling, I.6.1 Simulation theory, I.6.4 Model validation and analysis, I.6.5 Model development, 1.6.6 Simulation output analysis
General Terms: Modeling, Simulation, Business process reengineering
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1. INTRODUCTION

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Since the 1990s there has been a growing research interest in business process reengineering (BPR), also referred to as business process innovation (Davenport, 1993; Hammer, 1990 and Davenport and Short, 1990). The BPR-paradigm, defined as the radical redesign of business processes enabled by information technology (IT) in order to achieve dramatic improvements in their performance (Hammer, 1990), has been described abundantly in managerial journals (Earl, 1994; Hall, 1993; Hammer, 1990, Davenport and Short, 1990). Several management concepts, principles, guidelines, checklists and step approaches have been proposed to demonstrate how to make BPR work. In spite of all these, many BPR projects have failed. Mistakes are realized after the redesigned processes are implemented, and it is too late, costly, and difficult to reverse the situation (Hlupic and Robinson, 1998). To minimize the impact of these failures, simulation modeling has been used to identify the bottlenecks in the processes and to think of various alternative solutions before implementation. Simulation models can provide graphical display that can interactively be edited and animated to demonstrate the dynamics of the processes.

Although the technological environment has been changing since the industrial revolution, there has been little or no effort to show the imminent interrelationship between Business process and Information Technology infrastructure. Many have argued that IT infrastructure has little or no impact on business process both intra and inter-organization
(Attaran; 2004, Lee, 2004; Meel, 1995; Davenport, 1993). Furthermore, despite the many simulation environments that allow organizations to model both elements, there has been no attempt to model and identify the impacts and changes that one variable will have on the other (Painter, 1996). This paper investigates how simulation modeling can demonstrate the impact of IT infrastructure on Business Process Reengineering. The paper starts by discussing business process reengineering and IT infrastructure, followed by simulation modeling and system dynamics, conceptual model and hypothesis, methodology, results and discussion, and lastly model validation before the conclusion.

2. BUSINESS PROCESS REENGINEERING AND IT INFRASTRUCTURE

There are several literatures on business process re-engineering that support business processes as an essential element for organizations to achieve their goals (Ray and Serrano, 2003). How the business processes are designed and deployed determine the profitability and performance of the organization. BPR makes the business process efficient, effective and flexible. It is designed to meet and often exceed customer expectations. For an organization to maximize benefits from business process re-engineering, information technology plays a big role.

The IT infrastructure has been defined as the extent to which data and applications through communication networks can be shared and accessed for organizational use (Broadbent et al, 1999; Wyse and Higgins, 1993). The main purpose of IT infrastructure is to provide consistent and quick information support to the organization so as to respond to the dynamic changes in the market.

The IT infrastructure and BPR are interdependent in the sense that deciding the information requirements for the new business processes determines the IT infrastructure constituents, and recognition of IT capabilities provides alternatives for BPR (Ross, 1998; Venkatraman, 1993). Building a responsive IT infrastructure is highly dependent on an appropriate determination of business process information needs, which is based on the various activities in the business processes.

3. SIMULATION MODELING AND SYSTEMS DYNAMICS

The increasing popularity of simulation has resulted in its widespread use for modeling and analysis of systems in various application areas, such as manufacturing, transport, logistics, communication networks, health and military. Shannon (1975) has defined simulation as the process of designing a model of a real system and conducting experiments with this model for the purpose, either of understanding the behavior of the system or evaluating various strategies (within the limits imposed by the criterion or set of criteria) for the operation of the system. Simulation models provide a potentially powerful tool for conducting controlled experiments by systematically varying specific parameters and rerunning the model (Tumay, 1995).

System Dynamics (SD) enables a company to look beyond individual issues towards a broader perspective. SD uses computer simulations to create knowledge based on the data and information available. Computer simulations performed at different time intervals, generate results which can help in forecasting, solving problems and developing policies. Some of the benefits of simulation are the possibilities of exploring new policies, operating procedures and many others, without disrupting on going operations, and the ability to gain insights into system variables.

4. CONCEPTUAL MODEL AND HYPOTHESIS DEVELOPMENT

Figure 1 presents the conceptual model of the underlying hypothesis proposed in this paper. It shows the interaction and relationship of variables using cause and effect analysis that determine the behavior of variables over time. It contains four dominant feedback loops of which 3 are reinforcing (R) and the other one balancing loop (B)

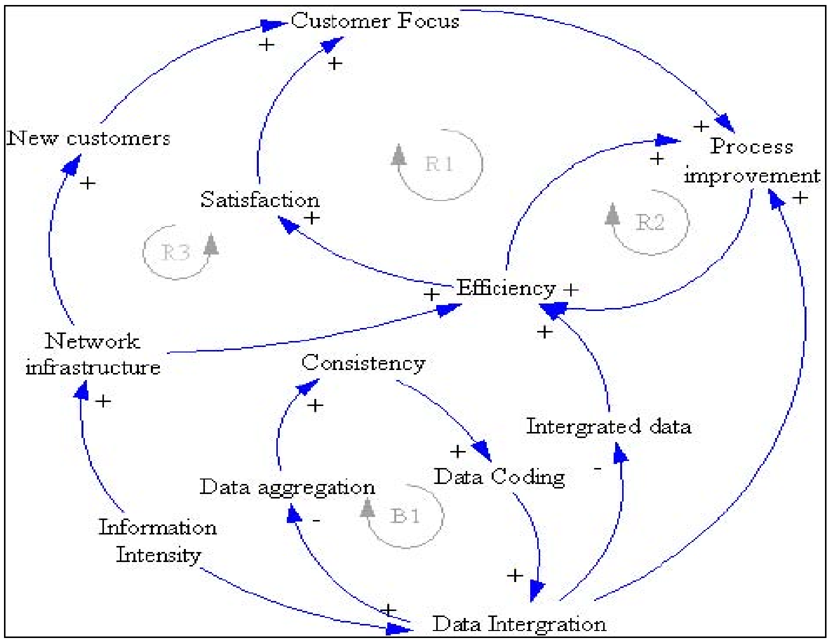

Figure 1: Conceptual Model

The model has four major variables to assess the impact of IT infrastructure on business process reengineering. Firstly, the network infrastructure that focuses on the integrative capability to coordinate different and disparate functions and activities. It helps in sharing IT resources within and across the boundaries of a firm. The measures include flexibility, connectivity, efficiency, accessibility, effectiveness and design. Secondly, the process improvement thrust which is the driving force of data integration, information intensity and network infrastructure on business process redesign. The measures include change, efficiency, coordination, flexibility, accuracy, response time and reliability.

Thirdly, data integration which is the standardization of data definition codes, and formats that allow organizations to easily manage their activities and compare their performance with similar and comparable functional units (Goodhue et al, 1992). The introduction of a shared-access database often introduces new ways of working, as many sequential processes can be handled in parallel (Barua and Lee, 1997). The measures are data coding, data consistency, accuracy and timeliness. And lastly, customer focus that looks at activities directed towards meeting and often exceeding customer expectations. It involves tracking of customer complaints, and the causes of their dissatisfaction, and subsequently corrects the root cause of customer dissatisfaction so they can provide innovative products and services (Davenport, 1993). The measures are quality of product or service, response rate, reliability, and innovativeness.

5. HYPOTHESIS DEVELOPMENT

The justification for each variable and the derived hypothesis are presented below. Information intensity of the industry and type of service are two moderator variables included in the study. The type of service, at firm-divisional level, is categorized into portfolio banking and general banking and currency. Information intensity of the industry is defined as the extent to which products and services of the divisions are dependent on information (Glazer, 1991). Complex services, such as the long-term mortgage and credit facilities extension, require a lot more information than those of simple services, such as deposit and withdraw of money. Moreover, in the operation of complex services, the contents of information also increase, as customer requirements become quite specific. In some cases, increasing information contents in the services enable customers to order for customized services, thus creating the need to capture, store, and manipulate customer-related information.

Research Hypothesis 1

The strengths of network infrastructure in regard to business lie in its integrative capability to co-ordinate different and disparate functions and activities (Davenport 1993). For example, electronic mail, video conferencing and computer to computer links such as Electronic Data Interchange increases not only the support to organizational processes by increasing the range and depth of information about business activities but also make it feasible for team members to co-ordinate their activities synchronously (across time zones) and geographically (across remote locations) more easily than ever before (Rockart and Short, 1991).

H1. *Higher level of networks infrastructure is associated with higher level of process improvement thrust.*

Research Hypothesis 2

Data integration solutions are very common in corporate and governmental organizations, where they continually acquire, merge, and transport data. When central management recognizes the interdependence of multiple units within the same function, it often enforces standards of data definition and data coding to co-ordinate activities for higher performance (Davenport, 1993).

It is presumed among many researchers that data integration is beneficial to a point of integrating disparate business processes, but beyond that data integration may not be useful (Goodhue *et al*., 1992). However, several studies argue that as the firms begin to become familiar with data integration methodologies, businesses will move toward a better fit between business planning and IS planning. For example, Teng et al (1995) reported that the key for aligning business planning with IS planning is related to the ability of the firm to plan for integrated databases. Furthermore, Richardson *et al*. (1990) in a case study with Texaco and Star Enterprises found the importance of data integration in businesses. They argued that data needs should be managed as corporate asset and data planning should be integral part of business process improvement.

H2. *Higher level of data integration is associated with higher level of Process improvement thrust*

Research Hypotheses 3 and 4

Some organizations generate a lot of information in their operations and are likely to make use of sophisticated IT infrastructure to meet customer demands in products and services (Glazer, 1991). Tasks and activities which were information intensive are affected by the use of IT, and often need high level of IT support to satisfy customer demands in products and services. Moreover, in higher information intensive environments, companies need a higher level of IS support for customizing products or services to meet customer demands (Glazer, 1991).

H3. *The greater the degree of information intensity of the industry, the stronger the effect of networks infrastructure on process improvement thrust*

H4. *The greater the degree of information intensity of the industry, the stronger the effect of data integration on process improvement thrust.*

Research Hypothesis 5

Many practitioners believe that the critical advantage of IS networking lies in its integrative capability. By integrating different core tasks and departments, a company can take advantage of efficiency and effectiveness (Davenport, 1993). The activities that were done serially can be done in parallel, reducing the cycle time by as much as 80 percent (Stalk and Hout, 1990). According to Boynton (1993), the creation of information architecture serves as a flexible structure to access and handle the rapidly changing demands of businesses. Systems built around information architecture provide enough flexibility to adapt to new products and production processes.

Railing and Housel (1990) in his study with TWRs space and defense sector found that the integrated communication networks offered advantages through quick response, cost reduction and fast decision making. Likewise, Kriebel and Strong (1984) in a survey of 48 firms found that the leading edge firms made more use of integrated systems as compared to the low-end firms. In a study of the insurance firms, Venkatraman and Zaheer (1990) found positive effects of electronic integration in the property and casualty market. Furthermore, Hall and McCauley (1987) reported that well integrated communication systems were related to product cycle time reduction, customer satisfaction and proactive management response.

H5. *A higher level of network infrastructure is associated with a higher level of customer Focus*

Research Hypothesis 6

There is a need for accurate, precise, and timely information when dealing with customers. Businesses aim at finding out customers requirements but turning these requirements into products and services requires a change in management philosophy. Scheter (1992) noted that to satisfy the timeliness constraint, inspecting and testing of products or processes must be done promptly. Accumulation of old data is often useless and mislead about the current problems. An integrated database support offers flexibility in collecting relevant data and analyzing problems quickly. At the same time, data integration reduces data redundancies and inconsistencies in customer information.

H6. *The greater the degree of information intensity of the industry, the stronger the effect of data integration on customer focus.*

6. METHODOLOGY

The methodology applied a systems dynamics approach based on the dynamic synthesis methodology (DSM) as the framework for analysis, model building and simulation (Williams 2002), to assess the impact of IT infrastructure on business processes. This was an iterative research process that covered: problem statement, field study, system dynamics model building, case studies, simulation experiments and model use, and theory extension, as described and illustrated by Williams (2002).

Dynamic Synthesis Methodology (DSM) refers to the integration of theoretical concepts and structuring of parts and elements of a process overtime in such a manner to form a formal functional entity by synthesis as a philosophy of science. Synthesis is an attempt to fuse the findings of various branches of science into coherent view, in order to explain why things operate the way they do (Williams, 2002).

The study combined a case study research method and system dynamic modeling approach as they provide the qualitative information that is used to understand the problem domain in the more detail.

The study was conducted in five commercial banks that were purposively selected due to their willingness to participate in the study, and were at the same time interconnected on the Bankom network. The principal data collection instrument was the questionnaire which was administered to 100 purposively selected IT personnel and middle level managers. The questionnaire was followed up with interviews. The Cronbach Alpha model of internal consistency was applied to establish the reliability of the instrument. An alpha of 0.9194 was generated which confirmed reliability of the instrument. On the other hand, to determine the validity of the instrument and its items, a Content Validity Index (CVI) was used and a CVI of 0.92 was generated which confirmed that the properties of measurement scales and the items of the instrument were reliable and acceptable since the CVI was greater than 0.5 (Grant and Davis, 1997; Rubio et al, 2003). The questionnaire administration was followed by interviews.

The causal loop diagram (CLD) in Figure 2 was created using the Vensim PLE software. The CLD is a tool that is used to identify, analyze and communicate feedback loop structures. It helps to understand the cause and effect variables, and how changes manifest in the problem whether positive or negative. The Stock and Flow diagram in Figure 3 was developed with the STELLA (version 8.1) software It was constructed from the causal loop diagram.

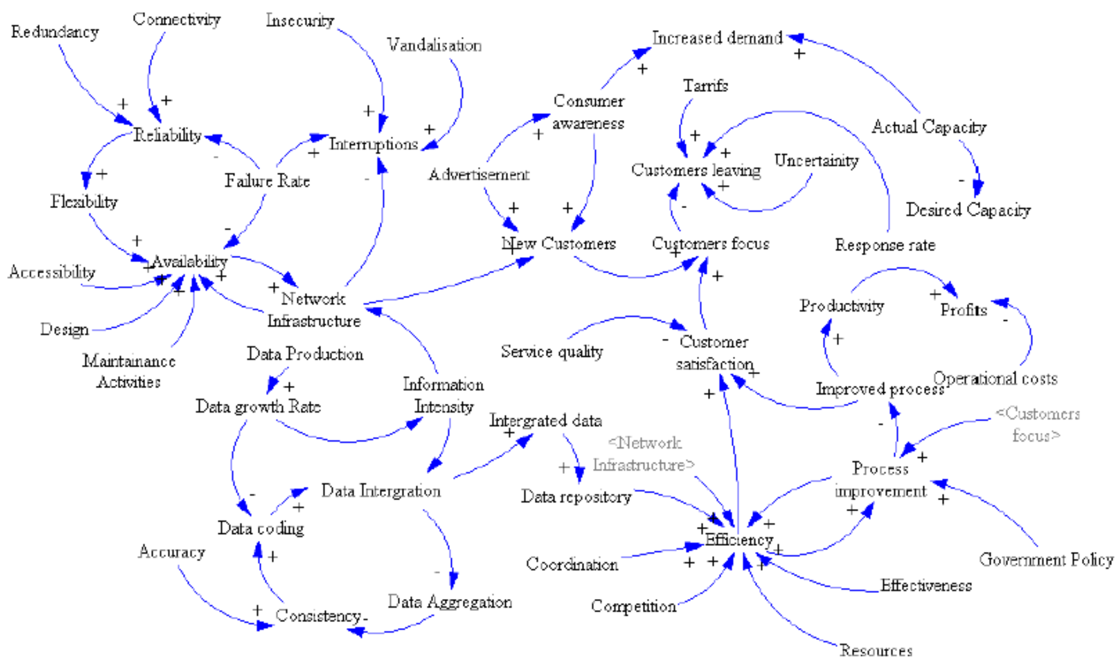

Figure 2: Causal loop diagram

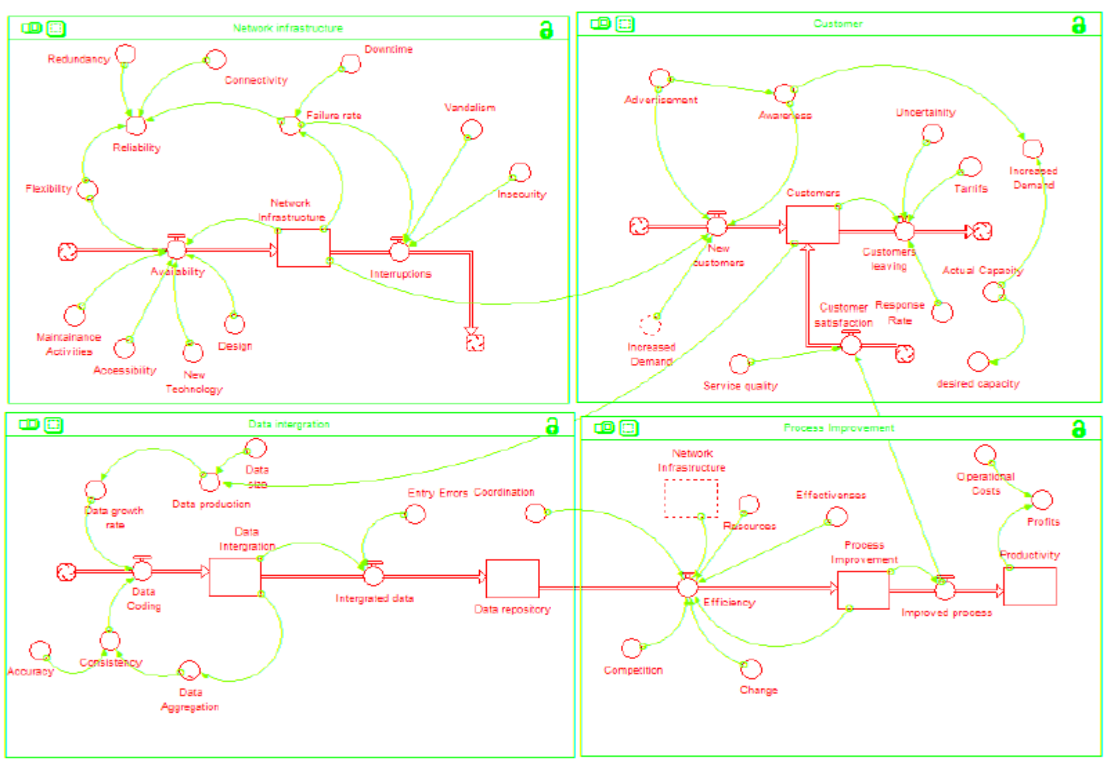

Figure 3: Stock and flow diagram

7. RESULTS AND DISCUSSIONS

The results from the simulation are discussed below together with the validation of the model.

Simulation results
Six key variables were used in generating the simulation results that were defined in the dynamic hypothesis. The figures 4, 5, and 6 present the simulation outputs based on the model.

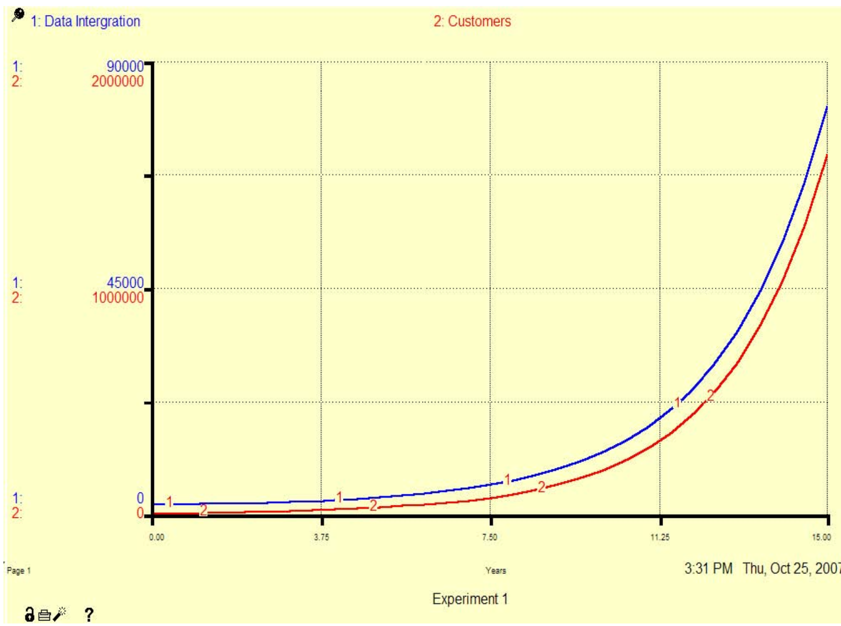

Figure 4: Simulation Experiment 1

The first simulation of the model examined data integration and customer focus. One observes a behavior defined by one of the key propositions in the dynamic hypothesis that a higher level of data integration (curve 1) leads to a higher level of customer focus (curve 2). In the first 4 years the number of customers is low at about 20500 customers, likewise not much data is integrated, in the later years as the number of customers grows as a result of improved service delivery because of the introduction of new technologies, integrated data from both the new customers and old ones steadily rises in the subsequent years. It can be observed that towards the 15th year customer growth continues to rise because the integration of data makes service provision much more effective and efficient and this leads to customer satisfaction and continued customer inflows. Also this is because the need for accurate, precise, and meaningful information is indispensable in customer focus by integrating core tasks and departments, banks can take advantage of efficiency and effectiveness. The creation of information architecture serves as a flexible structure to access and handle the rapidly changing demands of customers, because networks offer advantages through quick response, and cost reduction, this in turn lead to an increase in customer focus.

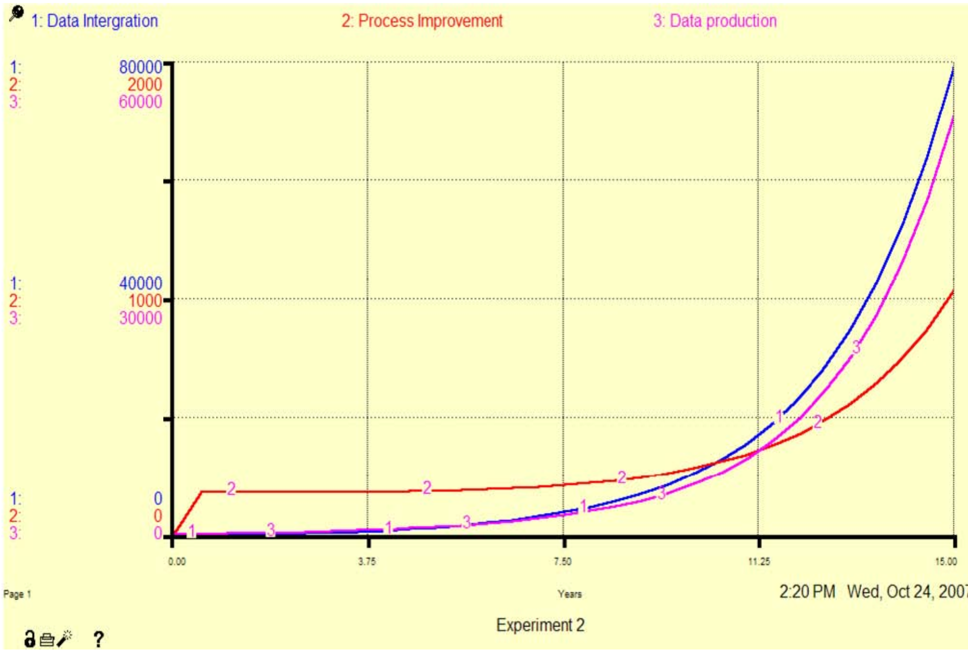

Figure 5: Simulation Experiment 2

The second simulation examined data integration, process improvement and data production. The simulation output shows, a rise in data production (curve 3) as a result of the increasing number of customers. Due to the need to access services from different points, there is a need for data Integration (curve 1) which makes it possible to have shared access to data bases. One also observes that process improvement (curve2) will rise slowly and this is fueled by the fact that data that was integrated can be accessed easily from shared databases, thus reducing delays in service provision. In year 1, process improvement increases sharply because available capacity exceeds required capacity; this is due to the low number of customers. As the customers' numbers grow, process improvement stabilizes rising at almost the same rates as compared to data production and data integration in the second half of the year 2 and this continues till the 12*th* year. In the 13*th* year, process improvement increases at a decreasing rate. The rate at which data production and data integration grow is higher as compared to process improvement. From the simulation experiment, a behaviors defined by one of the key propositions that a higher level of data Integration (curve 1) is associated with a highest level of process improvement (curve 2) can be deduced. This can also be supported by the fact that data Integration reduces data redundancies and inconsistencies in customer information.

The third simulation examines the bahaviour of network infrastructure and process improvement. The output from the simulation shows that an increase in network infrastructure is associated with a higher level of process improvement. This can be explained by the fact that management recognises the interdependence of multiple units and the need to co-ordinate different and disparate functions and activities such as electronic mail, peer to peer links such as those integral to Electronic Data Interchange by putting in place the necessary infrastructure. This not only increases support to organisational processes by increasing the range and depth of information about business activities but also makes it feasible for team members to co-ordinate their activities (across time zones) and geographically (across remote location) more easily than ever before. In the first six years network growth is slow because banks roll out a few equipment as they test for customer acceptance. In the later years network growth rises steadily because new access points are created to cater for the increasing number of customers, to reduce congestion in certain service centres so as to improve on service delivery. This is later followed by continuous process improvement.

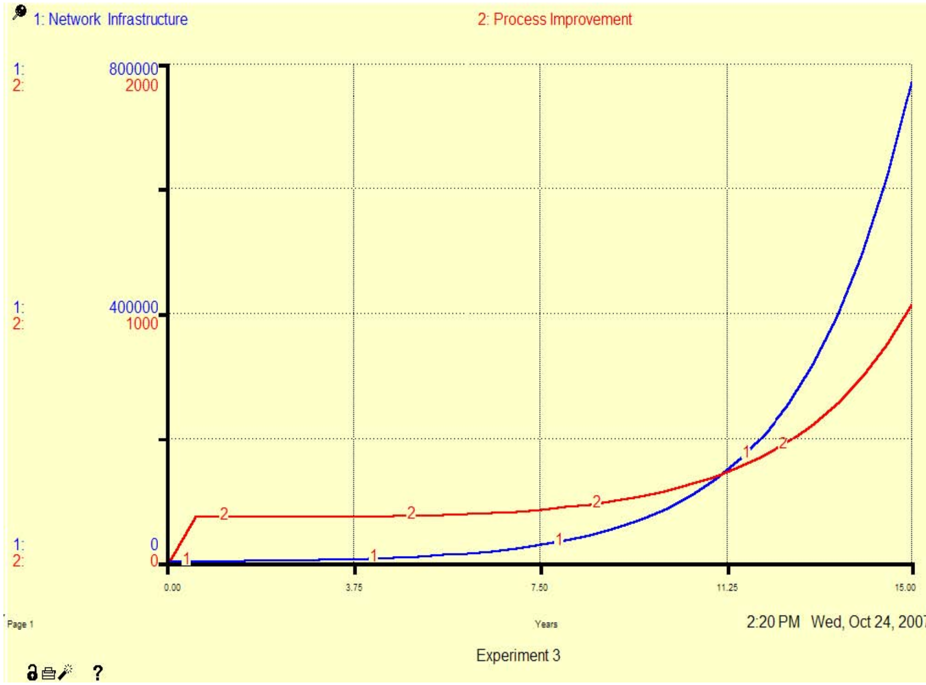

Figure 6: Experiment 3

The results from the simulation experiments have indicated that a strong network infrastructure, customer focus, and data integration can lead to process improvement thrust. The results provide support to the contention that an integrated technology environment is one of the important considerations in business improvement initiatives. The findings regarding network infrastructure dimensions were consistent with earlier studies on BPR (Bhatt G, 2000). Secondly it was observed that data integration is equally important in determining overall customer focus. Specifically creation of databases appears to rank slightly high when integrated database support offers flexibility in collecting relevant data and analyzing problems quickly. These results are consistent with Porter (1985) argument that with use of IT, organizations can provide a higher value to customers.

8. MODEL VALIDATION

The model was validated with empirical analysis, and the findings had similarities. Overall, the model shows a good fit to the data as evidenced by the significant F-values. The t-values accompanying the individual coefficients are obtained using SPSS package. The statistical significance of all individual relationships provides strong empirical support for the developed model. Networks infrastructure was found to be significantly related with process improvement thrust (f=4.09, sig=0.032) (p is less than 0.05), where as the relationship between network infrastructure and customer focus was not found to be significant (f=2.691, sig=0.105) (p less than 0.01), (Hypothesis 1 and 3). Data integration was also found to be significantly related with process improvement thrust (f=16.334, sig=0.000) (p is less than 0.01) and process improvement (f=9.234, sig=0.03) (p is less than 0.05) (Hypothesis 2 and 4). The effect of information intensity of the industry was not found to be significantly moderating the relationship between networks infrastructure and process improvement thrust, Similarly information intensity had little effect on customer focus and data integration, also Information intensity had little effect on process improvement thrust and customer focus (Hypothesis 5, and 6).

Hypothesis	Relationship			Coefficient	t-Value	P-value	Conclusion	Adjusted R2 (%)	F	Sig
H1	Network Infrastructure →		Process Improvement	0.255**	3.99	<0.05	Fail to reject H1	5.2	4.09	0.032
H2	Data integration →		Process Improvement	0.412**	6.711	<0.01	Fail to reject H2	15.9	16.334	0.000
H3	Network Infrastructure →		Customer focus	0.192	5.979	>0.01	Fail to reject H3	2.3	2.691	0.105
H4	Data integration →		Customer focus	0.318**	8.003	<0.01	Fail to reject H4	9	9.234	0.003
H5	Information intensity →	Network Infrastructure →	Process Improvement	-0.18	4.209	<0.05	Fail to reject H5	7.1	3.69	0.030
H6	Information intensity →	Data Integration →	Process Improvement	-0.124	5.434	<0.01	Fail to reject H6	16	8.262	0.000
	Information	Network								

Figure 7: Model validation results

9. CONCLUSION

Despite the continuing debate on the effect of IT on BPR, the strategic potential of IT in BPR cannot be denied, even though incompatible islands of IT may be a hindrance to BPR. The role of network infrastructure is critical to improve business processes and enhance customer services, by enabling sharing of real time information throughout the organization. Moreover a network infrastructure enables coordination between people, regardless of their physical locations and background. The IT infrastructure is an area where bank management should focus a large proportion of their resources, as there is growing evidence that customers associate quality of service with the bank's possession of a good IT infrastructure.

The current banking environment is ripe for the use of simulation. The pressure to control costs is higher than ever, so, there is a critical need for powerful tools which can help bank executives and administrators make good decisions on how to achieve objectives of reducing costs while maintaining high quality service. The highly stochastic nature of banking processes, as well as the complexity of subsystem interactions, makes simulation the decision-support tool of choice for analyzing the delivery of banking services.

10. LIMITATIONS AND FUTURE RESEARCH

In spite of the good findings, the study had limitations which were influenced first and foremost by resource constraints in terms of time and money. Secondly, the banks were reluctant to divulge detailed information about the utilization of IT facilities and functions in their institutions. Thirdly, the survey was conducted in only Kampala, extending the study to other areas would provide a better understanding of the way the hypothesized factors influence BPR and how managers can effectively apply Information Technology. More work need to be done to obtain more data to support the findings. Potential areas of research include analyzing the relationship of effective redundancy with factors such as reliability, cost of operations and maintenance, life-cycle costs for equipment and profitability of banking institutions.

Future studies can examine different dimensions of IT infrastructure in depth, such as comparing the role of IT expertise, and organizational capabilities in BPR. Researchers may also be interested in exploring the different contextual factors which could unduly influence the strength of the effect of IT infrastructure on BPR.

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