GREEN IT IN BANKING SYSTEMS IMPACTED BY PRUDENTIAL RULES – ERLANG MODELS FOR FORECASTING COMPUTER PERFORMANCE

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ABSTRACT

This paper surveys the contributions and applications of queueing theory in the field of banking data networks. We start by highlighting the history of IT and banks and we continue by providing information regarding the main prudential regulations on the banking area as Basel Accords and green IT regulations, that on one side generate more computing needs and on the other side promote conscientious use of the existing IT systems.

Continuing with a background of the network technologies used in Economics, the focus will be on the queueing theory, describing and giving an overview of the most important queueing models used in economical informatics. While the queueing theory is characterized by its practical, intuitive and subtle attributes, the queueing models are described by a set of 3 factors: an input process, a service process and a physical configuration of the queue or the queueing discipline.

The Erlang B and C mathematical definitions of formulas for a specific number of s servers, at the λ arrival rate, and the τ *average service time will be described, used and confirmed by computer simulations of real queues usually found in the banking computing systems.*

The goal is to provide sufficient information to computer performance analysts who are interested in using the queueing theory to model a network of banking computer systems using the right simulation model applied in real-life scenarios, e.g. overcoming the negative impacts of the European banking regulations while moving towards green computing.

KEYWORDS

queueing theory, banking system, Erlang B, Erlang C, computer network, economical informatics, banking regulation, computer simulation, Basel.

1. INTRODUCTION

From the first recorded bank in the world, Taula de la Ciudad, which opened in Barcelona in 1401, to the current known banks, the services provided by banks developed considerably. The Bank Taula de la Ciudad was founded as a treasury resource for the Catalonian government. Even if the bank is on record as the first official bank in the world, the practice of banking has been traced back for several centuries. [12]

Many histories position the crucial historical development of a banking system to medieval and Renaissance Italy and particularly the affluent cities of Florence, Venice and Genoa. The Bardi and Peruzzi families dominated banking in 14th century Florence, establishing branches in many other parts of Europe. [7]

DOI:10.5121/ijcsit.2016.8301

Perhaps the most famous Italian bank was the Medici bank, established by Giovanni Medici in 1397. [6] The oldest bank still in existence is Monte dei Paschi di Siena, headquartered in Siena, Italy, which has been operating continuously since 1472. (Boland, 2009).

The banking development spreads from northern Italy throughout the Holy Roman Empire, and to northern Europe in the 15th and 16th century. Another important point in time is the development of the important innovations that took place in the 17th century, in Amsterdam, during the Dutch Republic, and in the 18th century, in London. Of course, the development heavily continues with the innovations in telecommunications and computing, in the 20th century, when the size of the banks and the geographical coverage increase, due to the development of the operations' side of the banks. During the well-known financial crisis from 2007–2008, all the banks were affected, some of them more than others, causing a specific attention to the banking regulations in the upcoming years.

On the IT side, even if usually most observers prefer and are expected to discuss about what is coming and not about what happened, we would like to highlight at least the three most important events in the IT history. The first event may be considered the document "First Draft of a Report on the EDVAC" published by John Von Neumann end of June 1945, consisting of the first documented discussion of the stored program concept and the blueprint for computer architecture to this day [13]. It is also called "the technological basis for the worldwide computer industry" [1]. The second important event may be considered the giving birth of the Ethernet, by Bob Metcalfe, in 1973, at the Xerox Palo Alto Research Center (PARC). The third event is in 1989, when Tim Berners-Lee circulated "Information management: A proposal" at CERN in which he outlined a global hypertext system.

1.1 Banking And IT Regulations

All types of banks, being part of the banking system, have to comply with the banking regulations. It can be distinguished three classes of banking regulations: economic regulation, prudential regulation and monetary regulation. What we will deepen further is the prudential or prevented regulation, which is designed "to ensure efficient allocation of resources, to minimize the risks assumed by banks and to ensure stability and financial soundness of individual banks and of the banking system as a whole". [3]

On the IT side, the regulation topic become more and more discussed during the recent years due to the huge development of the IT world.

1.2 Basel Banking Accords and other banking regulation

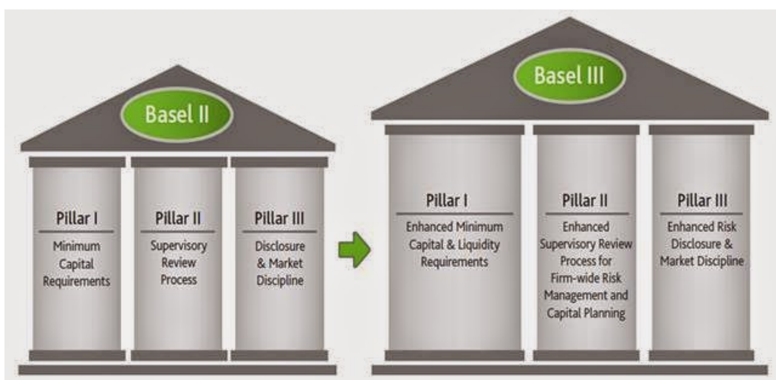
Nowadays, the most important international banking regulations are the Basel Accords. These accords are published in Basel, Switzerland, by the Bank for International Settlements BIS in Basel, which is the central body in charge to develop and standardize banking regulations.
Basel I was the first accord adopted in 1988 and had the objective to improve the equity of internationally active banks by establishing a relation between equity and risk-weighted assets. Thus, Basel I proposed a standard methodology for calculating the equity and two solvability indicators to ensure compliance with the minimum coverage of risky assets (net exposure) through the bank capital. AT the end, it was concluded that the first indicator is enough for satisfying the minimum level of the solvability ratio 1 and the net exposure was calculated based on the credit risk, considering four risk categories (0%, 20%, 50% and 100%), applied according to the category of considered assets [11].

Basel II was adopted in 2004 and had the objective to cover various complains followed by Basel I. This accord contains changes to supervisory, regulatory and international cooperation between various authorities, his objectives being organised in three pillars: Pilar 1, Pilar 2 and Pilar 3. [3]

Pillar 1, also referred as "Minimum Capital Requirements", contains minimum capital requirements for credit risk, market risk and operational risk.

Pillar 2, also referred as "Supervisory Review Process", covers a qualitative approach about prudential requirements through the supervisory process. In addition to the risk defined in the Basel I, in Basel II the following risks are covered: the liquidity risk, residual risk, strategic risk, reputational risk, concentration risk and interest rate risk for exposures which are not in the trading book.

Pillar 3, also referred as "Market discipline", offers to the shareholders and the investors the possibility to monitor more effectively the bank management, because it requires to the banks to develop a set of detailed reporting requirements for the supervisory authority and for the public.
Basel III was issued as a result of the well-known global financial crisis, from 2007 and is improving several aspects of Basel II, a visual comparison being visible in the Figure 1. This accord requires from banks to have more equity of a superior quality, in order to be prepared to the future crisis, using Capital "Requirements Directive CRD IV" and "Capital Requirements Regulation CRR". In addition, this accord defines a minimum leverage of 3% and two mandatory liquidity ratios: the rate of immediate liquidity and the long-term liquidity ratio. It is also enhancing the supervisory review process for firm-wide risk management and capital planning and the risk disclosure and the market discipline.



(Source: Srivastava, A., 2016)

Fig. 1: Comparison between Basel II and Basel III

Worldwide, are currently existing also some other financial development institutions that took the role of supporting financial environment to adapt to a changing word. One of the largest ones is the International Finance Corporation (IFC), which hosts an informal group of banking regulators and banking associations, called Sustainable Banking Network. The group is currently designed to help regulatory authorities of emerging markets to develop green credit policies and environment and social risk management guidelines by sharing knowledge and technical resources. At the moment, the network has members from Bangladesh, Brazil, China, Indonesia, Lao PDR, Mongolia, Nigeria, Peru, Thailand and Vietnam.

1.3 GREEN COMPUTING LEGISLATION

One of the first initiatives was taken place in USA, in 1992, and it was named Energy Star. This was a voluntary labelling program, created by the Environmental Protection Agency, having the purpose to promote energy efficiency in hardware components. In the recent years, the awareness about the necessity of a Green computing was increasing and therefore more directives appeared.
For example, the first WEEE Directive (Directive 2002/96/EC) entered into force in early 2003. WEEE stands for waste of electrical and electronical equipment such computers, TV-sets, fridges and cell phones. The directive has to goal to increase the recycling of WEEE and/or its reutilisation, by creating different collection schemes of WEEE, free of charge for population. [17]

The EU legislation (RoHS Directive 2002/95/EC) has to scope to restrict the use of hazardous substances in electrical and electronical equipment, referring specially to the heavy metals as mercury, lead, flame-retardants, cadmium, and why not, to find a cheaper and not that noxious substitutes. A newly revised directive by the European Commission became effective beginning of 2012. [17]

2. NETWORK TECHNOLOGIES USED IN ECONOMICS

With the global advancement seen in the last 20 years, especially with the increased volume, complexity, spread of exchanges in the economic and financial relations, all the computing systems, but especially the banking systems, had to adapt fast not only their banking regulations [16] [18] to the continuous changing world [12] but also their networking field, which had changed drastically over the time. Perhaps, the most fundamental change has been the rapid development of optical fiber technology. This has created limitless opportunities for new digital networks with greatly improved capabilities. The current broadband integrated service networks that provide integrated data, voice and video seem to have almost nothing in common with the data networks of the last 20 years, but in fact, many of the underlying principles, mathematical and statistical laws are the same.

3. QUEUEING THEORY BACKGROUNDS – PROBABILITY, STOCHASTIC PROCESSES AND MATHEMATICS

Probability is a beautiful field of mathematics that is rich in its depth of deductive reasoning and in its diversity of applications. With its roots in the 17th century, probability started with simple counting arguments that were used to answer questions concerning possible outcomes of games of chance. Over the centuries, probability has been established as a key tool in a wide range of diverse fields like biology, chemistry, computer science, finance, medicine, physics, etc.
Probability served as the basis for deriving results to study stochastic processes. A stochastic process can be thought of as being a set of outcomes of a random experiment indexed by time. As an example, $X_n, n = 1, 2, 3, ...,$ could be the total number of tails obtained from the first n tosses of a fair coin in an experiment that continues for an indefinite period of time. The following set, $\{X_1, X_2, X_3, ...,\}$ represents a process to indicate that there is a relationship or dependency between the random variables X_n [5]. For continuous time processes, $X(t)$ is a stochastic process and the values of $X(t)$ and $X(t')$, for $t < t'$ have some kind of relationship or dependency.
A frequent application area for probability and stochastic processes is the queueing theory. The nomenclature used in queuing applications can be easily explained by the terms in Fig.2:

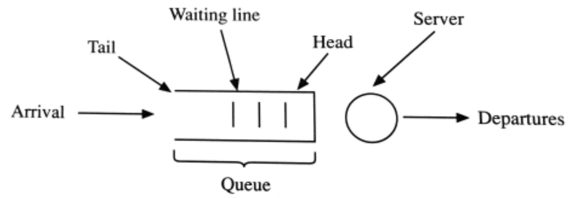


Fig.2. A single server queue

A single server queue consists of a server that processes customer requests, a waiting line or queue where customers wait before receiving service and an arrival stream of customers. For example, customers can arrive at the tail of the queue and are served on a first-come-first-served (FCFS or FIFO) basis [2]. In a computer model, the server could correspond to a hard drive that processes read or write requests, a CPU that processes customer requests or to a router serving a network of computers sending network requests. Typically, if the waiting room is finite, then any customer coming during the time when the waiting queue (the so called “buffer” in computer science terminology) is full is assumed to be lost to the system, just like if the customer never arrived.

The queuing theory is described by 3 fundamental characteristics:

- practical, as it has direct practical applications, for example, in modeling a network of computers in a banking or cloud environment
- intuitive, making it simpler to generate real-life models.
- subtle, making it intellectually interesting, because it uses probability to describe reality.

When speaking about a real-life model, it is common to have a multiple server queue, especially in modern CPU systems. Customers arrive at random, and try to find a server. If a server is available, they take it and hold it for a random amount of time, named onwards service time. If not, one possibility is that the customers that arrive when all servers are busy overflow and are lost (Erlang B formula). It is also possible that these customers wait in a queue (Erlang C formula).

A queueing model is defined by its:

- input process – a random process that defines the way in which the customers arrive, which are represented by the arrows in Fig.3.
- service process – a random process that defines the length of the service times needed by the arriving customers, which may be seen graphically by the height of the black bars above the arrows in Fig.3.

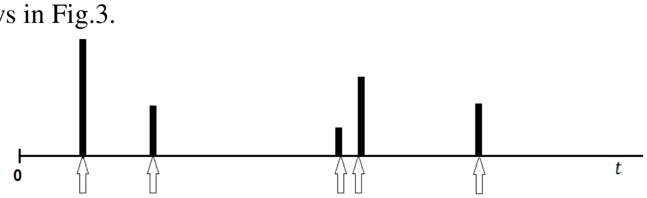


Fig.3. Random arrival with Random service times

- physical configuration or the queue discipline which defines what happens if a customer is blocked or waits in a queue. When the customers wait in a queue, more information is needed to describe the queue discipline, for example, the size of the queue, if a customer waits indefinitely or drops after a certain amount of time, the order in which a customer is served, e.g. last-come-first-served (LCFS) or in a random order etc.

4. THE ERLANG B FORMULA – PROBABILITY OF BLOCKING

For analysing this model, we are going to assume:

- *s* servers
- requests that arrive at a certain arrival rate λ
- an average service time τ

This queue will be intuitively analysed by using the classical *rate-up=rate-down* argument used in engineering, then the model will be limited and confirmed by using computer simulations.
The Fig. 3 below describes the system states for a queue with 3 services. Understanding the mechanism from Fig. 3 will help define a mathematical model and later develop the computer model simulation used to confirm the specific cases where this is available.

For this specific system we could be in state 0, 1, 2 or 3, which represents the number of customers present in the system - *N(t)*. We start at state 0, where no request is present in the system. Once the first customer arrives, the system jumps to state 1, it will stay there a while, until either that request completes or another request arrives. If another call arrives before the first one completes, then the system jumps to state 2, and stays there a while. Consequently, jumps down to 1, then it jumps up to state 2, and then maybe to state 3, and so one. If a customer arrives in state 3, then because all servers are busy, that would be a lost request. Practically every jump up corresponds to an arrival and all the jumps down correspond to a departure. *Rate up=rate down* means in this case that on the long term the number of the customers that arrive will equal to the number of customers that leave the system.

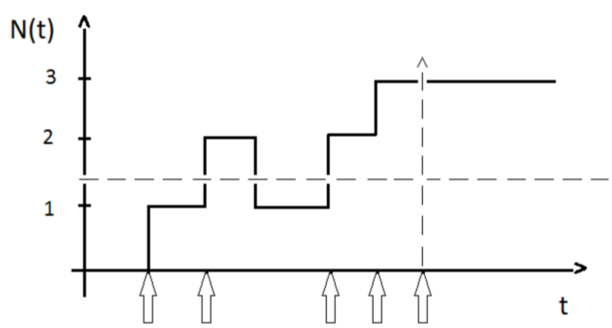


Fig.4. Random arrivals and random service times in a multi-server queue

The model will be analyzed by equating for each state the rate at which the system jumps up from that state to the rate the system jumps down from the state above it. If we look at the Fig.4., the dotted line shows that the number of jumps up and the number of jumps down will differ by at most 1, which in limit does not matter. That means that by dividing the number of jumps up by the total amount of time we get the rate up, and by dividing the number of jumps down by the total amount of time results the rate down. The rate up from $P_0 = \lambda P_0 = \frac{1}{\tau} P_1$=rate down from P_1.

By the same argument, λP_1 would be the rate up from state 1, and $\frac{2}{\tau} P_2$ is the rate down from state 2, since from state 2 there are 2 chances for a completed request. Going further with this argument, the following set of equations is developed:

$$\begin{aligned} \lambda P_0 &= \frac{1}{\tau} P_1 \\ \lambda P_1 &= \frac{2}{\tau} P_2 \\ \lambda P_2 &= \frac{3}{\tau} P_3 \\ &\vdots \\ \lambda P_{s-1} &= \frac{s}{\tau} P_s \end{aligned} \qquad \textbf{(1)}$$

The problem is reduced to solving this set of equations and finding P_s - the probability that all servers are busy. By normalizing and using the notation $\lambda\tau = a$, it is hints that the solution would depend on the number of servers and on the product $\lambda\tau = a$, called offered load, and not by the individual values of either λ or τ .

$$\begin{aligned} P_1 &= \lambda\tau P_0 = aP_0 \\ P_2 &= \lambda\tau P_1 = \frac{a^2}{2} P_0 \\ P_3 &= \lambda\tau P_2 = \frac{a^3}{3!} P_0 \\ &\vdots \\ P_s &= \lambda\tau P_{s-1} = \frac{a^s}{s!} P_0 \end{aligned} \quad \Rightarrow \quad P_j = \frac{a^j}{j!} P_0,\ j = 1,2,...,s \quad \textbf{(2)}$$

The set of equations is completed by the fact that:

$P_0 + P_1 + ... + P_s = 1 \Rightarrow P_0 + \frac{a^1}{1!} P_0 + \frac{a^2}{2!} P_0 + ... + \frac{a^s}{s!} P_0 = 1$, therefore,

$P_0 = \frac{1}{1 + \frac{a^1}{1!} + \frac{a^2}{2!} + ... + \frac{a^s}{s!}}$, resulting that $P_s = \frac{\frac{a^s}{s!}}{1 + \frac{a^1}{1!} + \frac{a^2}{2!} + ... + \frac{a^s}{s!}} = E_{1,s}(a) = B(s,a)$ **(3)**, also named the Erlang B formula, giving the probability of blocking, which is the probability that all servers are busy.

At this moment, it is quite easy to calculate how many servers would be needed in order to have, let’s say less than 1% dropped requests. This is important on both financial and quality aspects. If too many servers are provided, then the service will be good, but the entire system will be more expensive than necessary. Looking at Fig. 5, we would draw the line corresponding to 0.01, estimate the offered load, and then search for the first curve that would lie below point of intersection. This points out the practical application of the Erlang B formula that helps engineers to calculate the number of servers needed for given values of the offered load and percent of lost requests.

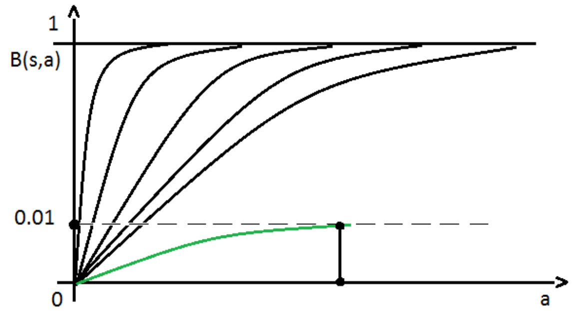


Fig.5. Erlang B graph

5. Subtleties of the Erlang B formula – Computer simulations

Looking at Fig.6 we can observe the following arrival processes that have the same rate of arrival λ:

- constant arrival process – green
- random arrival process – black
- in between arrival process – red

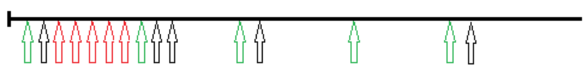


Fig.6. Different types of arrival processes

The question is which type of arrival process is described by the previous rationale. The rationale could be always right, never or just sometimes (Poisson exponential arrivals). Also this could be extended to the service process. To easily demonstrate that, a computer simulation will be developed.

The physical interpretation of B(s,a)=20% is one of the subtleties of the Erlang B formula. Is it that 20% of all requests are going to be lost? Another possibility is that 20% of the time all servers are busy. Further, is another question arises: what exactly is P_2 - the probability of being in state 2? Is that the fraction of arrivals who finds the system in state 2, or the fraction of time the system is in state 2?

The following computer code written in BASIC will calculate the fraction of time the system is in the blocking state (a ratio of times) and the fraction of customers who arrive during the blocking state (ration of integers – number of customers that overflow divided by the total number of customers who arrive). So the left and the right sides of the (1) equations are measured in complete different ways. The computer code assumes the arrival rate to be 4, the average service times to be 2.4 resulting an offered load of 4x2.4=9.6 erlangs, and the number of servers to be 10. The simulation will run for 100000 arriving requests, and the types of arrival and service time processes will be considered as follows:

- Poisson arrivals, exponential service times
- Poisson arrivals, constant service times
- Constant inter-arrival times, exponential service times
- Constant inter-arrival times, constant service times

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100 DIM C(50) (50 is max number of servers)
110 INPUT S,NSTOP (S,NSTOP = number of servers, customers to
be simulated)
120 FOR D=1 TO NSTOP
130 IA= (IA = interarrival time)
140 A=A+IA (A = arrival time)
150 J=0
160 J=J+1 (J = index of server being probed)
170 IF J=S+1 THEN K=K+1 (K = number of customers that are
blocked)
180 IF J=S+1 THEN 270
190 IF A<C(J) THEN 160 (C(J) = completion time for server J)
200 X= (X = service time)
210 C(J)=A+X
220 M=C(1) (M = shortest server-completion time)
230 FOR I=2 TO S
240 IF C(I)<M THEN M=C(I)
250 NEXT I
260 IF M>A THEN AB=AB+M-A (AB = cumulative time during which
all servers busy)
270 NEXT D
280 PRINT K/NSTOP,AB/A (fraction of customers blocked,
fraction of time all servers are simultaneously busy)
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6. SIMULATION INPUTS AND RESULTS FOR ERLANG B

Table 1. Erlang B – Simulation inputs and outputs

	IA[10]	X	K/NSTOP	AB/A	B(*s*,*a*)	
1	-(1/4) * LOG(1-RND)	-2.4*LOG(1-RND)	0.19652	0.1958451	19.6% [16]	
2	-(1/4) * LOG(1-RND)	2.4	0.19652	0.1958451		
3	1/4	-2.4*LOG(1-RND)	0.13366	.2360997	N/A	N/A
4	1/4	2.4	0	0.6009062	N/A	N/A

As seen in Table 1, the variability in the service times does not affect the answer, but the variability in the arrival process does.

No matter what distribution function we use to describe service times, the answer is unaffected. From a practical point of view, something that is difficult to measure, does not have to be measured because the final answer does not depend on it. We can completely disregard the statistical characteristics of the service times, once this model is understood. That is why these formulas are so robust and safe to use.

7. THE ERLANG C FORMULA – BLOCKED CUSTOMERS DELAYED

By extending the heuristic conservation-of-flow to include the case in which all customers who find all servers busy wait until they are served, and by following the same intuitive approach, rate up=rate down, we get the following set of formulas:

$$\begin{aligned} &\lambda P_0 = \frac{1}{\tau} P_1 \\ &\lambda P_1 = \frac{2}{\tau} P_2 \\ &\lambda P_2 = \frac{3}{\tau} P_3 \\ &\vdots \\ &\lambda P_{s-1} = \frac{s}{\tau} P_s \end{aligned} \quad \Rightarrow P_j = \frac{a^j}{j!} P_0,\ j = 0,1,...,s-1 \quad \textbf{(4)}$$

Further, when looking at the first set of formulas it was concluded that the rate down from state 2 is $\frac{2}{\tau}$, but at the point where all servers are busy, the aggregate service completion rate would be constant and equal to $\frac{s}{\tau}$ because all servers are busy, and only *s* customers are served. This leads to the following set of equations:

$$\begin{aligned} &\lambda P_s = \frac{s}{\tau} P_{s+1} \\ &\lambda P_{s+1} = \frac{s}{\tau} P_{s+2} \\ &\lambda P_{s+2} = \frac{s}{\tau} P_{s+3} \\ &\vdots \end{aligned} \quad \textbf{(5)} \quad \Rightarrow \quad \begin{aligned} &P_{s+1} = \frac{a}{s} P_s = \frac{a^{s+1}}{s!s^1} \\ &P_{s+2} = \frac{a^{s+2}}{s!s^2} \end{aligned}$$

By combining equations (4) and (5), the following formula is deducted for this model:

$$P_j = \begin{cases} \dfrac{a^j}{j!} P_0, (j = 1,2,...,s-1) \\ \dfrac{a^j}{s!s^{j-s}}, (j = s, s+1,...) \end{cases} \quad \textbf{(6)}$$

By normalization (requirement that all probabilities add up to 1) we get:

$$P_0 + P_1 + ... + P_s + P_{s+1} + ... = 1 \Rightarrow P_0(1 + \frac{a^1}{1!} + \frac{a^2}{2!} + ... + \underbrace{\frac{a^{s-1}}{(s-1)!} + \frac{a^s}{s!} + \frac{a^{s+1}}{s!s^1} + \frac{a^{s+2}}{s!s^2} + ...}_{\frac{a^s}{s!}(1+\left(\frac{a}{s}\right)^1+\left(\frac{a}{s}\right)^2+...)}) = 1 \quad \textbf{(7)}$$

It is obvious that the right part of the above equation is an infinite geometric series and the formula only makes sense if the series converges. By mathematical reasoning, the series converges to $\frac{1}{1-\left(\frac{a}{s}\right)}$; therefore, the formula makes sense if and only if *a*<*s*. We conclude that

$$P_0 = \frac{1}{\sum_{k=0}^{s-1} \frac{a^k}{k!} + \frac{a^s}{s!\left(1-\frac{a}{s}\right)}} \quad \textbf{(8)}, \text{ if } \frac{a}{s} < 1.$$

8. SUBTLETIES OF THE ERLANG C FORMULA

Since $\frac{a}{s}$ must be less than 1, then a has to be less than s, it results that $\lambda\tau < s$, therefore $\lambda < \frac{s}{\tau}$. This means that the arrival rate must be less than the maximum average completion rate, otherwise the queue is going to grow to infinity, being impossible to find an equilibrium state.
The Erlang B formula calculates the probability of the system to be in the blocking state, which is equal to the fraction of customers who find the blocking state and therefore are lost. In the case of the Erlang C formula, the fraction of time when the system finds itself in the blocking state is calculated, but in this case, the blocking state (probability of queueing) means not only state s, but also state s+1, s+2, etc., while limiting this rationale to Poisson input.

$C(s,a) = P_s + P_{s+1} + P_{s+2} + ... = E(2,a)$ (by definition)

$$C(s,a) = P_s + P_{s+1} + P_{s+2} + ... = P_0 \frac{\frac{a^s}{s!}}{a - \left(\frac{a}{s}\right)} = \frac{\frac{a^s}{s!\left(1-\frac{a}{s}\right)}}{\sum_{k=0}^{s-1} \frac{a^k}{k!} + \frac{a^s}{s!\left(1-\frac{a}{s}\right)}} = E_{2,s}(a) = \frac{sB(s,a)}{s - a(1-B(s,a)}$$ **(9)**, giving the fraction of customers who have to wait in the queue in a model in which all blocked customers wait as long as necessary to be served.

Getting back to the *rate-up=rate-down* assumption, the following is true:

$$\lambda P_j = \mu_{j+1} P_{j+1}, \text{ where } \mu_k = \begin{cases} \frac{k}{\tau}, (k < s) \\ \frac{s}{\tau}, (k \geq s) \end{cases} \quad \textbf{(10)}$$

When considering the rate-up=rate-down argument, how long the system is in any particular state was not taken into consideration, but only that the system is in that state. The rate at which the system goes up from state j depends only on j - the number of customers present - , but it does not depend on the past history of the system, except that that the past history produces this current state. Likewise, if the system is in state j+1, the rate at which the system goes down (rate at which customers leave the system) depends only on how many customers are currently present and not on the past history of the system. In other words, it does not depend on when the last arrival occurred, it depends on how much service remains for each of the customers who are being served. By using the *rate-up=rate-down* argument, the past history is neglected, and this implies that the underlying variables are exponential, because of the Markov property [9], which states that the only thing that affects the future evolution of a random variable that is exponential is its basic parameters but not how long it has been in progress. This is also an intuitive interpretation as to why a sufficient condition to this rationale is that all the underlying variables are exponential. One exception to this rule was analyzed earlier under the Erlang B formula when the blocked customers are cleared. The requirement for this is that we have Poisson input and exponential service times, where for Erlang B having Poisson arrivals but not necessarily exponential service times was enough.

In Fig.4, for the Erlang B as the offered load increases, the probability of blocking increases and is asymptotic to 1, getting a sequence of curves. For an increasing number of servers, the curve for a larger number of servers s lies below the curve for a smaller number of servers, because the larger number of servers will reduce the probability of blocking for the same value of a – offered load.

By plotting the Erlang C values, the result is similar, but not exactly the same, because now we have the condition that a must be less than s ($a < s$). For 1 server, when a is equal to 1 erlang, the curve would not be asymptotic to 1, but it will reach 1, because when the offered load is 1 or more, it means that the infinite series does not converge and the probability of waiting in a queue is 100%. Redoing the before mentioned thinking, we get the following graph:

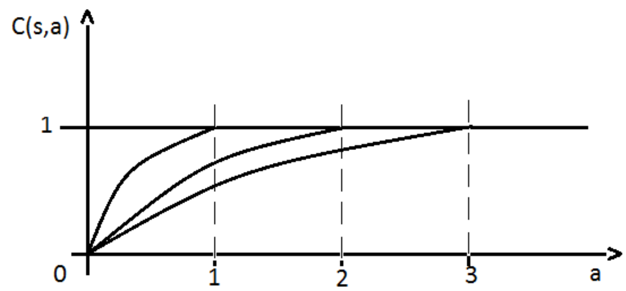

Fig.7. Erlang C graph

The model used in the Erlang C simulation is called M/M/s by the conventional queueing theory notation. The general model introduced by Kendall [19] in 1953 can be summarized as follows: *a/b/c*, where:

- *a* indicates the arrival process, where M represents the memoryless Markov property – Poisson input
- *b* indicates the service process, where M represents Markov memoryless property – exponential service times
- *c* is the number of servers, and it is implicitly that there is an infinite queueing capacity

The Erlang B model is by the same notation M/G/s/s, having Poisson input, general service times, *s* servers and the *s* capacity of the system (no waiting positions). Further details on the M/G/1 [9] model, including a simulation can be found in the reference [4].

The following computer code written in BASIC will simulate the same problem as with the Erlang B case, with the only difference that the blocked customers are now allowed to wait in a queue. The simulation will calculate what the customers see, more exactly the fraction of customers who have to wait in the queue, which is equal to the fraction of time the system is blocked, according to the PASTA Theorem [14]. The computer code assumes the arrival rate to be 4, the average service times to be 2.4 resulting an offered load of 4x2.4=9.6 erlangs, and the number of servers to be 10. The simulation will be run for 100000 arriving requests, and the types of arrival and service time processes will be considered as follows:

- Poisson arrivals, exponential service times. (M/M/s)
- Poisson arrivals, constant service times. (M/D/s)
- Constant inter-arrival times, exponential service times. (D/M/s)
- Constant inter-arrival times, constant service times. (D/D/s)

```
100 DIM C(50)
110 INPUT S, NSTOP
120 FOR D = 1 TO NSTOP
    130 IA = -(1 / 4) * LOG(1 - RND)
```

```
    140 A = A + IA
    180 M = C(1): z = 1
    190 FOR I = 2 TO S
        200 IF C(I) < M THEN M = C(I): z = I
    210 NEXT I
    220 X = -2.4 * LOG(1 - RND)
    221 sx = sx + X
    230 IF A > C(z) THEN C(z) = A + X ELSE C(z) = C(z) + X:
w = C(z) - A: K = K + 1
    231 sw = sw + w
250 NEXT D
PRINT sx / A / 10, sw / A, K / NSTOP,SW/NSTOP
```

9. SIMULATION INPUTS AND RESULTS FOR ERLANG C

Table 2. Erlang C – Simulation inputs and outputs.

s=10	1		2		3		4	
$\lambda = 4$	**Theory**	**simulation**	**Theory**	**simulation**	**Theory**	**simulation**	**Theory**	**simulation**
$\rho = \frac{a}{s}$	96%	0.9650543	96%	0.9704734	96%	0.9497337	96%	0.9600935
$E(W) = \frac{C(s,a)}{(1-\rho)s}\tau$ [8]	6.45762	6.469176	N/A	5.999352	N/A	4.222098	0	0
$P(W > 0) = C(s,a)$	0.859046	0.85792	N/A	0.8586	N/A	0.7386	0	0

10. IDEAS FOR A BETTER INTERLINKAGE BETWEEN ENVIRONMENT AND PRUDENTIAL RULES OF THE BANKING AND IT SYSTEMS

10.1 BANKING ENVIRONMENTAL INITIATIVE

In 2010, The Chief Executives of some of the world's largest banks created the Banking Environment Initiative (BEI) and lunch it at IMC, in Geneva. His scope is to lead the banking industry in collectively directing capital towards environmentally and socially sustainable economic development. For the foundation of BEI, a landscape mapping was created in order to identify the need for a fresh approach. Between 2012 and 2013, the ideas were tested and it was developed and refined the BEI's model of change that can be seen below, in the Figure 8, creating trial partnerships with commodity and energy sectors. Starting 2014, the execution of the initiative started, by launching the work on products, standards and regulation. Based on this different bridges were created in order to have a faster-growth economies and new customer partnerships.

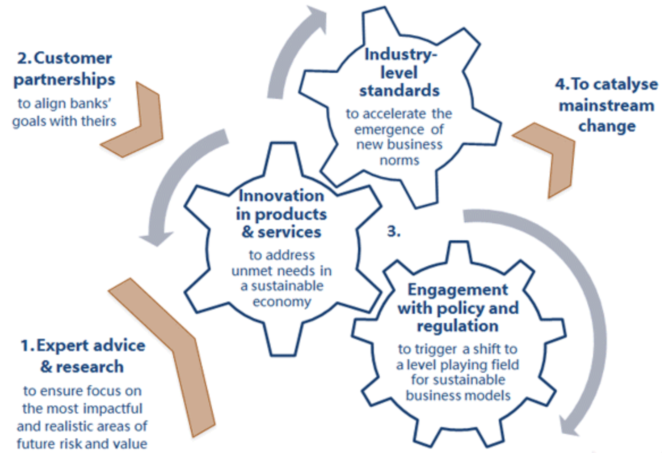

Figure 8: BEI's Model of change [19]

Until now 11 leading banks joined the initiative, headquartered across USA, Europe, ASIA and Australia: Barclays, BNP Paribas, BNY Mellon, Deutsche Bank, Goldman Sachs, Lloyds Banking Group, Northern Trust, RBS- The Royal Bank of Scotland, Santander, Standard Chartered, and Westpac.

The basis of the Banking Environment Initiative's vision is the idea that banks work for their clients and an initiative like this will only work if it is aligned with their interests and vice versa. Therefore, BEI achieves its mission by focusing on topics where industry-wide action is needed, working in partnership with its customer base by bringing independent thinking to bear on the issues and through the active leadership of its Chief Executives. [20]
Currently, the Banking Environment Initiative has 2 work streams: "Soft commodities" and "Financial regulation".

The 'Soft Commodities' Compact is a unique, client-led initiative that aims to mobilise the banking industry to help transform soft commodity supply chains, thereby helping corporate clients to achieve zero net deforestation by 2020. In order to achieve this scope, the banks from the BEI formed an alliance with the Consumer Goods Forum (CGF) and together should investigate what it would mean to align the banking industry's services with the CGF's 2010 resolution. The banks committed to 2 main points: financing the transformation of supply chain and raising industry-wide standards. The first one, financing the transformation of supply chain, means that the banks will use all reasonable endeavours to work with CGF supply chains to explore how they can finance the growth of the markets producing palm oil, timber products, soy and beef to the CGF's required zero net deforestation standards in ways appropriate to their individual business models. When CGF member companies identify suppliers needing access to finance to make the transition to the CGF's required standards, Compact banks will endeavour to work with both parties to test appropriate financing mechanisms, including pre-export finance approaches. The second commitment, raising industry-wide standards, means the Compact banks will review the provision of their services with the procurement policies being implemented by the CGF and align those services where possible to reinforce the development of new market norms. [19]

The "Financial regulation" has the goal to establish an engagement with regulators on how to address the links between sustainability and financial stability, supported by expert analysis. In the work is not involved only the University of Cambridge Institute for Sustainability Leadership

(CISL, working with and on behalf of the Banking Environment Initiative – BEI), but also the United Nations Environment Programme Finance Initiative (UNEP FI).

At the beginning of 2015, the leaders of BEI reviewed the strategy in order to establish how the group might expand its agenda based on the learning to date on what has been successful about its partnership-based, solution-driven model of change. The output was to create 3 new areas: Circular resource use, Green bonds and Hard commodities.

The 'Circular' business models represent a radical move away from linear 'take, make, dispose' models of resource use to sustainable models that account realistically for the finite natural of energy and natural resources. The BEI is working in partnership with energy-intensive companies to identify how financiers can support the growth of circular business models. The Green bonds are issued to raise finance for climate change solutions, and support projects with positive environmental benefits. The BEI is engaging with issuers, investors and other relevant bodies to find ways the group can support the stable growth of the green bonds market. For the Hard commodities, the BEI is also engaging in a dialogue with representatives of banks' customers in the extractive sector to identify whether there are suitable opportunities to collaborate on sustainability goals in this area. [20]

An overview of the BEI Programme may be seen below in the Figure 9.

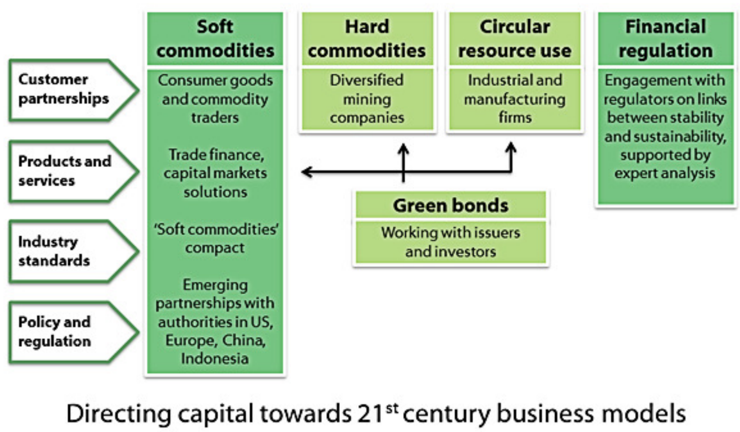

Figure 9: BEI's Programme overview [19]

10.2 INVESTMENT LEADERS GROUP

The Investment Leaders Group (ILG) was conceived in 2013, by the University of Cambridge Institute for Sustainability Leadership (CISL) and Natixis Asset Management, and supported by financial economists at the Cambridge Judge Business School. The Investment Leaders Group comprises Allianz Global Investors, Aviva Investors, First State Investments, Loomis Sayles, Natixis Asset Management, Nordea, Old Mutual, Pension Denmark, Standard Life, TIAA-CREF Asset Management and Zurich Insurance Group. The motivations of the members vary from contributing positively to society, to enhancing returns and mitigating long-term risks to economic stability, all of them willing to improve the impact that their decisions are creating on the environment, economy and society. [19]

Currently the programme is structured in 3 work streams: Vision, Impact and Risk. The Vision stream comprises of a foundational report on the value of responsible investment, which was delivered in June 2014, and a communication tool for building consensus on the importance of integrating social and environmental issues in investment decisions as a function of fiduciary responsibility, tool provided in March 2015. The Impact stream has the scope to create a model investment mandate which should encourage the long-term investment management that takes social and environmental impact and risks into account, model expected in May 2016. In addition, a framework for measuring the social and environmental impact of investments is expected in May 2016. The Risk stream should provide an analytical tool to assess the impact on portfolio value of future carbon regulation, focusing on the most sensitive industries and geographies, tool provided in November 2015. This stream should also provide a research study examining how shifts in the market sentiment induced by the awareness of the future climate risks could impact the global financial markets in the short term, study expected in May 2016 [19].

10.3 Green IT Approaches and Certifications

The Organisation for Economic Co-operation and Development (OECD) has published a survey of over 90 government and industry initiatives on "Green ICTs", i.e. information and communication technologies, the environment and climate change. The report concludes that initiatives tend to concentrate on the greening ICTs themselves rather than on their actual implementation to tackle global warming and environmental degradation. In general, only 20% of initiatives have measurable targets, with government programs tending to include targets more frequently than business associations (Organization for Economic Co-operation and Development, 2016).

Data center facilities are heavy consumers of energy, accounting for between 1.1% and 1.5% of the world's total energy use in 2010. The U.S. Department of Energy estimates that data center facilities consume up to 100 to 200 times more energy than standard office buildings (Federal Energy Management Program, 2016).

Energy efficient data center design should address all of the energy use aspects included in a data center: from the IT equipment to the HVAC equipment to the actual location, configuration and construction of the building.

The U.S. Department of Energy specifies five primary areas on which to focus energy efficient data center design best practices [21]:

- Information technology (IT) systems
- Environmental conditions
- Air management
- Cooling systems
- Electrical systems

Additional energy efficient design opportunities specified by the U.S. Department of Energy include on-site electrical generation and recycling of waste heat. Energy efficient data center design should help to better utilize a data center's space, and increase performance and efficiency. On the other side, the efficiency of algorithms has an impact on the amount of computer resources required for any given computing function and there are many efficiency trade-offs in writing programs. Algorithm changes, such as switching from a slow (e.g. linear) search algorithm to a fast (e.g. hashed or indexed) search algorithm can reduce resource usage for a given task from substantial to close to zero. In 2009, a study by a physicist at Harvard estimated that the average Google search released 7 grams of carbon dioxide (CO_2). However, Google disputed this figure, arguing instead that a typical search produced only 0.2 grams of CO_2 [22].

This consequently leads to a hardware/software approach towards Green IT, making the consumer conscious about computing needs and optimized programming techniques.

10.4 OTHER PROPOSALS FOR A BETTER INTERCONNECTION

From our perspective, the overall things can be improved in order to have a stronger linkage between environment and IT and banking systems.

One of the proposals is to increase the general awareness about the currently strong links known between all 3, referring here not only to the banking and IT leaders, but also to their employees, and why not, to all countries' leaders and all countries' people. In this way everybody will be aware about the impact of different actions resulted from the IT and banking systems- and not only- towards environment, all persons being correctly informed and conscious of the results of their actions.

All previous achievements may be made using proper marketing and communication tools. For example, the frequency of the BEI Forum can be increased from once per year to more times per year, but at least 2 times, with a definitely more international broader audience. In addition, would be good to have some information campaigns in every country of the world, via different traditional and new media channels as publications, television, radio, billboards, postal service, websites, blogs, social media, e-mail, etc.

For the short term perspective, in case the IT and banking companies cannot actively contribute in the immediate period to different environmental actions because of different reasons as resource deficit, etc., they can at least be aware about the latest reports on the market in order to include the latest findings in their future strategy. For example, the results of the reports provided by the Cambridge Institute for Sustainability Leadership should be known by every bank.

Another idea to be applicable as fast as possible is to create in every bank and IT company a special unit responsible for the environment management. In order to give the proper importance to the new unit, from our perspective, in the organizational chart, the unit responsible should report directly to the Holding board of the banking and IT companies.

The main role of the unit should be to integrate environmental protection and ecological sustainability into the daily business activities, taking responsibilities as:

- Being the corporate interface for environmental activities and promoting environmental awareness
- Taking the lead on environmental issues and representing the company in national and international meetings
- Being the first point of contact for the environmental matters in the company
- Developing annual programmes based on the latest researches
- Coordinating internally the agreement of the environmental programmes with all company's departments
- Planning and holding environmental team meetings
- Organising training courses internally in order to increase the employees' environmental awareness
- Performing the necessary activities in the area of environmental legal compliance

Adopting such a separate department, the banking and IT companies will accept their social responsibility and will actively work to serve as an example that doing business and protecting the environment are not mutually exclusive.

In addition, the content of some already existing IT and banking regulations and initiatives should be extended. For example, from our perspective, the scope of the Banking Environment Initiative may be enriched. One of the extends may be applied to the commodities' list, that may consider in the future also other commodities as other type of meat (chicken, horse, turkey, etc.) or other types of banking services. Another improvement can be to come with clear defined new financing solutions that support the transformation of businesses in relevant soft commodity supply chains away from driving deforestation.

Another proposal is referring to the coverage. The mandatory IT and banking regulations should be applicable worldwide, not only to some regions, as Europe. The regulators should team up and think more and more broader, to the entire world, leaving the silo thinking behind, considering that the impacts will be only initially on the local level and after that the impact may be propagated to the entire world. Therefore, in order to combat the destroying of the environment at least the Banking and IT leaders should be in strong contact to the environmental leaders, conceiving all together long term strategies, not only short term ones, considering only local regions.

CONCLUSIONS

Considering the facts presented in the paper, the environment, the IT and the banking systems should not be seen as single independent entities and the strong existing interlinkage between all of them should be considered. Currently, are already existing few regulations that are connecting the environment with the IT and the banking systems and some initiatives are planned for the upcoming years, but the maturity is not that high.

By using the Erlang formulas, we are able to use the above stated probabilities to represent both the point of view of an outside observer simply by looking at a system over the total time and calculating these probabilities as a fraction of time, and the point of view of the arriving customers who see the system only at the instance at which they arrive, meaning finding the system in blocking state and therefore waiting in a queue.

For the Erlang B formula, the variability in the service times does not affect the answer, but the variability in the arrival process does. No matter what distribution function we use to describe service times, the answer is unaffected. From a practical point of view, something that is difficult to measure, does not have to be measured because the final answer does not depend on it. We can completely disregard the statistical characteristics of the service times, once this model is understood. This is the reason why these formulas are so robust and safe to use.

Based on all information presented in this paper, we can conclude that computer simulation is an important tool for the analysis of queues whose service times have any arbitrary specified distribution. In addition, the theoretical results for the special case of Poisson arrivals and exponential service times are extremely important because they can be used to check the logic and accuracy of the simulation, before extending it to more complex situations.

Moreover, such a simulation gives insight on how such a queue would behave as a result of different arrival processes and service times. Further, we consider that it offers a methodology for looking into more complicated cases not only like getting input times from a network of banking systems trying to implement a new set of banking regulations where a mathematical approach cannot help, but also in other complex areas.

Another important point of the paper is to have mandatory environmental enriched IT and banking regulations applicable worldwide, not only to some regions or countries as it is happening today. In this way, the regulators will be challenged to not think in silos anymore, on a short term, and to adopt a broader view applicable for a long term period, because everything is connected and the environmental impacts are affecting the entire world.

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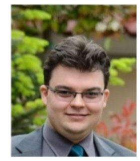
ACKNOWLEDGEMENTS

The authors would like to thank their families for support!

Authors



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