Final master’s Project
Industrial Engineering

The Ripple Effect as a shortage propagation. Four different metrics to analyse disruption propagation in Supply Chains.

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Department: Organización Industrial y Gestión de Empresas I
Escuela Técnica Superior de Ingeniería

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The Selection Board appointed to judge the above-mentioned project is composed of the following members:

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Seville, 2023

The Secretary of the Selection board

To my family and friends

To my professors

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I would like to thank the Department of Industrial Organisation and Business Management I for giving me the opportunity to learn about university research, and to awaken my interest in the fascinating world of supply chains. Thanks to this, I have been building my professional career in a field that I am more and more passionate about every day.

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Laura Tobajas Machín

Student of the Double Master's Degree in Industrial Engineering and Industrial Organisation and Business Management

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Abstract

This project aims to deepen the analysis of supply chains. Supply chain managers are often confronted with problems that affect the performance of the chain. This study focuses in particular on one of them, the Ripple Effect. But what does this phenomenon imply? The reality is that there is currently no single definition among the authors. But, there is a common part in all the definitions found. The Ripple Effect always involves the propagation of disruptions along the supply chain. In this project, the opinion of different authors is analysed and a definition is established. In particular, it has been decided to restrict the term to only those disruptions that somehow generate an inability to supply between nodes. This definition allows us to apply our conclusions to such high-profile cases as the Suez Canal blockage, the microchip crisis, the Listeria problem in South Africa and, of course, Covid-19. In all of them, the disruption caused an inability to supply between nodes that spread to other downstream nodes in the chain.

The devastating consequences of the Ripple Effect for the supply chain manager and the participating companies justifies the boom of studies that have been developed in recent years in this framework. The vast majority of studies focus on analysing chain performance in the face of propagating disruptions, in some cases proposing measures both before and after the onset of a disruption to mitigate the negative effects. After an extensive literature review, the conclusion drawn is that all these studies need to rely in some way on metrics to see how the Ripple Effect impacts. This project proposes to continue the research developed in the book chapter *"Measuring the ripple effect: A simulation based study of supply chains resilience using new metrics"* (2022) by Laura Tobajas, in which it is proposed to use metrics based on the backlog variable (quantity pending delivery to the next node), which through a series of time restrictions makes it possible to clearly delimit whether a node is being affected by the Ripple Effect or not. The study focused on carrying out a sensitivity analysis of certain parameters and common chain factors using a metric oriented to the node closest to the end customer, the retailer. From the conclusions of this study, it became clear that the propagation of this inability to supply along the different nodes was, to say the least, intriguing. Therefore, this project retrieves that model and includes a series of new metrics, all based on the backlog variable. These metrics allow us to analyse the actual propagation of disruptions along the chain through every echelon involved. Focusing on how this inability to supply evolves node by node, it has been able to obtain relevant conclusions about the Ripple Effect and its behaviour in a supply chain. Among other things, it has been seen how there is clearly an important random component when it comes to whether the node receives the Ripple Effect or not. This is noticeably reduced as the node moves away from the disturbance.

The supply chain model on which the study is based is a four-step serial chain with one node at each echelon. Matlab software has been used to perform a simulation based on the daily operations of a supply chain. The equations used to model the operation of the chain can be found in the model section from the report.

Resumen

Con este proyecto se busca profundizar en el análisis de las cadenas de suministro. Los gestores de la cadena tienen que afrontar a menudo problemas que afectan al rendimiento de la misma. Este estudio se centra en uno de ellos, el *Ripple Effect* (Efecto Cascada). Pero, ¿qué implica este fenómeno? La realidad es que a día de hoy no existe una definición única entre los autores. Pero, sí hay una parte común en todas las definiciones encontradas. El Efecto Cascada implica siempre propagación de *disruptions* (perturbaciones) a lo largo de la cadena de suministro. En este proyecto se analiza la opinión de distintos autores y se establece una definición. En concreto, se ha decidido restringir el término para únicamente aquellas perturbaciones que generan de alguna forma incapacidad de suministrar entre los nodos. Esta definición nos permite aplicar nuestras conclusiones a casos tan sonados como puedan ser: el bloqueo del canal de Suez, la crisis de microchips, el problema de Listeria que se vivió en Sudáfrica… y por supuesto el Covid-19. En todas ellas la perturbación provocó una incapacidad de suministrar entre nodos que se propagó a otros eslabones de aguas abajo de la cadena.

Viendo los efectos devastadores del Efecto Cascada para el gestor de la cadena y las empresas participantes, se justifica el auge de estudios que se han desarrollado en los últimos años en este marco. La gran mayoría de estudios se centra en analizar el rendimiento de la cadena ante perturbaciones con propagación, proponiendo en algunos casos medidas tanto previas como posteriores al comienzo de una perturbación para mitigar los efectos negativos. Tras un extenso análisis de literatura, la conclusión obtenida es que todos estos estudios necesitan de alguna forma basarse en métricas para ver cómo impacta el Efecto Cascada. En este proyecto se propone continuar con la investigación desarrollada en el capítulo de libro "*Measuring the ripple effect: A simulation based study of supply chains resilience using new metrics*" (2022) de Laura Tobajas, en el que se utilizan métricas basadas en la variable *backlog* (cantidad pendiente a entregar al siguiente nodo), que mediante una serie de restricciones temporales permite delimitar claramente si un nodo está siendo afectado por el Efecto Cascada o no. El estudio se centró en realizar un análisis de sensibilidad de ciertos parámetros y factores habituales de la cadena basado en una métrica orientada al nodo más cercano al cliente final, el minorista. De las conclusiones de este estudio se concretó que la propagación en sí de esa incapacidad de suministrar a lo largo de los distintos nodos resultaba cuanto menos interesante. Por tanto, este proyecto recupera ese modelo e incluye una serie de métricas nuevas basadas todas en el backlog. Estas métricas permiten analizar la propagación propiamente dicha de las perturbaciones a lo largo de la cadena. Centrándonos en cómo evoluciona esa incapacidad de suministrar nodo a nodo se han conseguido obtener conclusiones relevantes sobre el *Ripple Effect* y su comportamiento en una cadena de suministro. Viendo, entre otras cosas, cómo claramente hay una componente aleatoria importante a la hora de que el nodo reciba los efectos de *Ripple Effect* o no. La cual se reduce notoriamente a medida que el nodo se aleja de la perturbación.

El modelo de cadena de suministro en el que se sustenta el estudio es una cadena serial de cuatro escalones con un nodo en cada escalón. Se ha utilizado el software Matlab para realizar una simulación en base a la operativa diaria de una cadena de suministro. Las ecuaciones utilizadas para modelar el funcionamiento de la cadena pueden encontrarse en el apartado referido al modelo de la memoria.

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1 INTRODUCTION

This introduction section is organised as follows. First of all, the reader is put in context by clarifying concepts related to the Ripple Effect, such as disruptions. Next, the objectives of this study are explained, and finally, the structure of the rest of the document is presented.

1.1 Understanding the Ripple Effect in a Supply Chain

Before talking about the Ripple Effect (RE), the term disruption in relation to supply chains (SCs) needs to be addressed. Disruptions are always present in business. However, most of them we do not realise. The small unforeseen events that the shop assistant has to deal with on a daily basis are not known to the owner if he or she has several shops. The same is true in interconnected SCs. Setbacks that happen in the factory in the course of a day usually do not matter much and do not have an impact on the chain. However, when we talk about disruptions in this framework, we mean disruptions that generate an impact. Specifically, we will talk about high impact with low probability risks (see Figure 1).

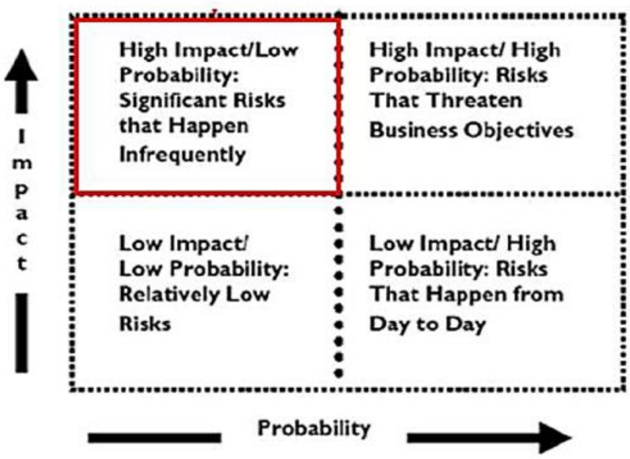

Figure 1. Risk and Impact matrix. Source: Madhavi and Wickramarachchi, 2022.

In other words, in this study, disruptions are events that alter the normal and expected functioning of SCs. They are caused by external phenomena that are generally infrequent in nature but have a major impact (Zhuye Li et al., 2021; Rezapour et al., 2018). The risks of supply chain disruptions are an attractive topic for researchers, part of the field of Risk Management, these studies are complementary to the analysis of the impact of disruptions. It is just as important to know what risks the chain is subject to as it is to know the consequences. Some examples of disruption risk-related studies are: Ming Liu et al., 2022; M. Christopher and H. Peck, 2004; Ghadge et al., 2022.

Disruptions have been classified in the literature in many ways. For example, by the origin of the event causing the disruption (natural phenomena, strikes, economic crises, wars...). Or even by how it affects the chain (instability in demand far from typically expected ranges, blockage of nodes, blockage of internodal transport, disappearance of labour, price increases...). Some examples of disruptions and consequences along the chain are the following: Mercedes-Benz had to stop the production of a vehicle plant in Alabama in 2020 due to a shortage of components made in Europe due to the COVID-19 pandemic (WBRC, 2020); in January 2021 Honda suspended production at its Swindon plant (United Kingdom), due to the delay caused by the epidemic (The Guardian 2021); in 2017 and 2018 an outbreak of listeriosis cause several disruptions in the South African food and beverage sector, the manufacturer Tiger Brands Ltd and other competitors had to shut down factories reporting a loss of almost 18 million of euros (converted from South African Rand) (Ermes et al., 2022).

Although disruptions can have many different effects on SCs, one of the most common outcomes is that they result in the inability to supply. That is to say, a node may be blocked by a strike of its workers (e.g. in the distribution company) but in the end the phenomenon translates into that node being unable to continue supplying for a period of time. Furthermore, the retailer may be affected by a fire at his premises, which causes a blockage at the node resulting in the inability to supply. The same can happen if transport between nodes suffers the ravages of a sudden border closure. In summary, disruptions cause certain problems in the chain, but the vast majority can be modelled as a temporary inability to supply, either partial inability or complete inability (Muralidharan et al., 2022). Some authors even go further, they model disruption as simply the disappearance of nodes or edges (connection between nodes). This is very common in studies with large numbers of nodes forming complex networks (A. Barabási et al., 1999; S. Shen, 2013; H. Zhong et al., 2015).

However, what happens if that disruption spreads down the chain, what effects does it have, and how can we measure that spread or impact? Well, it depends on what causes the disruption. Since, as we have already seen it is not an outrage to say that many disruptions lead to an inability to supply, we can start by asking what happens when the inability to supply spreads through the supply chain.

The fact that a disruption can be propagated is logical since the nodes that make up the chain are interconnected and depend on each other. Whether they are part of the same company or business group, or they are totally independent organisations. Interdependence is something undeniable, so the possibility that the inability to supply could spread seems reasonable. We can see how in a computer network, malware spreads through a connected computer or server, and it can damage system performance and even shut down the whole network. The failure of a station in a power grid may cause a power outage resulting in the disconnection of the dependent installation (Ho Young et al., 2023). No doubting that propagation may naturally happen, in this study we have addressed that spread or propagation and answered the questions posed in this introduction by creating 4 new metrics that can give visibility on how it impacts the SC.

This propagation of disruptions was dubbed the RE by Ivanov in 2014 with the study called: "The ripple effect in supply chains: trade-off 'efficiency-flexibility-resilience' in disruption management" (Ivanov et al., 2014). Although the term has been used to refer to disruption propagation not all authors give the RE the same exact definition. The most common one is the following: a phenomenon which denotes a disruption that rather than remaining localized or being contained to one part of the SC, cascades down-stream and impacts part or even the entire SC (Ivanov, 2019; Ivanov et al., 2019; Ivanov, 2020, Ming Liu et al., 2022). Other authors have employed the term to refer to any kind of disruption propagation along the chain (Zhuyue Li et al., 2022; Park et al., 2022; Burgert and Lasch, 2022; Hosseini and Sarder, 2019).

However, this study is a bit more restrictive with the term. This study refers to RE as a phenomenon that implies a disruption propagation from upstream to downstream. Yet, this propagation must imply inability to supply. In other words, when a SC suffers a disruption of any kind, if it causes inability to supply at one or several nodes (we have already seen that inability to supply can be caused by a wide variety of disruptions) and this partial or complete inability to supply propagates along the chain affecting more a more nodes, only then we are dealing with RE. The term RE has been considered in this study to cover only these types of disruptions. Other phenomena such as sudden cessation of demand, problems in chain communication, sudden price increases, failed strategies, etc., among other examples, would not be within the scope. Either because they are disruptions that are not generated from upstream to downstream, or because they do not result in an inability to supply, but rather in mere performance deficiencies in the chain, or even because they are localised and do not propagate.

1.2. This study´s main objectives

Specifically, this study focuses on quantifying the spread of the inability to supply. The aim is not to quantify the impact in economic terms, service level or similar..., but rather to quantify the mere propagation of the inability to supply. If we leave aside the costs and focus on metrics that tell us only if the node is being affected by shortage or not and for how long, allows us to move away from assumptions that have prevent researchers from generalising the results.

In this work we model a SC with 4 echelons and 4 nodes (one for each echelon). This model is based on the one presented by Laura Tobajas in 2022 (Machin et al., 2022). Using the same variable proposed in the study, the backlog, and together with a series of temporal restrictions, 4 different metrics have been constructed that allow insights to be drawn from the RE in serial SCs.

1.3. This study´s main structure

The rest of the document is organised as follows. In Section 2 the state of the art of disruptions and RE in SCs is discussed. Several classifications of these studies are made, and the metrics found in the literature to measure the impact of RE are explored in depth. In addition, the conceptual framework on which this study is based is defined. Within Section 3, the model used to conduct the experiments is discussed. In particular, the variables, parameters and constants are presented, as well as the dynamics of the experiments. In Section 4 we can find the main metrics analysed, with a detailed explanation of their definition, as well as the results obtained after the experiments. Finally, in Section 5 we find the conclusions and the proposal of new research lines.

2 QUANTIFYING THE RIPPLE EFFECT

The RE is a phenomenon defined differently according to each author. Therefore, quantifying the impacts on a SC may also be treated quite widely among authors. Indeed, even the mathematical approach of the study will limit the author enormously, as there are many different mathematical approaches for modelling a SC (discrete event simulation, linear programming, network related simulations, graphs theory based…). In this section we will first talk about a general classification of RE related literature, and then, we will dive into the RE quantification. We will see that it is widely common to measure the impact of the RE using performance metrics of any kind. However, we propose to measure the impact in terms of propagation exclusively, which goes in line with the last part of the section, the framework of definitions used for this study.

2.1 State of art

As abovementioned the RE can be studied from many different perspectives. Researchers have mainly focused on studying the impact of the propagation along the chain and/or studying different strategies that can help reduce the impact of disruptions (before or after the disruption occurs). Sometimes it is combination of both (as in, e.g., Muralidharan et al., 2022; Ivanov et al., 2019 or Carvalho et al., 2012). But what they all have in common is that both to measure impact and to look for strategies to reduce the consequences, some kind of metrics must be used to compare results.

Before we dive into metrics, it is worth noting that this study is focused on analysing the RE along the SC. Analysing the RE in SCs typically involves studying the propagation and amplification of disruptions or changes from upstream to downstream stages. Along these years, authors and researchers have employed various methods and techniques to examine and quantify the effects. Some common approaches used in analysing the RE are:

1. Quantitative models:

Researchers develop mathematical models that simulate the dynamics of SCs to study the RE. These models incorporate factors such as demand variability, lead times, inventory levels, and order policies to assess how disruptions or changes propagate through the system. Simulation techniques like discrete event simulation or system dynamics modelling are often employed to analyse the behaviour and quantify the impact. Sometimes, strategies are tested based on the quantitative model built (Jeong et al., 2023; Muralidharan et al., 2022; Ivanov, 2022; Park et al., 2022; Ivanov et al., 2019).

2. Case studies:

Authors conduct in-depth case studies of real-world supply chains to understand the specific dynamics and consequences of the RE. They may analyse historical data, interview SC participants, and observe the flow of goods and information to identify patterns and impacts of disruptions or changes. Case studies provide rich insights into the complexities of SC operations and the ramifications of the RE in practice. As an example, Zhao (Zhao et al., 2019) analysed a SC network composed of 2971 firms over 90 industry sectors. In addition, authors sometimes build a mathematical model based on the case observed. An example is Hosseini et al., 2016, analysing disruptions in a sulphuric acid manufacturing plant; other examples may be Jeong et al., 2023; Peixin

Zhao et al., 2022; Ermes et al., 2022.

3. Data analysis:

Researchers analyse historical SC data to identify and measure the RE. They may examine data on order quantities, inventory levels, lead times, demand patterns, network behaviour across multiple stages of the SC. Statistical techniques, such as time series analysis or regression analysis, can be employed to quantify the relationships between upstream and downstream variables and assess the magnitude of the RE. Some examples are: Jeong et al., 2023; Madhavi and Wickramarachchi, 2022; Li et al., 2021.

4. Network analysis:

Authors use network analysis techniques to map the interconnected relationships among SC participants and identify how disruptions or changes propagate through the network. They may analyse information flows, communication channels, and decision-making processes to understand how information and actions are transmitted and amplified along the SC. The Bayesian Network is commonly use among authors and has been used to quantify the RE impact. Some examples of network studies are studies as: Ming Liu et al., 2022; Hosseini et al., 2020; Liu et al., 2021b; Ojha et al., 2018; Zhuyue Li et al., 2022; Peixin Zhao et al., 2022; Li et al., 2022.

5. Sensitivity analysis:

Researchers perform sensitivity analyses to assess the vulnerability of the SC to disruptions and quantify the potential impact of different scenarios. They systematically vary input parameters, such as demand variability, lead times, or order policies, to observe how changes in one part of the SC propagate and affect other echelons. (Hosseini et al., 2022; Machin et al., 2022; Llaguno et al., 2021).

By employing these analytical approaches, we can gain insights into the dynamics and consequences of the RE, understand the underlying mechanisms, and explore strategies to mitigate its negative impacts. The RE approach is being widely studied since during the recent years the world has experienced many different unpredictable events that have turned into the form of disruptions along the SCs of most of the goods from all over the economies from every existing continent (Zhuye Li et al., 2021; Sawik T., 2020; Rameshwar et al., 2019; Choi TM. et al., 2021; Azadegan et al., 2021; Peixin Zhao et al., 2022). We are mainly talking about Covid-19, but we cannot forget the ongoing war in Ukraine along with Western vetoes for Russia, the microchip crisis, the blockade of the Suez Canal... among others.

In any case, any approach and their findings can help practitioners and decision-makers make informed decisions to improve SC resilience, responsiveness, and overall performance.

This study is based on the first (quantitative models) approach abovementioned. Although it may be also considered as sensitivity analysis. It has been developed a mathematical representation of a common basic SC and it has been used a simulation technique to analyse the propagation of the RE in SCs. This model has captured the dynamics of SCs, including typical factors such as demand variability, inventory levels, and order policies, to simulate and understand how disruptions propagate and affect different stages of the SC. Based on this study many strategies may be proven using the metrics proposed.

As mentioned above, what all approaches have in common is the need to use metrics to compare results and scenarios. The downside of the existing literature is that the metrics are often very specific to the problem or case that the author chooses to analyse. They look at cost or profits (e.g. Ivanov, 2022; Ivanov, 2019; Carvalho et al., 2012), they look at the service level of the retailer (e.g. Ivanov, 2022; Park et al., 2021), they look at the graphics from the inventory held (Muralidharan et al., 2022), but few metrics allow researchers generalise results. Either they have to be based on assumptions that complicates generalization, or replicas cannot be modelled as the propagation is observed in the graphics of common variables such as inventories. Specifically, within the field of simulation, the usual approach is to carry out some experiments and visualise the results in graphs to see the effects of the RE. But in this field, there is no common metric as there is, for example when studying other phenomena such as the Bullwhip Effect. The Bullwhip Effect (BE) is a common phenomenon widely studied over the years that refers to the amplification of the variability of the orders from downstream to upstream of a SC. (Ivanov et al., 2019).

Usually, studies that analyse the RE along the SC employ various metrics to assess its consequences. These metrics aim to quantify the effects of disruptions or changes on key performance indicators (KPIs) or other relevant indicators. Here are some common ways in which the impact of the RE is measured:

1. Inventory levels:

Researchers may examine how disruptions or changes in upstream stages affect inventory levels throughout the SC. This can involve measuring changes in stock levels, backorders, or excess inventory resulting from the RE. (Muralidharan et al., 2022; Park et al., 2022)

2. Lead time variability:

The impact of the RE on lead times, i.e., the time between placing an order and receiving it, can be measured. This can include analysing the increase in lead time variability or assessing the delays experienced in the SC due to the propagation of disruptions. Carvalho used the lead time ratio as a performance impact (Carvalho et al., 2012). Another example is the one from Ivanov (Ivanov, 2022).

3. Financial metrics:

Researchers often measure the financial impact of the RE. This can involve analysing increased costs associated with rush orders, expedited transportation, inventory carrying costs, or penalties incurred due to disruptions. Researchers may analyse the impact of the RE on financial indicators, such as revenue, profit margins, or return on investment (ROI), to understand the financial consequences of disruptions or changes in the SC. For example, Rezapour et al., 2017, focused on maximizing profits. Ivanov used the profit as a financial SC performance in a simulation study (Ivanov, 2022). Other examples are Carvalho et al., 2012; Ivanov et al., 2019 or Burgert and Lasch, 2022.

4. Customer service levels:

The impact on customer service metrics, such as order fulfilment rates, on-time delivery, or customer satisfaction scores, can be assessed. This helps understand how disruptions or changes propagate through the SC and affect customer experiences. For example, Peixin Zhao et al., 2022, employed the service level as one of the metrics involved in the calculation of the resilience against disruption propagation. Another example is the one from Muralidharan (Muralidharan et al., 2022) where the disruption-propagation-impact on the SC was measured using the service level. Park (Park et al., 2022) also employed a similar approach, using the demand satisfaction level understood as the cumulative production quantity divided into the cumulative demand.

5. Other supply chain performance metrics:

Various performance metrics can be utilized to measure the impact of the RE on SC performance. These may include metrics like order cycle time, order fill rate, on-time delivery performance, or overall supply chain responsiveness. As an example, Ivanov used what he called expected lead time service level to measure the performance of the SC (on time deliveries at customers divided into all outgoing orders) (Ivanov, 2022). Park based the calculation of the robustness of a SC on the production level understood as the ratio between the production quantity and the demand of the final product (Park et al., 2022).

6. Network related metrics:

Many researchers that have focused on complex networks have simplified the problem by using Graph Tehory based- programming. For example, Young employed the mean latency as a metric (Jeong et al., 2023). Other examples of network-related metrics are Ming Liu et al., 2022 and Liu et al., 2021b, among others.

This study aims to quantify the propagation itself leaving out KPIs or common indicators and enabling to know what happens along the SC whenever disruptions occur upstream. Specifically, it is based on the variable backlog which is related to the inventory levels held by the nodes. Therefore, it can be classified as the first approach abovementioned. However, there is no study in this approach focalised in generalising results by consolidating metrics capable of being recalculated as many times as needed.

On the other hand, if a KPI or some sort of performance indicator as the ones listed above, is being analysed, to determine whether a node is suffering RE authors need to stablish some limits in a variable (most of the times performance variables) to consider that the RE is taking place. The problem with stablishing limits in the value of a variable is that those limits can be crossed for many different circumstances making it difficult to narrow down the RE.

This study proposes to narrow down the RE by considering that each node suffers from it whenever they have a positive backlog. Considering that we can model when a disruption will take place the use of some temporal restrictions allows us to limit those potential periods of RE without stablishing actual limits to the value of the variable. The model incorporates other restrictions needed to ensure that the results are representative and valid.

2.2 The Ripple Effect approach in this study

Before diving into the framework of definitions of this study it is important to go back to the classification of disruptions initially referred to in the Introduction section. We have seen some classifications of disruptions but, one not discussed yet and perhaps the most important (it directly affects the way in which the problem is modelled and mathematically treated) is the one that arises from the following key question: ¿is the disruption initially localised?, ¿or are there several disruptions of the same or different nature affecting the same SC? Phenomena such as COVID-19 has led to SCs being disrupted in many ways at the same time. Therefore, their analysis is more complex than when the disruptions are localised. (Muralidharan et al., 2022). In this study, only localised one-time disruptions will be considered to simply the measurement of propagation (as this is the main objective of this study).

As already discussed, disruptions are defined as alterations on the SCs. However, only alterations which lead to high impact on performance of the SC are considered for the purpose of the study. Generally, those high impact disruptions are originated from low frequency events. Specifically, the disruptions considered are the ones that may cause inability to supply in nodes of the SC. What is going to be measured in this study is if the propagation of this specific type of disruption occurs and how, throughout the SC.

Therefore, the term Ripple Effect will refer as the propagation of the above explained disruption, or in other words, propagation of the inability to supply. Therefore, the only possible propagation of the inability to supply will be from upstream to downstream as the SC studied is serial.

3 QUANTITATIVE MODEL OF THE SUPPLY CHAIN

The quantitative model that enables the simulation of a SC employed in this document is the one presented in the study from Laura Tobajas (Machin et al., 2022). Based on that model it was possible to extend the study to the analysis of the propagation along a complete SC, gaining insights in the propagation itself instead of referring to performance metrics typically obtained from the retailer. First of all, the variables, parameters and constants are presented. Then, the model dynamics are approached.

3.1 Variables, parameters, and constants

The model employed is constructed in the mathematical software MATLAB, which enables simulation. The schema of the SC analyzed can be found on Figure 2.

The demand information flows from the final client to the retailer. Initially, the information on the requested demand is passed from the end customer to the retailer. The retailer analyses how much demand was received. The retailer, who is not in the business of manufacturing this good, has to buy it from a wholesaler. The wholesaler thus receives a demand from the retailer. This situation is repeated along the chain until it reaches the factory.

Once the factory starts to manufacture this product, it will start to spread along the chain. The nodes will deliver the demand they have received and keep a certain amount of stock for unforeseen events.

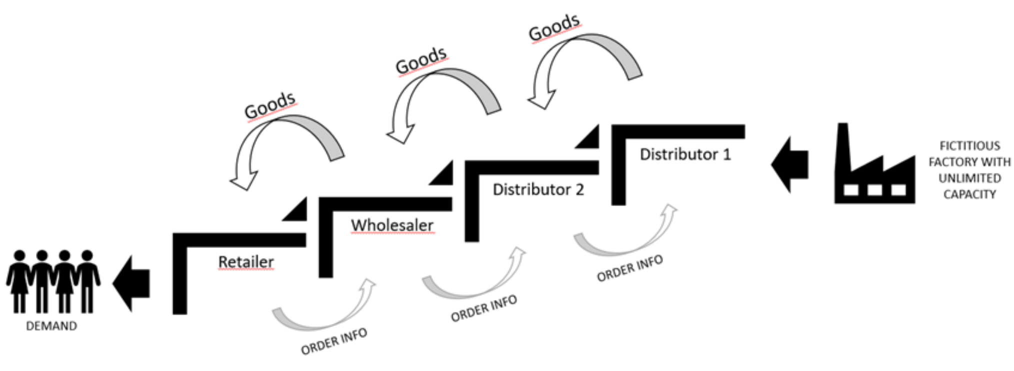

Figure 2. Supply Chain Structure.

The 4- echelon and 4-nodes serial SC was modelled based on the following assumptions from Table 1.

Assumption 1	Stochastic demand (normal distribution)

Assumption 2	Order-up-to policy
Assumption 3	Deterministic lead time
Assumption 4	Nodes calculate forecast using n-period moving average demand
Assumption 5	The factory is an endless source provider (when not disrupted)
Assumption 6	Backlogging is permitted (in all the nodes forming the SC)

Table 1. Assumptions of the model.

The main variables, parameters and constants employed for modelling the SC are listed below.

$$j = 1,2,3,4$$

- j=1, referring to the retailer.
- j=2, referring to the wholesaler.
- j=3, referring to the distributor.
- j=4, referring to the factory.

KEY VARIABLES AND CONSTANTS	DESCRIPTION
$\mathbf{I_j}(\boldsymbol{t})$	Inventory level held by node j in period *t*.
$\mathbf{WIP_j}(\boldsymbol{t})$	Work in progress in node j in period *t*.
$\boldsymbol{\delta_j}$ (t)	Quantity of product units delivered by node j, in each period *t*.
$\boldsymbol{B_j}(\boldsymbol{t})$	Backlog held by node j in period *t*.
$\boldsymbol{O_j}(\boldsymbol{t})$	Number of product units that node j orders from node j+*1*, in period *t*.
$\boldsymbol{SS_j}(\boldsymbol{t})$	Security inventory that node j intends to hold in period *t*.
d(t)	Quantity of product units demanded by the final customer in period *t*.
LT	Number of minimum periods required for one product to travel between nodes (Minimum Lead Time).
$\overline{\boldsymbol{LT}}_{\boldsymbol{j}}(\boldsymbol{t})$	Moving average of the Lead Time from node j+*1* to node j in period *t*. (Real Lead Time).
$\bar{\boldsymbol{d}}_{\boldsymbol{j}}(\boldsymbol{t})$	Moving demand by node j-*1* in period *t*. In the case of j=*1*, the demand corresponds to the final customer.
$\bar{\boldsymbol{\sigma}}_{\boldsymbol{j}}^{\boldsymbol{d}}(\boldsymbol{t})$	Moving standard deviation by node j-*1* in period *t*. In the case of j=*1*, the demand corresponds to the final customer.
R	Constant value used in the Safety Stock calculation.
Z	Safety factor used in the Safety Stock calculation.
M	Number of previous periods used in the calculation of the moving average Lead Time.

DT	Number of disrupted periods.
μ	Average demand used to model demand of the final customer.
σ	Standard deviation used to model demand of the final customer.
N	Number of previous periods used in the calculation of the moving average demand.
n	Number of periods simulated

Table 2. Variables and constants of the model (Machin et al., 2022).

3.2 Dynamics

The operations of each node of the SC can be summed up to the Figure 3. The details of each operation can be found bellow, within the equations.

In this SC, a tipical working day in a node involves, first of all, the recalculation of the saefty stock that the node wants to hold. This operation can be done at the end of the day or at the beginning (it has been decided to calculate it at the beginning, although for the dynamics it is not a critical decisión). The next operations are the one concerning the reception of the godos from previous orders. The main updates involve the inventory checks and the work in progress check (meaning the orders that have not arrived yet but that have been launched). After this, the node delivers the orders received from their customers the day before. Then, the node has to change again the inventories. The node cannot forget about the backlog, if any, that is holding (they may owe the client goods). The last operations that the node will do before their workers go home that day are the ones related to the orders to their suppliers. The node needs to calculate the amount that is going to order and after they launch an order they will update the work in progress.

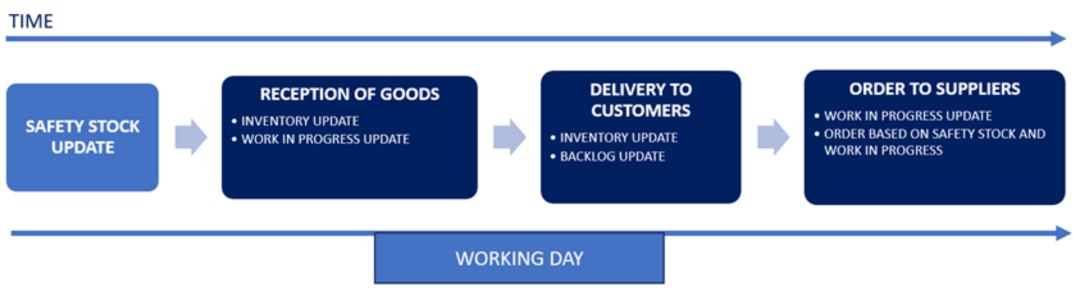

Figure 3. Operations in a working day of a node.

Equation 1. *Safety stock*

$$SS_j(t) = round((\overline{LT}_j(t) + R) * \bar{d}_j(t) + Z * \sqrt{(\overline{LT}_j(t) + R) * \bar{\sigma}_j^d(t)})$$
$$j = 1,2,3,4.$$

Equation 2. *Inventory update 1*

$$I_j(t) = I_j(t-1) + \delta_{j+1}(t - LT)$$
$$j = 1,2,3,4.$$

Equation 3. *Work in progress update 1*

$$WIP_j(t) = WIP_j(t-1) - \delta_{j+1}(t - LT)$$
$$j = 1,2,3,4.$$

Equation 4. *Delivery to the customer*

$$\delta_j(t) = min\left(I_j(t),\ d(t) + B_j(t-1)\right)$$
$$j = 1.$$

Equation 5. *Delivery*

$$\delta_j(t) = min\left(I_j(t),\ O_{j-1}(t-1) + B_j(t-1)\right)$$
$$j = 2,3,4.$$

Equation 6. *Inventory update 2*

$$I_j(t) = I_j(t) - \delta_j(t)$$
$$j = 1,2,3,4.$$

Equation 7.*Backlog of the final* customer

$$B_j(t) = B_j(t-1) + d(t) - \delta_j(t)$$
$$j = 1.$$

Equation 8. *Backlog*

$$B_j(t) = B_j(t-1) + O_{j-1}(t-1) - \delta_j(t)$$
$$j = 2,3,4.$$

Equation 9. *Order*

$$O_j(t) = max\ (0,\ SS_j(t) - I_j(t) + B_j(t) - WIP_j(t))$$
$$j = 1,2,3,4.$$

Equation 10. *Work in progress update 2*

$$WIP_j(t) = WIP_j(t) + O_j(t)$$
$$j = 1,2,3,4.$$

Equation 11. *Hypothetical delivery*

$$\delta_5(t) = O_4(t-1)$$

All the equations explained above represent the main ones employed in the MATLAB model. There are many more aditional equations used to carry out the simulations needed.

As already explained before, the variable backlog is crucial in the calculation of the metrics. This idea was firstly introduced in the study from Laura Tobajas (Machin et al., 2022). As in this mentioned study, in this one there has been used some temporal restrictions in order to delimit the time frame in which the shortage may appear as a cause of the Ripple Effect. For example, if a certain node appears to have shortage in the simulated period *x* and the disruption is modelled to start in the simulated period *y* (being *y* later tan *x*), this certain node is obviously not being affected by shortage in the simulated period *x*. In addition, other aspects as the lead time have been considered. Shortage will not affect a node which is inmediately downstream of another until the needed periods to receive the last possible shipment have passed.

On the other hand, the disruption modelled is a disruption that involves the paralysis of the factory for a certain period of time. The factory stops supplying Distributor 1 and the latter must subsist on its stock during the time delimited in the simulation. The interesting thing is to see how (if it is the case) this shortage is cascaded from upstream to downstream.

4 ANALYSING DISRUPTION PROPAGATION

Once we have already seen how the model works, we can now explain the metrics proposed. This section is organised as follows, first we define those metrics, and then we dive into the results obtained. etc.

4.1 Main metrics analysed

This study aims to analyse many different metrics that can be calculated taking into account the definition of the RE as a shortage propagation. Therefore, from now on, when we refer to a node or chain affected by RE, we mean that this node or chain is suffering shortage and cannot supply products to its customer. The reasons for this assumption were already discussed in the previous sections.

All these metrics were created based on the same variable, backlog. It is used as a reference to know if the node is being affected by the initial disruption. It is important to mention that the study also uses a series of temporal restrictions that allow us to delimit whether the node is really being affected by the original disruption, or by the usual operability of the chain.

4.1.1 Ripple Effect duration along the chain

Sometimes, it may be interesting to know whether the whole SC chain has RE or not and for how long. In the study made by Laura Tobajas (Machin et al., 2022) the metric was just focused on the retailer, but it is more and more common to find SCs controlled by a SC specialist/manager where some information is shared among the different enterprises that conform the SC. We may also find that the whole SC is from the same enterprise. In either case, it is quite interesting to know how the RE may impact the whole SC performance.

This metric aims to give visibility on the RE duration, understood as shortage at the nodes, of the entire chain. In other words, it tells us how long one or several nodes in the chain are unable to supply as a result of not having more stock. It is important to note that there may be periods where more than one node is affected by shortage.

The definition of this metrics is also explained in Figure 4 for a better understanding.

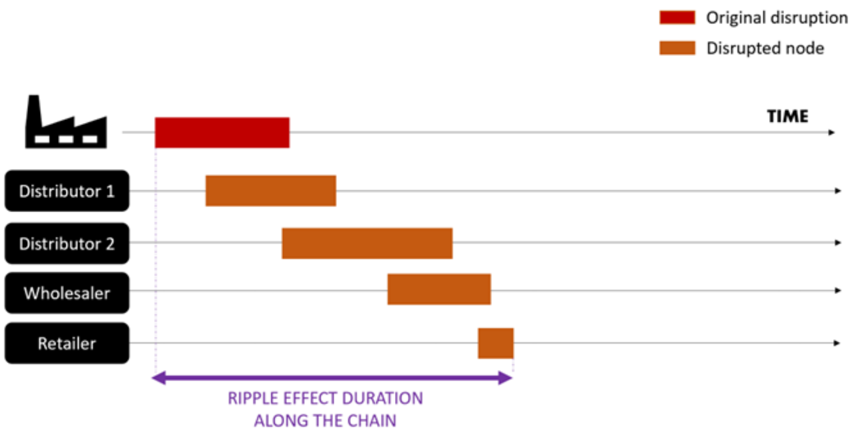

Figure 4. Visual representation of the RE duration along the chain.

4.1.2 Probbaility of infection of each node individually

Since our model has 4 nodes there are 4 different results that we need to take into account:

- PROBABILITY OF INFECTION OF THE NODE 4 (DISTRIBUTOR 1)
- PROBABILITY OF INFECTION OF THE NODE 3 (DISTRIBUTOR 2)
- PROBABILITY OF INFECTION OF THE NODE 2 (WHOLESALER)
- PROBABILITY OF INFECTION OF THE NODE 1 (RETAILER)

Each of these metrics abovementioned gives us the probability of infection of a node. It is calculated based on the results of the simulation. During the 500 replications, for example, node 1 has been affected by shortage "x" times. Therefore, if we divide x/500 we get the percentage of times node 1 has been affected by shortage.

This metric turns quite interesting when we use that result to calculate an empirical probability. For example, if a decision-maker knows that only the safety stock calculation factor can vary at his node, he can look for the value that allows him to have a lower probability of infection, performing a sensitivity analysis on this factor.

4.1.3 Reach in the Supply Chain

The RE in the SC can also be analysed from the perspective of how many nodes have been affected by shortage. This metric can be a starting point for studies that may consider longer SCs that enable a deeper analysis. In this study, since the SC is modelled with only 4 echelons only 5 different scenarios can be obtained:

- RE affected 100% of the nodes (4/4)
- RE affected 75% of the nodes (3/4)
- RE affected 50% of the nodes (2/4)
- RE affected 25% of the nodes (1/4)
- RE affected 0% of the nodes (0/4)

In any case, results from this analysis are also quite interesting for SC managers.

4.1.4 Duration of the shortage in each node

As a result of a 4 node SC model, we have 4 different scenarios:

- DURATION OF THE SHORTAGE OF NODE 4 (DISTRIBUTOR 1)
- DURATION OF THE SHORTAGE OF NODE 3 (DISTRIBUTOR 2)
- DURATION OF THE SHORTAGE OF NODE 2 (WHOLESALER)
- DURATION OF THE SHORTAGE OF NODE 1 (RETAILER)

These metrics are a twist on the one studied in Machin et al., 2022. Where the duration of RE in the node 1 and a brief comparison with node 4 were analysed. In this study we want to point out that not only the retailer may be analysed in deep, but all other nodes from the SC can also be considered by using the same metric.

Sometimes the RE occurs but it ends before reaching the retailer. Not having the final client affected by the incapacity to buy does not mean that other nodes from the SC have not suffered from the consequences of the original disruption.

Therefore, with this metrics the whole SC can be analysed, SC managers will only need to take into account whether they are interested in knowing how the whole SC is being affected or just one node.

4.2 Results from simulations

For the remainder of the Section 4 we can see that the metrics have been analysed using the following values for the parameters of the quantitative model explained in section 3 (Table 3, Table 4). The values were selected based on the results from the precedent study Machin et al., 2022. It has been decided to select non-extreme values for simplicity purposes. In the sub-section below, results obtained can be found for each of the above-mentioned metrics.

μ (product units)	R	Z	M
100	1	2	8

Table 3. Parameters and values used in the mode I.

N	8
DT	20
σ	20
LT	4

Table 4. Parameters and values used in the mode II.

In addition, the simulation time and the disruption initial time are also defined in Table 5.

SIMULATION TIME (periods)	PERIOD IN WHICH THE DISRUPTION BEGINS
1150	1000

Table 5. Simulation parameters.

4.2.1 Ripple Effect duration along the chain

From 500 replications we have obtained that the median is 22 and the mean value is 19,136 periods. The Histogram reflects that not being affected by shortage is one of the most common responses. However, if affected, it appears that the total amount of time that the SC is affected by shortage is an amount similar to the original disruption time.

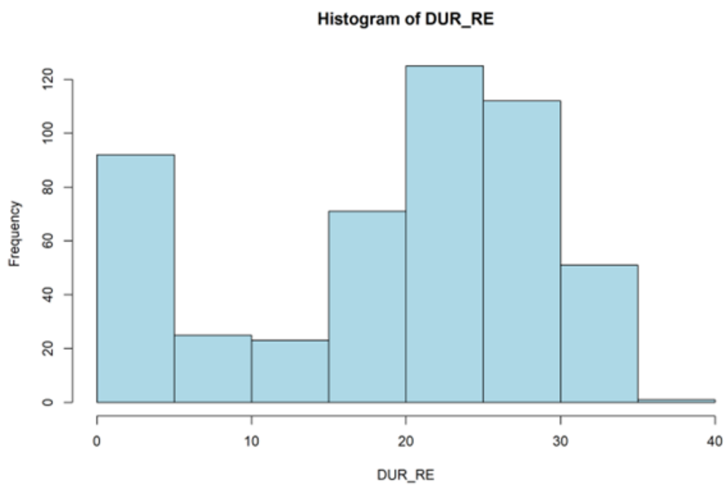

Figure 5. Duration of the RE along the chain with an original disruption of 20 periods.

Since the median and the mean are quite similar to the Disruption Original Time, it has been decided to analyse if the same tendency is obtained varying the Disruption Original Time.

Sensitivity Analisys

❖ DT=10

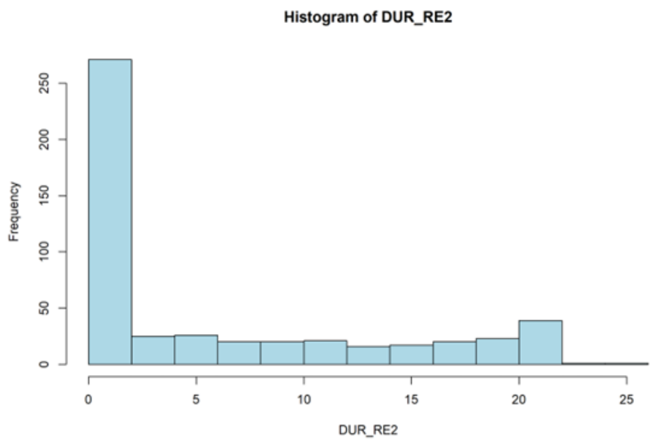

Figure 6. Duration of the RE along the chain with an original disruption of 10 periods.

❖ DT= 30

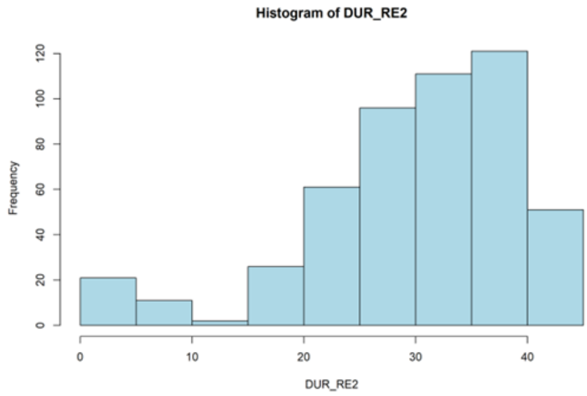

Figure 7. Duration of the RE along the chain with an original disruption of 30 periods.

- DT= 40

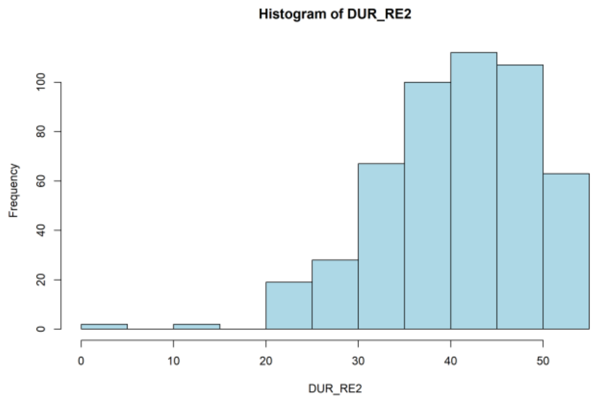

Figure 8. Duration of the RE along the chain with an original disruption of 40 periods.

It seems that the tendency is repeated. As we increase the value of the original disruption, we see how the chain is affected by shortage (in at least one of its nodes) for a similar number of periods most of the time. This tendency seems reasonable as when the nodes end their safety stock and the shortage is still going on they will not recover until the original disruption ends (taking into account the lead time from the factory to each node).

4.2.2 Probablity of infection of each node individually

The probability of infection for each node after 500 replicas is the following:

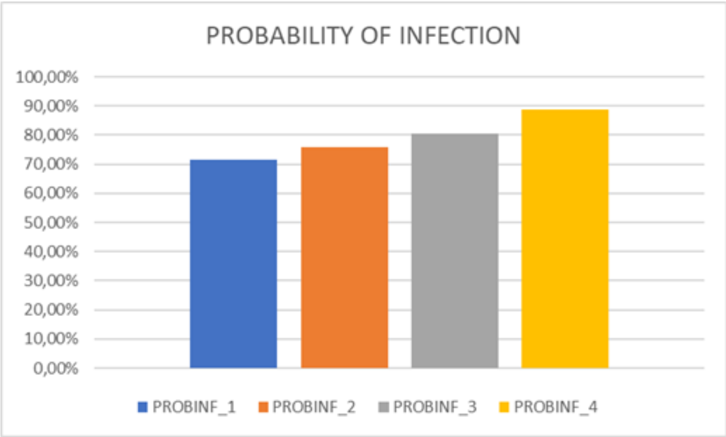

Figure 9. Probablity of infection with an original disruption of 20 periods

It can be noticed that, as expected, the probability of being infected/ affected by shortage increases if the node is closer to the original disruption. Which, as a recall, in this study is located in the factory.

Like with the last metric it may be interesting to analyse how this probability may change when the disruption time (DT factor) varies.

	PROBINF_1	**PROBINF_2**	**PROBINF_3**	**PROBINF_4**
DT 10	18,60%	26,40%	36,00%	54,80%
DT 20	71,60%	75,80%	80,40%	88,60%
DT 30	92,80%	93,60%	95,40%	97,40%
DT 40	99,40%	99,60%	99,60%	99,60%

Table 6. Sensitivity analisys of the probability of infection based on the original disruption time I.

From the Table 6, the underlined line corresponds to our initial experiment with an original disruption tiem of 20 periods. But with a sensitivity analysis we can see how if the disruption time is increased the probability of having a node infected by shortage is turns to nearly the same in every node.

Therefore, as a conclusion we can say that the number of periods in which the original disruption is still present is quite critical (when the disruption time is long enough pretty much every node will be affected), as well as the proximity of the node to the disruption (which makes sense since the safety stock of the nodes that are closer to the factory will disappear first than the others, letting those downstream nodes take advantage of that safety stock).

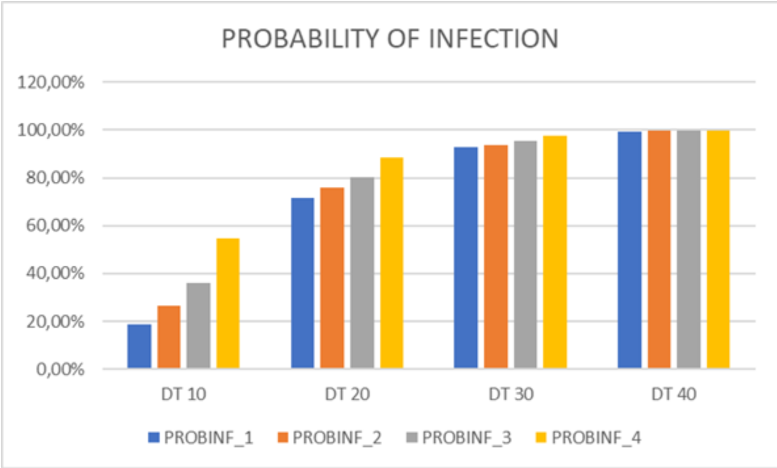

Figure 10. Sensitivity analysis of the probablity of infection based on the original disruption time II.

4.2.3 Reach in the Supply Chain

Another interesting way to measure the impact of the RE is knowing how many nodes of the SC have been infected by shortage. The results are the following:

Nodes Affected	100%	75%	50%	25%	0%
Frequency	358	21	23	41	57

Table 7. Frequency the results from the nodes affected.

It seems that with an original disruption time of 20 periods, the most common scenario is having the whole SC affecetd by shortage. It is quite important to notice that the second most frequent one is having zero nodes affected. Therefore, as we have been seeing from the previous metrics analysed, the variability of a SC makes it difficult to know for sure what will happen when a disruption occurs. Specially, when de dirsuption time takes certain values, as we will see in the following sensitivity analysis.

By varying the factor DT we can see how results change. Frequency has been changed to percentage in order to see the evolution in a better perspective.

Nodes Affected					
FREQUENCY (%)	**100% of nodes**	**75% of nodes**	**50% of nodes**	**25% of nodes**	**0% of nodes**
DT 10	18,60%	7,80%	9,60%	18,80%	45,20%
DT 20	71,60%	4,20%	4,60%	8,20%	11,40%
DT 30	92,80%	0,80%	1,80%	2,00%	2,60%
DT 40	99,40%	0,20%	0,00%	0,00%	0,40%

Table 8. Sensistivity analysis of the frequency (in percentage) of the nodes affected.

It may also be more visual a graph where the comparison between each disruption time can be reflected. In Figure 11 we can see the evolution.

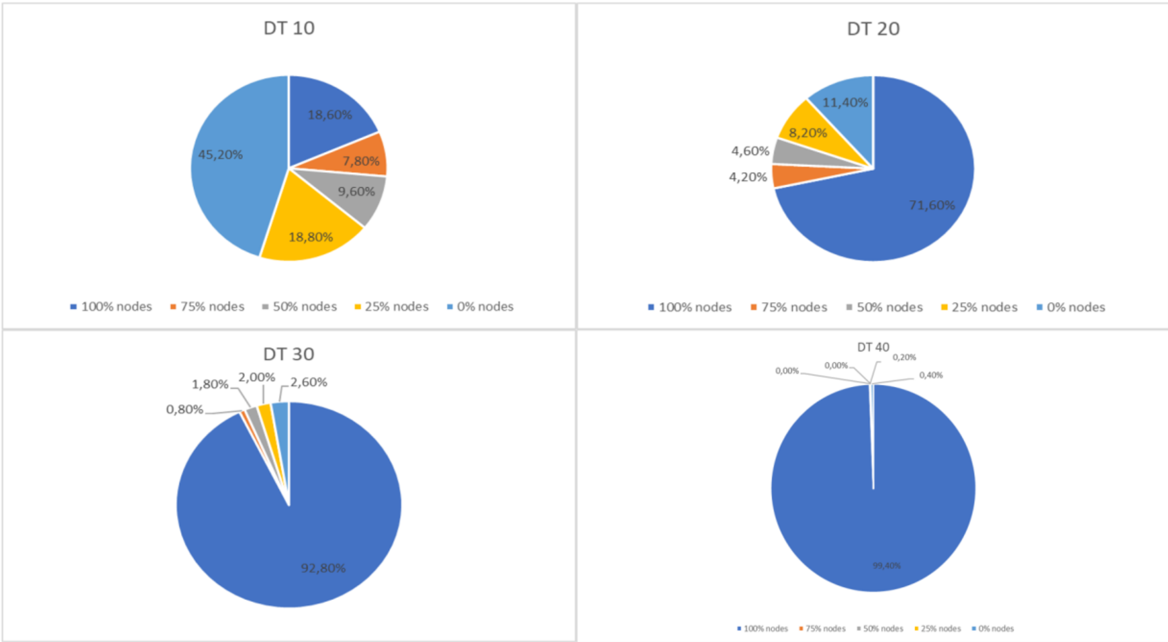

Figure 11. Evolution of the percentage of nodes affected by RE based on the original disruption time.

In the Figure 11 we can see the aggressive evolution of the nodes affected. As we already observed from the previous metric, the disruption time and the number of nodes of a SC are critical. Long SCs will stand better disruption times that last longer, however, short SCs as this one should pay attention to control the whichever is causing the original disruption.

4.2.4 Duration of the shortage in each node

With the following graphics we can notice how shortage affects each node from the SC, being the node 4 (Distributor 1) the one with worst results and the node 1 (retailer) the one with best results.

- Node 1. Frequency & Density Diagram

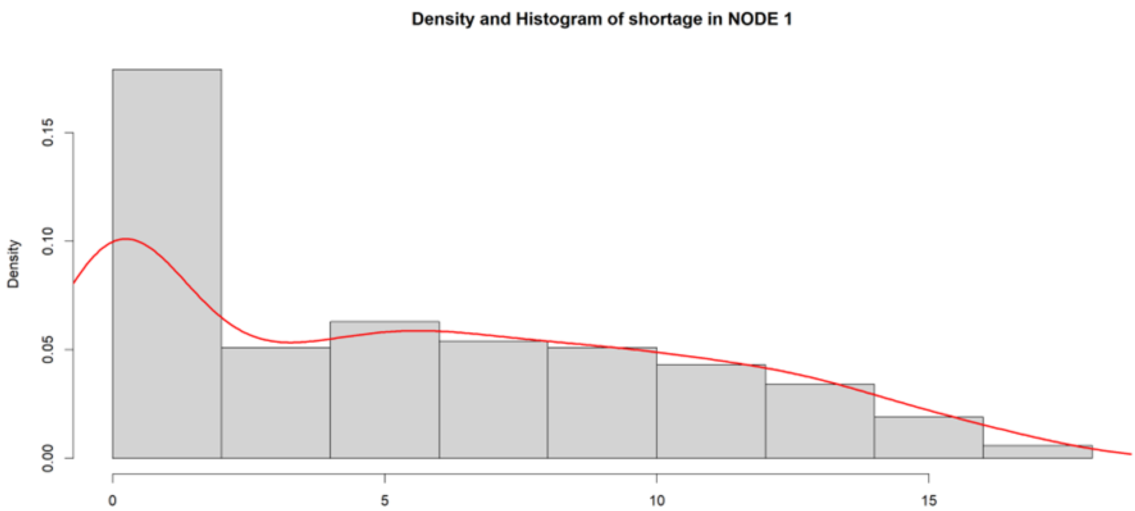

Figure 12. Density Diagram of the duration of the shortage in node 1, with the frequency in the background.

❖ Node 2. Frequency & Density Diagram

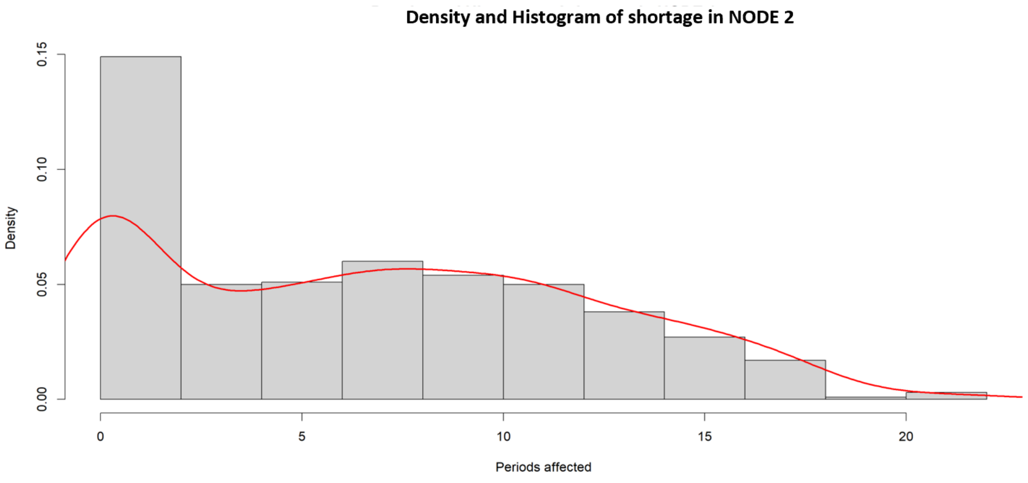

Figure 13. Density Diagram of the duration of the shortage in node 2, with the frequency in the background.

❖ Node 3. Frequency & Density Diagram

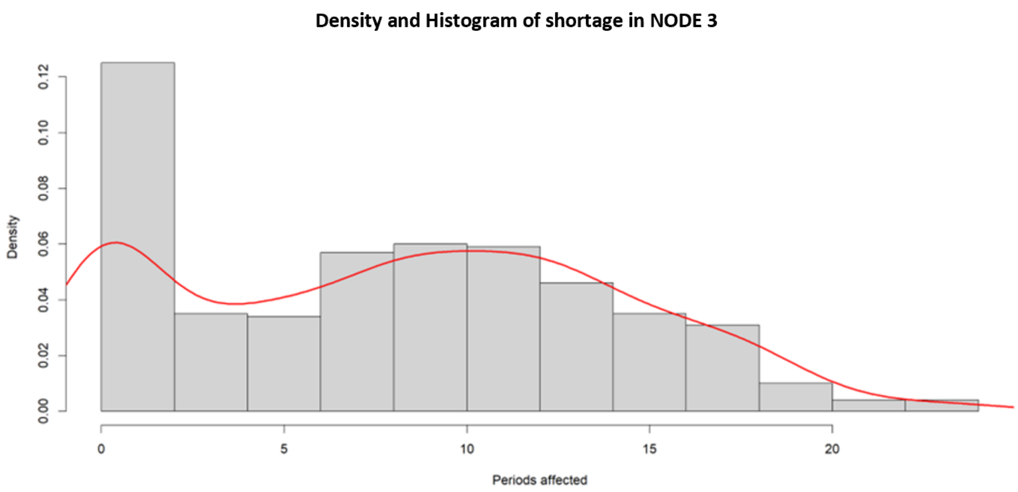

Figure 14. Density Diagram of the duration of the shortage in node 3, with the frequency in the background.

❖ Node 4. Frequency & Density Diagram

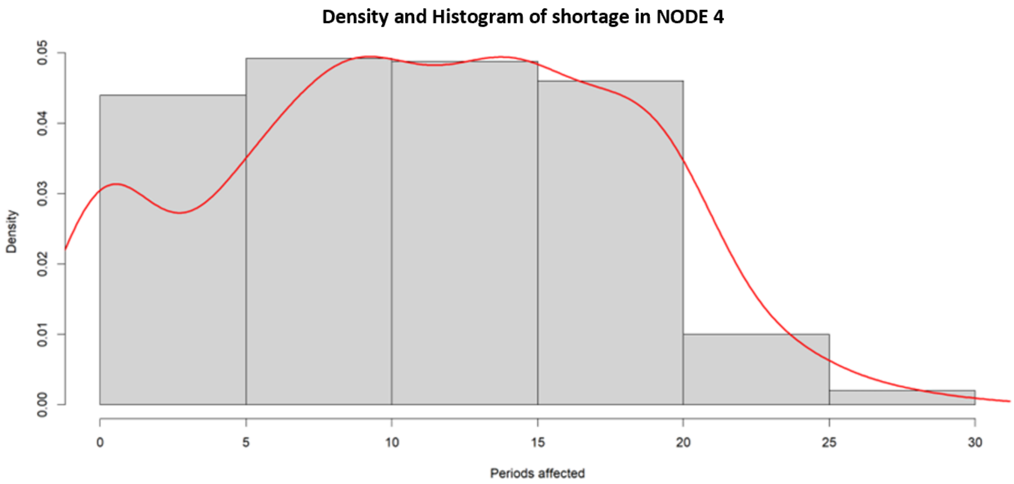

Figure 15. Density Diagram of the duration of the shortage in node 4, with the frequency in the background.

As a sum up we can see how the curve tends to shift to the left as we move away from the origin of the disruption. The following images show the tendency of the frequency diagram, as well as the tendency of the density function.

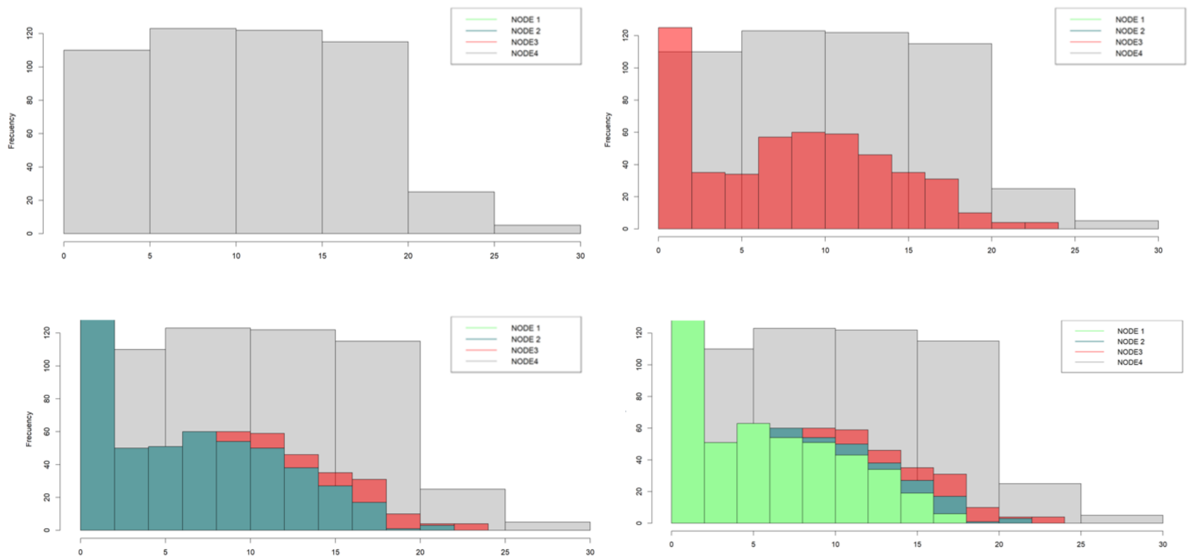

Figure 16. Evolution of the frequencies of the duration of the shortage in each node.

When comparing just the density function we can see how the curves tend to soften upstream of the SC.

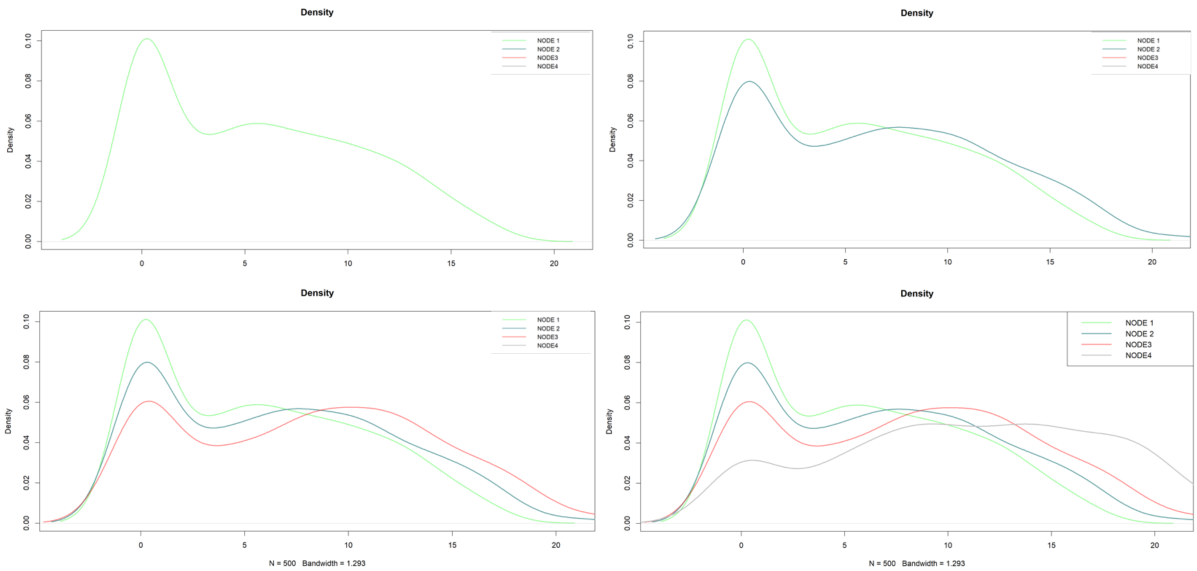

Figure 17. Evolution of the densities of the duration of shortage in each node.

As with al lof the previous metrics, the behaviour of the curve when the duration is close to zero stands out. It seems that there are times when, due to the usual operation of the chain, sufficient inventory is accumulated in previous periods, which means that the RE does not take place or affects the chain only slightly. However, if sufficient inventory has not been stored, it seems that RE occurs and causes a shortage following a similar density curve in all cases.

The accumulation of inventory that occurs is due to the BE phenomenon, already mentioned in the Introduction section. Since the modelled end-customer demand is a variable that follows a normal distribution with a certain standard deviation, it is logical to suffer from the BE phenomenon, so well-known and studied since Jay Forrester´s contribution (Forrester, 1997). The BE sometimes causes the chain to accumulate unnecessary inventory, however, with similar disruptions of inability to supply, that inventory is used by the chain to circumvent the RE.

In addition, it can be noted that node 4 suffers the most from the ravages of the RE since it is the closest node to the factory (affected by the inability to supply). Although it would be the one that could accumulate the most inventory due to the BE, it is rarely enough to withstand the RE. However, node 1, which is generally not quite affected by the BE, has the highest frequency of times not affected by shortage. This is because for the RE to reach node 1 it must first have passed through the previous nodes. This means that the accumulated inventory of all previous nodes must be used up. In conclusion, it seems that the BE of the nodes that you supply to a given node play an important role in determining whether or not the RE reaches the given node. What is clear is that the more inventory the less periods the SC is affected by shortage. Whether this is due to the presence of a high BE or other causes.

5 INSIGHTS AND FUTURE RESEARCH AGENDA

Knowing the results obtained, it is possible to draw conclusions that allow SC managers to learn a little more about the propagation of the inability to supply, defined in this study as the Ripple Effect. Furthermore, in this section we leave open the possibility of continuing with similar studies based on these metrics that allow us to clearly understand how the RE evolves in a SC, offering some examples of these new possible studies.

5.1 Study´s main Insights

First of all, it is important to compare the conclusions obtained in the study by Laura Tobajas (Machin et al., 2022) with those obtained here. The results with the metrics used in that study are in line with the results obtained with the new metrics calculated in this study. Therefore, the conclusions obtained are pertinent to the results of this study. In addition, we can corroborate one of the most important conclusions obtained in the 2022 study, that the variability of the chain is very important to take into account. We have seen that there are replicates in which the RE does not even appear in the chain.

From this complementary study we can conclude with the following insights:

- The aforementioned presence of high variability. The fact that a SC may suffer from RE is not so easy to predict, even in the simulated cases with very high values of original disruption we see that the RE may not occur in the chain.
- The total duration of RE along the SC depends to a large extent on the initial duration of the disruption. Without leaving aside the variability we mentioned, we can see how the graphs shift as we shift the values of the original disruption (losing weight in those scenarios in which RE does not affect).
- SC managers can use simulations based on these metrics to calculate the probability of infection of one or more nodes when a disruption occurs. This also lays the foundations inside of the field of Risk Management, which is nowadays very much addressed by researchers.
- The nodes closer to the original disruption suffer the RE for a longer period of time and are more likely to suffer it. With the study by Laura Tobajas (Machin et al., 2022) we had intuited this behaviour, but after this analysis it has been possible to clearly contrast this difference in impact. It is also interesting to note that the most distant nodes of the disruption will always benefit from the security inventory held by those upstream. Therefore, longer chains will always protect the customer better (if this is the objective).

5.2 Future research agenda for the RE

It would be interesting to see if BE is indeed responsible for the fact that certain simulations occur with zero or close to zero RE. The order rate of the chain in these simulations could be compared with the results of some of the metrics used that represent very well the existence and propagation of the inability to supply (RE).

Another line of research based on this study could be the in-depth analysis of the values at which the chain suffers from shortage with a certain degree of confidence. Extending the analysis to different chains and topologies.

On the other hand, the constraints of a serial chain largely limit these results to chains with similar typologies. However, constructing a serial chain and performing a similar study would allow us to know if propagation occurs in a similar way or if there are noticeable changes.

In addition, the use of the infection probability can lay the groundwork for further studies based on graph theory and the study of more complex chains.

It may also be of interest to know what happens in chains with circular economy, where part of the product returns again to the SC.

There are also numerous studies that test strategies or test the involvement of certain factors that build the SCs. This model and these metrics can be used to test different strategies to reduce the impact of SR.

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ANNEX I

In this Annex I you may find the original results obtained from the experiments carried out for a disruption time with a value of 20.

REPLICAS	DT	RE ALONG THE CHAIN	REACH	RE 1	RE 2	RE 3	RE 4
1	20	20	1	6	7	8	9
2	20	22	1	1	2	5	11
3	20	5	0,5	0	0	1	3
4	20	21	1	4	7	8	10
5	20	27	1	13	14	15	16
6	20	5	0,25	0	0	0	6
7	20	22	1	8	9	12	11
8	20	22	0,75	0	1	2	15
9	20	0	0	0	0	0	0
10	20	30	1	12	13	24	19
11	20	31	1	13	14	15	20
12	20	0	0	0	0	0	0
13	20	24	1	10	11	12	13
14	20	26	1	5	11	9	14
15	20	31	1	13	14	17	22
16	20	3	0,25	0	0	0	4
17	20	10	0,75	0	1	2	6
18	20	1	0,25	0	0	0	1
19	20	11	0,5	0	0	3	8
20	20	16	0,75	0	1	3	9
21	20	2	0,25	0	0	0	3
22	20	20	1	3	3	7	8
23	20	19	1	1	3	4	8
24	20	31	1	10	11	13	23
25	20	0	0	0	0	0	0
26	20	26	1	7	11	11	15
27	20	10	0,75	0	1	5	6
28	20	19	1	2	3	5	8
29	20	31	1	15	16	21	26
30	20	26	1	9	14	14	15
31	20	31	1	11	12	17	20
32	20	31	1	15	17	19	24
33	20	6	0,5	0	0	1	3
34	20	16	1	1	3	4	8

35	20	18	0,5	0	0	2	15
36	20	18	1	4	5	6	7
37	20	30	1	10	11	17	23
38	20	21	1	7	8	9	10
39	20	28	1	8	9	10	17
40	20	19	1	5	6	7	8
41	20	27	1	12	14	15	16
42	20	32	1	13	14	17	21
43	20	30	1	11	15	24	18
44	20	17	1	2	3	4	6
45	20	31	1	12	13	14	30
46	20	23	1	9	10	11	12
47	20	26	1	5	6	12	15
48	20	19	1	4	5	7	8
49	20	21	1	3	4	6	10
50	20	19	1	5	6	7	8
51	20	25	1	11	12	13	14
52	20	26	1	6	10	11	21
53	20	27	1	12	13	14	16
54	20	21	1	7	8	9	10
55	20	31	1	17	21	23	20
56	20	31	1	14	15	16	20
57	20	0	0	0	0	0	0
58	20	31	1	8	9	10	20
59	20	19	1	3	4	5	8
60	20	0	0	0	0	0	0
61	20	0	0	0	0	0	0
62	20	22	1	8	9	10	11
63	20	21	1	1	2	4	10
64	20	16	1	2	3	4	5
65	20	7	0,5	0	0	2	4
66	20	24	1	6	7	8	13
67	20	20	1	3	4	6	9
68	20	15	1	1	2	3	4
69	20	31	1	4	5	7	20
70	20	0	0	0	0	0	0
71	20	25	1	8	8	9	13
72	20	28	1	4	5	11	27
73	20	0	0	0	0	0	0
74	20	1	0,25	0	0	0	2
75	20	19	1	5	6	7	8
76	20	0	0	0	0	0	0
77	20	30	1	16	17	18	19
78	20	9	0,25	0	0	0	10
79	20	19	1	5	6	7	10
80	20	24	1	2	4	5	13

81	20	29	1	12	13	16	22
82	20	26	1	12	13	14	15
83	20	28	1	13	14	16	19
84	20	25	1	8	9	13	14
85	20	23	1	6	8	8	12
86	20	0	0	0	0	0	0
87	20	22	1	8	9	10	11
88	20	28	1	9	11	13	17
89	20	0	0	0	0	0	0
90	20	4	0,25	0	0	0	5
91	20	24	1	7	9	10	13
92	20	12	0,5	0	0	2	9
93	20	21	1	7	8	9	10
94	20	0	0	0	0	0	0
95	20	30	1	16	17	18	19
96	20	31	1	10	11	19	20
97	20	31	1	15	17	19	20
98	20	0	0	0	0	0	0
99	20	1	0,25	0	0	0	2
100	20	26	1	9	8	11	12
101	20	21	1	6	8	9	10
102	20	22	1	3	4	15	9
103	20	25	1	5	9	15	14
104	20	28	1	9	11	12	17
105	20	32	1	8	9	10	24
106	20	0	0	0	0	0	0
107	20	9	0,5	0	0	1	6
108	20	25	1	10	11	13	15
109	20	29	1	15	16	17	18
110	20	32	1	13	10	11	17
111	20	18	1	1	2	4	7
112	20	19	1	2	3	7	8
113	20	27	1	10	11	13	16
114	20	20	1	6	6	7	8
115	20	3	0,25	0	0	0	4
116	20	19	1	4	5	7	8
117	20	31	1	10	12	19	20
118	20	31	1	14	16	17	15
119	20	23	1	9	10	12	16
120	20	30	1	12	13	15	19
121	20	25	1	9	10	11	14
122	20	13	0,75	0	1	2	6
123	20	9	0,5	0	0	2	6
124	20	13	0,75	0	1	3	6
125	20	0	0	0	0	0	0
126	20	30	1	13	15	18	19

127	20	30	1	14	15	16	19
128	20	24	1	8	9	10	13
129	20	31	1	14	16	18	20
130	20	26	1	11	12	14	15
131	20	28	1	13	14	16	18
132	20	0	0	0	0	0	0
133	20	21	1	7	8	9	10
134	20	25	1	9	14	13	14
135	20	20	1	6	7	8	9
136	20	37	1	11	22	16	20
137	20	25	1	6	7	9	14
138	20	31	1	11	12	14	22
139	20	25	1	7	11	9	14
140	20	13	0,75	0	1	2	6
141	20	3	0,25	0	0	0	4
142	20	23	1	6	12	13	9
143	20	14	0,75	0	1	2	7
144	20	19	1	5	6	7	8
145	20	12	0,75	0	2	3	8
146	20	12	0,75	0	2	4	6
147	20	28	1	11	10	12	14
148	20	25	1	4	6	8	14
149	20	0	0	0	0	0	0
150	20	22	1	5	6	9	11
151	20	0	0	0	0	0	0
152	20	5	0,25	0	0	0	6
153	20	24	1	6	9	12	13
154	20	23	1	6	7	9	12
155	20	15	1	1	3	4	3
156	20	12	0,75	0	2	4	5
157	20	31	1	17	18	19	20
158	20	22	1	5	6	10	11
159	20	29	1	6	7	12	18
160	20	22	1	8	9	10	16
161	20	3	0,25	0	0	0	4
162	20	0	0	0	0	0	0
163	20	28	1	9	10	11	18
164	20	0	0	0	0	0	0
165	20	20	1	2	4	6	10
166	20	19	1	5	6	7	8
167	20	20	1	5	7	7	9
168	20	0	0	0	0	0	0
169	20	27	1	10	11	13	23
170	20	25	1	5	7	9	14
171	20	21	1	3	4	7	10
172	20	23	1	7	12	11	12

173	20	6	0,25	0	0	0	7
174	20	4	0,25	0	0	0	5
175	20	20	1	3	5	7	9
176	20	31	1	10	17	12	15
177	20	17	1	3	4	5	6
178	20	12	0,25	0	0	0	13
179	20	26	1	6	7	8	17
180	20	33	1	14	20	13	18
181	20	11	0,75	0	1	4	2
182	20	31	1	17	18	19	21
183	20	27	1	7	8	9	17
184	20	0	0	0	0	0	0
185	20	27	1	7	8	15	16
186	20	0	0	0	0	0	0
187	20	20	0,75	0	1	2	13
188	20	31	1	13	14	15	20
189	20	15	0,75	0	1	4	8
190	20	18	1	2	4	5	7
191	20	23	1	1	3	10	12
192	20	31	1	15	16	18	20
193	20	11	0,75	0	2	5	7
194	20	17	1	3	4	10	6
195	20	28	1	9	10	11	18
196	20	0	0	0	0	0	0
197	20	17	1	3	4	5	7
198	20	30	1	14	16	18	19
199	20	21	1	7	8	9	10
200	20	13	0,75	0	1	5	6
201	20	22	1	6	7	10	11
202	20	25	1	10	11	12	14
203	20	28	1	11	12	13	17
204	20	26	1	7	10	11	15
205	20	18	1	4	5	6	7
206	20	7	0,25	0	0	0	8
207	20	19	1	1	3	3	8
208	20	10	0,5	0	0	2	7
209	20	22	1	4	6	9	18
210	20	31	1	15	17	18	20
211	20	20	1	6	7	9	10
212	20	24	1	9	12	14	12
213	20	16	1	2	3	4	5
214	20	28	1	8	10	11	17
215	20	29	1	15	16	17	18
216	20	28	1	10	11	16	17
217	20	31	1	10	12	14	20
218	20	25	1	6	8	9	14

219	20	22	1	7	9	10	11
220	20	18	1	2	3	4	7
221	20	0	0	0	0	0	0
222	20	21	1	3	4	7	12
223	20	0	0	0	0	0	0
224	20	17	1	1	3	5	7
225	20	21	1	3	4	8	10
226	20	19	1	3	5	7	8
227	20	22	1	5	6	8	11
228	20	9	0,5	0	0	1	6
229	20	1	0,25	0	0	0	2
230	20	0	0	0	0	0	0
231	20	27	1	13	14	15	16
232	20	0	0	0	0	0	0
233	20	31	1	17	18	19	22
234	20	29	1	11	12	22	17
235	20	26	1	8	9	10	15
236	20	24	1	10	11	12	13
237	20	29	1	13	14	15	18
238	20	20	1	6	7	8	9
239	20	12	0,75	0	2	4	5
240	20	14	0,75	0	1	2	7
241	20	3	0,25	0	0	0	4
242	20	27	1	11	12	15	16
243	20	28	1	12	13	15	17
244	20	24	1	9	10	11	14
245	20	29	1	14	15	16	18
246	20	8	0,5	0	0	1	5
247	20	22	1	4	6	8	11
248	20	27	1	6	7	13	16
249	20	12	0,75	0	2	4	5
250	20	31	1	13	14	15	20
251	20	8	0,25	0	0	0	9
252	20	20	1	6	7	12	9
253	20	6	0,5	0	0	2	4
254	20	22	1	6	7	8	12
255	20	1	0,25	0	0	0	2
256	20	0	0	0	0	0	0
257	20	33	1	11	8	9	18
258	20	6	0,25	0	0	0	7
259	20	5	0,5	0	0	1	2
260	20	0	0	0	0	0	0
261	20	31	1	8	9	10	24
262	20	20	1	5	6	8	9
263	20	12	0,5	0	0	5	9
264	20	31	1	15	16	17	20

265	20	26	1	9	11	12	15
266	20	29	1	9	13	13	18
267	20	25	1	8	10	13	14
268	20	7	0,25	0	0	0	8
269	20	29	1	14	15	17	22
270	20	19	1	1	2	6	8
271	20	24	1	10	11	12	13
272	20	4	0,25	0	0	0	5
273	20	0	0	0	0	0	0
274	20	25	1	11	12	13	14
275	20	14	0,75	0	1	2	7
276	20	24	1	8	9	11	13
277	20	25	1	11	12	13	14
278	20	0	0	0	0	0	0
279	20	22	1	6	8	9	11
280	20	25	1	9	11	13	14
281	20	31	1	11	12	17	20
282	20	23	1	3	4	5	12
283	20	30	1	11	13	13	19
284	20	22	1	2	3	6	11
285	20	30	1	13	14	17	19
286	20	23	1	5	7	9	12
287	20	0	0	0	0	0	0
288	20	0	0	0	0	0	0
289	20	28	1	7	8	9	19
290	20	6	0,5	0	0	2	4
291	20	6	0,5	0	0	1	3
292	20	16	1	2	3	8	5
293	20	20	1	1	6	2	6
294	20	0	0	0	0	0	0
295	20	27	1	10	11	12	16
296	20	1	0,25	0	0	0	2
297	20	0	0	0	0	0	0
298	20	0	0	0	0	0	0
299	20	27	1	9	10	14	16
300	20	17	1	3	4	9	6
301	20	19	1	3	4	5	12
302	20	29	1	14	16	17	18
303	20	28	1	11	10	14	15
304	20	24	1	8	10	12	13
305	20	21	1	3	4	7	10
306	20	31	1	17	18	23	28
307	20	31	1	17	18	21	20
308	20	32	1	12	11	12	19
309	20	31	1	14	15	17	20
310	20	0	0	0	0	0	0

311	20	20	1	3	5	7	9
312	20	0	0	0	0	0	0
313	20	21	1	7	8	9	10
314	20	10	0,5	0	0	5	7
315	20	20	1	5	7	8	9
316	20	8	0,5	0	0	4	5
317	20	1	0,25	0	0	0	1
318	20	25	1	10	11	13	14
319	20	21	1	2	3	5	10
320	20	2	0,25	0	0	0	3
321	20	29	1	15	16	17	18
322	20	31	1	13	14	15	20
323	20	28	1	5	6	7	18
324	20	19	1	5	6	7	8
325	20	31	1	11	12	19	27
326	20	29	1	13	14	15	19
327	20	20	1	5	7	8	9
328	20	23	1	4	5	7	12
329	20	24	1	5	8	9	13
330	20	21	1	4	6	12	9
331	20	0	0	0	0	0	0
332	20	31	1	10	12	13	21
333	20	31	1	12	13	16	24
334	20	21	1	4	5	10	16
335	20	32	1	15	11	12	16
336	20	6	0,5	0	0	1	5
337	20	23	1	9	10	11	12
338	20	24	1	4	5	10	13
339	20	20	1	3	4	7	9
340	20	7	0,5	0	0	3	7
341	20	25	1	2	3	5	14
342	20	24	1	6	9	11	13
343	20	19	1	5	6	7	8
344	20	16	1	2	6	4	5
345	20	28	1	2	4	4	17
346	20	4	0,25	0	0	0	5
347	20	28	1	13	15	16	17
348	20	19	1	4	5	7	8
349	20	21	1	4	5	6	10
350	20	28	1	8	9	10	21
351	20	23	1	9	10	11	12
352	20	22	1	8	9	10	11
353	20	30	1	7	8	12	19
354	20	29	1	13	14	15	18
355	20	21	1	5	7	9	10
356	20	29	1	8	10	11	18

357	20	25	1	3	4	5	14
358	20	29	1	7	8	9	18
359	20	7	0,5	0	0	3	4
360	20	21	1	4	5	7	10
361	20	27	1	6	7	11	16
362	20	3	0,25	0	0	0	4
363	20	26	1	9	10	12	15
364	20	23	1	4	6	9	12
365	20	30	1	7	8	11	18
366	20	3	0,25	0	0	0	4
367	20	0	0	0	0	0	0
368	20	25	1	7	8	12	18
369	20	2	0,25	0	0	0	3
370	20	0	0	0	0	0	0
371	20	23	1	4	6	8	12
372	20	25	1	10	11	13	18
373	20	29	1	8	9	10	22
374	20	5	0,25	0	0	0	6
375	20	0	0	0	0	0	0
376	20	17	1	3	4	5	6
377	20	7	0,5	0	0	1	4
378	20	31	1	13	16	15	20
379	20	29	1	13	15	19	18
380	20	25	1	11	12	13	14
381	20	28	1	11	16	13	17
382	20	1	0,25	0	0	0	1
383	20	25	1	10	12	13	14
384	20	21	1	6	7	8	10
385	20	0	0	0	0	0	0
386	20	22	1	6	7	10	11
387	20	0	0	0	0	0	0
388	20	29	1	15	17	17	18
389	20	9	0,5	0	0	2	6
390	20	22	1	8	9	10	11
391	20	31	1	15	16	18	20
392	20	0	0	0	0	0	0
393	20	24	1	7	8	11	13
394	20	29	1	13	14	16	18
395	20	23	1	6	8	9	12
396	20	25	1	4	5	7	14
397	20	29	1	12	14	16	18
398	20	31	1	7	8	12	24
399	20	26	1	7	8	9	15
400	20	25	1	8	10	12	14
401	20	3	0,25	0	0	0	4
402	20	21	1	7	8	9	10

403	20	25	1	5	6	9	14
404	20	24	1	10	10	11	12
405	20	25	1	11	12	13	14
406	20	20	1	3	4	5	9
407	20	3	0,25	0	0	0	4
408	20	30	1	16	18	18	19
409	20	30	1	12	14	17	19
410	20	23	1	7	8	13	12
411	20	20	1	4	5	6	9
412	20	31	1	10	11	13	20
413	20	31	1	16	17	18	20
414	20	29	1	15	16	17	18
415	20	24	1	9	11	12	13
416	20	26	1	12	13	14	15
417	20	31	1	5	6	11	24
418	20	18	1	3	4	9	9
419	20	22	1	5	4	6	9
420	20	14	0,75	0	1	2	7
421	20	0	0	0	0	0	0
422	20	24	1	5	6	7	13
423	20	12	0,25	0	0	0	13
424	20	17	1	2	3	4	6
425	20	27	1	13	14	15	16
426	20	0	0	0	0	0	0
427	20	30	1	16	17	18	19
428	20	25	1	5	6	9	14
429	20	0	0	0	0	0	0
430	20	3	0,25	0	0	0	4
431	20	23	1	2	3	4	12
432	20	20	1	2	3	5	9
433	20	30	1	12	21	14	15
434	20	22	1	7	8	10	11
435	20	2	0,25	0	0	0	3
436	20	29	1	9	10	11	21
437	20	27	1	4	5	7	16
438	20	23	1	9	10	11	12
439	20	30	1	12	16	18	23
440	20	25	1	8	9	12	14
441	20	16	1	1	2	4	5
442	20	31	1	12	16	14	20
443	20	29	1	13	13	14	16
444	20	19	1	1	3	4	8
445	20	26	1	12	13	14	15
446	20	30	1	6	7	8	25
447	20	27	1	4	7	7	16
448	20	23	1	6	10	8	12

449	20	3	0,25	0	0	0	4
450	20	26	1	9	10	11	15
451	20	20	1	3	5	8	9
452	20	2	0,25	0	0	0	3
453	20	27	1	7	12	20	15
454	20	22	1	8	9	10	11
455	20	30	1	12	15	15	18
456	20	19	1	4	5	6	8
457	20	27	1	12	14	15	16
458	20	20	1	6	7	8	9
459	20	26	1	11	14	21	15
460	20	24	1	9	10	12	13
461	20	28	1	11	13	15	17
462	20	0	0	0	0	0	0
463	20	22	1	2	7	3	10
464	20	21	1	7	8	9	11
465	20	0	0	0	0	0	0
466	20	16	1	2	3	4	5
467	20	23	1	5	2	3	8
468	20	19	1	2	3	5	8
469	20	24	1	3	4	7	13
470	20	29	1	8	9	10	20
471	20	0	0	0	0	0	0
472	20	30	1	16	17	18	19
473	20	0	0	0	0	0	0
474	20	5	0,25	0	0	0	6
475	20	30	1	10	11	12	21
476	20	22	1	5	7	8	11
477	20	28	1	8	9	13	25
478	20	27	1	13	14	15	16
479	20	0	0	0	0	0	0
480	20	28	1	10	11	15	17
481	20	17	1	2	3	4	6
482	20	21	1	6	7	8	10
483	20	21	1	4	5	6	10
484	20	29	1	14	15	17	18
485	20	26	1	9	10	12	15
486	20	23	1	5	6	7	12
487	20	25	1	5	6	13	14
488	20	26	1	9	10	11	15
489	20	0	0	0	0	0	0
490	20	28	1	11	12	13	17
491	20	0	0	0	0	0	0
492	20	0	0	0	0	0	0
493	20	4	0,25	0	0	0	5
494	20	19	1	4	5	7	8

495	20	27	1	7	8	11	16
496	20	22	1	5	7	10	11
497	20	24	1	10	11	12	13
498	20	19	1	1	3	4	8
499	20	31	1	9	10	13	20
500	20	30	1	11	17	11	15

ANNEX II

In this Annex II you may find the original results obtained from the experiments carried out for a disruption time with a value of 10.

REPLICAS	DT	RE ALONG THE CHAIN	REACH	RE 1	RE 2	RE 3	RE 4
1	10	0	0	0	0	0	0
2	10	12	0,75	0	1	2	5
3	10	21	1	5	7	9	10
4	10	0	0	0	0	0	0
5	10	0	0	0	0	0	0
6	10	0	0	0	0	0	0
7	10	0	0	0	0	0	0
8	10	0	0	0	0	0	0
9	10	0	0	0	0	0	0
10	10	17	0,75	0	3	5	10
11	10	0	0	0	0	0	0
12	10	21	1	6	7	8	10
13	10	0	0	0	0	0	0
14	10	10	0,5	0	0	1	7
15	10	15	0,75	0	1	5	8
16	10	21	1	4	5	8	10
17	10	5	0,25	0	0	0	6
18	10	13	0,75	0	1	6	6
19	10	0	0	0	0	0	0
20	10	0	0	0	0	0	0
21	10	3	0,25	0	0	0	4
22	10	21	1	7	8	9	10
23	10	4	0,25	0	0	0	5
24	10	0	0	0	0	0	0
25	10	9	0,25	0	0	0	10
26	10	0	0	0	0	0	0
27	10	18	1	1	3	4	7
28	10	20	1	2	3	4	9
29	10	1	0,25	0	0	0	1
30	10	0	0	0	0	0	0
31	10	0	0	0	0	0	0
32	10	0	0	0	0	0	0
33	10	0	0	0	0	0	0
34	10	0	0	0	0	0	0

35	10	0	0	0	0	0	0
36	10	17	1	1	3	4	6
37	10	1	0,25	0	0	0	1
38	10	0	0	0	0	0	0
39	10	1	0,25	0	0	0	2
40	10	7	0,5	0	0	3	6
41	10	12	0,75	0	1	3	5
42	10	1	0,25	0	0	0	2
43	10	21	1	6	8	9	10
44	10	0	0	0	0	0	0
45	10	0	0	0	0	0	0
46	10	3	0,25	0	0	0	4
47	10	0	0	0	0	0	0
48	10	1	0,25	0	0	0	2
49	10	0	0	0	0	0	0
50	10	0	0	0	0	0	0
51	10	14	0,75	0	1	6	7
52	10	0	0	0	0	0	0
53	10	22	1	7	4	6	7
54	10	0	0	0	0	0	0
55	10	19	1	1	4	6	8
56	10	12	0,5	0	0	5	9
57	10	0	0	0	0	0	0
58	10	0	0	0	0	0	0
59	10	9	0,5	0	0	1	6
60	10	0	0	0	0	0	0
61	10	7	0,5	0	0	3	4
62	10	14	0,75	0	1	5	7
63	10	0	0	0	0	0	0
64	10	0	0	0	0	0	0
65	10	1	0,25	0	0	0	2
66	10	0	0	0	0	0	0
67	10	0	0	0	0	0	0
68	10	20	1	1	3	4	9
69	10	0	0	0	0	0	0
70	10	0	0	0	0	0	0
71	10	0	0	0	0	0	0
72	10	0	0	0	0	0	0
73	10	0	0	0	0	0	0
74	10	1	0,25	0	0	0	1
75	10	0	0	0	0	0	0
76	10	21	1	3	5	8	10
77	10	0	0	0	0	0	0
78	10	0	0	0	0	0	0
79	10	21	1	4	5	6	10
80	10	0	0	0	0	0	0

81	10	0	0	0	0	0	0
82	10	9	0,25	0	0	0	10
83	10	12	0,5	0	0	1	9
84	10	16	1	2	3	4	5
85	10	0	0	0	0	0	0
86	10	4	0,25	0	0	0	5
87	10	0	0	0	0	0	0
88	10	10	0,75	0	1	3	9
89	10	4	0,25	0	0	0	5
90	10	0	0	0	0	0	0
91	10	10	0,5	0	0	5	7
92	10	0	0	0	0	0	0
93	10	0	0	0	0	0	0
94	10	0	0	0	0	0	0
95	10	0	0	0	0	0	0
96	10	0	0	0	0	0	0
97	10	0	0	0	0	0	0
98	10	11	0,5	0	0	3	8
99	10	21	1	3	4	6	10
100	10	0	0	0	0	0	0
101	10	19	1	5	6	7	8
102	10	8	0,5	0	0	4	6
103	10	11	0,5	0	0	5	4
104	10	21	1	2	3	7	10
105	10	13	0,75	0	1	5	6
106	10	1	0,25	0	0	0	2
107	10	19	1	2	4	7	8
108	10	21	1	2	3	4	10
109	10	21	1	5	7	8	10
110	10	21	1	4	6	9	10
111	10	15	1	1	3	5	7
112	10	0	0	0	0	0	0
113	10	9	0,5	0	0	1	6
114	10	6	0,25	0	0	0	7
115	10	0	0	0	0	0	0
116	10	20	1	4	5	7	9
117	10	0	0	0	0	0	0
118	10	0	0	0	0	0	0
119	10	1	0,25	0	0	0	2
120	10	0	0	0	0	0	0
121	10	13	0,75	0	3	5	10
122	10	19	1	2	3	6	8
123	10	6	0,5	0	0	1	4
124	10	20	1	4	5	8	9
125	10	5	0,5	0	0	1	2
126	10	14	0,75	0	1	6	7

127	10	0	0	0	0	0	0
128	10	0	0	0	0	0	0
129	10	10	0,5	0	0	1	7
130	10	7	0,5	0	0	2	4
131	10	21	1	5	7	9	10
132	10	1	0,25	0	0	0	1
133	10	0	0	0	0	0	0
134	10	21	1	5	8	9	10
135	10	17	1	3	4	5	6
136	10	3	0,25	0	0	0	4
137	10	18	1	3	4	5	11
138	10	0	0	0	0	0	0
139	10	17	1	1	3	5	6
140	10	0	0	0	0	0	0
141	10	0	0	0	0	0	0
142	10	0	0	0	0	0	0
143	10	2	0,25	0	0	0	3
144	10	0	0	0	0	0	0
145	10	11	0,5	0	0	2	8
146	10	5	0,25	0	0	0	6
147	10	9	0,25	0	0	0	10
148	10	0	0	0	0	0	0
149	10	5	0,25	0	0	0	6
150	10	1	0,25	0	0	0	1
151	10	6	0,25	0	0	0	7
152	10	7	0,5	0	0	1	4
153	10	13	0,75	0	1	4	6
154	10	0	0	0	0	0	0
155	10	7	0,5	0	0	2	4
156	10	0	0	0	0	0	0
157	10	3	0,25	0	0	0	4
158	10	0	0	0	0	0	0
159	10	0	0	0	0	0	0
160	10	21	1	7	10	9	10
161	10	2	0,25	0	0	0	3
162	10	21	1	5	6	7	10
163	10	21	1	6	7	9	10
164	10	3	0,25	0	0	0	4
165	10	9	0,25	0	0	0	10
166	10	0	0	0	0	0	0
167	10	0	0	0	0	0	0
168	10	0	0	0	0	0	0
169	10	0	0	0	0	0	0
170	10	8	0,5	0	0	2	5
171	10	13	0,75	0	1	2	6
172	10	0	0	0	0	0	0

173	10	0	0	0	0	0	0
174	10	1	0,25	0	0	0	2
175	10	15	1	1	3	9	4
176	10	0	0	0	0	0	0
177	10	0	0	0	0	0	0
178	10	19	1	5	6	7	9
179	10	3	0,25	0	0	0	4
180	10	0	0	0	0	0	0
181	10	1	0,25	0	0	0	1
182	10	17	0,75	0	2	3	9
183	10	5	0,25	0	0	0	6
184	10	8	0,5	0	0	4	6
185	10	0	0	0	0	0	0
186	10	5	0,5	0	0	1	3
187	10	0	0	0	0	0	0
188	10	3	0,25	0	0	0	4
189	10	10	0,75	0	1	2	3
190	10	0	0	0	0	0	0
191	10	5	0,25	0	0	0	6
192	10	0	0	0	0	0	0
193	10	0	0	0	0	0	0
194	10	15	1	1	2	4	5
195	10	0	0	0	0	0	0
196	10	0	0	0	0	0	0
197	10	0	0	0	0	0	0
198	10	0	0	0	0	0	0
199	10	0	0	0	0	0	0
200	10	12	0,75	0	1	4	5
201	10	0	0	0	0	0	0
202	10	1	0,25	0	0	0	2
203	10	21	1	1	2	5	10
204	10	11	0,75	0	1	7	2
205	10	0	0	0	0	0	0
206	10	2	0,25	0	0	0	3
207	10	0	0	0	0	0	0
208	10	0	0	0	0	0	0
209	10	0	0	0	0	0	0
210	10	0	0	0	0	0	0
211	10	17	1	1	3	5	6
212	10	0	0	0	0	0	0
213	10	8	0,5	0	0	1	5
214	10	2	0,25	0	0	0	3
215	10	11	0,5	0	0	5	8
216	10	0	0	0	0	0	0
217	10	0	0	0	0	0	0
218	10	0	0	0	0	0	0

219	10	0	0	0	0	0	0
220	10	0	0	0	0	0	0
221	10	0	0	0	0	0	0
222	10	15	1	1	2	4	5
223	10	16	1	2	3	4	5
224	10	8	0,5	0	0	1	5
225	10	11	0,5	0	0	2	7
226	10	21	1	1	2	6	10
227	10	0	0	0	0	0	0
228	10	21	1	1	3	4	10
229	10	9	0,5	0	0	2	6
230	10	0	0	0	0	0	0
231	10	22	1	6	6	7	10
232	10	1	0,25	0	0	0	1
233	10	21	1	5	6	8	10
234	10	13	0,5	0	0	1	10
235	10	0	0	0	0	0	0
236	10	0	0	0	0	0	0
237	10	0	0	0	0	0	0
238	10	0	0	0	0	0	0
239	10	0	0	0	0	0	0
240	10	21	1	6	7	9	12
241	10	2	0,25	0	0	0	3
242	10	0	0	0	0	0	0
243	10	0	0	0	0	0	0
244	10	0	0	0	0	0	0
245	10	19	1	2	4	6	8
246	10	4	0,25	0	0	0	5
247	10	21	1	4	6	7	10
248	10	21	1	3	6	8	10
249	10	0	0	0	0	0	0
250	10	0	0	0	0	0	0
251	10	3	0,25	0	0	0	4
252	10	0	0	0	0	0	0
253	10	0	0	0	0	0	0
254	10	19	1	2	3	4	8
255	10	0	0	0	0	0	0
256	10	7	0,25	0	0	0	8
257	10	0	0	0	0	0	0
258	10	0	0	0	0	0	0
259	10	0	0	0	0	0	0
260	10	11	0,75	0	1	3	4
261	10	0	0	0	0	0	0
262	10	0	0	0	0	0	0
263	10	12	0,5	0	0	1	9
264	10	0	0	0	0	0	0

265	10	0	0	0	0	0	0
266	10	0	0	0	0	0	0
267	10	0	0	0	0	0	0
268	10	0	0	0	0	0	0
269	10	14	0,75	0	1	5	7
270	10	0	0	0	0	0	0
271	10	4	0,25	0	0	0	5
272	10	0	0	0	0	0	0
273	10	6	0,25	0	0	0	7
274	10	10	0,75	0	1	5	3
275	10	0	0	0	0	0	0
276	10	2	0,25	0	0	0	3
277	10	0	0	0	0	0	0
278	10	0	0	0	0	0	0
279	10	1	0,25	0	0	0	2
280	10	0	0	0	0	0	0
281	10	21	1	7	8	9	10
282	10	23	1	5	3	7	9
283	10	5	0,25	0	0	0	6
284	10	0	0	0	0	0	0
285	10	4	0,25	0	0	0	5
286	10	19	1	3	5	6	8
287	10	1	0,25	0	0	0	1
288	10	0	0	0	0	0	0
289	10	0	0	0	0	0	0
290	10	4	0,25	0	0	0	5
291	10	0	0	0	0	0	0
292	10	15	1	1	6	7	9
293	10	21	1	6	5	6	8
294	10	0	0	0	0	0	0
295	10	20	1	5	6	8	9
296	10	6	0,5	0	0	1	3
297	10	0	0	0	0	0	0
298	10	0	0	0	0	0	0
299	10	6	0,25	0	0	0	7
300	10	0	0	0	0	0	0
301	10	18	1	4	5	6	7
302	10	0	0	0	0	0	0
303	10	17	1	2	4	5	6
304	10	10	0,75	0	1	2	3
305	10	0	0	0	0	0	0
306	10	0	0	0	0	0	0
307	10	0	0	0	0	0	0
308	10	5	0,25	0	0	0	6
309	10	2	0,25	0	0	0	3
310	10	1	0,25	0	0	0	2

311	10	20	1	2	4	6	9
312	10	0	0	0	0	0	0
313	10	0	0	0	0	0	0
314	10	7	0,5	0	0	3	5
315	10	0	0	0	0	0	0
316	10	15	1	1	2	5	7
317	10	21	1	1	3	7	10
318	10	10	0,75	0	1	2	3
319	10	4	0,25	0	0	0	5
320	10	6	0,25	0	0	0	7
321	10	0	0	0	0	0	0
322	10	4	0,25	0	0	0	5
323	10	0	0	0	0	0	0
324	10	13	0,75	0	1	3	6
325	10	11	0,75	0	2	3	5
326	10	15	1	1	2	3	5
327	10	0	0	0	0	0	0
328	10	0	0	0	0	0	0
329	10	7	0,5	0	0	2	4
330	10	0	0	0	0	0	0
331	10	0	0	0	0	0	0
332	10	0	0	0	0	0	0
333	10	14	0,75	0	1	3	7
334	10	5	0,25	0	0	0	6
335	10	1	0,25	0	0	0	2
336	10	21	1	3	4	9	10
337	10	0	0	0	0	0	0
338	10	4	0,25	0	0	0	5
339	10	21	1	3	4	7	10
340	10	14	0,75	0	1	5	7
341	10	11	0,5	0	0	2	8
342	10	1	0,25	0	0	0	1
343	10	0	0	0	0	0	0
344	10	17	1	1	3	5	6
345	10	1	0,25	0	0	0	1
346	10	0	0	0	0	0	0
347	10	25	1	3	5	2	10
348	10	17	1	1	2	3	6
349	10	20	1	2	3	4	9
350	10	16	1	2	3	7	11
351	10	21	1	4	5	9	10
352	10	0	0	0	0	0	0
353	10	0	0	0	0	0	0
354	10	13	0,5	0	0	2	10
355	10	0	0	0	0	0	0
356	10	0	0	0	0	0	0

357	10	21	1	4	5	7	10
358	10	0	0	0	0	0	0
359	10	2	0,25	0	0	0	3
360	10	0	0	0	0	0	0
361	10	4	0,25	0	0	0	5
362	10	13	0,75	0	1	2	6
363	10	7	0,5	0	0	1	4
364	10	2	0,25	0	0	0	3
365	10	0	0	0	0	0	0
366	10	1	0,25	0	0	0	1
367	10	0	0	0	0	0	0
368	10	19	1	3	4	5	8
369	10	6	0,25	0	0	0	7
370	10	0	0	0	0	0	0
371	10	0	0	0	0	0	0
372	10	0	0	0	0	0	0
373	10	0	0	0	0	0	0
374	10	2	0,25	0	0	0	3
375	10	0	0	0	0	0	0
376	10	0	0	0	0	0	0
377	10	1	0,25	0	0	0	2
378	10	0	0	0	0	0	0
379	10	0	0	0	0	0	0
380	10	0	0	0	0	0	0
381	10	16	0,75	0	2	2	8
382	10	0	0	0	0	0	0
383	10	0	0	0	0	0	0
384	10	20	1	5	6	9	12
385	10	0	0	0	0	0	0
386	10	20	1	4	5	7	9
387	10	0	0	0	0	0	0
388	10	0	0	0	0	0	0
389	10	21	1	6	7	9	10
390	10	17	1	3	4	5	6
391	10	0	0	0	0	0	0
392	10	2	0,25	0	0	0	3
393	10	0	0	0	0	0	0
394	10	11	0,75	0	1	3	5
395	10	0	0	0	0	0	0
396	10	0	0	0	0	0	0
397	10	21	1	1	2	6	10
398	10	12	0,75	0	1	2	5
399	10	19	1	2	2	4	7
400	10	0	0	0	0	0	0
401	10	1	0,25	0	0	0	1
402	10	0	0	0	0	0	0

403	10	0	0	0	0	0	0
404	10	10	0,5	0	0	1	7
405	10	4	0,25	0	0	0	5
406	10	6	0,25	0	0	0	7
407	10	11	0,75	0	2	3	5
408	10	8	0,25	0	0	0	9
409	10	20	1	4	5	9	14
410	10	10	0,5	0	0	1	7
411	10	5	0,5	0	0	1	2
412	10	1	0,25	0	0	0	2
413	10	0	0	0	0	0	0
414	10	17	0,75	0	1	2	10
415	10	0	0	0	0	0	0
416	10	0	0	0	0	0	0
417	10	16	0,75	0	1	4	9
418	10	0	0	0	0	0	0
419	10	17	0,75	0	1	5	10
420	10	6	0,25	0	0	0	7
421	10	0	0	0	0	0	0
422	10	0	0	0	0	0	0
423	10	1	0,25	0	0	0	1
424	10	7	0,5	0	0	3	4
425	10	0	0	0	0	0	0
426	10	0	0	0	0	0	0
427	10	5	0,5	0	0	1	2
428	10	15	1	1	3	5	9
429	10	0	0	0	0	0	0
430	10	3	0,25	0	0	0	4
431	10	2	0,25	0	0	0	3
432	10	8	0,5	0	0	2	5
433	10	12	0,75	0	2	3	5
434	10	0	0	0	0	0	0
435	10	16	1	2	3	5	6
436	10	20	1	4	5	9	9
437	10	5	0,25	0	0	0	6
438	10	2	0,25	0	0	0	3
439	10	9	0,5	0	0	1	6
440	10	0	0	0	0	0	0
441	10	1	0,25	0	0	0	2
442	10	0	0	0	0	0	0
443	10	0	0	0	0	0	0
444	10	7	0,5	0	0	3	5
445	10	0	0	0	0	0	0
446	10	20	1	1	3	8	9
447	10	0	0	0	0	0	0
448	10	0	0	0	0	0	0

449	10	0	0	0	0	0	0
450	10	16	0,75	0	2	3	9
451	10	7	0,5	0	0	1	4
452	10	6	0,5	0	0	1	4
453	10	2	0,25	0	0	0	3
454	10	20	1	2	3	6	9
455	10	0	0	0	0	0	0
456	10	16	1	2	3	4	7
457	10	0	0	0	0	0	0
458	10	1	0,25	0	0	0	2
459	10	0	0	0	0	0	0
460	10	10	0,5	0	0	1	7
461	10	1	0,25	0	0	0	2
462	10	10	0,5	0	0	1	7
463	10	3	0,25	0	0	0	4
464	10	11	0,75	0	1	3	5
465	10	0	0	0	0	0	0
466	10	0	0	0	0	0	0
467	10	4	0,25	0	0	0	5
468	10	0	0	0	0	0	0
469	10	21	1	2	3	8	10
470	10	21	1	3	4	5	10
471	10	18	1	2	4	10	6
472	10	0	0	0	0	0	0
473	10	0	0	0	0	0	0
474	10	14	0,75	0	1	5	7
475	10	21	1	7	8	9	10
476	10	5	0,5	0	0	1	2
477	10	4	0,25	0	0	0	5
478	10	18	1	2	3	6	7
479	10	1	0,25	0	0	0	1
480	10	18	1	4	5	6	7
481	10	0	0	0	0	0	0
482	10	0	0	0	0	0	0
483	10	0	0	0	0	0	0
484	10	0	0	0	0	0	0
485	10	18	1	3	5	6	7
486	10	18	1	1	2	5	7
487	10	6	0,25	0	0	0	7
488	10	21	1	5	6	9	10
489	10	0	0	0	0	0	0
490	10	7	0,5	0	0	3	5
491	10	0	0	0	0	0	0
492	10	0	0	0	0	0	0
493	10	0	0	0	0	0	0
494	10	3	0,25	0	0	0	4

495	10	0	0	0	0	0	0
496	10	0	0	0	0	0	0
497	10	0	0	0	0	0	0
498	10	1	0,25	0	0	0	2
499	10	0	0	0	0	0	0
500	10	12	0,75	0	2	4	5

ANNEX III

In this Annex III you may find the original results obtained from the experiments carried out for a disruption time with a value of 30.

REPLICAS	DT	RE ALONG THE CHAIN	REACH	RE 1	RE 2	RE 3	RE 4
1	30	32	1	11	12	13	21
2	30	32	1	12	13	14	21
3	30	35	1	16	17	19	24
4	30	23	1	2	3	5	12
5	30	37	1	18	20	22	28
6	30	37	1	22	24	24	26
7	30	35	1	15	19	17	24
8	30	32	1	13	14	19	25
9	30	21	1	2	4	7	10
10	30	38	1	24	25	26	27
11	30	38	1	17	18	22	27
12	30	16	1	2	3	5	6
13	30	33	1	15	16	17	22
14	30	29	1	14	20	16	17
15	30	16	0,75	0	1	5	9
16	30	29	1	9	10	19	18
17	30	41	1	27	28	29	30
18	30	31	1	13	11	14	17
19	30	22	1	1	4	9	11
20	30	28	1	14	15	16	17
21	30	31	1	11	12	13	22
22	30	25	1	11	12	13	14
23	30	20	1	5	6	7	9
24	30	30	1	13	14	19	22
25	30	30	1	13	14	15	19
26	30	6	0,25	0	0	0	7
27	30	40	1	20	22	23	29
28	30	26	1	7	9	11	15
29	30	34	1	15	20	26	23
30	30	25	1	8	10	14	14
31	30	38	1	18	19	22	28
32	30	25	1	10	11	12	14
33	30	41	1	22	24	26	33
34	30	24	1	8	9	10	13

35	30	42	1	21	30	31	27
36	30	36	1	15	18	21	25
37	30	38	1	24	25	26	27
38	30	36	1	20	25	23	25
39	30	30	1	14	15	18	19
40	30	33	1	16	17	19	22
41	30	23	1	7	8	11	12
42	30	41	1	27	28	29	30
43	30	25	1	11	8	9	12
44	30	33	1	18	19	22	27
45	30	4	0,25	0	0	0	5
46	30	37	1	18	19	21	24
47	30	34	1	15	19	17	24
48	30	30	1	11	12	13	19
49	30	39	1	20	22	25	28
50	30	33	1	16	17	18	22
51	30	41	1	18	19	20	30
52	30	26	1	12	13	14	15
53	30	28	1	9	14	14	17
54	30	36	1	22	23	24	25
55	30	41	1	26	29	37	30
56	30	32	1	13	15	14	23
57	30	28	1	10	12	15	17
58	30	36	1	16	18	26	26
59	30	40	1	26	27	30	29
60	30	38	1	22	23	25	27
61	30	34	1	19	20	21	23
62	30	26	1	11	12	13	15
63	30	41	1	27	28	29	30
64	30	13	0,75	0	1	2	6
65	30	37	1	23	27	25	26
66	30	0	0	0	0	0	0
67	30	0	0	0	0	0	0
68	30	31	1	12	15	16	20
69	30	35	1	21	24	23	24
70	30	20	1	6	7	8	9
71	30	35	1	17	18	19	24
72	30	24	1	5	6	12	13
73	30	20	1	6	7	8	9
74	30	26	1	12	13	14	15
75	30	41	1	25	26	27	32
76	30	43	1	28	33	27	28
77	30	38	1	21	22	24	29
78	30	38	1	22	23	24	27
79	30	32	1	17	18	19	21
80	30	34	1	17	18	21	23

81	30	41	1	27	28	29	31
82	30	27	1	8	9	14	16
83	30	35	1	20	22	25	30
84	30	21	1	6	7	9	10
85	30	29	1	15	16	17	18
86	30	38	1	17	18	19	27
87	30	5	0,25	0	0	0	6
88	30	39	1	20	30	31	23
89	30	6	0,5	0	0	2	3
90	30	44	1	24	33	26	29
91	30	40	1	23	24	25	29
92	30	34	1	20	22	30	23
93	30	39	1	14	15	21	28
94	30	41	1	25	26	29	30
95	30	0	0	0	0	0	0
96	30	29	1	15	16	17	18
97	30	1	0,25	0	0	0	1
98	30	34	1	20	21	26	33
99	30	32	1	17	18	20	21
100	30	34	1	19	20	21	23
101	30	37	1	21	23	24	26
102	30	16	1	1	3	4	5
103	30	35	1	9	10	11	29
104	30	41	1	23	24	34	29
105	30	39	1	24	25	27	28
106	30	30	1	12	15	17	19
107	30	37	1	19	20	22	28
108	30	35	1	15	16	23	24
109	30	27	1	13	14	15	16
110	30	26	1	12	13	14	15
111	30	34	1	16	17	21	26
112	30	36	1	18	20	21	25
113	30	28	1	8	9	11	17
114	30	25	1	11	12	13	14
115	30	26	1	12	13	14	15
116	30	35	1	15	17	25	27
117	30	37	1	16	17	18	26
118	30	30	1	16	17	18	19
119	30	28	1	14	18	16	17
120	30	26	1	12	14	14	15
121	30	36	1	20	22	24	25
122	30	30	1	10	11	15	21
123	30	38	1	14	23	16	23
124	30	30	1	12	15	16	18
125	30	38	1	14	17	19	30
126	30	40	1	26	27	28	29

127	30	31	1	16	17	18	20
128	30	34	1	18	20	24	27
129	30	29	1	15	16	17	18
130	30	28	1	5	6	8	17
131	30	22	1	7	8	10	11
132	30	41	1	27	28	29	34
133	30	10	0,75	0	1	2	5
134	30	20	1	3	4	7	9
135	30	18	1	1	2	6	7
136	30	39	1	22	26	29	31
137	30	28	1	14	15	16	17
138	30	36	1	22	23	24	26
139	30	30	1	10	11	13	22
140	30	35	1	18	20	23	24
141	30	40	1	21	25	27	32
142	30	29	1	10	11	12	18
143	30	41	1	25	26	28	30
144	30	30	1	16	17	18	19
145	30	28	1	13	14	15	17
146	30	41	1	27	28	31	33
147	30	35	1	18	19	21	24
148	30	40	1	22	23	26	32
149	30	41	1	24	25	28	30
150	30	28	1	5	8	7	16
151	30	18	1	2	3	5	9
152	30	40	1	17	22	19	29
153	30	35	1	20	22	21	23
154	30	34	1	15	16	17	23
155	30	41	1	26	27	28	30
156	30	33	1	19	20	21	22
157	30	35	1	20	21	22	24
158	30	41	1	25	26	29	30
159	30	30	1	9	10	11	20
160	30	27	1	13	14	15	16
161	30	40	1	26	27	32	29
162	30	39	1	19	20	22	29
163	30	32	1	13	14	15	21
164	30	37	1	16	17	21	26
165	30	33	1	17	18	19	22
166	30	34	1	17	18	21	23
167	30	23	1	3	6	10	12
168	30	33	1	19	20	21	22
169	30	31	1	13	14	19	21
170	30	27	1	12	14	15	16
171	30	6	0,25	0	0	0	7
172	30	28	0,75	0	2	10	16

173	30	18	1	3	5	6	9
174	30	37	1	19	21	21	26
175	30	27	1	11	12	14	16
176	30	35	1	21	22	23	24
177	30	23	1	8	9	10	14
178	30	30	1	16	17	18	19
179	30	0	0	0	0	0	0
180	30	35	1	20	21	22	24
181	30	20	1	3	5	7	9
182	30	40	1	21	22	24	29
183	30	41	1	26	28	29	30
184	30	36	1	15	16	20	26
185	30	38	1	16	17	18	27
186	30	32	1	13	14	17	21
187	30	40	1	17	18	22	30
188	30	34	1	16	17	18	23
189	30	25	1	10	11	13	14
190	30	26	1	6	8	12	15
191	30	35	1	21	22	23	24
192	30	37	1	16	17	18	26
193	30	39	1	16	17	20	32
194	30	35	1	17	18	23	34
195	30	1	0,25	0	0	0	2
196	30	24	1	10	11	16	17
197	30	40	1	18	19	20	29
198	30	0	0	0	0	0	0
199	30	40	1	19	20	22	29
200	30	35	1	18	19	24	27
201	30	9	0,5	0	0	2	6
202	30	22	1	4	7	8	11
203	30	39	1	20	21	26	28
204	30	29	1	11	13	15	18
205	30	39	1	20	21	22	28
206	30	16	1	2	3	4	5
207	30	19	1	5	6	7	8
208	30	30	1	16	17	18	19
209	30	27	1	11	12	13	16
210	30	16	1	1	2	7	5
211	30	41	1	20	21	24	30
212	30	39	1	15	16	17	28
213	30	29	1	15	16	17	18
214	30	25	1	7	8	10	14
215	30	37	1	21	22	25	26
216	30	25	1	3	4	5	14
217	30	25	1	9	10	18	14
218	30	38	1	18	22	21	27

219	30	8	0,5	0	0	1	5
220	30	41	1	19	20	21	30
221	30	34	1	16	17	19	23
222	30	24	1	7	8	17	13
223	30	37	1	23	24	25	26
224	30	41	1	15	16	17	30
225	30	41	1	20	22	25	30
226	30	34	1	16	17	18	23
227	30	37	1	21	22	24	26
228	30	19	1	5	6	12	8
229	30	34	1	20	23	22	23
230	30	26	1	3	4	5	15
231	30	34	1	16	15	16	21
232	30	0	0	0	0	0	0
233	30	26	1	6	7	8	19
234	30	20	1	6	7	8	9
235	30	28	1	14	15	16	17
236	30	30	1	14	15	16	19
237	30	29	1	12	13	15	22
238	30	36	1	22	23	24	25
239	30	36	1	20	23	27	28
240	30	32	1	18	19	20	21
241	30	29	1	15	16	17	18
242	30	36	1	18	20	21	25
243	30	35	1	20	21	22	24
244	30	25	1	5	10	8	14
245	30	31	1	8	9	12	20
246	30	37	1	21	22	27	28
247	30	41	1	23	25	27	30
248	30	2	0,25	0	0	0	3
249	30	1	0,25	0	0	0	2
250	30	22	1	5	6	10	11
251	30	29	1	7	13	12	18
252	30	37	1	23	24	26	26
253	30	41	1	25	26	27	30
254	30	27	1	1	3	10	16
255	30	39	1	17	18	20	28
256	30	29	1	9	10	11	18
257	30	28	1	11	12	16	17
258	30	33	1	5	7	11	22
259	30	35	1	20	21	30	24
260	30	33	1	19	20	21	22
261	30	41	1	27	28	29	30
262	30	26	1	5	6	7	15
263	30	34	1	18	22	20	23
264	30	39	1	21	22	23	28

265	30	37	1	20	21	22	28
266	30	26	1	11	12	14	15
267	30	34	1	18	19	20	23
268	30	31	1	8	20	13	14
269	30	30	1	16	17	18	19
270	30	41	1	20	21	22	30
271	30	27	1	13	16	15	16
272	30	27	1	12	13	15	16
273	30	13	0,5	0	0	1	10
274	30	41	1	27	28	30	30
275	30	27	1	7	8	12	16
276	30	36	1	18	19	20	25
277	30	36	1	15	16	17	25
278	30	30	1	13	14	15	19
279	30	22	1	8	9	10	11
280	30	35	1	17	19	22	24
281	30	34	1	19	21	22	25
282	30	38	1	21	23	28	27
283	30	29	1	13	14	17	19
284	30	25	1	11	12	13	14
285	30	32	1	14	15	16	21
286	30	31	1	14	15	20	23
287	30	22	1	2	4	7	11
288	30	22	1	8	9	10	11
289	30	0	0	0	0	0	0
290	30	41	1	21	18	21	26
291	30	21	1	4	7	9	10
292	30	37	1	16	17	19	26
293	30	38	1	24	25	26	27
294	30	36	1	15	17	21	29
295	30	31	1	12	13	16	21
296	30	24	1	7	8	9	12
297	30	21	1	6	7	9	10
298	30	34	1	14	16	21	23
299	30	40	1	23	24	28	30
300	30	40	1	24	24	27	28
301	30	27	1	11	12	13	16
302	30	23	1	9	10	11	12
303	30	36	1	16	17	18	25
304	30	42	1	24	32	34	39
305	30	19	1	2	4	6	8
306	30	28	1	12	13	14	17
307	30	0	0	0	0	0	0
308	30	29	1	9	10	20	18
309	30	32	1	15	16	17	23
310	30	31	1	12	13	15	20

311	30	37	1	17	18	20	26
312	30	29	1	9	10	12	18
313	30	24	1	1	2	4	13
314	30	23	1	7	8	11	12
315	30	39	1	21	22	25	28
316	30	36	1	17	18	21	25
317	30	41	1	24	25	27	30
318	30	27	1	12	13	14	16
319	30	32	1	17	18	19	21
320	30	36	1	22	23	24	25
321	30	21	1	5	6	8	10
322	30	21	1	3	5	8	10
323	30	0	0	0	0	0	0
324	30	31	1	11	12	15	27
325	30	0	0	0	0	0	0
326	30	37	1	20	21	23	26
327	30	24	1	10	11	12	13
328	30	25	1	11	12	13	14
329	30	27	1	12	13	14	16
330	30	31	1	8	9	13	20
331	30	27	1	9	10	21	14
332	30	8	0,5	0	0	1	5
333	30	36	1	17	19	21	25
334	30	41	1	27	28	29	30
335	30	27	1	11	13	15	16
336	30	40	1	17	18	20	29
337	30	39	1	21	22	25	28
338	30	41	1	27	28	29	30
339	30	29	1	12	13	16	20
340	30	32	1	17	22	19	21
341	30	37	1	16	17	18	26
342	30	30	1	14	17	18	19
343	30	34	1	18	19	20	23
344	30	29	1	8	9	13	17
345	30	38	1	21	17	18	22
346	30	32	1	16	17	18	21
347	30	31	1	14	15	17	21
348	30	36	1	21	22	24	25
349	30	36	1	20	25	28	33
350	30	34	1	20	21	28	23
351	30	24	1	8	10	11	13
352	30	35	1	15	17	18	24
353	30	38	1	17	19	24	27
354	30	27	1	5	7	7	16
355	30	35	1	16	17	18	24
356	30	21	1	2	3	4	10

357	30	40	1	20	21	22	29
358	30	44	1	24	24	27	32
359	30	41	1	23	24	30	30
360	30	26	1	12	13	16	15
361	30	18	1	2	8	9	14
362	30	21	1	6	7	8	10
363	30	35	1	21	22	23	24
364	30	23	1	8	9	11	12
365	30	18	1	4	5	6	7
366	30	27	1	8	11	12	16
367	30	40	1	19	20	22	29
368	30	24	1	9	10	14	13
369	30	24	1	8	10	12	13
370	30	41	1	15	16	17	30
371	30	27	1	13	14	15	16
372	30	6	0,5	0	0	2	4
373	30	3	0,25	0	0	0	4
374	30	40	1	26	28	29	30
375	30	35	1	16	17	20	25
376	30	41	1	25	21	22	25
377	30	20	1	6	7	8	13
378	30	39	1	20	21	25	28
379	30	19	1	5	6	7	8
380	30	40	1	20	23	27	29
381	30	30	1	13	14	18	24
382	30	31	1	12	14	17	20
383	30	16	1	2	3	4	5
384	30	25	1	10	11	13	14
385	30	35	1	20	22	31	24
386	30	8	0,5	0	0	2	5
387	30	34	1	16	17	23	27
388	30	36	1	19	20	23	25
389	30	40	1	19	20	21	29
390	30	23	1	9	10	11	12
391	30	41	1	24	25	28	30
392	30	31	1	14	16	22	20
393	30	39	1	21	23	26	32
394	30	35	1	15	16	17	24
395	30	24	1	8	10	11	14
396	30	0	0	0	0	0	0
397	30	27	1	8	9	14	16
398	30	40	1	23	24	26	29
399	30	23	1	9	10	11	12
400	30	37	1	18	19	20	26
401	30	28	1	9	10	11	17
402	30	32	1	12	13	14	22

403	30	31	1	14	16	16	20
404	30	33	1	15	16	17	22
405	30	38	1	22	22	25	26
406	30	35	1	20	21	23	24
407	30	23	1	9	10	11	12
408	30	25	1	8	10	11	14
409	30	22	1	6	8	10	11
410	30	27	1	7	8	9	17
411	30	41	1	21	22	23	30
412	30	17	1	2	3	5	6
413	30	4	0,25	0	0	0	5
414	30	34	1	13	18	28	21
415	30	27	1	8	12	11	16
416	30	41	1	26	27	29	30
417	30	30	1	14	17	16	18
418	30	19	1	2	4	6	8
419	30	36	1	17	18	19	25
420	30	27	1	7	7	8	15
421	30	35	1	20	21	23	24
422	30	36	1	13	14	15	25
423	30	35	1	16	14	15	21
424	30	33	1	19	20	23	24
425	30	31	1	13	14	15	20
426	30	23	1	8	9	10	3
427	30	38	1	22	24	26	27
428	30	41	1	24	26	29	30
429	30	36	1	15	16	24	26
430	30	31	1	11	12	13	21
431	30	40	1	23	24	27	32
432	30	34	1	16	17	18	23
433	30	35	1	17	18	23	26
434	30	24	1	2	4	5	17
435	30	41	1	25	27	29	31
436	30	36	1	12	22	29	21
437	30	41	1	25	26	29	30
438	30	24	1	7	9	12	13
439	30	8	0,5	0	0	3	6
440	30	27	1	11	12	13	16
441	30	34	1	19	20	22	23
442	30	30	1	8	9	10	20
443	30	34	1	20	17	18	19
444	30	33	1	17	21	20	22
445	30	39	1	23	24	27	28
446	30	41	1	27	28	29	30
447	30	0	0	0	0	0	0
448	30	35	1	18	20	19	20

449	30	21	1	6	10	8	10
450	30	37	1	9	16	17	23
451	30	32	1	14	14	17	18
452	30	24	1	10	11	12	13
453	30	30	1	10	11	20	19
454	30	37	1	23	24	25	26
455	30	37	1	20	21	22	26
456	30	37	1	17	19	22	29
457	30	27	1	8	9	10	16
458	30	37	1	23	24	25	26
459	30	29	1	11	12	16	18
460	30	41	1	19	20	27	30
461	30	41	1	21	22	23	32
462	30	29	1	6	7	8	18
463	30	38	1	19	20	22	27
464	30	37	1	22	23	24	31
465	30	36	1	19	20	21	25
466	30	38	1	21	22	23	27
467	30	8	0,5	0	0	4	5
468	30	34	1	13	14	15	23
469	30	35	1	18	19	21	24
470	30	16	1	2	3	5	6
471	30	35	1	19	20	23	24
472	30	34	1	13	15	18	25
473	30	39	1	23	26	27	28
474	30	37	1	18	19	22	26
475	30	24	1	8	9	10	15
476	30	41	1	22	24	31	32
477	30	20	1	6	8	8	9
478	30	39	1	25	26	27	28
479	30	22	1	4	5	6	11
480	30	28	1	11	12	13	17
481	30	38	1	24	25	26	27
482	30	27	1	13	14	15	18
483	30	22	1	4	6	8	11
484	30	0	0	0	0	0	0
485	30	44	1	26	25	26	30
486	30	23	1	1	2	5	12
487	30	23	1	9	10	11	12
488	30	35	1	12	13	14	24
489	30	26	1	2	3	5	15
490	30	41	1	24	25	26	30
491	30	38	1	21	22	23	27
492	30	35	1	15	16	18	24
493	30	29	1	12	13	14	18
494	30	36	1	18	19	21	26

495	30	35	1	21	22	23	24
496	30	38	1	23	25	26	27
497	30	38	1	23	24	27	28
498	30	41	1	22	24	27	30
499	30	38	1	19	20	22	27
500	30	29	1	13	15	16	18

ANNEX IV

In this Annex IV you may find the original results obtained from the experiments carried out for a disruption time with a value of 40.

REPLICAS	DT	RE ALONG THE CHAIN	REACH	RE 1	RE 2	RE 3	RE 4
1	40	43	1	23	24	26	32
2	40	23	1	5	6	7	12
3	40	42	1	27	30	34	37
4	40	45	1	29	30	31	34
5	40	29	1	10	11	12	18
6	40	46	1	25	26	31	35
7	40	44	1	30	31	32	33
8	40	46	1	29	32	32	34
9	40	48	1	34	35	36	39
10	40	35	1	17	23	19	23
11	40	46	1	30	33	36	38
12	40	32	1	13	14	19	21
13	40	11	0,75	0	2	3	5
14	40	51	1	36	38	39	40
15	40	41	1	21	23	28	36
16	40	44	1	30	31	32	33
17	40	32	1	18	19	25	31
18	40	51	1	37	38	39	41
19	40	45	1	30	31	33	34
20	40	49	1	28	32	34	41
21	40	36	1	22	23	24	25
22	40	45	1	31	32	33	34
23	40	36	1	16	17	18	25
24	40	38	1	20	22	26	28
25	40	34	1	14	15	17	23
26	40	36	1	21	22	24	25
27	40	44	1	20	21	27	38
28	40	37	1	23	24	25	26
29	40	35	1	17	19	23	26

30	40	41	1	24	26	27	30
31	40	25	1	8	9	10	16
32	40	43	1	20	21	26	32
33	40	51	1	32	33	35	40
34	40	27	1	13	14	15	16
35	40	51	1	37	38	39	41
36	40	25	1	3	2	7	12
37	40	39	1	24	26	31	33
38	40	36	1	18	19	20	25
39	40	38	1	24	25	26	27
40	40	38	1	18	19	23	31
41	40	46	1	26	27	30	35
42	40	43	1	26	26	29	31
43	40	38	1	24	25	28	33
44	40	36	1	17	18	20	27
45	40	48	1	28	30	35	37
46	40	37	1	23	24	25	26
47	40	0	0	0	0	0	0
48	40	37	1	20	21	22	26
49	40	30	1	12	14	17	19
50	40	34	1	17	16	21	25
51	40	43	1	26	27	28	32
52	40	29	1	13	14	15	18
53	40	36	1	20	21	23	25
54	40	46	1	25	26	27	35
55	40	50	1	26	31	32	42
56	40	38	1	24	25	26	27
57	40	26	1	12	13	14	15
58	40	45	1	30	32	33	34
59	40	43	1	24	27	29	32
60	40	35	1	21	22	29	24
61	40	54	1	32	28	29	38
62	40	45	1	27	28	29	34
63	40	34	1	20	21	27	22
64	40	48	1	31	32	33	37
65	40	39	1	24	25	27	28
66	40	52	1	32	34	33	40
67	40	39	1	19	20	21	33
68	40	41	1	23	24	27	30
69	40	42	1	28	29	30	31
70	40	41	1	22	25	27	30
71	40	34	1	10	11	19	23
72	40	36	1	22	23	24	25
73	40	50	1	24	25	26	39
74	40	30	1	15	16	18	19
75	40	45	1	28	29	33	34

76	40	34	1	15	16	21	25
77	40	39	1	24	25	26	28
78	40	41	1	22	24	27	30
79	40	51	1	34	35	39	40
80	40	51	1	34	37	38	40
81	40	49	1	23	24	25	38
82	40	37	1	21	22	23	26
83	40	43	1	20	21	25	32
84	40	27	1	12	13	15	16
85	40	53	1	30	37	38	50
86	40	37	1	23	24	25	26
87	40	35	1	16	21	20	24
88	40	21	1	7	8	9	10
89	40	51	1	21	22	33	38
90	40	38	1	19	20	22	27
91	40	47	1	30	31	32	36
92	40	27	1	9	10	14	20
93	40	40	1	23	25	28	29
94	40	28	1	14	15	16	17
95	40	42	1	23	24	30	31
96	40	50	1	28	27	31	36
97	40	30	1	16	17	18	19
98	40	49	1	30	31	37	38
99	40	47	1	31	33	34	36
100	40	51	1	37	38	39	40
101	40	42	1	25	29	34	37
102	40	0	0	0	0	0	0
103	40	51	1	27	28	33	40
104	40	34	1	15	17	19	26
105	40	46	1	31	32	34	35
106	40	37	1	18	19	21	31
107	40	43	1	26	30	23	24
108	40	45	1	27	28	29	34
109	40	51	1	36	39	39	40
110	40	34	1	18	19	20	23
111	40	51	1	35	37	38	40
112	40	49	1	31	32	33	38
113	40	48	1	33	34	35	37
114	40	25	1	10	12	13	14
115	40	45	1	24	28	27	34
116	40	38	1	20	21	25	27
117	40	38	1	20	21	23	27
118	40	51	1	33	34	35	40
119	40	35	1	20	21	22	24
120	40	40	1	22	23	27	29
121	40	37	1	21	22	23	26

122	40	49	1	32	33	36	38
123	40	38	1	24	25	26	27
124	40	22	1	8	9	10	11
125	40	45	1	29	30	32	34
126	40	34	1	11	13	16	23
127	40	28	1	11	12	14	17
128	40	50	1	32	33	34	39
129	40	21	1	6	7	8	10
130	40	28	1	14	15	16	17
131	40	39	1	23	24	26	28
132	40	32	1	17	18	20	21
133	40	49	1	33	37	40	38
134	40	37	1	18	21	20	26
135	40	35	1	18	19	23	26
136	40	47	1	33	34	35	36
137	40	37	1	21	23	24	25
138	40	45	1	31	32	33	34
139	40	37	1	19	20	21	26
140	40	37	1	15	14	16	27
141	40	41	1	26	27	29	30
142	40	51	1	28	30	30	40
143	40	39	1	21	21	23	27
144	40	40	1	25	26	28	29
145	40	46	1	25	27	28	35
146	40	49	1	34	36	41	38
147	40	51	1	37	38	39	40
148	40	46	1	31	33	34	35
149	40	41	1	23	24	28	30
150	40	25	1	9	10	13	14
151	40	38	1	21	22	25	27
152	40	32	1	18	19	22	21
153	40	45	1	28	32	29	33
154	40	34	1	19	20	22	23
155	40	37	1	21	22	23	26
156	40	47	1	27	28	31	36
157	40	51	1	37	38	39	40
158	40	28	1	13	14	15	17
159	40	30	1	16	17	18	19
160	40	25	1	7	8	15	14
161	40	28	1	13	14	15	19
162	40	42	1	27	28	30	31
163	40	39	1	22	23	27	28
164	40	51	1	33	34	36	40
165	40	51	1	34	36	38	40
166	40	44	1	30	31	38	33
167	40	51	1	23	24	25	40

168	40	40	1	26	27	28	29
169	40	50	1	32	33	38	43
170	40	47	1	32	35	34	36
171	40	25	1	9	11	13	14
172	40	51	1	34	36	39	40
173	40	23	1	9	10	11	12
174	40	43	1	28	30	31	32
175	40	36	1	18	20	23	25
176	40	39	1	22	23	27	28
177	40	44	1	23	24	26	37
178	40	34	1	19	20	21	23
179	40	44	1	23	24	27	33
180	40	36	1	15	16	19	25
181	40	46	1	27	28	29	38
182	40	36	1	22	23	24	25
183	40	45	1	30	31	32	34
184	40	23	1	7	8	13	12
185	40	45	1	26	27	35	34
186	40	25	1	8	10	11	14
187	40	45	1	27	26	31	32
188	40	50	1	33	34	37	39
189	40	44	1	23	26	27	33
190	40	44	1	30	32	33	36
191	40	36	1	20	21	23	25
192	40	41	1	25	26	27	31
193	40	36	1	17	18	23	25
194	40	50	1	28	29	31	40
195	40	40	1	22	24	28	29
196	40	51	1	36	38	39	40
197	40	54	1	33	34	40	40
198	40	51	1	34	36	38	40
199	40	47	1	30	31	33	36
200	40	47	1	31	33	35	36
201	40	33	1	14	16	17	22
202	40	49	1	30	31	32	39
203	40	49	1	33	34	35	38
204	40	42	1	25	26	29	31
205	40	50	1	34	35	38	40
206	40	29	1	15	16	17	18
207	40	41	1	26	27	29	30
208	40	51	1	31	32	34	40
209	40	30	1	9	10	15	19
210	40	31	1	15	16	21	20
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