ESCUELA TÉCNICA SUPERIOR DE INGENIEROS INDUSTRIALES Y DE TELECOMUNICACIÓN

Titulación:

INGENIERO INDUSTRIAL

Título del proyecto:

LOGISTICS AND DECISION CHAINS IN DISASTER MANAGEMENT; FLOODS IN AUSTRIA / CASE SIMULATION: KREMS-MAUTERN AN DER DONAU

Proyecto de Fin de Carrera realizado en el Departamento de Logística y Producción de BOKU (University of Natural Resources and Life Science), Viena, Austria.

BOKU Supervisor: PATRICK HIRSCH

Alumno: Francisco Javier Larraya Eraso

Tutor – Director: Javier Faulín Fajardo

Universität für Bodenkultur Wien
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Pamplona, 27 Abril 2015

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PUBLIC UNIVERSITY OF NAVARRA (UPNA)- BOKU, INSTITUTE OF PRODUCTION AND LOGISTICS

LOGISTICS AND DECISION CHAINS IN DISASTER MANAGEMENT

FLOODS IN AUSTRIA / CASE SIMULATION: KREMS-MAUTERN AN DER DONAU

Francisco Javier Larraya Eraso, Industrial Engineering

30/03/2015

In this document, it is analysed the impact and the coordination of disaster situations and so the logistic and decisions needed to deal with. Due to the variety of this topic, the document focused on disaster flooding event located in Lower Austria.

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This work has required a big research, a significant back-up and, even more important, the support and conviction of many people involved in this Final Master Thesis. It is very significant and really necessary to give them all my gratefulness, before starting this work. After the six – month residence in Vienna, it can be said that I have left friends, more than colleagues.

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But for the help and support of this group of qualified people, it would not have been possible to develop this thesis and experiment this interesting, amazing and fulfilling experience.

Abstract

The main purpose of this final master thesis is to analyse the analysis of the chain of decisions concerning a disaster situation as well as its consequences. Furthermore, the logistical issues concerning resource distribution in case of a flooding event are investigated. A particular disaster event situated in Lower Austria is used, due to the fact that the final master thesis is developed in Austria. Concerning this main objective, the study begins at an international level, where cooperation and coordination of several organizations are studied, to focus afterwards on Austrian organization. A case study is conducted to compare practice and guidelines regarding the main decision chains. In addition to this, a hypothetical situation is generated in terms of deciding and finding out which the best logistical decision is as far as it concerns the satisfaction of the population. The main objective is to reduce the number of unsatisfied customers to the minimum and to guarantee the minimum stocks to the local distribution centres. This operation is restricted to a limited governmental budget. Therefore, it is necessary to explain all the cooperating and coordinating organizations involved in a disaster situation.

The simulation and subsequent conclusions are carried out with the simulation software AnyLogic. The simulation problem has not only the restriction of the available budget bounded to the supplying chain, but also technical (resources, trucks) constraints. The main objective is to minimize the number of unsatisfied people in the area. The final master thesis is developed with the collaboration of the BOKU University (University of Natural Resources and Life Science) of Vienna, in particular with the Institute of Production and Logistics.

In contrast to the first theoretical part, the simulation offers a very wide range of possibilities to model different scenarios. It is a very dynamic and interesting procedure, capable itself to give important results. In this final master thesis, four different scenarios are simulated, implying each of them different constraints. In each of the scenarios the total demand of each store is given as well as the number of total satisfied customers and units in stock. Furthermore, the results obtained are very useful to get quite an exact approach to the real situation of a flood. In addition to this, technical parameters like the needed stock to satisfy the demand or the optimal number of trucks to ship stock are established. All the results are compared within different graphics and charts, finding out the best solution in each simulated scenario.

In summary, and due to the lack of studies around this topic, this document becomes very interesting and a useful tool to start within the study of natural hazards.

Key words and acronyms

Key words

Agent type: Type of agent, intending of agent any entity existing in a determinate environment in a simulation of agent-based modelling.

Agent-based modelling: An agent-based model is one of a class of computational models for simulating the actions and interactions of autonomous agents (both individual and collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole *(Grimm et al., 2005)* .

AnyLogic: Multimethod simulation software developed by the AnyLogic Company *(AnyLogic, 2015).*

Adonis: BPM tool which provides intuitive tool for documenting processes as well as simulation, performance monitoring, and risk management support. It is also a very useful tool for decision making and decision chains *(Adonis-community, 2015).*

Coordination: The synchronization and integration of activities, responsibilities, and command and control structures to ensure that the resources dedicated to any task are used most efficiently in pursuit of the specified objectives *(Business dictionary, 2015).*

Disaster relief*:* Set of actions that provide an orderly and continuing means of assistance by the federal government to state and local governments, which enables them to fulfil their responsibilities to alleviate the suffering and damage caused by disasters such as floods, earthquakes and hurricanes *(Investopedia, 2015).*

Disaster relief organization: Organization in charge of performing the actions according to the disaster relief planning, as well as providing the affected population with the resources available.

Disaster risk management: The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster *(UNISDR, 2015).*

Geographic Information System: A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can show many different kinds of data on one map. This enables people to more easily see, analyze, and understand patterns and relationships *(National Geographic, 2015)*.

Guidelines: Set of rules or instructions that shows or tells how something should be done *(Merriam-Webster, 2015).*

Java*:* A high-level programming language developed by Sun Microsystems *(Webopedia, 2015)*.

Liaison organs*:* Representatives from disaster relief organizations that take part in the disaster coordination meetings and communicate the information from the coordination organs to the disaster relief organizations.

Logistics: The science of planning, organizing and managing activities that provide goods or services *(Logistics World, 1997).*

Natural disaster*:* major adverse event resulting from natural processes of the Earth (*Bankoff et al., 2003*).

Optimization: act, process, or methodology of making something (as a design, system, or decision) as fully perfect, functional, or effective as possible; *specifically*: the mathematical procedures (as finding the maximum of a function) involved in this *(Merriam-Webster, 2015).*

Resources: supply of something (such as money) that someone has and can use when it is needed *(Merriam-Webster, 2015).*

Statistics: collection of quantitative data *(Merriam-Webster, 2015).*

Social disaster*:* major adverse social event usually occurring as a consequence from natural disasters.

Simulation: the imitative representation of the functioning of one system or process by means of the functioning of another (a computer *simulation* of an industrial process) *(Merriam-Webster, 2015).*

Acronyms

ABM: Agent-based modeling

CRED: Centre for Research on the Epidemiology of Disasters

GIS: Geographic Information System

INSARAG: International Search and Rescue Advisory Group

ISDR: International Strategy for Disaster Reduction

FCSS: Field Coordination Support Section

FIFO: First Input First Output

LEMA: Local Emergency Authorities

LIFO: Last Input First Output

LRLC: League of Red Cross and Red Crescent

LO: Linear Optimization problem

NGOs: non-governmental organizations

OCHA: Office for the Coordination of Humanitarian Affairs

OSOCC: On-Site Operation Coordination Centre

PLE: Personal Learning Edition

RDC: Reception / Departure Centre

UN: United Nations

UNDAC: United Nations Disaster Assessment and Coordination

USAR: Urban Search and Rescue

WRDCC: World Conference on Disaster Risk Reduction.

1. INTRODUCTION

1.1 Natural disasters

We live in a continuously changing and developing world. This is happening so fast that even for humans it is difficult to catch up with. It is well-known that the ecosystem of the Earth is not prepared to face up such a drastic change. Furthermore, the year 2013 was marked by a very high number of humanitarian crisis and disasters, and great vulnerability (*European commission, 2014*).

Annual trends indicate that needs are increasingly outweighing resources available. The delivery of humanitarian aid and civil protection is also becoming more complex and due to the frequency and intensity of natural disasters with major consequences, humanitarian crises are occurring with less warning than before. (*European commission, 2014*)

As a consequence, many theories around climate change have been developed. The only proved fact is that the number of natural disasters, such as flooding, earthquakes, hurricanes, tropical storms, big snow falls and tsunamis has increased and it is expected to increase even more. In addition to this, the potential and scope of damages resulting from large scale natural disasters is undisputed. Additionally, the risks that societies are facing continue to grow along with the global population (*Kumar, 2013).*

"Statistics published by the CRED (*Centre for Research on the Epidemiology of Disasters)* and the UN (*United Nations)* office, UNISDR *(United Nations Office for Disaster Risk Reduction)* show that there were 356 natural disasters of variable magnitude in 2013. These disasters killed over 20.000 people and affected 99 million people worldwide" (*European commission, 2014*).

Any occurrence of natural disasters, such as earthquakes, typhoons, floods, or drought, will cause huge property damage and human injuries (*Chang et al., 2006*). The decision to focus this thesis on floods is a direct consequence of the analysis of historical disaster episodes; floods are the main natural disaster cause all among history. One of the main facts supporting this statement is the number of floods in the period 1980-2011: 3455 worldwide floods according to the UN data (*UN, 2014*). Furthermore, in many countries, the flood disaster has the highest frequency of occurrence among all natural disasters (*Chang et al., 2006).*

Furthermore, not only by their frequency, but also for its behaviour and natural complexity, flooding events turn up as a very interesting subject to study. In contrast with other phenomena such as earthquakes, flood disasters are more easily predicted and prevented (*Chang et al., 2006)*. Therefore, it is very important for flood disaster management teams to make a prudent and comprehensive plan to improve flooding disaster prevention. Consequently, government agencies are investing tremendous amounts of money and manpower in flood disaster prevention and rescue. Flood logistics become then a very important and serious matter to study.In this document, an intense investigation around the logistics and the decision chain in disaster management, providing a case study and a simulation, is conducted. Chances to improve the process with the objective of optimizing the resources and reducing the money invest, are also, whenever possible, analysed. A concrete case study, "The flood event in Lower Austria, Danube River in 2013" is used to compare the theoretical guidelines process and the real working case.

The aim of this project resides in the analysis and comprehension of both, theoretical guidelines and real practice and, afterwards, the simulation of the main logistical problems around transport and communications in the affected area with the objective of providing the residents with the supplies needed. The simulation will be developed with the software AnyLogic.

1.2 Definition

At first, a definition of natural disaster is needed. A **natural disaster** is a major adverse event resulting from natural processes of the Earth; examples include floods, volcanic eruptions, earthquakes, tsunamis, and other geologic processes. A natural disaster can cause loss of life or property damage, and typically leaves some economic damage in its wake, the severity of which depends on the affected population's resilience, or ability to recover (*Bankoff et al., 2003*).

However, a natural phenomenon occurred in a non-populated area, does not achieve the level of disaster *(Ballesteros L., 2008)*. That means that an adverse event, a flooding for example, taking place in the middle of the Amazon jungle, is not considered a natural disaster. In conclusion, a complete detailed definition of natural disaster is a major adverse occurring in a populated area, due to natural causes. The two main factors, as the NDMC (national South African disaster management centre) explains, are: vulnerability and hazard; what means:

VULNERABILITY + HAZARD = DISASTER

Vulnerability is the tendency or the chance of suffering a disaster, and the hazard is the natural cause or event that produces the suffering. For example: People living on steep hillsides or in areas prone to floods are particularly vulnerable during periods of intense rainfall (vulnerability) and hazards, caused by extremes in natural processes (such as floods) are exacerbated if they occur in areas where the vulnerability and risk to such events is high *(NDMC, 2015).*

A disaster event, despite the nature, is formed by two different phases: Prevention phase which involves prevention and preparedness; and Disaster relief, which includes coping with the disaster and restoring the initial situation (*Jachs, 2014*). The four different phases are shown in Fig. 1.

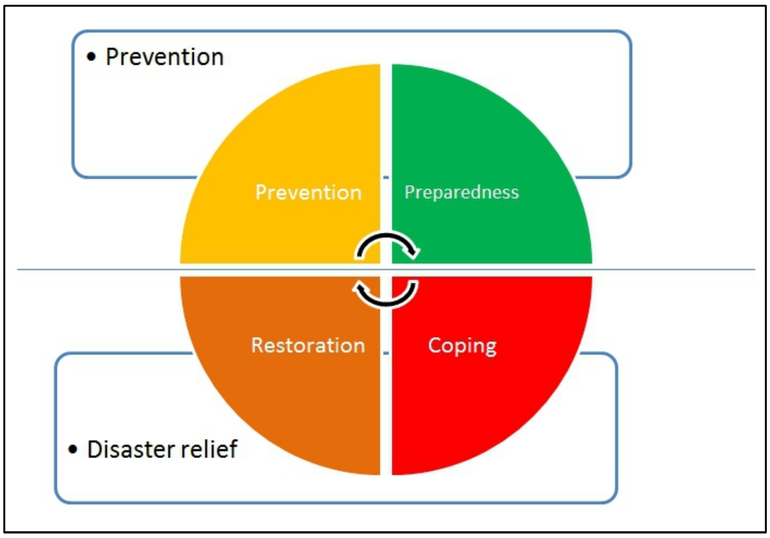


Fig. 1 ***"Disaster management phases"*** **(Based on Jachs, 2014)**

1.3 Need for collaboration

Due to climate change and the rising global average temperature, the number of extreme weather events is supposed to rise in the future. In consequence, this will lead to an increase of natural disasters with such important social impact. “*The international community must "risk proof" development because disasters are taking a heavy toll on rich and poor countries as well as outpacing their ability to respond"* (*UNISDR Secretary-General Ban Ki-moo, February 2011*).

This assumption can be supported with many facts; the main fact is the increase of natural disasters all around the world. Just some dates about the increasing of these disasters and their repercussion in the human life across the following two graphics (from UNISDR), Fig.1 and Fig. 2, with the disasters per year and their repercussion, as well as a chart with the most serious disasters in the last years.

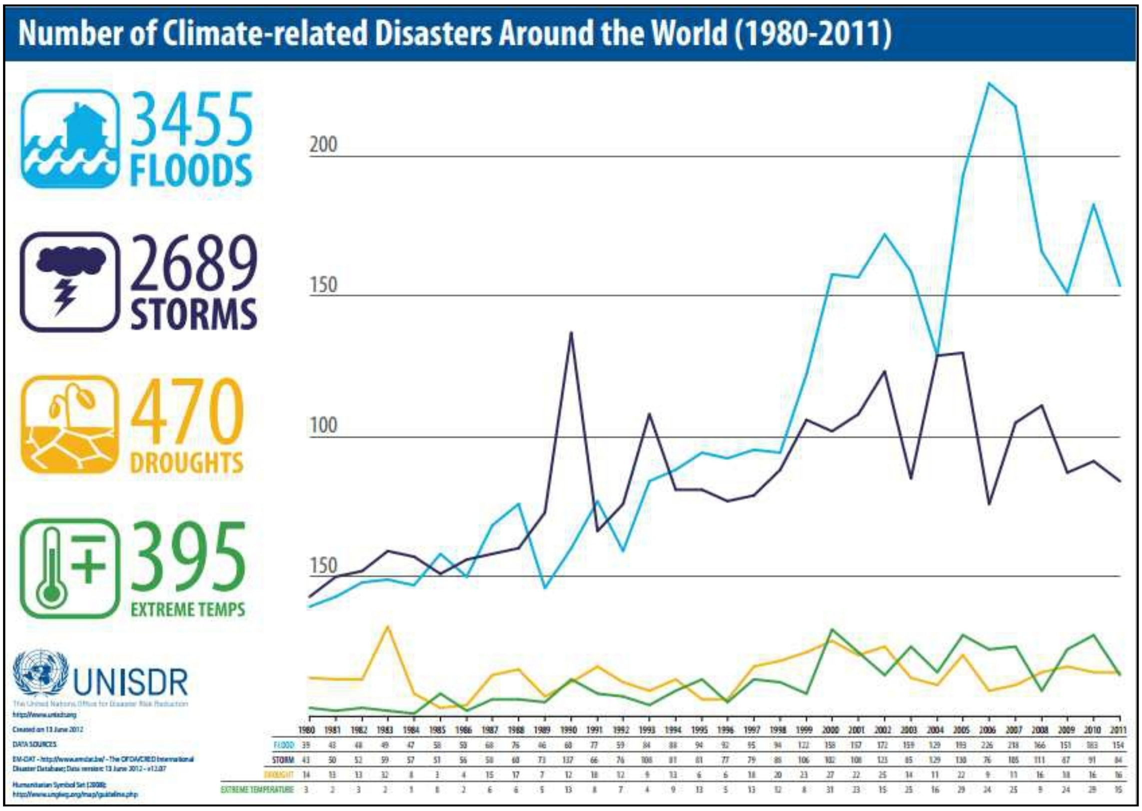


Fig. 2 *“Number of disasters 1980 – 2011”* (UNISDR, 2011).

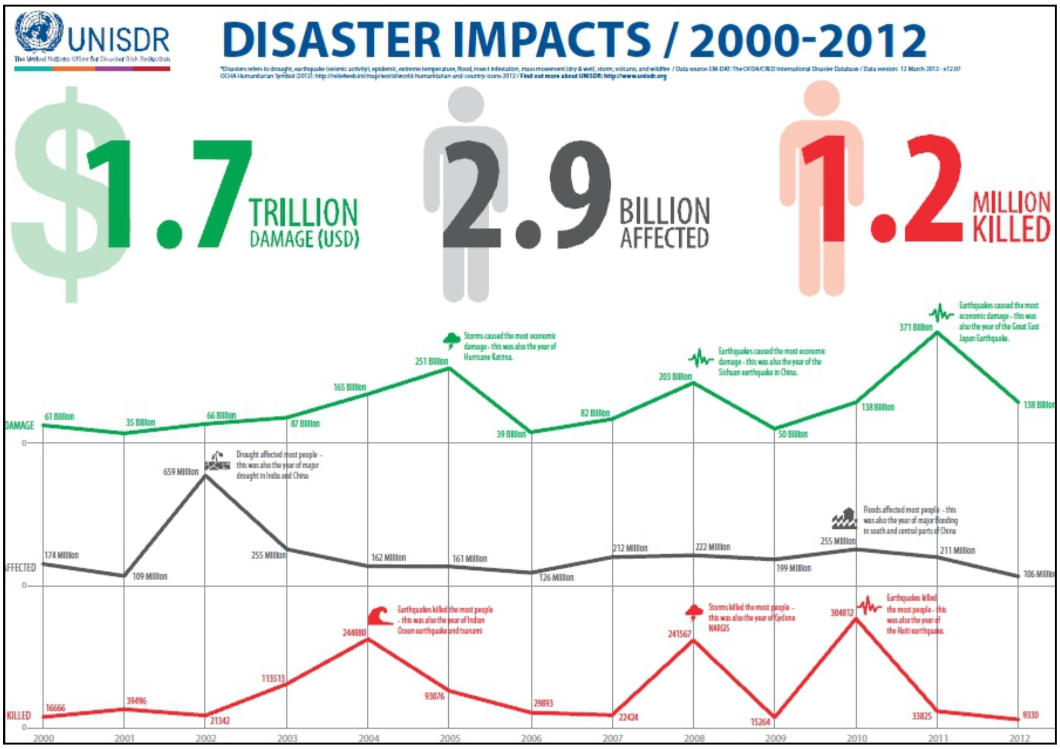


Fig. 3 *"Disaster Impacts 2000 - 2012"* (UNISDR, 2013).

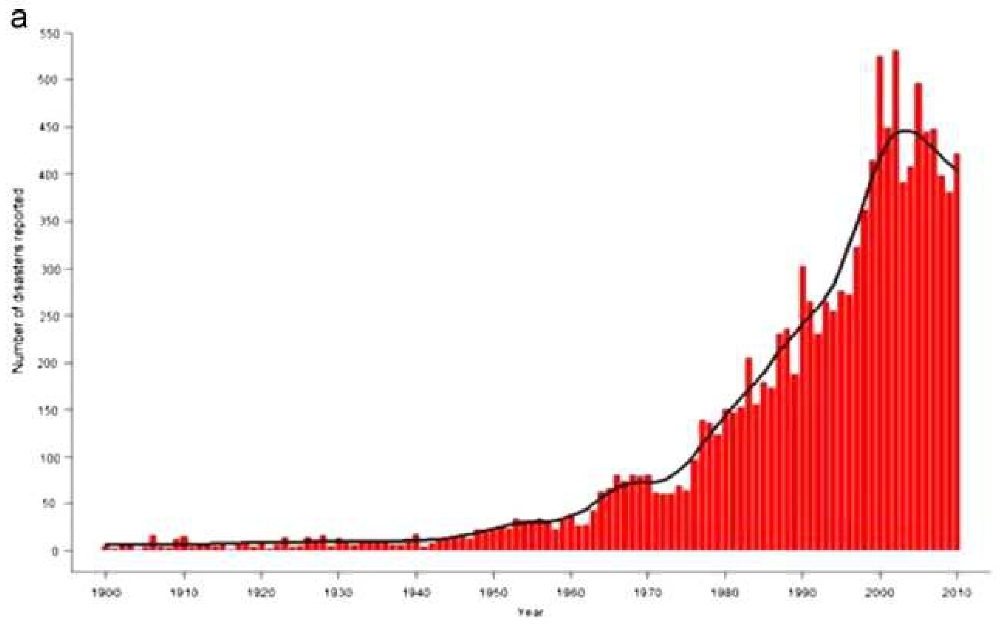
In the chart below the 10 most devastating disasters in the last ten years are showed, with the location, the type of natural disaster, and the number of deaths it forced.

Year	Location	Type	Num. deaths
2004	Indonesia	Tsunami	165708
2005	Pakistan	Earthquake	73338
2005	EE.UU	Tropical cyclone	1833
2006	Indonesia	Earthquake	5778
2008	Myanmar	Tropical cyclone	138366
2008	China	Earthquake	87476
2010	Pakistan	Flooding	1985
2010	Russia	Hot wave	55753
2010	Haiti	Earthquake	222570
2011	Japan	Tsunami	28050

Fig. 4 "Ten most important disasters in 21th"

As it can be observed, the most affected zone by the worst natural events is the zone of the Malay Archipelago, one of the poorest and most undeveloped areas in the world.

In the next graphic, Fig. 5, the number of natural disasters per year since 1900 can be observed. Quite often this graphic seems to be the most representative evidence of how have the disasters augmented and with such an incredibly high speed (*Kumar, 2013*).



Year	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
Number of disasters	5	5	8	10	15	30	45	65	120	250	450	400

Fig. 5 "Number of disasters per year" (Kumar, 2013)

Because of these facts, a need of collaboration grows up and provides the big countries the responsibility to develop special plans. According with this last appointment, the UNISDR (United Nations Office for Disaster and Risk Reduction), has developed an international cooperation plan, focusing on the year 2015, to minimize the impact of these disasters. The programme will execute the UN General Assembly decisions of Member States related to disaster risk reduction. It is formed within 7 big points (*UNISDR, 2014*):

- The 3rd World Conference on Disaster Risk Reduction in 2015
- Six Regional Platforms for building commitment to action
- Stakeholder commitment to implement the post-2015 framework for disaster risk reduction
- Coherent and coordinated action by the UN System
- Global reports on progress
- Coherence between international agendas.
- Gender-sensitive disaster risk reduction applied and monitored.

1.4 Objective of the thesis

As much as the number of natural disasters has increased, so have the necessity and the difficulty to affront them. It seems quite logical, that the combined plan to work against them has to be improved.

In this work, at first, a theoretical introduction and analysis of how the organizations are coordinated in an adverse situation will be explained, as well as a case study, where the performance will be studied. Afterwards, a comparison between the guidelines and the case study is done.

In addition to this first theoretical part, a simulation of a flooding situation, where logistical decisions around providing the affected population with the provisions needed, will be done. This simulation is developed in the second big block of this project and is realized with AnyLogic: This final master thesis wants to improve this action, optimizing resources and minimizing risks for life.

As introduced before, the aim of this final master thesis is to simulate a disaster situation (concrete case of flooding) and to improve and optimize, whenever possible, the logistics procedures and the resources invested. The simulation focuses in the needed stock to satisfy the demand during a critical flooding situation. For this simulation, it is also necessary to develop a theoretical analysis, where the coordination and guidelines of the different associations involved will be explained.

In the fig. 6, the developing process of the thesis can be observed, starting with the analysis of the guidelines and finishing with the case simulation.

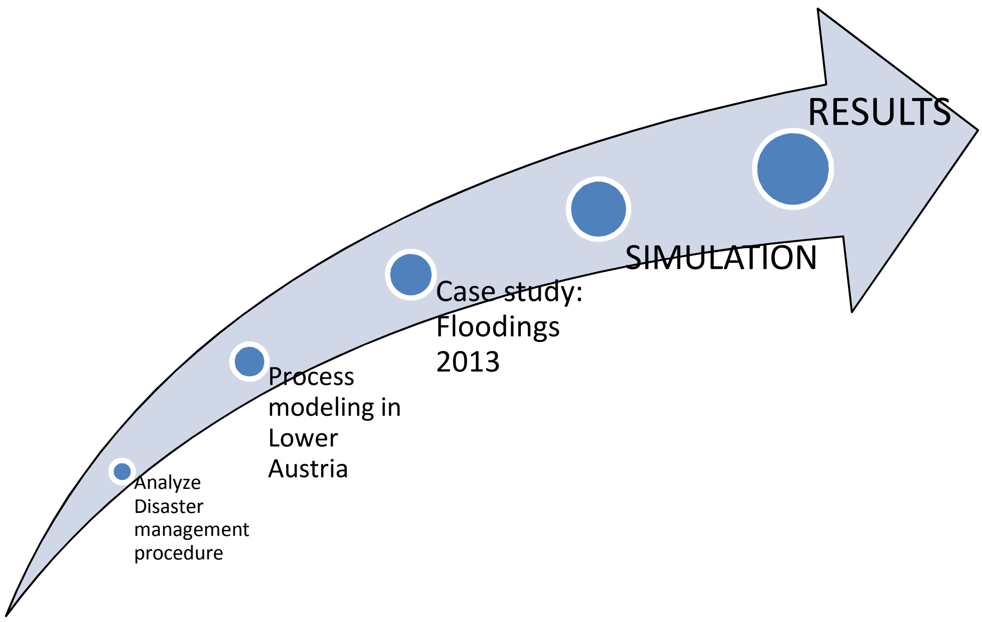


Fig. 6 “Model Approach”

1.5 Procedure Method

1.5.1 Literature Review

Conducting a literature review in this field is of value because it is an understudied topic and yet the implications of the recent failures in disaster relief management have demonstrated the urgent need to address these issues.

With the objective of developing this work, an intensive study and information searched have been realised. As the subject is very wide and extended, and it is not possible to simulate different disasters at the same time, it is decided to focus the study in flooding in Lower Austria, taking as reference the flooding event of the year 2013. Just to document, it was necessary to search for information about flooding logistics and cooperation from scientific web pages as "*www.ScienceDirect.com*" and other scientific web as "*Springer*". The database, bibliography and licenses available at BOKU were also very helpful. Terms like "liaison organs" were directly extracted from the Austrian Federal Ministry. Finally, after a whispered and fulfilled search, this paper sorted out in a way of explaining this phenomenon and the best decisions to deal with it.

1.5.2 Process Modelling

The modelling tool used to build the coordination diagrams is ADONIS.

ADONIS is a Business Process Analysis (BPA) tool supporting business process management based on BPMS framework created at the University of Vienna. It is developed by the BOC Information Technologies Consulting GmbH. It allows business process modelling using BPMS notation and BPMN 2.0, process analysis, simulation, evaluation as well as publishing and process automation with BPMN 2.0 XML (BPMN DI) and XPDL (*boc - group, 2014*).

This tool is very useful to study the decision chain and the consequences that each decision or changes in statements can produce. Adonis establishes a very useful tool to illustrate and explain directly and clearly the different relations and both, coordination and communication flows.

1.5.3 Simulation

The simulation is considered as the main point of this thesis, because it represents the real situation, and it is the best source to focus on and based all the logistical decision. The simulation will be developed with software called AnyLogic.

AnyLogic is a multimethod simulation modelling tool developed by The AnyLogic Company. AnyLogic models can be based on any of the main simulation modelling paradigms: discrete event or process-centric (DE), systems dynamics (SD), and agent-based (AB).System dynamics and discrete event are traditional simulation approaches, agent based is new. Technically, the system dynamics approach deals mostly with continuous processes whereas "discrete event" (by which we mean all descendants of GPSS also known as process-centric simulation approach) and agent based models work mostly in discrete time, i.e. jump from one event to another (*AnyLogic, 2014*).

2. DISASTER MANAGEMENT IN AN INTERNATIONAL LEVEL

2.1 Main Organizations Involved

Due to the magnitude of a natural disaster and due to the diversity of tasks and abilities, many organisations are involved in an international level and work together to get over those critical situations. In this document, the study of these organizations, how they work together, their synergies and management will be analysed. Firstly, it will be distinguished in two different branches: the organizations focusing on prevention, which are supposed to develop plans to reduce disaster risk; and the performance, or the disaster relief organizations, which are the responsible for the disaster management when it occurs. Both branches belong to the main international institution: the UN.

The UN is an intergovernmental organization established on 24 October 1945 to promote international co-operation. At its founding, the UN had 51 member states; there are now 193. The headquarters of the United Nations is situated in Manhattan and New York City, and enjoys extraterritoriality. The organization is financed by assessed and voluntary contributions from its member states. Its objectives include maintaining international peace and security, promoting human rights and economic development, protecting the environment, and providing humanitarian aid in cases of famine, natural disaster and armed conflict. (*UN, 2014*)

2.1.1 Disaster prevention: UNISDR

The articulated department of the UN in what disaster management and reducing risks concerns, it is named as UNISDR. "The International Strategy for Disaster Reduction reflects a major shift from the traditional emphasis on disaster response to disaster reduction, and in effect seeks to promote a "culture of prevention" (UNISDR guidelines, 2014).

Created in December 1999, the UNISDR is the secretariat of the ISDR (International Strategy for Disaster Reduction). UNISDR's mandate is to serve as the focal point in the United Nations system for the coordination of disaster reduction and to ensure synergies among disaster reduction activities. The main objective of this organization is to reduce the risk of disaster, DRR (Disaster Risk Reduction); DRR aims to reduce the damage caused by natural hazards like earthquakes, floods, droughts and cyclones, through an ethic of prevention (*UNISDR, 2014*). "*There is no such thing as a 'natural' disaster, only natural hazards" (UNISDR, 2014)*

In the year 2013, the UNISDR has developed a program within the next two years: 2014-2015 for international collaboration. This programme will drive accelerated and scaled-up action to reduce disaster risk through international coordination and partnership. It will promote coherence and mutual reinforcement between international frameworks covering disaster risk reduction, climate change, and sustainable development. The Programme will execute the UN General Assembly decisions of Member States related to disaster risk reduction (*UNISDR, 2013*).

The program, as it has been introduced, counts with seven main statements, resumed above.

- <u>The 3rd World Conference on Disaster Risk Reduction in 2015:</u> Recognized also with the initials WRDCC. The Office will support the design of a suitable schedule and help prepare the participants to deliver the agreed outcomes

- <u>Six Regional Platforms for building commitment to action:</u> UNISDR, in cooperation with host governments and regional institutions, will establish Regional Platforms and Ministerial Conferences in the Arab States, Europe, Africa, Americas, Asia and Pacific (plus a consultation in Central Asia) in the first half of 2014. Regional Platforms identify priorities, build consensus for regional solutions, and exchange knowledge and innovation.

- <u>Stakeholder commitment to implement the post-2015 framework for disaster risk reduction:</u> UNISDR will continue to promote ownership among partners of the post-2015 framework by building on the office's active engagement with all the different sectors.

- Global reports on progress: UNISDR will redevelop the HFA Online Monitor, the unique global monitoring tool on disaster risk reduction. The tool will become increasingly useful as an instrument for governments to review progress and guide development and implementation of national strategies.

- Coherent and coordinated action by the UN System

- Complementarity and coherence between international agendas: UNISDR will support the work of the High-Level Political Forum (successor mechanism of the Commission for Sustainable Development), the Open Ended Working Group on Sustainable Development Goals.

- Gender-sensitive disaster risk reduction applied and monitored: UNISDR will reach out to member states, to provide guidance on gender issues within disaster risk reduction. It will enlist women parliamentarians and grassroots women's organizations and work with regional training centres and national platforms to build capacity of government officials to apply gender policy guidance and report on gender issues through the HFA Monitor tool.

Within the next chart, Fig. 7, the estimated investment, per each planning statement, in $ is shown. As it is observed, the most important invest is centred in disaster reduction in the Third World, while the lowest consists in Gender-sensitive.

2014-2015 Resource Requirements (All figures in '000 US$)	
1. INTERNATIONAL COOPERATION TO REDUCE DISASTER RISK	**27,298**
1.1 The 3rd World Conference on Disaster Risk Reduction in March 2015	10,000
1.2 Six Regional Platforms for building commitment to action	4,400
1.3 Commitment from stakeholders to implement the post-2015 framework for disaster risk reduction	5,000
1.4 Coherent and coordinated action by the UN System	500
1.5 Complementarity and coherence among international agendas	3,000
1.6 Global reports on progress	1,000
1.7 Gender-sensitive disaster risk reduction applied and monitored	258
Programme Support Costs (PSC)	3,140

Fig. 7 "2014-2015 Resource Requirements" (*UNISDR, 2014*)

The Global Platform for Disaster Risk Reduction

The Global Platform for Disaster Risk Reduction was established in 2007 as a biennial (celebrated every two years) forum for information exchange, discussion of latest development and knowledge and partnership building across sectors, with the goal to improve implementation of disaster risk reduction through better communication and coordination amongst stakeholders. The Global Platform is organized by UNISDR, the UN's office for disaster risk reduction and secretariat of the International Strategy for Disaster Reduction (*UNISDR, 2014*). In Figure 8 the different logotipes of the already four Global Platform celebrated, are shown.

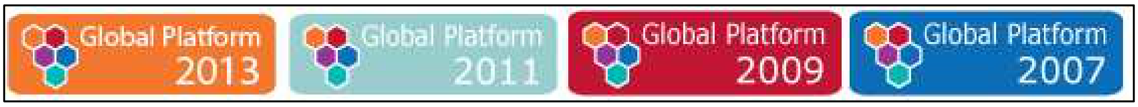


Fig. 8 "Global platform since its creation" ***(UNISDR, 2014)***

2.1.2 Disaster relief

The performance, or "*the actuation against a natural disaster*", has two different levels: the coordination (main structures from the UN), and the direct execution of the guidelines and order in the field, which is performed by the local forces and international alliances. Between these two levels the liaison organs are located, as a connecting entity.

The organizations focused on coordination, directly dependant from the UN, are the OCHA (*Office for the Coordination of Humanitarian Affairs*) as main organism, the UNDAC (*United Nations Disaster Assessment and Coordination*) and the INSARAG (*International Search and Rescue Advisory Group*), being these latter coordination tools of the OCHA. Both organisms, OCHA and INSARAG, established and configured the OSOCC (*On-Site Operation Coordination Centre*), main on-site disaster management tool, explained in the following chapter (*International guidelines).*

In the other hand, the direct execution organizations could be a very large range of different cooperation groups, either voluntary or professional, depending on the land. These organizations are competence of each country or region. The main disaster relief organizations studied in this document in an international level are:

- International Federation of Red Cross and Red Crescent Societies
- Military Association
- Fire Brigades.

In the following lines, some information just to understand how they work will be exposed.

2.1.2.1Coordination: OCHA

The OCHA, created in 1998, is the articulated branch of the United Nations to deal with natural disasters attending, depending on the affected country necessities, to the guarantee of resources and mediums so to ensure an effective response to a disaster situation (*OCHA, 2014*).

Within this mission, the OCHA main guidelines are (*OCHA, 2014*):

- Mobilize and coordinate effective and principled humanitarian action in partnership with national and international organizations in order to alleviate human suffering in disasters and emergencies.
- Advocate the rights of people in need.
- Promote preparedness and prevention.
- Facilitate sustainable solutions.

With the objective of providing a quick an effective solution, in 1993 the OCHA created a new variant named as UNDAC with the aim of helping the UN and governments of disaster affected countries during the first episode of a sudden on-set emergency (*UNDAC, 2014*). The principles characteristics of this section are:

- Fast deployment: 12-48 hours all over the world.
- Free charged for the affected country: As all the UN services, the costs will be assumed by the proper UN.
- Assessment, coordination and Information.
- Qualified and experienced stuff: special training and personal equipment for each situation.
- Pre-defined and standardized methodology for organizing and facilitating assessments and information management during the first phase of a sudden-onset disaster.

The UNDAC system is managed by the FCSS (*Field Coordination Support Section*) in the Emergency Services Branch of OCHA Geneva. It is in charge of setting up, whenever a disaster situation, the OSOCC. This tool is established under the guidelines established by the INSARAG department which developed the concept OSOCC.

INSARAG was performed in 1991 under the domain of the OCHA in a cooperative effort by countries that are prone to earthquakes or disaster situation, or countries that are providers of international USAR *(Urban Search and Rescue)* assistance and the UN. It was formally established in 1991 following a report by the LRLC (*League of Red Cross and Red Crescent*) which is also introduced in this document *(INSARAG, 2012*). This section has both, disaster relief and prevention departments. Its aim is to continue with the development of effective international USAR procedures and operation standards (disaster relief); as well as increase the awareness between disasters (prevention). When a disaster occurred INSARAG gives support applying their methodology to USAR and LEMA resulting in a "*coordinated and efficient effort*" (*Preface*; "*INSARAG guidelines; 2012"*). The INSARAG guidelines gained much importance, nor just because it intention but for establishing and developing the OSOCC guidelines *(OCHA, 2009).*

In Fig 9.the international structure of the INSARAG group can be observed. It is divided in five big blocks, including the operational territory sections which are divided in three differentiated zones, each one with its regional working group. In addition to this, the international USAR team leaders and the working groups complete the INSARAG structure: Regional group Americas, Regional Group Africa/Europe/Middle-East and the Regional Group of Asia / Pacific. The secretary division is located in Genève under the OCHA coordination. Furthermore, each regional group has its own regional office in charge of the coordination of the region (*INSARAG, 2012*).

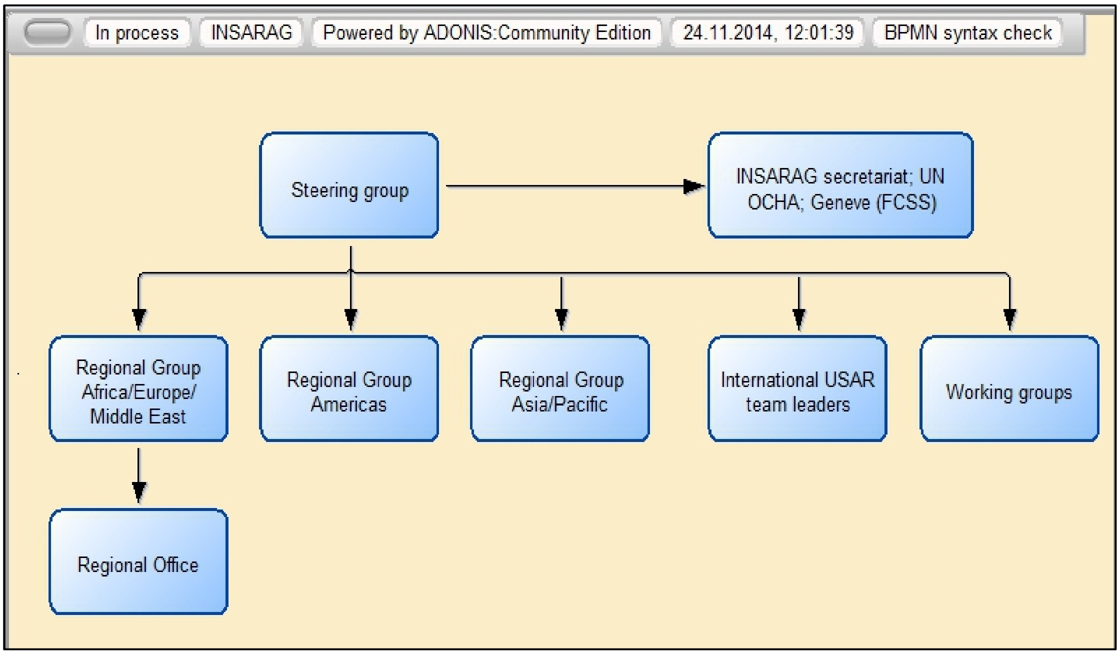


Fig. 9 *"INSARAG structure"* (INSARAG guidelines, 2012)

2.1.2.2Disaster relief organizations

The direct work or treatment with the disaster situation and persons affected, what in this document will be named as "*disaster relief*" is usually realized but the local authorities and groups, grouped under the name of LEMA. Nevertheless, they exists organizations coordinated in an international level.

International Federation of Red Cross and Red Crescent Societies

The International Federation of Red Cross and Red Crescent Societies (IFRC) is the world's largest humanitarian and development network, with millions of volunteers in 187 member National Societies. Their main objective is continuing 'saving lives and changing minds' by focusing in three key areas (*International Federation of Red Cross and Red Crescent Societies, 2012)*:

- Disaster response and recovery.
- Development.
- Promotion of social inclusion and peace.

In November 2007, the 30th International Conference of the Red Cross and Red Crescent adopted the IDRL Guidelines. The IDRL Guidelines provide a set of recommendations to governments on how to prepare their disaster laws and plans to overcome the common regulatory problems in international disaster relief. The Conference encouraged states to make use of the IDRL Guidelines both to develop their own national legal frameworks and as a basis for bilateral and regional agreements. It also called on IFRC and National Societies to support governments in doing so (*International Federation of Red Cross and Red Crescent Societies, 2012).*

- Supported National Societies in over a dozen countries to provide focused technical assistance to their governmental authorities on the implementation of the IDRL Guidelines, provided ad hoc advice in several other countries, and collaborated in the development of a new model act on IDRL;

- Organized the first annual disaster law short course, three regional training workshops, provided a number of country-level briefings and developed additional language versions of its online introductory training; and

- Advocated for attention to legal preparedness for disasters in over two dozen major global and regional form, including the collaborative organization of a major "international dialogue" on bridging domestic and international disaster response systems and the preparation of debate on disaster law issues at the 31st International Conference, and undertook research projects on law and disaster risk reduction and regulatory barriers to post-disaster shelter.

There is another organism provided by the Red Cross, the ICRC (International Red Cross Committee) that responds to help people affected by armed conflict. They also respond to disasters in conflict zones, because the effects of a disaster are compounded if a country is already at war. That is why we mentioned them (*International Federation of Red Cross and Red Crescent Societies, 2012).*

Military Alliance

The military performance, with the Fire brigade, could be the most famous or known actuation whenever a disaster occurred because they are the ones that arrived first and act before anyone.

On an international level, historical events have denied the world a global military association. However, during the history several alliances have existed. Up for today, the only one existing is the NATO (North Atlantic Treaty Organization). This organization is formed by more than 70 countries, members, partnerships or collaborators. It is the only real international cooperative military association because, in other cases, the military competence of each land is the one who acts *(NATO*, 2011*).* In Fig.10 we can observe all the members, direct or indirect, who configured the NATO.

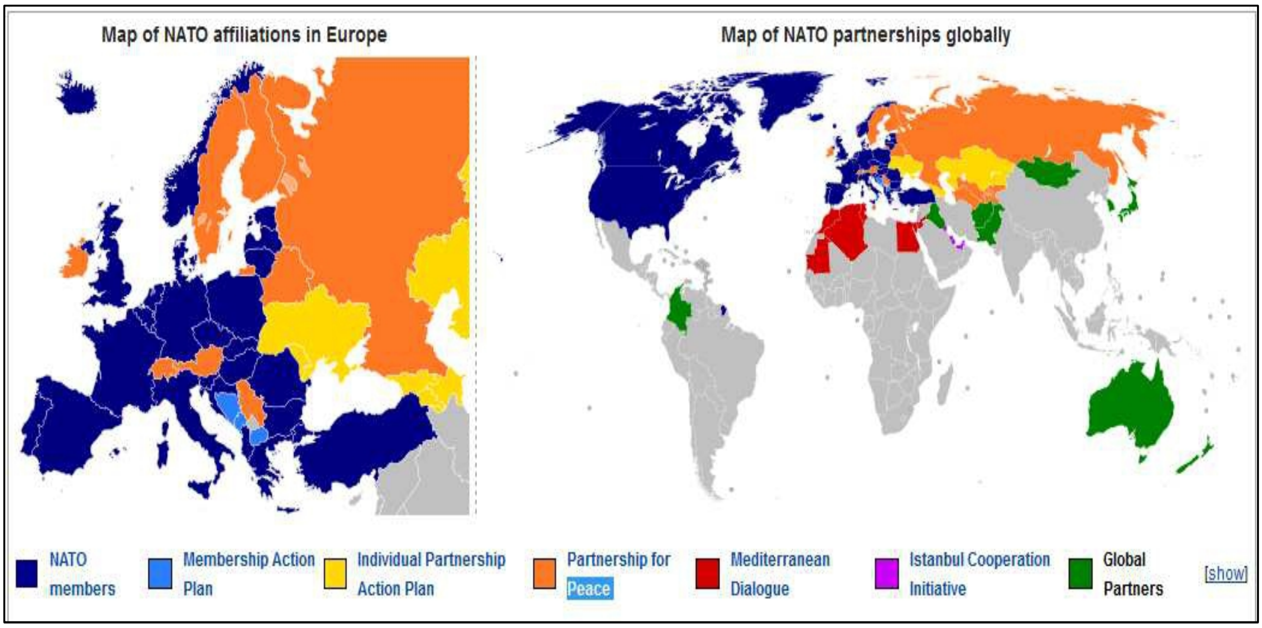


Fig. 10 "Nato Partner" *(UN, 2014)*

The role of the military service during a disaster is to give support to the local police and fire brigades in evacuating and preventing people, as well as keeping the order and the law. They are more an extra help against critical situation more than an independent organism that acts in its own function.

Fire Brigades

The case of the Fire Brigade is even more complex than the Military forces because it does not exist an international alliance or structure. It is competence of each country or government. Even though, it is important to mention this sector, because, with the military forces, they are the first to act in all the disasters. Fire brigades, compounded of fire-fighters, can be either volunteer or professional. Usually, a fire brigade meets the following functions *(Pizarro Gamarra, 2005)*:

- Defeat the fire
- Remove debris to prevent further accidents
- Demolishing homes and buildings affected
- Search for missing people in different places
- Save injured persons
- Evacuate people affected by floods and fires
- Give alarm

Due to the fact that an international fire brigade does not exist, it is often very related the USAR (Urban search and Rescue) with the fire brigades, that why some international guidelines are established.

Just to point, maybe the closest organization of fire brigades that could be consider international is the named: "*Pompiers sans frontiers*", French ONG that means "Fire-fighters without barriers". This non-lucrative organization is quite recent (created in 1991) and has the next mission: "POSF (Pompiers sans frontiers) tends to contribute reducing the impact of disasters on vulnerable populations and the environment"(*Pompiers sans frontieres, 2015*).

2.1.2.3Liaison organs

A very common mistake is to confuse and identify the disaster relief organizations as the "*liaison organs".* Nevertheless, they are not even the same anyway. A correct definition of this entity is to say that they are members of the disaster relief organisations, in charge of taking part in the coordination meetings and communicating, afterwards, the information to the chefs from the field. They are the link, union between the coordination and the field divisions. That is why the name of "*liaison organs"* fits perfectly to their main function (*Jachs, 2014).*

2.1.3 International Cooperation Organization chart

In Fig.11 the organization chart making out process of the International organisations can be observed as well as the existing interrelations. In addition to this, it is observed that Prevention and the disaster relief are not isolated sections; there has to exist a continuing chain information between them. In the next level of the organization chart, the main head department of each branch is exposed, and bellow the department subsidiaries.

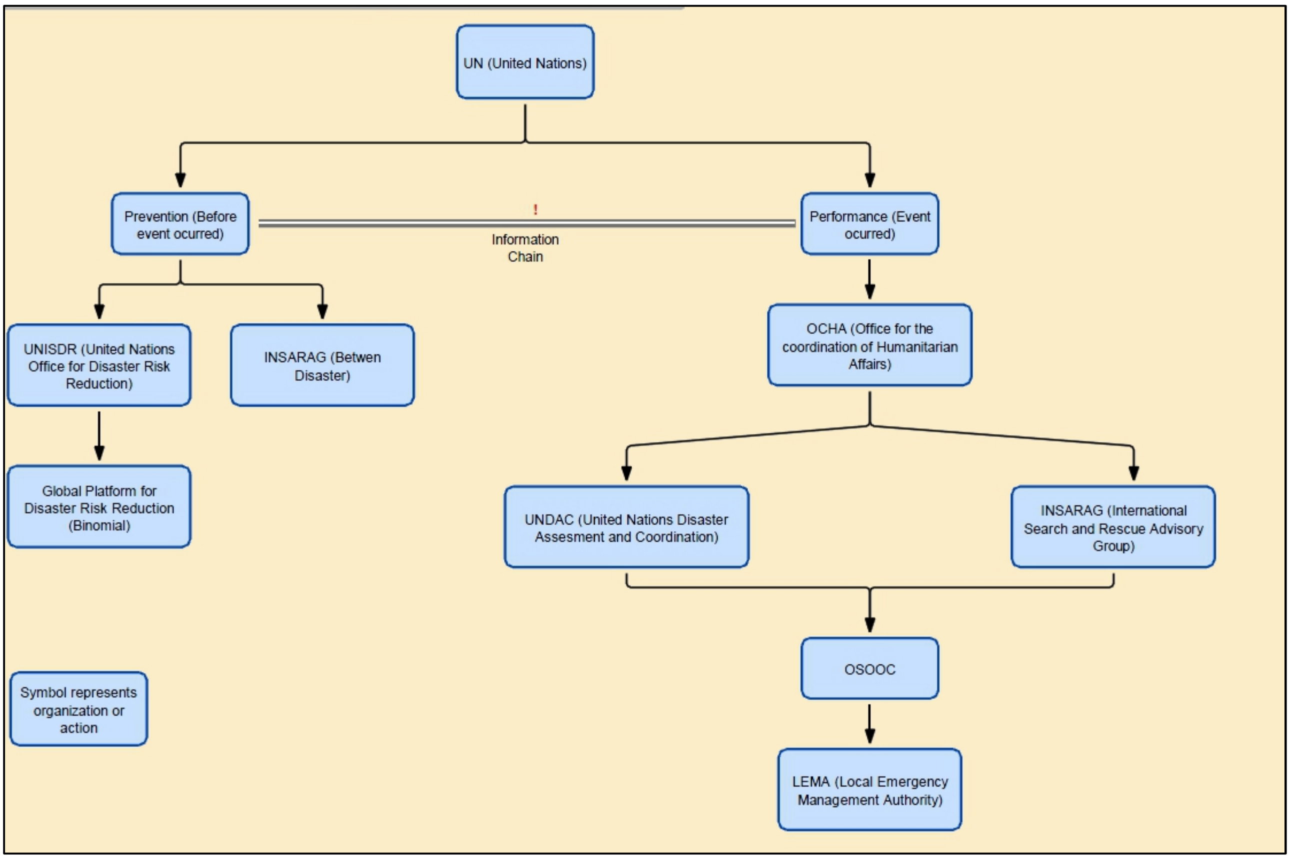


Fig. 11. "International cooperation Organization Chart"

Concreting in each branch of the scheme:

- **PREVENTION**: Involves the UNISDR and its binomial tool, the global platform for Disaster Risk Reduction. In between-disasters time, INSARAG, as explained before, has also the main objective to prevention and awareness, so would be also included.

- **DISASTER RELIEF**: This articulated branch is much more explicated than the prevention one, with many crossing relations and switches between offices and departments. The main responsible is the OCHA (Office for the coordination of Humanitarian Affairs) which involves two particular tools to deal with the coordination of the disaster. The UNDAC (United Nations Disaster Assessment and Coordination) and the INSARAG (International Search and Rescue Advisory Group). Nevertheless, both institutions work together coordinating themselves to develop the OSOCC tool (On-Site Operation Coordination Centre). The OSOCC is the tool and disposition to coordinate the operations and strategies in-field against the disaster. OSOCC would coordinate the local authorities and institutions such as Red Cross, fire brigades and military. Those local organisations are grouped under the supervision of LEMA (Local Emergency Management Authority). LEMA is the term used to describe the Local Emergency Management Authority and is the ultimate responsible authority for the overall command, coordination and management of the response operation. LEMA refers to local authorities or combinations therefore, which are collectively responsible for the disaster response operation.

2.2 Guidelines and Principles for collaboration in an international level

The immediately actions taken that follow a destroying event with origin in natural forces are critical. It is usual that the number of deaths and the aftermaths in the population are further more important in the following days or weeks after the disaster than during the time it is produced. The main objectives of the quickly response so to recover and deal with is:

- To save lives in danger
- To reduce suffering
- Minimize the risk of the original emergency contingency (chaining)
- Restore the original conditions of live
- Minimize the environmental impact.

Within these objectives, the main activities are established:

- Immediate attention: rescue, evacuation and emergency assistance
- Restore and guarantee of minimum services
- Obtain information so to make the recover process easier.

The main guidelines and procedures administration in an international collaboration level are established by the UN that, as it is explained before, delays in sub departments to coordinate and deal with those critical unfair situations. (*UN, 2014*)

2.2.1 OSOCC (On-Site Operation Coordination Centre)

The main international tool deployed in a disaster situation is called OSOCC.

The OSOCC concept is intended as a rapid response tool that works in close cooperation with the affected country's Local Emergency Management Authority (LEMA). To optimise its effectiveness, it should be initiated in the immediate aftermath of a disaster requiring international assistance ideally before, or simultaneously with, the arrival of international relief resources. It is expected that an OSOCC in some form would be operational during the relief phase of an emergency until the Government of the affected country together with UN agencies and NGOs can resume the responsibility of coordination of international resources.

This cooperation tool involves the main organisms in charge of dealing with those critical situations such as INSARAG and UNDAC. *(OCHA, 2009)*

The OSOCC Guidelines provide guidance to an UNDAC team and/or other organizations that are the first to arrive at the site of a disaster and required to establish a coordination structure. The coordination structure should be designed to assist the Government of the affected country with coordination and facilitation of international humanitarian assistance. The guidelines have been developed by OCHA's Field Coordination Support Section (FCSS), which serves as the permanent INSARAG Secretariat, in cooperation with the International Federation of Red Cross and Red Crescent Societies (IFRC), the United Nations Disaster Assessment and Coordination (UNDAC) system and experts from international USAR-teams.

An OSOCC has three primary objectives *(OCHA, 2009)*:

1. To act as a link between international responders and the government of the affected country.

2. To provide a system for coordinating and facilitating the activities of international relief efforts at the site of a disaster; notably in the case of an earthquake where the coordination of many international USAR teams is critical to ensure optimal rescue efforts

3. To provide a platform for cooperation, coordination and information management amongst the international humanitarian agencies.

In Fig 12.the basic structure of an OSOCC is shown. However, this is a dynamic structure, which means that it can be modified according to the situation, disaster magnitude and circumstances surrounding the event. In other words, it *"should be modified to suit the requirements of the situation" (OCHA, 2009).*

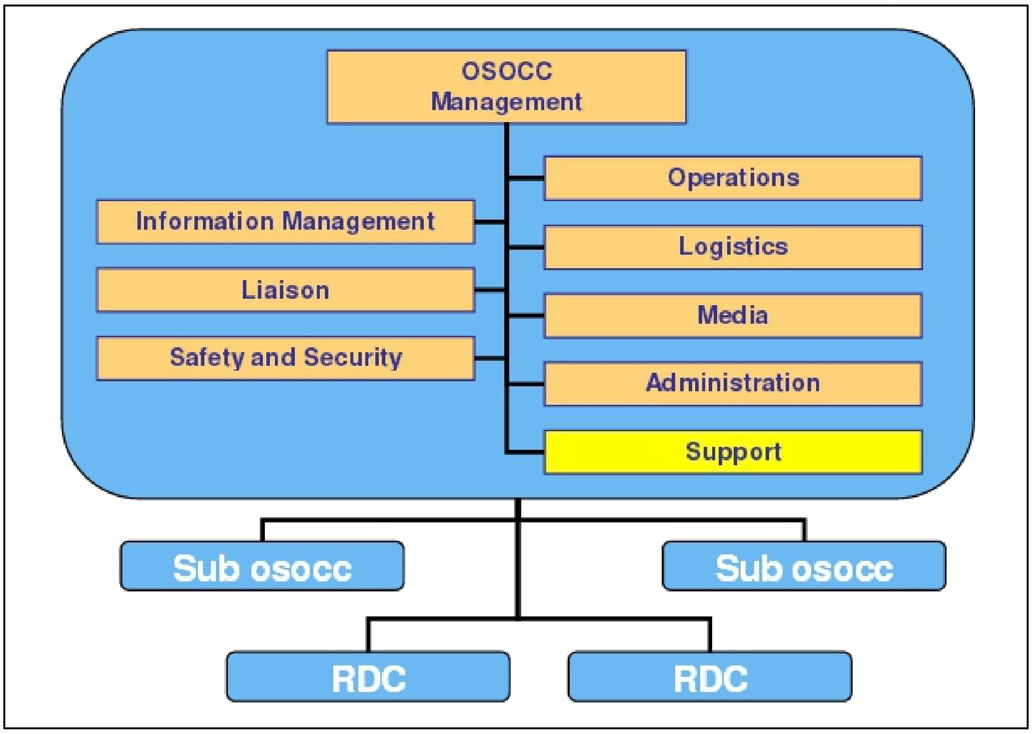


Fig. 12 "OSOCC structure" ***(OCHA, 2009)***

In disasters located in irregular and spread out areas, there might appear the need to establish one or several sub-OSOCC(s) which are in charge of coordinating and overseeing operations in less accessible areas that cannot be controlled by the general OSOCC.

The OSOCC is structured in eight different elements and one support cell; it is important to notice that, even if it is a dynamic and variant structure, all the elements are necessary no matter the circumstances or the type of the disaster. The eight elements are briefly explained in the following lines *(OCHA, 2009)*.

- **OSOCC Manager**: Develop an overall work plan for the OSOCC, allocate tasks, and supervise the work of the functional elements. In cooperation with the UNDAC Team Leader, the Management cell should facilitate the organization of resources to enhance the effectiveness of the OSOCC.
- **OSOCC Operations**: Maintain an overview of ongoing relief activities and facilitate the development of the disaster relief plan in cooperation with LEMA and international relief actors.
- **OSOCC Information Management:** In charge of disseminating the information received from outside sources (RDC, assessment reports, situation reports, media, etc.) by consolidating it into the appropriate output formats for distribution to stakeholders, e.g. situation reports, forecasts or databases.

- **OSOCC Logistics:** Provide logistics support to the OSOCC, and establish links with other relief organizations.
- **OSOCC Liaison:** Establish and maintain formal information exchange procedures between the OSOCC and other international coordination bodies and undertake Civil Military Coordination (CMCoord) functions as needed.
- **OSOCC Media:** Coordinate all external relations. Works in coordination with the Information Management.
- **OSOCC Safety & Security**: Monitor the safety and security situation, exchange regular information with the UN Designated Official (DO) for security and security officers from other relief organizations.
- **OSOCC Administration**: Organize the administration of the OSOCC and ensure that internal procedures for the day-to-day running of the OSOCC are established and maintained. As a result, it has to be coordinated and closely related to the OSOCC Manager.

2.2.2 Disaster Relief

"Disaster relief (or emergency management) refers to the process of responding to a catastrophic situation, providing aid to persons and communities who have suffered from some form of disaster. It involves dealing with and avoiding risks and preparing, supporting, and rebuilding society when natural or human-made disasters occur" (Asian National Institute of Disaster Management, 2014). According to this definition of disaster relief, in this part of the thesis the general disaster relief, whenever an OSOCC is established or not, is explained.

The usual deployment of an OSOCC is also described in Fig.13, as a functional part of the general disaster relief.

At first, the initial event, the disaster occurs and the Local authorities (LEMA) deploy itself in an attempt of controlling the situation. If they are capable and strong enough to afford the situation, there will be necessity to the international forces to come and the situation will be coordinated by the local authorities, which, when the situation is controlled and the critical phase passed, will draw up an information sheet with all the details, that will be directed to the International United Nations office for disaster risk reduction, UNISDR.

In the other hand, whenever the disaster is too strong, or the local authorities lack the resources needed, the UN will be noticed and the international organism would start on its mechanism. At first, the event would be scaled up in an International Level; the OCHA would assume the coordination of the situation, acting by both, the UNDAC and INSARAG; depending on the importance and the circumstances and characteristics of the event. The OSOCC is then developed. The first step is to test out whenever the existing resources are sufficient to afford the actual demand or not. In a negative case, international resources will be sent ad the OSOCC will give out and allocate them. Whenever the needed of resources is satisfied, the OSOCC will coordinate the deployment and actuation of the international forces until the situation reaches a controlled status, where the LEMA, local authorities, can assume the control.

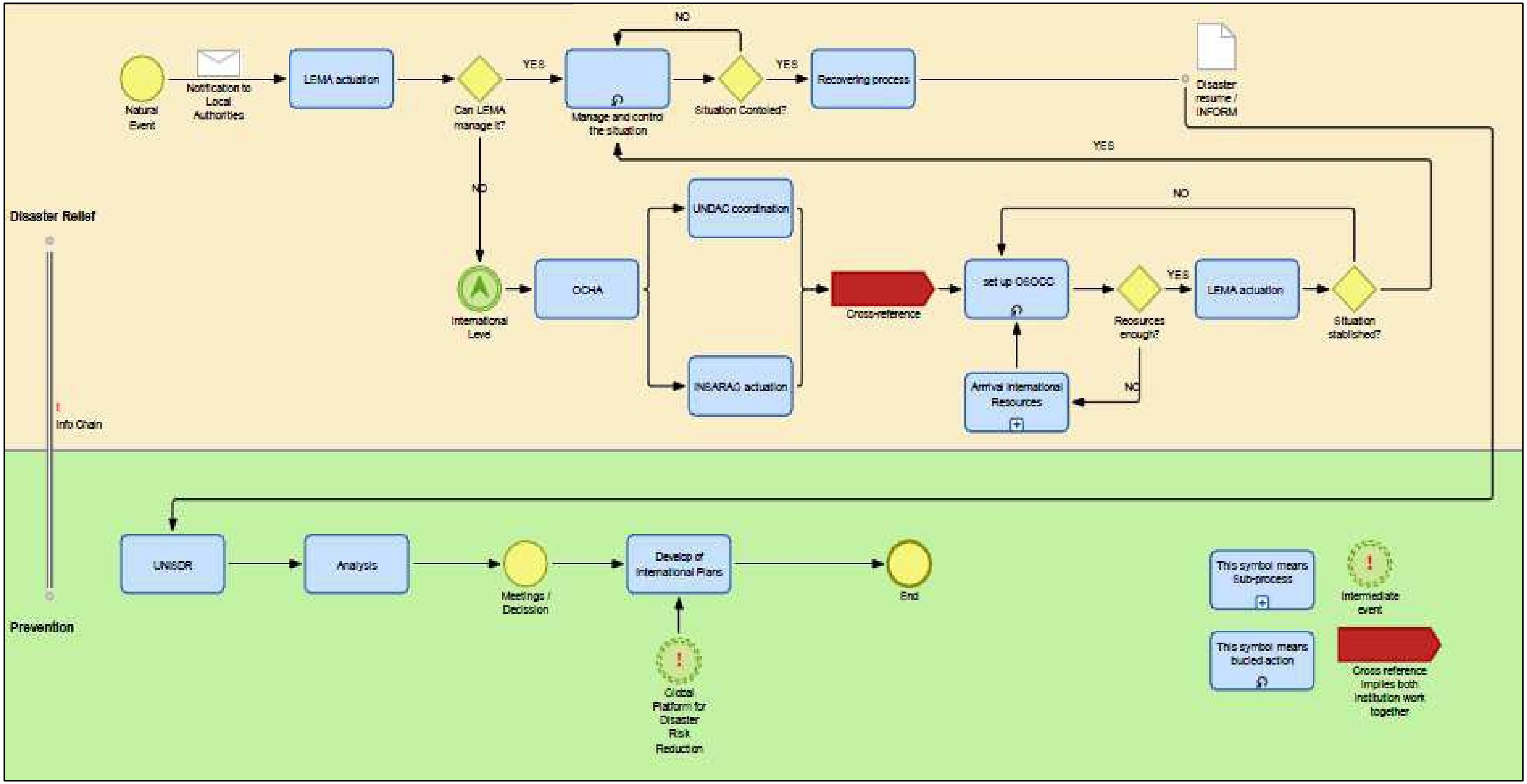


Fig. 13 "Disaster relief" *(Based on UN, 2014)*

3. DISASTER MANAGEMENT IN LOWER AUSTRIA

3.1 Administration organizations

In Austria, and consecutively in Lower Austria, the organization is similar to the international level scheme configuration. In Fig.14 the organization diagram within importance level is shown. The Federal Ministries are in the top of the diagram, in charge of the whole territory. The federal Ministries are the different ministries in charge of different matters but all around the territory. Afterwards are the State governments, in charge of the affairs of the state. Austria is divided in nine states so the same number of state governments is given. At the next level are the district controllers and administrators. Finally, the Municipality is the last organizational institution. As explained in the chapter of international cooperation, depending on the importance of the disaster, the institution in charge can be any of the diagrams.

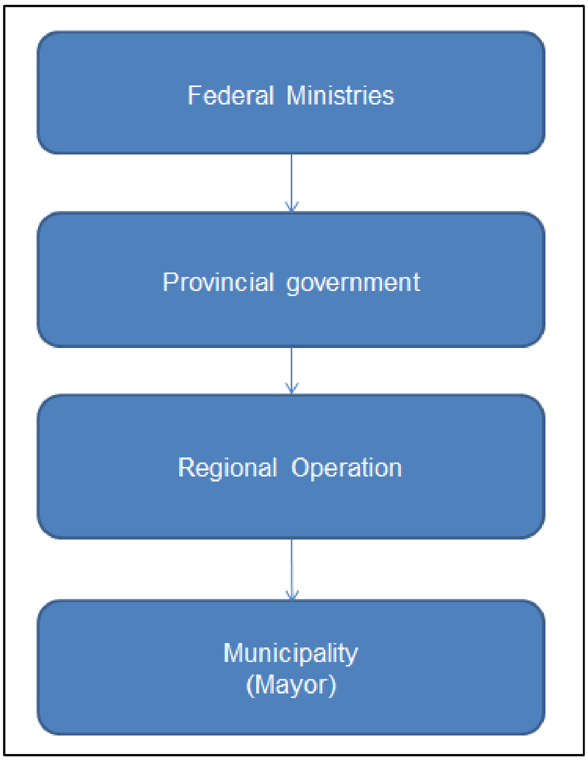


Fig. 14 "Austrian Disaster organization diagram" (*Based on: Jachs, March 2011*)

In addition to this chart, simple but concrete information of each organism is given.

First of all, the Federal Ministries are the general public organism in charge of the decision and political, social, economic affairs all around Austria. They are, then, the last step in a disaster importance stair, what means, if a disaster relief is important enough to transcend all the institutions bellow, then the Federal Ministries act and become the responsible of the disaster management. *(Jachs, 2011)*

So going down in the regional and political disaster organisation diagram, the next institution is the federal state government, which in general lines is the same as the federal ministry but in a restricted state of Austria, nor in the hole territory. As explained before with the federal ministries, the responsibility of the federal state government in a disaster situation shows up when the importance of the disaster is great enough. Substantially, it has to be said that when reaching a situation of natural disaster, this one is important enough to reach at less the level of the federal state governments. If not, the most common extended concept is not to talk about disaster.

Directly dependant of the federal state governments is the Regional Operation Controllers: institutions in charge of coordinating and managing the local resources and forces such us volunteers, fire brigades and local police, what in this study are called *"disaster relief organizations".* The last institution is the Municipality of each Municipal. It can be observed that is a very simple organization, ordered as a decreasing scheme from the organisation which are in charge of the whole nation coordination, until the most simple institution which, in this case, are the municipalities.

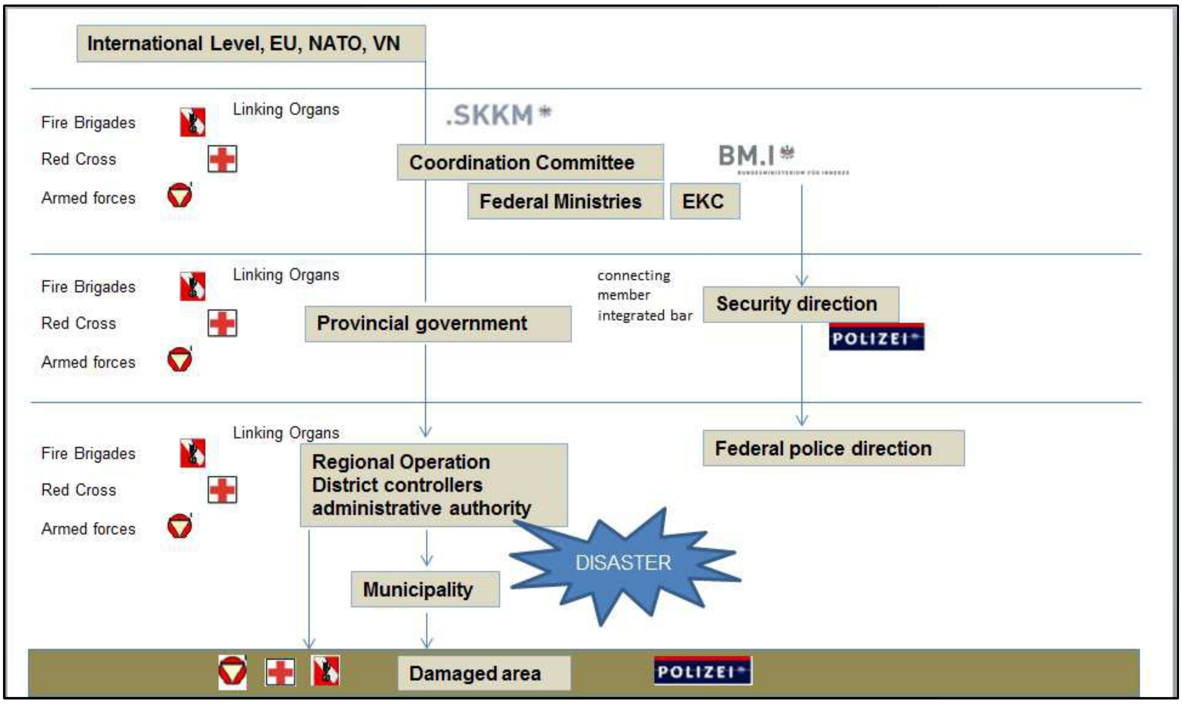
3.2 Disaster relief

According to this hierarchical organisation, a process setting diagram can be designed within all the synergies, relations and cooperation between the different organisations is shown. As it is established in Fig.14, the action protocol in a disaster situation is ordered in different importance level, within a strategic objective. When the disaster occurred, the immediate answer is given by the local forces and the Municipality in charge of the affected region. Normally the Municipalities work together with the regional operators due to the fact that they are very closed each other. This relation can clearly be observed in Fig.15. *(Jachs, 2011)*

In contrast of the organisational scheme explanation, given in a decreasing importance level, the process is explained just the opposite, going from the basis of the disaster, until the upper level. Notice that, as a disaster situation is analysed, it is supposed always that the gravity and importance of the disaster reaches the highest level.

Consequently, once the local forces act and, due to the importance of the phenomenon, the different federal governments and ministries act. As it is observed in the flow chart, the fire brigades, red cross and armed forces, which are called "*disaster relief organizations*" , have an important role in each of the different administration levels. As it can be observed, the Police is the organ in charge of the security direction and depends directly of the BM.I (Bundesministerium für Inneres). In the top of the diagram but before reaching an international level, NATO actuation, the SKKM (Staatliches Krisen- und Katastrophenmanagement) is the main organ in charge of the disaster relief *(Bundesministerium für Inneres, 2014).*

In the next figure, Fig. 15, the process within the organizations involved is shown.



').

Caption:

- Fire Brigades:
- Red Cross:
- Armed forces:
- Crisis situation and disaster prevention management (Statliches krises und Katastrophenschutz Management): .SKKM
- Ministry of internal affairs (Bundesministerium für Inneres): BM.I
- Austrian Police: POLIZEI
- Event:
- Organism:

3.3 Flooding

"Due to its topography, Austria is exposed to many natural hazards. Inadequate spatial planning aggravates natural exposure to risks, 12% of all buildings are potentially exposed to flooding almost 9% are considered to be at an extreme risk" (Sinabell and Url, 2008). That is the reason for what it is important to analyse the disaster response.

As shown in Fig.16 *"Risk flooding cycle"*, the cycle starts with the Incident. Once the event has been noticed, the Deployment of different measures comes up with: warning, rescue and damage mitigation, which means reducing the injuries or harms produced by the incident. The next phase of the cycle contains the corrective maintenance, which includes temporary repair, minimum supply and restabilising transport and communication in case that they were affected. Afterwards, the most expensive and laborious task is the reconstruction, including the definite repair of both buildings and primary services, reconstruction and, for the first time since the event occurred, analysis and improvements. These three phases of the cycle combined; shape what it is called "*disaster relief*", main study of this thesis *(Habersack et al., 2005).*

At the moment when the disaster has been overcome, the prevention stage of the cycle begins, with both preventative and precautionary measures. On the one hand, the preventative measures include spatial planning, passive flood control, technical flood control and hazard zone planning. On the other one, the precautionary measures contain diverse tasks including risk management, personal provision, planning of resources and claim settlement and risk transfer *(Habersack et al., 2005).*

Within this cycle, all the authorities and Austrian organisations presented before, act in their different levels and competences.

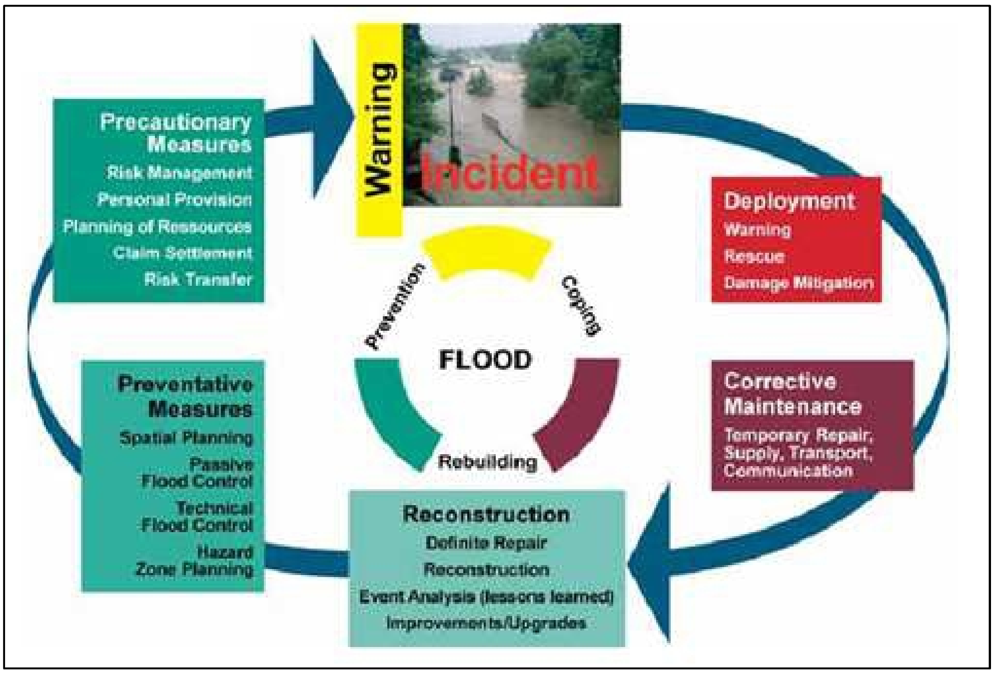


Fig. 16 "Integrated flood management" *(*Habersack H. et al., 2014*)*

4. CASE STUDY: FLOODING IN LOWER AUSTRIA 2013

4.1 Factors

Between the end of May and the beginning of June 2013, one of the worst historic flooding events, the worst in the last two centuries, in central Europe occurred affecting regions from Germany, Austria, Hungary, Czech Republic and Slovakia. An atmospheric blocking situation produced precipitation exceeding 300 mm over four days at the northern rim of the Alps. The high precipitation, along with high antecedent soil moisture, gave rise to extreme flood discharges in a number of tributaries including the *"Tiroles axe", "Saalach", "Salzach" and" Inn"*. The main affected rivers were the Inn and the Danube, which both converged in the city of Passau (experimenting levels similar to the highest recorded dating of 1501) *(Blöschl et al., 2013).*

To get an idea of the extraordinary precipitations, Fig.17 shows the precipitations (in mm) registered in Salzburg from the thirteenth May 2013 until the thirtieth June 2013. It can be clearly observed the top of precipitations during the flooding days, where the registration is more than tripled of the highest register in the rest of the period measured. This graphic has been obtained from an extended analysis of the flooding in the Danube in 2013, developed in Hungary.

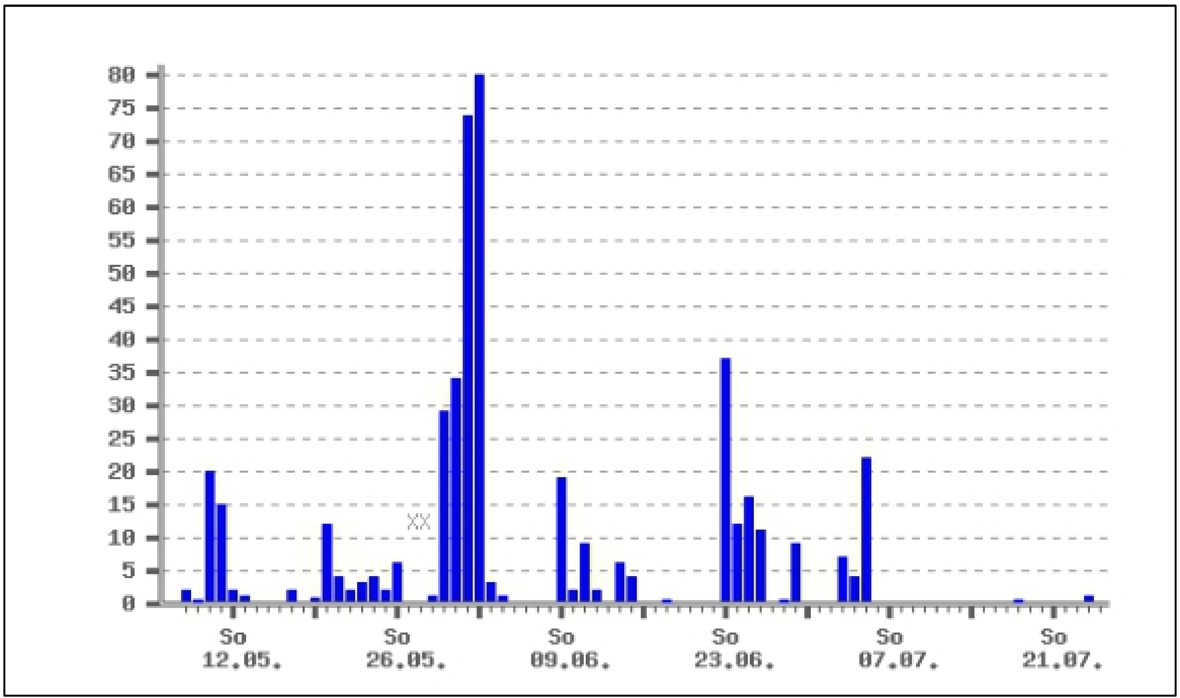


Fig. 17 "The daily precipitation amounts (mm) at the Austrian Salzburg station, between 13.04.2013 - 30.06.2013" ***(Konecsny et al., 2013).***

Precipitation was distributed over two blocks separated by a few hours, which resulted in a single peak, long-duration flood wave at the Inn and Danube. At the confluence of the Bavarian Danube and the Inn, the small time lag between the two flood waves exacerbated the downstream flood at the Danube. The intensity and notoriety of the flood, as well as the widespread of the affected territory was so bright that people accepted the term *"century flood".* Figure 17 shows the amount of the precipitation off between 30.05.2013.6 UTC and 03.06.2013.6 UTC.

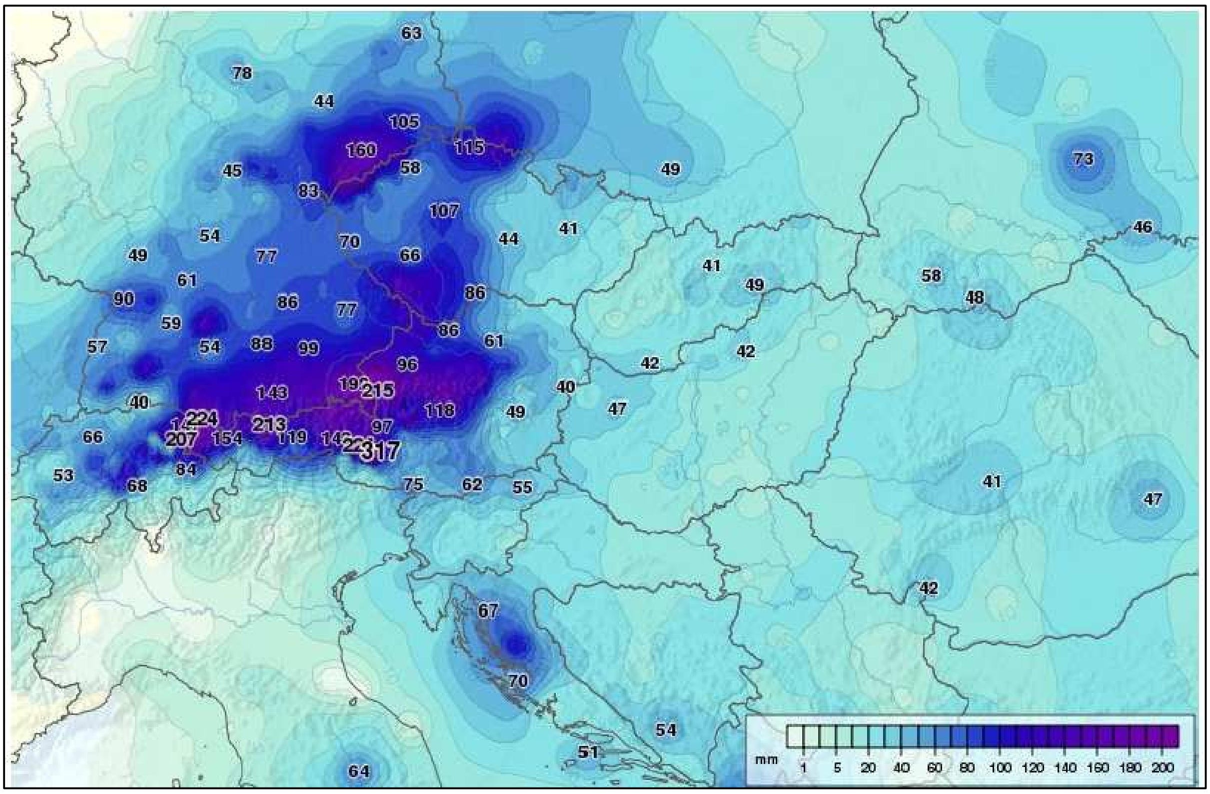


Fig. 18 "The amount of the precipitation off between 30.05.2013: 6 UTC" ***(OMSZ, 2013)***

4.2 Disaster Response

According to the objective of this final master thesis, the attention is going to be focused in the response of the Austrian government and institutions to this situation, nor in the natural causes of the flooding.

Due to heavy precipitation along the entire northern edge of the Alps, a once in a century flood wave ran through the Danube valley, which caused enormous damage. Regions which have no flood protection against such catastrophes at their disposal, such as the *"Eferdinger Becken"* area, were particularly affected. Just to show somehow the magnitude of the floods, Fig. 19 shows two pictures; the first one shows one of the power plants located along the Danube river just in the limit of its capacity while the second one shows the security dams and fences installed to prevent the floods all around the affected zone; the picture particularly is from the city of *"Wachau"*.

Fig. 19 "Floods in Lower Austria" ***(AMT der Niederösterreichischen Landesregierung, 2014)***

At first, an important aspect was the prevention about the flooding and the immediate actuation in the power plants and dams, both first mechanisms to try to avoid flooding. In the Austrian part of the Danube, they exists a total of 10 retention barriers or dams to control the quantity of water and prevent flooding.

Already on 30 May, when the initial signs of very heavy rainfall became apparent, the team at the power plant was alerted in advance. On the following day already, staff was sent to the power plant, which is normally controlled via long distance. At the same time, the internal crisis management group came together in order to keep control of the situation and to make use of all resources *(Verbund, 2014).* To the point, in what the barriers and power plants concerns, the prevention and managing of the situation was perfectly developed at first.

In what the management of the situation concerns and the logistics decisions concerns, the actuation was also successful and quite well achieved. According to this idea, all the entities involved in the disaster relief, both coordination and disaster relief organizations were successfully coordinated. The coordination of the event was in charge of the regional operators in cooperation with the field organisations (fire brigades, Red Cross) through the “liaison organs” explained before. Figure 20 clearly shows a disaster relief management meeting where organizations coordinate the actions. The liaison organs can be also observed as members of the fire brigade are also taking part in the meeting. This picture was taken at the state warning center in Tulln where the disaster management was coordinated during the floods in 2013.

Fig. 20 “Disaster management committees” ***(AMT der Niederösterreichischen Landesregierung, 2014)***

In relation to international cooperation, due to the magnitude of the floods, affecting five different countries, and due to the fact that there had been important previous flooding episodes in the year 2002, the the path of the northeast crisis management began on a leading level in Europe and the good reputation at home and abroad strengthened *(AMT der Niederösterreichischen Landesregierung, 2014)*. The cooperation and coordination was quick and effective. The event, with international repercussion, was covered by TV, radio and Internet, with important influence of social Medias.

Figure 21 completely describes the chronology of events and some of the decisions taken according to the disaster relief. It can observe the actuation of different organizations as well as the coordination and cooperation between them.

Friday 31.05	First floods occurrence and HW alarm in Wien District and surroundings. Down areas closed to the river in danger.
Saturday 01.06	HW Alarm in AM.ME districts. Danube prognosis HQ20-HQ30. Flood protections built. First drains and security works.
Sunday 02.06	11:00 prognosis HQ100 for 04.06; Convening country management team, squad leader Councillor Pernkopf from 1700: classification as a disaster. Full expansion of flood mobile protections. First evacuation.
Monday 03.06	238 evacuated. Dams increase, large-scale operation from fire brigades: 260.000 sandbags given. 100 Drain pumps and power generators in use.
Tuesday 04.06	Peak in AM.ME districts. Peak in Wachau predicted for Wednesday. Security reinforcement and enhancement levees. Evacuation of people and animals; 1, 4 mio. sandbags.
Wednesday 05.06	Peak in Vienna and the area. Dam‘s reinforcement. Failure of the water supply system in Stockerau. 5 injured person.
Thursday 06.06	Peak in Wildungsmauer. Distribution of a cross bar at the Russbachbauer. Massive use of drain pumps and power generators. Overall: 1, 8 mio. sandbags.
Friday 07.06	Large-scale clean-up work in the municipalities with the help of fire fighters. Participation of Austria’s team and many different help-disaster organizations for the next week.

Fig. 21 “Flood events sequence” (Based on AMT der Niederösterreichischen Landesregierung, 2014)

4.3 Consequences – Results of the measures

The result of this raining episode was the worst flooding event in Europe for the last one hundred years. In the following image, Fig. 21, the entire affected zone, with the corresponding destruction caused by the flooding can be observed.

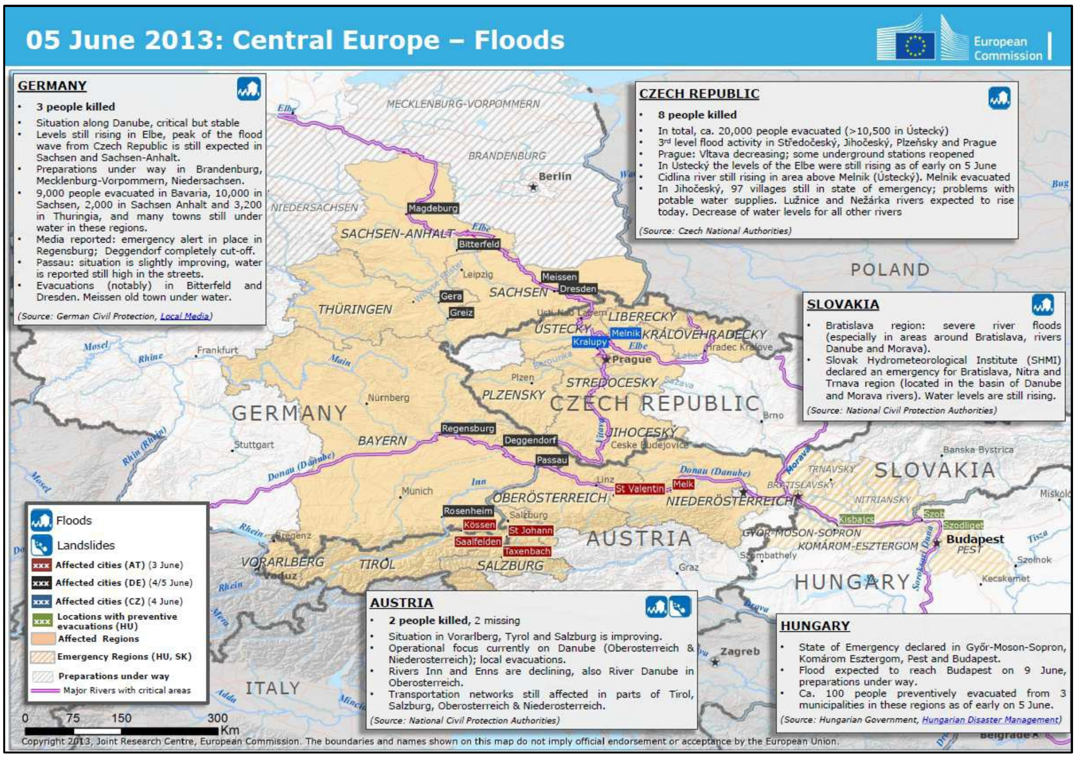


Fig. 22 "Central Europe floods" *(European commission, 2013)*

No matter the importance of the impact of this flooding episode, the Austrian authorities manage to solve it with such a grateful power and organization.

"Lower Austria was affected in June 2013 by extremely high water, which provided us all with enormous challenges. However, looking back, together we have done very well at this difficult situation. Because we were well prepared: already in previous years, Lower Austria has invested in the development of flood protection, in the training and equipping of a sentence organizations in the disaster-protection and cross-border cooperation. All this has been proven in June 2013 well." (Stephan Pernkopf)

The result of this flooding episode was not only this significant material and human hurts but also chances to improve and the possibility to develop new plans and new measures against natural disasters. *"While there was significant damage during the 2013 flood there is no doubt that, overall, the flood protections measures put into place throughout the past two centuries have vastly reduced the damage relative to a scenario without protection" (Blöschl. et al., 2013).*

Other measures

Traditionally most of the measures against floods consisted in structural barriers or constructions, such as dams or polders for flood retention. However, it has been proved along the years and after several flooding episodes that non-structural measures such as spatial planning and improving the preparedness of local citizens are also crucial. Flood management measures such as early evacuation and reliable warning systems conducted by hydrological forecast models are needed as a perfect complement to the structural measures. The 2013 flooding episode is a great example of prediction due to the fact that the peak level of water was predicted within 24 – 48 hours *(Blöschl et al., 2013).* Increasingly longer lead times are expected from warning agencies and there have been established several plans and measures, involving important invests of money, to achieve this objective. Nevertheless this objective requires the estimation of forecast uncertainties to quantify the confidence one has in the predictions *(Cloke and Pappenberger, 2009; Komma el al., 2008; Laurent et al., 2010).*

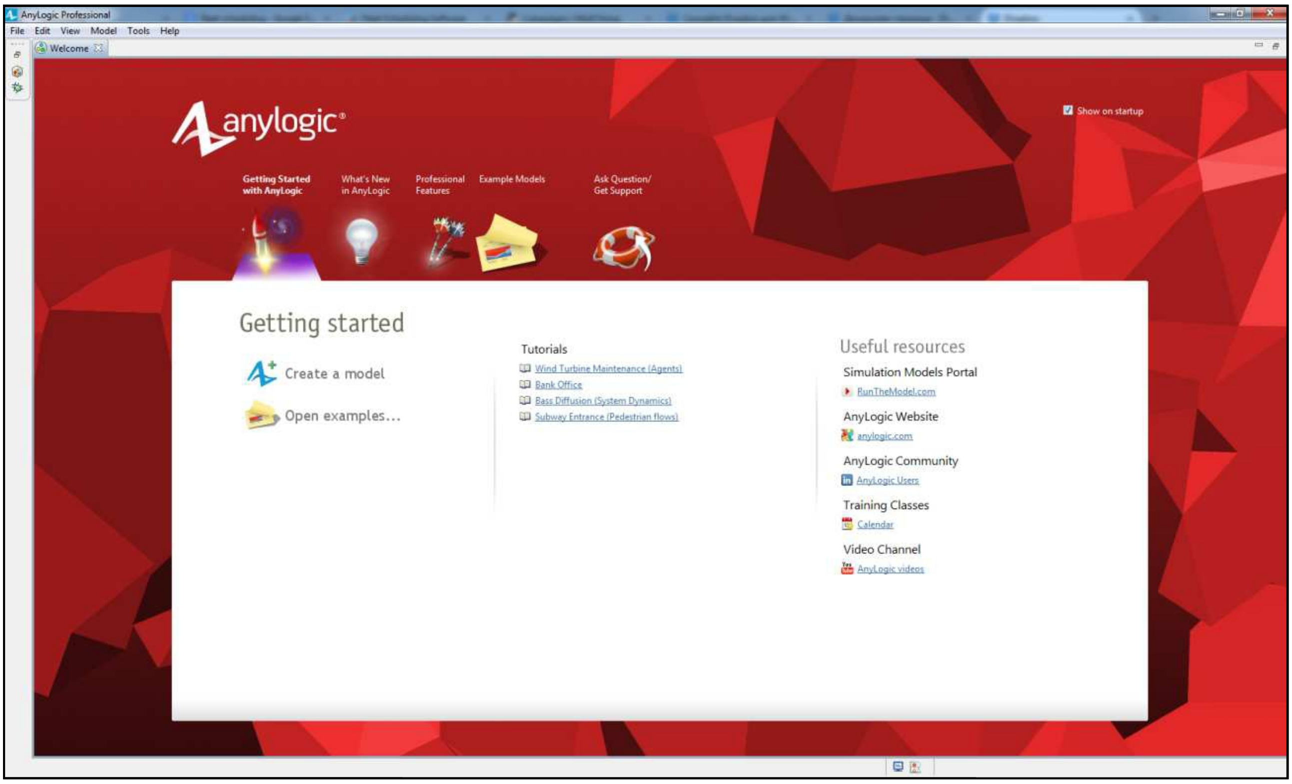
5. SIMULATION

5.1 Simulation Software

5.1.1 AnyLogic

AnyLogic is multimethod simulation software developed by the AnyLogic Company. It the only simulation tool that that supports Discrete Event, Agent Based, and System Dynamics Simulation *(AnyLogic website, 2015).* Each of these methods serves a particular range of abstraction levels and different objectives. System dynamics assumes a very high abstraction and it is typically used for strategic modelling. Discrete event modelling supports medium and medium-low abstraction. Between those two methods, it is the agent based modelling, which can vary from very detailed models to highly abstract models where the agents are competing companies or governments *(Grigoryev, 2012)*.

AnyLogic offers four different version of the simulation software which includes: Professional, advanced, Educational / Research and the learning version called PLE (Personal Learning Edition). The simulation has been developed with the PLE version due to the highly priced licenses for the professional version. However the simulation runs and replications to obtain the results are ran with the professional version (available at BOKU).The display of the software is not only simple and functional but also nice to the view and very complete.



5.1.2 Reasons to the selection

The main reasons to use AnyLogic are the flexibility and chances of different scenario settings simulation that are available. It is one of the most extended and most skilled simulation software and, as introduced before, it is the only one to support Discrete Event, Agent Based, and System Dynamics Simulation. This versatility makes the program very useful for such a work that it is afforded here. Another important aspect is the use of Java codification to program the actions which makes easier and quicker the process of getting used to the program. Is also provides very strong dynamic graphic generator which allows to ease and improve the simulations and their appearance.

Other important pro facts to select this software are typically:

- Reduce development cost and time
- Develop more models with one tool
- Improve the visual impact of your models
- Run models anywhere

(AnyLogic, 2015).

According to this characteristic, the price of the licenses is sometimes even excessively high. That is the reason why it is no so often available in a university department. Fortunately in BOKU are available both, the professional and the student version so the thesis can be completely developed.

5.2 Situation

5.2.1 Location

The flooding event simulation is located in Krems an der Donau and Mautern an der Donau both located in the margins of the river Danube, *"Donau"* in Austrian, around seventy kilometres far west from Vienna. Geographically located both in the North-East of Austria, the specific situation one fast in front of the other (Mautern on the right side of the river and Krems on the left side) they are the perfect place to allocate the simulation due to the proximity of the river and the disposition of roads, bridges and stores. The existence of little tributaries crossing both cities is also a very interesting aspect for the simulation. In addition to this, both populations have suffered flooding episodes. Due to this fact, and to the severity of this phenomenon, contention bars were built all along the river in the area so nowadays the floods are less probable. The vulnerability has been notably reduced.

In Fig.24 the Austrian territory is shown, and both locations situated.

Fig. 24 "Location Krems and Mautern an der Donau" ***(2015)***

Focusing in the geographical location, on the one hand, Krems is located at the confluence of the Krems and Danube Rivers at the eastern end of "*Wachau*" valley, in the southern Waldviertel. Krems borders the following municipalities: Stratzing, Langenlois, Rohrendorf bei Krems, Gedersdorf, Traismauer, Nußdorf ob der Traisen, Paudorf, Furth bei Göttweig, Mautern an der Donau, Dürnstein, and Senftenberg. On the other hand, Mautern is situated on the southern bank of the Danube opposite Krems. In the figure above, the GIS map (Geographic Information System) can be shown within the entire road and transport net as well as the location of the population related to the river. In this GIS map is developed the simulation.

Fig. 25 "GIS Map" *(AnyLogic, 2015)*

Constraints

The geographical constraints are the following:

- Danube river dividing and acting as a natural separating world which gets worse the communication between both population cores
- Only two bridges which communicate between Mautern an der Donau and Krems an der Donau
- Terrain very flat that favours the floods and water retentions.
- Wet terrains and floor composition in the surroundings of the Danube which implies more time the floor to dry the water.

5.3 Objective of the simulation

As it is known, the simulation consists in the resources logistics and distribution during a flooding episode, within different scenarios. At first, the original normal situation, where there exist the stores or resources distributors, the demanding points and the customers. After simulating this scenario and establishing stores stock and many different parameters, the different circumstances and constraints, according to each scenario, are simulated. As a general common introduction, they are three different scenarios non counting this original, what we call scenario 0. In the first scenario the flood has already occurred and the closest stores to the river are closed, so the demand of the still available stores has changed drastically. The simulation tries to sort out the problem of providing resources to the maximum number of customers so the number of unsatisfied customers is as low as possible. In the second scenario the possibility of shipments and supplies from the main army centre to the needing sock ester will be available. Finally; in the third scenario; the worst case of the flooding episode, with one of the main bridges closed, is set up.

The simulation consists on the supply system, from stores to customers, what means the "normal" action of buying the needing that the people daily requires. This action implies three main elements: the stores, the customers and the home of the customers, and many various and complex factors such us total demand, available stock or distance to store. As it has been already introduced the simulation is developed with the software AnyLogic using a multhimethod modelling based in Agent-based modelling. The reason is that we want to simulate the behaviour and reaction of customers in a flooding episode and then how the demand changes. Furthermore, it is also necessary and useful to use with discrete modelling tools and network-based modelling. Agent-based modelling is another way to look throws the system in which the modeller can have some insight into how the system´s behave individually. It allows building the model starting from identifying the objects (agents) and then defining their behaviours as well as the internal connections between them. The global behaviour of the system then emerges out of much concurrent individual behaviour. This Agent-based modelling is quite recent, simulation practitioners start using it in 2002-2003, and appeared due to the desire to get deeper in the traditional system modelling method as well as the particularly behaviours of each entity. This development was also stimulated by the increase in the capacity and speed of the computers CPU and simulating technologies *(Borshchev, 2013)*. To ease the understanding of this variant of modelling here are two important tips:

- Agents are not the same thing as a cellular automata
- Agents are not only people but also objects, organizations and anything required to modelling, no matter if they are active or passive, moving or static.

Agent-based modelling mainly has two components: agents and an environment where they are located. As the simulation is base in this way of modelling, all the entities are modulated as agents and the location and general constraints are modelled in the environment.

5.4 Modelling method

Modelling the simulation is the most challenging part of this final master thesis. The order follow to describe the method starts from the best general attributes (GIS map, location of stores and homes) and get deeper to the most precise details as how the customers decide in what store to buy or how the shipment of store is delivered.

Placing the elements in the GIS map

At first, the GIS map is introduces in the *main* agent and located in Krems and Mautern an der Donau coordinates. To locate both*, stores* and *homelocation* of customers an excel file, called *"Stores"*, with the coordinates is imported. Nevertheless, before importing the location it is necessary to explain how to allocate the population. It is almost impossible to store each person in his own home, it would require an incredibly powerful CPU and even though, it might be very difficult to deal with. The problem is solved by grouping the population or customers by sectors obtained from the census information of both localities. Once this problem, a excel file is set with the **id, name, longitude** and **latitude** for each *store* and the **id, name, longitude, latitude** and **population** for each *homelocation.* Each *customer* from the *Customer* type population of agents is now set it the correspondent *homelocation*.

The information about the closed bridge in scenario three is alto imported from the excel file. The rest of agents needed to be placed in the GIS map, only the *truckstation,* are placed manually introducing their coordinates in the agent properties.

Modelling the customer´s behaviour

As it has been already explained, the customers are configured as a population of agents of type *Customer*. If modelling the behaviour of a person is quite difficult in a normal situation, the task becomes even more difficult when it concerns a critical, non-ordinary situation like a flooding event.The customers are initially located at home (*atHome* = TRUE) and with the variable *satisfaction* with the value FALSE. The first decision is to decide the store objective in which each customer is going to satisfy the necessity. In this choice of store, the first step is to get the distance from the corresponding customer's *homeLocation* to each of the stores. This distances are calculated and store in a collection, in one of the code actions in the action chart, at the beginning of the simulation when the stores a home of customers are output from the excel file. Once the distance is stores, a probability is associated to each store, depending on the individual distance to each of them compared with the rest of the distances. This probability is obtained with a particular created method, based in variations of a *gravity model*. The first attempt was to use a *gravity model* to get the probability based in the particular distance compared with the rest. The main problem was the absence of a second parameter in the decision. As known, a gravity model returns the probability in relation with the macroscopic relationships between places *(Allen, B. 1984). "It has long been posited that the interaction between two locations declines with increasing (distance, time, and cost) between them, but is positively associated with the amount of activity at each location" (Isard, 1956).* This second parameter is what is missing in this model.

Due to this impossibility of applying a *gravity model,* a new method was established following the next expression:

$$P_{\,Customer\ i, Store\ j} = \frac{\frac{1/d_{CiS_j}}{\sum_1^n d_{C_1 S_j}}}{\sum_1^n \left(\frac{1/d_{CiS_j}}{\sum_1^n d_{C_1 S_j}}\right)}$$

$P_{C_i S_j}$: probability of customer i to go to store j.

$d_{C_i S_j}$: distance from homeLocation customer i to store j

This method is a result to an attempt to compare the particular distance from a customer's homeLocation to a store to the distances from this point to the rest of stores. The motive of using inverses is to get a value contained in [0,1] so to compare with the generated random number.

The formula appears to be at first very complicated but in the end it is not so difficult to apply. Once the method is fixed, all the distances are calculated and store in the collection *probabilities.* Then, with a clear and notable influence of a *Montecarlo model,* another method to select the store is established. At first, the *customer* generates a random number in the range [0, 1]. This number is compared to the probabilities associate to each store until the same probability or just the instant following is found. The store, *s,* associate to this probability is selected as objective to the *customer.* Then, the variable *currentStore = s.*

A graphical way to explain this method, maybe easier to understand, is the one that follows:

$$Collection\ of\ probabilities\ to\ each\ store\ (store = s|probabilities\ (p))$$

$Generate\ random\ number\ \in [0,1]: R_N$

$Bucle$: $\boldsymbol{for}\ \ Store\ s{:}\ stores$

$$Compare\ R_N\ to\ the\ stored\ values\ in\ the\ collection$$

$$sumOfProb = \sum_1^i P_{s,i}\ \ ;\ P_{s,i}{:}\ Probability\ i\ to\ store\ s$$

$$\boldsymbol{Condition}{:}\ \boldsymbol{if}\ (sumOfProb\ > R_N)$$

$$currentStore = s$$

Once the store is selected, the customer moves to the location and, if the store has still stock, enters and access to the Queue. As soon as the customer enters the store, the variable *satisfy* change its value to TRUE an, when the customer leaves the Queue returns to the *homeLocation.*

Determining the value of the stock for each store

The stock established for each stock is obtained from a first simulation where, in ordinary – common conditions and infinite stock (modelled establishing a very high number of initial units in stock), where averages demand for each store is obtained. Based on this average demand, and following the next criteria, the stock is calculated:

$$Stock = Average\ demand + security\ stock;$$

$$security\ stock = 20\% Average\ demand$$

Modelling the closure of the roads

Even if in this simulation only one road, the secondary bridge connecting Krems and Mautern, the method followed to model this closure would be the same to close as many roads as desired. This method is modelled through three different Java classes: ***Blocking Weighting, MyGraphHopper*** and ***RoutingGraph.*** In addition to this three Java classes, different function and variables, already introduced in the *"Agents"* section, are required. The method to change the actual system of roads is quite easy to understand, even though the programming is quite hard. At first it is important to distinct between the two different types of transport available in this simulation system: by foot or by truck. The walking path is different from the driving one so it is mandatory to do two different processes, but with the same structure. In addition to this, an important aspect to take in account is that some roads, which are real because they are import from the GIS map, can have one, two, three or even four different paths, depending on the size and the direction of the objects. When the closure of a road is set it up, it is mandatory to make sure that the road is closed in all its senses and paths; otherwise it will not compile or. If compiling, it will not run adequately.

Attending to the fact that AnyLogic selects the way from one point, origin, to another, destiny, based on the total time invested, what this method does is to change the timing of the paths, so that the one wanted to be selected is the shorter. But for modelling this change, it is necessary to divide each street in straight segments and then recalculate all of them. That is why, due to all those new calculus, sometimes, the simulation really slows itself.

5.5 Setting up the agents

Modelling and setting up the scenario and the simulation environment and properties is one of the main and most complicated tasks of the thesis. Furthermore, the agents modelling and configuration becomes one great challenging task. This study is going to be divided in different sub-parts, one for each customer.

An agent is an entity in a simulation environment. As an agent is created, it is mandatory to create the name of the Agent type, and the name of the agent, or the population of agents depending of the type, that will be deployed in the simulation environment. This configuration can be easily described within Fig.26 where the setting up menu while creating an agent is shown.

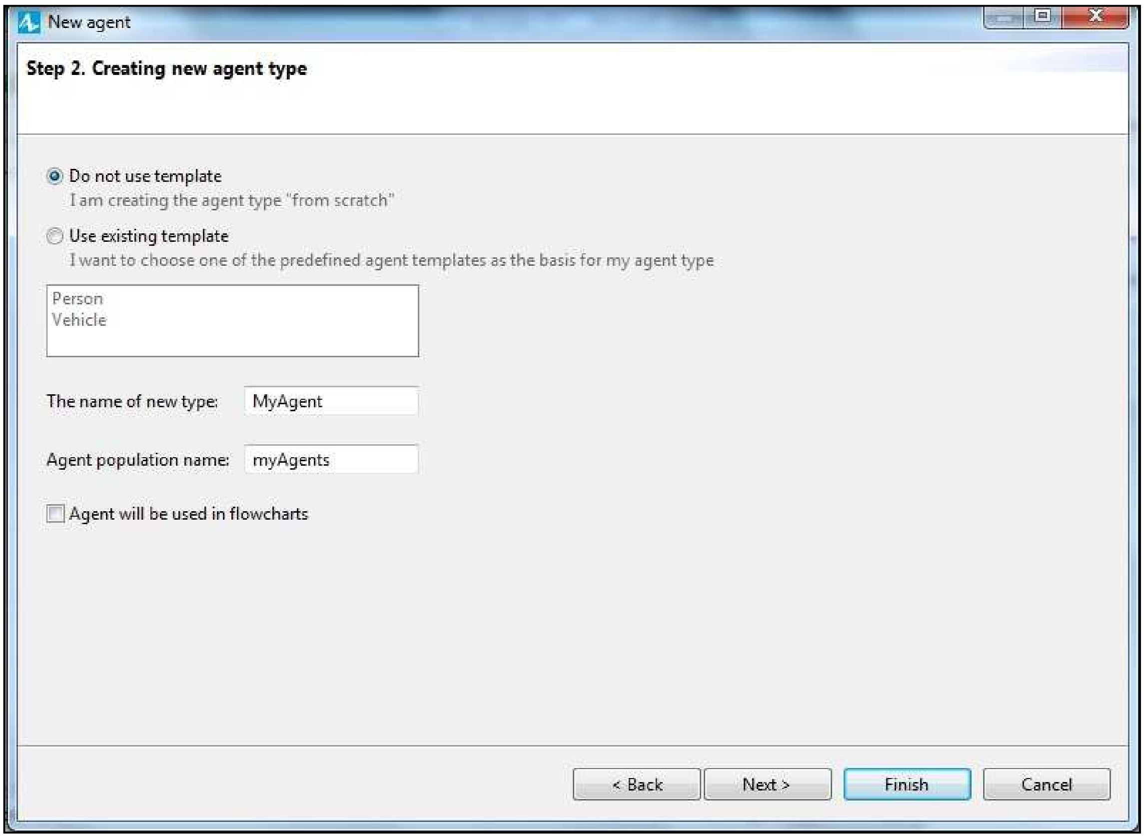


Fig. 26 "Creating an Agent" ***(AnyLogic, 2015)***

From now on, the different agents needed to set up the simulation are described and explicated, following always the next title structure for each agent: *New type agent – agent population name*. All the characteristics, variables, charts and parameters of the different agents are set up in the main window of the agent type (which is easily opened double clicking the name of the agent). This set up is configured in each of the members of the population in the main environment where the simulation is run. The description of each agent type is organised within four different categories: variables, parameters, functions and others, which includes different elements as collections, events, queues, graphics and state charts. As it is known, AnyLogic works with Java language as programming code so all the codification is written down within the Java code.

5.5.1 ClosedRoad – closedRoads

Agent type set to a population of agents that is used to set the up and identify the closure of a road. This agent is necessary only in the third scenario of the simulation where the closing roads event is introduced. It is a simple agent with only one function and three parameters.

Variables

No variables indeed.

Parameters

Three different parameters are used to model the agent:

- ***Id*** (integer type): parameter used to identify the id of the road.
- ***startTimeInMin*** (double type)**:** parameter established to identify the exact moment of occurrence of the closure. It is store in minutes.
- ***endTimeInMin*** (double type)**:** parameter used to established the exact moment when the closure ends, what means the road has been restored.

Functions

- **init** (Just action): function set up to initialize the closure of the road. I has quite a complex code:

```
oval.setVisible(true);
//change roads
int edgeNr =
main.truckRoutingGraph.graph.determineForbiddenEdges(getLatitude(),
getLongitude());
main.truckRoutingGraph.graph.addForbiddenEdge(edgeNr);
main.truckRoutingGraph.graph.createWeighting("BLOCKING",
main.truckRoutingGraph.graph.getEncodingManager().getEncoder("car"));
//walk
edgeNr = main.walkRoutingGraph.graph.determineForbiddenEdges(getLatitude(),
getLongitude());
main.walkRoutingGraph.graph.addForbiddenEdge(edgeNr);
main.walkRoutingGraph.graph.createWeighting("BLOCKING",
main.walkRoutingGraph.graph.getEncodingManager().getEncoder("foot"));
```

5.5.2 Customer - customers

The customers are also modelled within a population of agents of type Customer. The customers appear to be the biggest programming challenge because it is difficult to get a certain exact approach to the behaviour of a normal person. The choice to go and buy to one store or to another is established depending on the distance to the store. This behaviour is completely explicated in a different sub-chapter of this thesis.

Variables

The Customer type is set up within three different variables: ***atHome*** (Boolean), ***currentStore*** (Store), ***satisfaction*** (Boolean), **route** (Other, GIS Route), ***segmentCount*** (integer.)

- ***atHome*** (Boolean type): variable to identify whether a customer is at home or not. When the customer is at home, the value of the variable is TRUE. Otherwise, it is FALSE.
- ***currentStore*** (Store type): variable of type Store used to identify the current store of each customer.
- ***satisfaction*** (Boolean type): Variable that identifies the necessity of a customer. When the customer is able to buy the needed resources at the store, it becomes satisfied, which involves that the variable sets its value to TRUE: Otherwise; when the customer cannot satisfy its necessity or, has not arrive to the store jet, the variable stays as FALSE value.
- ***route*** (GIS route) and ***segmentCount*** (integer) are both variables to identify and modelled the movement of the customer when the roads are closed in scenario three.

Parameters

In addition to these variables, a parameter called ***homeLocation*** is established.

- ***homeLocation*****:** parameter used to identify the home of each customer, what means, the place where it is supposed to return after buying.

Functions

Due to the complex modelling that the Customer type requires, three different functions are set up**.** The first function is called ***findStore*** and its task is to give the customer the choice of the store in which he is going to satisfy the necessities. The choice of the store is consequence of a probability method based on the distance to each store. The model to arrive to this probability value as well as the method to calculate the distances is carefully explained afterwards.

The code action of the function is the next:

```
double randomNumber =
main.getDefaultRandomGenerator().nextDouble();
double sumOfProb = 0.0;

//Decide on store
for (Store s : main.stores)
{
	sumOfProb +=
homeLocation.probabilities.get(s);
	if (sumOfProb > randomNumber)
	{
		currentStore = s;
		return s;
	}
}

return null;
```

Basically, this code performs the following actions: generates a random number contained in the interval [0, 1]. Then, the variable *sumOfProb* is initialized with value cero. This variable is used to sum the probabilities of each store and to compare it with he generate number. Once this step is done, the code enters in a loop, a *for* loop, where the collection of stores is explored, adding each store's probability to the variable *sumOfProb.* Within the *if* condition, the value of the variable is compared, per iteration, and, as soon as it is higher than the random number, the actual stores is attributed to the variable *currentStore* and returned to the system. The logic behind this codification is consequence of the choice method explained in the last chapter. The customer choices the store constrained by a probability which is a result of the comparison of each store's distance with the rest. Because several aspects can affect the customer's decision, it is not always sure that he is going to choose the store with the highest probability. That is why the random number is generated, to add certain variability to the decision. Then, constrained to the probability but with certain freedom due to the random number generation, is how the decision of the store is selected.

The next function is named ***consuming*** and it is very simple. The reason to create it is just to improve the comprehension of the Java code and the modelling of the simulation. According to this, the code of the function is:

```
currentStore.stock -= 1;
```

The third function is ***arriveAtStore*** and it is the main function of the Customer type. Within this function the customer moves to the selected stores and consumes (the function consuming is then executed inside this function code). This function is also programmed to take stats of the total demand of each store and to update statistics. The main body code becomes more difficult as soon as the closing roads code is introduced.

```
if (atHome == false)
{
	if (currentStore.stock > 0)
	{
		currentStore.enter.take(this);
		consuming();
		System.out.println("ARRIVED");
		currentStore.totalDemand++;
		main.updateStats();
		//satisfaction = true;
		//this.onChange();
	}
	else

	{
		Store target = findStore();
		route = new
GISRoute(main.map,main.walkRoutingGraph.getPathData(getLatitude(), getLongitude(),
target.getLatitude(), target.getLongitude()));
		route.setVisible(false);
		segmentCount = 0;
		arriveAtStore();
	}
}
else
{
	statechart.receiveMessage("arrivedHome");
}
```

Others

- ***generateDemand***: event triggered out to generate the demand of the customers, which involves, as it is observed in the code, two conditions: the customer must be at home (*atHome* = TRUE) and the customer has to be unsatisfied (*satisfaction* = FALSE). The event triggered out once per day in standard conditions (non disaster) and the customer consumes. This event is important because it allows the users to modify the frequency of the customer's necessities. Due to the fact that in a disaster episode the behaviour of the population changes dramatically and the panic is traduced in a continuing desire of buying and getting as much as resources as possible, the event is triggered twice per day when the flood occurs.

```
if (atHome == true && satisfaction == false)
{
	Store target = findStore();
	route = new
GISRoute(main.map,main.walkRoutingGraph.getPathData(getLatitude(),
getLongitude(), target.getLatitude(), target.getLongitude()));
	route.setVisible(false);
	segmentCount = 0;
	arriveAtStore();
	atHome = false;
}
```

- **State Chart:** state chart used to establish the status of the store depending on the available stock. When the store has enough stock to satisfy the customers, the status is: *"enoughStock"* but whenever the stock gets down a value (established by user in a 20% the initial value of stock, which is normally called security stock) the status of the store change automatically to the *"needStock"* status. As all the state and to make a more exact approach to a normal situation, the state chart has return transition to *"enoughStock"* status, as soon as the store is provided with resources.

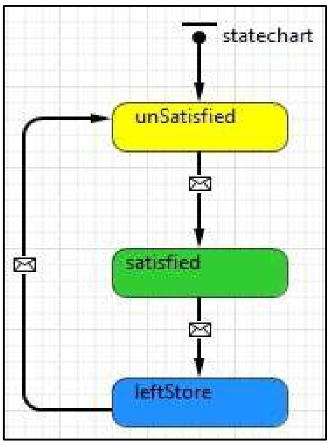


Fig. 27 "Customer state chart" *(AnyLogic, 2015)*

5.5.3 HomeCustomer – Homecustomers

This agent type is used to established and store the home of each customer. The main problem modelling this agent is the lack of information and data due to privacy issues, as it can be expected. Another minor problem is the data required. As it is logical, it not possible, with the available resources, to store the real house of each customer because the simulation will need a huge memory and will be extremely slows. In the model, the distribution of the home of the customers it is modelled within the census of both cities. This modelled will be explained in the next chapter.

This agent type is modelled also as a population of agents, due to the facts that in the locations exist more than a house, but in a different way from both, *Customer* and *Store*, that have been previously explained.

Variables

The *HomeCustomer* agent needs no variable.

Parameters

In addition to this, only one parameter is required.

- ***population***: this parameter seizes the population contained in each home.

Functions

The unique function set up in HomeCustomer is the ***distance*** function.

- ***distance***: This function establishes the probability or chance of a customer to go to each store from its *homeLocation*. This probability is calculated in relation with all the distances between stores and Homecustomers. The function calculates the probability and stores it in a collection. For this function two collections are directly needed: ***inverseDistanceToStore*** and ***probabilities***.

The code of the function:

```
double sumOfInverseDistances = 0.0;
for (Store s : main.stores)
{
	sumOfInverseDistances +=
inverseDistanceToStore.get(s);
}
double probability = 0.0;
for (Store s: main.stores)
{
	probability = inverseDistanceToStore.get(s)
/ sumOfInverseDistances;
	probabilities.put(s, probability);
}
```

<u>Others</u>

To store the information acquired in this agent, the distances and probabilities, three collections are used. A collection, in AnyLogic, is a group of objects, known as its elements, used to store, retrieve and manipulate aggregate data. Typically, they represent data items that form a natural group, such as a queue (in this case elements represent people waiting in a queue), or a truck park (elements are trucks), or a telephone directory (a collection performs mapping of names to phone numbers) *(AnyLogic, 2015)*.

- ***distanceToStore*** (Linked Hash Mao; Key element Store; value element class: double): stores the information about the distance from each *homeLocation* of each customer to each store.
- ***inverseDistanceToStore*** (Linked Hash Mao; Key element Store; value element class: double): Stores the inverse of each value from *distanceToStore.*
- ***probabilities*** (Linked Hash Mao; Key element Store; value element class: double): stores the probability of each customer to go to each store.

5.5.4 Main – Agent type

Agent type used to set up the environment where the simulation takes place. It is a special agent, where all the population of agents established are located and connect ones with the other. This special configuration of the agent *Main* also affects to the entities and the objects that are included in its set up. At first, as it has been explained, all the collection of agents from the different agent types are located here, which includes: *stores, Homecustomers, customers, trucks, truckstation and closedRoads.* In addition to this, another important distinct element, present in the agent *Main*, is the GIS map where the simulation takes place.

- **GIS map**: As introduced, the GIS map is the graphical representation of the real geographical location of the simulation. . GIS can show many different kinds of data on one map. This enables people to more easily see, analyze, and understand patterns and relationships and to give a real support structure to the simulation.

<u>Variables</u>

In contrast to the rest of agents, most of the variables implemented in *Main* are used to store statistics or set up simulation options, nor to configure the agent type.

- ***scenarioDefinition*** (integer type): variable used to store the scenario of simulation selected by the user so the system can access it and set the simulation configuration
- ***totalSatisfaction*** (integer type)***:*** variable used to store the total number of satisfied customers.
- ***availableStock*** (integer type): as the name of the variable indicates, it is use to give the available stock in the hole stores system instantly.

- ***walkRoutingGraph – truckRoutingGraph*** (Routing Graph type): both variables used to set the new routing graph, either walk or truck, in scenario 3.

Parameters

The parameters set up in *Main* are used afterwards in the sensitivity analysis.

- ***initialStoreStock*** (integer type): seizes the initial stock (individually) for all the stores. It is used to see how the demand and the satisfied customers vary when establishing the same stock for all the stores and varying its value in a closed range of values.
- ***numberOfTrucks*** (integer type): number of trucks available to ship stock. It is also used to change the settings of the sensitivity analysis and observe the results (in the annex provided with this document with the simulation technical information this value is set to 2).

Functions

- ***getSumOfItemsInStores***: This function returns the total sum of items available in the stores, in the whole system. It is created to graphically show the result in a chart, so the user can access in any moment the total stock available.
- ***getSumOfCustomersEnteringStores:*** This function it is also aimed to return the total number of customers that had already enter to any of the stores in the system.

The code of the getSumOfItemsInStores is:

```
int sumOfItems = 0;
for(Store st : stores)
      {
      sumOfItems += st.stock;
      }
availableStock = sumOfItems;
return sumOfItems;
```

The code of the getSumOfCustomersEnteringStores is:

```
int SumOfCustomers = 0;
for(Store st : stores)
      {
      SumOfCustomers += st.enter.count();
      }
return SumOfCustomers;
```

Others

- **Results Outputs**: Time plot, bar chart and time stack chart use to graphically show the different values of the variables and parameters during the simulation run.
- **Action Chart** (Import data): Chart with different codes in charge of importing the GIS information of *stores* and *homelocation* so to allocate then in the map. The coordinates are given in longitude and latitude for both, *stores* and *homelocation*, and also the population of each *homelocation* is stored. The procedure is detailed in the next section of the thesis.

5.5.5 Order – Agent type

This agent type has nor population agent and either physical representation during the simulation. It is established to model the order send to the *truckstation* whenever a store needs stock. This option, truck shipment, is only disposed in scenarios two and three.

Variables

No variables.

Parameters

Two parameters both needed to set up the order:

- ***amount*** (integer type): parameter used to size the amount of stock delivered. The value is established from a uniform distribution, with parameters 250, 500 units: uniform (250,500).

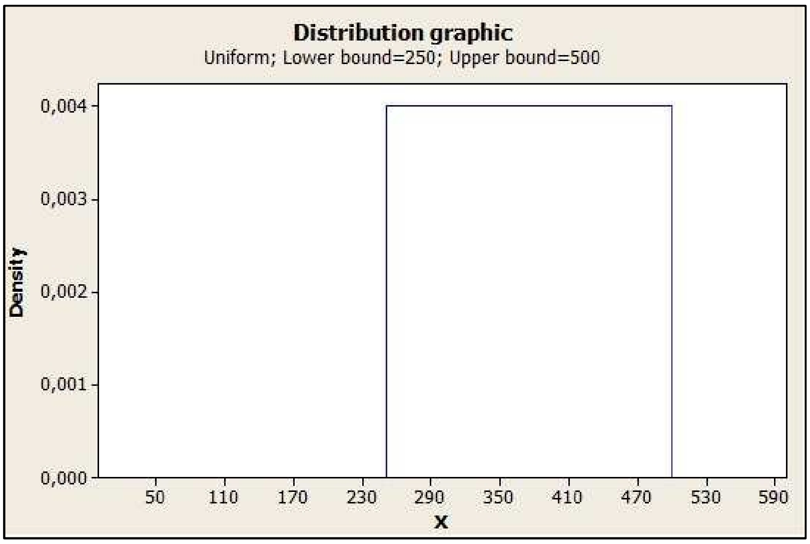


Fig. 28 "Uniform (250, 500) *(Minitab 16, 2013)*

- ***store*** (Store type): this parameter stores the store which needs the stock. The objective location of the truck.

5.5.6 Store – stores

The different stores, distribution centres of resources, are modelled as a population of agents. As it is indicated in the section title, the name of the agent type is *"Store"* and the different agents in the population deployed in the main environment are called *"stores"*.

Variables

The Store type is set up within three different variables: ***totalDemand*** (integer), ***stock*** (integer), ***necessity*** (Boolean).

- ***totalDemand*** (integer type): it is a variable used to count the total demand of each store. Initially it is set to the value cero and it increases in one unit each time a customer arrives at the store.
- ***stock*** (integer type): variable that takes the instant value of the stock in the store at each moment. It sets the available stock in at the beginning of the simulation of the stores.
- ***necessity*** (Boolean type): as a Boolean variable it can take the value TRUE or FALSE. This variable is set up to size whether the store is running out of stock, it needs stock. In this case it will take the value TRUE. In other case, the variable takes the value FALSE, which is also the initial value of the variable.

Parameters

In addition to these variables, a parameter called ***name*** is established.

- ***name*:** parameter used to set the name of each store.

Functions

There is only one function set in the type store called ***determinatingNecesity.*** The function is set up to change the value of the ***necessity***. The code of the function is the following:

```
if (stock < 100)
{
	necesity = true;
}
```

Others

- ***generateShipment***: event triggered out each time the necessity variable takes the value TRUE what means that the stock is running out of stock. The task of the event is to create an order and send it to the truck station so that a truck is programmed to deliver a certain amount of stock to the remittent stock. Both *"if"* conditions are established due to the fact that only in the second and third scenario of simulation, it exits the possibility of stock shipment with delivering trucks. The code of the event is the following:

```
if(main.scenarioDefinition == 2)
{
	Order order = new Order ( uniform_discr(250,500), this);
	send (order, main.truckstation );
	necesity = false;
}
else if(main.scenarioDefinition == 3)
{
	Order order = new Order ( uniform_discr(250,500), this);
	send (order, main.truckstation );
	necesity = false;
}
//generateShipment.restart();
```

Store Queue: Chain of blocks which configures the actions inside the store. When a customer enters a store a chain of actions is started, modelled with different blocks and actions. The Store Queue is formed by the following blocks:

- ***Enter*** (enter block): Block use to take the customer into the Queue
- ***Buying*** (delay block): Delay block used to represent the time that the customer needs to take all the resources needed and add them to the shopping char. This action also takes in account the possible dudes and wondering time, as well as the traffic and interaction with other customers. The delay time is modelled within a normal (20, 10) with minutes as unit, which means a normal distribution with mean equal to 20 minutes, and a variance of 10 minutes.
- ***Cash Queue*** (queue block)**:** block that sizes the waiting time of a customer in the cash to be attended. It is modelled with allowing the maximum capacity because we are simulating an extraordinary situation where all the people intend to buy and where all the mediums available are disposed. It is modelled within a FIFO (First Input First Output) queuing priority.
- ***Payment*** (delay block): Action of payment. In a normal situation it will not take more than a minute, but due to the extraordinary circumstances it is set to a delay following a normal distribution with mean 2 minutes and variance equal to 1 minute.

- ***Exit*** (exit block): As soon as the customer leaves the store it is automatically delivered to the home location. This block, as the **Enter** block, is also used to collect statistic of number of customers as well as to control some parameters like the satisfaction.

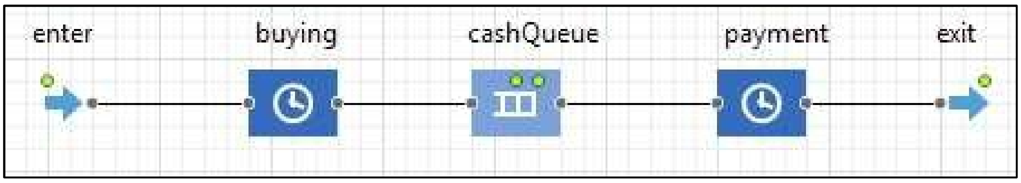


Fig. 29 "Blocks Chain, Store" *(AnyLogic, 2015)*

- **State Chart:** state chart used to establish the status of the store depending on the available stock. When the store has enough stock to satisfy the customers, the status is: *"enoughStock"* but whenever the stock gets down a value (established by user in a 20% the initial value of stock, which is normally called security stock) the status of the store change automatically to the *"needStock"* status. As all the state and to make a more exact approach to a normal situation, the state chart has return transition to *"enoughStock"* status, as soon as the store is provided with resources.

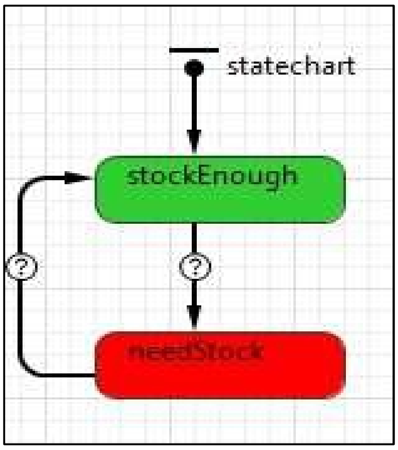


Fig. 30 "State chart, Store" *(AnyLogic, 2015)*

5.5.7 Truck – trucks

The transport of new stock to the distribution centres, *stores*, is carry out with the set up of an agent type modelling the distribution trucks. It consists in a population of agents, initially set to cero, and that are introduced afterwards within a fleet box in the *truckstation* type. Their behaviour is modelled with an state chart.

Variables

The T*ruck* type is set up within four different variables: ***order*** (Order), ***route*** (GIS route), ***segmentCount*** (integer) and ***wayHome*** (Boolean).

- ***order*** (Order type): variable that stores the *order* emitted by the store
- ***route*** (GIS route): variable, used to modify the route of the trucks when the closing roads event is added.
- ***segmentCount*** (integer type; initial value = 0): As *route,* it is established to model the closing roads event. It is set to store the number of segments of the new route.
- ***wayHome*** (Boolean type; initial value FALSE): Boolean variable established to determinate whether a truck is on the way home or not.

Parameters

No parameters.

Functions

There is only one function set in the type *Truck* called ***drive****.* The function is set up to establish the driving route that the truck is going to follow. The code of the function is the following:

```
if (wayHome)
{
      statechart1.receiveMessage("arrivedHome");
}
else
{
      statechart1.receiveMessage("arrivedStore");
}
```

<u>Others</u>

- ***State chart***: Complex state chart used to control the behaviour of the trucks, how they receive the order, load the shipment and then delivered it. Each transition is delivered within a different condition. In the beginning of the simulation all the trucks are stored in the main truck station, for disaster events, located in the military base in Mautern. First transition, from the stop state to the loading process is triggered by message, message of type order, emitted from any of the stores when they are running out of stock. During the loading state, the truck picks up the amount of stock ordered. This process is modelled by a uniform (30, 60) sized in minutes. Once the load is completed, the truck moves to the ordered store. The next transition, transition three, is triggered by message, when the truck arrives the objective store. As in the first state, and within the same modelling, the stock is unloaded. Once again the transition is triggered by timeout following a uniform (30, 60). Then the truck changes to *returningToTruckstation* state which transition to *atTruckStation* is triggered, as in *movingToNeedStockStore,* by message. In the following figure the complete state chart is shown.

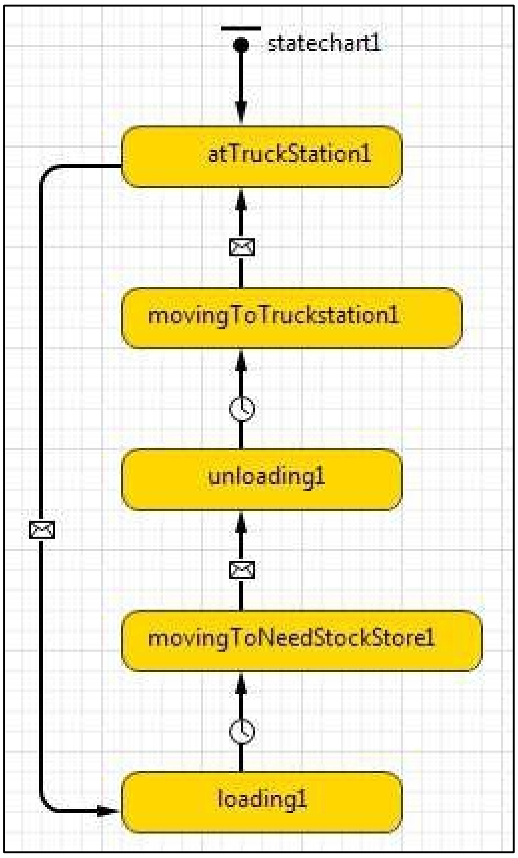


Fig. 31 "Truck type state chart" *(AnyLogic, 2015)*

5.5.8 Truckstation – truckstation

Agent unique type (it is modelled as a population of agents, because there is only one station), used as truck storing centre. Here is where the trucks are initially located and where the emergency stock is available, so to take it and deliver to the distribution centres. It is located in Mautern, in the military based, with coordinates: (48.391789, 15.583952)

Variables

- ***stockResources*** (integer type): Variable this takes the value of the available stock in the station. It is an indicator of the over-stock needed.

Parameters

No parameters.

Functions

No functions.

Others

TruckStation Queue: Chain of blocks used to configure the process within the order emitted by a store is processed in the *truckstation*. The chain is formed by seven different elements:

- ***processingOrder*** (enter block): Block use to orders into the process.
- ***ordersQueue*** (queue block): block that represents the queue of waiting orders. It is set to maximum capacity and modelled within a FIFO queuing system
- ***taketruck*** (seize block)**:** block that sizes the number of resources from the given Resource Pool call *fleetTruck.* This block is necessary when a Resource pool is used. This step provides the queue with the trucks so they can be selected and loaded. It is modelled with maximum capacity.
- ***fleetTruck*** (Resource Pool block): Resources that provides the queue with the resource unit *truck.* The number of trucks is set by the user with the parameter in main: *numberOfTrucks.*
- ***delivering*** (delay block): Delay until the truck finished the delivery, what includes returning to the *truckstation.* It is modelled as a "*Until stopDelay () is called",* so the delay does not stop until the truck arrives the station.
- ***Release*** (release block): block necessary when a fleet is used. It releases the resources introduced in the queue, the trucks in this case.
- ***Sink*** (sink block): end of the queue. The elements are disposed.

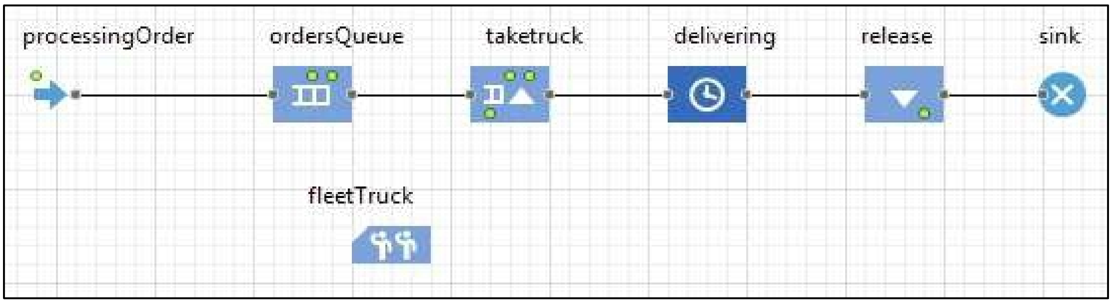


Fig. 32 "Truckstation Queue" *(AnyLogic, 2015)*

5.6 Simulation Problem

The simulation problem consists of kind of robust optimization, due to the fact that we are using the simulation results because of the uncertainty of the facts. Typically, the data of real world LOs (Linear Optimization problems) is not known exactly. This uncertainty can be consequence of many causes *(Ben-Tal et al., 2009)*:

- Some of the data or constraints do not exist yet, as it occurs in this problem, because they are future data or feedback *(Ben-Tal et al., 2009)*.
- Some of the data are parameters or characteristics that are not possible to be measured in an exact way, or whenever it is possible, the method is not reliable. An example is the behavior of a person, or the parameters associated to technological systems *(Ben-Tal et al., 2009)*.
- Some of the parameters are simply immeasurable and cannot be programmed with a 100% certainty: the chance of a customer or the intensity of some action.

First of all, the model is set up according to the explained modelling configuration. As it has been explained, the available stock, in the whole system, is the maximum average value of the demand among all stores in the area. This is the main restriction: the disposable stock is restricted. In consequence, restricted to this value the first segment of this problem is how to distribute the disposable stock between the working stores when the flood happens. In the first scenario, due to the flood, some of the stores are going to be closed down an indeterminate period of time. Depending on the demand of each store, the problem is to reduce to minimize the unsatisfied customers in the area of simulation. Supposing that there is not a limited stock for each individual store, different from the disposable stock, the average demand of each store, in this new situation, is established as a constraint. Due to the fact that a flood is a dynamic phenomenon, the stores closed are not always the same and so the main objective function of the problem changes in every simulation. The consequence of this dynamism is that for each simulation, depending on the closed stores, the objective functions varies and also do the constraints, due to the fact that the average demand is going to vary. The will of this simulation is to give important and strong guidelines to follow in case of flooding.

5.6.1 Scenario 0

In the first scenario, called *"Scenario 0"*, the simulation is run with ordinary circumstances, what means, all the distribution centres operating and an ordinary demand. This means, as main constraint, that the event in charge of generating the demand for each customer, *generateDemand* (explained in the agents section), is triggered with a frequency of one per day. This scenario establishes the available stock for each store; stock that is going to keep constant for all the following scenarios. This stock is calculated as explained before.

In addition to this, this first scenario of the simulation also provides the average ordinary demands per store, as well as the total number of satisfied customers during a normal working day. Both important parameters to compare, afterwards, with a critical day (disaster occurring).

5.6.2 Scenario 1

Situation: Flood event, many stores (randomly selected in those located near the river) closed due to the water. Customers redistributed to the operating stores. Demand changes and so does the number of customers whiling to satisfy their needing. In contrast to "*Scenario 0*", the event in charge of generating the demand is now triggered twice per day so to reproduce this sense of panic that generates the flood. This characteristic of the situation simulated is the best difficult parameter to model. Each person is different and has, in consequence, a different response and behaviour to an special frightening situation. It is for this variability that the best way to introduce this parameter in the simulation is to double the frequency of customers to attend the stores so, some of them, can even buy twice per day resources.

The main objective is to satisfy the highest number as possible of customers. In an attempt of writing down this objective and these circumstances, the robust optimization problem is:

$$\min \sum_{i=1}^{n} U_i \ ;$$

Where:

U_i: *each unsatisfied customer*

n: *number of insatisfied customers*

The constraints then are the available stock and the demand of each operating store:

$$\left\{ \begin{array}{l} \sum_i X_i < S \\ X_i > d_i \\ \sum_i d_i = D \end{array} \right\}$$

where X_i: *stock of store i*

S: *Available stock*

d: *demand of store i*

D: *totally demand*

It is supposed to know that all the demands and data used it is obtained directly from the simulation, that is the reason why it is commonly known as *"expected"* demand.

5.6.3 Scenario 2

Situation: In this second scenario, shipments from the truck station, provided with an exceptional stock, are displayed. It is important to indicate that the original exceptional stock, also call critical stock, is set to 3,000 stock units but that this value is just indicative like other parameters of the simulation. Not only but also, one of the main results of these two following scenarios, "*Scenarios 2 and 3",* is to establish the quantity of critical stock is needed to reach the maximum value of satisfied customers.

The shipments are performed with a variable number of trucks. This variable but restricted number directly affects the demand and the number of satisfied customers. The main objective is to vary the number o displayed trucks until the best on is found. The objective number of trucks is the one that provides the highest number of satisfied customers or, what is the same, the one that minimizes the total number of unsatisfied customers. The truck station is located in the army base in Mautern der Donau, in the southern bank of the river. As in the first two scenarios, the main objective is to maximize the number of satisfied customers.

$$\max \sum_{i=1}^{n} S_i \ ;$$

Where:

S_i: *Satisfied customer i*

n: *number of satisfied customers*

The constraints then are the available stock and the demand of each operating store as well as the total demand and the maximum shipments according to the available fuel and costs of each shipment:

$$\left\{ \begin{array}{l} \sum_i X_i < S \\ X_i > d_i \\ \sum_i d_i = D \\ \sum_i X_i > D \\ \sum_{i=1}^{n} T_i < A \end{array} \right\}$$

where X_i: *stock of store i*

S: *Available stock*

d: *demand of store i*

D: *totally demand*

A: *number of maximum shipments*

5.6.4 Scenario 3

Situation: Scenario 3 is a combination of scenarios 1 and 2 adding the difficulty that they appear also closed bridges due to the level of the water. More precisely, the secondary bridge connecting both banks of the river is closed. This bridge is the one located in the locality of Mautern and it is closed due to the location of its extremes, very close to the water level. The remaining connecting bridge is almost impossible to be closed, due to its elevation from the surface of the water.

This scenario is the closest to a real case and has the same constraints as scenario. However, the main objective of the simulation, and also the main objective function is to maximize the number of satisfied customers, subjected to the same conditions as in the past scenarios. The only difference is that another constraint is given, due to the fact that not all the connections are operating. The objectives functions will be then:

$$\max \sum_{i=1}^{n} S_i$$

Where:

$S_i: satisfied\ customer\ i$

$n: number\ of\ satisfied\ customers$

The constraints are the same as in scenario 2:

$$\left\{\begin{array}{l} \sum_i X_i < S \\ X_i > d_i \\ \sum_i d_i = D \\ \sum_i X_i > D \\ \sum_{i=1}^{n} T_i < A \end{array}\right\}$$

where $X_i: stock\ of\ store\ i$

$S: Available\ stock$

$d: demand\ of\ store\ i$

$D: totally\ demand$

$A: number\ of\ maximum\ shipments$

5.7 Considerations

Due to the complexity of the simulation, many suppositions and considerations has been accepted to run it and validate the results:

- In ordinary circumstances, each customer demands once per day. In critical circumstances this demand is doubled

- Due to the adverse circumstances and the panic of the customers, it is not contemplate the possibility of a customer to leave the Queue due to "*timeout*"

- The number of trucks is restricted up to 10 trucks due to economical and geographical conditions

- Each store can only be served with additional stock once per simulation, which is the same to say that the shipments of stock can only be performed once per store

- The simulation time is fixed to 12 hours, from 8 am to 8 pm, what is considered the most usual and common operating timetable of supermarkets and distribution centres

- When consuming, each customer takes one stock unit

- The customer gets *satisfied* as soon as entering the store due to the fact that when the simulation ends there are still people inside the stores

- The closed stores due to the flooding are always the same and are the three more close to the river. This assumption is taken in consequence of the historical of floods in the region

- Exceptional stock in *truckstation* set to 3,000 units stock.

6. RESULTS OF THE SIMULATION

Before writing down the simulation results, it is important to set how these results are obtained. The results are the mean of 25 simulations all ran in a row. To perform the several simulations, the sensitivity analysis available in AnyLogic is used. When the run finishes, the mean values of the whole 25 simulations are calculated and assumed as results of this study. In all of the chart results the variance between the results is also showed. It is important to remark that, in some cases, this variance can be quite high or even too high (reaches 44% in one of the cases). These values are acceptable in this study due to the uncertainty of the behaviour of the customers when affronting such an unusual situation. As it has been explained in the last section, the behaviour of each customer cannot be predicted, several non programmed aspects affect. That is the reason to accept these variances; otherwise they will not be acceptable.

6.1 Scenario 0

In this first scenario, called *"scenario 0"*, where an ordinary consuming day is simulated, the results obtained are used to calculate the ordinary daily stock for each store in the location. Within the already introduced criteria, in Fig.32, the ordinary stock for each store is showed. In the figure are also calculated the deviations in the measures obtaining a global variance of 15% which , as explained in the considerations, is assumed due to assumptions and complexity of the simulation.

Store	Average	Max. Val.	Min.Val.	Max.dev.	% MAX.DEV.	Ord.Stock
Billa	559	606	507	99	0.177013	671
Billa	827	911	776	135	0.163328	992
Billa	761	804	708	96	0.126143	913
Billa	524	577	461	116	0.221323	629
Billa	469	516	408	108	0.230375	563
Hofer	671	731	635	96	0.143147	805
Hofer	499	547	465	82	0.164315	599
Hofer	257	292	224	68	0.264098	309
Lidl	556	603	491	112	0.201598	667
Merkur	499	526	465	61	0.122244	599
Penny	753	796	711	85	0.112810	904
Penny	722	776	653	123	0.170379	866
Spar	1243	1320	1150	170	0.136753	1492
Spar	801	864	729	135	0.168522	961
Spar	887	948	836	112	0.126337	1064
Spar	569	622	513	109	0.191456	683
Spar	552	598	523	75	0.135752	663
Interspar	539	567	505	62	0.115088	646
Eurospar	562	609	509	100	0.177784	675
TOTAL Satisfied	12251	12489	11902	587	0.047916	14701
					0.159819	

Fig. 33 "Scenario 0 results", (*AnyLogic, 2015)*

In Fig.34 the different values of total satisfied customers per simulation can be observed, and so the mean value obtained. This figure is used, only in scenario 0, to show how the obtained values varying from one simulation to another and to justify the variances assumed.

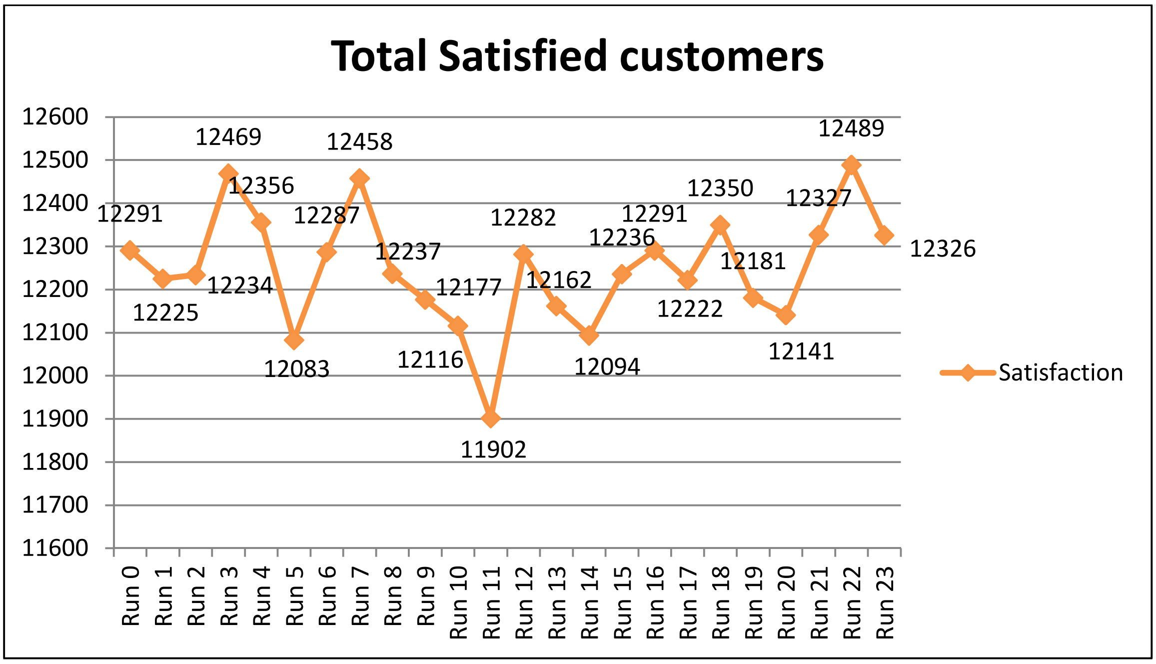


Fig. 34 "Total number of customers satisfied per run in scenario 0", *(AnyLogic, 2015)*

In the next figure, Fig.34, the average demand per store, comparing to the ordinary stock established is showed. The difference between the stock and the demand obtained from the simulation is the security stock.

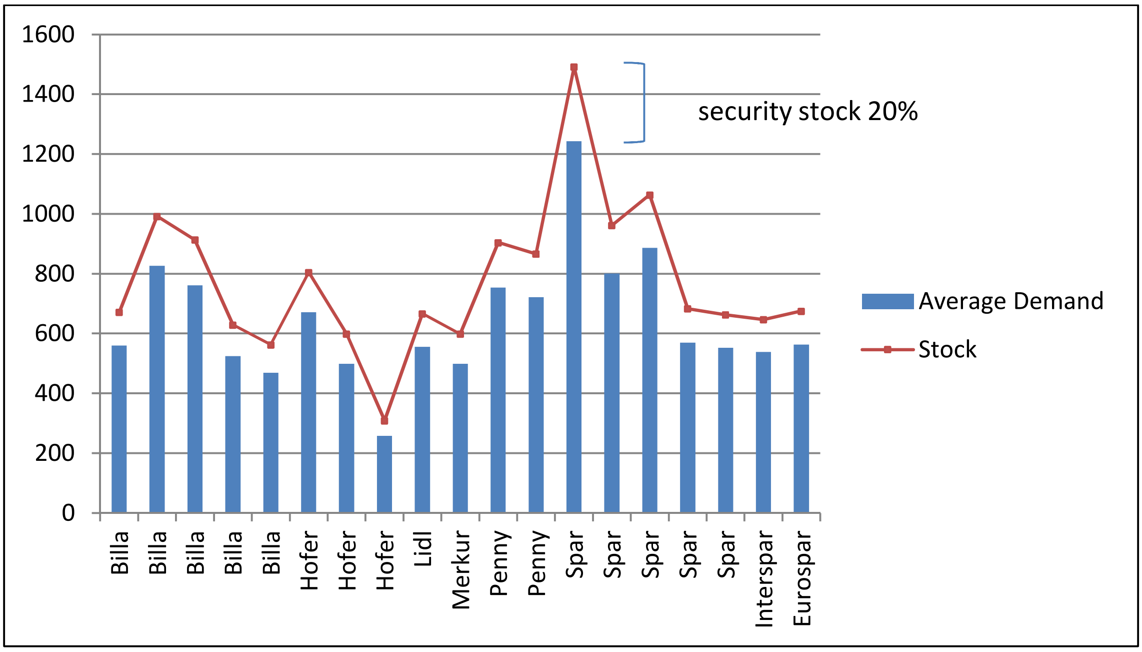


Fig. 35 "Average demand and real stock per store" *(AnyLogic, 2015)*

6.2 Scenario 1

In Scenario 1 the situation is drastically modified. The flooding event has already occurred and due to this fact, only sixteen stores are in service, which means an 84.21% of the total distributing service. In this first "critical" scenario, the total demand in the system is calculated; this is the value to take as reference to solve the simulation main problem: reduce to the minimum the number of unsatisfied customers.

Several measures are taken and many variants form this scenario is simulated to obtained the objective results. At first, in the first simulation the demand is maintained as it was configured for the first scenario, scenario 0, so that the generating demand event is triggered once per day. This run is realized to compare the ordinary stock that the new situation, with only sixteen stores working, would requires, to the ordinary stock that has been set for each store.

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock	GAP
Billa	704	757	654	103	0.146274	845	671	174
Billa	1048	1168	994	174	0.166069	1257	992	265
Billa	630	685	585	100	0.158710	756	629	127
Billa	564	612	509	103	0.182637	677	563	114
Hofer	604	639	559	80	0.132354	725	599	126
Hofer	322	373	296	77	0.239012	387	309	78
Lidl	679	737	621	116	0.170950	814	667	148
Merkur	605	647	562	85	0.140514	726	599	127
Penny	934	966	879	87	0.093140	1121	904	217
Penny	923	967	868	99	0.107245	1108	866	241
Spar	1492	1570	1398	172	0.115319	1790	1492	298
Spar	994	1059	930	129	0.129800	1193	961	231
Spar	670	721	637	84	0.125441	804	683	120
Spar	704	755	671	84	0.119366	844	663	181
Interspar	666	705	624	81	0.121680	799	646	152
Eurospar	685	727	652	75	0.109476	822	675	147
Total Satisf.	12223	12449	11991	458	0.037471	14667	11919	2748
					0.135027			

Fig. 36 "Scenario 1; ordinary demand", *(AnyLogic, 2015)*

As it can be observed in Fig.35, the theoretical required stock in this situation, logically, is always superior to the one established (real stock). This difference is called *"Gap"* and represents the additional resources needed to satisfy the population requirements. This difference between stocks is observed in Figure 36. It is important to explain that the Gap is not the difference between the average demand and the stock available; the values in the gap column are the difference between the real stock, and, within the criteria established to calculate the real stock, the theoretical stock that would be necessary to supply al the customers (this stock includes also the 20% security stock).

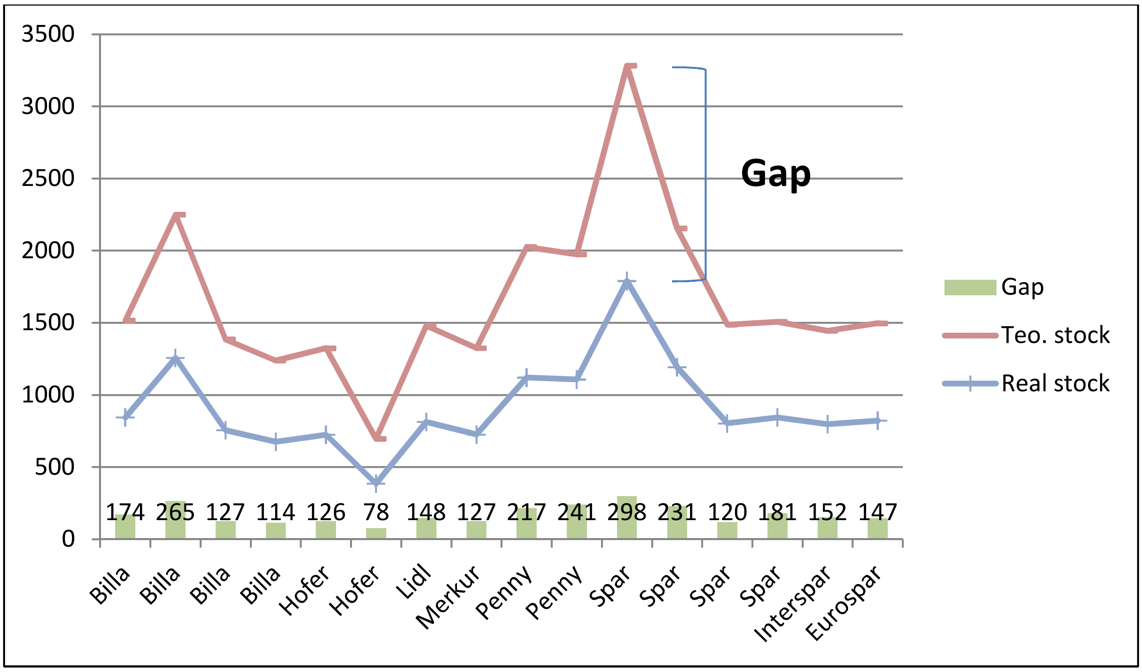


Fig. 37 "Theoretical stock – real stock; Gap" *(AnyLogic, 2015)*

In Figure 38 the difference between the total potential customers and the total ones that can be satisfied with the real available stock, which was set up for the ordinary situation, is showed.

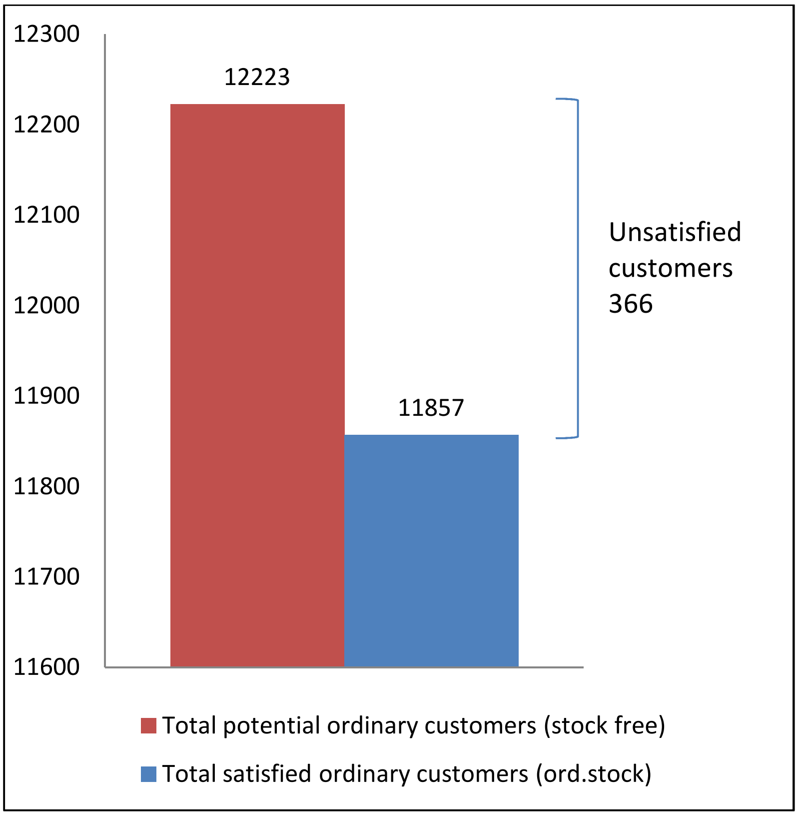


Fig. 38 "Unsatisfied customers" *(AnyLogic, 2015)*

In the next step, the scenario 1 is simulated but with the critical established demand, which means triggering the demand event twice per day. The stock available in the stores is the same, but a real increase is going to be observed in the total potential customers demanding resources. Nevertheless, the number of customers that the stores, with the actual resources, are capable to satisfy is the same as in the last run except little discrepancies due to the in exactitude of the simulation and obtained results. As assumed before, we are looking for tendencies and not exact results; a flooding situation like this is impossible to be exactly predicted.

Store	Average	Max. Val.	Min.Val.	Max.dev.	% MAX.DEV.	Re. Stock
Billa	671	671	671	0	0.000000	671
Billa	991	991	991	0	0.000000	992
Billa	628	628	628	0	0.000000	629
Billa	562	562	562	0	0.000000	563
Hofer	598	598	598	0	0.000000	599
Hofer	308	308	308	0	0.000000	309
Lidl	666	666	666	0	0.000000	667
Merkur	598	598	598	0	0.000000	599
Penny	904	904	904	0	0.000000	904
Penny	866	866	866	0	0.000000	866
Spar	1491	1491	1491	0	0.000000	1492
Spar	961	961	961	0	0.000000	961
Spar	683	683	683	0	0.000000	683
Spar	662	662	662	0	0.000000	663
Interspar	646	646	646	0	0.000000	646
Eurospar	674	674	674	0	0.000000	675
TOTAL Satisfied	11909	11909	11909	0	0.000000	11919
					0.000000	

Fig. 39 "Total satisfied customers with the ordinary stock, critical demand" ***(AnyLogic, 2015)***

As it can be observed in Fig.39, with the ordinary stock only 11,909 customers are satisfied, which represents just the half of the total potential customers whiling to get resources. The null value in the "*max.dev.*" box is due to the fact that all the stock is consumed in all the simulations. This result is easily understood due to the fact that the demand is so high that in all the simulations, despite the different conditions and customer's behaviour, the stock is totally required. This result can be observed in the next figure, Fig.39, where the same parameters are showed but with no a limit of stock, method use to obtain the total potential customers that attend the stores. In this case it exits a variance because the stock required in each simulation run is not the same.

Store	Average	Max. Val.	Min.Val.	Max.dev.	% MAX.DEV.	Teo.Stock	Re. Stock	GAP
Billa	1324	1387	1272	115	0.086834	1589	671	918
Billa	1955	2075	1886	189	0.096665	2346	992	1354
Billa	1204	1277	1119	158	0.131225	1445	629	816
Billa	1069	1124	994	130	0.121641	1282	563	720
Hofer	1141	1205	1082	123	0.107842	1369	599	770
Hofer	603	637	562	75	0.124419	723	309	414
Lidl	1297	1352	1237	115	0.088696	1556	667	889
Merkur	1166	1225	1122	103	0.088330	1399	599	800
Penny	1764	1830	1672	158	0.089589	2116	904	1212
Penny	1717	1796	1616	180	0.104834	2060	866	1194
Spar	2823	2960	2729	231	0.081836	3387	1492	1896
Spar	1897	2002	1800	202	0.106475	2277	961	1315
Spar	1296	1365	1253	112	0.086430	1555	683	872
Spar	1346	1414	1292	122	0.090612	1616	663	953
Interspar	1253	1314	1188	126	0.100559	1504	646	857
Eurospar	1312	1419	1208	211	0.160804	1575	675	900
Total Satisfied	23166	23513	22909	604	0.026072	27799	11919	15881
					0.0995803			

Fig. 40 "Total potential customers, critical demand" ***(AnyLogic, 2015)***

In the next two figures, the same elements as before are shown, but this time with the critical demand, the one used to model the flood and with the one the simulation is configures in all the scenarios from now on.

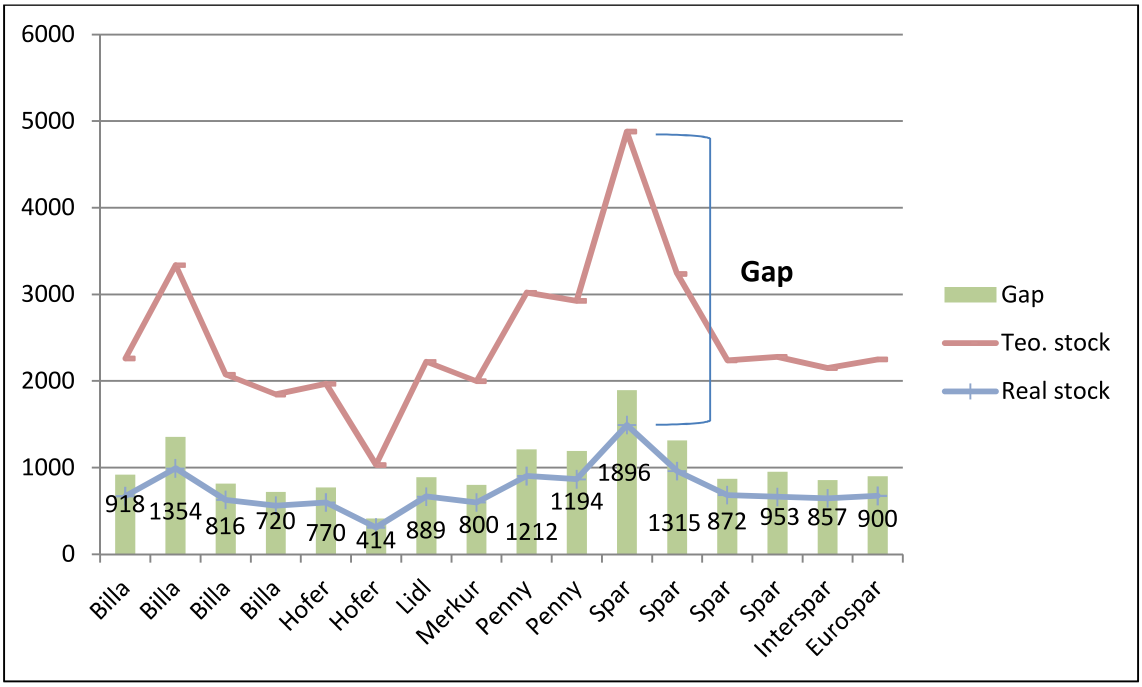


Fig. 41 "Theoretical stock – real stock; Gap" *(AnyLogic, 2015)*

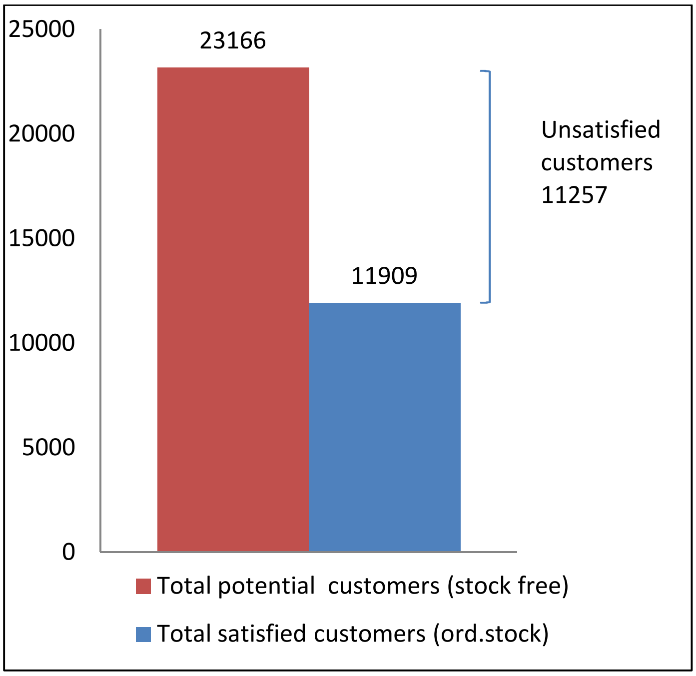


Fig. 42 "Unsatisfied customers" *(AnyLogic, 2015)*

As it can be observed in Fig.42, the number of unsatisfied costumers is increased in thousands in this case simulation; logical due to the enormous increase in the demand, direct effect of the flooding. In this graphic is perfectly demonstrated how incapable is the system to support the requirements of the customers in a critical, exceptional, situation. In the next two scenarios the main objective is to satisfy the maximum number of customers, with the resources available.

6.3 Scenario 2

In scenario 2, as explained before, the possibility of shipping resources from the truck station is possible. This option change the way of simulating and of course the results. In the next figures, the results depending on the number of trucks available are shown. Due to the possibility of taking resources from the station, a new parameter appears in the results charts. *"Forced resources"* is a parameter to seize the number of units from the station that are used. Normally, and due to the high volume of the demand, this parameter takes a negative value; that means the system needs more than the 3,000 units established as exceptional resources. This value is recorded and shown in the results charts. As in the two scenarios before, the results chart also record the average demand per store, the maximum and the minimum value during the runs (to get the variance), the variance in units and percentage, the theoretical store with the given conditions and the real ordinary stock set up for each store. The mean value of the variance or deviation of the values measured is also given, to achieve the certainty of the values.

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	1029	1166	671	495	0.481135	1235	671
Billa	991	991	991	0	0.000000	1189	992
Billa	652	888	628	260	0.398996	782	629
Billa	652	964	562	402	0.616736	782	563
Hofer	665	1004	598	406	0.610944	797	599
Hofer	644	747	518	229	0.355791	772	309
Lidl	716	957	666	291	0.406270	860	667
Merkur	698	1089	598	491	0.703072	838	599
Penny	904	904	904	0	0.000000	1085	904
Penny	901	1246	866	380	0.421966	1081	866
Spar	1491	1491	1491	0	0.000000	1789	1492
Spar	961	961	961	0	0.000000	1153	961
Spar	752	1104	683	421	0.560044	902	683
Spar	905	1141	662	479	0.529069	1086	663
Interspar	722	1097	646	451	0.624261	867	646
Eurospar	702	986	674	312	0.444214	843	675
Total Satisfied	13385	13824	13020	804	0.060069	16061	11919
Forced Resourc.	1287	1813	804	1009	0.783883	1545	3000
					0.388692		

Fig. 43 "Results with 1 operative truck" *(AnyLogic, 2015)*

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	955	1054	671	383	0.401162	1146	671
Billa	1037	1482	992	490	0.472724	1244	992
Billa	699	1083	629	454	0.649668	839	629
Billa	671	1031	563	468	0.697089	806	563
Hofer	817	1042	599	443	0.542107	981	599
Hofer	671	794	571	223	0.332385	805	309
Lidl	832	1113	667	446	0.535941	999	667
Merkur	798	1087	599	488	0.611738	957	599
Penny	975	1362	904	458	0.469744	1170	904
Penny	1142	1303	866	437	0.382814	1370	866
Spar	1492	1492	1492	0	0.000000	1790	1492
Spar	1032	1379	961	418	0.405039	1238	961
Spar	766	1058	683	375	0.489324	920	683
Spar	990	1152	663	489	0.493758	1188	663
Interspar	881	1128	646	482	0.547162	1057	646
Eurospar	839	1174	675	499	0.594820	1007	675
TOTAL Satisfied	14515	14993	14084	909	0.062624	17418	11919
Forced Resourc.	-462	-220	-600	380	0.061000	-554	3000
					0.427117		

Fig. 44 "Results with 2 operative trucks" ***(AnyLogic, 2015)***

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	934	1156	671	485	0.519272	1121	671
Billa	1235	1416	991	425	0.344180	1482	992
Billa	846	1073	628	445	0.525835	1016	629
Billa	748	1049	562	487	0.650832	898	563
Hofer	876	1080	598	482	0.550457	1051	599
Hofer	684	798	540	258	0.377343	820	309
Lidl	909	1142	666	476	0.523757	1091	667
Merkur	902	1098	598	500	0.554491	1082	599
Penny	1148	1356	904	452	0.393697	1378	904
Penny	1153	1335	866	469	0.406733	1384	866
Spar	1524	1853	1491	362	0.237547	1829	1492
Spar	1262	1457	961	496	0.393112	1514	961
Spar	772	1050	683	367	0.475389	926	683
Spar	1063	1148	942	206	0.193708	1276	663
Interspar	1016	1122	925	197	0.193950	1219	646
Eurospar	913	1149	674	475	0.520211	1096	675
Total satisfied	15984	16500	15662	838	0.052426	19181	11919
Forced Resourc.	-1765	-1226	-2175	949	0.537649	-2118	3000
					0.413922		

Fig. 45 "Results with 3 operative trucks" ***(AnyLogic, 2015)***

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	1020	1122	671	451	0.442117	1224	671
Billa	1374	1471	1289	182	0.132495	1648	992
Billa	998	1129	904	225	0.225410	1198	629
Billa	907	1062	813	249	0.274421	1089	563
Hofer	925	1081	770	311	0.336084	1110	599
Hofer	632	757	543	214	0.338413	759	309
Lidl	948	1126	667	459	0.484409	1137	667
Merkur	955	1078	774	304	0.318203	1146	599
Penny	1259	1398	965	433	0.343800	1511	904
Penny	1214	1330	1093	237	0.195266	1456	866
Spar	1607	1832	1492	340	0.211562	1929	1492
Spar	1292	1444	961	483	0.373734	1551	961
Spar	939	1106	683	423	0.450610	1126	683
Spar	1051	1145	932	213	0.202612	1262	663
Interspar	1017	1123	898	225	0.221239	1220	646
Eurospar	971	1110	675	435	0.448034	1165	675
Total satisfied	17110	17614	16652	962	0.056223	20533	11919
Forced Resourc.	-476	-2316	-3194	878	0.307591	-572	3000
					0.297901		

Fig. 46 "Results with 4 operative trucks" *(AnyLogic, 2015)*

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	1042	1166	946	220	0.211040	1251	671
Billa	1366	1479	1250	229	0.167676	1639	992
Billa	1031	1125	906	219	0.212340	1238	629
Billa	894	1037	813	224	0.250508	1073	563
Hofer	999	1073	922	151	0.151220	1198	599
Hofer	685	789	570	219	0.319793	822	309
Lidl	1003	1145	922	223	0.222293	1204	667
Merkur	952	1028	864	164	0.172351	1142	599
Penny	1319	1380	1164	216	0.163817	1582	904
Penny	1203	1325	1120	205	0.170407	1444	866
Spar	1903	1981	1751	230	0.120844	2284	1492
Spar	1360	1430	1252	178	0.130882	1632	961
Spar	1055	1174	936	238	0.225534	1266	683
Spar	1047	1155	967	188	0.179498	1257	663
Interspar	1032	1126	919	207	0.200493	1239	646
Eurospar	1079	1163	989	174	0.161220	1295	675
Total satisfied	17971	18238	17641	597	0.033220	21565	11919
Forced Resourc.	-3071	-2754	-3353	599	0.195027	-3686	3000
					0.182676		

Fig. 47 "Results with 6 operative trucks" *(AnyLogic, 2015)*

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	1045	1169	928	241	0.2306421	1254	671
Billa	1368	1487	1258	229	0.1673754	1642	992
Billa	988	1108	878	230	0.2328792	1185	629
Billa	964	1047	842	205	0.2127559	1156	563
Hofer	994	1097	858	239	0.2403547	1193	599
Hofer	670	792	560	232	0.3462217	804	309
Lidl	1049	1146	927	219	0.2088245	1258	667
Merkur	982	1076	874	202	0.2057026	1178	599
Penny	1246	1354	1165	189	0.1517407	1495	904
Penny	1264	1360	1146	214	0.1693038	1517	866
Spar	1877	1985	1759	226	0.1203816	2253	1492
Spar	1356	1456	1219	237	0.174767	1627	961
Spar	1060	1180	983	197	0.1858172	1272	683
Spar	1028	1160	914	246	0.2393419	1233	663
Interspar	993	1105	901	204	0.2055321	1191	646
Eurospar	1041	1169	946	223	0.2141797	1249	675
Total satisfied	17924	18546	17291	1255	0.0700171	21509	11919
Forced Resources	-3024	-2399	-3649	1250	0.4133598	-3629	3000
					0.210511		

Fig. 48 "Results with 8 operative trucks" ***(AnyLogic, 2015)***

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	1053	1156	958	198	0.188099	1263	671
Billa	1392	1477	1262	215	0.154424	1671	992
Billa	991	1103	920	183	0.184662	1189	629
Billa	950	1040	817	223	0.234669	1140	563
Hofer	986	1092	896	196	0.198728	1184	599
Hofer	665	778	539	239	0.359300	798	309
Lidl	1054	1143	919	224	0.212597	1264	667
Merkur	982	1096	858	238	0.242363	1178	599
Penny	1296	1396	1169	227	0.175142	1555	904
Penny	1226	1352	1116	236	0.192567	1471	866
Spar	1814	1925	1752	173	0.095379	2177	1492
Spar	1347	1453	1250	203	0.150746	1616	961
Spar	1032	1155	958	197	0.190824	1239	683
Spar	994	1082	919	163	0.163984	1193	663
Interspar	1020	1140	905	235	0.230310	1224	646
Eurospar	1087	1172	979	193	0.177612	1304	675
Total satisfied	17889	18279	17555	724	0.040472	21466	11919
Forced Resourc.	-2998	-2669	-3394	725	0.241828	-3598	3000
					0.190762		

Fig. 49 "Results with 10 operative trucks" ***(AnyLogic, 2015)***

Analysing the results, it is demonstrated that the more number of trucks used does not mean the more customers satisfied. The maximum number of satisfied customers is reached with six operative trucks. Since then, the number of satisfied customers stays constant, even though small deviations are observed, even decreasing, but that is due to the simulation deviations, as happened before. This total number of satisfied customers depending on the number of disposed trucks is clearly observed in Figure 49.

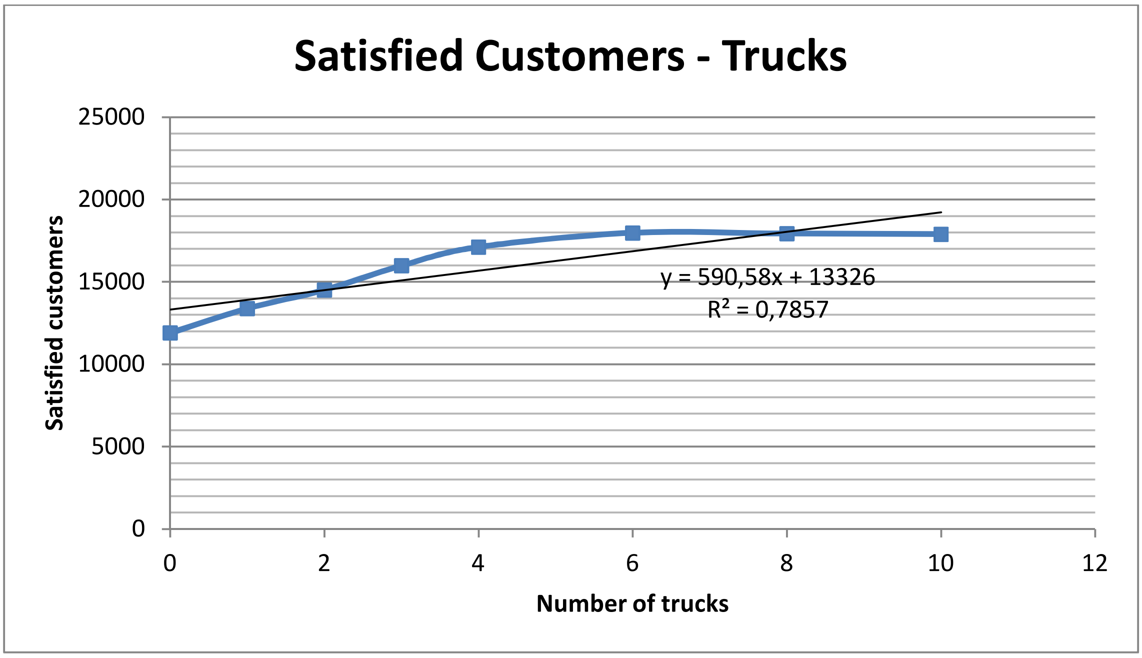


Fig. 50 "Satisfied customers – number of trucks" ***(AnyLogic, 2015)***

As it is observed, the maximum value is reached in the point six, which means the use of six trucks. In the table appears also the linear regression of the curve. It is not surprising, according to the curve, that the value of R^2 is that high, R^2 = 0.7857, which means that there is a quite strong relation between the satisfied customers and the number of truck in use. According to this result, in scenario 2, the most appropriate number of truck disposed to get the maximum satisfied number of customers is six. This is the result for the simulation problem in this case. In addition to this result, as six is the number of trucks with which the satisfied number of customers is the highest, it is also the value with the highest average demands for each store. In Figure 50 this fact can be observed.

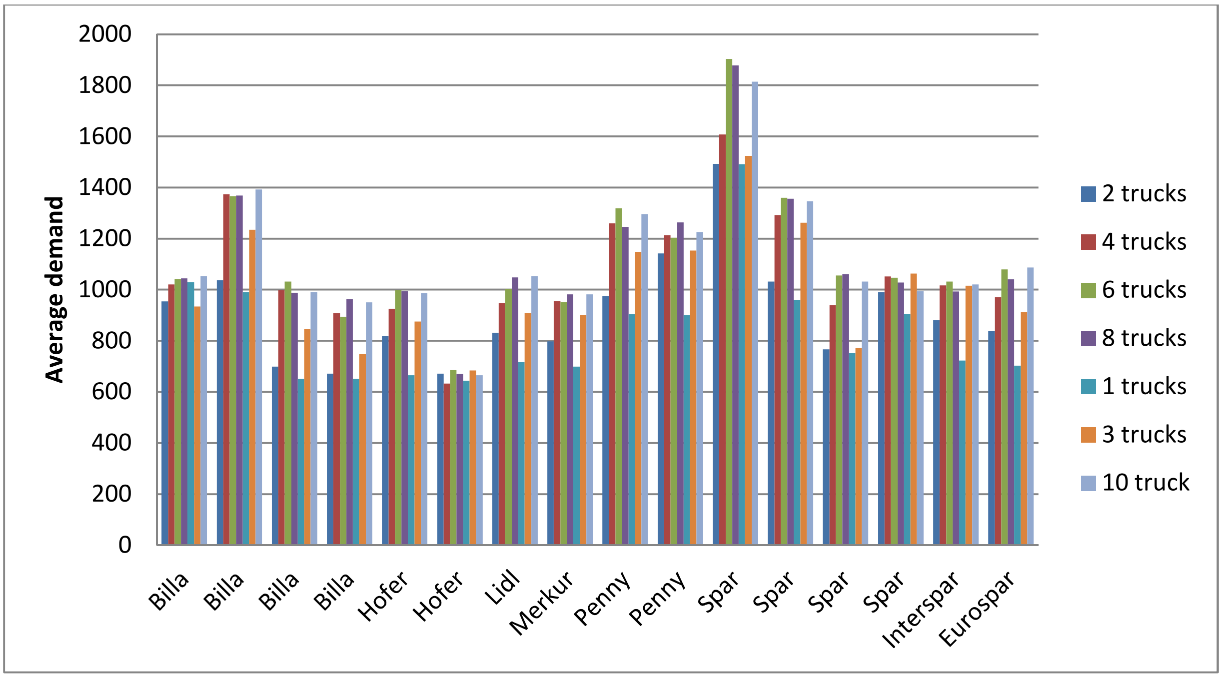
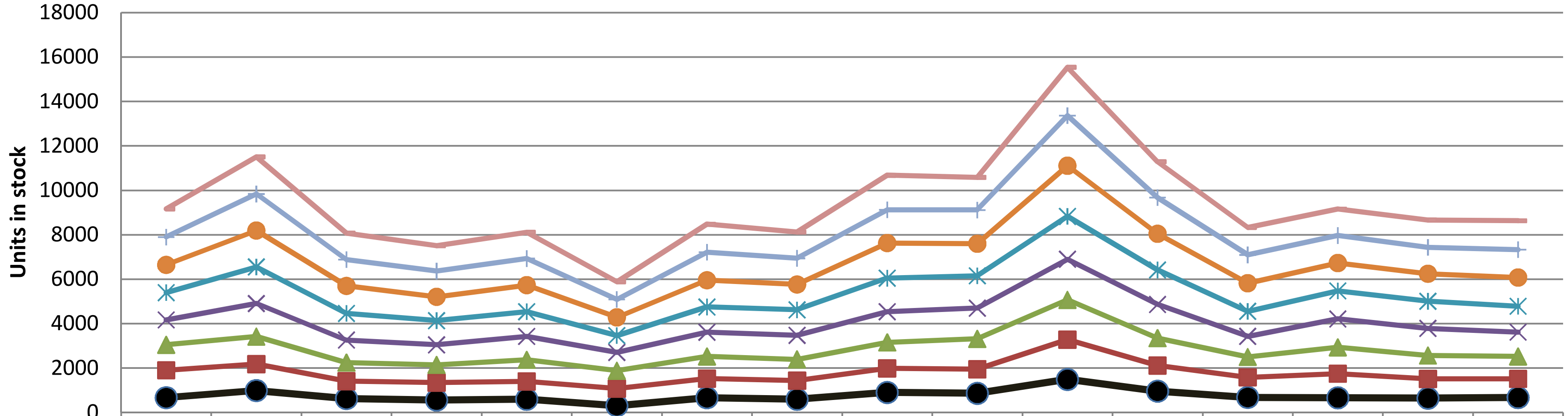


Fig. 51 "Average demand per store depending on the number of trucks" ***(AnyLogic, 2015)***

According to this last graphic, the stock per store is also an important subject of study. As it is logical, as more demand in each store, the more stock it is required and so the more gap between the ordinary stock available in each store and the theoretical required one. This result can be observed in the next graphic, where the real stock and the theoretical one depending on the number of trucks are represented. The gap between them is also easily recognised.

In addition to this, in Figure 52 an important parameter is studied. The "*forced resources*" are, as it was explained before, the number of extra units required by the number of satisfied customers reached. This value is important to take in account because it provides the user idea of the value of the exceptional stock needed in the truck station to, at least, satisfy the maximum number of customers, already calculated. It is a very important parameter to model the system in the reality. The results are quite closed to the reality and easy to understand. In the case where only one truck is displayed, during the 12 hours of simulation, the truck has not got enough time to supply all the stores and that is why the number of forced resources is positive and quite high: 1,287. In the rest of the cases, as the number of truck is increased, more shipments are displayed and the more forced resources needed. The maximum value, as expected, is reached in the point of maximum satisfied demand.



	Billa	Billa	Billa	Billa	Hofer	Hofer	Lidl	Merkur	Penny	Penny	Spar	Spar	Spar	Spar	Interspar	Eurospar
Teo.Stock - 10 trucks	1263	1671	1189	1140	1184	798	1264	1178	1555	1471	2177	1616	1239	1193	1224	1304
Teo.Stock - 8 trucks	1254	1642	1185	1156	1193	804	1258	1178	1495	1517	2253	1627	1272	1233	1191	1249
Teo.Stock - 6 trucks	1251	1639	1238	1073	1198	822	1204	1142	1582	1444	2284	1632	1266	1257	1239	1295
Teo.Stock - 4 trucks	1224	1648	1198	1089	1110	759	1137	1146	1511	1456	1929	1551	1126	1262	1220	1165
Teo.Stock - 3 trucks	1121	1482	1016	898	1051	820	1091	1082	1378	1384	1829	1514	926	1276	1219	1096
Teo.Stock - 2 trucks	1146	1244	839	806	981	805	999	957	1170	1370	1790	1238	920	1188	1057	1007
Teo.Stock - 1 truck	1235	1189	782	782	797	772	860	838	1085	1081	1789	1153	902	1086	867	843
Real stock	671	992	629	563	599	309	667	599	904	866	1492	961	683	663	646	675

Fig. 52 "Theoretical stock – real stock; depending on the number of trucks" ***(AnyLogic, 2015)***

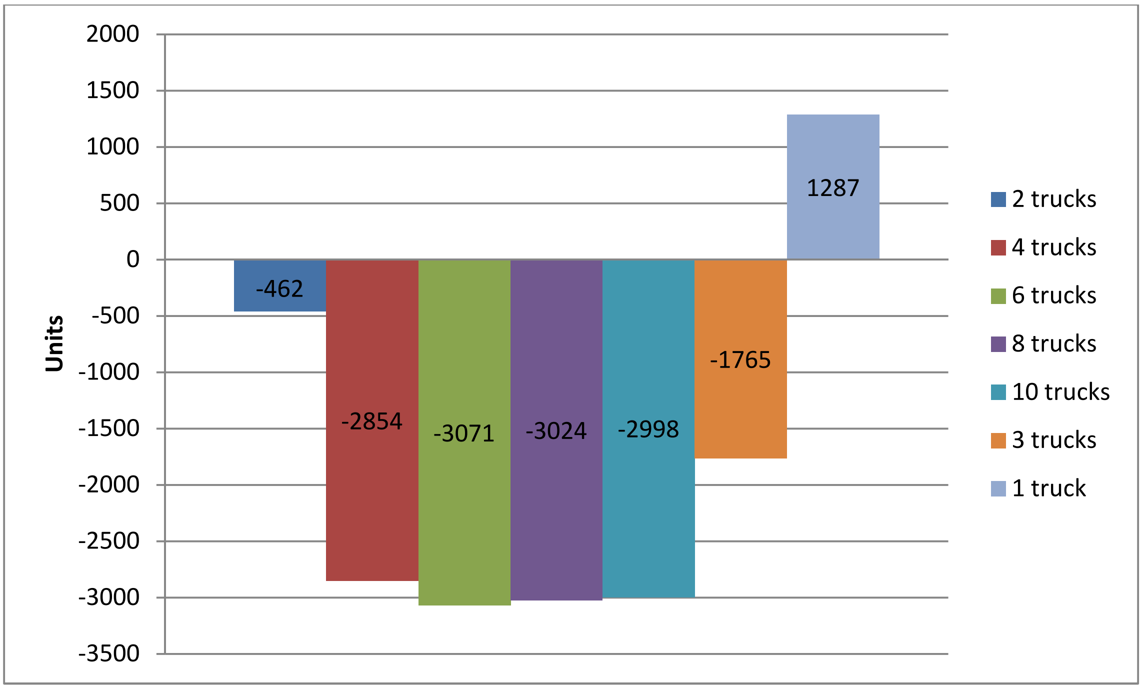


Fig. 53 "Forced resources depending on the number of trucks" ***(AnyLogic, 2015)***

6.4 Scenario 3

The third scenario represents the most closed situation to a real one, where all the situations individually studied happened together, in addition of the closure of one of the main bridges that connect both populations. The results obtained are treated in the same way as it was followed in scenario 2. The charts with the results, depending on the number of trucks, are the following:

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	671	671	671	0	0.000000	805	671
Billa	1046	1453	991	462	0.441885	1255	992
Billa	694	1124	628	496	0.714656	833	629
Billa	733	1055	562	493	0.672872	879	563
Hofer	704	1096	598	498	0.706985	845	599
Hofer	660	802	308	494	0.748485	792	309
Lidl	782	1144	666	478	0.610941	939	667
Merkur	736	1048	598	450	0.611015	884	599
Penny	932	1295	904	391	0.419672	1118	904
Penny	989	1356	866	490	0.495230	1187	866
Spar	1491	1491	1491	0	0.000000	1789	1492
Spar	989	1311	961	350	0.354065	1186	961
Spar	710	1036	683	353	0.497099	852	683
Spar	662	662	662	0	0.000000	794	663
Interspar	718	1063	646	417	0.580942	861	646
Eurospar	750	1151	674	477	0.635627	901	675
Total satisfied	13268	13553	12838	715	0.053891	15921	11919
Forced resourc.	1419	1660	1036	624	0.439672	1703	3000
					0.443502		

Fig. 54 "Results with 1 operative truck" ***(AnyLogic, 2015)***

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	671	671	671	0	0.000000	805	671
Billa	1191	1487	991	496	0.416373	1429	992
Billa	823	1108	628	480	0.583516	987	629
Billa	802	1041	562	479	0.596929	963	563
Hofer	796	1081	598	483	0.606997	955	599
Hofer	687	796	566	230	0.334808	824	309
Lidl	845	1165	666	499	0.590868	1013	667
Merkur	837	1082	598	484	0.578090	1005	599
Penny	1034	1387	904	483	0.467190	1241	904
Penny	1076	1352	866	486	0.451522	1292	866
Spar	1491	1491	1491	0	0.000000	1789	1492
Spar	1125	1362	961	401	0.356419	1350	961
Spar	802	1065	683	382	0.476238	963	683
Spar	662	662	662	0	0.000000	794	663
Interspar	878	1107	646	461	0.525129	1053	646
Eurospar	840	1132	674	458	0.545030	1008	675
Total satisfied	14560	14907	13992	915	0.062842	17472	11919
Forced resourc.	-40	307	-704	1011	25	21	3000
					0.366220		

Fig. 55 "Results with 2 operative trucks" *(AnyLogic, 2015)*

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	671	671	671	0	0.000000	805	671
Billa	1283	1486	991	495	0.385863	1539	992
Billa	939	1123	628	495	0.526955	1127	629
Billa	863	1041	562	479	0.555015	1036	563
Hofer	924	1087	598	489	0.529335	1109	599
Hofer	672	795	537	258	0.384020	806	309
Lidl	957	1128	666	462	0.482557	1149	667
Merkur	954	1098	598	500	0.523933	1145	599
Penny	1108	1365	904	461	0.415960	1330	904
Penny	1176	1330	866	464	0.394679	1411	866
Spar	1504	1804	1491	313	0.208178	1804	1492
Spar	1216	1457	961	496	0.407761	1460	961
Spar	851	1168	683	485	0.570159	1021	683
Spar	662	662	662	0	0.000000	794	663
Interspar	1019	1144	646	498	0.488676	1223	646
Eurospar	1022	1165	674	491	0.480637	1226	675
Total satisfied	15821	16447	15073	1374	0.086848	18985	11919
Forced resourc.	-1614	-1179	-2273	1094	-0.677718	-1937	3000
					0.320159		

Fig. 56 "Results with 3 operative trucks" *(AnyLogic, 2015)*

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	690	849	671	178	0.257971	828	671
Billa	1361	1487	1245	242	0.177826	1633	992
Billa	976	1089	628	461	0.472143	1172	629
Billa	933	1060	832	228	0.244383	1120	563
Hofer	966	1097	841	256	0.265043	1159	599
Hofer	661	767	568	199	0.301077	793	309
Lidl	1054	1158	931	227	0.215419	1265	667
Merkur	966	1098	848	250	0.258928	1159	599
Penny	1271	1404	1150	254	0.199849	1525	904
Penny	1229	1329	1122	207	0.168479	1474	866
Spar	1724	1960	1491	469	0.272035	2069	1492
Spar	1340	1460	1213	247	0.184389	1607	961
Spar	1025	1169	683	486	0.474368	1229	683
Spar	695	936	662	274	0.394358	834	663
Interspar	997	1130	886	244	0.244616	1197	646
Eurospar	1052	1171	944	227	0.215706	1263	675
Total satisfied	16939	17642	15767	1875	0.110693	20326	11919
Forced resourc.	-2923	-2036	-3462	1426	0.487802	-3508	3000
					0.274727		

Fig. 57 "Results with 4 operative trucks" ***(AnyLogic, 2015)***

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	1019	1162	768	394	0.386654	1223	671
Billa	1361	1487	1246	241	0.177091	1633	992
Billa	966	1100	891	209	0.216356	1159	629
Billa	947	1055	812	243	0.256546	1137	563
Hofer	974	1089	848	241	0.247545	1168	599
Hofer	697	802	553	249	0.357020	837	309
Lidl	1060	1145	925	220	0.207492	1272	667
Merkur	977	1081	854	227	0.232353	1172	599
Penny	1270	1401	1165	236	0.185827	1524	904
Penny	1260	1366	1121	245	0.194475	1512	866
Spar	1862	1986	1671	315	0.169217	2234	1492
Spar	1337	1445	1214	231	0.172759	1605	961
Spar	1065	1183	862	321	0.301295	1278	683
Spar	998	1159	824	335	0.335577	1198	663
Interspar	1011	1144	896	248	0.245418	1213	646
Eurospar	1029	1156	854	302	0.293569	1234	675
Total satisfied	17833	18430	16498	1932	0.108340	21399	11919
Forced resourc.	-3028	-2534	-3553	1019	0.336490	-3634	3000
					0.245779		

Fig. 58 "Results with 6 operative trucks" ***(AnyLogic, 2015)***

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	1056	1167	944	223	0.211126	1267	671
Billa	1351	1474	1242	232	0.171765	1621	992
Billa	995	1125	886	239	0.240085	1195	629
Billa	951	1059	824	235	0.246994	1142	563
Hofer	987	1058	854	204	0.206729	1184	599
Hofer	666	804	537	267	0.401118	799	309
Lidl	1036	1126	916	210	0.202609	1244	667
Merkur	973	1098	853	245	0.251778	1168	599
Penny	1283	1397	1158	239	0.186282	1540	904
Penny	1240	1364	1121	243	0.195955	1488	866
Spar	1879	1989	1745	244	0.129881	2254	1492
Spar	1320	1454	1213	241	0.182626	1584	961
Spar	1055	1168	935	233	0.220853	1266	683
Spar	1017	1124	945	179	0.176084	1220	663
Interspar	1022	1140	896	244	0.238776	1226	646
Eurospar	1033	1174	926	248	0.240050	1240	675
Total Satisfied	17864	18338	16990	1348	0.075460	21437	11919
Forced resourc.	-2971	-2101	-3439	1338	0.450366	-3565	3000
					0.223808		

Fig. 59 "Results with 8 operative trucks" ***(AnyLogic, 2015)***

Store	Average	Max. Val.	Min.Val.	Max.dev.	% Max.dev.	Teo.Stock	Re. Stock
Billa	1051	1164	923	241	0.229271	1261	671
Billa	1363	1487	1243	244	0.179033	1635	992
Billa	1002	1116	895	221	0.220471	1203	629
Billa	931	1050	820	230	0.247099	1117	563
Hofer	986	1079	855	224	0.227171	1183	599
Hofer	679	800	560	240	0.353628	814	309
Lidl	1025	1152	919	233	0.227353	1230	667
Merkur	989	1097	860	237	0.239646	1187	599
Penny	1282	1397	1165	232	0.180979	1538	904
Penny	1254	1366	1116	250	0.199311	1505	866
Spar	1851	1961	1752	209	0.112892	2222	1492
Spar	1343	1458	1211	247	0.183982	1611	961
Spar	1074	1182	936	246	0.229119	1288	683
Spar	1048	1157	933	224	0.213643	1258	663
Interspar	1050	1145	942	203	0.193289	1260	646
Eurospar	1070	1169	937	232	0.216912	1283	675
Total satisfied	17998	18536	17179	1357	0.075398	21597	11919
Forced resourc.	-3098	-2283	-3627	1344	0.433867	-3717	3000
					0.220170		

Fig. 60 "Results with 10 operative trucks" ***(AnyLogic, 2015)***

Observing the results obtained in this scenario, it sorts out that they are quite similar to those in scenario 2. It seems that the closure of one of the two bridges connecting Mautern with Krems does not really affect so directly to the number of total satisfied customers. This phenomenon can be explained because of the existence of a railway crossing the river in the other bridge, the most important one. Thanks to this, the trucks can rapidly ship the stock so that the stores can have the same stock available as if the other bridge was opened. Another reasons to sustain this consistency of the total number of satisfied customer despite the closure of one of the bridges, is that the most of the stores are located in Krems an der Donau, and also does the population so the biggest amount of customers are not affected with the closure.

In the next graph, Figure 60, the total number of satisfied customers depending on the number of trucks displayed can be observed.

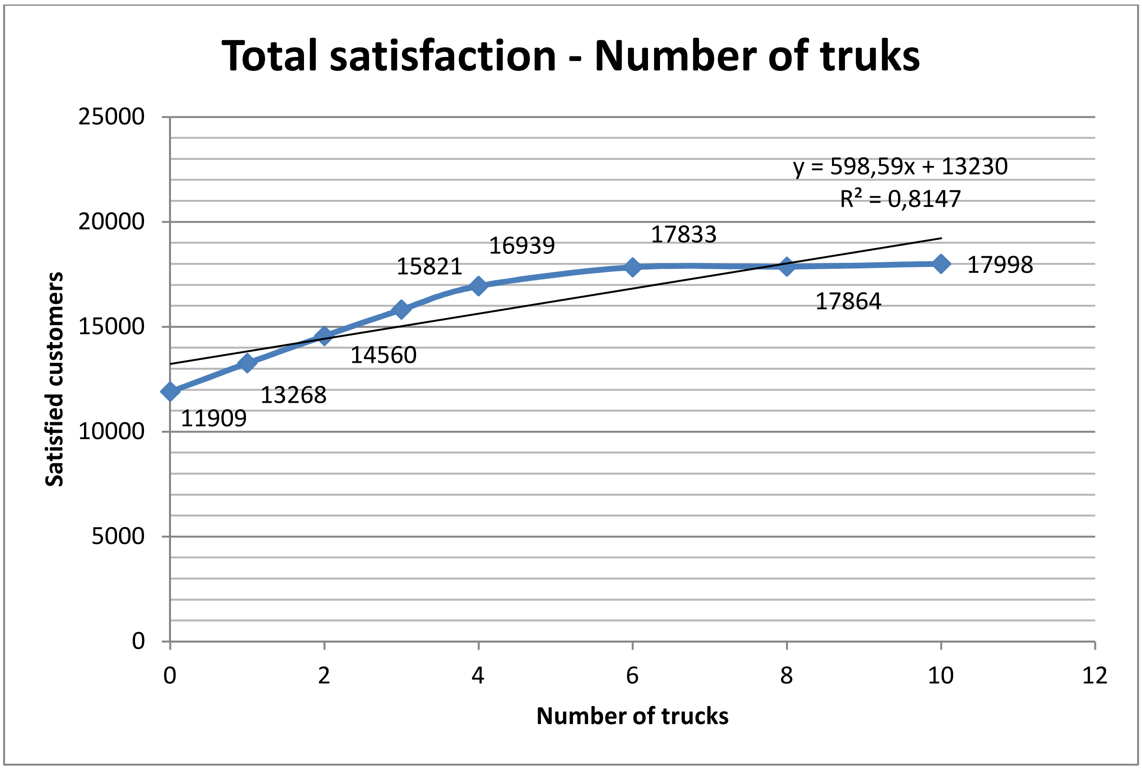


Fig. 61 "Satisfied customers – number of trucks" ***(AnyLogic, 2015)***

In this case, it can be observed that, despite the fact that the total number of satisfied customers with six, eight or ten trucks is almost the same; the highest number is achieved with the display of ten trucks. In this scenario then, the solution to the simulation problem will be ten trucks with a total number of satisfied customers of 17,998. It is also deduced form the charts, and it happened the same in scenario 2, that the forced resources are always negative, except in the case that only one car is displayed. The reason is the same as in scenario 2, with only one car the number of possible shipments performed during the simulation time is less than with more trucks. The consequence of this lack of shipments is the running out of stock in the distribution centres and so the less satisfied customers achieved. This is the reason why the graphic has this curved form. Studying the average demands per store, as it happened in the rest of scenarios, as less available trucks to ship stock, which means less available stock in the stores and, then, less satisfied customers, the average demand per store also decrease. This observation is deduced from the chart above.

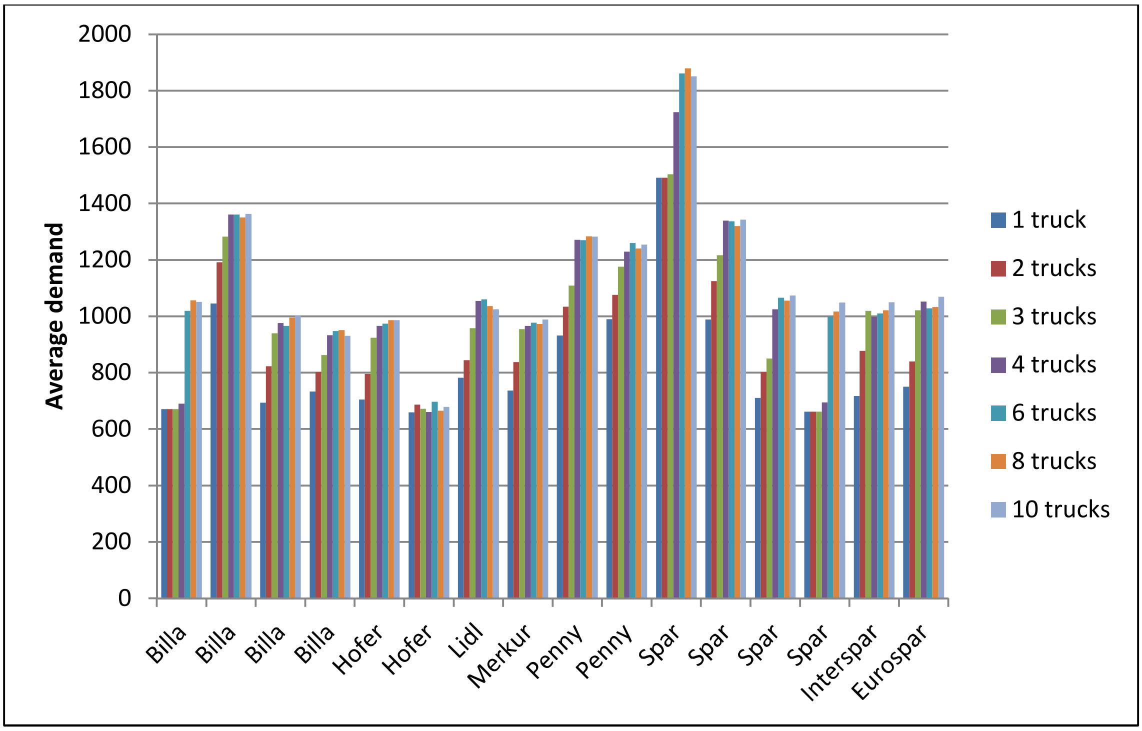


Fig. 62 "Average demand per store depending on the number of trucks" ***(AnyLogic, 2015)***

In this graphic is also observed that, despite the fact that the maximum number of satisfied customers is reached with ten trucks, the maximum value of an individually average demand per store is reached with eight trucks and in the first Spar. That is just something anecdotic, because the total average demand obtained is higher with ten trucks.

Analysing the forced resources, the conclusions are very similar to those obtained in scenario 2. Only in the first case, when one truck is display, the, at first established 3,000 exceptional stock units are enough to attend the shipments and that is why the forced resourced are equal to 1,419. From this point, as the number of trucks increases also does (always negative) the value of the forced resources. The maximum value is reached, once again, when the average demand is the highest, and so does the number f satisfied customers. In this case 10 trucks, which carry a number of -3,098 forced resources. This value of the forced resources, written in stock units, means a necessity of 3000 + 3098 = 6,098 exceptional stock units in the truck station.

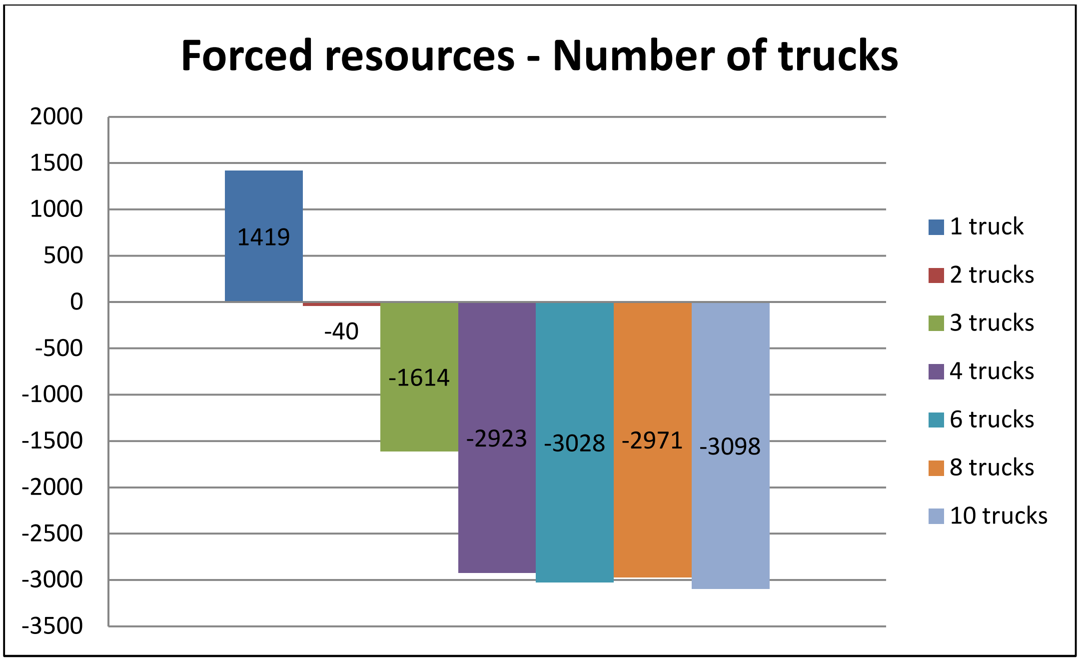


Fig. 63 "Forced resources depending on the number of trucks" ***(AnyLogic, 2015)***

7. DISCUSSION OF THE RESULTS

In this chapter, the results of the simulation are analysed and discussed. In a first look through the results, what can be more disappointing is the fact that the total number of satisfied customers, in the best case, is 17,998, far from the total demanding customers, or what it is also called as *"total potential customers"* in this document, that is obtained in the scenario 1 with a value of: 23,166. As it can be observed, even in the best case, there is a difference, between the demand and the cover of the distribution centres, up to 5,168 customers. This result clearly shows that, with the conditions simulated, and is not possible to afford a flooding situation like it has been simulated. Not with the resources established as constraints of this simulation. Nevertheless, the number of unsatisfied customers, always referring to the best case, represents less than the 20% of the total demanding customers, which is quite acceptable. One of the most probable causes to the existence of unsatisfied customers is the time parameter of the simulation. Trying to make a better approach to the problem and to obtain better conclusions from the results, each scenario is going to be analysed separately.

7.1 Scenario 0

The first simulated scenario, or what in this document is called "*Scenario 0"*, is only used to obtain the ordinary values of the demand with the objective of calculating and establishing the ordinary stock necessary in each store so to afford the demand in ordinary, normal, conditions. Thanks to this first simulation, the stock for each store is calculated; this option is closer to the reality than to establish a general stock for all the stores. As it has been explained and can be also observed in the results charts, this stock is established for all the scenarios. The total number of satisfied customers obtained is 12,251. This value, which is the same as the total demand of the whole stores (because the simulation is run with unlimited stock), sizes the normal daily demand in 12,251. The stock is set then summing the 20% security stock. With this established ordinary stock, the daily demand is ensured. All the values measured in this scenario have a variance of 15.9819% what means that the values can vary in maximum a 15.9819% from the obtained average.

7.2 Scenario 1

In the second simulated scenario, called "Scenario 1", the number of distribution centres available is reduced in three due to the flooding event. Restricted to these conditions, the first simulation is run with objective of observing how the ordinary demand changes when there is a lower number of distribution centres available. This means that each customer is programmed still to one only once per day to the store (event still triggered once per day). Comparing to the first scenario, the number of total satisfied customers is almost the same: 12,223 (little variation due to the variability of the results; in the real world the daily demand is never the same) but the average demand per store changes due to the fact that there are less stores available. In this scenario, the variance of the measures varies from 0% to 14.1124% with an average value of 9.2522%.

Figure 64 shows the variation per store within the ordinary demand. In the next graphic, Fig.65, the average demand per store with a critical demand is also shown. As it has been explained, the critical demand consists on doubling the triggered frequency of the *generateDemand* event that controls the necessity of each customer. In these following figures, the differences and variations between these two scenarios can be easily observed.

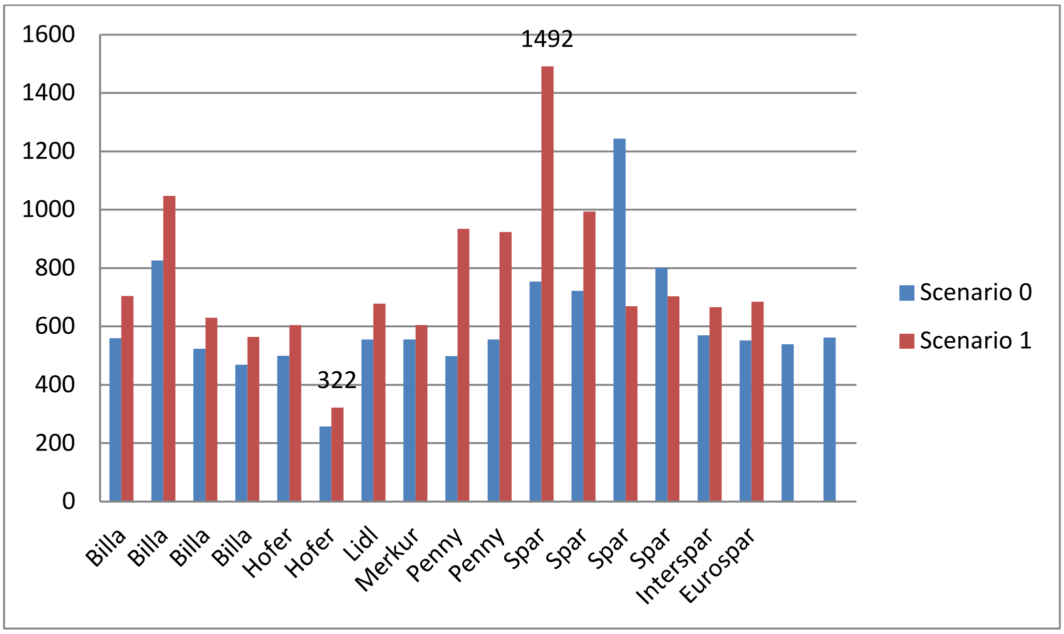


Fig. 64 "Average demand per store" ***(AnyLogic, 2015)***

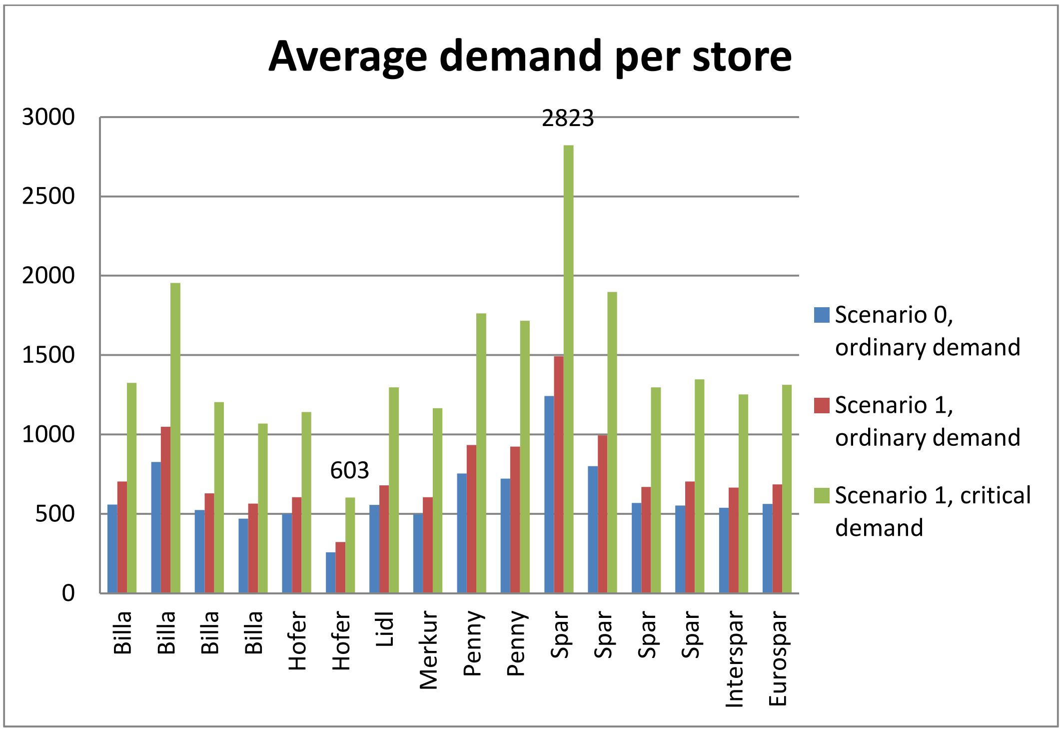


Fig. 65"Average demand per store" ***(AnyLogic, 2015)***

As it can be observed, when the flooding occurs and the demand increases, the average demand per store is much higher in both, minimum and maximum values. These two graphics are very useful to see how the demand changes and then, to decide how to act in a situation like this.

A bit disappointing observation is that, even in the simulation with critical demand and non-limited stock as parameters, the total number of satisfied customers does no reach the total number of potential customers, population, set in the system: 26,556. This phenomenon can be explained due to the fact that the simulation is configured to last 12 hours, until 6 pm. A customer which *generateDemand* triggers at 5:59 pm has not time enough to arrive to the store so when the simulation ends the satisfaction variable is still FALSE and then, it appears as *unsatisfied*. That is the cause of this gap between the total demand and the satisfied customers even when the simulation is run without limit of stock.

7.3 Scenario 2

In this third scenario, "*Scenario 2",* the situation changes, as the option to ship extra stock from the truck station, set up only in disaster situation, is introduced. The logical thing, taking in account the results obtained in the first two scenarios, is that the total number of satisfied customers increases as well as it has done the demand. The results confirmed this suspect, even in the worst case, when there is only a truck available to perform the shipments, the number of satisfied customers and so the average demand per store is superior to that in the first two scenarios (with restrictions of stock of course). The minimum value of total number of satisfied customers is obtained with one available truck and it is 13,384. On the other hand, the maximum, obtained with 6 displayed trucks, is 17,971. Another important aspect to analyze is the variance of the results. It has been observed in scenarios 2 and, afterwards scenario 3 that, as the demand increases, also does the variance of the results, which reaches in some case 40%, a value much higher than the values obtained in scenarios 0 and 1. It is also observed that this variance is reduced, and then the confidence of the results increases, as the number of trucks is increased. In consequence, the minimum value is reached in the run with 6 trucks and it is set in 18.1190%. The maximum value of variance is obtained with 42.70%. The average value of variance in the measures is then 30.0985%.

7.4 Scenario 3

In the fourth different simulated scenario, called "*Scenario 3*", the results are very similar to those obtained in scenario 2, despite the added event of the closure of one of the bridges. Afterwards, in Fig.66, the results compared to those in scenario 2 are analysed. In this case the variances are also similar to those in scenario 2 and the tendency the same, as the number of displayed trucks increases, so does the confidence of the measures. The average value in this case is 29.9195%.

Comparing scenarios 2 and 3 an interesting fact is that the total number of satisfied customers in scenarios 2 and 3 is almost the same, despite the fact that in scenario 3, one of the connections from Mautern, where the truck station is located, to Krems is closed. As it was already advised, this phenomenon can be due to the existence of another big bridge, bigger than the closed one and with a railway on it. This connection eases the transport by truck to the point that there is almost no difference. In addition to this, another potential reason to this equality is the fact that in Mautern exits also couple of stores so that the customers living in this location have no necessity to cross the river and move to Krems. It is true that some of them are forced to walk for a longer time but that does not really affect the number of satisfied customers in the end. Furthermore, the whole maximum number of satisfied customers is reached in scenario 3, with 17,998 satisfied customers. A part from this first observation, with the objective of getting a deeper approach to the results, in Figure 64, scenarios 2 and 3 are compared in each of the cases simulated.

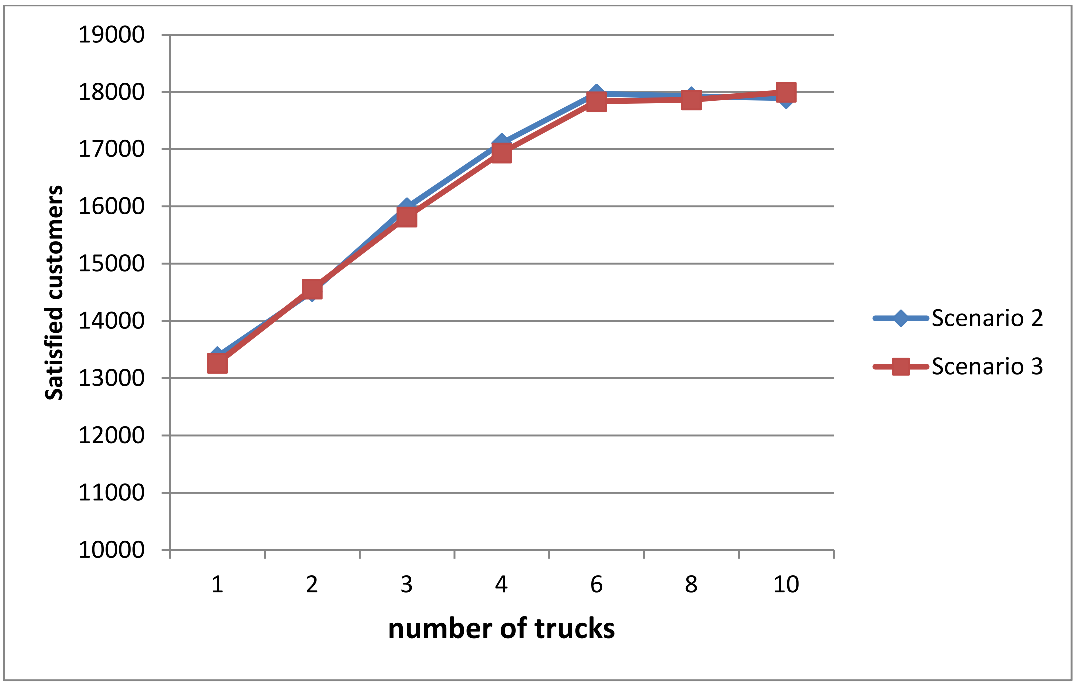


Fig. 66 "Scenario 2 - Scenario 3" ***(AnyLogic, 2015)***

As it can be observed in Figure 64, the behaviour of the number of satisfied customers in both scenarios is almost the same. However, it is observed that the results in scenario 2 are always a bit higher. That is very interesting and, due to the setting of each scenario, perfectly expected. This little gap is due to the closure of the road in scenario 3. As worst as the scenario gets, and even if it has been already demonstrated that the closure is not so hard related with the satisfaction, it is logical to have lees number of total satisfied customers. That is why somehow in some of the results the variance between the outputs is big, even unacceptable in other kind of experiments.

8. CONCLUSIONS

This final master thesis has intended firstly, to show and explain the connections and cooperation among the international organs in a disaster situation. This task is not easy due to the complexity of the relations and the difficult accessible data. In the next step the Austrian disaster relief and organisation is described. In this step the information was more accessible and even a simulation of disaster was attended so to put on with the subject. A case study was analysed and the results are more than positives in what the disaster relief concerns.

The first theoretical part introduces important information to a better understanding of the decision chain in a disaster situation; in both, international and Austrian level. Most of the entities have been studied and their inside organizations showed. Diagrams detailing the decision chain and guidelines in case of a disaster situation have also been displayed. In relation with this topic, the document provides important information.

In the other big part of the thesis, the simulation, the cities of Krems and Mautern an der Donau were taken as location to develop the flooding phenomenon. Those locations were carefully selected, due to the historical study of events and to the availability of data. Different simulation scenarios are run out, all with the main objective of minimizing the number of unsatisfied customers in a critical situation. The aim of this final master thesis was to get deeper in an unstudied field, like it is the decision chains and logistic in disaster management, with the simulation of one scenario as big sustaining point. The conclusion is very positive, with many new data and knowledge around the topic given.

In what concerns to the simulation, the main objective was to establish the logistic and stock guidelines to guarantee the highest number of satisfied customers. Observing the results, a detailed study in different situations has been displayed, obtaining almost the real value (scenario 3 is the closest to the real situation) of the number of trucks and the number of extra units necessary to satisfy this objective. The results are quite interesting although it can appears to be that within the given circumstances and constraints, it is not possible to satisfy all the demand. This affirmation can be justified concerning to the time of the simulation; not all the customers have got enough time to arrive to the distribution centre before the simulation stops. Therefore, the extra stock (*extraordinary* or *exceptional* as they are called in this document) is exactly established for each situation. This result provides very useful information and a great approach to that, otherwise, would not be possible to reach.

Nevertheless the information and results obtained in each of the four scenarios is very useful to get an approach to the real necessities in case of flood in this location and, in a more extended way, to any of the location wanted to simulate; it is only necessary to change population and distribution centres parameters. Always taking into account the assumptions assumed for the simulation model (e.g.: each customer takes only one stock unit each time). All the technical information of the simulation is detailed in the first annex, Annex I, attached with this thesis. This extra document includes all the technical aspects and characteristics of the simulation and it is provided by the simulation software, AnyLogic.

As it is already explained, the results are clear and confident and they established the main principles, guidelines and parameters to deal with a flooding event. It is important to repeat, once again before ending, the importance of the study of this phenomenon: flooding events are increasing very quickly. In addition to this, a second annex, Annex II, is attached to this document with a little review of the last flooding episode in Navarra in the end of February 2015.

9. BIBLIOGRAPHY

Adonis CE (Community Edition) (2015), available at: http://www.es.adonis-community.com/ (accessed 20 November 2014).

Allen, B. (1984), "Trip Distribution Using Composite Impedance Transportation Research Record" pp. 118–127.

AnyLogic Company (2015), *"About us",* available at: http://www.anylogic.com/about-us (accessed 25 Mars 2015).

AnyLogic Company (2015), "AnyLogic *Features",* available at: http://www.anylogic.com/about-us (accessed 25 Mars 2015).

AMT der Niederösterreichischen Landesregierung (2014), *"Hochwasser 2013: Analysen, Schlussfolgerungen, Massnahmen",* Gruppe Wasser, St. Pölten.

Ballesteros L. (2008), *"What determines a disaster?",* 54 Pesos.

Ben-Tal A., El Ghaoui L. and Nemirovski A. (2009), "Robust Optimization", Princeton series in Applied Mathematics 539pp.

Berariu R., Fikar C., Gronalt M. and Hirsch P. (2015), *"Understanding the impact of cascade effects of natural disasters on disaster relief operations",* Institute of Production and Logistics, University of Natural Resources and Life Sciences, Feistmantelstrasse 4, 1180 Vienna, Austria.

BMLFUW (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft), "*Elektronische Daten zu den Ausgaben des Bundes, übermittelt von der Abteilung VII/5, Stand 5. 10. 2006"*, mimeo, 2006, Vienna.

Blöschl G., Nester T., Komma J., Parajka J., and Perdigão R.A.P., Institute of Hydraulic Engineering and Water Resources Management, Vienna University of Technology, *"The June 2013 flood in the Upper Danube Basin, and comparisons with the 2002, 1954 and 1899 floods",* Vienna, Austria, July 2013.

BOC Group (2015), *"Products: ADONIS",* available at: http://www.boc-group.com/products/adonis/ (accessed 25 November 2014).

Borshchev A. (January 2014), "The Big Book of Simulation Modeling: Multimethod Modeling with AnyLogic 6", AnyLogic; North America.

Bundesministerium für Inneres , March 2011. "Koordination von Krisen und Katastrophenschutz Management, Fachgespräch mit Innenministerin Maria Fekter, 24 Mary 2011".

Business Dictionary (2015), "Coordination", available at: http://www.businessdictionary.com/definition/coordination.html (accessed 28 Februar 2015).

European Commission (2015), , available at http://ec.europa.eu/index_en.htm (accessed 12 January 2015).

Grigoryev I. (October 2012), "AnyLogic *6 in Three Days: A Quick Course in Simulation Modelling",* AnyLogic, North America.

Grimm, Volker; Railsback, Steven F. (2005), "*Individual-based Modeling and Ecology"*, Princeton University Press. p. 485.

Habersack H., Bürgel J., Petraschek A., Stiefelmeyer H., (2005), "*Analysis of the Floods of August 2002 – Flood Risk",* Federal Ministry of Agriculture and Forestry, Environment and Water Management, Vienna.

Holzmann H, Habersack H, Schober B, (2014), *"Integrated Flood Risk Management"* , BOKU (University of natural resources and life science), Vienna.

International Federation of Red Cross and Red Crescent Societies (2012), *"International Disaster Response Laws, Rules and Principles (IDRL) Programme",* International Federation of Red Cross and Red Crescent Societies.

Investopedia (2015), "Disaster relief act". Available at: http://www.investopedia.com/terms/d/disaster-relief-act.asp (accessed 27 Mars 2015).

Jachs S. (2014), *"Can we measure the Performance of Disaster Management?"*, Book of Papers, Crisis Management Days, Zagreb, 2014

Konecsny K., Nagy Z. (2013), *"Hydrological analysis of the June 2013 flood on the Danube along the Hungarian reach",* disaster management, Nr.XII Vol 13, Hungary.

Magistrat der Stadt Krems (2015), "Krems an der Donau". Available at: http://www.krems.gv.at/system/web/default.aspx?sprache=2 (accessed 6 April 2015).

Landeskatastrophenschutzübung 2014; Magistrat Wiener Neustadt, Bezirkshauptmannschaft Wiener Neustadt, Bezirkshauptmannschaft Neunkirchen, November 2014. *"Landeskatastrophenschutzübung in Bezirk Neunkirchen".*

Landeskatastrophenschutzübung 2014; Magistrat Wiener Neustadt, Bezirkshauptmannschaft Wiener Neustadt, Bezirkshauptmannschaft Neunkirchen (2014), *"Übungsinformation Erdbeben Thermenregion am 12.-13.11.2014",* Wiener Neustadt, Austria.

Logistics World / MDC, LogLink (1997), *"Logistics".* Available at: http://www.logisticsworld.com/logistics.htm (accessed 2 January 2015).

Merriam-Webster (2015), "Guideline". Available at: http://www.merriam-webster.com/dictionary/guideline (accessed 22 Mars 2015).

Merriam-Webster (2015), "Resources". Available at: http://www.merriam-webster.com/dictionary/guideline (accessed 27 Mars 2015).

Merriam-Webster (2015), "Optimization". Available at: http://www.merriam-webster.com/dictionary/guideline (accessed 28 Mars 2015).

Merriam-Webster (2015), "Statistics". Available at: http://www.merriam-webster.com/dictionary/guideline (accessed 22 Mars 2015).

Merriam-Webster (2015), "Simulation". Available at: http://www.merriam-webster.com/dictionary/guideline (accessed 22 Mars 2015).

Mei-Shiang Chang, Ya-Ling Tseng, Jing-Wen Chen (2006), "A scenario planning approach for the flood emergency logistics preparation problem under uncertainty".

Minitab Inc (2012), *"Minitab 16"*. Available at: http://www.minitab.com/en-us/ (accessed 02 Mars 2015).

National Geographic (2015), *"GIS (Geographic Information System) ".* Available at: http://education.nationalgeographic.com/education/encyclopedia/geographic-information-system-gis/?ar_a=1 (accessed 2 February 2015).

National New Dehli Institute of Disaster Management (2014) *"East Asia Summit Earthquake Risk Reduction Centre",* National Institute of Disaster Management, New Dehli.

NATO (North Atlantic Treaty Organization) (2011), *"Washington Treaty"*, Washington.

OCHA (Office for the Coordination of Humanitarian Affairs) (2009), "*OSOCC guidelines".*

OCHA (Office for the Coordination of Humanitarian Affairs), UNDAC, *"What we do". A*vailable at http://www.unocha.org/what-we-do/coordination-tools/undac/overview (accessed 30 November 2014).

OCHA (Office for the Coordination of Humanitarian Affairs), UNDAC *"Methodology and Training".* Available at http://www.unocha.org/what-we-do/coordination-tools/undac/overview (accessed 30 November 2014).

OCHA (United Nations Office for the Coordination of Humanitarian Affairs), Field Coordination Support Section, INSARAG Secretariat (2012), *"International Search and Rescue Advisory Group Guidelines and Methodology".*

OCHA (Office for the Coordination of Humanitarian Affairs), OSOCC and RDC: *"What is an On-Site Operations Coordination Centre".* Available at: http://www.unocha.org/what-we-do/coordination-tools/osocc-rdc/overview (accessed 04 December 2014).

Oracle (2014),*"The Java tutorials".* Available at www.oracle.com (accessed 23 February 2015).

Report from the commission to the European Parliament and the council; 2014. "Annual Report on the European Union's Humanitarian Aid and Civil Protection Policies and their Implementation in 2013"

Seidl F. (2014), *"Verbund and the Danube Floods in June 2013",* Verbund AG. Available at http://www.verbund.com/pp/en/waters/donau-hochwasser-2013 (accessed 08 February 2015).

Sinabell F., Url Th. (2008), "Flood risk exposure in Austria – options for bearing risk efficiently" , Schmollers Jahrbuch, 593-614, Berlin.

Tatham P., Christopher M. (Second edition 2014), *"Humanitarian Logistics: Meeting the challenge of preparing for and responding to disasters"*, The Chartered Institute of Logistics and Transport, Kogan Page, London, Philadelphia, New Delhi.

United Nations, *"UN at a glance". Available at http://www.un.org/* (accessed 04 December 2014).

UNISDR (United Nations Office for Disaster Risk Reduction) (2014), *"International Cooperation to Reduce Disaster Risk".* Available at www.unisdr.org (accessed 25 November 2014).

UNISDR (United Nations Office for Disaster Risk Reduction), 2013, *"International Cooperation Plan".* Available at www.unisdr.org (accessed 20 January 2015).

Webopedia (2015), *"Java",* available at: http://www.webopedia.com/TERM/J/Java.html (accessed 06 April 2015)

ESCUELA TÉCNICA SUPERIOR DE INGENIEROS INDUSTRIALES Y DE TELECOMUNICACIÓN

Titulación:

INGENIERO INDUSTRIAL

Título del proyecto:

LOGISTICS AND DECISION CHAINS IN DISASTER MANAGEMENT; FLOODS IN AUSTRIA / CASE SIMULATION: KREMS-MAUTERN AN DER DONAU

Proyecto de Fin de Carrera realizado en el Departamento de Logística y Producción de BOKU (University of Natural Resources and Life Science), Viena, Austria.

BOKU Supervisor: PATRICK HIRSCH

ANEXO 1: INFORMACIÓN TÉCNICA SIMULACIÓN

Alumno: Francisco Javier Larraya Eraso

Tutor – Director: Javier Faulín Fajardo

Universität für Bodenkultur Wien
University of Natural Resources and Applied Life Sciences, Vienna

Pamplona, 27 Abril 2015

Model: Sicherheit version

Name	Value
General	
Model Time Units	minutes
Numerical methods	
Differention Equations Method	Euler
Algebraic Equations Method	Modified Newton
Mixed Equations Method	RK45+Newton
Absolute Accuracy	1.0E-5
Time Accuracy	1.0E-5
Relative Accuracy	1.0E-5
Fixed Time Step	0.001
Advanced	
Java Package Name	simulation
File Name	C:\Users\larry\Desktop\Javier\Simulation\Sicherheit version\Sicherheit version.alp

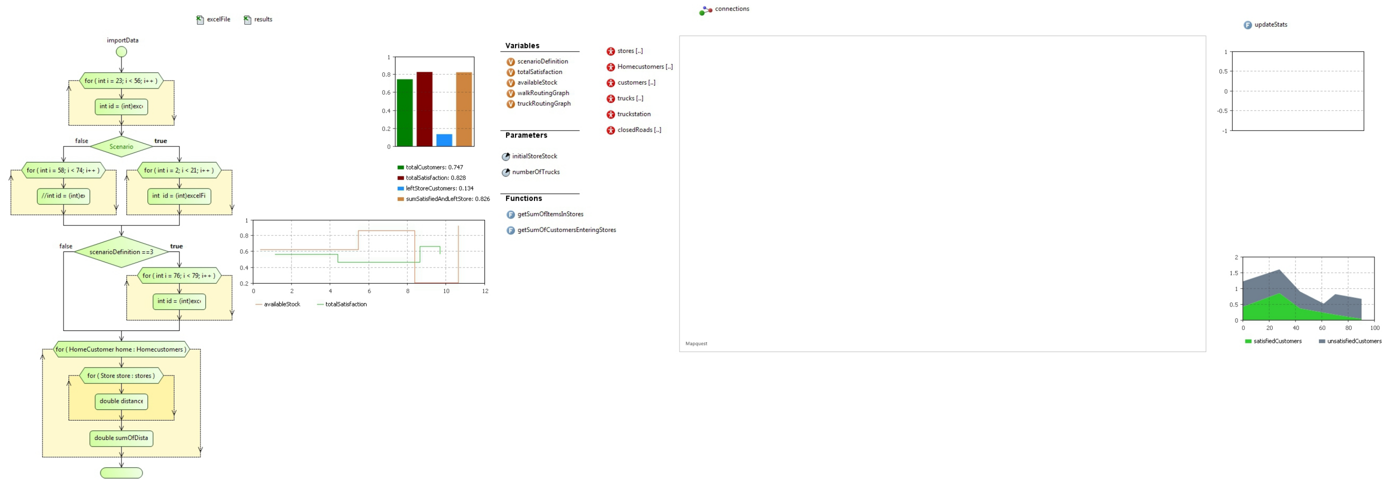
Agent Type: Main

Name	Value
Agent actions	
Startup Code	importData();

Destroy Code	results.readFile();
	results.setCellValue("----Next Run-----", 1, results.getLastRowNum(1)+1, 1);
	results.setCellValue("Total Satisfication", 1, results.getLastRowNum(1)+1, 1);
	results.setCellValue(totalSatisfaction, 1, results.getLastRowNum(1), 2);
	results.setCellValue("ForcedResources", 1, results.getLastRowNum(1)+1, 1);
	results.setCellValue(truckstation.stockResources, 1, results.getLastRowNum(1), 2);
	//Entry for each store
	for (Store st: stores)
	{
	results.setCellValue(st.name, 1, results.getLastRowNum(1)+1, 1);
	results.setCellValue(st.totalDemand, 1, results.getLastRowNum(1), 2);
	}
	results.writeFile();
	results.close();

Agent in flowcharts	
Use in flowcharts as	Agent
Movement	
Speed	10 meters per second
Rotate animation towards movement	true
Rotate vertically as well (along Z-axis)	false
Space and network	
Enable Steps	false
Advanced Java	
Import	import org.json.simple.ItemList;
Generic	false
Advanced	
Auto-create Datasets	true
Use model time	true

Name	Value
Update time (absolute)	0 minutes
Recurrence time	1 minutes
Limit the number of data samples	false



Parameter: initialStoreStock

Name	Value
General	
Array	false
Default Value	0
Type	int
Show At Runtime	true
Show name	true
Value editor	
Editor Control	Text
Advanced	
System dynamics units	false
Save In Snapshot	true

Parameter: numberOfTrucks

Name	Value
General	
Array	false
Default Value	2
Type	int
Show At Runtime	true
Show name	true
Value editor	
Editor Control	Text
Advanced	
System dynamics units	false
Save In Snapshot	true

Function: updateStats

Name	Value
General	
Return type:	Just action (returns nothing)
Show At Runtime	true
Show name	true
Function body	

Body	chart.removeAll();
	for (Store store : stores)
	{
	DataItem item = new DataItem();
	item.setValue(store.totalDemand);
	chart.addDataItem(item, store.name, randomColor());
	}

Advanced	
Static	false
Access Type	default
System dynamics units	false

Function: getSumOfItemsInStores

Name	Value
General	
Return Type	int
Return type:	Returns value
Show At Runtime	true
Show name	true
Function body	

Body	int sumOfItems = 0;
	for(Store st : stores)
	{
	sumOfItems += st.stock;
	}
	/* similar code
	for (int i = 0; i < stores.size(); i++)
	{
	sumOfItems += stores.get(i);
	}
	*/
	availableStock = sumOfItems;
	//initialTotalItemsInStock = sumOfItems;
	return sumOfItems;

Advanced	
Static	false
Access Type	default
System dynamics units	false

Function: getSumOfCustomersEnteringStores

Name	Value
General	
Return Type	int
Return type:	Returns value
Show At Runtime	true
Show name	true

Name	Value
Function body	

Body	int SumOfCustomers = 0;
	for(Store st : stores)
	{
	SumOfCustomers += st.enter.count();
	}
	/* similar code
	for (int i = 0; i < stores.size(); i++)
	{
	sumOfItems += stores.get(i);
	}
	*/
	return SumOfCustomers;

Advanced	
Static	false
Access Type	default
System dynamics units	false

Variable: totalSatisfaction

Name	Value
General	
Initial Value	0
Type	int
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Variable: scenarioDefinition

Name	Value
General	
Type	int
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Variable: availableStock

Name	Value
General	
Initial Value	0
Type	int

Name	Value
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Variable: truckRoutingGraph

Name	Value
General	
Initial Value	new RoutingGraph(false)
Type	RoutingGraph
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

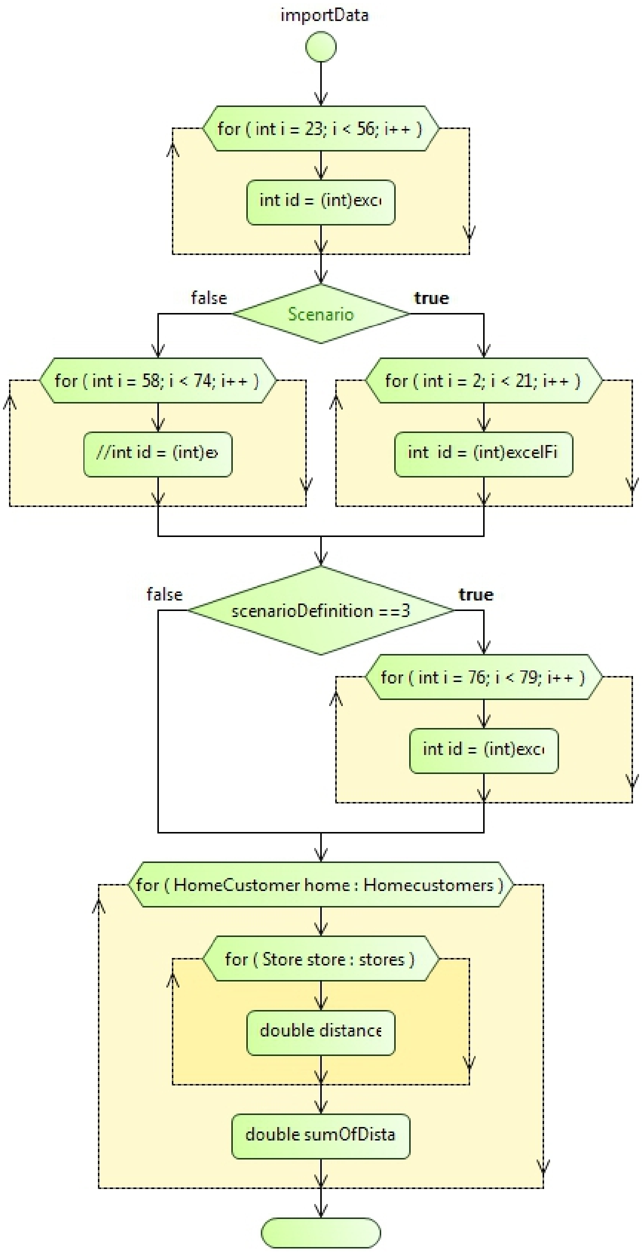
Variable: walkRoutingGraph

Name	Value
General	
Initial Value	new RoutingGraph(true)
Type	RoutingGraph
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Action Chart: importData

Name	Value
General	
Return type:	Just action (returns nothing)
Show At Runtime	false
Show name	true
Advanced	
Static	false
Access Type	default

Name	Value
System dynamics units	false



Decision: decision1

Name	Value
General	
Condition	scenarioDefinition ==3

For Loop: forLoop5

Name	Value
General	
Counting	i++
Condition	i < 79

Name	Value
Initializer	int i = 76
Collection Iterator	false

Code: code5

Name	Value
General	

Action	int id = (int)excelFile.getCellNumericValue(1, i, 1);
	double longt = excelFile.getCellNumericValue(1, i, 3);
	double lat = excelFile.getCellNumericValue(1, i, 4);
	double startTime = excelFile.getCellNumericValue(1, i, 5);
	double endTime = excelFile.getCellNumericValue(1, i, 6);
	add_closedRoads(startTime, endTime, id);
	ClosedRoad tmpS = closedRoads.get(closedRoads.size()-1);
	tmpS.setLatLon(lat, longt);
	tmpS.init();

For Loop: forLoop2

Name	Value
General	
Collection	Homecustomers
Item	HomeCustomer home
Collection Iterator	true

For Loop: forLoop3

Name	Value
General	
Collection	stores
Item	Store store
Collection Iterator	true

Code: code3

Name	Value
General	
Action	double distance = walkRoutingGraph.getDistanceInKm(home.getLatitude(), home.getLongitude(), store.getLatitude(), store.getLongitude())*1000;

Code: code2

Name	Value
General	

Action	double sumOfDistances = 0.0;
	for (Store s : stores)
	{
	sumOfDistances += home.distanceToStore.get(s);
	}
	for (Store s : stores)
	{
	double inverseDistance =
	sumOfDistances/home.distanceToStore.get(s);
	home.inverseDistanceToStore.put(s,inverseDistance);
	}

Name	Value
	home.distance();

Return: returnStatement

Decision: decision

Name	Value
General	
Condition	scenarioDefinition == 0
Advanced	
Comment	Scenario

For Loop: forLoop4

Name	Value
General	
Counting	i++
Condition	i < 74
Initializer	int i = 58
Collection Iterator	false

Code: code4

Name	Value
General	

Action	//int id = (int)excelFile.getCellNumericValue(1, i, 1);
	//String name = excelFile.getCellStringValue(1, i, 2);
	//double longt = excelFile.getCellNumericValue(1, i, 3);
	//double lat = excelFile.getCellNumericValue(1, i, 4);
	//String condition = excelFile.getCellStringValue(1, i, 5);
	//if (condition == "Y")
	//{
	//add_stores(name);
	//Store tmpS = stores.get(stores.size()-1);
	//tmpS.setLatLon(lat, longt);
	//}
	int id = (int)excelFile.getCellNumericValue(1, i, 1);
	String name = excelFile.getCellStringValue(1, i, 2);
	double longt = excelFile.getCellNumericValue(1, i, 3);
	double lat = excelFile.getCellNumericValue(1, i, 4);
	int stockstore = (int) excelFile.getCellNumericValue(1, i, 5);
	add_stores(name);
	Store tmpS = stores.get(stores.size()-1);
	tmpS.setLatLon(lat, longt);
	tmpS.stock = stockstore;

For Loop: forLoop

Name	Value
General	
Counting	i++
Condition	i < 21
Initializer	int i = 2
Collection Iterator	false

Code: code

Name	Value
General	

Action	int id = (int)excelFile.getCellNumericValue(1, i, 1);
	String name = excelFile.getCellStringValue(1, i, 2);
	double longt = excelFile.getCellNumericValue(1, i, 3);
	double lat = excelFile.getCellNumericValue(1, i, 4);
	int stockstore = (int) excelFile.getCellNumericValue(1, i, 5);
	add_stores(name);
	Store tmpS = stores.get(stores.size()-1);
	tmpS.setLatLon(lat, longt);
	tmpS.stock = stockstore;

For Loop: forLoop1

Name	Value
General	
Counting	i++
Condition	i < 56
Initializer	int i = 23
Collection Iterator	false

Code: code1

Name	Value
General	

Action	int id = (int)excelFile.getCellNumericValue(1, i, 1);
	String name = excelFile.getCellStringValue(1, i, 2);
	double longt = excelFile.getCellNumericValue(1, i, 4);
	double lat = excelFile.getCellNumericValue(1, i, 5);
	int pop = (int)excelFile.getCellNumericValue(1, i, 6);
	add_Homecustomers(pop);
	HomeCustomer tmpHome =
	Homecustomers.get(Homecustomers.size()-1);
	tmpHome.setLatLon(lat, longt);
	for (int j = 0; j < pop; j++)
	{
	add_customers(tmpHome);
	Customer tmpC = customers.get(customers.size()-1);
	tmpC.setLatLon(lat, longt);
	}

HomeCustomer: Homecustomers

Name	Value
General	
Replication	0
Population of agents	true
Replication	0
Population of agents	true
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Statistics	
Statistics	[customersStat - Agent Statistics]
Advanced	

Name	Value
Model/library	ClassReference: simulation.HomeCustomer (Resolved: true)
Show At Runtime	true
Public	true
Embedded Object Collection Type	Access by index (ArrayList)

Population Statistics:

Name	Type	Expression	Condition
customersStat	count		

Store: stores

Name	Value
General	
Replication	0
Population of agents	true
Replication	0
Population of agents	true
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Statistics	
Statistics	[]
Advanced	
Model/library	ClassReference: simulation.Store (Resolved: true)
Show At Runtime	true
Public	false
Embedded Object Collection Type	Access by index (ArrayList)

Customer: customers

Name	Value
General	
Replication	0
Population of agents	true
Replication	0
Population of agents	true
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Statistics	
Statistics	[satisfiedCustomers - Agent Statistics, unsatisfiedCustomers - Agent Statistics, leftStoreCustomers - Agent Statistics]
Advanced	
Model/library	ClassReference: simulation.Customer (Resolved: true)
Show At Runtime	true
Public	false
Embedded Object Collection Type	Access by index (ArrayList)

Population Statistics:

Name	Type	Expression	Condition

Population Statistics:

Name	Type	Expression	Condition
satisfiedCustomers	count		item.statechart.isStateActive(Customer.satisfied);
unsatisfiedCustomers	count		item.statechart.isStateActive(Customer.unSatisfied);
leftStoreCustomers	count		item.statechart.isStateActive(Customer.leftStore);

Truck: trucks

Name	Value
General	
Replication	0
Population of agents	true
Replication	0
Population of agents	true
Show name	true
Initial location	
Place agent(s)	in the specified point
Latitude	48.391789
Longitude	15.583952
Statistics	
Statistics	[]
Advanced	
Model/library	ClassReference: simulation.Truck (Resolved: true)
Show At Runtime	true
Public	false
Embedded Object Collection Type	Access by index (ArrayList)

Truckstation: truckstation

Name	Value
General	
Population of agents	false
Population of agents	false
Show name	true
Initial location	
Place agent(s)	in the specified point
Latitude	48.391789
Longitude	15.583952
Advanced	
Model/library	ClassReference: simulation.Truckstation (Resolved: true)
Show At Runtime	true
Public	false

ClosedRoad: closedRoads

Name	Value

Name	Value
General	
Replication	0
Population of agents	true
Replication	0
Population of agents	true
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Statistics	
Statistics	[]
Advanced	
Model/library	ClassReference: simulation.ClosedRoad (Resolved: true)
Show At Runtime	true
Public	false
Embedded Object Collection Type	Access by index (ArrayList)

Bar Chart: chart

Name	Value
General	
Scale Type	Auto
Public	true
Data update	
Analysis Auto Update	true
Use model time	true
Update time (absolute)	0 seconds
Recurrence time	1 seconds
Appearance	
Bars Relative Width	0.85
Labels Vertical Position	DEFAULT
Labels Text Color	darkGray
Chart Area Grid Color	darkGray
Position and size	
x	1000.0
Width	320.0
y	0.0
Height	360.0
Legend	
Show Legend	true
Legend Size	150.0
Legend Text Color	black
Chart area	
Chart Area: X Offset	50.0
Chart Area: Width	250.0
Chart Area: Y Offset	30.0
Chart Area: Height	150.0
Chart Area: Background Color	white
Chart Area Border Color	black
Advanced	

Name	Value
Show name	false

Bar Chart: SumOfCustomersEnteringStores

Name	Value
General	
Scale Type	Auto
Public	true
Data update	
Analysis Auto Update	true
Use model time	true
Update time (absolute)	0 minutes
Recurrence time	1 minutes
Appearance	
Bars Relative Width	0.8
Labels Vertical Position	DEFAULT
Labels Text Color	darkGray
Chart Area Grid Color	darkGray
Position and size	
x	-590.0
Width	240.0
y	10.0
Height	320.0
Legend	
Show Legend	true
Legend Size	90.0
Legend Text Color	black
Chart area	
Chart Area: X Offset	50.0
Chart Area: Width	150.0
Chart Area: Y Offset	30.0
Chart Area: Height	170.0
Chart Area: Background Color	white
Chart Area Border Color	black
Advanced	
Show name	false

Chart Items:

Title	Color	Value
totalCustomers	green	getSumOfCustomersEnteringStores()
totalSatisfaction	maroon	totalSatisfaction
leftStoreCustomers	dodgerBlue	customers.leftStoreCustomers()
sumSatisfiedAndLeftStore	peru	totalSatisfaction + customers.leftStoreCustomers()

Time Plot: getSumOfItemsIn

Name	Value
General	
Public	true

Name	Value
Data update	
Analysis Auto Update	true
Use model time	true
Update time (absolute)	0 minutes
Recurrence time	1 minutes
Dataset Samples To Keep	100
Scale	
Time Window	12
Time	hours
Vertical Scale	Auto
Appearance	
Labels Horizontal Position	DEFAULT
Labels Vertical Position	DEFAULT
Label Format	Model time units
Background Color	white
Labels Text Color	darkGray
Chart Area Grid Color	darkGray
Draw Line	true
Interpolation	Step
Position and size	
x	-860.0
Width	520.0
y	320.0
Height	210.0
Legend	
Show Legend	true
Legend Size	30.0
Legend Text Color	black
Chart area	
Chart Area: X Offset	50.0
Chart Area: Width	440.0
Chart Area: Y Offset	30.0
Chart Area: Height	120.0
Chart Area: Background Color	white
Chart Area Border Color	black
Advanced	
Time window moves	Continuously
Show name	false

Plot Items:

Title	Type	Dataset / Value	Point Style	Color	Line	Width	Interpolation
availableStock	value	getSumOfItemsInStores()	NONE	coral	true	1.0	STEP
totalSatisfaction	value	totalSatisfaction	NONE	limeGreen	true	1.0	STEP

Time Stack Chart: chart1

Name	Value
General	
Public	true

Name	Value
Data update	
Analysis Auto Update	true
Use model time	true
Update time (absolute)	0 minutes
Recurrence time	1 minutes
Dataset Samples To Keep	100
Scale	
Time Window	100
Time	model time units
Vertical Scale	Auto
Appearance	
Labels Horizontal Position	DEFAULT
Labels Vertical Position	DEFAULT
Label Format	Model time units
Labels Text Color	darkGray
Chart Area Grid Color	darkGray
Position and size	
x	1020.0
Width	330.0
y	390.0
Height	210.0
Legend	
Show Legend	true
Legend Size	30.0
Legend Text Color	black
Chart area	
Chart Area: X Offset	50.0
Chart Area: Width	250.0
Chart Area: Y Offset	30.0
Chart Area: Height	120.0
Chart Area: Background Color	white
Chart Area Border Color	black
Advanced	
Time window moves	Continuously
Show name	false

Plot Items:

Title	Type	Dataset / Value	Color
satisfiedCustomers	value	customers.satisfiedCustomers()	limeGreen
unsatisfiedCustomers	value	customers.unsatisfiedCustomers()	slateGray

Agent Presentation: Homecustomers_presentation

Name	Value
General	
Show At Runtime	true
Public	true
Position and size	

Name	Value
Latitude	0.0
Longitude	0.0
Rotation	0.0
Scale	Automatically calculated
Real size when map scale is under	1000
Fixed size when map scale is under	1000000000
Advanced	
Show in	2D and 3D
Draw agent with offset to this position	false
Show name	false

Agent Presentation: stores_presentation

Name	Value
General	
Show At Runtime	true
Public	true
Position and size	
Latitude	0.0
Longitude	0.0
Rotation	0.0
Scale	Automatically calculated
Real size when map scale is under	1000
Fixed size when map scale is under	1000000000
Advanced	
Show in	2D and 3D
Draw agent with offset to this position	false
Show name	false

Agent Presentation: customers_presentation

Name	Value
General	
Show At Runtime	true
Public	true
Position and size	
Latitude	0.0
Longitude	0.0
Rotation	0.0
Scale	Automatically calculated
Real size when map scale is under	1000
Fixed size when map scale is under	1000000000
Advanced	
Show in	2D and 3D
Draw agent with offset to this position	false
Show name	false

Agent Presentation: trucks_presentation

Name	Value
General	
Show At Runtime	true
Public	false
Position and size	
Latitude	0.41151
Longitude	0.60266
Rotation	0.0
Scale	Automatically calculated
Real size when map scale is under	1000
Fixed size when map scale is under	1000000000
Advanced	
Show in	2D and 3D
Draw agent with offset to this position	false
Show name	false

Agent Presentation: truckstation_presentation

Name	Value
General	
Show At Runtime	true
Public	true
Position and size	
Latitude	0.41151
Longitude	0.60266
Rotation	0.0
Scale	Automatically calculated
Real size when map scale is under	1000
Fixed size when map scale is under	1000000000
Advanced	
Show in	2D and 3D
Draw agent with offset to this position	false
Show name	false

Agent Presentation: closedRoads_presentation

Name	Value
General	
Show At Runtime	true
Public	true
Position and size	
Latitude	0.40604
Longitude	0.60264
Rotation	0.0
Scale	Automatically calculated
Real size when map scale is under	1000
Fixed size when map scale is under	1000000000
Advanced	
Show in	2D and 3D
Draw agent with offset to this position	false

Name	Value
Show name	false

GIS Map: map

Name	Value
General	
Show At Runtime	true
Lock	false
Public	true
Tiles	
Show tiles	true
Tile provider	Mapquest
Routing	
Routes are	Loaded from PBF file
Routing method	Fastest
Pathfinding algorithm	bidirectional A*
If route not found	Create straight route
Center and scale	
Latitude	48.40604109180511
Longitude	15.602642163923399
Scale	38000
Appearance	
Border Color	silver
Fill Color	white
Position and size	
x	0.0
Width	1000.0
y	0.0
Height	600.0
Advanced	
Projection type	Mercator
Use custom tile provider	false
Use custom route provider	false
Routes and regions generalization uses Current map scale	true

Group: group

Name	Value
General	
Show At Runtime	true
Lock	false
Embedded Icon	false
Public	true
Position and size	
x	-300.0
y	20.0
z	0.0
Rotation	0.0

Name	Value
Advanced	
Show in	2D and 3D
Show name	false

Text: Variables

Name	Value
General	
Show At Runtime	true
Lock	false
Embedded Icon	false
Public	true
Text	
Text	Variables
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line

Name	Value
General	
Show At Runtime	true
Lock	false
Embedded Icon	false
Public	true
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0

Name	Value
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group1

Name	Value
General	
Show At Runtime	true
Lock	false
Embedded Icon	false
Public	true
Position and size	
x	-300.0
y	170.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Parameters

Name	Value
General	
Show At Runtime	true
Lock	false
Embedded Icon	false
Public	true
Text	
Text	Parameters
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line1

Name	Value
General	
Show At Runtime	true
Lock	false
Embedded Icon	false
Public	true
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group2

Name	Value
General	
Show At Runtime	true
Lock	false
Embedded Icon	false
Public	true
Position and size	
x	-300.0
y	290.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Functions

Name	Value
General	
Show At Runtime	true
Lock	false
Embedded Icon	false
Public	true
Text	
Text	Functions

Name	Value
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line2

Name	Value
General	
Show At Runtime	true
Lock	false
Embedded Icon	false
Public	true
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Excel File: excelFile

Name	Value
General	
File name	Stores.xlsx
Show At Runtime	true
Show name	true
Advanced	
Load on model startup	true

Name	Value
Save on model termination	true
Save In Snapshot	false

Excel File: results

Name	Value
General	
File name	Results II (Sensitivity).xlsx
Show At Runtime	true
Show name	true
Advanced	
Load on model startup	true
Save on model termination	true
Save In Snapshot	false

Agent Type: HomeCustomer

Name	Value
Agent in flowcharts	
Use in flowcharts as	Agent
Movement	
Speed	10 meters per second
Rotate animation towards movement	true
Rotate vertically as well (along Z-axis)	false
Space and network	
Space Type	Continuous
Advanced Java	
Generic	false
Advanced	
Auto-create Datasets	true
Use model time	true
Update time (absolute)	0 minutes
Recurrence time	1 minutes
Limit the number of data samples	false

Parameter: population

Name	Value
General	

Name	Value
Array	false
Type	int
Show At Runtime	true
Show name	true
Value editor	
Editor Control	Text
Advanced	
System dynamics units	false
Save In Snapshot	true

Function: distance

Name	Value
General	
Return type:	Just action (returns nothing)
Show At Runtime	true
Show name	true
Function body	

Body	double sumOfInverseDistances = 0.0;
	for (Store s : main.stores)
	{
	sumOfInverseDistances += inverseDistanceToStore.get(s);
	}
	double probability = 0.0;
	for (Store s: main.stores)
	{
	probability = inverseDistanceToStore.get(s) /
	sumOfInverseDistances;
	probabilities.put(s, probability);
	}

Advanced	
Static	false
Access Type	default
System dynamics units	false

Collection: distanceToStore

Name	Value
General	
Value Element Class	Double
Element Class	Store
Collection Class	LinkedHashMap
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Save In Snapshot	true
Static	false

Collection: inverseDistanceToStore

Name	Value
General	

Name	Value
Value Element Class	Double
Element Class	Store
Collection Class	LinkedHashMap
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Save In Snapshot	true
Static	false

Collection: probabilities

Name	Value
General	
Value Element Class	Double
Element Class	Store
Collection Class	LinkedHashMap
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Save In Snapshot	true
Static	false

3D Object: house

Name	Value
General	
Scale	0.5
File Name	x3d/house.x3d
Show At Runtime	true
Lock	false
Public	true
Position and size	
x	0.0
y	0.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Enable AnyLogic light shaders	true
Show name	false

Group: group

Name	Value
General	
Show At Runtime	true

Name	Value
Lock	false
Public	false
Position and size	
x	70.0
y	20.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Variables

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Variables
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0

Name	Value
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group1

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	250.0
y	20.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Parameters

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Collections
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line1

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group2

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	420.0
y	20.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Functions

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Functions
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black

Name	Value
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

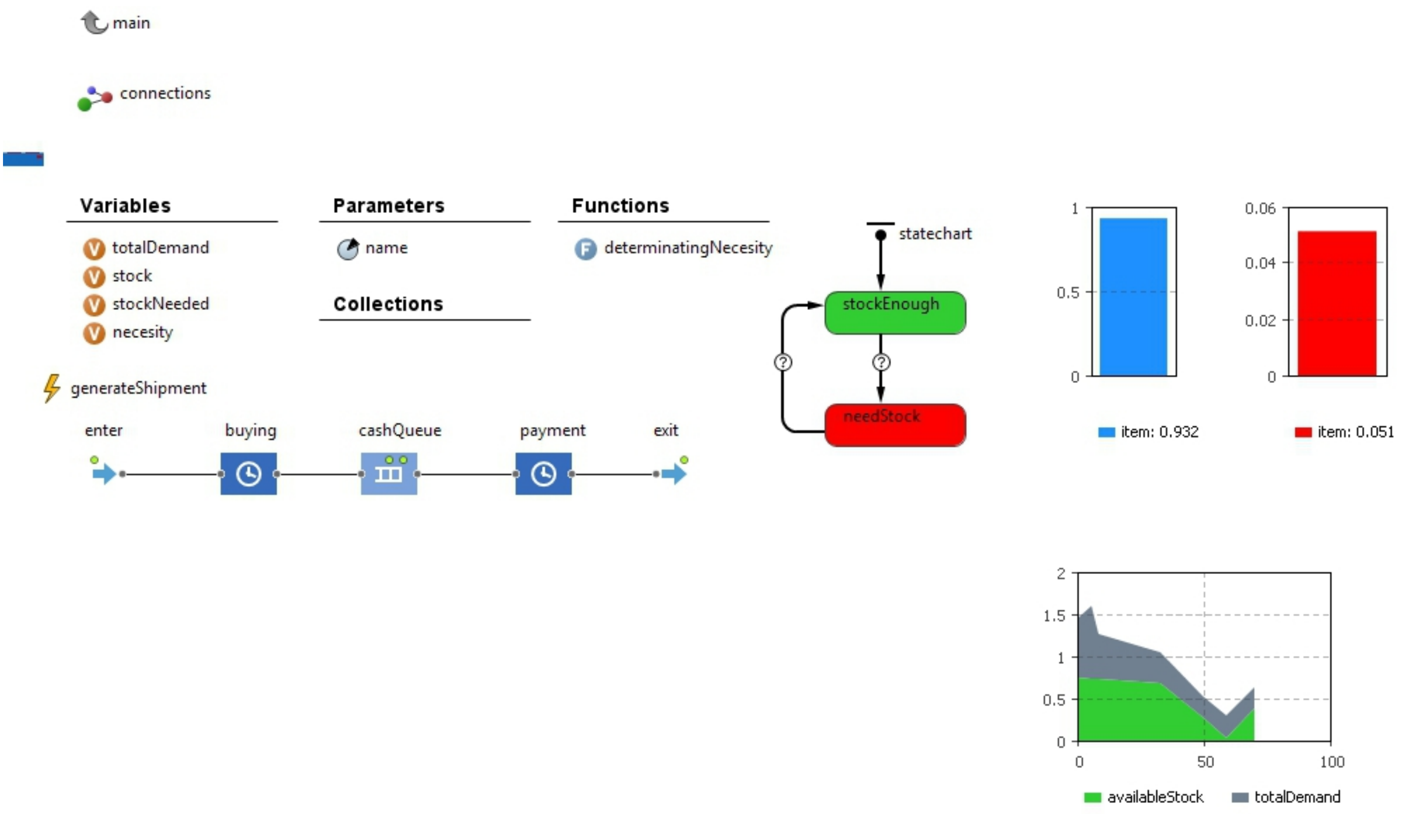
Line: line2

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Agent Type: Store

Name	Value
Agent in flowcharts	
Use in flowcharts as	Agent
Movement	
Speed	0 meters per second
Rotate animation towards movement	true
Rotate vertically as well (along Z-axis)	false
Space and network	
Space Type	Continuous
Advanced Java	
Generic	false
Advanced	
Auto-create Datasets	true
Use model time	true
Update time (absolute)	0 minutes

Name	Value
Recurrence time	1 minutes
Limit the number of data samples	false



Parameter: name

Name	Value
General	
Array	false
Type	String
Show At Runtime	true
Show name	true
Value editor	
Editor Control	Text
Advanced	
System dynamics units	false
Save In Snapshot	true

Function: determinatingNecesity

Name	Value
General	
Return type:	Just action (returns nothing)
Show At Runtime	true
Show name	true
Function body	

Name	Value

Body	if (stock < 100)
	{
	necesity = true;
	}

Advanced	
Static	false
Access Type	default
System dynamics units	false

Event: generateShipment

Name	Value
General	
Condition	necesity
Trigger Type	Condition
Show At Runtime	true
Show name	true
Action	

Action	if(main.scenarioDefinition == 2)
	{
	Order order = new Order (uniform_discr(250,500), this);
	send (order, main.truckstation);
	necesity = false;
	}
	else if(main.scenarioDefinition == 3)
	{
	Order order = new Order (uniform_discr(250,500), this);
	send (order, main.truckstation);
	necesity = false;
	}
	//generateShipment.restart();

Variable: totalDemand

Name	Value
General	
Initial Value	0
Type	int
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Variable: stock

Name	Value
General	
Initial Value	main.initialStoreStock
Type	int
Show At Runtime	true

Name	Value
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Variable: stockNeeded

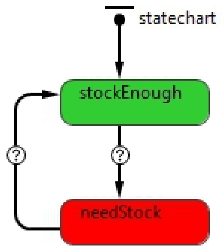
Name	Value
General	
Initial Value	0
Type	double
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Variable: necesity

Name	Value
General	
Initial Value	false
Type	boolean
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Statechart Entry Point: statechart

Name	Value
General	
Show At Runtime	true
Show name	true



Transition: transition

Name	Value
General	
Action	necesity = true;
Condition	stock < 100;
Trigger Type	Condition
Show name	false

Transition: transition1

Name	Value
General	
Action	necesity = false;
Condition	stock > 100;
Trigger Type	Condition
Show name	false

State: stockEnough

Name	Value
General	
Fill Color	limeGreen
Show name	true

State: needStock

Name	Value
General	
Entry Action	statechart.onChange()
Fill Color	red
Show name	true

Enter: enter

Name	Value
General	
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute: Customer]
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute: Customer]
Show name	true
Initial location	

Name	Value
Place agent(s)	at the agent animation location
Advanced	
Model/library	ClassReference: com.anylogic.libraries.processmodeling.Enter (Resolved: true)
Show At Runtime	true
Public	false

Agent Parameters:

Name	Value
New location	self.LOCATION_NOT_SPECIFIED
Add newborns to:	false
Forced pushing	true

On enter	agent.satisfaction = true;
	agent.statechart.receiveMessage("Satisfied");
	agent.onChange();

Delay: buying

Name	Value
General	
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Advanced	
Model/library	ClassReference: com.anylogic.libraries.processmodeling.Delay (Resolved: true)
Show At Runtime	true
Public	false

Agent Parameters:

Name	Value
Type	self.TIMEOUT
Delay time	normal(20, 10)
Maximum capacity	true
Agent location	//rectangularnodeBuying
Forced pushing	false
Restore agent location on exit	true
Force statistics collection	false
On exit	//agent.moveTo(cashQueue);

Queue: cashQueue

Name	Value
General	
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Population of agents	false

Name	Value
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Advanced	
Model/library	ClassReference: com.anylogic.libraries.processmodeling.Queue (Resolved: true)
Show At Runtime	true
Public	false

Agent Parameters:

Name	Value
Maximum capacity	true
Agent location	//pathQueue
Queuing	self.QUEUING_FIFO
Enable exit on timeout	false
Enable preemption	false
Restore agent location on exit	true
Force statistics collection	true

Delay: payment

Name	Value
General	
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Advanced	
Model/library	ClassReference: com.anylogic.libraries.processmodeling.Delay (Resolved: true)
Show At Runtime	true
Public	false

Agent Parameters:

Name	Value
Type	self.TIMEOUT
Delay time	normal(0.5, 1)
Capacity	3
Maximum capacity	false
Agent location	//rectangularnodePayment
Forced pushing	false
Restore agent location on exit	true
Force statistics collection	false

Exit: exit

Name	Value
General	
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Advanced	
Model/library	ClassReference: com.anylogic.libraries.processmodeling.Exit (Resolved: true)
Show At Runtime	true
Public	false

Agent Parameters:

Name	Value

On exit	agent.statechart.receiveMessage("leftTheStore");
	agent.onChange();
	//getOwner().

Bar Chart: paymentUtilization

Name	Value
General	
Scale Type	Auto
Public	false
Data update	
Analysis Auto Update	true
Use model time	true
Update time (absolute)	0 minutes
Recurrence time	1 minutes
Appearance	
Bars Relative Width	0.8
Labels Vertical Position	DEFAULT
Labels Text Color	darkGray
Chart Area Grid Color	darkGray
Position and size	
x	710.0
Width	140.0
y	0.0
Height	210.0
Legend	
Show Legend	true
Legend Size	30.0
Legend Text Color	black
Chart area	
Chart Area: X Offset	50.0
Chart Area: Width	60.0
Chart Area: Y Offset	30.0
Chart Area: Height	120.0

Name	Value
Chart Area: Background Color	white
Chart Area Border Color	black
Advanced	
Show name	false

Chart Items:

Title	Color	Value
item	dodgerBlue	payment.statsUtilization.mean()

Bar Chart: averageQueueSize

Name	Value
General	
Scale Type	Auto
Public	false
Data update	
Analysis Auto Update	true
Use model time	true
Update time (absolute)	0 minutes
Recurrence time	1 minutes
Appearance	
Bars Relative Width	0.8
Labels Vertical Position	DEFAULT
Labels Text Color	darkGray
Chart Area Grid Color	darkGray
Position and size	
x	850.0
Width	150.0
y	0.0
Height	210.0
Legend	
Show Legend	true
Legend Size	30.0
Legend Text Color	black
Chart area	
Chart Area: X Offset	50.0
Chart Area: Width	70.0
Chart Area: Y Offset	30.0
Chart Area: Height	120.0
Chart Area: Background Color	white
Chart Area Border Color	black
Advanced	
Show name	false

Chart Items:

Title	Color	Value
item	red	cashQueue.statsSize.mean()

Time Stack Chart: chart

Name	Value
General	
Public	false
Data update	
Analysis Auto Update	true
Use model time	true
Update time (absolute)	0 minutes
Recurrence time	1 minutes
Dataset Samples To Keep	100
Scale	
Time Window	100
Time	model time units
Vertical Scale	Auto
Appearance	
Labels Horizontal Position	DEFAULT
Labels Vertical Position	DEFAULT
Label Format	Model time units
Labels Text Color	darkGray
Chart Area Grid Color	darkGray
Position and size	
x	700.0
Width	260.0
y	260.0
Height	210.0
Legend	
Show Legend	true
Legend Size	30.0
Legend Text Color	black
Chart area	
Chart Area: X Offset	50.0
Chart Area: Width	180.0
Chart Area: Y Offset	30.0
Chart Area: Height	120.0
Chart Area: Background Color	white
Chart Area Border Color	black
Advanced	
Time window moves	Continuously
Show name	false

Plot Items:

Title	Type	Dataset / Value	Color
availableStock	value	stock	limeGreen
totalDemand	value	totalDemand	slateGray

3D Object: warehouse_2

Name	Value
General	
Scale	0.35
File Name	x3d/warehouse_2.x3d

Name	Value
Show At Runtime	true
Lock	false
Public	true
Position and size	
x	0.0
y	0.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Enable AnyLogic light shaders	true
Show name	false

Agent Presentation: enter_presentation

Name	Value
General	
Show At Runtime	true
Public	true
Position and size	
x	0.0
y	0.0
z	0.0
Rotation	0.0
Scale	Automatically calculated
Advanced	
Show in	2D and 3D
Draw agent with offset to this position	false
Show name	false

Group: group

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	70.0
y	30.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Variables

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Variables
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group1

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false

Name	Value
Position and size	
x	250.0
y	30.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Parameters

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Parameters
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line1

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0

Name	Value
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group2

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	420.0
y	30.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Functions

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Functions
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line2

Name	Value
General	

Name	Value
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group3

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	250.0
y	100.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Parameters1

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Collections
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT

Name	Value
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line3

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Agent Type: Order

Name	Value
Agent in flowcharts	
Use in flowcharts as	Agent
Movement	
Speed	10 meters per second
Rotate animation towards movement	true
Rotate vertically as well (along Z-axis)	false
Space and network	
Space Type	Continuous
Advanced Java	
Generic	false
Advanced	
Auto-create Datasets	true
Use model time	true
Update time (absolute)	0 minutes
Recurrence time	1 minutes

Name	Value
Limit the number of data samples	false

connections

Variables	Parameters	Functions
	amount	
	store	
	closestStoreWithStock	

Parameter: amount

Name	Value
General	
Array	false
Type	int
Show At Runtime	true
Show name	true
Value editor	
Editor Control	Text
Advanced	
System dynamics units	false
Save In Snapshot	true

Parameter: store

Name	Value
General	
Array	false
Type	Store
Show At Runtime	true
Show name	true
Value editor	
Editor Control	Text
Advanced	
System dynamics units	false
Save In Snapshot	true

Group: group

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	50.0

Name	Value
y	20.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Variables

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Variables
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0

Name	Value
Advanced	
Show in	2D and 3D
Show name	false

Group: group1

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	230.0
y	20.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Parameters

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Parameters
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line1

Name	Value
General	
Show At Runtime	true
Lock	false

Name	Value
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group2

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	400.0
y	20.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Functions

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Functions
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0

Name	Value
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

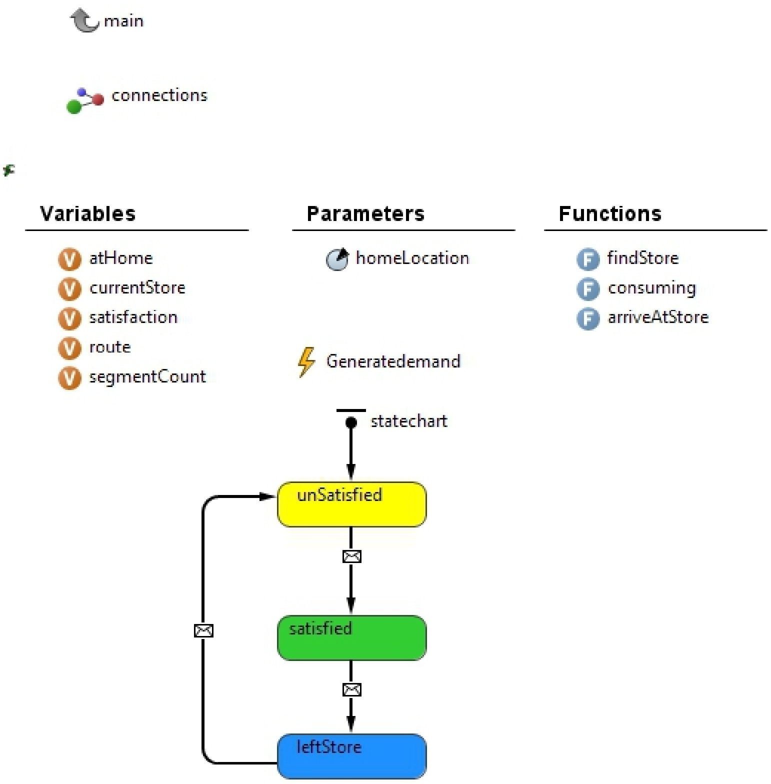
Line: line2

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Agent Type: Customer

Name	Value
Agent actions	
On Arrival	arriveAtStore();
Agent in flowcharts	
Use in flowcharts as	Agent
Movement	
Speed	5 kilometers per hour
Rotate animation towards movement	true
Rotate vertically as well (along Z-axis)	false
Space and network	
Space Type	Continuous
Advanced Java	
Generic	false
Advanced	
Auto-create Datasets	true
Use model time	true
Update time (absolute)	0 minutes
Recurrence time	1 minutes

Name	Value
Limit the number of data samples	false



Parameter: homeLocation

Name	Value
General	
Array	false
Type	HomeCustomer
Show At Runtime	true
Show name	true
Value editor	
Editor Control	Text
Advanced	
System dynamics units	false
Save In Snapshot	true

Function: arriveAtStore

Name	Value
General	
Return type:	Just action (returns nothing)
Show At Runtime	true
Show name	true
Function body	

Body	if (route.getSegmentCount() == segmentCount)
	{//arrival at the final destination of the route
	segmentCount = 0;
	route = null;

Name	Value

	if (atHome == false)
	{
	if (currentStore.stock > 0)
	{
	currentStore.enter.take(this);
	consuming();
	System.out.println("ARRIVED");
	currentStore.totalDemand++;
	main.updateStats();
	//satisfaction = true;
	//this.onChange();
	}
	else
	{
	Store target = findStore();
	route = new
	GISRoute(main.map,main.walkRoutingGraph.getPathData(getLatitude(), getLongitude(), target.getLatitude(), target.getLongitude()));
	route.setVisible(false);
	segmentCount = 0;
	arriveAtStore();
	}
	}
	else
	{
	statechart.receiveMessage("arrivedHome");
	}
	}
	else
	{//keep moving along current path
	segmentCount++; //order important as otherwise stack overflow error occurs
	double durationForNextSegment =
	main.walkRoutingGraph.getDurationInMin(getLatitude(), getLongitude(), route.getSegment(segmentCount-1).getEnd(null).getLatitude(), route.getSegment(segmentCount-1).getEnd(null).getLongitude());
	//------
	if (durationForNextSegment != 0.0)
	{//otherwise if duration is 0.0 arrive at location is not called in moveToStraightInTime
	if (durationForNextSegment != Double.MAX_VALUE)
	{
	moveToStraightInTime(route.getSegment(segmentCount-1).getEnd(null),durationForNextSegment,MINUTE);
	}
	else
	{
	System.err.println("ERROR: invalid truck speed, infinite duration");
	arriveAtStore();
	}
	}
	else
	{
	arriveAtStore();
	}
	//--
	}

Advanced	
Static	false
Access Type	default
System dynamics units	false

Function: findStore

Name	Value
General	

Name	Value
Return Type	Store
Return type:	Returns value
Show At Runtime	true
Show name	true
Function body	

Body	double randomNumber =
	main.getDefaultRandomGenerator().nextDouble();
	double sumOfProb = 0.0;
	//Decide on store
	//if (currentStore.stock <= 0)
	//{
	//main.remove_stores (currentStore);
	//}
	//else
	for (Store s : main.stores)
	{
	sumOfProb += homeLocation.probabilities.get(s);
	if (sumOfProb > randomNumber)
	{
	currentStore = s;
	return s;
	}
	}
	//}
	System.err.println("Error: " + sumOfProb + "/" + randomNumber);
	//Error
	return null;

Advanced	
Static	false
Access Type	default
System dynamics units	false

Function: consuming

Name	Value
General	
Return type:	Just action (returns nothing)
Show At Runtime	true
Show name	true
Function body	
Body	currentStore.stock -= 1;
Advanced	
Static	false
Access Type	default
System dynamics units	false

Event: Generatedemand

Name	Value
General	
Rate	2 per day
Trigger Type	Rate
Show At Runtime	true
Show name	true
Action	
Action	if (atHome == true && satisfaction == false)

Name	Value
	{ Store target = findStore(); route = new GISRoute(main.map,main.walkRoutingGraph.getPathData(getLatitude(), getLongitude(), target.getLatitude(), target.getLongitude())); route.setVisible(false); segmentCount = 0; arriveAtStore(); atHome = false; }

Variable: atHome

Name	Value
General	
Initial Value	true
Type	boolean
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Variable: currentStore

Name	Value
General	
Initial Value	null
Type	Store
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Variable: satisfaction

Name	Value
General	
Initial Value	false
Type	boolean
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false

Name	Value
Constant	false
Save In Snapshot	true
System dynamics units	false

Variable: route

Name	Value
General	
Type	GISRoute
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

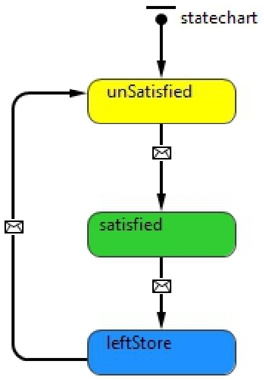
Variable: segmentCount

Description: indicates on which segment of the route the truck is currently moving

Name	Value
General	
Initial Value	0
Type	int
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false
Description	
Description	indicates on which segment of the route the truck is currently moving

Statechart Entry Point: statechart

Name	Value
General	
Show At Runtime	true
Show name	true



Transition: transition1

Name	Value
General	
Action	main.totalSatisfaction++;
Equals	"Satisfied"
Filter Type	On particular message
Message Type	Object
Trigger Type	Message
Show name	false

Transition: transition2

Name	Value
General	
Equals	"leftTheStore"
Filter Type	On particular message
Message Type	Object
Trigger Type	Message
Show name	false

Transition: transition3

Name	Value
General	
Equals	"arrivedHome"
Filter Type	On particular message
Message Type	Object
Trigger Type	Message
Show name	false

State: unSatisfied

Name	Value
General	
Entry Action	satisfaction = false; //person.setFillColor(silver);
Fill Color	yellow
Show name	true

State: satisfied

Name	Value
General	
Fill Color	limeGreen
Show name	true

State: leftStore

Name	Value
General	

Entry Action	atHome = true;
	route = new GISRoute(main.map,main.walkRoutingGraph.getPathData(getLatitude(), getLongitude(), homeLocation.getLatitude(), homeLocation.getLongitude()));
	route.setVisible(false);
	segmentCount = 0;

Fill Color	dodgerBlue
Show name	true

3D Object: person

Name	Value
General	
Scale	1.0
File Name	x3d/person.x3d
Show At Runtime	true
Lock	false
Public	true
Position and size	
x	0.0
y	0.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Enable AnyLogic light shaders	true
Show name	false

Group: group

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	50.0
y	30.0
z	0.0

Name	Value
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Variables

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Variables
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D

Name	Value
Show name	false

Group: group1

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	230.0
y	30.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Parameters

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Parameters
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line1

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black

Name	Value
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group2

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	400.0
y	30.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Functions

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Functions
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0

Name	Value
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line2

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

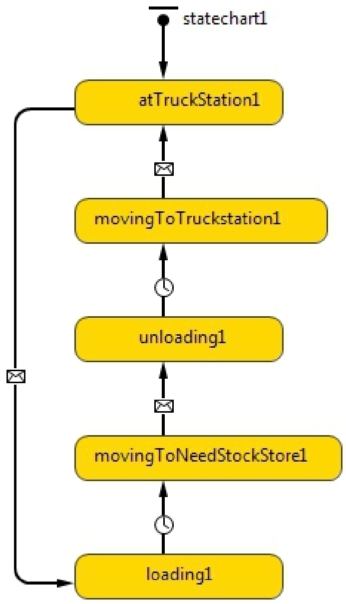
Agent Type: Truck

Name	Value
Agent actions	
On Arrival	drive();
Agent in flowcharts	
Use in flowcharts as	Agent
Movement	
Speed	70 kilometers per hour
Rotate animation towards movement	true
Rotate vertically as well (along Z-axis)	false
Space and network	
Space Type	Continuous
Advanced Java	
Generic	false
Advanced	
Auto-create Datasets	true
Use model time	true
Update time (absolute)	0 minutes
Recurrence time	1 minutes
Limit the number of data samples	false

main

connections

Variables	Parameters	Functions
order		drive
route		
segmentCount		
wayHome		



Function: drive

Name	Value
General	
Return type:	Just action (returns nothing)
Show At Runtime	true
Show name	true
Function body	

Body	if (route.getSegmentCount() == segmentCount)
	{//arrival at the final destination of the route
	segmentCount = 0;
	route = null;
	if (wayHome)
	{
	statechart1.receiveMessage("arrivedHome");
	}
	else
	{
	statechart1.receiveMessage("arrivedStore");
	}
	}
	else
	{//keep moving along current path
	segmentCount++; //order important as otherwise stack overflow error occurs
	double durationForNextSegment = main.truckRoutingGraph.getDurationInMin(getLatitude(), getLongitude(), route.getSegment(segmentCount-1).getEnd(null).getLatitude(), route.getSegment(segmentCount-1).getEnd(null).getLongitude());
	//------
	if (durationForNextSegment != 0.0)

Name	Value

	moveToStraightInTime
	if (durationForNextSegment != Double.MAX_VALUE)
	{
	moveToStraightInTime(route.getSegment(segmentCount-1).getEnd(null),durationForNextSegment,MINUTE);
	}
	else
	{
	System.err.println("ERROR: invalid truck speed, infinite duration");
	drive();
	}
	}
	else
	{
	drive();
	}
	//---
	}

Advanced	
Static	false
Access Type	default
System dynamics units	false

Variable: order

Name	Value
General	
Type	Order
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Variable: route

Name	Value
General	
Type	GISRoute
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Variable: segmentCount

Description: indicates on which segment of the route the truck is currently moving

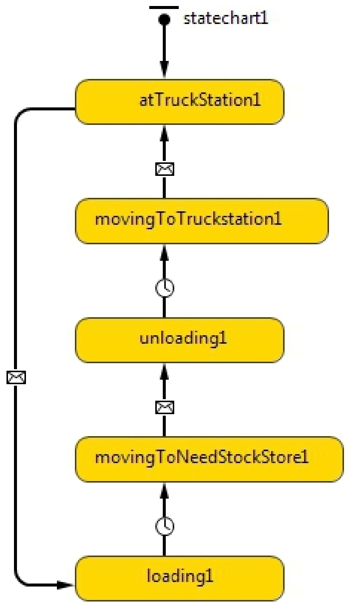
Name	Value
General	
Initial Value	0
Type	int
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false
Description	
Description	indicates on which segment of the route the truck is currently moving

Variable: wayHome

Name	Value
General	
Initial Value	false
Type	boolean
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Statechart Entry Point: statechart1

Name	Value
General	
Show At Runtime	true
Show name	true



Transition: transition8

Name	Value
General	
Action	order = msg;
Filter Type	Unconditionally
Message Type	Order
Trigger Type	Message
Show name	false

Transition: transition6

Name	Value
General	
Timeout	uniform (30 , 60) minutes
Trigger Type	Timeout
Show name	false

Transition: transition7

Name	Value
General	
Equals	"arrivedStore"
Filter Type	On particular message
Message Type	Object
Trigger Type	Message
Show name	false

Transition: transition10

Name	Value
General	

Name	Value
Timeout	uniform (30, 60) minutes
Trigger Type	Timeout
Show name	false

Transition: transition11

Name	Value
General	
Action	main.truckstation.delivering.stopDelay(order);
Equals	"arrivedHome"
Filter Type	On particular message
Message Type	Object
Trigger Type	Message
Show name	false

State: atTruckStation1

Name	Value
General	
Entry Action	wayHome = false;
Show name	true

State: loading1

Name	Value
General	
Exit Action	main.truckstation.stockResources = main.truckstation.stockResources - order.amount
Show name	true

State: movingToNeedStockStore1

Name	Value
General	

Entry Action	Store target = order.store;
	route = new
	GISRoute(main.map,main.truckRoutingGraph.getPathData(getLatit
	ude(), getLongitude(), target.getLatitude(), target.getLongitude()));
	route.setVisible(false);
	segmentCount = 0;
	drive();

Show name	true

State: unloading1

Name	Value
General	
Exit Action	order.store.stock = order.amount;
Show name	true

State: movingToTruckstation1

Name	Value
General	

Entry Action	Truckstation target = main.truckstation;
	route = new
	GISRoute(main.map,main.truckRoutingGraph.getPathData(getLatitude(), getLongitude(), target.getLatitude(), target.getLongitude()));
	route.setVisible(false);
	segmentCount = 0;
	drive();
	wayHome = true;

Show name	true

3D Object: truck

Name	Value
General	
Scale	0.25
File Name	x3d/truck.x3d
Show At Runtime	true
Lock	false
Public	true
Position and size	
x	0.0
y	0.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Enable AnyLogic light shaders	true
Show name	false

Group: group

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	50.0
y	30.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Variables

Name	Value
General	

Name	Value
Show At Runtime	true
Lock	false
Text	
Text	Variables
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group1

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	

Name	Value
x	230.0
y	30.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Parameters

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Parameters
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line1

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0

Name	Value
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group2

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	400.0
y	30.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Functions

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Functions
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line2

Name	Value
General	
Show At Runtime	true

Name	Value
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

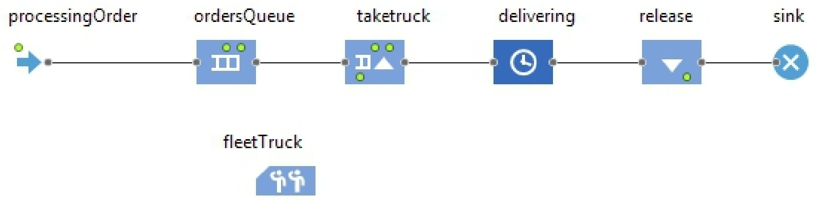
Agent Type: Truckstation

Name	Value
Agent in flowcharts	
Use in flowcharts as	Agent
Movement	
Speed	10 meters per second
Rotate animation towards movement	true
Rotate vertically as well (along Z-axis)	false
Space and network	
Space Type	Continuous
Advanced Java	
Generic	false
Advanced	
Auto-create Datasets	true
Use model time	true
Update time (absolute)	0 minutes
Recurrence time	1 minutes
Limit the number of data samples	false

main

connections

Variables	Parameters	Functions
stockResources		



Variable: stockResources

Name	Value
General	
Initial Value	3000
Type	int
Show At Runtime	true
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Enter: processingOrder

Name	Value
General	
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute: Order]
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute: Order]
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Advanced	
Model/library	ClassReference: com.anylogic.libraries.processmodeling.Enter (Resolved: true)
Show At Runtime	true
Public	false

Agent Parameters:

Agent Parameters:

Name	Value
New location	self.LOCATION_NOT_SPECIFIED
Add newborns to:	false
Forced pushing	true

Queue: ordersQueue

Name	Value
General	
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Advanced	
Model/library	ClassReference: com.anylogic.libraries.processmodeling.Queue (Resolved: true)
Show At Runtime	true
Public	false

Agent Parameters:

Name	Value
Maximum capacity	true
Queuing	self.QUEUING_FIFO
Enable exit on timeout	false
Enable preemption	false
Restore agent location on exit	true
Force statistics collection	false

ResourcePool: fleetTruck

Name	Value
General	
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Advanced	
Model/library	ClassReference: com.anylogic.libraries.processmodeling.ResourcePool (Resolved:
Show At Runtime	true
Public	false

Agent Parameters:

Name	Value

Agent Parameters:

Name	Value
Resource type	self.RESOURCE_MOVING
Capacity defined	self.CAPACITY_DIRECT
Capacity	main.numberOfTrucks
When capacity decreases	false
New resource unit	new Truck()
Speed	30
Home location is	self.HOME_SINGLE_NODE
Home location (nodes)	{}
'End of shift' priority	100
'End of shift' preemption policy	self.PP_NO_PREEMPTION
'End of shift' may preempt	true
Breaks	false
Failures / repairs	false
Maintenance	false
Custom tasks	false
Add units to:	true
Population	main.trucks
Force statistics collection	true

Delay: delivering

Name	Value
General	
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Advanced	
Model/library	ClassReference: com.anylogic.libraries.processmodeling.Delay (Resolved: true)
Show At Runtime	true
Public	false

Agent Parameters:

Name	Value
Type	self.MANUAL
Maximum capacity	true
Forced pushing	false
Restore agent location on exit	true
Force statistics collection	false

Seize: taketruck

Name	Value
General	

Name	Value
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Advanced	
Model/library	ClassReference: com.anylogic.libraries.processmodeling.Seize (Resolved: true)
Show At Runtime	true
Public	false

Agent Parameters:

Name	Value
Seize	false
Resource sets	{ { fleetTruck } }
Seize policy	self.SEIZE_WHOLE_SET
Maximum queue capacity	true
Send seized resources	false
Attach seized resources	false
Task priority	0
Task may preempt	true
Task preemption policy	self.PP_NO_PREEMPTION
Customize resource choice	false
Define preparation tasks by	true
Enable exit on timeout	false
Enable preemption	false
Canceled units:	self.CANCELED_UNITS_STAY_WHERE_THEY_AR E
Forced pushing	false
Restore agent location on exit	true
Force statistics collection	false
On seize unit	send(agent, unit);
"agent1 is preferred to agent2"	false
Attach seized resources	false

Release: release

Name	Value
General	
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Advanced	

Name	Value
Model/library	ClassReference: com.anylogic.libraries.processmodeling.Release (Resolved: true)
Show At Runtime	true
Public	false

Agent Parameters:

Name	Value
Release	self.ALL
Moving resources	true
Wrap up (e.g. move home)	self.WRAP_UP_ALWAYS
'Wrap up' usage statistics are:	self.USAGE_BUSY

Sink: sink

Name	Value
General	
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Population of agents	false
Generic Parameters Substitutes	[GenericParameterSubstitute:]
Show name	true
Initial location	
Place agent(s)	at the agent animation location
Advanced	
Model/library	ClassReference: com.anylogic.libraries.processmodeling.Sink (Resolved: true)
Show At Runtime	true
Public	false

Agent Parameters:

Name	Value
Destroy policy:	com.anylogic.libraries.processmodeling.Sink.DESTROY_ONLY_CREATED_IN_SOURCE

3D Object: hangar_open

Name	Value
General	
Scale	0.18
File Name	x3d/hangar_open.x3d
Show At Runtime	true
Lock	false
Public	true
Position and size	
x	0.0
y	0.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D

Name	Value
Enable AnyLogic light shaders	true
Show name	false

Group: group

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	80.0
y	40.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Variables

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Variables
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line

Name	Value
General	
Show At Runtime	true
Lock	false

Name	Value
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group1

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	260.0
y	40.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Parameters

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Parameters
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0

Name	Value
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

Line: line1

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Group: group2

Name	Value
General	
Show At Runtime	true
Lock	false
Public	false
Position and size	
x	430.0
y	40.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

Text: Functions

Name	Value
General	

Name	Value
Show At Runtime	true
Lock	false
Text	
Text	Functions
Appearance	
Bold Font Style	true
Font Size	14
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	-30.0
y	-10.0
z	0.0
Rotation	0.0
Advanced	
Show in	2D only
Show name	false

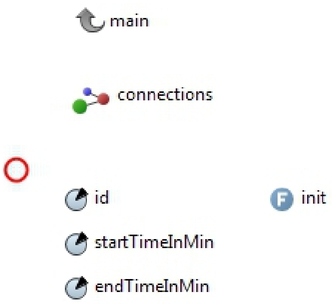
Line: line2

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	-40.0
dX	150.0
y	10.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show in	2D and 3D
Show name	false

Agent Type: ClosedRoad

Name	Value
Agent in flowcharts	
Use in flowcharts as	Agent
Movement	
Speed	10 meters per second
Rotate animation towards movement	true

Name	Value
Rotate vertically as well (along Z-axis)	false
Space and network	
Space Type	Continuous
Advanced Java	
Generic	false
Advanced	
Auto-create Datasets	true
Use model time	true
Update time (absolute)	0 seconds
Recurrence time	1 seconds
Limit the number of data samples	false



Parameter: startTimeInMin

Name	Value
General	
Array	false
Type	double
Show At Runtime	true
Show name	true
Value editor	
Editor Control	Text
Advanced	
System dynamics units	false
Save In Snapshot	true

Parameter: endTimeInMin

Name	Value
General	
Array	false
Type	double
Show At Runtime	true
Show name	true
Value editor	
Editor Control	Text
Advanced	
System dynamics units	false
Save In Snapshot	true

Parameter: id

Name	Value
General	
Array	false
Type	int
Show At Runtime	true
Show name	true
Value editor	
Editor Control	Text
Advanced	
System dynamics units	false
Save In Snapshot	true

Function: init

Name	Value
General	
Return type:	Just action (returns nothing)
Show At Runtime	true
Show name	true
Function body	

Body	oval.setVisible(true);
	//text.setVisible(true);
	//change roads
	int edgeNr =
	main.truckRoutingGraph.graph.determineForbiddenEdges(getLatitu
	de(), getLongitude());
	main.truckRoutingGraph.graph.addForbiddenEdge(edgeNr);
	main.truckRoutingGraph.graph.createWeighting("BLOCKING",
	main.truckRoutingGraph.graph.getEncodingManager().getEncoder(
	"car"));
	//walk
	edgeNr =
	main.walkRoutingGraph.graph.determineForbiddenEdges(getLatitu
	de(), getLongitude());
	main.walkRoutingGraph.graph.addForbiddenEdge(edgeNr);
	main.walkRoutingGraph.graph.createWeighting("BLOCKING",

Advanced	
Static	false
Access Type	default
System dynamics units	false

Oval: oval

Name	Value
General	
Show At Runtime	false
Lock	false
Embedded Icon	false
Public	true
Appearance	
Fill Color	white

Name	Value
Line Color	red
Line Width	2.0
Line Style	SOLID
Position and size	
Circle	true
x	0.0
Radius X	7.5
y	0.0
z	0.0
z Height	10.0
Rotation	0.0
Advanced	
Show in	2D and 3D
Show name	false

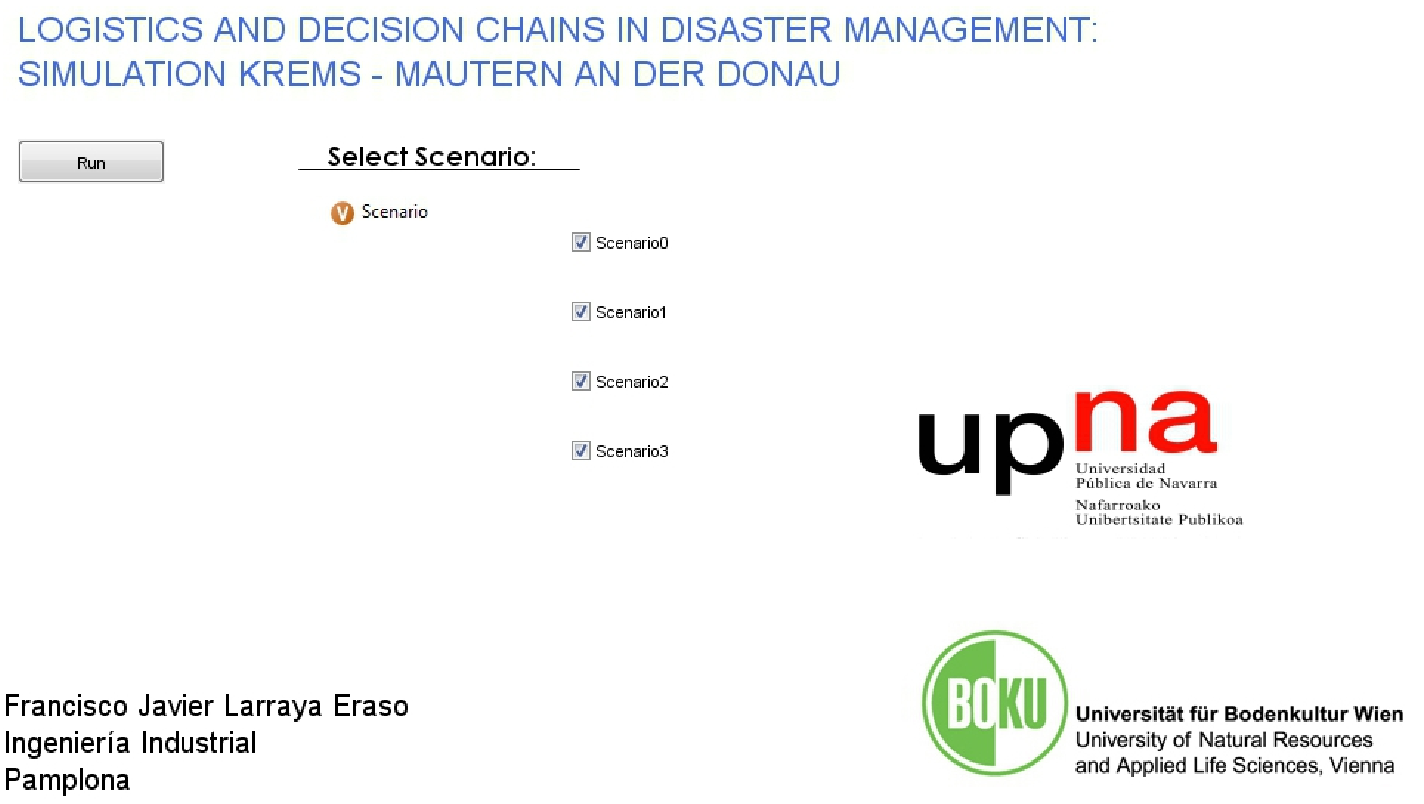
Simulation Experiment: Simulation

Name	Value
General	
Maximum Available Memory	4096
Agent Type	Main
Model time	
Execution Mode	Real time with scale
Real Time Scale	1.0
Use Calendar	true
Stop Option	Stop at specified date
Initial Time	0.0
Initial Date	Mon Jan 26 08:00:00 GMT 2015
Final Date	Mon Jan 26 20:00:00 GMT 2015
Randomness	
Random Number Generation Type	Random seed (unique simulation runs)
Selection Mode For Simultaneous Events	LIFO (in the reverse order of scheduling)
Window	
Real Time Of Simulation	false
Model Date	true
Title	Simulation : Simulation
Width	1000.0
Height	600.0
Enable Panning	true
Enable Zoom	true
Maximized size	false
Close confirmation	false
Java actions	

Before Simulation Run	//this.Scenario=3;
	root.scenarioDefinition = this.Scenario;

Advanced	
Enable Antialiasing	true
Enable Enhanced Model Elements Animation	true

Name	Value
Adaptive Frame Management	true
CPU Time Balance	1 : 2
Load Root From Snapshot	false



Variable: Scenario

Name	Value
General	
Initial Value	0
Type	int
Show At Runtime	false
Show name	true
Advanced	
Access Type	public
Static	false
Constant	false
Save In Snapshot	true
System dynamics units	false

Text: text

Name	Value
General	
Show At Runtime	true
Lock	false

Name	Value
Text	
Text	LOGISTICS AND DECISION CHAINS IN DISASTER MANAGEMENT: SIMULATION KREMS - MAUTERN AN DER DONAU
Appearance	
Font Size	24
Font Name	SansSerif
Color	royalBlue
Alignment	LEFT
Position and size	
x	40.0
y	30.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Text: text1

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Francisco Javier Larraya Eraso Ingeniería Industrial Pamplona
Appearance	
Font Size	20
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	30.0
y	490.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Image: image1

Name	Value
General	
Images	Logo_BOKU.jpg
Show At Runtime	true
Lock	false
Position and size	
x	650.0
Width	330.0
y	450.0

Name	Value
Height	102.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Text: text2

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Select Scenario:
Appearance	
Bold Font Style	true
Font Size	18
Font Name	Century Gothic
Color	black
Alignment	LEFT
Position and size	
x	250.0
y	120.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Line: line

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	230.0
dX	190.0
y	140.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show name	false

Image: image

Name	Value
General	
Images	NuevoLogoUPNA-Sept2008 (1).jpg
Show At Runtime	true
Lock	false
Position and size	
x	650.0
Width	220.0
y	290.0
Height	110.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Group: group

Name	Value
General	
Show At Runtime	true
Lock	false
Position and size	
x	490.0
y	260.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Check Box: checkbox1

Name	Value
General	
Enabled	true
Default Value	false
Link To	false
Label Text	Scenario1
Action	

Action	if (self.isSelected())
	{
	this.checkbox0.setSelected(false);
	this.checkbox3.setSelected(false);
	this.checkbox2.setSelected(false);
	this.Scenario = 1;
	}

Position and size	
x	-78.713
Width	157.0
y	-47.107

Name	Value
Height	47.0
Advanced	
Font Size	11
Font Name	Dialog
Show name	false

Check Box: checkbox2

Name	Value
General	
Enabled	true
Default Value	false
Link To	false
Label Text	Scenario2
Action	

Action	if (self.isSelected())
	{
	this.checkbox0.setSelected(false);
	this.checkbox1.setSelected(false);
	this.checkbox3.setSelected(false);
	this.Scenario = 2;
	}

Position and size	
x	-78.713
Width	157.0
y	0.0
Height	47.0
Advanced	
Font Size	11
Font Name	Dialog
Show name	false

Check Box: checkbox3

Name	Value
General	
Enabled	true
Default Value	false
Link To	false
Label Text	Scenario3
Action	

Action	if (self.isSelected())
	{
	this.checkbox1.setSelected(false);
	this.checkbox0.setSelected(false);
	this.checkbox2.setSelected(false);
	this.Scenario = 3;
	}

Position and size	
x	-78.713
Width	157.0
y	47.107
Height	47.0

Name	Value
Advanced	
Font Size	11
Font Name	Dialog
Show name	false

Check Box: checkbox0

Name	Value
General	
Enabled	true
Default Value	false
Link To	false
Label Text	Scenario0
Action	

Action	if (self.isSelected())
	{
	this.checkbox1.setSelected(false);
	this.checkbox2.setSelected(false);
	this.checkbox3.setSelected(false);
	this.Scenario = 0;
	}

Position and size	
x	-78.713
Width	157.0
y	-94.215
Height	47.0
Advanced	
Font Size	11
Font Name	Dialog
Show name	false

Button: button

Name	Value
General	
Enabled	true
Dynamic: Label	getState() == IDLE ? "Run" : "Top level agent"
Label Text	Run
Action	

Action	if (getState() == IDLE)
	run();
	getPresentation().setPresentable(getEngine().getRoot());

Position and size	
x	40.0
Width	100.0
y	120.0
Height	30.0
Advanced	
Font Size	11
Font Name	Dialog
Show name	false

Parameter Variation Experiment: SensitivityAnalysis

Name	Value
General	
Number Of Runs	10
Use Freeform Parameters	false
Maximum Available Memory	4096
Agent Type	Main
Model time	
Use Calendar	true
Stop Option	Stop at specified date
Initial Time	0.0
Initial Date	Mon Jan 26 08:00:00 GMT 2015
Final Date	Mon Jan 26 20:00:00 GMT 2015
Randomness	
Random Number Generation Type	Random seed (unique simulation runs)
Selection Mode For Simultaneous Events	LIFO (in the reverse order of scheduling)
Replications	
Use Replications	true
Fixed Replications Number	true
Replications Per Iteration	25
Window	
Experiment Progress	true
Title	Simulation Def : SensitivityAnalysis
Width	1000.0
Height	600.0
Enable Panning	true
Enable Zoom	true
Maximized size	false
Close confirmation	false
Advanced	
Allow Parallel Evaluations	true
Load Root From Snapshot	false

Parameter Variation Experiment Parameters:

Parameter	Type	Value		
		Min	Max	Step
initialStoreStock	FIXED			
numberOfTrucks	FIXED			

Simulation Def : SensitivityAnalysis

Run

Varied Parameter

numbreOfTrucks ? Number of runs: ?

Charts

Text: text

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Simulation Def : SensitivityAnalysis
Appearance	
Font Size	24
Font Name	SansSerif
Color	royalBlue
Alignment	LEFT
Position and size	
x	40.0
y	30.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Text: text1

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Varied Parameter
Appearance	
Bold Font Style	true
Font Size	12
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	40.0
y	120.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Line: line

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0

Name	Value
Line Style	SOLID
Position and size	
x	150.0
dX	650.0
y	130.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show name	false

Text: text2

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	numbreOfTrucks
Appearance	
Font Size	12
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	40.0
y	140.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Text: text3

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	?
Appearance	
Font Size	12
Font Name	SansSerif
Color	darkSlateBlue
Alignment	RIGHT
Position and size	
x	260.0
y	140.0

Name	Value
z	0.0
Rotation	0.0
Advanced	
Show name	false

Text: text4

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Number of runs:
Appearance	
Font Size	12
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	420.0
y	140.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Text: text5

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	?
Dynamic: Text	format(getEngine().getRunCount())
Appearance	
Font Size	12
Font Name	SansSerif
Color	darkSlateBlue
Alignment	RIGHT
Position and size	
x	640.0
y	140.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Text: text6

Name	Value
General	
Show At Runtime	true
Lock	false
Text	
Text	Charts
Appearance	
Bold Font Style	true
Font Size	12
Font Name	SansSerif
Color	black
Alignment	LEFT
Position and size	
x	40.0
y	160.0
z	0.0
Rotation	0.0
Advanced	
Show name	false

Line: line1

Name	Value
General	
Show At Runtime	true
Lock	false
Appearance	
Line Color	black
Line Width	1.0
Line Style	SOLID
Position and size	
x	90.0
dX	710.0
y	170.0
dY	0.0
z	0.0
dZ	0.0
z Height	10.0
Advanced	
Show name	false

Button: button

Name	Value
General	
Dynamic: Enable	getState() == IDLE
Enabled	true
Label Text	Run
Action	
Action	run();

Name	Value
Position and size	
x	40.0
Width	100.0
y	80.0
Height	30.0
Advanced	
Font Size	11
Font Name	Dialog
Show name	false

ESCUELA TÉCNICA SUPERIOR DE INGENIEROS INDUSTRIALES Y DE TELECOMUNICACIÓN

Titulación:

INGENIERO INDUSTRIAL

Título del proyecto:

LOGISTICS AND DECISION CHAINS IN DISASTER MANAGEMENT; FLOODS IN AUSTRIA / CASE SIMULATION: KREMS-MAUTERN AN DER DONAU

Proyecto de Fin de Carrera realizado en el Departamento de Logística y Producción de BOKU (University of Natural Resources and Life Science), Viena, Austria.

BOKU Supervisor: PATRICK HIRSCH

ANEXO 2: INUNDACIONES EN NAVARRA 2015

Alumno: Francisco Javier Larraya Eraso

Tutor – Director: Javier Faulín Fajardo

Universität für Bodenkultur Wien
University of Natural Resources and Applied Life Sciences, Vienna

Pamplona, 27 Abril 2015

ANNEX II: FLOODS IN NAVARRA 2015

Flooding events have been increasing in the last few years, and Navarra is not an exception. Many flooding episodes have occurred in the past years. In this document, a fast analysis and comparison with the Austrian one, main subject of the thesis, is performed.

At first, the study is focused in the floods occurred this year 2015, describing the most remarkable aspects, characteristics, causes and consequences. In addition to this part, a comparison between the Spanish and the Austrian rivers and responses is developed.

Flood in Navarra year 2015

During the development of this final master thesis, two major unusual floods occurred in Navarra and all the Ebro's basin: the first was in the early days of February and the second, and strongest, in the last days of February and the first of March. The worst floods in Navarra and Aragon since 2007. The attention and study is going to be focused in the second flooding event. This phenomenon involved not only the Ebro, but also important rivers in the community like the Arga, main river crossing Pamplona (capital). Due to the magnitude of the floods, accompanied with a great quantity of snow, zones that usually are not affected by flooding episodes were affected. Important grows in the ordinary discharge of the Ebro and all its tributaries (considering the river Arga as main tributary in this study), are common each year but not so early and so huge; this phenomenon happened earlier than ever, in the end of February. This variability of the season's timing is also supported by the fact that during June 2014, historical floods affected the north of Navarra, an area where it is very rare to happen.

Focusing in the 2015 floods, this document involves the study of the factors, weather and geographical conditions that advantaged this phenomenon.

Factors

In the last days of February, a low pressure temporal involving high winds (150 km/h, the worst temporal in the last 5 years), strong precipitations, both snow and rain, low temperatures and high waves, affected the whole Spain. This temporal performed historical windy achievements as well as records in precipitation. Navarra was the most affected region in what precipitations concerns. In the mountains, more than 3 meters of new snow were accumulated. In addition to this, the whole month of February was very cold and extremely wet *(Gobierno de Navarra, 2015).* Literally taken from the Navarra government review, "*Rainfall is distributed throughout the month, being more intense between the days 21 and 26. As a result of high rainfall the Arakil, Arga, Ega, Larraun, Irati and Ebro rivers overflowed, in some cases even twice the same month" (Gobierno de Navarra, 2015).*

In the following figure, Figure 1, the measures in several weather stations during the month of February 2015 are shown. The historical measures are also exposed to compare with. As it can be observed, all the measures in all the stations are higher during February 2015. In Figure 2, a graphic comparing the amount of precipitation measured during this month is shown.

Reference station	Month measures				Historical measures (1981 - 2010)			
	Prec.	Accumulated	Prec. days	Prec. Max in 24h.	Prec.	Accumulated	Prec. days	Prec. Max in 24h.
Abaurrea Alta	256	1,150.50	18	34	123.1	835.80	13	63
Alsasua	328.5	1,108	20	46.4	113.6	721.5	15	55
Arroniz	100.4	484.4	16	21	42.7	316.6	10	36
Buñuel	26.1	256.2	14	9,8	19.5	167.9	8	35.4
Caparroso	47	317.4	13	11.6	25.2	243.9	8	17.9
Carcastillo	61.2	280.2	15	11.3	25.2	243.9	8	17.9
Corella	28.1	264.6	10	8	21.1	179.2	8	38.2
Santesteban	363.8	1,156.6	15	63.1	133.4	856.8	15	79.8
Pamplona	209.1	698.8	18	48.8	62.7	436.2	14	33.4
Yesa	172.5	535.5	13	47	61.4	428.5	9	55

Fig. 1 "Measures of precipitation in different stations in Navarra February 2015" *(Gobierno Navarra, 2015)*

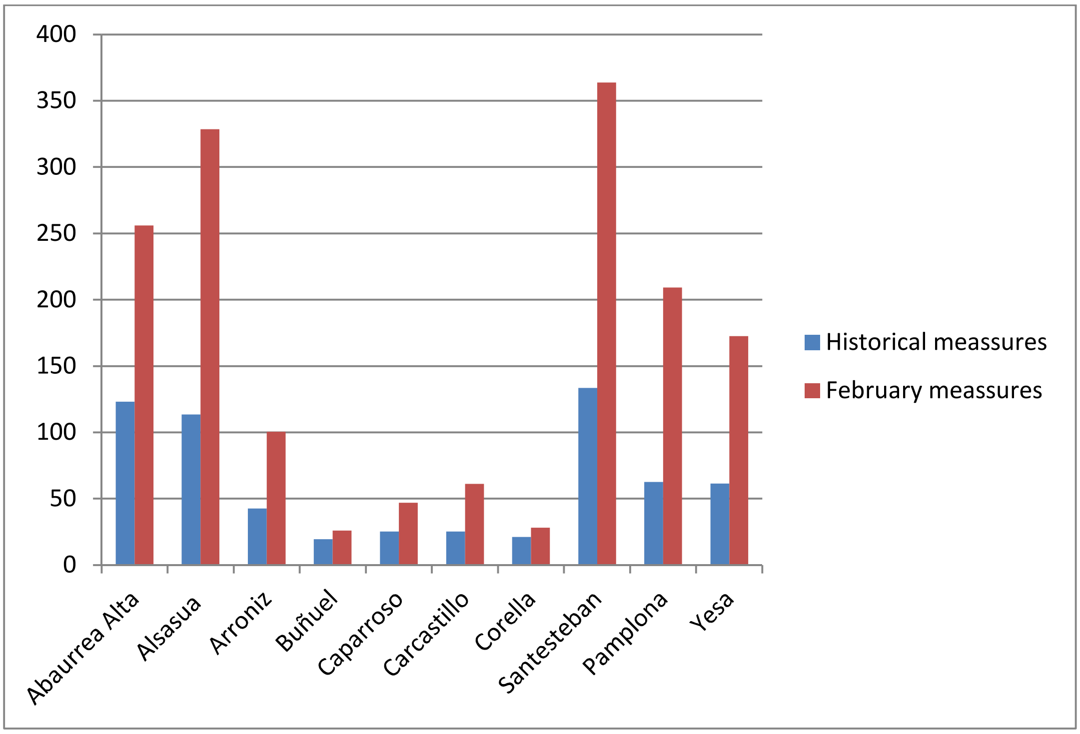


Fig. 2 "Historical – February measures in weather stations" *(Gobierno de Navarra, 2015)*

Consequences

The main consequence of this amount of precipitations was, as mentioned, the biggest flood in 10 years. In the next figure, the discharge and high of the Ebro River in Castejón (Navarra measuring station) are shown. As it can be observed, this year both are the highest.

Date	Discharge (m2/seg)	High (m)
6/02/2003 (initial)	3,320	7.54
6/02/2003 (definitive)	2,882	7.54
25/01/2004	1,431.6	5.4
31/12/2005	957.25	4.65
12/03/2005	2,260.5	6.42
03/04/2007	2,825.6	7.33
02/06/2008	2,170	6.71
13/02/2009	1,706.91	6.71
16/01/2010	1,935.49	7.06
24/02/2011	1,176.29	5.59
16/12/2012	864.4	4.88
21/01/2013	2,235.14	7.47
05/03/2014	1,523	6.44
27/02/2015 (initial)	**2,406**	**7.78**
27/02/2015 (definitive)	**2,850**	**7.78**

Fig. 3 "Discharge and high of the Ebro River in the past floods" *(Diario de Navarra, 2015)*

Despite the fact that numerical quantification of the impact can notably change depending on the source, the total costs of the floods were estimated in around 4,000,000€ (only in Navarra). More than 9,000 hectares were affected by water *(Gobierno de Navarra, 2015), 2015).*Spanish government has recently announced and amount of 11,500,000€ for the three most affected communities: Navarra, Aragón and La Rioja *(Diario de Navarra, 2015)*. Figure 3 shows an example of the magnitude of the floods.

Fig. 4 "Panoramic of the Ebro flooding" *(Gobierno de Navarra, 2015)*

Contrast Austria – Navarra

Characteristics of the rivers

The first aspect to study is the geography and the characteristics of each of the rivers causing this phenomenon. The main rivers are the Danube River, in Austria, and the Ebro River in Spain, both carrying important volume of water. In the following lines some technical details of each are described.

Danube River

- European's second longest river, it is located in Central and Eastern Europe
- **Countries:** Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Bulgaria, Romania, Moldova, Ukraine *(International Commission for the protection of the Danube River, 2013)*
- **Length:** 2,860 km
- **Average discharge (caudal):** 7,000 m^3/s
- **Number of Tributaries (most important):** 31
- **Main organization in charge:** ICDR (*International Commission for the protection of the Danube River).* Also several different organizations, depending on the country.

Fig. 5 "Donau River passing through Vienna" *(wien-vienna.at, 2015)*

Ebro River

- Second longest river in the Iberian Peninsula but the biggest in discharge
- **Countries:** Spain
- **Length:** 930 km
- **Average discharge (caudal):** 426 m^3/s
- **Number of Tributaries (most important):** 21
- **Main organization in charge:** CHE (Hydrological Ebro Confederation, acronym in Spanish).

Fig. 6 "Ebro River passing through Zaragoza" *()*

As it is observed, concerning to the magnitude of the river, the Danube is much more important than the Ebro; quite logical taking into account the size of both rivers. Nevertheless, the shape and the basin of both rivers are very similar. Both have their primary source in the mountains (Ebro: 1,980m; Danube: 1,078m). In addition to this, both have the same way of dropping in the sea: a delta. A delta is a "*piece of land shaped like a triangle that is formed when a river splits into smaller rivers before it flows into an ocean*" *(Merriam-Webster, 2015).* This type of flowing is very unusual and involves a special ecosystem with rare species. In Figure 3, both deltas, Ebro's and Danube's can be observed.

Fig. 7 "Ebro and Danube Deltas" *(_)*

Response

Continuing with this comparison between the Spanish floods and the Austrian, the next step is to compare how they deal with, as well as the consequences in both cases. According to the guidelines established by the CHE *(available at http://www.chebro.es/inicio.ponerIdioma.do),* the dealing method with the phenomenon is almost the same in Austria and Navarra (Spain). As it has been explained for the Austrian case, depending on the importance and magnitude of the floods, different coordinating and acting organizations are involved. In the next figure, some members of a fire brigade move on with the help of a boat through the flooded streets of Tudela (second biggest city in Navarra). This image supports the affirmation that the disaster relief organizations in Navarra are almost the same as the Austrian ones.

Fig. 8 "Fire brigade sailing through the streets" ***(Diario de Navarra, 2015)***

In what the economical aids to overcome the floods concerns, the Navarra's government already presented a document were it afforded the total costs remaining after the central aids given by the Spanish government *(Gobierno de Navarra 2015).* In this field, both Navarra's and Austrian government are equal and very sensible to this extraordinary situation.

A significant difference concerns the cleaning of the rivers. Recently, in the Spanish city of Zaragoza, a manifestation, to claim for an intense cleaning in the affected zone of the river Ebro, has taken place. This observation is quite disappointing because due to the volume of water carried, it seems that the Ebro is easier to clean. This assumption would imply that the Austrian organization is better in what this matter concerns. In addition to this, it is important to remark the polemic around the dredge of the Ebro River.

<u>"Dredging of the Ebro"</u>

An important claimed solution is the dredge of the Ebro. As it is known, to dredge is to clean and restore the path of a river so to be navigated. This action is requested due to the amount of sediments that can easily produce another flooding event each time that the precipitations are severe. That is why the involved organizations, groups of farmers and little commerce claim for this measure which has not been performed jet. More than 2,000 people were manifesting Sunday 12th April in Zaragoza claiming for this measure as complement of the cleaning of the river *(Diario de Navarra, 2015).*

Even though, it has to be remarked that both governments, Austrian and Spanish are very sensible with this phenomenon and have quite good achievements dealing with. Both governments, Spanish and Navarra's, dedicate important amounts of money to help and restore the situation after a disaster of this magnitude. Important founds are also dedicated to prevention.

Bibliography

ABC (2015), *"The temporal in live"*, ABC. Available at: http://www.abc.es/sociedad/20150130/abci-temporal-directo-201501301217.html (accessed 02 April 2015).

Efe.Zaragoza (2015), "*More than 2000 people claim in Zaragoza for the cleaning of the river Ebro",* Diario de Navarra (Navarra's newspaper), 13 April 2015, pp 4.

El País (2015), "*Floods".* Available at http://elpais.com/tag/inundaciones/a/ (accessed 2 April 2015).

Gobierno de Navarra (2015), *"Navarra's government will complete the central aids to reach the 100% of the costs"*. Available at http://www.navarra.es/NR/rdonlyres/B1F24A85-1CF3-4BAD-B25B-C1F80EAA237C/309885/complementoayudasinundaciones.pdf (accessed 29 Mars 2015).

International Commission for the protection of the Danube River (2013), *"Countries of the Danube River Basin".* Available at http://www.icpdr.org/main/danube-basin/countries-danube-river-basin (accessed 20 Mars 2015).

Merriam-Webster (2015), "Delta", Available at: http://www.merriam-webster.com/dictionary/guideline (accessed 27 Mars 2015).

Meteorology and Climatology from Navarra (2015), *"Metrological examination February 2015",* Gobierno de Navarra. Available at: http://meteo.navarra.es/archivo/comentariosdelmes/ (accessed 25 Mars 2015).

UNDP (United Nations Development Program) (2015), "The *Danube and its network"***.** Available at http://www.undp-drp.org/drp/danube_danube_network.html (accessed 16 Mars 2015).