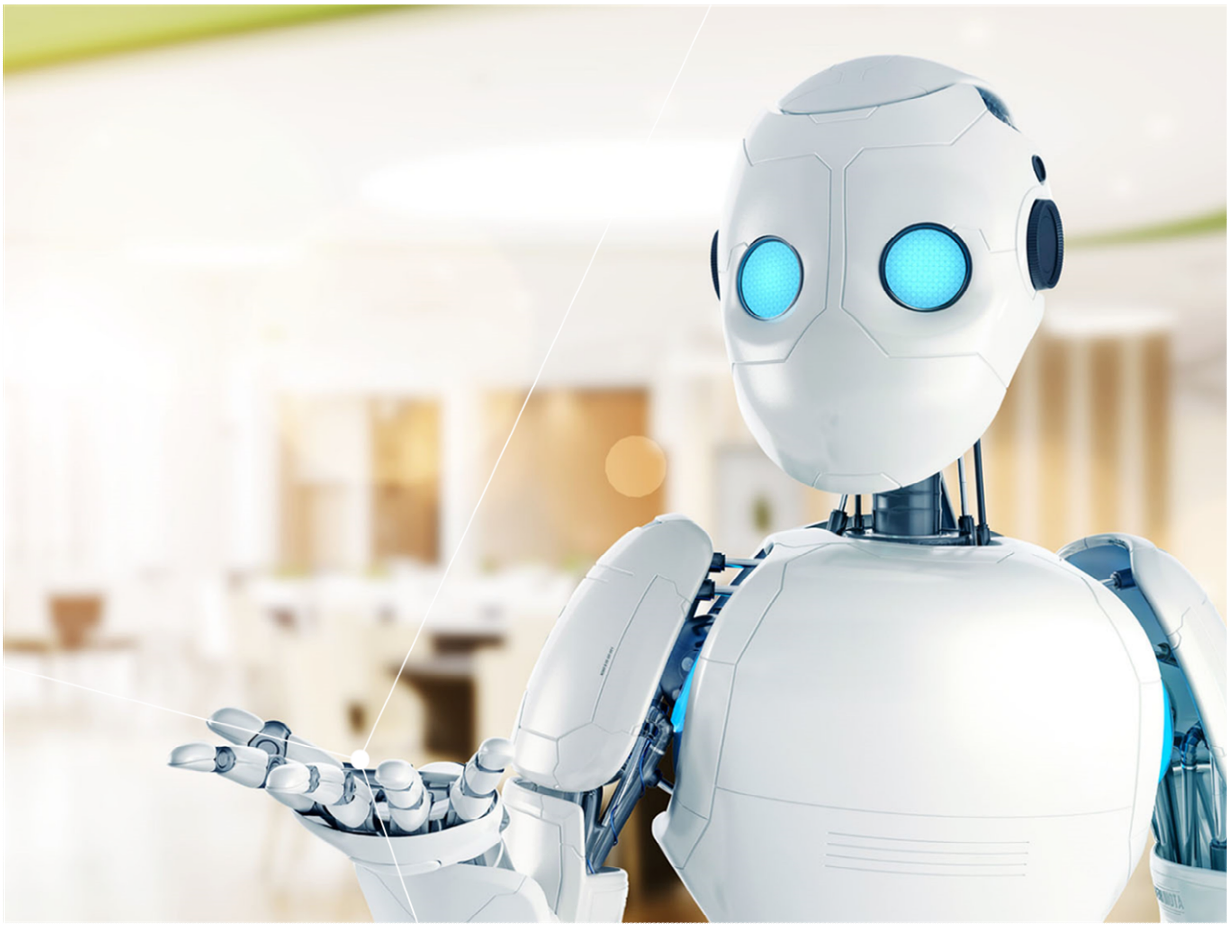
Infineon Technologies – 15 April 2020 to 31 August 2020.

Internship Report

Amaury Chapelle



Innovation in Top-Level Supply Chain Challenges

Internship Supervisor: Dr. Thomas Ponsignon

Academic Supervisor: M. Stéphane Bernard-Tremolet

University: INSA Lyon - Domaine scientifique de la Doua - 20, avenue Albert Einstein - 69621 Villeurbanne Cedex - France

Host Company: Infineon Technologies AG - Am *Campeon* 1-15 - 85579 Neubiberg - Germany

Preface

Pandemic Context

As the Covid-19 pandemic hits Europe in February 2020, Bavaria is among the first regions to be placed under containment. On March 24, Hans Ehm, head of the Supply Chain Innovation department, organizes a meeting to launch a simulation in his department to predict the impact of the pandemic on Infineon Technologies' supply chain.

The pandemic has already severely affected the company. The cancellation of passenger flights, priority delivery mode for semiconductors, has caused transport times and costs to skyrocket. Some customers are no longer accepting deliveries because their factories are closed. Demand has fallen sharply and some production sites have come to a complete standstill.

Taking action against this severe crisis, Hans Ehm would like to start studying the development of the pandemic in the ten countries where Infineon Technologies' production and distribution sites are located: Austria, the United States, China, Germany, Hungary, Malaysia, Mexico, Singapore, the Philippines and Taiwan.

In addition to this, this large-scale project could provide work for the many students who started their internships at that time. Indeed, the company did not cancel or postpone any contracts and sent the necessary material to the students' homes, even as far away as Texas.

As I was boarded on April 15 in the middle of the lockdown period, I was directly integrated into the pandemic simulation group within the Supply Chain Innovation department. As the team launched a few other projects around the Covid-19 pandemics, Hans Ehm gave me the opportunity to be in charge of one of them.

I also worked on three other projects during my 20-week internship at Infineon. One of them was about Supply Chain simulation, while the other two dealt with long-term availability request issues. The first project I worked on was internal to my department, but other divisions of Infineon requested the three others.

Aim of the report

Because it is not possible to link all my projects together under a single problematic, I decided to treat them separately in this internship report. In order to problematize my main mission and reflect on the other projects of the department in this global crisis context, I will develop on the role of *System Dynamics* modeling in the central part of the report.

Acknowledgements

I would like to warmly thank Hans Ehm and Thomas Ponsignon without whom I would not have had the chance to do this internship. Their guidance and advice pushed me to do my best on the tasks they assigned to me. I would like to thank them in particular for their trust in such interesting and strategic projects for Infineon Technologies.

I would also like to thank all the colleagues I have worked with, especially Abdelgafar Ismail. His feedback on my work has always been of great value and has allowed me to understand much more about both the technical and philosophical aspects of modelling.

Furthermore, I would like to thank the Unitech network as well as INSA Lyon without whom this internship would not have been possible. This year of international studies, marked by both an academic exchange in Barcelona and an internship in Munich, made me grow a lot. In addition to having made considerable progress on my language skills, I realized how much working in a multicultural environment is important to me.

Finally, I would like to thank the company Infineon Technologies who did not give up hiring its trainees and even during this huge health crisis. I was very impressed by their ability to work from home and the step back they took from this crisis to manage it better.

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Introduction

Description of the company

Infineon Technologies AG is a global leader in the semiconductor industry. In fiscal year 2019, the company has generated sales of approximately €8 billion with more than 47,400 collaborators in over 100 countries.

Infineon Technologies was founded in 1999, but the company's roots date back to the 1940s, when in 1946 the Siemens Board of Directors established a laboratory for basic semiconductor research in the village of Pretzfeld, Germany. In the summer of 1946, a small group of researchers began working there, laying the foundation for Infineon Technologies. Today, and since 2012, Dr. Reinhard Ploss heads the company; he received his doctorate from the Technical University of Munich in 1990.

Infineon Technologies is divided into four business areas: Automotive, Power and Sensors Systems, Connected Secure Systems and Industrial Power Control, which are distributed worldwide.

With regard to sustainability, Infineon Technologies ranks among the 10% most sustainable companies in the world and it is part of the Dow Jones Sustainability™ World Index. To this end, Infineon Technologies addresses global societal challenges such as climate protection, energy efficiency and resource management with innovative products. With its products and innovation in combination with efficient production, Infineon achieved a net benefit of more than 54 million ton of CO_2 equivalents in 2019.

In the early stages of the Covid-19 pandemic, Infineon Technologies announced the closing of the acquisition of Cypress Semiconductor Corporation. With the new acquisition of Cypress, Infineon Technologies has achieved the number one position in the automotive and power market and the number two position in Security Integrated Circuit's market in 2019-2020, becoming a leading player in all its target markets. The acquisition of Cypress is an important step in Infineon Technologies' strategic development from a leader in components to a leader in system solutions.

The semiconductor industry

According to Fortune Business Insights, "the global Semiconductor Market is projected to reach USD 730.29 billion by 2026, exhibiting a CAGR (Compound Annual Growth Rate) of 5.2%"[1]. With the growing development of Artificial Intelligence, Internet of Things and

[1] Pune, March 02, 2020, Globenewswire.com

machine learning there are plenty of opportunities for semiconductor market development in the next years.

We call semiconductors the chips made from materials that have an electrical resistance between metals and insulators, usually silicon. Based on the same materials but with different integrated circuits (IC), we can differentiate four main kind of semiconductors: memory chips, microprocessors, standard chips and complex systems-on-a-chip.

Semiconductor manufacturing is divided into two big processes. The frontend production creates the different layers on a semiconductor. For that, the process of lithography, photo resistance, exposure and development is repeated multiple times. The second process is the dicing, assembly, packaging and testing, also called backend production.

Depending on the complexity of the semiconductor, the frontend cycle-time is between 40 and 100 days while the backend cycle-time is between 5 and 20 days. Passenger flights insure most of the traffic between the frontend factories and backend sites within short lead times.

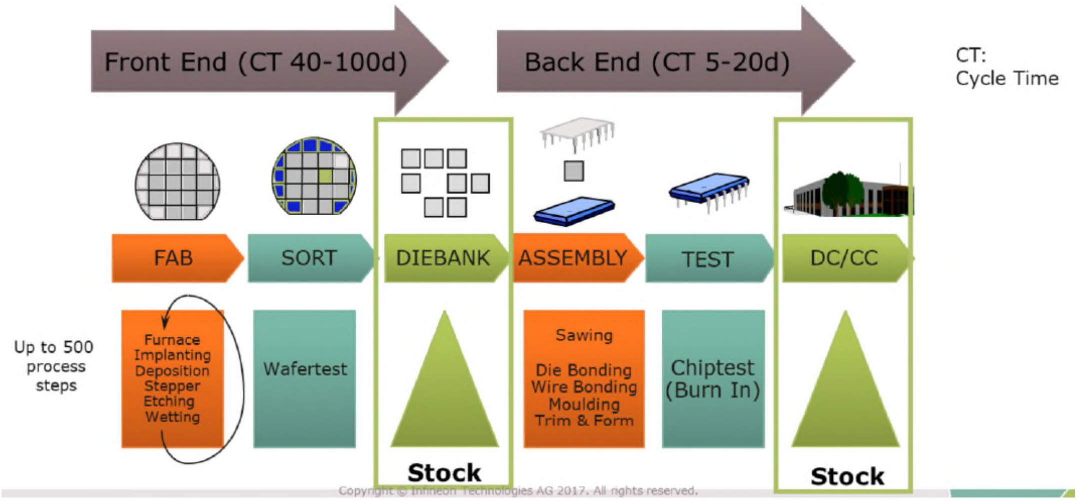

Figure 1 Production steps of a semiconductor

Ehm and Lachner (2016) describe the semiconductor industry as follows: "From the multitude of complex manufacturing steps to the globally distributed production network and the fast changing business environment, there is no other industry which has similar needs to meet"[2]

Besides the process complexity, the technology of these products is even more complicated over time. This is what Moore describes in 1965 when stating, "The number of transistor per

[2] Ehm, H. & Lachner, F. (2016) Realisierung von Flexibilität in komplexen Versorgungsnetzwerken am Beispiel der Infineon Technologies AG. In: Göpfert I. (eds) Logistik der Zukunft - Logistics for the Future. Springer Gabler, Wiesbaden. https://doi.org/10.1007/978-3-658-12256-0_5

square inch on integrated circuits had doubled every year since their invention"[3]. Indeed, he foresaw the continuation of this trend even if today the risk of stagnation appears to be inevitable, given the technical barrier that we are getting to know.

Another aspect of Moore's law is the technology obsolescence. With each new generation of chips, prices fall and the market declines and that is why semiconductor companies must constantly innovate.

Supply Chain Management and Innovation

In order to be competitive, semiconductor companies must deal with contradicting challenges such as high expenditures for innovation and operation and low sales price, fast time to market with long lead times and high product diversification with short product lifecycle. Supply Chain management addresses most of these tradeoffs and it is considered as one of the competitive advantages of Infineon Technologies. The department that I worked with insures that Infineon's Supply Chain remains a sustainable long lasting competitive advantage in all business cycles. The Supply Chain Innovation department is based on a broad portfolio of technologies and knowledge in artificial intelligence, machine learning, chatbots, simulation, programming, and semantic web. It was created on the principle of Gartner's infinite loop, which divides the innovation process into five stages: Definition of business objectives, exploration of new technologies, the production of content, their scaling and governance before measuring, optimizing and repeating.

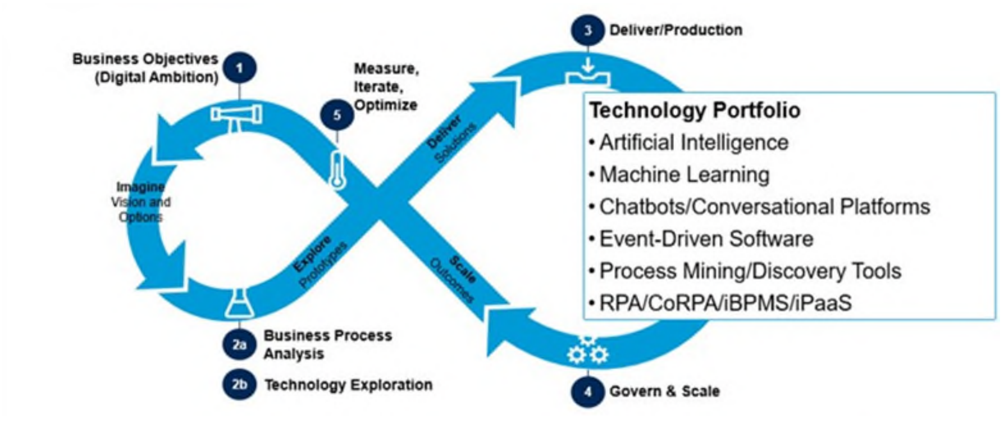

Figure 2 Gartner's infinite loop of innovation (Supply Chain Innovation department)

Hans Ehm and four column heads (units of the department) lead it. The four columns are Knowledge Management, Education and Supply Chain Audits; Supply Chain Roadmap, Artificial Intelligence, Simulation and Modeling; Supply Chain Digitalization, Automation, and

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[3] G. E. Moore, "Cramming more components onto integrated circuits, Reprinted from Electronics, volume 38, number 8, April 19, 1965, pp.114 ff.," in IEEE Solid-State Circuits Society Newsletter, vol. 11, no. 3, pp. 33-35, Sept. 2006, doi: 10.1109/N-SSC.2006.4785860.

Funded Projects; and Semantic Web. At the time of my internship, it included about eighty collaborators, most of them being students. The department hires students under different forms of contracts: internship, master thesis, PhD or working student.

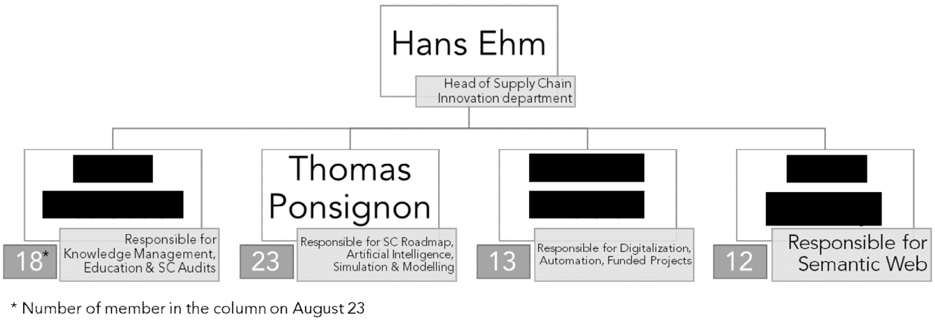

Figure 3 Organizational Chart of the Supply Chain Innovation Department

During my internship, I was part of the second column Supply Chain Roadmap, Artificial Intelligence, Simulation and Modeling with Dr. Thomas Ponsignon as my supervisor. This column is divided into five sub columns and I was part of the Top-Level Supply Chain Challenges one. The team takes care of modeling risks for our Supply Chain in order to anticipate and avoid them. For example, the team is currently focused on sustainable development, economic trade wars, bullwhip effect and Covid-19 Pandemics.

Abdelgafar Ismail is in charge of this sub column where modeling techniques are at the heart of our work. Indeed, finding the best models and combination allows us to go always further in our simulation and make them accurate. During a team workshop, we identified diversity as one of our strengths. The team counts eight nationalities for nine team members.

Every student integrating the Supply Chain Innovation department does a dozen of e-Learnings concerning the SCOR model on which Infineon's Supply Chain is based. This well-known model allows a better visibility and harmonization within the processes and is the common basis for our Supply Chain management.

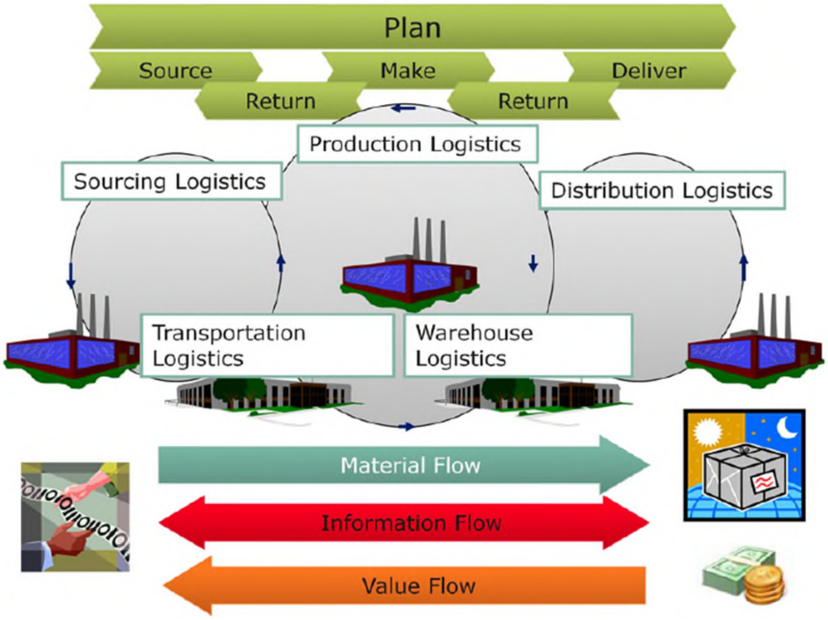

Figure 4 The SCOR model and five major processes

Incoming students also participate in a two-day classroom training with presentations from different departments of the company and serious games based on the SCOR model. This training aims to provide a better understanding of the different planning processes and KPIs (Key Performance Indicators). The serious games focus on grasping how Artificial Intelligence can help improving demand forecasting or apprehending the bullwhip effect in the End-To-End Supply Chain.

Description of the internship assignments

As mentioned in the preface, I joined the Pandemic Simulation taskforce at the beginning of my internship. My first mission was to create a PowerPoint presentation for the monthly management meeting of the project. Then, Hans Ehm offered me to help him with the decision-making at Campeon (Infineon's campus) by creating an agent-based model to simulate an eventual virus spread between employees.

In the meantime, a Product Line Marketing manager for Infineon France requested a study from our department on long-term availability issues.

A colleague of mine in SC Innovation team and I were involved in this less technical project that could put us in contact with the French division of Infineon.

My third task was to model the internal Supply Chain of the automotive division of Infineon with a System Dynamics simulation. Requested by the director of Digitalization and SPM (Supply Chain and Production Management) Excellence, this simulation aims to evaluate the level of inventories in Die-Bank and Distribution Centers and associated binding capitals. The automotive industry is one of the most affected by the effect of the pandemic on the end market demand globally. The model aim is to test different end market scenarios to help understand the demand evolution along the entire supply chain in general and on Infineon in particular.

Requested by a team for Life Cycle Management of the automotive division, my task was about programming a macro to support the complex process of extending product's availability in time.

During my internship, I also supported two colleagues in their application to the Supply Chain Excellence Awards by creating two promotional videos. The team applied to the Innovation and the Technology awards and we wrote two papers on how Infineon handled the Covid-19 crisis.

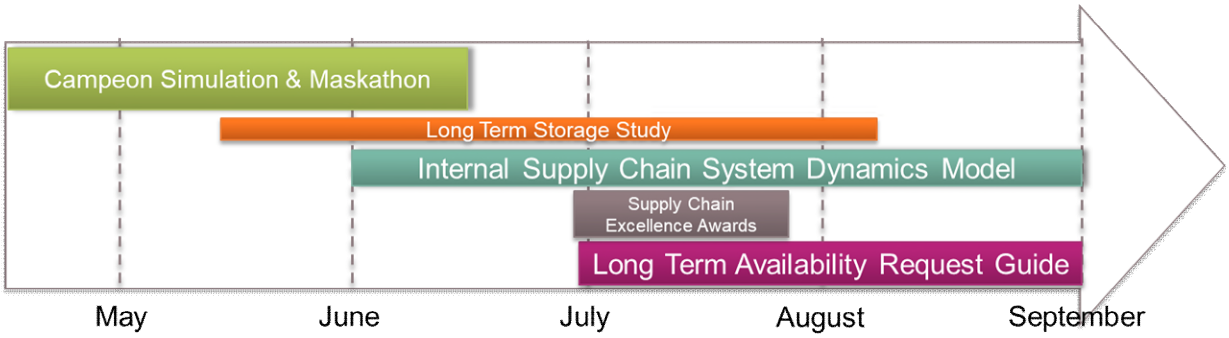

Figure 5 Timeline of my different assignments

This timeline shows the organization between the different assignments I worked on during my internship. The thickness of the boxes roughly represents the workload associated to each task.

Introduction to modelling: The Campeon Simulation

The goal of this mission was to find out how Infineon could ensure a smooth return to normal to all its employees. More specifically, how to ensure that the employees return to work at *Campeon* (Infineon's headquarters) under normal conditions, without a wave of infection breaking out. The idea was to create an agent-based simulation model capable of testing different scenarios.

As this was my first experience with simulation, I first took the time to train myself with *Anylogic* software and went through different e-Learnings and tutorials. It turns out that there exists such simulations online to estimate the risks of contamination for example in an airport such as the ones available in Anylogic Cloud hyperlink. After this training, I was able to create two models representing infected employees on Infineon's Campeon. The first model could represent the whole campus and daily displacements from the train station or the parking to the different buildings and the second model only the interactions inside a specific building (e.g. the canteen).

Hybrid Models

A hybrid model is a combination of two modeling techniques or more. Indeed, the first model combined the GIS library and the properties of the agent. The GIS (Geographic Information System) library is useful for modelling agents in a real geospatial environment. GIS has information about all the buildings, roads and infrastructure on the planet in a form that software such as *Anylogic* can use.

In order to give each agent certain properties and especially a state of infection, I used an agent-based approach. Each agent has two possible states: susceptible or infected. When infected, the agents can transmit the virus to another agent in the model if, for example, they are at a close distance for a certain period of time with a certain probability. Another property of these agents is that they have a daily routine, i.e. they move from one place to another at certain times of the day.

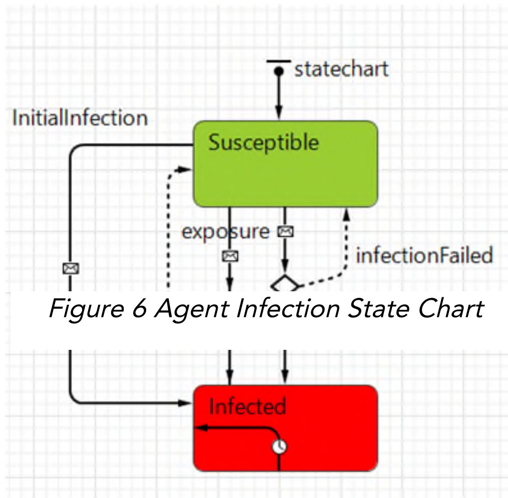

Figure 6 Agent Infection State Chart

Even if the first model could represent the whole campus and be more accurate on large-scale decisions, it turns out that contagions happen mostly inside closed buildings. Therefore, we chose to focus only on the building-level model representing less agents but with more interactions.

The challenges of modeling an epidemic

The building-level model is based on two *Anylogic* libraries: the pedestrian library and the agent library. Whereas the pedestrian flowchart controls the movement of the agents, the agent's flowchart represents the infection state and daily routine of each employee.

We know that every agent in an organization behaves differently throughout the day and this is the difficulty when modeling agent-based interactions. In order to generate contagion between two individuals, they must be either in a physical contact or in a close interaction. On top of that, social distancing measures help to avoid these contagions and the model had to consider them. The last possible risk of becoming infected is touching an infected surface and then touching your face directly. Considering all those possible risks, I fine-tuned my model so that it is able to compute the number of infected people after one day at work, given the initial number of infected and different parameters.

Scaling the model to reality

The second step of the model creation was to make it specific to one building of Campeon and with realistic conditions. We chose to focus on the building number fifteen of *Campeon*, building where most of the collaborators of the Supply Chain Innovation department work. This building has three floors, two main entrances and is composed of open-space offices as well as some closed offices. Furthermore, it has a food court inside where the collaborators can go to eat at lunch. (The model can be seen in the appendices)

Based on the information provided by Campeon site management, I modeled the second wave of home-office return. This second wave corresponds to a maximum total on-site presence of 60% keeping a distance of two meters between each employee working at his or her desk. Wearing a mask is mandatory everywhere inside the building, except when the employee is working alone at his office.

To do so, I imported the building plans and started to recreate the environment with the objects from *Anylogic*'s pedestrian library. In order to ensure a fluid and natural movement of the employees in the model, I recreated all the walls, tables, stairs and doors of the building. Seats are modeled by attraction nodes inside a so-called waiting area.

As mentioned above, it is difficult to generate the randomness of such a model. In fact, it would be possible for agents to have a pedestrian flowchart in addition to their two existing flowcharts. Unfortunately, this is not possible in *Anylogic* since the pedestrian library is designed to study the flow of people in space and we cannot generate a pedestrian flowchart per agent. Therefore, I had to group the agents sharing the same open-space in the model and this constrained a lot my capacity to generate randomness. I generated these groups of employees according to a database that associates to each working area an entrance and exit door, a staircase and a maximum number of employee.

Modeling the infected surfaces

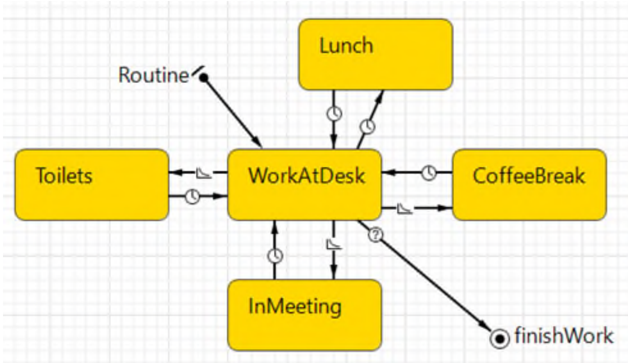

Figure 7 Daily Routine State Chart

In addition to modeling possible infections while the agent is traveling and sitting at his desk, I had to model the rest of the interactions. For this reason, I included a second flowchart for each agent. While the main state is working at his or her desk, each agent can also go to meetings, have lunch, go to the bathroom or take a coffee break. All of these actions may result in an additional risk of infection given the number of surfaces that have been touched. Each infectious employee will spread the virus on one of the different objects (meeting rooms, toilets, lunchroom…). Then, the probability of being exposed follows the ratio of infected objects to the total number of objects. As the viral load is also lower on surfaces, the probability of successful infection is lower than between two humans.

In order to track and record which surface was touched, I used a second type of agent in my model. I counted approximately the possible elements that could be touched and infected by a person and added them to the model. Each element has two possible states: uninfected or infected. They can become infected when touched by an infected agent in the model and return to normal when cleaned.

Finally, to monitor the evolution of the model, the program calculates at regular intervals different variables: the cumulative number of infections, the risk of infection in toilets, the risk of infection in meeting rooms, the risk of infection from a monitor. By plotting these variables in a graph, it is possible to determine the general level of infection inside the building and to compare several runs with each other.

Participation in an internal contest specific to Covid-19

On May 13, Campeon site management team invited all employees to participate in a Virtual *Maskathon*. The Infineon *Maskathon* is a Makeathon where ideas or problems are submitted and teams are formed to develop these ideas into prototype solutions within two days. One of the goals of this *Maskathon* was to seek ideas on how to integrate the masks into our daily lives within two weeks.

Hans Ehm offered me to participate in this competition with the support of four other team members. He wanted to take this model to the next step and to be able to test different scenarios to see which of them could most significantly reduce the risk of infection. I tested the following scenarios on my model: working in shifts, wearing facemask all the time and cleaning twice a day.

The idea behind the work in shift was to bring more students back to the office with the same number of seats. The morning shift was from 7am to 1pm and the afternoon shift was from 1pm to 8pm. With this scenario, we could almost double the amount of presence time for the students of the department and reduce the risk of infection by 25%. This improvement was because students did not eat in restaurants, the main reason for infections.

The other two scenarios also reduced the risk of infection. The permanent wearing of the facemask was the most effective because it prevented all one-to-one contagion. Finally yet importantly, increasing the frequency of cleaning was the least effective, only decreasing the reproduction rate from 2 to 1.6.

Concrete outcomes of the project

The last part of this project consisted of presenting my simulation in a video and writing a description for our participation in the *Maskathon*. After a one-week voting period, our project won third prize in the *Maskathon* with 309 votes.

Finally, the site management team adopted some of the ideas of this contest and the direct result of my simulation is that the cleaning frequency was changed to comply with my recommendations. The department head also used the simulation to lead a discussion on how to bring back more students and especially on shift work.

From a personal point of view, this project helped me to get started with *Anylogic* and to understand the different concepts behind modeling. I also enjoyed participating in the *Maskathon* contest that pushed me to do my best and was ultimately rewarding. I know that this simulation will be reused to model the winter period in *Campeon* and I have already worked in this direction by adding the two other floors of the building to the model. A big improvement will be to model non-compliant agents (e.g. employee not wearing mask) and hotspots like the Campeon’s café.

Development

Top-Level Supply Chain Challenges

The semiconductor industry is one of the upstream parts of the production chain for automobiles, electronic devices, safety devices and other electrical machinery. In times of crisis, it is the main victim of a change in demand, with variations multiplying all along the supply chain. Jay Forrester conceptualized this snowball effect also called the bullwhip effect in 1961[4], it refers to the increasing oscillations in inventory in response to a change in customer demand as one moves through the Supply Chain.

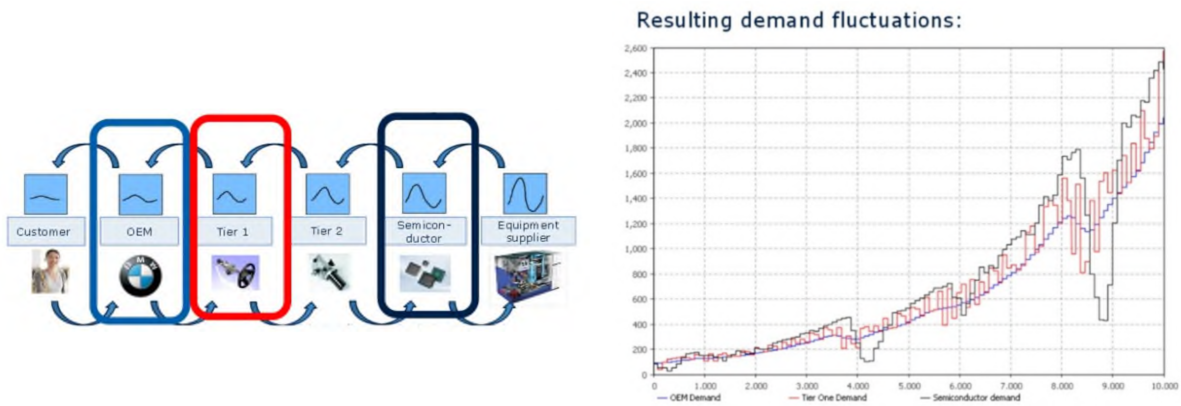

Figure 8 Bullwhip effect in semiconductor supply chain (Anylogic.com)

Together with the bullwhip effect, financial crisis, natural disasters, trade wars or cyber-attacks are examples of the top-level supply chain challenges that we study in our sub column. They both can affect either our supply (natural disaster or cyber-attack) or our demand (financial crisis) but a pandemic outbreak affects both supply and demand and transit time as well. In fact, it affects the whole supply chain.

This pandemic has shown us that supply chains around the world are dependent on each other, and especially upon Asian countries. This succession of shortages of hydro-alcoholic gel, then masks, then respirators but also essential products such as toilet paper or pastas showed the fragility of our global supply chain. Indeed, after years of economic growth without any major crisis where the goal was to work on a just-in-time basis, our supply chains have become flexible, fast and profitable, but this at the price of their fragility. In other words the pandemic challenged the design paradigm of supply chains from being cost-efficiency oriented towards being resilience oriented network design.

In addition, we know that the coronavirus crisis is just the beginning. As shown in Figure 9, this crisis will have several waves and will likely be followed by an amplified liquidity crisis in many

[4] Industrial Dynamics, Jay Forrester 1961

companies in the coming years and possibly a long-term debt crisis. That is why all companies need to be prepared to be hit several times and start thinking about how to manage their supply chain.

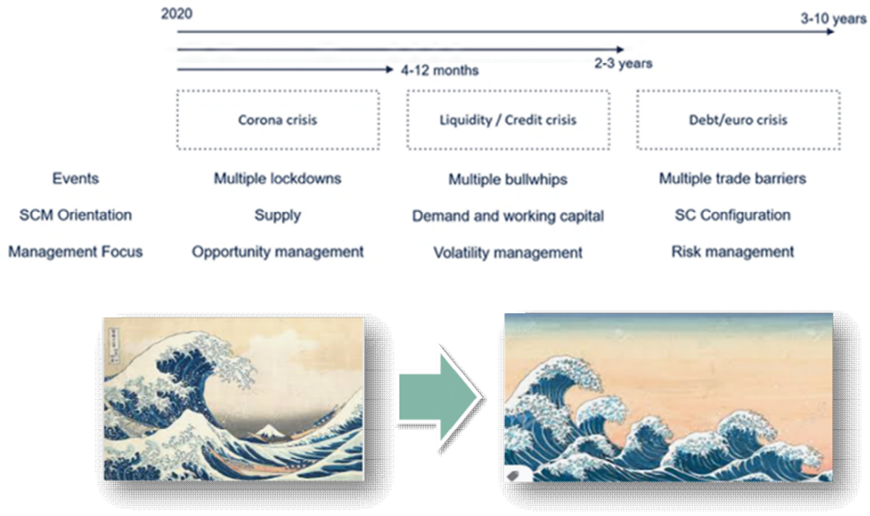

Figure 9 The multiple waves of the coronavirus crisis[5]

Problematic

Our Supply Chain Innovation department is at the heart of this crisis and we have been involved in creating models to predict the waves of this crisis and help in the decision making process. Personally involved in two models, I wanted to address these issues as part of my internship problematic.

In this development, I will discuss how simulation and systems dynamics enable an end-to-end supply chain agility and resilience amid disruptions such as the Covid-19 pandemic.

I- System Dynamics methodology

Definition of a model

A model is a set of elements that represent how a system works. Like symbols, they help us communicate thoughts and ideas about how an object or system works. There are different types of models: conceptual models (for example, an organizational chart), mathematical models (for example, differential equations), physical models (e.g. heat transfers), simulation models, etc.

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[5] Involvation & Flostock Webinar, Managing upcoming volatilities in automotive supply chains (April 22, 2020)

The ability of creating models is actually one attribute that humans possess relative to other species. It is part of our ability to anticipate and plan events and understand how our world works. Our brain either can build models by intuition or by experience and this is the mechanism that influences our actions. For example, if we know that we have a limited quantity of water when we go on a hike, our brain will regulate our consumption according to the need of the body, the amount of water left and probably the duration of the hike. In other words, we built our daily decisions on mental models.

Simulation models try to explain how something works by building a replica of it. They are extremely useful for practical decision-making because we can test them with different parameters and scenarios. They help performing what-if analyses on systems without having to build expensive prototypes or make potentially dangerous decisions in reality. While physical models have been used extensively to test phenomena on a small scale, numerical models have mostly replaced them in recent years. Numerical models are today the fastest and cheapest way to test scenarios on a system with ever-increasing levels of accuracy.

There are different types of models: static or dynamic, deterministic or stochastic, continuous or discrete. These concepts refer to the different ways in which models approximate reality, but are also ways of simplifying their execution, since the less detail in the model, the easier and faster it is to calculate it.

Different modeling techniques:

Depending on the system and its level of abstraction, we can use different simulation methods to study it and test different scenarios. The three main dynamic simulation methods are system dynamics, discrete event modeling and agent-based modeling. The figure below shows that the three techniques correspond to different levels of abstraction and accuracy.

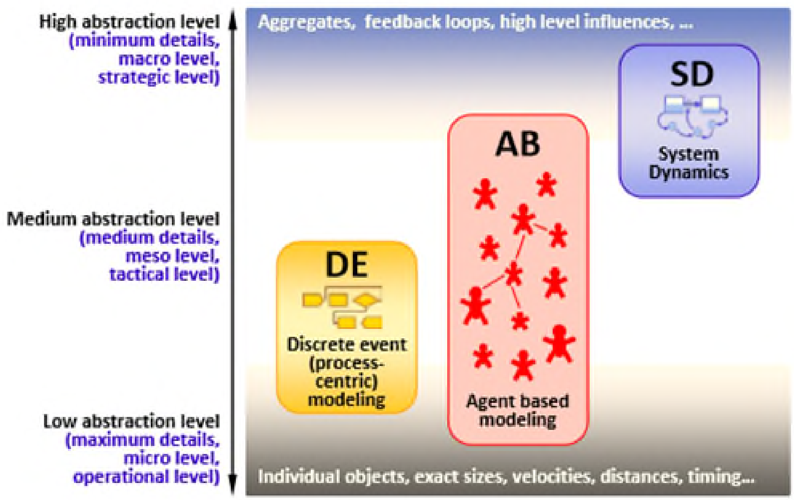


Figure 10 Three main methods of dynamic simulation[6]

System dynamics is the most abstract method that focuses only on the behavior of the system and not on the individual properties of its components. It is used at a strategic level to understand the interrelationship between causes and consequences. We have used this technique to model the end-to-end supply chain of the automotive industry, Infineon's internal supply chain, and for the pandemic simulation.

Agent-based modeling consists of subsystems that can either work independently or collaborate. It is based on the idea that collective behavior emerges from the behaviors of many individuals. We used this technique in the Campeon simulation where the agents were the employees, the objects and are the group of pedestrians.

Finally, process-centric modeling or discrete event modeling focuses on systems that perform a sequence of operations. For example, it can be used to model the different operations of a machine in a production line with a very high level of detail. This method can also model a production line with the different processes and their respective cycle times.

System dynamics and system thinking

Created in the 1950s by Jay Forrester, a professor at MIT (Massachusetts Institute of Technology), systems dynamics is a high-level modeling approach. It is used to understand the behavior of complex systems over time using stocks, flows, delays and feedback loops. All characteristics are linked together by a system of first-order coupled differential equations that are solved by numerical methods.

Unlike other modelling approaches, system dynamics reflects the fact that the structure of a system is as important in determining its behavior as the individual components that make it work. For this reason, it has been used to analyze strategies, policies and their application in the public or commercial domain.

The development of practical graphical user interfaces and systems dynamics software in the 1990s facilitated the use of this modelling approach. However, systems dynamics has been used since its development, first in business applications but also to model scenarios for the growth of our civilization. A well-known example of such a simulation is "The Limits to Growth" (1972)[7], a systems dynamics model capable of predicting an economic collapse in the 21st century due to the limited amount of resources on earth and an ever-increasing population.

[6] Ilya Grigoryev, AnyLogic in Three Days: Modeling and Simulation Textbook, March 20, 2015

[7] Meadows, Donella H; Meadows, Dennis L; Randers, Jørgen; Behrens III, William W (1972). The Limits to Growth; A Report for the Club of Rome's Project on the Predicament of Mankind

In 2000, John D. Sterman, professor at the MIT and director of MIT's System Dynamics Group publishes *Business Dynamics, System Thinking and Modeling for a Complex World*, giving a set of tools to model complex system dynamics. Among the many examples and applications presented in this book there are models of infectious disease dynamics, the design of supply chains or the diffusion of new technologies. In charge of modeling Top-Level Supply Chain challenges, it is clear that the team has a particular interest in using system dynamics in its models.

Furthermore, systems dynamics is part of the systems thinking approach, a holistic way of looking at systems. In contrast to positivist and reductionist thinking, systems thinking "encourages us to explore inter-relationships (context and connections), perspectives (each actor has his or her own unique perception of the situations) and boundaries" (scope and scale of a system)[8]

As in the case of a global pandemic, it is clear that solutions cannot be found without a global overview of the situation. In addition to being affected by the behavior of each individual in a country, the global health situation depends on the actions of governments directly influenced by the capacity of hospitals. Moreover, even if the situation is under control in one country, the perspective is even more global as infected people may travel from one country to another and shortages of essential life-saving equipment may originate elsewhere.

Elements in system dynamics diagrams

The principal elements in system dynamics diagrams are feedback, stocks, flows and time delays.

- Feedback loops:

There exists two different feedback loops, the positive reinforcement (labeled R) and the balancing loop (labeled B). As shown in Figure 11, a reinforcement loops strengthen a behavior. For example, in the event of a fire, the more people run, the more panic and the more people will run. On the contrary, balancing loop limits a behavior. If the number of predators increases, they will kill more prey, and since there is no food for all, the number of predators will decrease.

[8] Learning for sustainability.net, Systems thinking

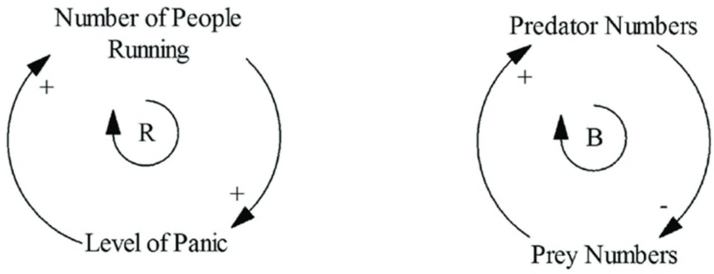


Figure 11 Positive and negative reinforcement loop

Causal loop diagrams allow to visualize the structure of a system and to define it qualitatively. In my experience, they can be particularly useful for conducting conversations about complex behaviors.

- Stocks and flow diagrams:

Stocks and flows are useful for understanding behavior in a quantitative way. While causal loop diagrams are generally used to represent information flows, we use stock and flow diagrams to represent physical flows. In systems dynamics, a stock is a box that represents an entity that accumulates or depletes over time. Stocks are filled and consumed by the incoming and outgoing flows that are linked to the stock.

- Time delays:

This last element allows to represent a shift between to variables. In fact, in an organization, there are some delays between when the information perceived and when it is measured and acknowledged. Time delays are especially useful when representing human behaviors because unlike machines, human cannot (always) treat information directly after receiving it.

For example, when a person is trying to achieve a goal, it takes time to realize that the desired objective is not being achieved, then time to implement the corrective action, and again time to see an improvement. This is why, we sometimes see oscillating systems, unable to reach their goal.

Now that we have covered the basics of modeling with system dynamics, we will show several examples that have been created at Infineon.

II- Case study of different models

During my internship, I worked in the column in charge of simulation and I had the chance to follow the development of three different models.

As I first worked with the pandemic simulation team, I followed the development of their model capable of reproducing the infection curve in more than 10 countries. Then I became responsible for the internal supply chain model, which I developed independently but also as an extension of the end-to-end supply chain model created by another student in the department.

This is why I have chosen to present these different models in the following paragraphs and not only the one I have created. I will first present the Internal Supply Chain System Dynamics model, then the Pandemic Simulation model and finally the end-to-end supply chain model. After explaining how they work and their main features, I will conclude on how these models can be used together to ensure the agility and resilience of the supply chain in the event of disruptions such as the Covid 19 pandemic.

A. Internal Supply Chain System Dynamics model

Inspired by some literature such as John D. Sterman's book[9] on systems dynamics, I have created a model representing the internal supply chain of a semiconductor manufacturer. For this simulation, I used Anylogic software just like for the Campeon simulation.

In the next paragraphs, I will present the general structure of the model and some of its features. Then I will explain how it is calibrated and specific to Infineon’s automotive division supply chain. Finally, I will present the obtained results and the possible improvements for the future.

General structure

The model is composed of four main stocks: the work in progress in frontend manufacturing, the die bank, the work in progress in the backend manufacturing and the distribution centers inventories.

[9] Business Dynamics, System Thinking and Modeling for a Complex World, John Sterman, 2000/01/01

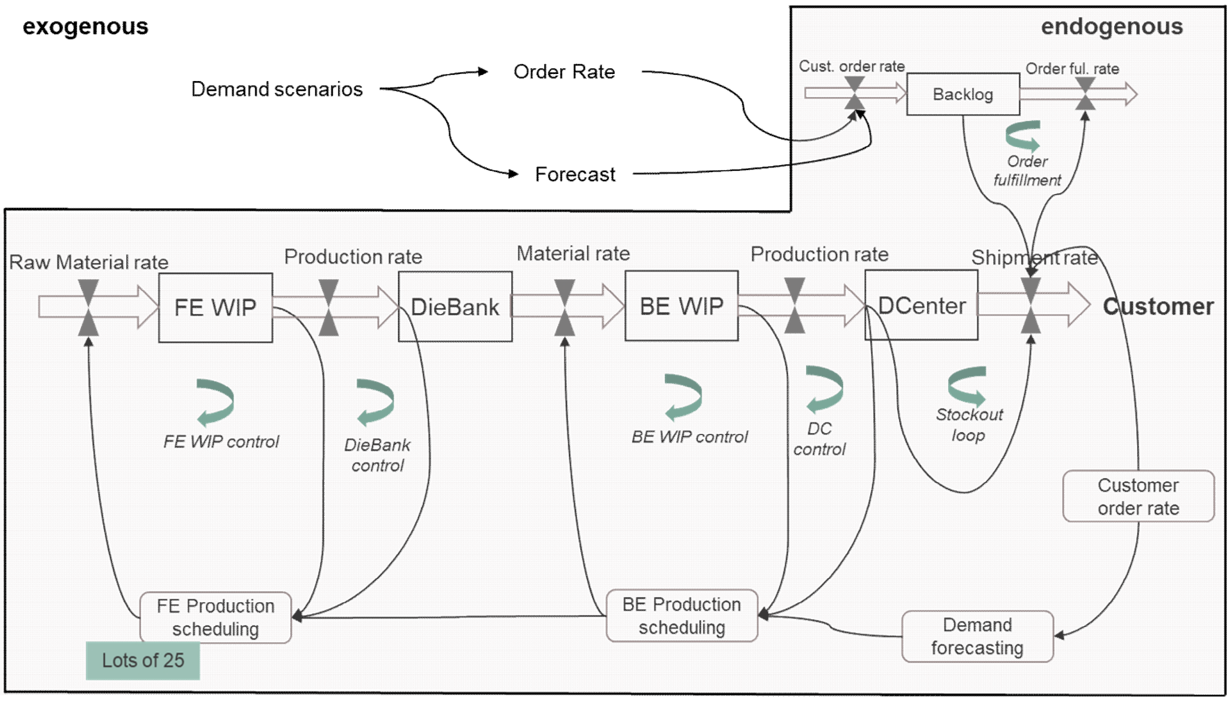


Figure 12 The overall internal supply chain system dynamics model (Author's own figure)

The work in progress in frontend manufacturing represents all the products in the form of wafers under manufacturing. For a global company like Infineon, the production is located in different sites and the wafers may differ in size or complexity. Once finished, the wafers are placed in stock (called the die bank) until backend manufacturing begins.

Backend manufacturing involves assembling and testing the chips with different technologies. Once finished, the chips are stored in a distribution center, usually where they have been tested, until they are delivered to the customer.

In addition to these four stocks, the model also includes information stocks like the backlogs, the forecast and the backend capacities. Backlogs represents the amount of order that need to be treated. The forecast is the predicted number of orders on a period and the backend capacities represent the maximum number of chips that can be produced on a period.

All the information and material flows are controlled by different loops in this model. The work-in-progress in frontend, in backend, the inventory level in die bank and in the distribution centers are regulated thanks to adjustments to the original scheduling based on forecast. The forecast is exogenous to the model and triggers the production while the deliveries follow the customer order rate. This represents the fact that, in reality, a company bases its production partially upon forecasts but its deliveries directly upon the customer orders and backlog levels.

Specific features

There are many different features in this model but explaining them in detail would be quite extensive. In this section, we will only focus on explaining the frontend and backend capacity loops, the main parts of semiconductor manufacturing.

Frontend capacities loop

As mentioned in the introduction, frontend production is characterized by long cycle times that depend on the complexity of the semiconductor. The usual trade-off when planning the frontend production is between a high plant utilization and short cycle times. Indeed, the higher the utilization, the greater the number of disturbances in the line and the longer the waiting times. The law of Little (1961) defines the cycle time as the ratio between the work in progress by the going rate:

$$Cycle\ Time = \frac{Work\ in\ Progress}{Going\ Rate}$$

Frontend production is usually the bottleneck in the semiconductor industry. As the equipment is very expensive, the utilization must always be very high. On the other hand, although each wafer has an own raw processing time (time if the plant is empty), this processing time increases with the level of plant utilization. We call the factor between actual cycle time and raw processing time the flow factor.

$$FlowFactor = \frac{Cycle\ Time}{Raw\ Process\ Time}$$

Frontend manufacturing represents more than a eight hundred steps and the flow factor is usually between 2,5 to 3 times the raw process time. Infineon’s frontend factories work 365 days a year, 24 hours a day and some of them are fully automated. The dependence between the flow factor, the utilization and the variability of the process (alpha) is formalized by the following relationship:

$$FlowFactor = \alpha \frac{Utilization}{1 - Utilization} + 1$$

With,

$$Utilization = \frac{Going\ Rate}{Capacity\ (Production\ Unit)}$$

We call this function the operating curve.

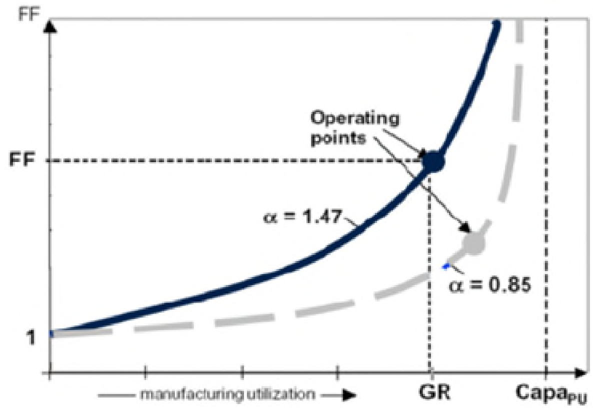


Figure 13 Operating curve in frontend manufacturing[10]

The best possible utilization would be 100% and the best flow factor would be one. Good management of operating curves aims at reaching the inflection point between flow factor and utilization. As shown in Figure 13, for the same going rate that a smaller alpha means a shorter cycle time and therefore much better performance.

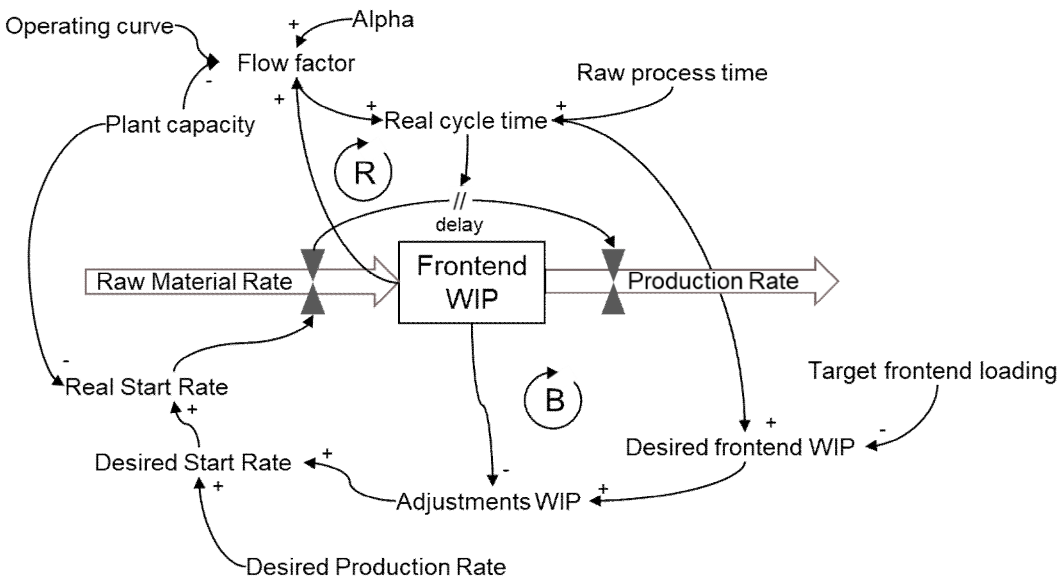


Figure 14 Frontend production control loop (Author's own figure)

To implement this compromise between high utilization and short cycle times in my model, I created two different feedback loops. As can be seen in Figure 14, on one side a balancing feedback loop insures that the work in progress remains at a certain level and on the other side a reinforcement loop makes the cycle time raise with utilization.

[10] Hopp, W. J., Spearman, M. L. (1996) Factory Physics: Foundations of Manufacturing Management, Irwi

The first loop acts controls the level of work-in-progress by adjusting the desired production start rate. For simplification, the desired level of work-in-progress is set to be constant at a target loading and this allows production to run smoothly without exceeding capacity and increasing cycle times dramatically.

The second loop increases the cycle time as a function of plant utilization, variability (alpha) and plant capacity, all of which are linked together by the operating curve function. The plant capacity is also able to limit the rate of production start-up to a certain extent to avoid overshooting.

This rather simple approach to front-end capacity management has not yielded to very good results. Indeed, we should have observed oscillations in the level of work-in-progress and flow factor and this control loop based on the operating curve function did not reproduce them. I believe an improvement could be to link the loading and the cycle times directly together with a certain delay. Indeed, between the moment where we observe high utilization and the moment where we measure the flow factor, there is a delay of at least the cycle time and this is not taken into account in the model.

Instead, the operating-curve management could be modeled by a balancing loop with three different delays (action, decision, and measurement) and this would generate oscillations around the desired cycle times without causing an elevation of the work-in-progress.

Backend capacities addition loop

As this model is created for a time horizon of two to three years, there is no question of increasing frontend capacities in this period of economic recession. However, we have studied the possibility of adding backend capacity.

The backend manufacturing consists of two processes: assembling dies and testing. The typical cycle time of backend production is between 5 and 20 days. Backend capacities are subject to more frequent decisions than frontend capacities. They are less expensive, and increase or reduce them is easier and takes less time.

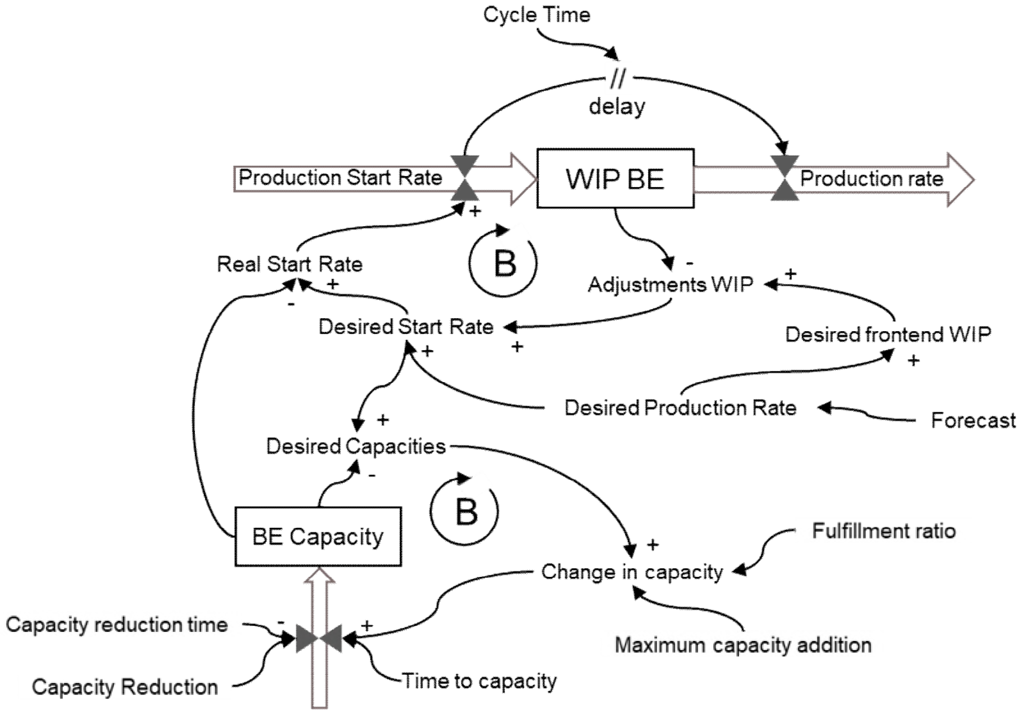


Figure 15 Backend production control loop (Author's own figure)

As shown in Figure 14, there are two balancing loops to manage the backend production. As for the frontend production, the work-in-progress is adjusted in a way that it keeps a desired level and counterbalances the potential excess of the desired production. The desired production rate is directly based on the forecast and the level of inventories in the distribution centers.

In order to limit the production based on the actual capacities of the company, I have put a variable called real start rate that can reduce the desired start rate to the capacities of the company and even reallocate them. Therefore, the inflows of the work-in-progress are balanced without exceeding the capacities.

The capacity addition or reduction decision loop is based on the desired capacities that correspond to the desired production start rate. The higher the desired capacities, the higher will be the change. However, this change in capacities is not linear and follows a fulfillment ratio curve as shown in Figure 16.

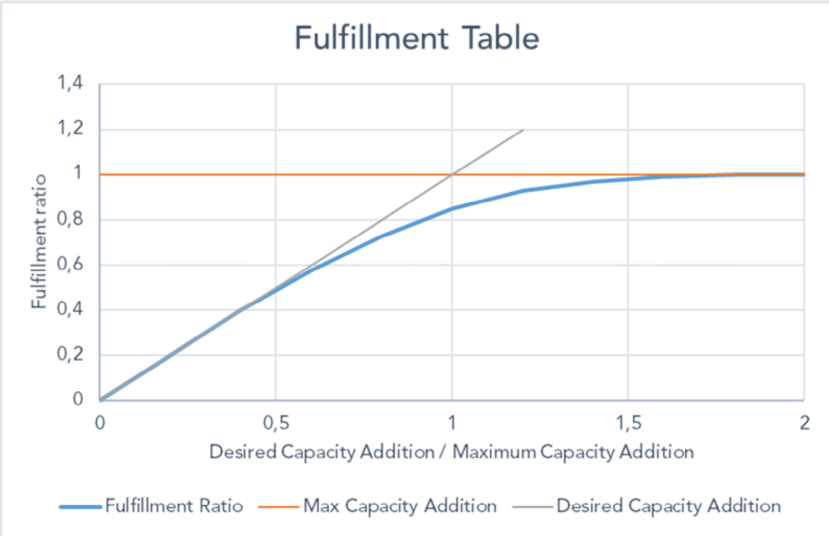


Figure 16 Fulfillment ratio for capacity addition (Author's own figure)

This figure shows that the fulfillment ratio is increasing with the pressure. The pressure is defined as the desired capacity addition divided by the maximum capacity addition. This has the role to regulate the capacity extension and take into account the fact that adding capacities is expensive for a company and especially in the semiconductor industry and this decision is based on the associated level of pressure. In other words, this reflects the conservative approach of companies to add capacity since semiconductor industry is the by far the most expensive industry.

In the same way, capacity can be decreased but only for the part of the production that is sub-contracted at Infineon.

Data and calibration

Differentiating locations and business lines

Infineon's supply chain is global and the products of the automotive divisions are manufactured in mostly eight locations: Dresden and Regensburg (Germany), Villach (Austria), Wuxi (China), Kulim and Malacca (Malaysia), Singapore and Batam (Indonesia).

In terms of products, the automotive division has six business lines: Body Power, High Power, Microcontroller, Sense & Control, Powertrain & Safety and Power Supply & Network. All these business lines have different shares and of the overall sales. As a reminder, the automotive division is Infineon's largest and is the number one in the global automotive semiconductor industry with a total market share of over 13%.

With such high volumes, it is very important to differentiate the sites and business areas within the model. Indeed, all products have different cycle times and the preferred production location that I have defined in the model.

Dynamic system models have the particularity of being highly aggregated and represent only material or information flows. However, it is possible to disaggregate stocks and flows thanks to a feature of Anylogic called dimension. A dimension is a characteristic of a variable and can be used to categorize it. For example, in this internal supply chain model, there are three dimensions: frontend locations, backend locations and business line. Like matrices, inventories are broken down into dimensions and can follow the evolution of a more specific value. In general, it is possible to track the number of high-power chips that are manufactured in Malacca.

However, there are different levels of aggregation in the model. While the frontend and backend work in progress have two dimensions, the die bank and the distribution center have only one. In fact, the die bank and distribution center are appropriate inventories and parts can be picked up from anywhere to be sent to back-end production elsewhere in the world. The same is true for the distribution centers and where the chips are flown to the customer. Gathering data to understand and reproduce realistic flows and quantities

Behavioral parameters, operational parameters and inputs

There is a quantity of different parameters to change the dynamic of the system and we can separate them into three categories: the behavioral parameters, the operational parameters and the inputs of the model.

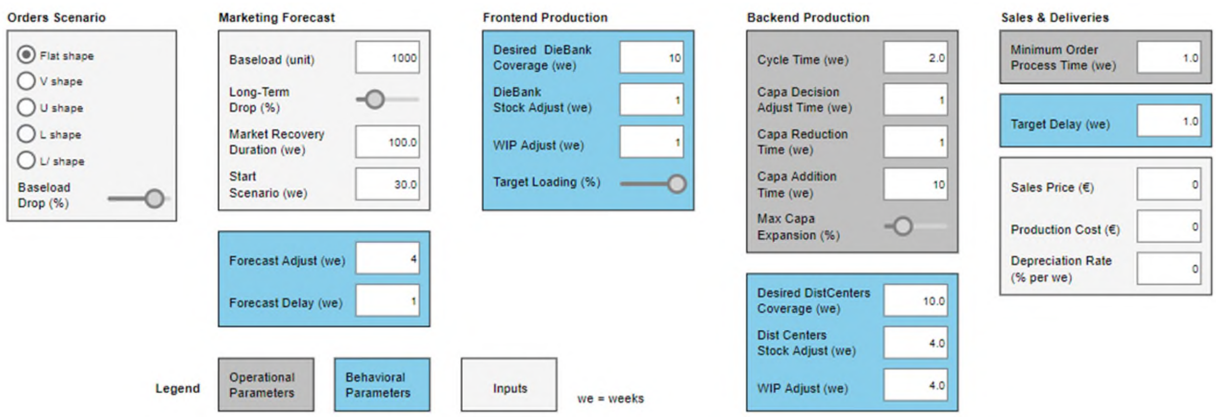


Figure 17 Internal supply chain system dynamics model parameters (dummy values)

As shown on Figure 17, the behavioral parameters refer to the adjustment times, desired coverage of the inventories, or delay that exist in the supply chain. By adjusting them, we can make the system be more or less responsive.

The operational parameters are the physical parameters such as the cycle times, the time needed to add capacity or to deliver an order for example. They also influence the behavior of the system but the company cannot play with them too much. The fine tuning for the model is done by using data from internal sources of Infineon.

Finally, inputs are all other variables that are external to the supply chain. For example, one can find the different end market demand scenarios U, V, L shapes of a crisis such as the Covid-19 pandemic, the forecast scenarios reflecting a long-term recession and the selling price of the chips or the depreciation rate to calculate the value of the stocks.

The model is then executed using a Java-encoded program that transcribes all the elements of the system dynamics diagram and calculates the variables for each iteration. In the next section we will present some results obtained by simulating the Covid-19 pandemics crisis.

Results

In Figure 18, we can see the different control graphs of the model the x-axis represents time in weeks. They show respectively, the cumulated demand that customers order from Infineon, the demand versus the fulfillment and the forecast, the inventory costs of die bank and distribution centers, the number of pieces out divided by the number of pieces in in frontend and backend, and two other KPIs for the production.

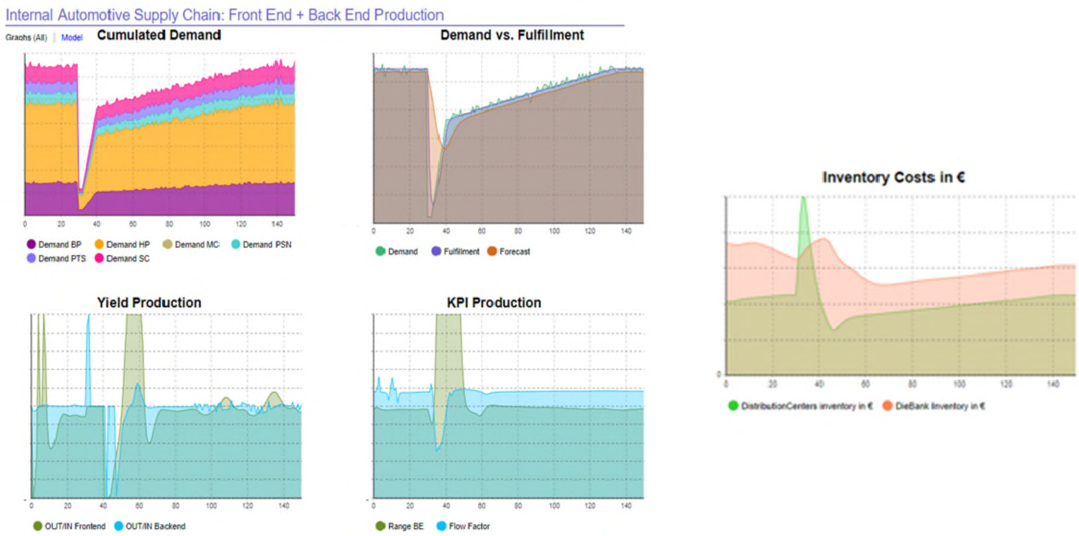


Figure 18 Graphs of the obtained results with a realistic Covid-19 pandemics scenario (hidden values)

The scenario represents how the Covid-19 crisis was perceived in the automotive division. Demand fell by almost 75% when the wave of closures began and recovered in about two months to a level that is still about 30% lower than before the crisis. The expected recovery time is two years, after which sales will return to their initial level.

The dynamics of inventory levels in distribution centers indicate that there is a sudden increase when the crisis occurs because and then a sudden drop after production stops then it recovers to reach a desired value. In the die bank, the dynamic is less reactive because the front production is upstream. Fluctuations are less important, but it also takes longer to return to a desired level.

B. Pandemic Simulation System Dynamics model

This project during the lockdown period and the first idea was to create a model based on a Washington Post article giving the keys to modeling the coronavirus: "The Hammer and Dance model"[11], published by Tomás Pueyo.

Model layout

An improved SEIR model

In general, when modeling outbreaks with system dynamics tool we use a SEIR model (Susceptible, Exposed, Infected, and Removed):

- Susceptible: population not yet infected and not at risk of infection
- Exposed: population not yet infected and at risk of infection
- Infected: portion of the population that carries the disease
- Removed or "Recovered": includes the diseased and immune population

Population stocks in a model can represent these four states with the flows that link them, but the model designers realized that these four stocks were not sufficient to capture the dynamics of the epidemic. In the end, they used a more sophisticated model found in the literature shown in Figure 19.

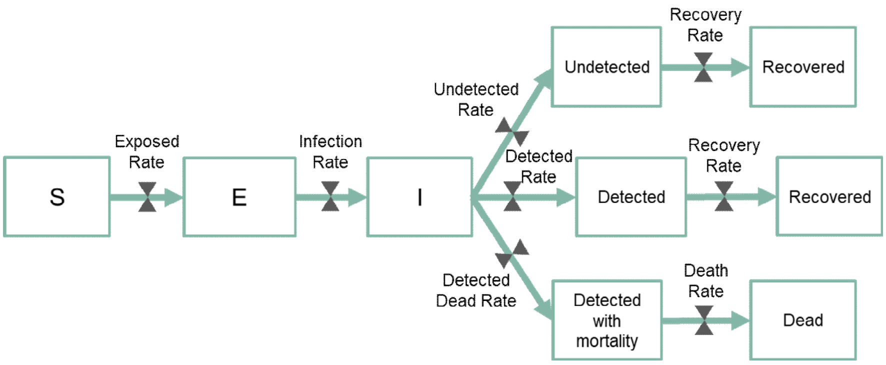


Figure 19 Principal stocks and flows of the pandemic simulation model

In addition to these main components, the model contains several other features that allow the dynamics to be adjusted for external influences. (The system dynamics model can be found in the appendices)

[11] The Hammer and Dance Model, Tomás Pueyo, published on Medium on March 19 2020

Specific features

- Detection rate:

Initially very low, the testing capacities of each country have increased over time and their efficiency has increased as well. As a result, countries have increased their detection rates and this has helped to contain the epidemic. Indeed, when they are detected, people have to limit their contacts and most of the time remain in quarantine.

- Transmission rates:

Finding appropriate values for the rate of transmission has been a challenge since Sars CoV-2 is a new virus and few studies can properly estimate its chances of transmission. However, after testing different values, the team estimated this rate and included a seasonal factor. In fact, it has been shown that transmission is lower when temperatures are higher.

- Control measures:

Each country is deploying different strategies to contain the spread of the pandemic. For example, while Italy has imposed very strict confinement on the population, Sweden has practically none. Government levels of stringency are based on closing schools, closing workplaces or cancelling public events and can be compared from country to country using a calculator the team developed. These measures then influence the development of epidemics with a delay.

In addition to predicting the curve of infected people, Infineon wants to be able to react to a potential closure or movement control in one of the countries in which they work. For this reason, the team developed a function capable of predicting control measures in the model. It is based on historical data and some tables that record the past correlation between stringency, new cases and delays in each transition.

The final important feature that can help predict government stringency is the pressure that governments exert when hospital capacity is too low relative to the number of infected people. This pressure pushes governments to be more stringent, resulting in lower caseloads, lower pressure and so on.

Data and calibration

In order to feed the model, it is necessary to collect reliable information on the number of positive coronavirus cases in different countries. A large database have been created and each country manager was responsible for finding reliable information on the number of cases and the measures taken by the governments in their countries.

Once the model was ready to be used, each country manager had to find the right simulation parameters for the model to correctly reproduce the curve of the number of infected. Then, the country managers could gather the parameters and the outputs of the model in the database and compute the accuracy they found. Every day, all the country managers join a 30-minutes meeting to present their results and help improving the model.

This laborious work was mainly dependent on the veracity of the information published by governments such as the number of infected per day. From the beginning of the project, a recurring problem was the hidden factor, a factor between the number of cases tested positive and the number of truly positive cases in a country. This factor can be as high as ten in some countries where testing capacity is very limited or where governments hide the true numbers.

This multitude of small simulation steps finally made it possible to obtain a model capable of reproducing the curve of infections in each of the countries studied as well as the governmental strategies. However, as this methodology required a great deal of time and effort from the country managers, an optimizer was then introduced into the model. The optimizer automates the process of selecting the best parameters to fit the curve of infected with numerical methods.

Results

Thanks to all the efforts given to make this model accurate both on the part of the model's developers and also thanks to feedback from country managers, this model is now able to reproduce the curve of infected people over the past period and to predict future developments as shown in Figure 20. We can see that the model predicts a new wave of coronavirus in Germany after the summer period. It also forecasts that the stringency level of the government will also become stricter, maybe cancelling public events or postponing the back-to-school period. The challenge with this model is now to find connections between the development of the outbreak and the decline of the economy or the fall in demand.

Figure 20 Simulation outputs for Germany

Some correlations have been established between the stringency levels and production cycle times or transportation times, but we know that governments will not impose such high levels of austerity again. Indeed, what the world has experienced in terms of containment and restrictions has never been experienced before and that is what makes the coronavirus crisis so special. Although the virus will continue to spread and probably cause deaths in the coming months or years, it is highly unlikely that we will be in quarantine again.

In conclusion, this project aimed to predict the next waves of the epidemic and the impact on demand, supply and transit times for Infineon through government stringency levels but has now turned its focus to the impact of the next waves on the economy. From this point of view, we can note that system dynamics is a tool particularly adapted to this type of modelling with a high level of abstraction. Indeed, including the economic dynamics of a country is perfectly possible and there are also reference models to help.

On the other hand, understanding the dynamics of a country is one thing, but obtaining precise values and determining the behavior of economic indicators is another. This is probably the only criticism that can be made of systems dynamics. Its level of abstraction is such that it does not take into account a multitude of micro factors which, when put together, can lead to fluctuations not predictable by the model.

C. End-to-end Supply Chain model and Bullwhip effect

The last model that we will study represents the four echelons of the end-to-end automotive supply chain. As shown in Figure 21, the four echelons are the following: the car manufacturers also called OEM (Original Equipment Manufacturer); the system integrator that prepares ready-to-use modules (for example, Bosch or Continental); the Tier 1 is another level of supplier that creates systems for the modules and finally the semiconductor level that manufactures the chips.

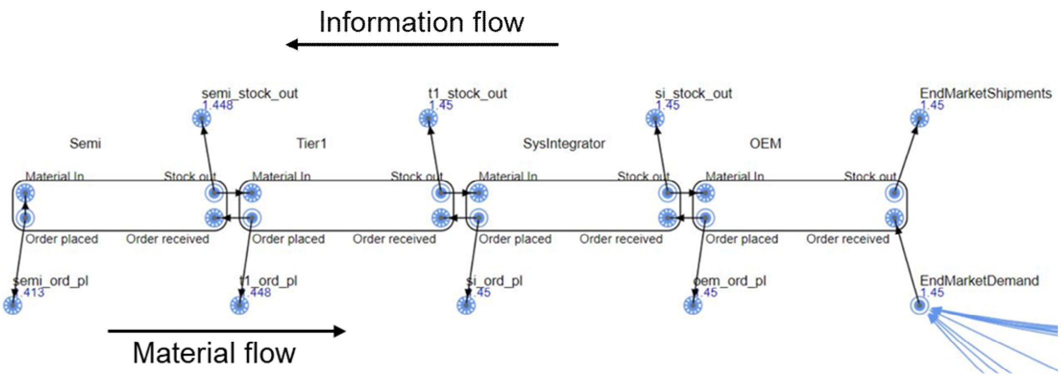


Figure 21 The four echelons end-to-end automotive supply chain model

The four tiers are linked together by the flow of information from the automotive manufacturer to the semiconductor manufacturer and the flow of materials in the other direction. Each echelon in the model contains an internal supply chain model that represents production and the various inventory adjustment decisions, deliveries, just as in the internal supply chain model. The input to the model is end market demand and is expressed in light vehicle sales, and then in the model all units are in car equivalent. For example, even if we need a thousand chips to build a modern car with a hundred subsystems and ten modules, in the model, that is the equivalent of one car.

In case of crisis, each company try to reduce their working capital by reducing level of inventory to maintain liquidity. For example, if demand falls by x percent for the car manufacturer, it will fall by 2x percent for the system integrator, etc. This is called the bullwhip effect and that tackling it is the purpose of this model.

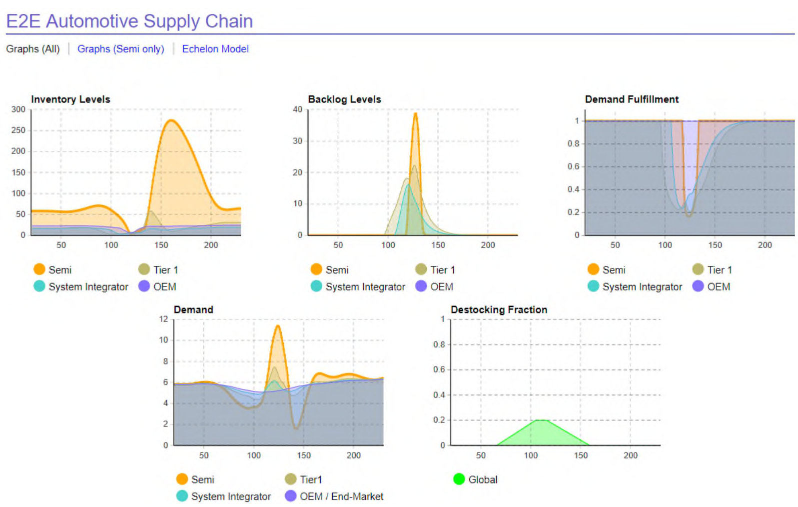


Figure 22 End-to-end automotive supply chain system dynamics model

In the figure above, we can see the amplifications within the end-to-end supply chain. The orange graphs correspond to what Infineon or any semiconductor company might experience in terms of inventory levels, demand, backlog levels, and demand satisfaction if the company does not educate its customer and act to reduce the whip.

It is interesting to look at the demand curve and see how it corresponds to what I experienced while playing the beer game. The beer game is a serious supply chain game that we played at a colloquium. Being one of the most upstream actors, I felt the bullwhip effect in exactly the same way as Infineon would feel with this scenario.

In conclusion, the modeling of such a crisis for the automotive division can greatly assist in the decision-making process. Even if Infineon is used to the bullwhip effect and its forecasts consider it, this crisis is unprecedented and tackling it by educating our customers all along the supply chain is of upmost importance.

III- Reflection on Top-Level Challenges modeling

Towards a modeling of the global picture

These three simulation projects aim to reproduce the impact of the Covid-19 pandemic crisis at different levels. In summary, the pandemic simulation models different country cases in order to reproduce the number of infected people and predict the next governmental measures. The end-to-end automotive supply chain model predicts the amplifications of the drop and recovery in demand throughout the four echelons. And the internal supply chain model can predict the actual response in inventory levels and associated binding capital for Infineon.

Through these examples, we can clearly see the potential of systems dynamics modeling to address top-level supply chain challenges, such as a global pandemic. If they were used together, we could probably model how the epidemic influenced governments to act and stalled countries and economies, leading to a larger crisis that affects global demand for cars to Infineon's production sites and the associated costs.

However, creating these models has not been an easy task and linking them all together is once again more difficult. System dynamics can model very high level abstraction problems, but it often results in lower accuracy. We always have to make a compromise between simplicity and accuracy of a model. A simple model can be understood by everyone but does not usually give accurate results. A more complex model may give better results, but it may also be more specific to a particular case and never be used again. In addition, it must be understood that models cannot predict reality but can only give an estimation of future behavior based on the structure of a system and external factors. “All models are wrong, but some are useful” George Box.

Making Infineon's supply chain agile and resilient

We can define resilience as the ability to recover quickly and effectively from a difficult situation. On the other side, agility refers to the ability to act quickly and decisively with ease and comfort. In fact, they both refer to the adaptive capacities that are put into practice when a change is made. These are the two adjectives used to describe the best supply chains, capable of responding to sudden and unexpected changes in markets.

Having a resilient and agile supply chain is what Infineon is striving for, including through its Supply Chain Innovation department. The launch of the various simulation projects was the response of this department to help manage this crisis and they involved more than ten students. Even though meeting these challenges with such an innovative perspective was impressive, it is not enough to guarantee the resilience of the supply chain, especially in the short term. And for this, Infineon can be proud of its operational teams who managed to control production and protect its supply chain.

Modeling for the future

Such disruptions to global supply chains may happen with a lower frequency but their impact will be devastating, so it is very interesting to have studied them. Indeed, it is in this time of crisis that we best see the interconnections in our society and the links between cause and effect. Cause and effect are not always related in space and time, the best way to understand this relation is through system thinking. Dramatic drop in demand is related to endogenous behavior of companies reacting to exogenous end market drop. The use of systems dynamics has been particularly interesting and I hope that such projects will be continued and enhanced in the future.

Even though I did not have enough time to complete and refine my internal supply chain model, there is still a lot of potential. The purpose of this model was to test different production strategies and evaluate which ones are the least cost-intensive for Infineon. In any case, such a simulation takes time and I would have needed more information on the decisions made within the companies. Almost like a consultant, I think a model developer should ask questions within the company to determine the key decisions and delays that have the greatest impact on the overall dynamics.

Launching so many systems dynamics projects this year will probably bring this systems thinking to the Supply Chain Innovation department for the future. Our company is facing increasing challenges and we need to think about systems to try to find solutions. We have seen an increased advertisement of global warming in those times in which we produced and polluted less and now many of us are hoping for a better future. Climate change is probably the biggest crisis that humanity will ever face and if we want to act, once again, it is a question of two approaches. Some will think that the sum of small individual behaviors can change the destiny and others will think that we can solve the problem understanding the global picture of the many resources we have on earth. In this way, just like agent-based models and systems dynamics, humans see things differently and sometimes the only thing to do is to act rather than think.

Long-Term Availability Requests in the Semiconductor Industry

Introduction and challenges

As mentioned in the introduction, semiconductors follow Moore's Law. With each new generation of chips, prices fall, and the market declines. In this industry, each chip has determined an end-of-life or planned obsolescence. After that date, they are considered waste and are either sold to another company at a very low price or scrapped. Indeed, one of the biggest challenges in the semiconductor industry is to offer a wide variety of products to the customers. This means innovating, creating new products and implies that products have short lifespans and are scrapped if not sold.

However, even though overall demand is declining and most customers are more interested in the next generation of products, some consumers want the products to be available over a longer period. We call that long-term availability requests and there are common problems in the semiconductor industry. During my internship, I worked on two topics related to this availability in time extension issue.

Not all companies change their product line every time a new generation of chips comes out. On the one hand, redesigning a product from an electronic point of view represents a certain cost, and on the other hand, it is beneficial to make products last longer for ecological reasons. Today, we have realized that the way we innovate and consume is not sustainable for the environment. In addition to being toxic and contaminating the environment, our electronic waste now represents more than 50 million cubic tons per year and becomes worst and worst every year. In Germany, this is the equivalent of 9.31 kilograms per capita and year and only 43.1% of it was collected in 2018[12]. Their recycling is very expensive and complex and most components cannot be reused even if they are still working.

Infineon offers to extend the end-of-life date of its products upon customer request, but not for all product lines. This is both a technical and strategic decision and a multitude of steps are required before confirming that a component's production can be extended.

[12] Umwelt Budesamt, www.umweltbundesamt.de

There is a big difference between the automotive industry and the radio frequency semiconductor industry because the lifespans of the final products are very different but also the cycle times in production. Therefore, when coming to long-term availability requests they do not deal with the same issues and through the two projects I worked on, we will present possible solutions to them.

Long-term storage viability study

Today, more and more customers require components for longer durations and especially in the market of connected measurement devices (gasometer, electricity meter) that is part of the IoT (Internet of Things) market. Those devices are connected together to collect real-time information and improve the production and distribution of the energy. Such devices have long rollout period and for example GRDF, French distribution system operator "has now begun the full-scale replacement of its 11 million mechanical meters with new smart devices" and aims to achieve it within 5 years[13].

Moreover, our annual Supply Chain Trends Colloquium identified new business models through product lifecycle as a growing trend for the coming years. Indeed, we are seeing more and more long-term contractual relationships with customers looking to extend the lifetime of their products and provide after-sales services. Going in this direction could be a real opportunity for Infineon. In addition to opening up to new markets such as IoT, it is a way to build customer loyalty and offering solutions for product obsolescence.

Problem statement

The smartphone market is a very competitive market for Infineon, many competitors and especially in Asia are able to produce at low costs and innovate. To remain competitive the production technology is disrupted after a short period, each new product being produced for 2 to 3 years at very high volumes and then changed for a new one. In addition, the chips' standard storage time is only of 2 years after the end of the production. In order to fulfill the demand during 5 to 10 years rollout period, Infineon has no other choice than either extending the availability in time of their production technology or storing the components for longer period.

This is the problem brought by a French product manager and that a colleague and I studied during our internship. After describing the problem precisely, we have looked for solutions to guarantee longer availability in time to Infineon's customers analyzing two different aspects: the technical aspect of long-term storage, and a possible business model.

[13] San Antonio, Jan. 23, 2018, PRNewswire

Finding solutions

My colleague realized the technical part of the study while I took care of the business part. We have been working on our own by having a weekly meeting with our manager Hans Ehm until we were able to present the study. The technical part required some documentation on the JEDEC[14] recommendations for electronic components storage. Corrosion, contamination, electrostatic fields and temperature effect are the common challenges to electronic component's storage. Long-term storage requires a controlled atmosphere with a maximum of 5% of relative humidity, specific packing material, a moisture barrier bag, some desiccant and having a humidity indicator card. Additionally, vibrations, temperature and humidity must be controlled and the variations minimized. A common solution for this kind of storage is to use dry cabinets. In fact, those cabinets can comply with the JEDEC standards and insure a dry atmosphere and a fast stabilization after each excursion.

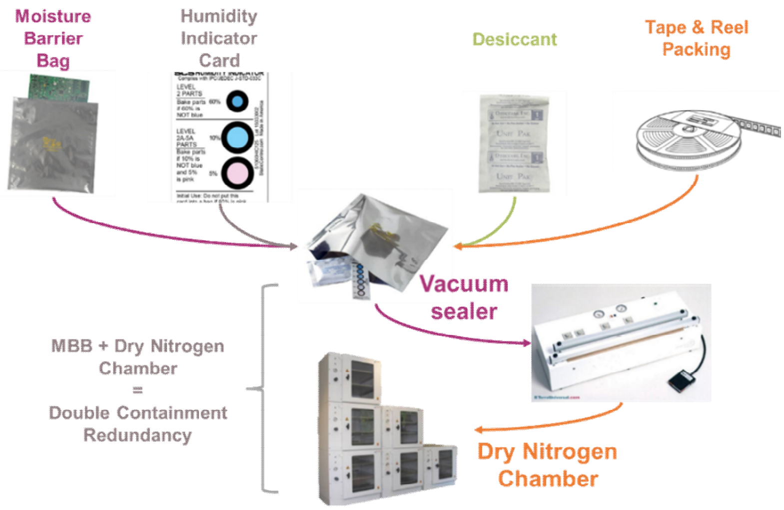


Figure 23 Proposition of technical solution for long-term storage of semiconductors

Based on this technical solution, my colleague and I were able to establish a budget estimating the desired storage capacities based on the forecast provided by the marketing manager. This budget was estimated in three parts: the initial investment, the variable costs and the fixed costs. The initial investment includes the research and development as well as the cost of the dry cabinets, nitrogen tanks and pipes. The variable costs are associated with the extra material needed for the double containment, moisture barrier bag, desiccant, special package. The fixed costs represents the general carrying costs but with extra resources (gas and electricity), human resources and administrative costs. After making some assumptions on the depreciation period and the sales price, we were able to present the impact of this long-term storage on the margins. Then we imagined different scenarios to plot the impact of the lack of

[14] JEDEC Publication JEP160_R , November 2011, JEDEC Publication J-STD-033D , August 2014, JEDEC Publication J-STD-020E , March 2008

accuracy on the forecast on the margins and to plot the extra cost per chip when the volume increases. Because the numbers are confidential, we won't display the graphs and outcomes of the study.

To define the market and the value proposition of Infineon, we decided to use a business model canvas. It allows quickly identifying the benefit of a business model and listing the different partners, resources, activities, relationships that are necessary (The business canvas can be found in the appendices)

Outcomes of the study

The last part of the study was to propose different concrete solutions to deal with this problem. Inventory turn rate and global inventory levels are synonymous of a company's wealth but also indicators for its valuation. Therefore, storing products for long-term application is not recommended in any way. Three propositions were suggested: the acquisition of a long-term storage third company, a closer collaboration with Rochester Electronics (World's largest Source for End Of Life electronic components), or an internal storage at Infineon.

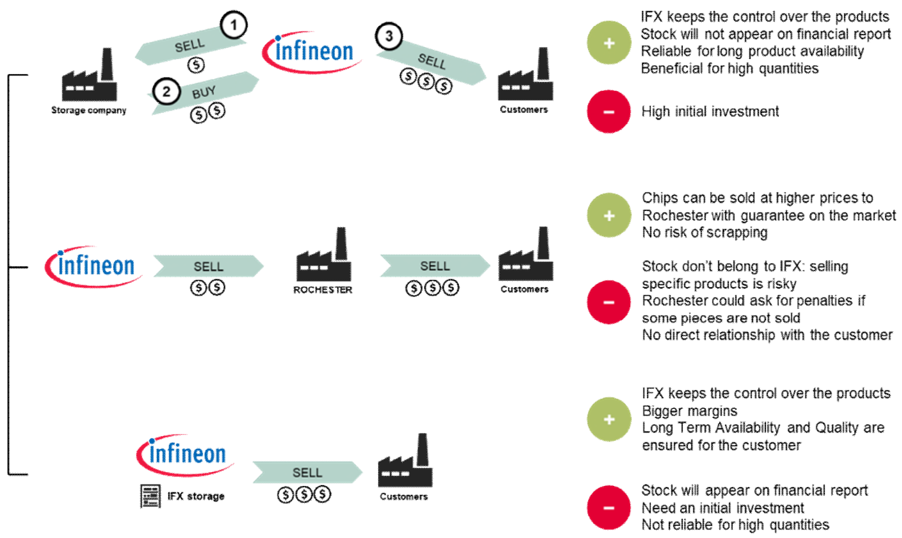


Figure 24 Different possible arrangements for a long-term storage business

We presented our study to the Director of Product Group Radio Frequency Mobile, the Head of Product Management RF Communication, our manager Hans Ehm and the Product Line Marketing Manager who first requested this study. The global feedback was that this had helped a lot understanding the problem and the possible solutions in terms of storage but also business plan. However, when looking closer at the potential investment and the generated extra costs, the managers decided that investing in such a new service should only result from a serious market assessment and a global need and in several divisions at Infineon.

Supporting Long-Term Availability Request process

Having worked on a similar long-term availability requests project and having some knowledge in VBA programming, I was approached by the automotive division to undertake a second project for them. Their Life Cycle Management team has recently developed a standardized process to support component's availability in time extension for customers. The process includes controls and checks to decide if, when and at what cost production can be expanded.

The objective of this project is to support product managers in this process and to be able to learn from best practices. And for this, the project manager thought of developing a checklist and automating it in a user-friendly and lean application.

Finding the appropriate way to guide the user

The first idea was to code a VBA Excel macro with pop out functions to indicate the user the steps to follow while filling out an Excel sheet. However, after a benchmark of the technical solutions, I suggested to code a VBA PowerPoint macro given it was easier to develop and more user-friendly. This PowerPoint could have different links, text boxes and buttons to guide the user smoothly.

After presenting a first draft of the technical solution and the different functionalities to the project manager, a weekly meeting was set up. Throughout this project, I worked in a fairly agile manner given that the deadline was only two months and that the majority of the final alignments took place in the last two weeks.

Design of the application and functionalities

Depending on the case, the process can involve several users. Insuring a good communication between the different users was therefore one of the critical aspects of this project. Indeed, VBA applications are not collaborative and working on different networks or upload locations can be problematic.

The selected solution to this problem was to place the PowerPoint Macro in a cloud location with a first page to be filled in by the user. This first page generates a name and a file location to save the Presentation in the appropriate folder. The user can then work on his own macro and be able to upload it again on the server when finished. We defined a specific nomenclature in order to make every link different and have a certain order in the folder to facilitate the archiving. Furthermore, two coded buttons were designed to generate pre-filled emails to send notifications to the next users and insure the collaboration between the teams.

Another functionality of this PowerPoint Macro was to generate a summary Excel sheet based on the steps and actions that were done during the process. This summary sheet would then be the reference to understand the process and to keep track of the past requests, leaving the PowerPoint in an archived folder. For that purpose, an intelligible Excel file was created to store the different information and links to retrace the process as well as an automatic program. This program creates a workbook based on the template, and copy all the information contained in the PowerPoint's textboxes and variables to the right location in the Excel worksheet. An Excel window then appears to the user letting it filling out the few missing information, for example the links to the uploaded materials. (Some screenshots can be found in the appendices)

Documentation and handover

One of the dimensions of this project was to create an application that is robust, that does not need a lot of maintenance, and that can be understood and modified easily. This is why I have worked on making the code understandable adding comments and naming correctly all the variables.

On my last day of internship, I handed over a complete documentation and provide a one and half hour training to members of the Life Cycle Management team to pass on the knowledge and keep improving the application after the end of my contract.

Conclusion

Amazement report

I am very happy to have done an internship in the innovation department of a large company. The topics covered are ahead of our time and the working methods too. Working in innovation requires being ambitious, passionate and optimistic and this is what I have seen in my colleagues. As mentioned in the introduction, innovation follows an infinite loop of small improvements driven by big visions. Far from being small and suitable for short internship missions, the projects of this department are often the subject of several theses and even PhDs. Especially in my case, I had the chance to work on strategic projects and it is only at the end of my internship that I became aware of it.

From a managerial point of view, there are also many things to remember in this department and this is the subject of my management report. Managing such a structure with such flexibility may seem impossible but it works. I think that this department can count on several key elements to ensure its good management. First of all, the vision of the director. Ideas don't come alone and giving work to so many people can be challenging. However, Hans Ehm knows how to give direction and drive the dynamic both in his teams and with his superiors. I think there are few middle managers with that kind of influence in a large company. The second strength is process management and digitalization. I was completely impressed to see that the department on boarded so many people in the middle of a lockdown. Even remotely, a buddy, e-learnings, a responsive IT department and good documentation were there to ensure the integration of the students. Last but not least, the greatest asset of this department is probably the quality of its students and the experts who supervise them. I think it's really smart to have so many skills together and organize them in this cross-functional way to optimize the dissemination of knowledge and points of view. In addition, structurally speaking, this department is fortunate not to be subject to production or business pressure and this allows it to be even more flexible.

Feedback on the internship

My feedback on this internship can only be very positive and mostly for two reasons. Firstly because I was interested in my tasks and also because I managed to become well integrated into the environment.

Indeed, all the tasks I was given are actually quite strategic for the company. I was lucky enough to be able to present a few projects to the company's senior managers and it was very rewarding. I think the fact of having a certain visibility in such a large structure is pretty motivating and this can be seen through the different interns in the department.

The second element that made me appreciate this internship is that my motivation was rewarded. Indeed, I think that you have to know how to gain the confidence of your colleagues, trigger things and have a bit of luck to be able to fully appreciate your internship. While this structure may seem overwhelming and impressive to some people, it is in fact a real opportunity to grow. You have to know how to manage and help each other among colleagues and not expect too much from your manager. It is thanks to this, and also to the Unitech network that made me meet some interns, that I was able to make friends and really benefit from my experience in Munich. I would particularly remember some encounters that made me open my eyes and think about things I had never thought about. Again, I would like to thank Thomas Ponsignon and Abdelgafar Ismail for their feedback on my internship. I had the impression that this experience was really beneficial for both sides.

Key learnings and future job perspectives

Working for twenty weeks in this environment that is far from anything I had ever done made me learn a lot about myself.

Through the tasks that I have done, I think I can say that I like to have a level of technicality in my work, but also at a fairly high level. That's why supply chain management, especially in industries where it is a challenge, really interests me. In addition, the coronavirus crisis has shown us that our supply chains can quickly get out of control and I am waiting to see what decisions will be taken in the future to address this.

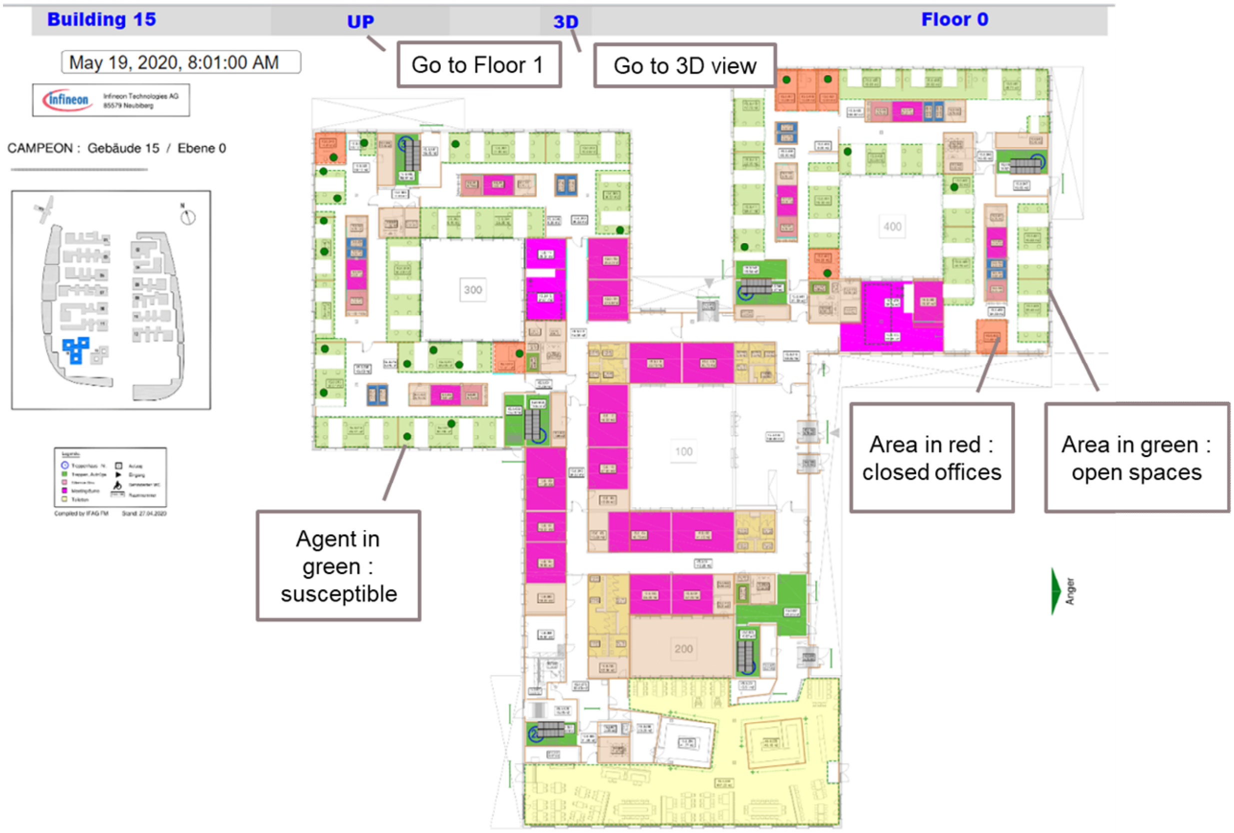
Working for a leader in semiconductors has been really interesting and I can confirm my desire to work either in new technologies or in the energy industry. In the future, I would also like to have some field experience to better understand the real difficulties encountered, which are sometimes quite different from those at the corporate level. In terms of the size of the company, I enjoyed working in a large structure that is both quite young and modern. I hope to find structures that are both big, quite flat and innovative.

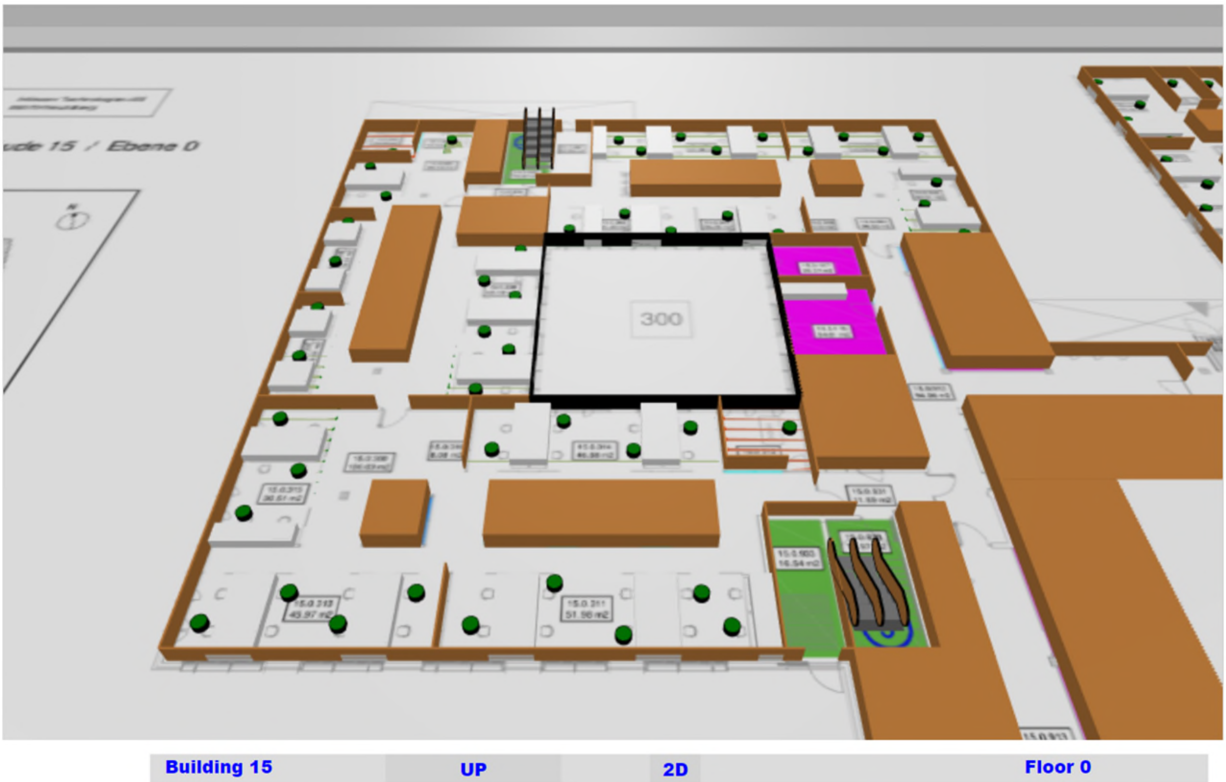
From a personal point of view, I think I have learned to acknowledge more the cultural differences, the different relationships to work or way of working but also the different visions. I think that any good leader today must know how to recognize these different ways of being and appreciate each one at its true value. This sometimes requires a lot of questioning but can only be beneficial for everyone's well-being.

In conclusion, I am quite impressed to see how in one year spent abroad I have been able to grow so much and forge the basis of what will be my future. However, this is a little bit scary and I deeply hope that I will be able to question my ideas and views defended in this conclusion in a few years’ time.

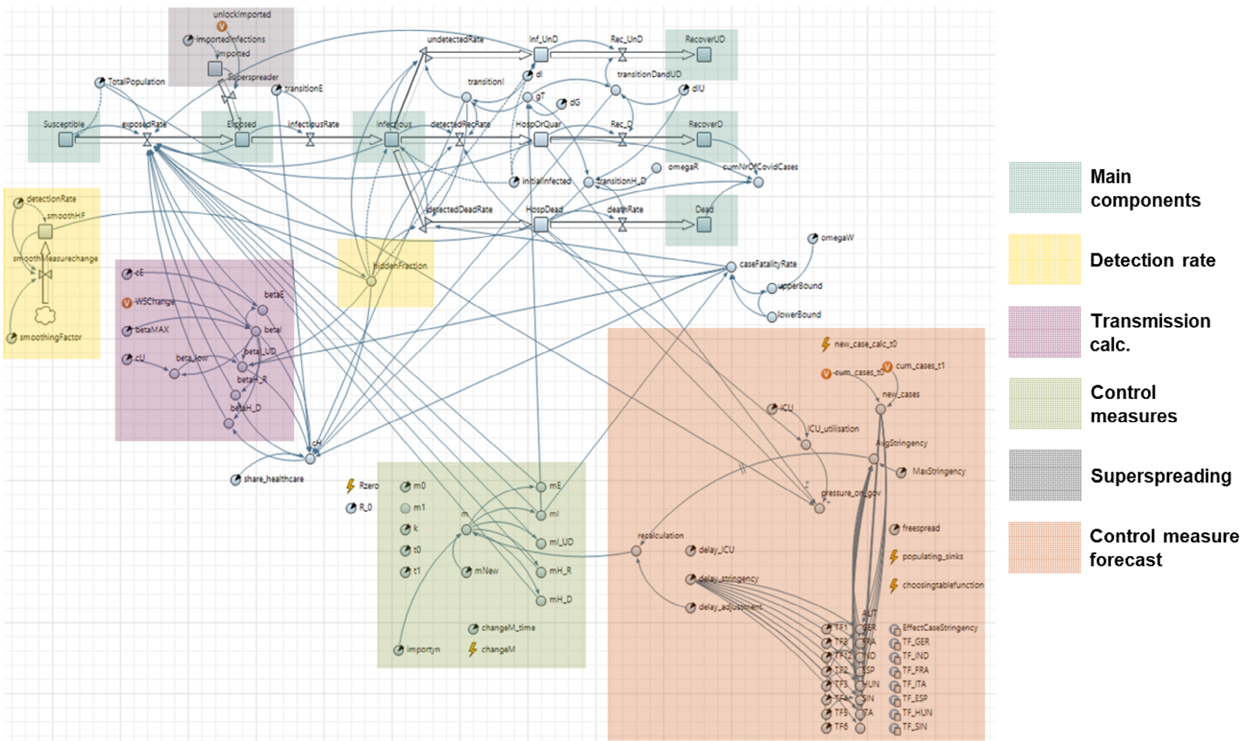
Appendices

Campeon Simulation

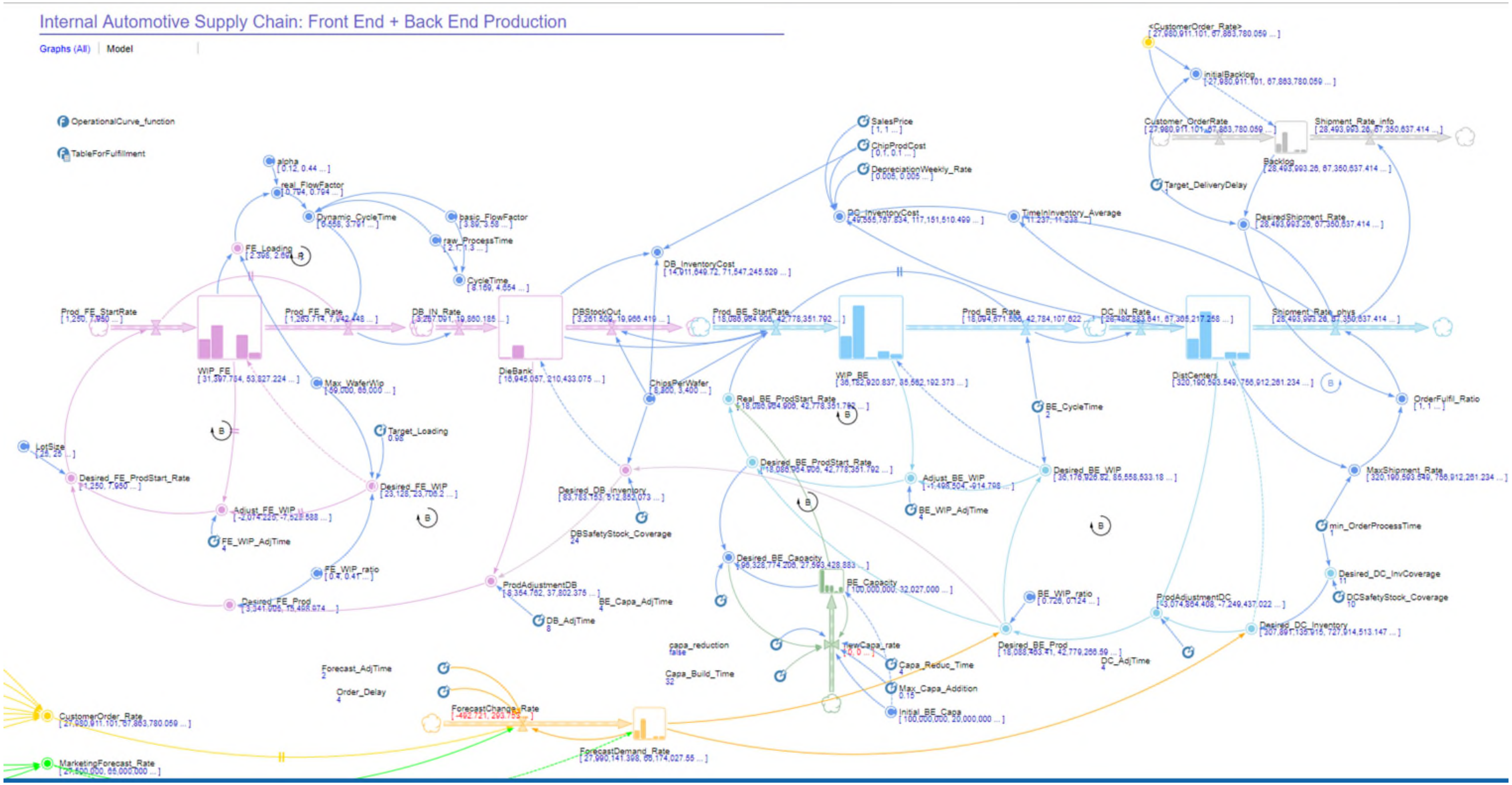




Pandemic Simulation System Dynamics Model



Internal Supply Chain System Dynamics model



Business Model Canvas for Long-Term Storage of chips

Key Partners

Internal:

Product Line 55 marketing managers.

Warehouse in Singapore.

Key Activities

Determining the **initial demand**. Storing chips in a neutral environment for several years. **Adjusting forecast** quantities.

Key Resources

Initial investment for a new long-term warehousing system. **Research and development** of new storage methods.

Value Propositions

Offer a **guarantee** of the **availability in time** on certain components intended for long **lifetime/ long rollout period** final products by storing chips in a neutral environment for several years.

Customer Relationships

First agreement on the **quantities** and **time period** for the storage. **Digital** customer relationship and **common forecast** on the desired quantities.

Channels

On-demand service that can be offered when customer needs an availability in time of the components **longer** than the **maximal normal storage time**.

Customer Segments

Customers of Product Line 55 who require components for **long lifetime** or **long roll-out time** final products.

Example: Gas consumption control devices.

Cost Structure

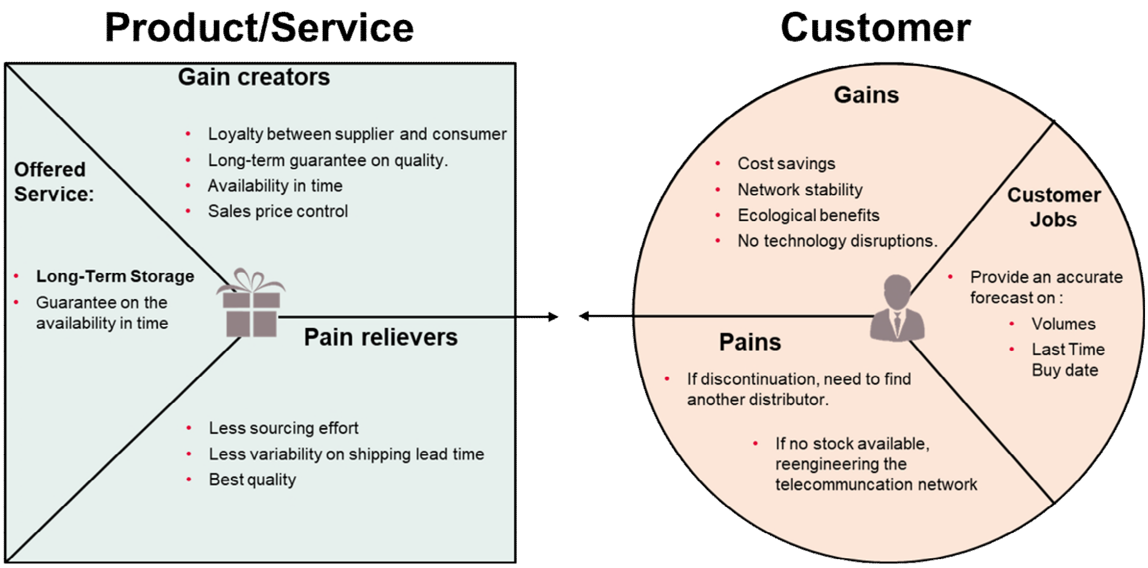
Initial investment: Storage technology development and installation in the warehouse.
Variable costs: Special packages, material handling, quality checks.
Fixed costs: Maintenance and security human resources. Gas and electricity.

Revenue Streams

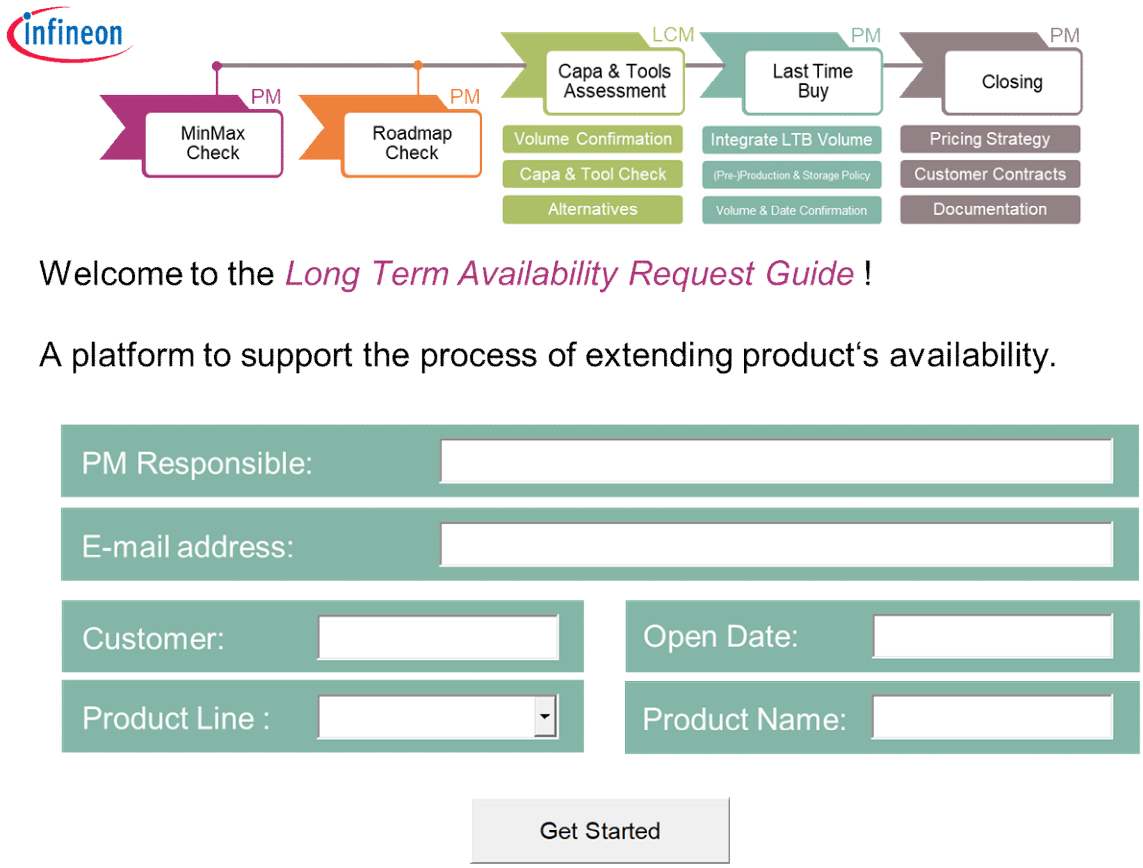
Subscription system: generates a continuous cash flow to absorb fixed costs and build customer loyalty.

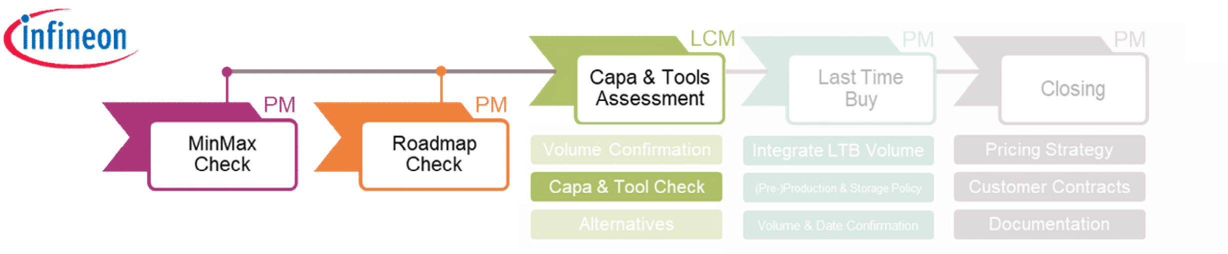
One-off payments: With higher sales price defined with the customer to spread the costs over the requested period of time. With higher margins for Infineon Technologies.

Value Proposition for Long-Term Storage of chips



Long-Term Availability Requests PowerPoint Macro





1. Volume reflected in the VRFC/MM Planning

2. Please check [Capacity & Tool availability and Corridor]

Is the Capacity available?

Yes | No

Last Step

Next Step

Long-Term Availability Request Excel Output

Checklist & Summary: Product Long-Term Availability Request (EoL case)			
	PM responsible:		**Product Line:**
	E-mail Address:		**Open Case Date:**
	Customer :		**Product Name:**

Topic	**Task/Subprocess**	**Feedback**	**Reference Materials**	**Uploaded Material Link**
Pre-Process		**Issued**		
MinMax Check		*Yes/No*	PM_FC within Long-term context report	
Roadmap Check		*Yes/No*	FE Roadmap; Test Roadmap	
		Not relevant/ Yes		
Date				
Capacity & Tools Assessment		*Not relevant/ Yes/ No*	MinMax Repository	
		Not relevant/ Yes/ No	Capacity and Tool Assessment	
		Not relevant / Conclusion from LCM		
Date		**LCM Responsibility:**		
Last Time Buy Policy			Last Time Buy procedures	
			Product Storage Materials; TR14	
		(insert your feedback here)		
Date		**LCM Responsibility:**		
Closing			Pricing Strategy Materials	
			Customer Contracts&Special Agreements Reference Material	
			Link to the central repository	
Case summary		*(insert your summary here)*		
		\\mucsdv032.eu.infineon.com\sc_1111\ATV_SCM_DM\20_SCM_DM_info\99_Projects\Portfolio_Management\Long Term Availability\10_WIP&Archived_cases		
Sign-off Date	**PM Responsibility:**			