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# Linking 4.0 Technologies and performance indicators based on a reference Model for supply chain

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## ABSTRACT:

*The challenge in the context of a supply chain is to provide a broad visibility of the decisions and imperatives necessary to achieve a reliable business network. Several performance models exist but none specifically related to supply chain decisions based on modelling. Moreover, the enormous amount of data collected for the control of supply chain leads often enterprise to implement technologies 4.0 without a clear vision of their requirements in terms of indicators. In this work we will present a complete methodology to help enterprises to control their supply chain and to choose the best technologies 4.0 to support their indicators. This methodology is based of supply chain decision reference models called Grailog based on the Grai method. The objective is to enrich the functions in order to provide decision support with the most comprehensive decisions. We will analyze how these technologies 4.0 are likely to support the reliability of performance indicators to make them “smarter” and best support decision-making throughout the supply chain.*

**KEYWORDS:** Industry 4.0, Technologies 4.0, Supply chain Model, Performance Indicator, Supply chain 4.0, Automobile industry

## 1 INTRODUCTION

The last decade has seen the emergence of the notions of corporate network, supply chain and extended enterprise. These notions highlight that any product is the result of group companies work, organized in more or less structured networks. The mastery of global logistics is a complex and transversal phenomenon (Morana 2017). Complex in the sense that the supply chain can be extended and involves multiple and varied partners (public authorities, industrialists, distributors, assemblers, etc.). The speed of traffic and the tension of flows is constantly increasing and the constraints to be respected, both contractual and regulatory, are becoming numerous (Baglin 2013).

To manage their supply chain, companies seek to manage their activities in an optimal way by playing both on the organization of their productive process on a global scale and on their information system allowing them to steer this organization. To meet this challenge, the logistics processes in companies in all industries must of course be digitized and optimised accordingly. Companies that operate in international markets, such as the automotive industry, and have a large customer base, in particular, must make heavy decisions and digitalise their internal and external logistics and more broadly their global supply chain in order to improve the flow of information and not threaten their sales.

The basics of digital logistics are processes and objects that can be controlled, organized and qualified as smart

(intelligent). In this context, we are also talking about intelligent logistics or 4.0 logistics. GPS, RFID, cloud computing architectures, computerized data interchange (EDI), large data, telematics and many others are used. A functional intralogistics system is the key to efficient production in Industry 4.0.

Beyond the production aspect described above, logistics 4.0 supports the performance of the global supply chain. It allows the networking and nesting of processes, objects, supply chain partners and customers through information and communication technologies with decentralized decision-making structures to increase effectiveness and efficiency

However, companies need to be guided to the most relevant technologies to use to drive their logistics. In order to ensure a better management organization for a global management of the global supply chain this work proposes an original methodology allowing companies to choose the best technologies from industry 4.0 to drive their supply chains. The originality of the proposed approach consists in starting from the decisions necessary for the management of the logistics. Then it deduces the objectives and the means of actions to manage it and finally select the most relevant technologies to make the system of indicators, reliable, available and manage from the strategic level to the real-time indicators. The originality of the proposed methodology is also to select steering decisions in a reference model that will also be explained in this paper. The technologies of industry 4.0 will be selected on the basis of the benchmarking indicators related to these

decisions, which will also be given in this article. Thus, section 2 proposes a state of the art of the reference models for supply chains and technologies of Industry 4.0. The proposed methodology will be presented in a second step, as well as the proposed reference model for supply chain management and the selected technologies. Finally, the most relevant technologies for each step of the indicator life cycle, the reference model of monitoring indicators to measure the performance of the supply chain and the technologies of Industry 4.0 most relevant to support each group of indicators in its reliability, availability and updating will be presented.

## 2 LITERATURE REVIEW

### 2.1 Methodology and reference models for supply chains

According to the literature review (Ducq 2007), there are several methods that allow to measure the performance of large industrial enterprises, and several works have been done on the modelling of the supply chain. Among these models one can mention the most famous in logistics: the SCOR model (Apics 2017), the reference model EVALOG (2004), the logistic guide ASLOG (2006), and the VRM (Value Chain Group, 2007). The table 1 below presents our comparative study of the supply chain management reference models.

Criteria of comparison		SCOR	SCM	ASLOG	BSC	EVALOG	GRAI	VRM
Sector	Industry					x		
	SMB		x					
	Distribution				x			
	All sectors	x		x			x	x
Modelling	Process	x		x		x		x
	Decisional						x	
	Indicators	x		x	x			
Decision level	Strategic level		x		x		x	x
	Tactical level						x	
	Operational level	x	x	x	x		x	x
Flows analysed	Physical flow	x	x					
	Information flow	x	x	x	x	x	x	x
	Financial flow	x		x	x			
Benchmark	Internal	x	x	x	x	x		x
	External	x			x			x

Table 1. Comparison of SCM reference models

This study shows that all of these models propose a process models and indicators, but excepted GRAI, none of them present a decisional reference model.

### 2.2 Technologies in Industry 4.0

The “Industry 4.0” concept was built on digital technologies to make manufacturing more flexible, agile and more responsive to customer needs. The real-time acquisition of data, the ability to process them with advanced means and the use of internet and sensors

make the factory better controlled. Today it is possible to create a smart factory where the Internet, wireless sensors, software and other advanced technologies are used to optimize production in cost and quality and improve customer satisfaction. According to (Moeuf 2017) Industry 4.0 is an industrial management concept aimed at real-time synchronization of different flows and customized product production.

According to (Mayer, 2017) the industry of the future refers to factories connected, made flexible and intelligent through the networking of machines, products and people. Several technologies have been identified in the literature.

The integration of different digital technologies in the industry offers many advantages especially when they are connected. These tools (table 2) enable the company to respond more quickly to market fluctuations, to offer more customized products and to increase its operational efficiency as part of a continuous improvement cycle. They are also very effective in supporting decision-making (Dombrowski et al.2017).

Pillars of Industry 4.0 enabling technologies	Description
<i>Big Data et Analytics</i>	The presence of sensors on machines and products makes it possible to collect large amounts of data. With the right processing and analysis tools, this data allows to optimize the production chain by identifying very fine problems that occur. They also increase knowledge of consumer habits and preferences.
<i>Robotization</i>	Today, we know how to create robots that work more autonomously, more flexibly, and in greater cooperation with operators.
<i>Horizontal and vertical information systems</i>	Information systems should facilitate intra- and inter-company integration and communication. They help to automate supply, production and distribution chains, but also to create closer links between the different departments of the companies, in order to best meet the demand.
<i>The Industrial Internet of Things</i>	Thanks to the sensors on the machines and the objects being manufactured, the machines can know the production history of the object, the corresponding final demand in order to respond to it in an automated way or via a central control station. You can also, through the Internet of Things, collect data during the use of the product in order to learn what features are used and to discover the modes of failure.
<i>Cybersecurity</i>	The diffusion of digital technology and the increase in communications that accompanies it make cybersecurity a major issue for industrial companies. Many “4.0 ready” hardware suppliers have thus joined forces with cybersecurity specialists to propose solutions that integrate this aspect.
<i>Cloud</i>	The cloud is already widely used for software and data management. The greater interconnection of production sites and departments within the company requires the sharing of large amounts of data, made easier by the cloud.
<i>Additive manufacturing</i>	This technology raises many hopes. In addition to the production of prototypes, additive manufacturing already allows the production of small series of complex parts, spare parts and even custom tools. Print speed and accuracy are expected to increase and enable larger-scale production.
<i>Augmented reality</i>	One possible use is to provide the service operator with information on repair techniques for a part, for example by wearing augmented reality glasses. This technology can also be used for training, or make design steps less abstract to involve more stakeholders.

Table 2. Technologies 4.0 commonly admitted in literature (Mayer 2018)

In the literature, numerous techniques and methods are cited for deploying digital transformation and improving performance towards a 4.0 enterprise. The choice of these techniques and methods depends in particular on the strategic orientations, the stakes, the internal and external contexts and the available resources, both human and technological. Although in (Hermann et

al.2015), the authors refer to Cyber-Physical Systems, the Internet of Services and the Internet of Things as the basis for Industry 4.0 technologies, other authors have taken a broader view: (Gamache 2019) conducted a study of 51 publications to highlight the tools most frequently associated with Industry 4.0 such as Big data, Smart factory, Cloud computing, Internet of things, M2M, Internet of services, additive manufacturing...

From our literature review one can highlight technology groups related to Industry 4.0. For this purpose, this work exploited a list of 15 most relevant technology groups that can be organized as follows: **Big Data / Artificial Intelligence, RFID, Digital Twin, Cloud Computing, Cyber Physical System, M2M Communication, Virtual Reality, Cyber Security, Internet of Things (IoT) Energy Internet, Collaborative Robots, Additive Manufacturing & 3D Printing, Machine Learning, Simulation and Internet of Services (IoS).**

The first vocation of 4.0 technologies will be to support the process of updating indicators in order to provide them as close as possible to decision makers and to make them reliable and displayed correctly. An analysis of the life cycle of a performance indicator was conducted to consistently support each of its development phases. The proposed contributions of Technologies 4.0 to the different phase of PI life cycle are detailed in the section 4.

### 3 METHODOLOGY

#### 3.1 The global PERFLOG Method

In parallel with the development of new forms of management, we have witnessed the emergence of new, more flexible Industry 4.0 technologies that are changing production methods and the operating rules of logistics systems. It is currently difficult for companies to choose which technologies are best suited to their management methods and generally to their needs.

The stated objective of the methodology proposed in our research work is to allow companies to choose in coherence the control and monitoring modes (decision and indicators) and technologies of the 4.0 industry in order to set up a real logistics 4.0. These modes of control and monitoring must be based on process models, some of which have been described in the previous section, but also on decision-making models.

The PERFLOG methodology proposed in Figure 1 achieves the objectives presented above. In a first step it proposes the decisional modeling of the supply chain design by proposing a reference model of SC design decisions. This reference model will not be presented in this article. In a second phase, PERFLOG proposes the modelling of the operating decisions of the supply chain, based on a second reference model that will be slightly presented below. The third, fourth and fifth steps are

dedicated to defining objectives, decision variables and performance indicators. The final stage is dedicated to linking indicators and technologies in Industry 4.0.

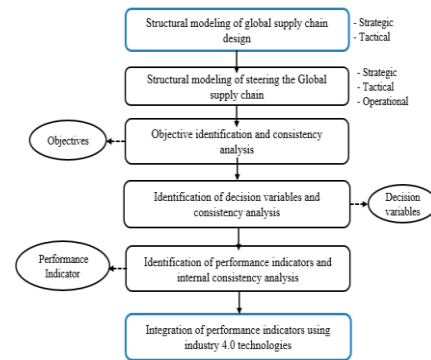


Figure 1 : PERFLOG Method

#### 3.2 Global Supply Chain decision modeling

Global supply chain decision modeling is a complex task because it requires mastery of the chain's components and modeling to optimize processes and reduce the logistics costs associated with production, storage and distribution.

To do so, this work wants to design a grid adapted to this perimeter which is more and more requested by the companies in order to better control the flows of their supply chain. Modeling is an essential step to understand, analyze and master the process of the entire supply chain. In this phase, we propose decisional reference models.

The originality is that companies can use these reference models to design and manage the supply chain. They are not obliged to select all the decisions proposed in the model but must at the end ensure the coherence between all the selected ones in order to have a real decision system and not only disparate decisions.

Two reference models (for SC design and SC operations) were therefore defined in this research work. These reference models are based on the GRAI model and in particular the GRAI grid.

The first GRAI grid of reference developed, GRAILOG-Cop, is a grid for the control of the SC design (how to control the design of the network of partners in a supply chain up to its implemented operation. In order to enrich the existing GRAI model the existing process models (as SCOR) were considered in order to achieve a better exhaustiveness in the functions (Summary Table 2). Therefore, it is important to converge towards design decisions in a supply chain, *this is the usefulness of the Grailog-cop proposal.*

The second reference model, GRAILOG-Exp, means Grailog Exploitation (operation) aims in step 2 to build the supply chain operations control.

This work intends to disconnect the design from the operation even if both must be coherent. This is why the first grid must be elaborated before the second one. Both reference models are intended to be modular, linking two phases. In the GRAILOG-Exp grid, the selected monitoring functions are also inspired from the SCOR model, which is essential in a supply chain because it allows visualization by key process: PLAN, SOURCE, MAKE, DELIVER, and RETURN and other added columns expressing the "vital functions" of monitoring a company or a network of companies: Manage sales, industrialization, and "more recent functions": Manage sustainable development and social responsibility and Manage crisis/risks. All the functions of the GRAILOG-Exp model are justified and referenced in the literature by standards such as RSE, ASLOG... and standards such as ISO 9001, ISO 26000 in order to have a global management of the supply chain.

Without going into the details, the table 3, presenting the Grailog grid of KPI's, shows the list of functions selected in the GRAILOG-Exp reference model.

### 3.3 Identification of performance indicators

The identification of performance indicators in the PERFLOG method is based on the ECOGRAI method (Ducq 2005) which proposes to define the indicators based on the objectives and decision variables relating to each decision. The identification of indicators is therefore divided into three phases.

Thus, the third phase of our methodology, consists in identifying the objectives for the global Supply Chain and then supply chain decisions. Based on the models studied, a set of main objectives is proposed by decision for each of the two grids GRAILOG-Cop and GRAILOG-Exp. The selected objectives come from a bibliographical research (SCOR, Value Reference Model (Mohammadi and Mukhtar, 2018) which showed a preponderance of certain objectives compared to others. Thus, 6 performance areas were selected: Reliability, responsiveness, cost, quality, innovation, environmental and social aspect. Then, in the fourth phase, decision variables are identified that represent the variables on which decision-makers act to make the system evolve so that it can achieve its objectives.

### Identification of performance indicators (PI Grid)

In the fifth phase, decision makers need to identify their performance indicators that will be consistent with their objectives and decision variables. To help them in this direction, the PERFLOG method proposes a KPI's grid for each proposed function of the exploitation grid (Table 3). The indicators chosen are based on three performance measurement frameworks: SCOR, ASLOG, and BSC. This KPI grid gives generic indicators for each function that appear to be important in any type of industrial sector. Of course, this grid is not exhaustive and other indicators can be proposed.

## 4 THE CONTRIBUTION OF INDUSTRY 4.0 TO PERFORMANCE INDICATORS

### 4.1 Industry 4.0 technologies at the service of performance indicators and supply chain management:

The first five steps of the PERFLOG methodology make possible to identify a number of relevant indicators. However, performance indicators must, on the one hand, be SMART (Simple, Measurable, Accessible, Realistic and Time-bound) and must therefore be updated where and when necessary for decision. For this reason, some technologies in Industry 4.0 can help in this direction, and the rest of this work proposes to list the main technologies useful for indicators for each step of their life cycle and to target more precisely which technique can be used for which group of indicators.

### 4.2 PI Life Cycle and Technologies 4.0

The first analysis starts by observing the different phases of obtaining a performance indicator. In order to make it more reliable and SMART, all phases of what could be called an "PI lifecycle" must be properly powered and supported by 4.0 technologies.

As shown in Figure 2, the obtaining of an indicator must begin with the acquisition of the required data. The "data acquisition or ETL" is the phase 1 of the birth of an IP, then follows the phase of "data storage or datawarehouse" then the phase of "calculation" and the final phase which is the display of indicator useful for the decision-maker.

The technologies identified in the previous paragraph form the basis of our cross-analysis. The Figure 2 below shows the contribution of each technology to a phase of the indicator's life cycle.

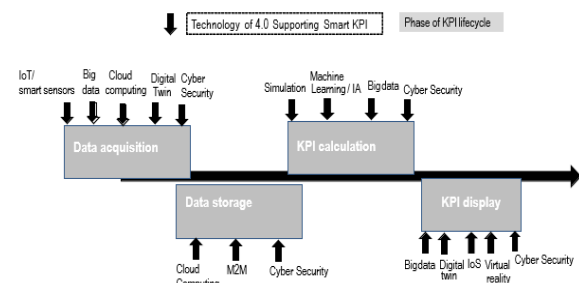


Figure.2: Technologies 4.0 supporting KPI lifecycle

**Data acquisition:** In this phase it is essential to have reliable, relevant data in the nearest field and in real time. Often, ETL (Extract Transform Load) tools are used but in a very traditional way. Big data is interesting in this phase to process all the required data. Given the importance of the data flow, it can be assigned to most phases of the acquisition, calculation and restitution life cycle. Data Storage is only a repository and data cleaning for which big data processing is not necessary. For the



digital twin, data is injected into a simulation and a virtual representation, which is made to evolve as its ages. This allows for interesting data capture and visual restitution to be considered in two phases: "acquisition data" and "KPI display". The Iot connects an ever-growing number of systems, devices, sensors, and people through both low-power extended wireless networks and high-capacity wired networks. It makes it possible to improve the data collection system, in particular via the RFID, RTLS, and its help is crucial in the data acquisition phase. Cloud computing naturally falls into the category of data acquisition but mainly data storage, as it includes cost-effective data processing and storage solutions. The growth of connected objects in production, mobile devices and the cloud requires a company to develop its security management (Cyber security) associated with data storage to ensure that data that are stored and transiting over the network are not vulnerable to cyber-attacks. In the KPI calculation the chosen technologies allow to do the calculation like simulation and machine learning / artificial intelligence. These techniques are interesting to support the concatenation of indicators. Machine Learning techniques make it possible to fully exploit the potential of Big Data in the calculation of performance. For the KPI display, are retained the technologies of display and communication that allow to visualize the instantaneous performance, in time in trend..., like the virtual reality, or the digital twin. They add visual information to reality in order to facilitate maintenance, assembly, equipment control, product design, etc.

The technologies analysed and considered interesting were selected for implementation and management assistance. Each decision-maker will be able to judge the criticality of one of the phases and implement the appropriate 4.0 technologies.

One can also consider that some technologies prove to be interesting at several phases of the life cycle (such as digital twin and cloud computing) but also that some technologies are useless for PI implementation and usage such as 3D printing which does not interfere in any of the phases of the PI life cycle.

### 4.3 Results and first application on PSA

The following grid (Table 3) reflects the functions and decision levels of the GRAILOG-Exp grid explained above. Decisions are not given but reference performance indicators are proposed for each function at each decision level. These performance indicators are necessary for decision-making by function throughout the SC.

The objective here is to show the contribution of each technology to the identified PI's. This analysis is complementary to the previous analysis concerning the link between technologies and the life cycle of each indicator.

A colour code is used to observe the contribution of each 4.0 technology in the implementation and usage of the indicators.

This work shows that all these techniques can be very useful for performance evaluation and can therefore help the company that wants to efficiently manage its supply chain to know which indicators would be the most relevant and which technologies can accompany these indicators.

The model has been applied in an automotive company of the PSA Morocco group. The PSA Group, with a more than 200 years as a history in the automotive world through its 3 brands "Peugeot, Citroën and DS", is the 2<sup>nd</sup> European automobile manufacturer operating worldwide. The PSA plant in Kenitra is an automotive production site located at the Atlantic Free Zone. The site has 3000 employees and produces the Peugeot 208. Its production capacity is 200,000 vehicles by year, with an integration rate of 60%. After analyzing the production process and the different activities of supply chain with production and logistics managers. About twenty interviews took place with these managers at the rate of one hour by interview, we identified on the basis of the reference models, decisions of monitoring with about twenty of them proposed by our model, seven objectives and about ten performance indicators are selected. The model allowed a decision support according to the three decisional levels to monitor the decisions of PSA supply chain. The model designed integrates all the functions of the supply chain, allows too well understand the PSA's supply chain which remains valid for any industry. We found that the decision system of the PSA Kénitra group is in adequacy with our model.

This study is under development and the enrichment of the decisions, objectives and indicators is still pursued. The proposed model is targeted to fit as much as possible the complex supply chain relativity with the majority of the functions (strategies, objectives, decision variables, indicators...) chosen with some specific adjustment to PSA Morocco.

A diagnosis of the supply chain is in progress on new technologies of the 4.0 industry to analyze their degree of integration in various supply chain activities and their impact on competitiveness. The results will be published in a forthcoming communication.

## 5 CONCLUSION

This paper presents the PERFLOG Methodology with the ideas for new reference decision-making models of the supply chain GRAILOG-Cop and GRAILOG-Exp from the design of a network of partners to the exploitation of the supply chain. During the operational phase, indicators become a key issue for decision making. So, this work presents also a reference grid for performance indicators. However, the implementation and usage of these PI is crucial for the appropriate control of the SC. So, it is proposed to link the 4.0 technologies to the different life cycle phases of the PI's and to each Pi presented in the reference grid.

This new methodology highlights big data, artificial intelligence, digital twin and IoT and brings factors of competitiveness, optimizing management on a large scale certainly useful for instance for the automotive industry and its ecosystem suppliers, customers, etc.

Table 3. The Grailog/Exp KPI'S grid integrating the new technologies from industry 4.0

	External Info	Manage commercial	Manage industrialization	Manage purchasing and procurement	Manage raw material quality	Manage production	Managing quality of the finished Product	Manage technical production resources	Manage production human resources	Manage the Social responsibility and sustainable development	Managing the crisis and risks	Manage distribution	Manage returns	Internal Info
<b>Strategic level</b> H= 5 years P= 6 months	Market evolution	Adopt an innovative business strategy - Sales achieved sales targets - Distribution cost sales - Cost of commercial function / sales	Multisite Productions - Speed in prototyping - Product cost - Reduced resources	Multisourcing/monosourcing strategy - Active suppliers monitored - Number of Partner suppliers - Quality of service from suppliers - Reliability of suppliers	Supplier Evaluation - Quality of service from suppliers - Reliability of suppliers	Perform the PIC - Purchase Forecast Reliability Rate - Machine availability rate	Deploy product traceability - Response time - Coverage and traceability rate - Inventory anomaly rate	Investing in machine equipment - Reliability of equipment - Use of equipment - Reliability rate	Personnel Management Strategy - Cost of training new recruits - Number of hours of training	Integrate environment into strategy (green logistics) - Pollution rate - Environmental impact rate - Resistance to competition - Loss of market	Analysis of the company and its environment - Communication - Reactivity	Define the Downstream Logistics Strategy - Average transportation duration CROSS-DOCKING - Number of return sites	Conception of the return chain - Customer satisfaction rate - Number of return sites	Half-yearly activity report DG
<b>Tactical level</b> H=1 years P=3 months	Customer Forecast orders	Define the commercial forecast plan - Reliability rate of sales forecast - Customer service rate - Cost of service rate	Industrial material investment and training - Ability to standardize the product - Investment of means - Planning Reliability - Procurement flexibility - Size of procurement lots	Define procurement policies - Quantity to be produced - Planning Reliability - Respecting deadlines - Compliance with the production plan	Internal quality audit - Suppliers satisfaction rate - Respecting deadlines - Compliance with the production plan	Production master plan - Production Capacity - Production Lead time - Compliance with the production plan	Quality control of finished Product - Customer satisfaction rate - Evolution of the number of maintenance actions - Rate of equipment accidents at work	Investment in maintenance equipment (training, machine purchase) - Number of new jobs offered each year - Number of workers - Rate of equipment accidents at work	Human Resources Planning - Number of new jobs offered each year - Number of workers - Rate of equipment accidents at work	Managing the environment at different stages of product manufacture - Compliance with environmental regulations - Cost per unit transported and per kilometre	Establish a crisis management plan - Number of people impacted - Preventive measure - Adapted to crisis management	Distribution Requirements Plan (DRP) - Vehicle traceability - Fill rate per vehicle - Number of shipments - Delay rate	Manage customer complaints - Customer satisfaction rate - Communication with customer - Delay rate	Outstanding Claims, Delay Break Rates
<b>Operational level</b> H=2 weeks P=1 Day	Customers information	Access orders or follow up - Forecasting accuracy - Reliability of market forecasts - Processing time - Cost of points of sale	Short-term intervention like emergencies - Set-up time - Number of target orders - Reliability of materials - Orders followed - Average time to process a Purchase request - Satisfaction rate of orders	Order releases - Order rate for deliveries - Delivery performance of raw materials - Orders followed - Average time to process a Purchase request - Satisfaction rate of orders	Verify product conformity - Compliance rate - Rate of compliant products - Inventory turnover rate - Non-compliance rate	Start production - Manufacturing cycle time - Stock reduction - Inventory turnover rate - Stopping rate	Controls and tests - Rate of compliant products - Scrap rate - Rate of non-programmed machine stoppages - Availability rate - maintainability rate	Machine control and maintenance - Failure rate - Machine utilization rate - Rate of non-programmed machine stoppages - Availability rate - maintainability rate	Assess and manage human resources - Number of redundancies per year - Cost of dismissal - Weekly absenteeism rate	Eco-production - Rate of recyclable products - Reduction of Financial losses - Percentage of recyclable materials that make up a product - CO2 emissions in kilograms - Volume of waste generated per year	Managing the way out of the crisis - Financial losses - Crisis exit plan	Tour management - Optimization of the tours - Warehouse fill rate - Truck fill rate - Traceability of transport packaging - Transport cost	Delayed or blocked order analysis and processing - Cycle time for return of products - Replacement or replacement periods	Payment And sales



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