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An analysis of supplier delivery performance: The FCA case

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INTRODUCTION

The automotive industry stands in today's market as an industry with high complexity in terms of products and network and for the presence of a close and collaborative relationship between the different actors of the supply chain. The customer's demand for an ever greater speed and flexibility and for a continuous improvement in the technological and innovative component of the product which leads the industry to face an increasing competition. In order to maintain its competitiveness a company must find a way to adapt it-self by creating relationships of great collaboration with the suppliers, adopting new technologies to allow a faster and more reliable exchange of information, introducing politics of management, like the risk analysis, which is turned to face the various situations of "emergency" that are caused by the intrinsic uncertainty of this type of industry.

In this scenario the analysis and the monitoring of the supplier delivery performance, considered in terms of on-time delivery, acquires great importance, as it allows to have a greater control of the processes and of the timing. A lot of studies have been carried out as to identify the factors tied up to the insolvency of the suppliers and, more generally, of the supply chain.

The context of this analysis will be reduced only to the transport step to reduce the influence of the upstream and downstream processes, usually made up by major uncertainty. This thesis is directed to identify and to analyse in depth the factors, which can influence the timing linked to the process of transport, starting from the literature and from the analysis of the processes realized during the internship in FCA. A better understanding of these aspects, from the customer's point of view, could bring notable improvements within the suppliers relationships. The tool used will be an analysis of the data about transport, gathered from FCA, with the help of the methodology of the ANOVA analysis.

The thesis is structured in three chapters, the first one consists in a review of the existing literature. From the point of view of our analysis some main themes are covered: the definition of supply chain and the supply chain management, the concept of vulnerability and risk management, the importance of an evaluation of the delivery performance, the main characteristics of the automotive industry and the concept of complexity.

Later, an identification and a classification of the factors influencing the delivery performance is realised distinguishing three main areas of elements: the flexibility, the information system and the network.

In the second chapter an overview of FCA and of its organization is realised, a major focus is put on the Material Track and Trace project, the supplier management and the supporting information system.

The third chapter is devoted to ANOVA analysis, it starts from the analysis of the descriptive statistic of the dataset, realises a description and a classification of the factors chosen for the analysis and, finally, it presents the outputs and the results of the ANOVA analyses with a focus on the limitations and on the possible future developments.

The aim of this work is to verify the existing bonds among the levels of the factors considered and the result that we want to study, in this case the quantity and the length of the supplier's delays, obtained by comparing the date of expected arrival and the real recording of the merchandise at the plant. The final purpose will be the identification of the factors influencing the delays to understand where to work to get improvements both at process and monitoring levels.

1. Literature Review

In this chapter we will present an overview of the existing studies about the concept of "Supplier delivery performance" and "Supplier Management", putting more attention on the core themes. We will start with the general concept of Supply Chain and Supply Chain Vulnerability to introduce the study of the delivery performance, in term of on-time delivery and responsiveness. Later a greater attention will be put on the automotive industry to identify the complexity as a key characteristic of this industry. Finally, a list and a classification of the factors influencing the delivery performances will be established starting from the information found in the literature.

1.1. Supply chain

The first aspect to be analysed and to be understood for developing in the best way our analysis is the concept of supply chain, always more considered due to increasing global competition and value demand. This concept has been central in research of the last decade and for this reason a number of different definitions can be found in the literature.

A general definition can be found in the Ahmad and Schroeder work: "A supply chain is an integrated system wherein a number of business entities such as suppliers, manufacturers, distributors, and retailers work together to deliver goods and/or services promptly at a competitive price." (Ahmad & Schroeder, 2001) or from Sadraoui and Mchirgui is seen as "an integrated system with physical flow of materials, manufacturing planning and control, as well as physical distribution". (Sadraoui & Mchirgui, 2014)

Instead, by considering a major focus on the automotive industry, a supply chain can be defined as "an input-output system. Inputs are the demand from the vehicle manufacturer and raw materials from the second-tier suppliers, outputs are the deliveries into the vehicle manufacturer and the orders that go out to the second-tier suppliers." (Holweg, 2005)

In general, a supply chain involves all activities associated with the flow and transformation of goods from raw material to the end customer.

What is important is the holistic and systemic view of the supply chain, considering the upstream and downstream relationships and not only the material flows, but also the information flow and so the bidirectional nature of the supply chain. (Vachon & Klassen, 2002)
Each definition puts its own focus on a different aspect, but what generally emerges is the presence of a flow of goods firstly, but also of information and the concept of interaction and co-working between the different levels. The idea of integration between the actors in the supply chain is a core element that must be kept under control and this is the role of the Supply chain management.
From the studies of the Global Supply Chain Forum (GSCF), a group of firms and academic researchers, the Supply chain Management can be defined as "the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders." (Lambert & Cooper, 2000)
The supply chain management is a competitive strategy with the purpose to reinforce the responsiveness and the flexibility, as priority elements, of the entire organization integrating suppliers and customers with the development of new models and approaches. (Sadraoui & Mchirgui, 2014).
The concept of supply chain is strictly correlated with the supply chain management and the understanding of one is essential for the other.

1.2. Supply chain vulnerability

Having a good supply chain performance is a critical element to reach success and a supply chain disruption can negatively affect this performance.
The consequences of a break-up can be of different entities and at different levels. Some examples are financial losses, problems of security and health and these usually come with a consequent damage of the image and reputation of the company that can conduct to a reduction in the demand.
In the current context, considering these elements, is even more stressed the importance to mitigate and control the vulnerability of the supply chain.
The vulnerability is defined as ''the exposure to serious disturbance, arising from risks within the supply chain as well as risks external to the supply chain'' (Thun & Hoenig, 2011).

To deal with and to reduce the vulnerability the management has to identify, analyse and understand how to manage the risks. This goes under the name of Supply Chain Risk Management (SCRM).

If we talk about the Supply Chain Risk Management (SCRM), with respect to the classical risk management, we have to underline some particular aspects:

- "the cross-company orientation": the efforts have to be focused on reducing the risks on the entire supply chain and not only on the company level and, for this, a carefully coordinated approach is necessary; (Thun & Hoenig, 2011)
- "The multitude of risks within a supply chain": this is a special challenge for the supply chain risk management. The identification of the importance of a certain risk as its likelihood and its impact on the supply chain is a central but also complex issue which ca be easily underestimated. (Thun & Hoenig, 2011)

Although the risk management starts to be generally recognised as important it is not so easy for a manager and for a company to see and even more to quantify the benefits derived by the implementation of a risk management system. As it is difficult to identify the gains it is also difficult to find an economic legitimization for it as no one wants to invest in something that might not happen.

There are different instruments used by risk management and the more commons do not eliminate the entire risk but have the purpose to reduce its probability to occur. One possibility is to focus on suppliers with certified operational performances ratio, in order to reduce delivery problems, or to use an intelligent supplier's relationship management, improving the transparency and the information transmission, that can help in reducing the uncertainty and lead to a decreased supply chain risk. (Giunipero & Aly Eltantawy, 2004)

A starting point in the reduction of the vulnerability of the supply chain as well as in a better supplier's relationship are the definition and the measuring of operational performance, but equally the trust and the collaboration within the different actors of the supply chain can gives a contribute. (Holweg, 2005)

1.3. Delivery performance: on-time delivery and responsiveness

There is no doubt about the importance of a fast and reliable delivery. Indeed, the delivery performance has become a critical metric of success.

There is more than one way to evaluate a delivery performance (throughput-lead time, average tardiness or quantity of late deliveries (in term of service level)…(1)), but the common point is often the link with the concept of time and responsiveness (Vachon & Klassen, 2002), so that there is a general acceptance of time as a source of competitive advantage.

The ability to serve the customer's needs in an appropriate time-scale, as well as the need to provide the right product, in terms of type, quality and price, within the shortest length of time is more and more important as the on-time based competition is taking place and becoming a key point in the company strategies. (Holweg, 2005)

We start now to speak about the concept of on-time delivery and its link with the concept of responsiveness, as a responsive supply chain is a key point to obtain a good level of on-time delivery and at the same time the on-time delivery can be an indicator of responsiveness as well as an indicator to evaluate the delivery performance.

There isn't a clear idea on the concept of supplier responsiveness. In the dictionary the responsiveness is defined as "the ability of a machine or system to adjust quickly to suddenly altered external conditions, as of speed, load, or temperature, and to resume stable operation without undue delay." More linked to our context, the responsiveness can be defined as the ability of a firm to react in a timely fashion to changes in the customer demand or in the market conditions in order to maintain a competitive advantage. (Kritchanchai & MacCarthy, 1999)

To better understand the concept of responsiveness the clarification of the concept of response and of the difference with the concept of reaction can help.

Ackoff, talking about the systems changes, defines the reaction of a system as: "a system event for which another event that occurs to the same system or its environment is sufficient. Thus, a reaction is a system event that is deterministically caused by another event" (Ackoff, 1971) and the response as "a system event for which another event that occurs to the same system or to its environment is necessary but not sufficient; that is, a system event produced by another system or environmental event (the stimulus). Thus, a response is an event of which the system itself is a coproducer." (Ackoff, 1971) So the response can change on the basis of the elements presence and it not must occur but can occur.

Few studies have been made about the concept of responsiveness and usually only in term of qualitative description or considering only a subset of factors. However, the findings make evident the need to analyse a system within its environment using a complete overview to investigate the whole set of interactions, considering both customers and suppliers to determine the inhibitors of responsiveness as the supplier responsiveness is constrained by both internal factors, derived from their own operations, and external factors, identified with both the up-stream and downstream players. (Holweg, 2005)

Once defined the notions linked to responsiveness, it is possible to return on the concept of on-time delivery. Measures as throughput time and lead time had been seen, in the past, as indicators of responsiveness to customers but they aren't an absolute measure since they vary widely at the variation of the production process and so they aren't the best solution for studying plants with different production processes. In this context the concept of on-time delivery is introduced. (Ahmad & Schroeder, 2001)

From the lean manufacture site, the on time delivery is defined as "a measure of process and supply chain efficiency which measures the amount of finish goods or services delivered to customers on time and in full. It helps determine how efficiently we are meeting our customer's or agreed deadlines." (2) In the FCA Supply Chain Academy Foundation Modules is considered as "ability of the supplier to deliver on-time and often to a specific delivery schedule." (APICS, 2017)

Although sometimes overlooked, on-time delivery is an immediate and simple measure and, also for this, can be considered as adapt to our scope, so to measure the delivery performance.

The relevance of an on-time delivery must be considered in particularly for firms competing internationally, in fact, in this environment, the complexity of the supply chain increase.

1.4. The automotive industry

The automotive industry represents an interesting case as, considering the treated themes, this industry has some particular characteristics that can be useful to deal with more in detail.
Although the majority of the researches about the automotive supply chain are more focused on the component supplier-production sections of the chain, (Turner & Williams, 2005) we have already introduced the necessity of an holistic view so we will consider both component and raw material supplier tiers and the link with vehicle manufacturers. (Holweg, 2005)
One more reason to take in consideration the automotive industry is the fact that is a good example of the importance of the risk management as in their business environment supplier losses and quality problems and all the other everyday problems are elements not to be underestimated because they can significantly change the delivery performance. (Thun & Hoenig, 2011)
A detail of the main characteristics of the automotive industry will be realised starting from "the challenges of a new car supply chain" identified by Turner and Williams. (Turner & Williams, 2005)

- COMPLEXITY OF THE PRODUCT
    - NATURE OF THE SUPPLY CHAIN

      In the past the downstream supply chain in the automotive industry has been creating with the idea of cars as a functional product due to the high volumes and so aligned with the idea of mass-production and the purpose of an efficient supply chain. (Turner & Williams, 2005)

      But speaking about the automotive industry, is essential to consider the fact that the products can be functional or innovative and that the suppliers and the manufacturing system can be the same for both. So, we have products thought with a different purpose and with a different nature sharing the same supply chain that is though more to be efficient than to be responsive. (Holweg, 2005)
    - PRODUCT VARIETY

      Product variety is a wide source of trouble in both upstream and downstream activities, and the automotive industry is very rich in term of variety with distinct specification of body, engine, colour, optional equipment etc. from the main aspects up to the smallest detail. (Turner & Williams, 2005) For example, the Fiat 500 in the EMEA region has a number of combinations that create almost 2.3 billion of configurations.

- COMPLEXITY OF THE SUPPLY NETWORK

  To obtain such a complex product a network with specific characteristics is necessary.

  A great number of components have to be supplied, and so a great number of suppliers, inventories and dealers to be managed. (Turner & Williams, 2005)

  The relationship between the actors in the automotive component supply chain has been widely discussed, the steps from an adversarial purchasing model to a collaborative partnership sourcing approach have been analysed with the unequivocal conclusion that a better performance and benefits can be obtained from a close and collaborative relationship (Holweg, 2005), and the growing demand for a flexible and responsive supply chain improves more and more the need for a close collaboration and a sharing of knowledge and information between the different actors.

  Finally, to obtain a responsive supply chain is necessary not only flexibility in the assembly step but also a component supply chain able to support it. (Holweg, 2005)

- CONSUMER BEHAVIOUR

  The consumer behaviour is a source of variability, even for the same model, each specification that can change the final configuration can be seen from the consumer point of view an element to obtain his unique car, so usually the requests are linked to the personal taste, but not only. Another element that influence the chose are the willingness to wait, as a car with specific chosen characteristics became a built-to-order products so need a longer time to be realized, instead a compromise can be to choose a car with only some of the desired characteristics but already in stock. The last aspect is money, some customers can afford to change the model to have always the more innovative configuration, with all the optional, others prefer to take advantage of the discounts obtainable choosing a specific configuration. (Turner & Williams, 2005)

- DEMAND SEASONALITY

  There is a seasonality in the monthly demand, furthermore the demand varies also in each different market. As a consequence, the car in stock are not always the same. (Turner & Williams, 2005)

- AGEING OF STOCK

  The variety in component, the multitude of possible vehicle configurations and the high risk of obsolescence in the automotive industry makes the strategy of holding more stock, to obtain a more responsive process and a better delivery performance, almost impossible for the bigger number of possible combinations. (Holweg, 2005)

  Already the high variability, creating from the consumer behaviour and demand seasonality, drives to an increase in inventory and the reduction of the finished cars in stock are one of the main objectives of the seller's efforts. The use of some aggressive sales techniques to drives the customers to make a specific choice and the offer of heavy discounting, encouraged by manufacturer incentives, to sell cars remained unsold are common aspects in the dealer life. (Turner & Williams, 2005)

All these elements cause an increasing in the complexity of the supply chain, so it is important also to analyse the concept of complexity as it is usually linked to difficulties in the obtaining of a good delivery performance.

In conclusion, after this analysis, we can say that the automotive industry is characterised by a close collaboration and high complex supply chain. (Vachon & Klassen, 2002).

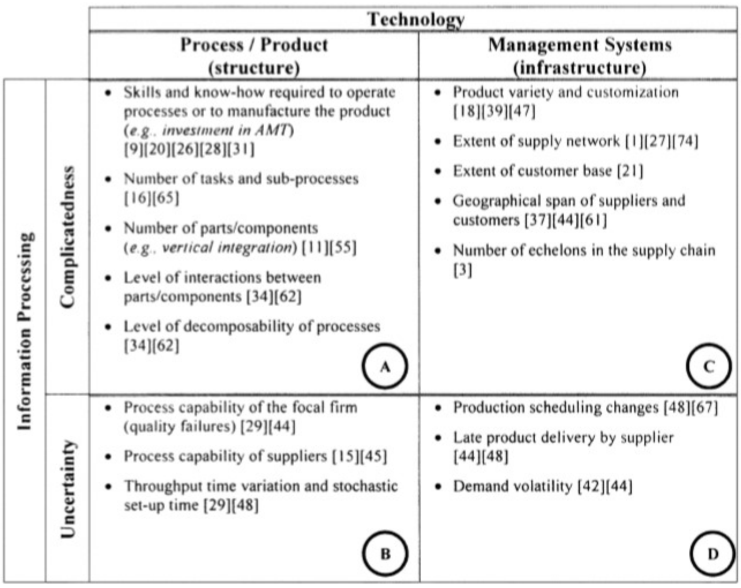
1.5. Complexity of the supply chain

As a critical dimension that characterize the automotive industry the complexity is an aspect to look into to begin to understand the connexion with the delivery performance.

The concept of complexity must include a variety of product, technological, and organizational variables and to talk about it is necessary to consider the fact that his consequences can be amplified or attenuated by both managerial action and external business environments; the direct link between complexity and supply chain risk must also be considered. (Thun & Hoenig, 2011)

As a principal concept linked to the supply chain the concept of complexity has been subject to studies in different field, as the manufacturing, the organizational and the information technology, in this way a collection of definitions has been written considering different perspectives.

Galbraith's defines complexity as derived from task uncertainty as "the difference between the amount of information required to perform the task and the amount of information already possessed by the organisation". (Galbraith , 1973)
Wilding see the complexity as a negative effect to be reduced and avoided, links this concept to the uncertainty and define the "supply chain complexity triangle", composed by three interacting but independent factors: deterministic chaos, parallel interactions and demand amplification, as the sources of the dynamic behaviour in the supply chain and in some ways the cause of generation of uncertainty. (Wilding, 1998)
From the first researches, the correlation between complexity and uncertainty seems evident, but further researches in the literature conduct to the definition of a two-dimensional matrix of supply chain complexity that will now be analysed using the Vachon and Klassen work. This matrix, detailed later, consider different aspects of complexity: the technological and information perspective, with inside both the concept of complicatedness and uncertainty and take into account the concepts of numerousness, interconnectivity and systems unpredictability. (Vachon & Klassen, 2002)



		Technology	
		Process / Product (structure)	**Management Systems (infrastructure)**
Information Processing	**Complicatedness**	• Skills and know-how required to operate processes or to manufacture the product (*e.g. investment in AMT*) [9][20][26][28][31] • Number of tasks and sub-processes [16][65] • Number of parts/components (*e.g. vertical integration*) [11][55] • Level of interactions between parts/components [34][62] • Level of decomposability of processes [34][62] (A)	• Product variety and customization [18][39][47] • Extent of supply network [1][27][74] • Extent of customer base [21] • Geographical span of suppliers and customers [37][44][61] • Number of echelons in the supply chain [3] (C)
	Uncertainty	• Process capability of the focal firm (quality failures) [29][44] • Process capability of suppliers [15][45] • Throughput time variation and stochastic set-up time [29][48] (B)	• Production scheduling changes [48][67] • Late product delivery by supplier [44][48] • Demand volatility [42][44] (D)

Figure 1: Complexity Matrix (source: Vachon & Klassen, 2002)

The technological dimension considers the fit between process, product and organization. These three elements must be considered to characterize the supply chain and be technological in nature, considering as technological the managerial techniques, methods and knowledge, that are the "infrastructural" part, but also the product and process aspects, that are referred as "structural", with a particular focus on time and space. The management part includes what is linked to the people-based relationships, instead the product and process aspects refers more on physical components and equipment.

In general, the supply chain includes both organizational and physical aspects and in particular elements like geography, organization, culture and electronic proximity are also be included.

Considering the information processing dimension two factors have to be taken into account, from one hand the different levels of complicatedness and on the other hand the levels of uncertainty.

The first one is related to the quantity and the structure of the interactions in the system, it is the fix element of complexity derived from the numerousness and the variety, it considers the situations where all the information is known but their analysis is complex because of the size or because it is not exploitable.

The second one is associated with the variations and the changes that can occur in the system. Thus, it is not deterministic and it is linked to the level of reliability and predictability of a system taking into account also the lack of information.

From the actual researches a little evidence was found considering the influence on delivery performance of the management system complicatedness, as well as of the process uncertainty, but this doesn't mean that there is absolutely no impact indeed other factors, as the product/process complicatedness, can, in a certain way, hide the effects derived from the two analysed aspects.

The level of influence of each factor could be not always the same and is necessary to not exclude the correlation and trade-off between the different aspects of complexity.

For example, an investment in the automation of the process, considered as a process complicatedness, can help the speed of the information transfer and in this way can reduce the negative effects of an increasing in the dimension of the supply network, included in the management system complicatedness. So, further researches have to be made to identify the real impact of each dimension. (Vachon & Klassen, 2002)

1.5.1. Management systems complicatedness

From the point of view of our research we will go more in detail in the infrastructural concept of complicatedness analysing the link between management systems complicatedness and delivery performance, instead we will overlook the other aspects of complicatedness as out of our scope.

The management system complicatedness can emerge from different elements, Galbraith highlights the link with goal diversity as product variety, the transformation of the market from a local to a global market, the customization and more in general all the factors which increase the need for coordinated management. (Galbraith , 1973)

Product variety increases problems linked to the inventory management, the purchasing and the scheduling, increasing the variety these processes have to be controlled with more attention and this asks for more time and efforts.

A big number of suppliers, also for the same part and from different countries, can help in reducing the risks of insolvency and costs but on the other hand it increases the request for coordination to obtain efficient operations and homogeneous inputs and makes more difficult the creation of close relationships between the supply chain's actors. (Vachon & Klassen, 2002)

A general evidence can be found on how the managerial decisions in this sense, if considered independently, have a negative impact on the supply chain and logistics performance, but all these aspects, that are causes for an increasing in the management systems complicatedness, should be viewed in a broader context and will be later reconsidered analysing the effects of the network structure in the supply chain.

1.6. Factors from the literature

After having defined from the literature the main aspects linked to the supply chain and the delivery performance, considered as the metric of success, is useful to identify the main classes of factors influencing the supplier performance, always taking in mind the influence of the complexity on these factors as an element that amplify the others factors' effects. To do this is useful to start from a general overview of the most mentioned factors and from an analysis of related risks, as key drivers in the identification and classification of the main elements. Later,

also considering the factors as greatly linked between them, a trial to identify three main macro-areas of the factors present in the literature has be done to try to cover the main themes.
The question about the factors influencing the delivery performance is a complex theme as different elements have to be considered along all the supply chain system. There isn't a clear picture of standard factors but is clear the impact of specific problems for each individual actor and for each particular circumstance in inhibiting the operations linked to production and distribution.
A general list of inhibiting factors perceived as problems in the different industry setting can be realised. The supply of tooling, labour absence rates, machine downtime, production quality, parts variety inventory levels, labour, facility and supplier related issues, production batch sizes, delivery lead-times and frequencies, distance, flexibility of volume and capacity levels, demand variability are elements to take into account in the achieving of a good delivery performance and so in the gain of competitive advantages; some are in common at the majority of contexts but not all are universally applicable. (Holweg, 2005)

1.7. Risks classification

The identification of the risks is a first step to identify the factors influencing more the delivery performance because the risk is the element that, if realised, can cause a delay.
Concerning the risks, in the past different classifications have been realized to better understand their area of interest and so their impact. There, is analysed an integration of the classification described by Thun and Hoenig and of the one of Cristopher and Peck.

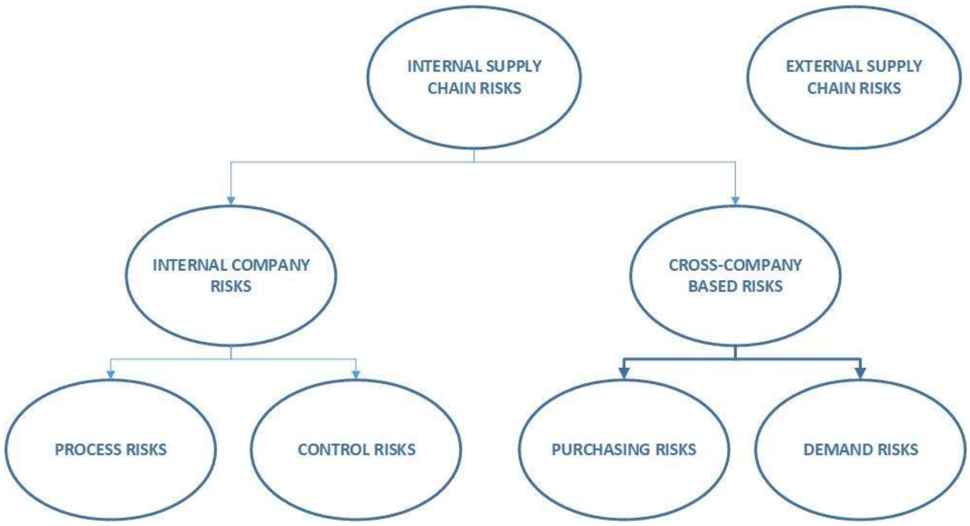


Figure 2: Risk classification (source: Cristopher & Peck,2004 and Thun & Hoening,2011)

A first division must be done in term of internal and external supply chain risks.
The internal supply chain risks consist of internal company risks, including the issues inside the single organization distinguished between process and control risks, and cross-company based risk, that are the risks external to the considered company but internal to the network of materials, products and information flows and that is ulterior differentiated between purchasing and demand risks.
Under the internal supply chain risks category, the first class (process risks) concerns the possible complications deriving from the execution of processes and depends on the answer of the managed assets, for example machine breakdown, and on the functioning infrastructure, like the internal transport or the communication structure, considering situations as IT problems.
The second one (control risks) includes problems arising from the application of rules, systems and procedures used to realize and control the process. Examples are the definitions of order quantity, batch sizes, safety stock, routines for the asset and transportation management. (Christopher & Peck, 2004)
Under the cross-company based risks category, the purchasing risk problems are the ones born in the supplier's management: quality problems, insolvency, lost of a supplier or difficulties in

react to technological changes and innovations, and so to adapt its systems and processes. In general, these risks are linked to the upstream activities.

Instead the demand risks consider the downstream activities, including complications in the distribution of products, in the information and cash flows and the consequences of uncertainty in demand like delivery gridlock, high inventories, poor capacity utilisation.

Finally, there are the external supply chain risks, usually less foreseeable and avoided because concerning environmental causes, they can have a direct or an indirect impact of different entity. Examples are socio-political elements, like political instabilities or terrorist attacks, economical, technological or geographical reasons and "act of God" like earthquakes or hurricanes.

The evaluation of the risk in quantitative terms, how often and with what impact, is very difficult but is possible to say that the internal risks are more probable as the environmental factors are usually exception and the external risks have usually a greater impact with respect to the first. (Thun & Hoenig, 2011)

So, we can say that the internal supply chain risks can be seen as ordinary risks, not uncommon, and for this are easier to be studied.

1.8. Factors classification

To better understand the principal topics, the main factors have been organised in three macro-areas: flexibility, information system and network; each of them have his own impact but is correlated to the others, from the point of view of the analysis, a major attention is needed on the last topic.

1.8.1. Flexibility

We have spoken about responsiveness as a core theme in the evaluation of the delivery performance; this concept is strictly correlated with the concept of flexibility as without flexibility is not possible to obtain a responsive system, in other words the absence of flexibility is recognised as a core inhibitor of responsiveness.

In the Oxford Dictionary the flexibility is defined as the general "ability to adapt", in the management environment we usually consider it as the ability to react and to adapt to uncertainty and influences derived by internal and external factors.

In the FCA Supply Chain Academy Foundation Modules the flexibility is seen as "a metric that measures how easily suppliers can accommodate changes in the purchase schedule, respond to an expedited order, or handle special requests." (APICS, 2017)

From these definitions and from other researches, is possible to say that the flexibility is usually considered as a competitive advantage and is generally linked to the concept of uncertain and changes. There are different dimensions of flexibility and each different organization, depending on the system's structure and environment, need one or more of these in order to be responsive to market needs. (Holweg, 2005)

Elements like technology, human resources, labour and routines can all be analysed from the point of view of the flexibility and linked to create a hierarchy called "system flexibility". (Slack, 2005)

Many classifications, creating a system flexibility, emerge from the literature, but almost all are due each other; the classification in figure 3, taken from Holweg's studies, will be described more in detail because it allows to clarify some important flexibility aspects. (Holweg, 2005)

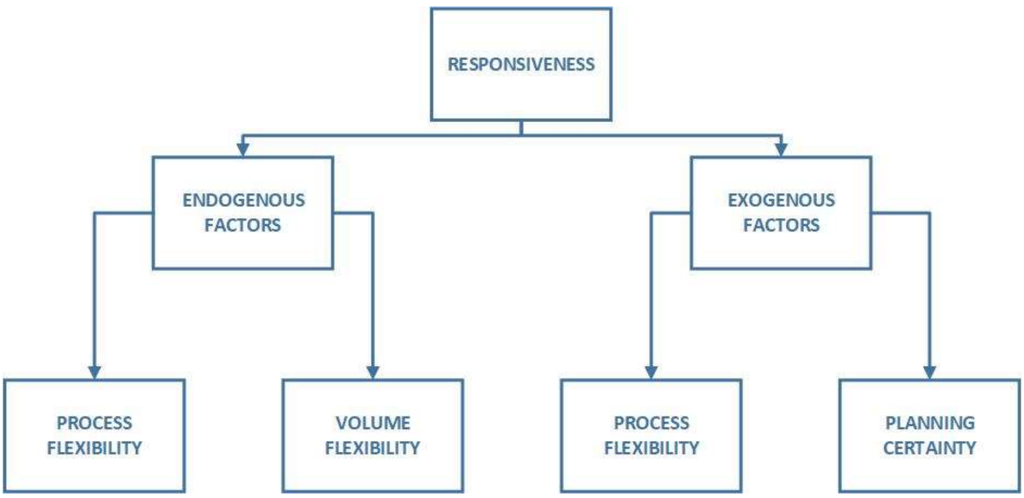


Figure 3: Sources of responsiveness (source: Holweg, 2005)

One of the pillars in the system flexibility is the volume flexibility, it is considered as the ability to quickly alter the capacity or provide an excess capacity, it is not simply about having capacity, but it is having the quickness and the possibility to adapt the capacity to the fluctuation of the demand. Beside the changing in the capacity, also the labour flexibility influences the concept of volume flexibility. To be underlined is the fact that the volume flexibility becomes much easier to be faced with the increase of the length of notice given.

The second aspect is linked to the concept of planning certainty, the unpredictability of the demand makes more difficult to respond to market variations, as a short time is let to adapt the system. In the model the planning certainty is considered in term of demand stability, forecast vs order, and of demand reliability, late amendments.

The variability of the demand measured as the difference between the forecast and the actual demand seems to influence the performance only partially, instead numerous confirmations was found about the negative impact of late amendments. The last-minute changes in the production program are difficult to be managed as a very little time is let to react and are usually not traced, an example is a call to change the order the day of the delivery.

Uncertainty can cause the production instability but is not the only effect, it can also influence other aspects like the complexity of the supply chain, the need of frequent exchange of information and so the information system. On the other end is not the only determinant of production instability other examples are machine breakdowns, implementation of new technology, priority to be given to a particular customer, the inventory management, no good coordination among different roles, etc. Being responsible for an increasing in the production instability these sources can have a negative impact on the deliver performance.

The last point is the process flexibility; in this case is necessary to differentiate between exogenous and endogenous factors.

As internal factors, influencing the process flexibility, can be considered the policy in term of production and order lot sizing, the synchronisation of production stages and the throughput reliability, instead as external factors are contemplated the supplier order lead time, the distance from the supplier, the sourcing complexity and all a group of factors that will be considered deeply in the network part as a separate class that directly influence the delivery performance. (Holweg, 2005)

The need to be more flexible to be responsive to market's requirements, answering to an uncertain environment, makes higher the interest in an efficient supply chain and need a frequent, fast and reliable exchange of information. (Ahmad & Schroeder, 2001)

1.8.2. Exchange of information: Information system

The information is a driver element for the success in the today industry, the relation between a first-tier and a second-tier supplier needs an exchange of information, the interaction between different departments and also the same work inside a department can't be realised without the right information.

Usually people referred independently to the need of data or information, but a distinction must be done; a data cannot always be considered as an information as the term information consists of a data which are relevant, accurate, timely, concise and determines a change in knowledge. (Tushman & Nadler, 1978)

The important aspect is not only the pure transfer of data but also the comprehension and the right elaboration of them as information, is possible to speak about information processing as the action of "gathering, interpreting, and synthesis of information in the context of organizational decision making." (Tushman & Nadler, 1978)

To makes the management easier and more structured the industries are more and more using information systems and in particular the automotive industry is at the vanguard with early adoption of new technologies in this area, such as EDI and business-to-business trading exchanges. (Turner & Williams, 2005).

What is clear, in this context, is that it is impossible to reach an effective supply chain without an efficient IT system.

The introduction of a real time communication and trade with the partners but also with customers permits to realise a major automation of the processes and to obtain a continuous exchange of information about products, services and transactions. To reach such a result a variety of information systems have to be used inside but also outside the company and all the information systems must be integrated between the actors, from the first raw material supplier to the last end customer. (Sadraoui & Mchirgui, 2014)

An information system can be evaluated from different point of view, in term of how efficient the exchange of information is, what computing power and processing capacity can support,

how much the information is reliable and how much fast is their interchange, not neglecting the importance of having compatibly systems along the whole supply chain.
The relevance of all these aspects of an information systems are confirmed by the studies about complexity, as they underline a low support for information technology, a weak communication infrastructure, the internal and external procedures of communications as elements amplifying the bad effect of complexity. (Vachon & Klassen, 2002) (Holweg, 2005)
The influences of a good information system on the effects of complexity has been confirmed from the Vachon and Klassen research, but an exploratory study on the link between a good information system and a good delivery performance must be added.
A key element in the new technologies improving the information system is the EDI, Electronic Data Interchange, that is the concept of an exchange of documents and information from a computer to a computer through the use of a standard electronic format in a business field. (3)
On the link between the use of an EDI and the increase in the on-time delivery ratio limited empirical researchers and with not uniform results have been done. The complexity in this type of researches can be caused by the ease in neglecting the impacts of some factors which can confound the results, so further researches have to exclude the impact of these external factors before to investigate the effects of an EDI and have also to take into account both the upstream and downstream link.
Ahmad and Schroeder in their studies explore the benefits expected from the use of an EDI.
"EDI provides integration among the elements of the supply chain through timely exchange of information." (Ahmad & Schroeder, 2001), it makes possible to reach the information needed and to share them with the right part of the supply chain, it represents a way to reduce the information asymmetry and ensure a quick flux of information.
Numerous others are the cited gains obtainable from the use of an EDI like reduction in cost and inventory, increase in the reliability of information and so the reduction of data entry errors, improvement in actors' relationships, in particular in the case of a big physical distance, and improvements in the customers' satisfaction with a more reactive response. (Dearing, 1990) As a plus, following the trend of the market that is asking more and more for a quick-response the EDI, or a similar system, is becoming a must to do business and to be competitive.
As seen previously, an inter-organizational communication system increase the information symmetry, this is an aspect not to underestimate as it means more transparency and it helps the

creation of trusted relationships, integration and alliances, and in addition makes organizational boundaries more permeable. (Ahmad & Schroeder, 2001)

The organizational structure must help the gathering of information from outside the boundaries and effectively processing them within and between subunits of the organization. (Tushman & Nadler, 1978)

The automotive industry is an example of implement of an EDI with an hub and spoke settlement, the hub is the large organization that push their suppliers to pass to this arrangement, as the extend of use of EDI is positively related to the delivery performance so the hub (the large organization) is stimulated to expand the network connected to obtain more gain, but sometimes the costs for a less powered partners, a spoke, are more than the advantages and an excessive influence, sometimes an exercised power, of the hub to pass to an EDI system can create some trouble in the inter-organizational relationships. (Hart & Saunders, 1997)

The right strategy must balance the advantage and disadvantages to obtain the better delivery performance.

Businesses depend on strategic relations with their customers and suppliers, interorganizational communication and collaboration for creating value systems that will provide a competitive advantage in the market. (Sadraoui & Mchirgui, 2014)

1.8.3. Network

If we analyse the network from the point of view of our analysis, we can find that some trends of the moment can strongly influence the relationship between the different actors acting.

Some evolutions in the business environment, in the last decade, have pushed the companies to change their mind, their strategies and their routines to maintain their competitive position.

Firstly, the strong competition forces the firms to search the maximum in term of efficiency rather than effectiveness to building up a lean supply chain and to change their procedures, reducing their inventory and adapt the delivery windows. (Vachon & Klassen, 2002)

The trend about suppliers is going toward a single sourcing with a single supplier delivering a single product or also a supplier with more delivery of different parts; instead of the multi-source strategy, that allow to reduce the delivery risk. A reduction of the supplier base is now preferred.

On the other hand, the new strategies follow also the trend towards the outsourcing, putting the focus on core competencies. This is a decision that increase the complexity and the risks, the lines of responsibility could be more easily confused as the boundaries between actors are less marked, some examples are the management of inventory costs for obsolescent products or the effects of a stockout. (Jüttner, Peck, & Christopher, 2003)

"A subunit performing a task which is fairly autonomous has little need for information from or collaboration with other areas. If the subunit's task is changed so that it is dependent upon the work of other units, the need for joint coordination and effective problem-solving increases." (Tushman & Nadler, 1978) This sentence well explains how these tendencies influence the relationships, the coordination and the management efforts needed.

A common point can be identified between these trends as all of them change the structure of the supply chain and impact on the risks concerning the network (Jüttner, Peck, & Christopher, 2003), increasing the dependency inside the supply chain with more and more reliable delivery asked.

Concerning that, two points of view are possible: a higher dependency can conduct to a more close and trusted relationship, but on the other hand this increase the efforts to be spent to coordinate it and makes it more vulnerable for disturbances due to integration.

An example of how a problem can influence all the actors in a widely integrated supply chain is the case of Robert Bosch, a German component supplier, that has paid a damage for millions of dollar for the delivery to his customers, in the beginning of the 2005, of no correctly functioning high-pressure pumps for diesel fuel injection systems, although the problem was caused by a mistake of a sub-supplier. As can be seen not only the guilty party have paid for the problems caused but all the supply chain has suffered, from this example can be inferred that also the structure of the firm and the dependence inside the supply chain have a widely impact on the success of a company, and that new risks could emerge from new trends. (Thun & Hoenig, 2011)

The already mentioned approaches seems to influence the complexity, but the strong evidence can be found in the impact derived from the trend toward globalisation and from the increase in the product variety.

In today's world, for a company is no more enough to focus on local markets, both for suppliers and customers, it must explore the potential of the global one, but considering that an increase in globalisation conducts also to an increase in risks as news problems, like cultural, transportations and exchange rate issues, have to be faced. (Thun & Hoenig, 2011)

With the expansion in an international context and with the creation of a global network more efficient and elaborated systems are needed to manage the variety of elements and some of them never faced before.

The technological and information processing dimensions have to be considered no more within a country, and so with a little variance, but in an international business context with the relative implications maintaining if not improving the quantity, the timeliness and the quality of information.

The more basic problem is the physical distance that grows when the market expands their own boundaries, the longer order lead time and the higher transportation's distance can create new problems in term of flexibility and increase the complexity. (Holweg, 2005) Not less important is the attention and the effort to be put on the management across different cultures: vastly degrees of economic development, the need of using different languages and as a consequence more difficulties in the comprehension, the study and the management of different technical standards and regulatory requirements for each nation. All these have to be added to a more and more interconnected supply chain in a way that every difficulty or problem is easily amplified in the upstream and downstream operations. (Vachon & Klassen, 2002)

Higher the extend in which is possible to found new customers larger is the difference between customers and so their requirements and their demand, so companies are pushed to offer a widely range of products and variants which conducts again to more vulnerability and complexity.

Harland, Brenchley and Walker identify various other dimensions of product complexity impacting on supply networks like "scale, technological novelty, quantity of sub-systems components, degree of customisation of components in the final product/service, quantity of alternative design and delivery paths, number of feedback loops in the production and delivery system, variety of distinct knowledge bases, skills and competencies incorporated in the product/service package, intensity and extent of end user involvement, uncertainty and change of end user requirements, extent of supplier involvement in the innovation and transformation process, regulatory involvement, number of actors in the network, web of financial arrangements supporting the product/service, and extent of political and stakeholder intervention" (Harland, Brenchley, & Walker, 2003)

The index of product variety, the value of the purchased materials used, the relative number of parts and components produced, the parts produced by others are all elements amplifying the complicatedness of the supply network as more coordination efforts are needed to coordinate all the different parts, in term of purchasing, schedule and follow up. (Holweg, 2005)

A key of lecture to see all these aspects derived from network choose is the sentence of Peck: "as more complex a network is, the more interfaces do exist and the higher the vulnerability will be." (Peck, 2005)

1.9. Conclusions

In the literature review articles that fully answer to the purposes of our analysis have not been found. Indeed, researches with the only scope to identify the factors influencing the suppliers' delivery delays are missing. However, the interested issue is mentioned in numerous articles as an element upstream or downstream to other themes, as can be for example the risk management or the complexity. These aspects cannot be regarded as negligible for our analysis, in fact they, as well as the politics of management linked to, are strictly correlated to the object of the analysis, the delivery performance, and they also exercise an influence on our metric of performance even if not always with a direct and quantifiable effect.

The supplier relationship theme is a key point and a lot of sources review this topic. It influences the greatest part of the aspects tied up to the productive processes of the whole supply chain. The identification of the factors causing delays just like the definition and the evaluation of the parameters of supplier performance can be considered as a step in the creation of efficient and stable relationships.

As seen before, the studies on the causes of a bad delivery performance are not so frequents nevertheless some useful information can be obtained from others related themes.

From the literature review it has been possible to identify some classes of factors as well as some specific factors that seems to influence the delivery performance. Even if the identification of these is not enough, it is interesting to determine if and in which way they influence the performance of the suppliers.

In the articles the importance to do the analyses with a holistic view, taking into account all the upstream and downstream parts, is often underlined, but at the same time the risk to not succeed in distinguishing the effects of the different factors is recognised.
Often the main issues are caused by conflicts between the supply chain goals and the reality of the complex networks, considered in every part. (Peck, 2005) Actions increasing complexity along one direction can be needed to offset the reductions in delivery performance caused by an increase in complexity on another direction. (Vachon & Klassen, 2002)
The novelty of the realised analysis will be the isolation of the only transportation phase from the supplier to the plant to permit to exclude almost totally the effects of some factors, that are sources of high variability and that can change a lot the final performances, as the demand uncertainty or the supplier politics in the production management.
The limitation to only this phase permits to obtain a clear result in the identification of the correlation between a single factor and the analysed response, the on-time delivery, without other influences.
As an extra, with the coming of the new trends of the markets like globalisation, lead time reductions, customer orientation and outsourcing the interest in advanced logistics services and so the attention given to the transportation's mechanisms are increasing more and more.
The role of logistics providers is changing: a new business is emerging with the diffusion of third-party logistics providers that manage logistics activities on behalf of the shippers. "New firms from different fields are entering the market competing with the traditional transport and warehousing firms". (Hertz & Alfredsson, 2003)
We will not explore the field linked to the uncertainty and to the need of flexibility to face it, they are complex aspects and not tightly correlated to the transportation phenomenon.
The information system won't be considered as a factor, but it will be at the basis of our analysis since without the use of an adapt system of exchange of information, like the one used to support the material track and trace project about which we will speak later, the necessary information to realize our analyses would not be available and we could not trust on the correctness of the same. In particular, without the data of the track and trace, we could not isolate the transportation process.
However, to obtain the studied results a comparison between the expected date furnished by the supplier and the arrival data coming from the plants is realised. Hence it is necessary to pay

attention to the quality of the data and to confide in a good supplier's relationship to get some valid results. To better understand this aspect, we will devote a paragraph to the description of the processes and systems used in FCA and particularly those linked to the project.
It is mainly beginning from the insight on the network that are determined the factors that will be used later for the analysis. They have been confirmed by the experience on the field and, in some cases, integrated with other aspects. They are the distance, the region of origin, the variety and the typology of the products, the frequency of delivery and the type of transport as detailed in table 1. In the following part, they will be described more in depth and adapted to the specific situation of FCA.

Table 1:Factors

FACTORS	SOURCES
DISTANCE	(Ghemawat, 2001); (Giunipero & Aly Eltantawy, 2004); (Holweg, 2005); (Dearing, 1990)
REGION	(Hornby, Goulding, & Poon, 2002); (Ghemawat, 2001); (Javalgi & Ramsey, 2001); (Limão & Venables, 2001); (Stępniak & Piotr, 2016); (Vachon & Klassen, 2002); (Galbraith , 1973); (Thun & Hoenig, 2011)
QUANTITY-FREQUENCY	(Ahmad & Schroeder, 2001); (Holweg, 2005); (Vachon & Klassen, 2002); (Jüttner, Peck, & Christopher, 2003); (Turner & Williams, 2005); (Hart & Saunders, 1997)
VARIETY	(Ahmad & Schroeder, 2001); (Peck, 2005); (Hertz & Alfredsson, 2003); (Galbraith , 1973); (Salvador, Forza, & Rungtusanatham, 2002); (Ulrich, 1995); (Vachon & Klassen, 2002); (Winston, 1985); (Medini & Boucher, 2015) ; (Harland, Brenchley, & Walker, 2003); (Holweg, 2005); (Turner & Williams, 2005)
PART-PLANT TYPE	(Gronberg & Meyer, 1982); (McGinni, 1979); (Vachon & Klassen, 2002); (Harland, Brenchley, & Walker, 2003); (Holweg, 2005); (Turner & Williams, 2005)
INCOTERM	(Ahmad & Schroeder, 2001) (Tushman & Nadler, 1978) (Hertz & Alfredsson, 2003) (Thun & Hoenig, 2011); (Jüttner, Peck, & Christopher, 2003) (Sadraoui & Mchirgui, 2014); (Holweg, 2005);

2. Something about FCA

The FCA group is a global automotive group that works worldwide through 159 manufacturing facilities and 87 research and development centres. The operations, the design, the engineer and the manufacture take place in more than 40 countries, instead the distributing and the selling of vehicles, components and production systems, made directly or through distributors and dealers, is realised in more than 140 countries.

The vehicles are thought and sold for the mass market under the Abarth, Alfa Romeo, Chrysler, Dodge, Fiat, Fiat Professional, Jeep, Lancia and Ram brands and the SRT performance vehicle designation, to face the mass market and the necessities of a global scale extension the design, the engineering, the development and the manufacturing operations are centralised, instead the operations of transport and shipment are supported with the sale of related service parts and accessories and with service contracts under the Mopar brand.

In parallel to the mass-market vehicles production and the after-sale services the group manage also the operations and the distribution of luxury vehicles under the Maserati brand and operate in the component and production system market with the Magneti Marelli, Teksid and Comau brands. (FCA, 2017 Annual Report, 2018)

A long history of development has created the company as it is known today, a global group that include 14 brands.

2.1. History and actual situation

Before talking about FCA, Fiat Chrysler Automobiles we have to start speaking about his predecessor: FIAT (Fabbrica Italiana Automobili).

The FIAT company starts his history in Turin the 11 July 1899 from the action of Giovanni Agnelli in collaboration with a group of rich people of Turin with the common passion for vehicles and engines.

The company opens his first factory in 1900 and is remembered as the author of the first Italian model of car. In the 1907, as a consequence of a crisis in the industry, it became an exclusive

property of Agnelli that, in this way. improves his role in the society becoming a key element in the management.
The First World War and later the Italian Fascism period helps the development and the growing of the company increasing the work requested, for example with the production of vehicles for the army, but also with the limitation to the expansion of competitive foreign companies in the Italian territory, but for the Second World War it was not the same indeed it has a bad effect causing destruction and damages of some FIAT factories.
In the after war, thanks to the economic boom, the company regains importance with the creation of the 500 (1955) and of the 600 (1957). In the 1966 the company pass to Gianni Agnelli that includes in the group the Ferrari, Lancia and Abarth brands and later, in the '80 years, also the Alfa Romeo brand. In parallel an expansion in all the Italian territory takes place during the '70 and '80 years with the opening of news factories.
In the '90 the company starts to expand also globally (ex. in Poland, India and Argentine) and Maserati enters in the group.
In the 2000, also linked to the death of Giovanni and Umberto Agnelli, the company has a difficult moment that drives to the partnerships with General Motors and has finally end only with the nomination of Sergio Marchionne as Chief Executive Officer that conducts the restyling of the Panda, the Grande Punto and some years later of the 500. (4)
From the beginning of the 2008 a new period starts, the need for a greater scale to maintain the competitive position pushes FIAT to expand the scope of its automotive operations.
In this period, FCA starts the negotiations concerning the Chrysler LLC ("Old Carco"), in April 2009 an agreement is signed in which the new group FCA US LLC, Chrysler group LLC, agreed to purchase the principal assets and some liabilities of the Old Carco. This was a first step, in the following years Chrysler enters in the FCA group and FIAT acquires always more ownership interests in the society until the final incorporation of the FCA Fiat Chrysler Automobiles as a public limited liability company under the laws of the Netherlands in the 1 April 2014. (5)
In parallel, in the 2011, the business concerning the non-automotive good is separated with the creation of Fiat Industrial (CNH Industrial).
The FCA business plan realised in the 2014 and covering the 2014-2018 period defines the main purpose and objectives of the new corporation: "the strengthening and differentiating of

the portfolio of brands, the volume growth, the converging on platform and an increasing attention on cost efficiencies, the enhancing of margins and the strengthening of the capital structure”. (FCA, 2017 Annual Report, 2018)
At the end of 2015 the Ferrari segment is classified as a discontinued operation with respect to the group and complete the spin-off at the beginning of the 2016, the initial plan is adapted to the new situation taking also into account the changes in customer trends, the political and economic uncertainties and conducts finally to the actual situation.
The results registered at the end of 2017 consists of 4.7 million of vehicles sold, a net revenue of 110.9 billion of euro and a net profit of 3.5 billion of euro and 4.3 billion invested in the research and development activities for 236000 employees. (6)
In the 2018 the company has again big changes, the death of his last Chief Executive Officer Sergio Marchionne, that was the one considered responsible for the lasts FCA success, and the appointment of Mike Manley as his successor makes the company future a little uncertainty.(7)
In October, under the new Chief Executive Officer Fca, has signed an agreement for the selling of Magneti Marelli S.p.A. ("Magneti Marelli") to the CK Holdings Co. Ltd. (8)

2.2. The organization

To understand the mechanisms behind the FCA supply chain is necessary to start understanding the geographical organization. The FCA network is divided in four Regions (NAFTA, LATAM, APAC, EMEA) each one is responsible for the management at the operational level, manages the plants in the area firstly but can also engages exchanges and relationships with the other manufacturing facilities and each region result is accounted in the company results. In the table 2 is presented a detail of the main brands managed in each region. (FCA, 2017 Annual Report, 2018)

Figure 4:Fca Regions (source: FCA documents)

Table 2:Brands for region

NAFTA	United States, Canada, Mexico and Caribbean islands	Abarth	Alfa Romeo	Chrysler	Dodge	Fiat	Jeep	Ram	
LATAM	South and Central America (focus on Brasil and Argentina)	Dodge	Fiat	Jeep	Ram				
APAC	Asia Pacific region (mostly in China, Japan, Australia, South Korea and India)	Abarth	Alfa Romeo	Chrysler	Dodge	Fiat Professional	Fiat	Jeep	
EMEA	Europe, Middle East and Africa	Abarth	Alfa Romeo	Dodge	Fiat	Fiat Professional	Jeep	Lancia	Ram

Beside the four geographical areas is necessary also to consider as other two reportable segment the Maserati brand that account for the luxury vehicles and the section concerning components under the brand Magneti Marelli, Teksid and Comau. In the table 3 a detail of the contribution of each brand to the total components production is presented.

Table 3:Components section

COMPONENTS SECTION								
Magneti Marelli	Lighting Components	Body and Engine Control Units	Suspensions	Shock Absorbers	Electronic and Exahust Systems	Powertrain Components	Plastic Molding Components
Teksid	Cast Iron Components for Engines	Gearboxes	Transmissions Systems	Suspension Systems	Aluminum Cylinder Heads	Engine Blocks	
Comau	Industrial Automation Systems						

Finally, there is also the group "Other Activities" that include the companies providing services like accounting, payroll, tax, insurance, purchasing, information technology, facility management and security for FCA. (FCA, 2017 Annual Report, 2018)

Once well-defined the global organisation of the FCA group we go to analyse the internal division of the supply chain management (figure 5), with the description of the involved departments and the corresponding managers.

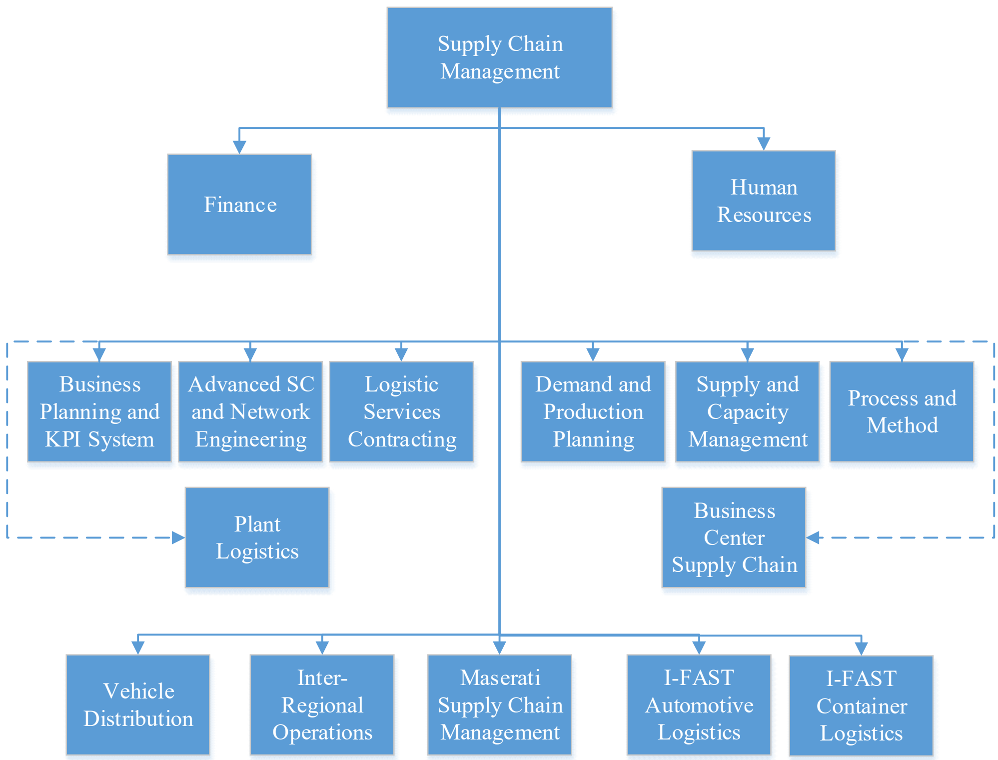


Figure 5:Fca Supply Chain Organization

Firstly, the supply chain management office has as a support his own finance and human resources managers that relate to the central level but permit a certain level of autonomy at the supply chain management.

The plant logistics manager (responsible for the management of the material flow into the plant) as well as the Business Center Supply Chain level (concerning the final distribution and the commercial activities in the region) are considered under the supply chain management at the functional level but directly report respectively to the plant and to the regional manager.

The main departments concerning the activities of the supply chain management are 6:

The Business Planning & KPI System is where the indicators used to evaluate the operational performance are managed. It has the role to define and control the chosen targets and to eventually conduct corrective actions.

The Advanced Supply Chain & Network Engineering is responsible for the supply chain network and has the purpose to optimise the nodes and flows concerning the inbound material transportation.

The Logistic Services Contracting deals with the negotiations of the terms imposed by the Logistic Service Providers and carriers and monitors the logistics in term of standards and requirements.

The Demand & Production Planning gather the real and provisional orders obtained from the information given by the markets, responsible for the forecast, to be able to plan the plant volume level requested to respond to the market demand.

The Supply & Capacity Management, in coordination with the purchasing department, helps in the definition of the volumes identifying and checking the constraints and the restrictions concerning the production and supply volumes with respect to the demand requested. The main types of constraints considered in testing the actual capacity are concerning the make (plant production limit), the buy (capacity constraints of the supplier) and the timing.

The Process & Methods is a sort of inter-department. It coordinates all the operations regarding the creation and the defining of new processes standards and methodologies, so works in collaboration with the other departments and manages transversal projects. For example, this department is the one responsible for the coordination of the Material Track and Trace project (the project followed during the already cited internship).

The other departments described are not directly linked to supply chain management main activities but are not less important.
The Vehicle Distribution is responsible for the management of the transport across the markets, instead the Inter-Regional Operations is responsible for the material flows among regions.
The Maserati brand reports to the central SCM but manages the supply chain management operations by himself so must be considered separately.
The I-FAST is a company owned by FCA that with others private company manages the transports. Is the FCA main supplier of the distribution services and also the responsible for the container logistics linked to the system of lease of standardised containers to the interested suppliers. (APICS, 2017)

2.3. Supplier Management

The role of the supplier is essential in the supply chain process, as the efficient delivery of raw materials is a central point to obtain an efficient supply chain. A good, capable and responsive supplier can help the industry in the reaching of a good level of quality and performance and this is even more true considering the demand of the market for a growing innovative and flexible supply chain.
As stated in the Group Code of Conduct, FCA "considers collaboration with the supply chain an integral part of our success and, therefore, strives to operate as an integrated team with suppliers". (FCA, Supplier Management Principles, 2018)
Following the trend of the industry of which FCA is part, the supplier management of the company is more oriented to maintain a collaborative approach with his suppliers, creating a system as much as possible integrated and transparent able to quickly resolve problems also outside the boundaries of the company to obtain a conflict-free supply chain.
The purpose is to use the collaboration to increase the value offered to the final customer and to easily exchange competencies and information.
The trend toward a collaborative approach it isn't the only point, to maintain a competitive position FCA follows some specific rules in the supplier contractual relationships.

Firstly, the partner must be ready and disposable to face the challenges together with the FCA company, they are chosen considering the quality, the competitiveness and the innovation of their products but have also to follow specific social, ethical and environmental principles.
In the defining of a partnership with a supplier FCA searches for a strong relationship and for this has listed some priorities principles (FCA, Supplier Management Principles, 2018):

1. Best in Class Quality: the research for zero defects and services over the customer expectation.
2. Innovation: asks to optimize the cost for innovation with respect to the result using components standardisation, architectural convergence and volume aggregation.
3. Capacity Management: incentives for initiatives to ensure on-time deliveries with the ability to align the capacity with the demand.
4. Total Life Cycle Cost Strategies: the cost considered is not only the product price but also all the related expenses.
5. Continuous Engagement: FCA searches for a collaboration that drives to an align in strategies and performances and prefers the creation of long period relationships.

Starting from these principles, FCA has a monitoring system to evaluate the supplier performance and the effectiveness of its own management.
For the supplier's evaluation it uses tools as external audits, periodic benchmarking activities and feedbacks and not less important it focusses his efforts on the correct establishing and the constant monitoring of the better KPIs (Key Process Indicators) for each situation.
Defining the correct way to measure a supplier performance is not an easy process, the performance goals must be possible to be reached in the defined timing and realistic and they require the supplier's participation to obtain the best choice. (APICS, 2017)
Take in mind the fact that each situation and project can develop its own metrics based on the exigences, we will see there some commonly used measurements:

- Products and services quality. The ability to offers a quality in line with the agreed requirements. The measure is usually based on the number of lots or parts rejected with respects to the received ones.
- On-time delivery. The ability to follow a specific delivery schedule. For example, in our case we will consider the supplier promise date versus the actual receipt date as a metric of the on-time delivery.

- Quantity received. This measurement looks at evaluate the match of the quantity ordered with the quantity received and is usually done considering a range of tolerance.
- Flexibility. This metric measure how easily suppliers can accommodate changes in the purchase schedule, respond to an unexpected order or handle special requests.
- Price. Measure how much competitive is a product price with respect to the offer present in the market. Is usually measured creating a price index.
- Conformance to contract. Metrics in this area focus on how well the supplier is meeting the terms of the purchasing contract. (APICS, 2017)

The process of following the supplier is not only regarding the monitoring but also to help him in align himself to the FCA requirements and systems offering an initial training with the purpose to explain the FCA logistics operations and equipping the suppliers with the specific tools needed during the supplier's FCA processes.

2.4. Material Track and Trace

We will now speak about the project followed during the internship, "The material Track and Trace".

This project is important because is a useful point in the understanding of how the FCA group manages the supplier relationships and extra-boundaries projects and also because it permits to obtain the used data and to isolate the transportation process that is the starting point of our analysis, so without this type of tracing it would be difficult to obtain the necessary information.

In the literature the "Tracking and Tracing" is seen as a mechanism that increase the transparency between customer and supplier giving more visibility to inbound and outbound flows and it helps the exchange of information so that can be considered as an action of supply chain risk management. (Thun & Hoenig, 2011)

The Track and Trace project consists in asking to the suppliers the sharing of the necessary information to permit to localise the product and determine his status during the transport process. In this way the customer is able to know exactly when each product is shipped and can obtain some reasonable estimations of when the product will be available at the plant, in other words the process implemented is similar to the package tracking provided by shippers.

In the FCA Material Track and Trace is asked to each supplier to send some specific information that are directly gathered in the company databases and is made visible in the related tools.
One of the key information required to the supplier is the estimated time of arrival (ETA), to make possible an almost real time exchange of information and to make the material covering prevision as much precise as possible this date can be updated also during the way, but in every case a trace of the first one furnished is maintained to make the correct evaluations.
The goal of the project is to provide an expected date of arrival for all the in-transit part numbers for all the inbound flows to FCA EMEA plants and warehouses to give material visibility from suppliers to plants and to make possible the management of the shipment status and of the ETA.
In the project the domestic flows have been considered firstly but also the overseas flows are evaluated.
The requested process is different in term of management of transport and information in case of I-FAST or of direct supplier transport, so another requested information is the transport qualification (DDP or FCA incoterm) to differentiate the two processes.
In the I-FAST case the supplier must send the AVIEXP, the electronic shipping notification at the time of departure and at the same time must print a QR code to be put in the delivery note, later the I-FAST carrier scans the QR code and transmits the transport status and the relative ETA to FCA system, at the plant level the information given from the supplier through the AVIEXP and the one given from the I-FAST carrier are matched at part number level.
In the direct supplier transportation case the supplier sends the AVIEXP with the ETA at the time of departure, later can send an update ETA with the same mean. In this case there isn't a direct exchange of information between the supplier's carrier and FCA and the plant receives only the information sends by the supplier.
To evaluate the performances of the suppliers concerning this project 4 different KPI have been considered, evaluating the presence of the needed data but also their quality and reliability, and for each of them a percentual target is defined as objective. They are:

- ETA Received: This evaluate the presence of ETA on the Aviexp message.
- ETA Reliability: The estimated date of arrival at the plant must be reliable. This value must correspond with the date of the effective receipt from the plant that is evaluated on the basis of the take in charge date given from the plant. This measure is the one concerning our further analysis.

- AVIEXP Sending Timeliness: The AVIEXP message must be sent on the same day of the delivery departure.
- Transport qualification: Evaluate the correct insertion of the qualification of transport (DDP or FCA incoterm). This qualification is essential to understand the responsibilities and to manage in the better way the information received.

To evaluate the supplier performances in the project, the trends of the explained indicators are summarised in a project dashboard and are presented weekly in the progress meeting where are also defined the actions to be taken to obtain always better results.

The Track and Trace for the local supplier, the EMEA one, has been the first to be implemented, now the process has been extended also to the overseas suppliers. In this case also if the process implemented is similar more complexity have to be considered. We will not talk in detail about this as the data used for our analysis are concerning only the first case.

2.4.1. Project Limitations

This project gives useful information to the plant for the planning of the production but also gives a useful instrument at the management to evaluate the supplier performances. The complexity of the actions required to implement and to use this instrument in the better way mustn't be underestimated.

The fact that the information are not exactly real time, but are given by the suppliers leaves the task to verify the quality, the consistency and the completeness of the received data, for example some suppliers use unreliable dates that give origin to early delivery for the system In the monitoring the advances are considered better than the delays and in some cases, in the measure of the targets, are evaluated at the same level of the reliable ones.

Another question is the one concerning the information system, this process requires systems able to receipt a big number of information and have to be integrated between customers and suppliers. The "Material Track and Trace" (MTT) project places new requirements on freight documents, requesting for a standardized shipping notification (AVIEXP), the creation of the QR code, the mechanisms needed to read the code, the mechanism of communication needed to communicate with the control centre. (9)

All these new mechanisms requested to obtain the success of the project need efforts also for the training of the suppliers and of the employes at the plant.

3. Anova analysis

3.1. Data collection

The data have been gathered during the internship activity in FCA in the Supply Chain-Process and Methods department.
The data are registered in the FCA database along a time period of 6 weeks from the week 13 to the week 18 for the transports in the EMEA region (Europe, Middle East, Africa), coming from 22 different countries and direct to 9 Italian plants 4 of the mechanics type and 5 of the body/assembly type, considering the transports managed directly by FCA (FCA incoterm), but also the transports managed by the suppliers (DDP incoterm).
The final database includes 56128 deliveries, 115296 observations if we consider the distinct types of products for each delivery and considers the deliveries from 663 suppliers for the shipment of 15310 different product codes.

Table 4:Data Resume

CATEGORY	UNITS
DELIVERY CODES	56128
GROUP PRODUCT DELIVERIES	115296
PRODUCT CODES	15310
SUPPLIERS	663
PLANTS	9
SUPPLIERS COUNTRY	22

For each delivery we have different information: the type of incoterm, the supplier code, the delivery code, the city of departure, the defined transit time, the destination plant, the ETA date (estimated time of arrival), that is calculated and transmitted by the supplier in the DDP case or by the I-FAST society, in the FCA case, the TKC date (take in charge) that is communicated by the plant at the time in which the goods enters the gate, the product codes for each delivery and the description of the product. From this information it was possible to derive also other useful information like the nations and the regions of the suppliers or the type of production for

each plant and in particular the response on which we realise the analysis: the days of delays, obtained by doing the difference between the date of take in charge of the plant and the estimated time of arrival, in this way we consider the delays on a day basis considering a value bigger than one as delay and a values lower than -1 as early delivery.
To obtain a correct database we have excluded the deliveries with an ETA in a year different from the 2018 in fact years like 2099, 2014, 1803, 2001, 2048 are considered as clear examples of error in the exchange of information or of bad management of the track and trace process and so are elements not significant for the analysis and that, if included, can drives to mistakes.
The analysis on the data will be done with the help of MINITAB 2018 statistical software.

3.2. Descriptive Statistics Analysis

The analysis on the data can be made on three levels based on what we are searching for changing the element that we consider as single observation. We can use as single observation the rows concerning different delivery codes or the association product-delivery (in this case the delivery codes that include more than one different product code will be duplicated) or the single supplier code (in this case the value considered to evaluate the delays is no more the single value, but the mean of the different days of delays for each delivery of the supplier).

Descriptive Statistics: Days of Delay - Delivery Code

	N	**N***	**CumN**	**CumPct**	**Mean**	**SE Mean**	**StDev**
VARIABLE	56128	0	56128	100	-0,0503	0,0109	2,579
Days of Delay	**Minimum**	**Q1**	**Median**	**Q3**	**Maximum**	**Range**	
	-183,000	0,0000	0,0000	0,0000	89,000	272,000	

The number of observations for the delivery code are 56128, the mean is -0,0503 with a range of 272, a minimum of -183 and a maximum of 89. From these values we can generally observe that the early deliveries are more marked than the delays and they influence more the means so that the mean value also if close to the value 0 is a little more in direction of the advances. The first and third quartile values are 0 as well as the median so, although the value range is wide, we can say that at least the 50% of the observations are 0, instead the 68% of the values can be considered between the interval [-0,0503-2,579;-0,0503+2,579], so that the greatest part of the deliveries stays in a range of days of delay (advances) between 0 and 3 (-3).

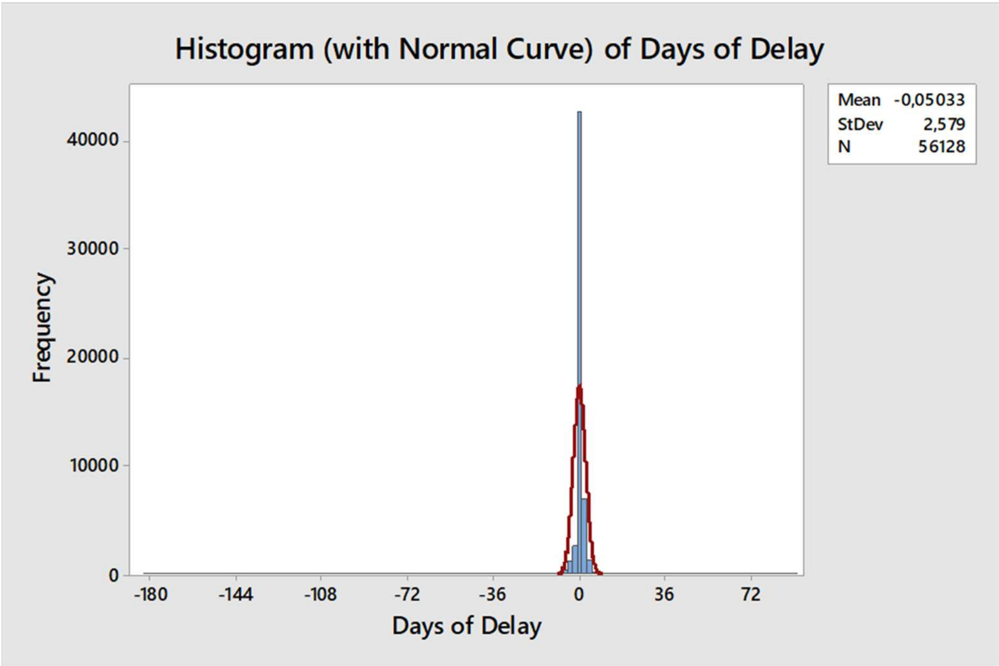


Figure 6:Histogram Days of Delay- Delivery Code

From the histogram graph (figure 6) is possible to see the distribution of the observations and we can note again that the most frequent value obtained is 0.

Concerning the shape of the distribution we can say that as the mean is lower than the medium the distribution has a negative asymmetry, with a longer tail in the negative direction.

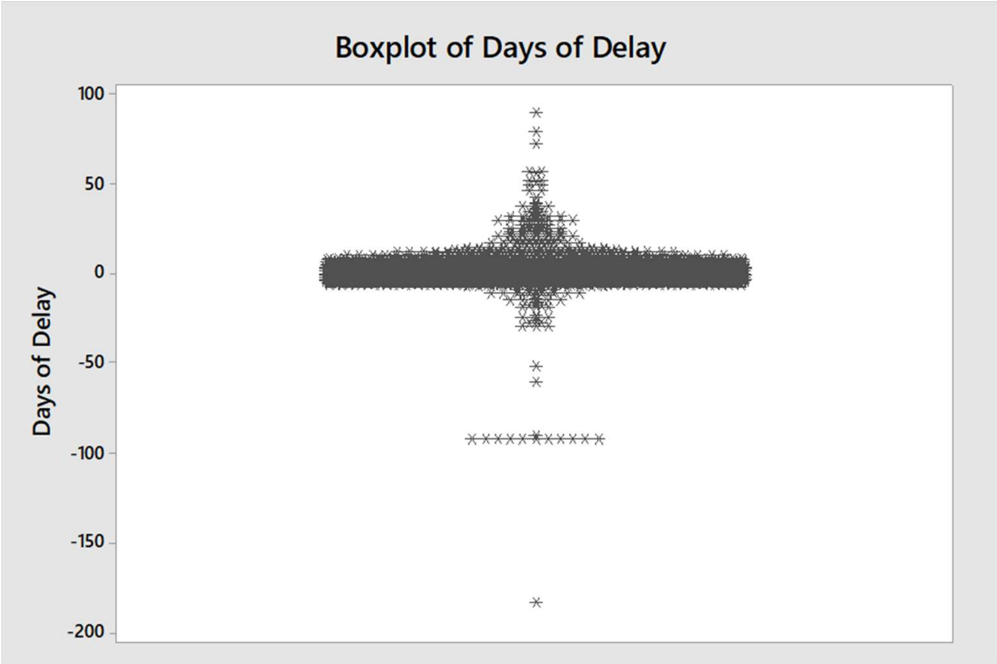


Figure 7:Boxplot Days of Delay- Delivery Code

The boxplot (figure 7) reflects the observations already done analysing the quartile values and the range, the majority of the values are around the 0 value. If we construct the limits of the box using the first and third quartile values the box will contains the 50% of the total values. The long tails are given by the wide range of value and a particular increase in the number of observations around the -100 value can be observed.

Descriptive Statistics: Days of Delay-Product Code

	N	N*	CumN	CumPct	Mean	SE Mean	StDev
VARIABLE	115296	0	115296	100	-0,0446	0,00668	2,269
Days of Delay	**Minimum**	**Q1**	**Median**	**Q3**	**Maximum**	**Range**	
	-183,000	0,00000	0,0000	0,00000	89,000	272,000	

Considering the association delivery-product, as expected, the number of observations is bigger and is 115296, so although the standard deviation is 2,269 and is changing only of 0,31 respect to the previous case the higher number of observations helps in the obtaining of a lower SE mean value.

The mean is -0,0446 and also in this case the early deliveries seems to have more impact than the delays. In term of range, minimum, maximum and values inside the first and third quartile the same observations done for the delivery code analysis can be used and the value 0 is the most frequent with respect to the others. The 68% of the values is in the deviation standard interval so between -0,0446 -2,269 and -0,0446 + 2,269.

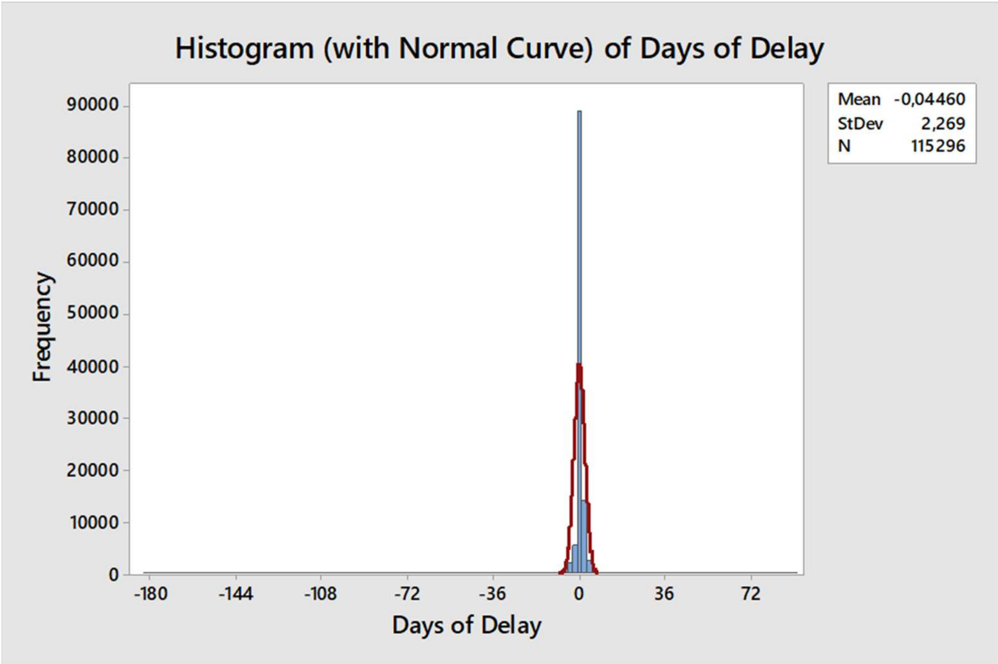


Figure 8:Histogram Days of Delay- Product Code

As before from the distribution of the data in the histogram graph (figure 8) we can confirm the affirmations already done. The most frequent value is 0 and as the mean is again lower than the median, we can say that the distribution has a negative asymmetry, with a longer tail in the negative direction.

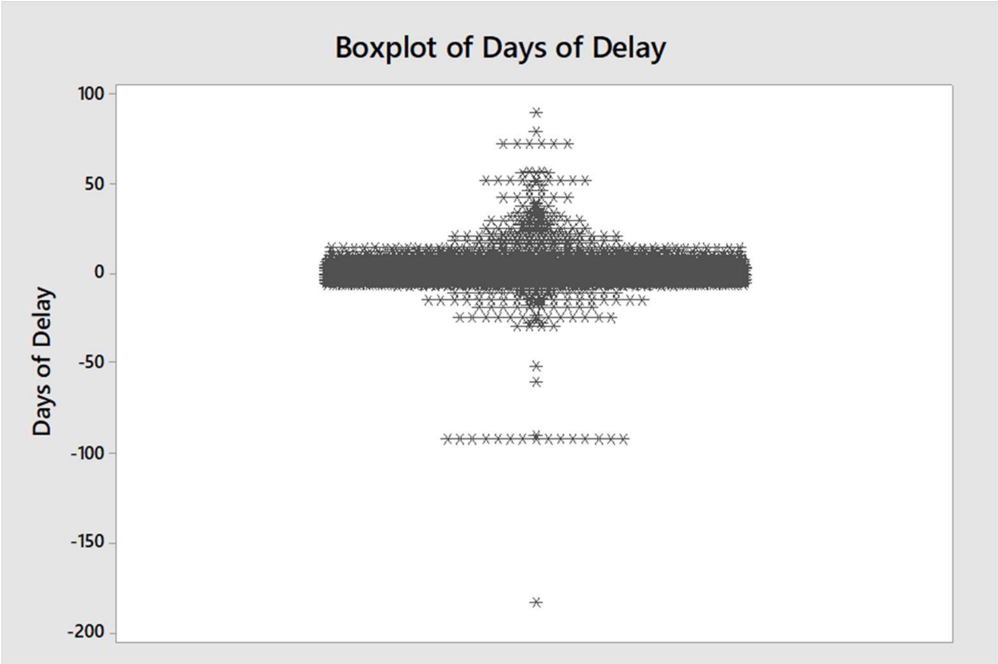


Figure 9:Boxplot Days of Delay- Product Code

In this case in the boxplot graph (figure 9) the observations are mainly distributed around the 0 value, we have a not so slight tail between 50 and -50 and over these values we have few observations that can be for this considered as outliers.

Descriptive Statistics: Average delay-Suppliers Code

	N	N*	CumN	CumPct	Mean	SE Mean	StDev
VARIABLE	663	0	663	100	0,203	0,144	3,701
Average delay	**Minimum**	**Q1**	**Median**	**Q3**	**Maximum**	**Range**	
	-52,000	-0,294	0,002	0,339	48,000	100,000	

This time the numerousness is reduced to 663 since the deliveries are grouped on the supplier basis. The mean is equal to 0,203 and so is no more on negative values, the standard deviation is increased to 3,701 and also the SE Mean increase for the growing of the standard deviation but also for the decrease in the number of observations.

The range value is reduced to 100, with -52 as minimum value and 48 as maximum. In this case the range is changed because, as already said, the considered response is no more the calculated value (TKC-ETA) but an average value obtained for each supplier.
The median is 0,002 and the first and third quartile values are now -0,294 and 0,339, so we have no more the 50% of the values on the 0 but from the standard deviation we can say that the 68% of the values are between the interval [0,203-3,701; 0,203+3,701] so, from this point of view, the population seems to be characterised by more delays.

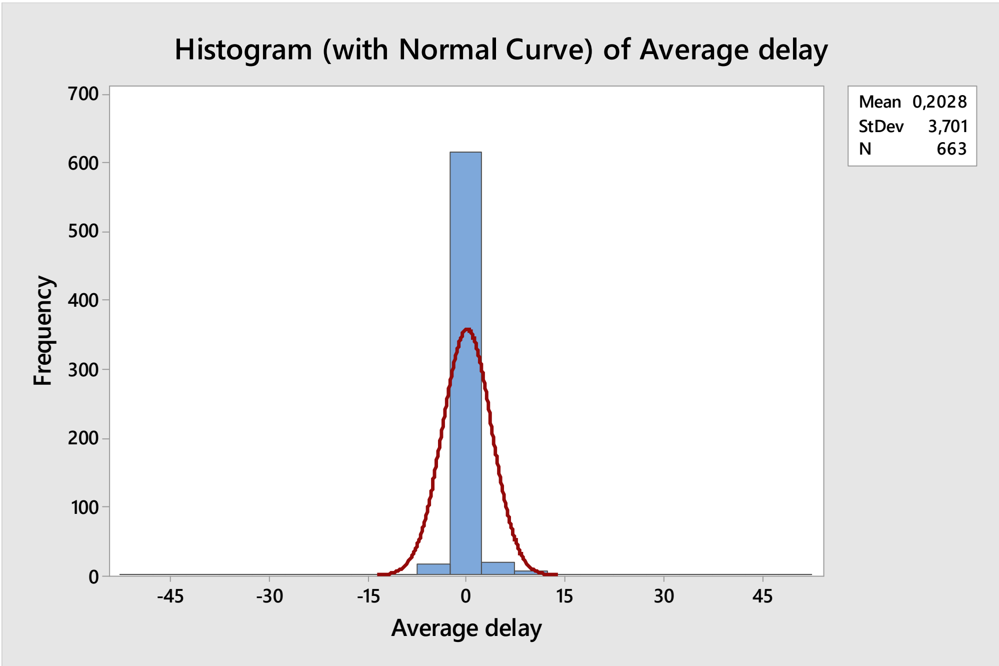


Figure 10:Histogram Days of Delay- Supplier Code

With respect to the previous case in the histogram for the average delays values (figure 10) is present a positive asymmetry as the mean is higher than the median. The tails are not so extended as the range is reduced and also the number of observations on the 0 is reduced.

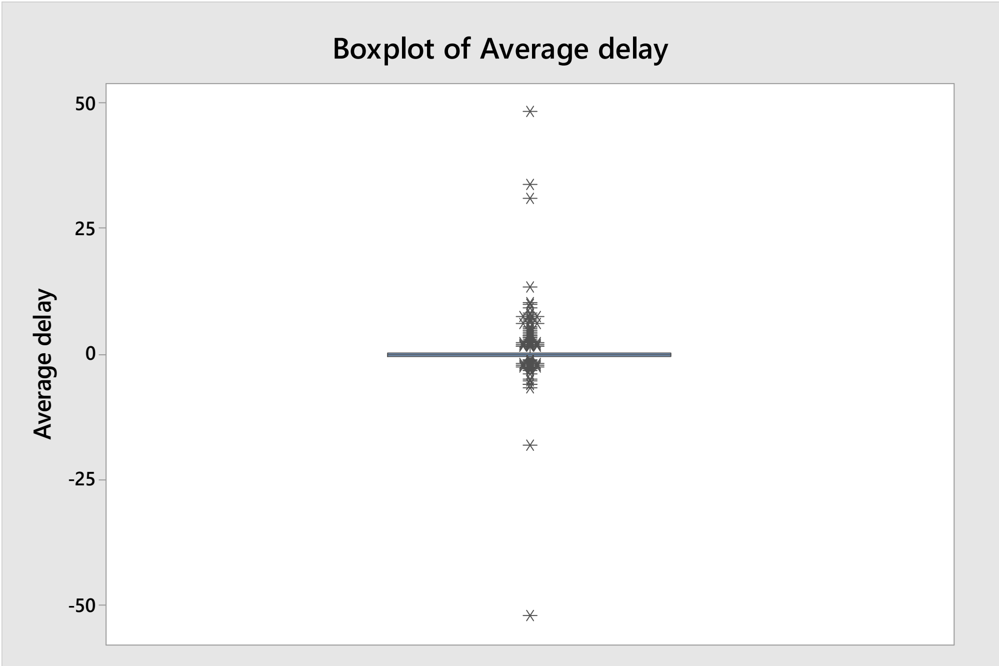


Figure 11:Boxplot Days of Delay- Supplier Code

From the boxplot (figure 11) can be seen that a large part of the observations remains on the 0, but the number of values close to 0 is reduced and the tails are slighter.

3.3. Normality

We use the probability plot to verify graphically if the data set follows a normal distribution with a confidence interval of 95%. The tested null hypothesis is therefore that the data follows a normal distribution.

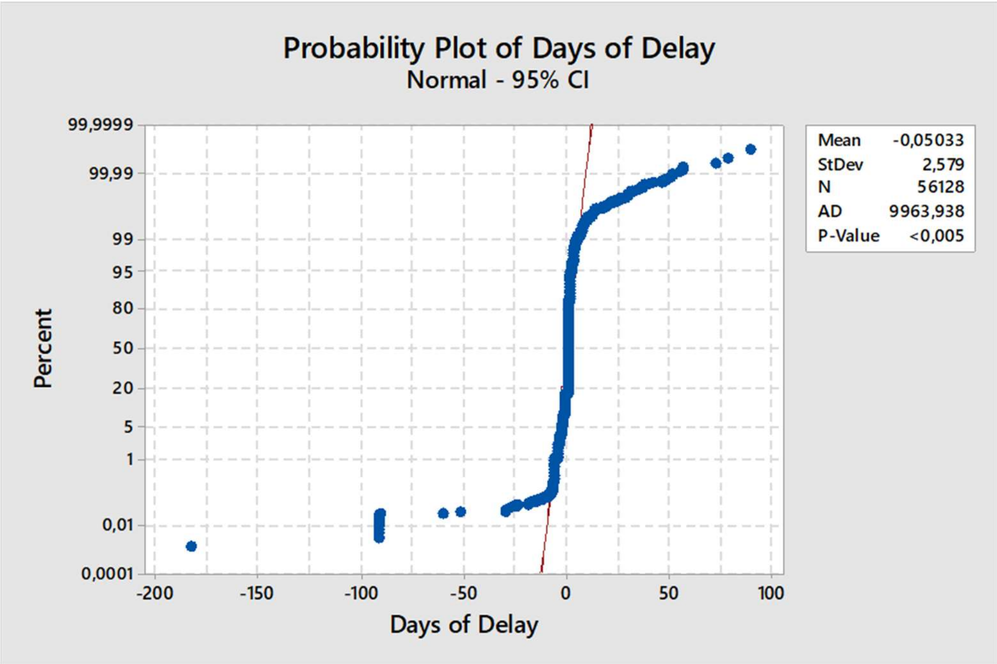


Figure 12:Probability Plot Days of Delays-Delivery Code

For the delivery code (figure 12) the p-value is lower than 0,005 so the null hypothesis must be rejected. The p-value is calculated starting from the Anderson-Darling goodness-of-fit statistic (AD-Value) that "is a value that measures the area between the fitted line and the empirical distribution function" (11) , is a squared distance that takes more in consideration the tails of the distribution.

In this case the AD value is equal to 9963,938 that is a large value and from this study we have to refuse the hypothesis of normality but, considering the high numerousness of the data, we can use the central limit theorem. This theorem states that "given a sufficiently large sample size from a population with a finite level of variance, the mean of all samples from the same population will be approximately equal to the mean of the population, specifically, as the sample sizes get larger, the distribution of means will approach normality." (12)

So, considering our data size sufficiently large we can approximate the distribution of our data to a normal.

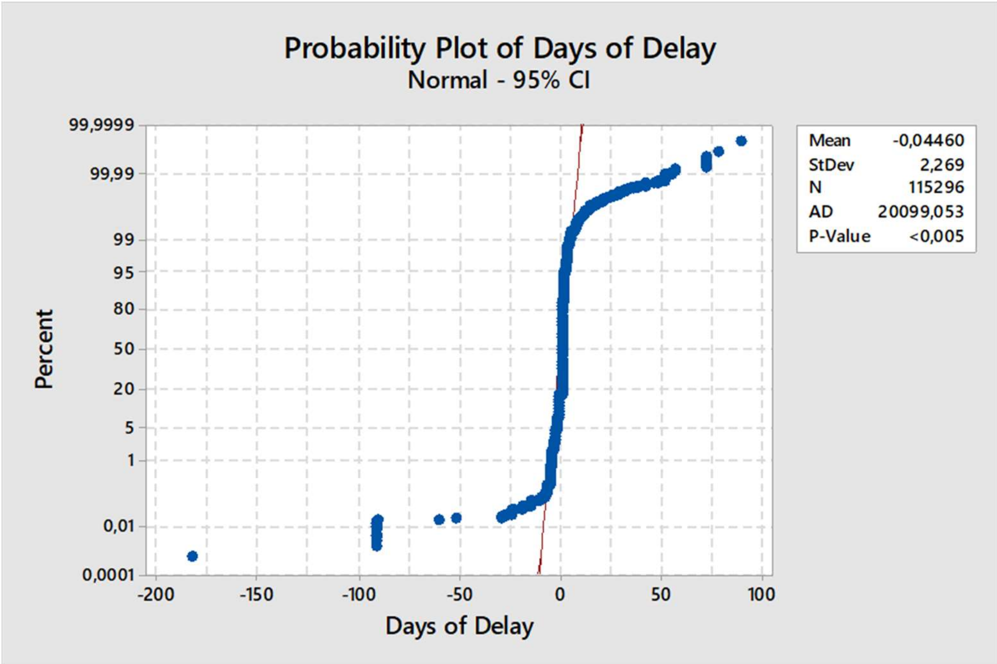


Figure 13:Probability Plot Days of Delays-Product Code

Also in this case (figure 13), the p-value is lower than 0,005 and the AD value is larger than before being equal to 20099,053, but also the numerousness of the observations is larger than before so, for the central limit theorem we will approximate the distribution of the data set to a normal.

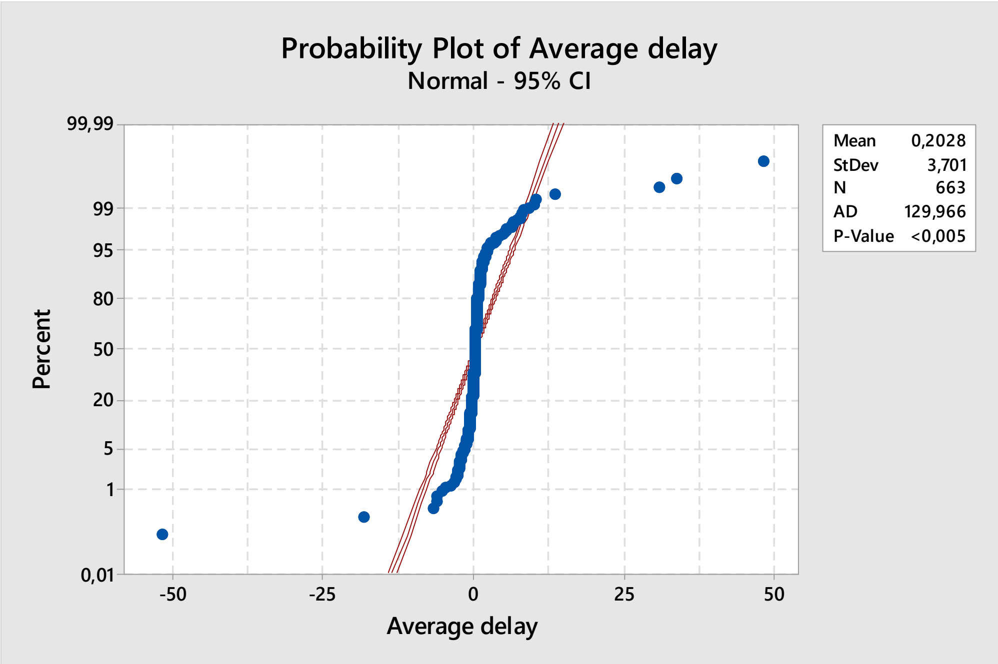


Figure 14:Probability Plot Days of Delays-Supplier Code

For the last grouping (figure 14) the situation is a little different. The distribution seems to follow a sine wave function and the p-value is again lower than 0,005 so we have to refuse the null hypothesis. The AD value is lower with respect to the other two cases and is equal to 129,966 but is necessary to consider the fact that also the numerousness is reduced to only 663 values (with respect to the previous 56128 and 115296 observations) and the size seems not sufficient to makes adapt the central limit theorem. For this, we have decided to not use the analysis realised using the supplier base as not considered significant.

3.4. Factors

In this paragraph the factors chosen for our analysis are presented supported by reference to the existent literature and by the correspondence in the FCA documents and practices.
The elements for each factor are clustered and go to define the different levels for the analysis, later a One-Way ANOVA for each of them is realised testing the null hypothesis that all means are equal versus the alternative hypothesis that not all the means are equal with a significance level of 0,05 (α). The final purpose is to identify the correlations between these factors and the delays.

3.4.1. Supplier

Distance-Transit time

With the tendencies toward globalisation and the extension of the business all over the world, the distance length between supplier and customer gains importance as well as the differences of distance between suppliers. The concept of geographic distance is, in some ways, the first and most intuitive factor influencing the deliveries and many confirmations can be found in the literature.
In the FCA Supply Chain Academy Foundation Modules the question "how far the load is to be transported?" is one of the critical factors around with the transport management have to focus, so the distance is an element affecting the transportation decisions. (APICS, 2017)
Distance adds uncertainty, longer is the time of transport longer will be the time in which problems can occurs (Giunipero & Aly Eltantawy, 2004). Having this added uncertainty to take into account the risk management becomes more important, but also more difficult. The distance of transport increases complexity and risks for the delivery, some examples of unforeseeable causes of shipment delays are "traffic congestion, climate changes or conditions that impact in-transit flow and mechanical breakdown of delivery vehicles". (APICS, 2017)

A longer length to be covered impact also on costs on two different levels, the variable cost increase with the distance, but on the other hand fixed cost can be divided over more kilometres so that the total cost curve increases at a decreasing rate. In this scenario, the concept of economies of distance (figure 15) is introduced and requires attention in the transport management decisions. (APICS, 2017)

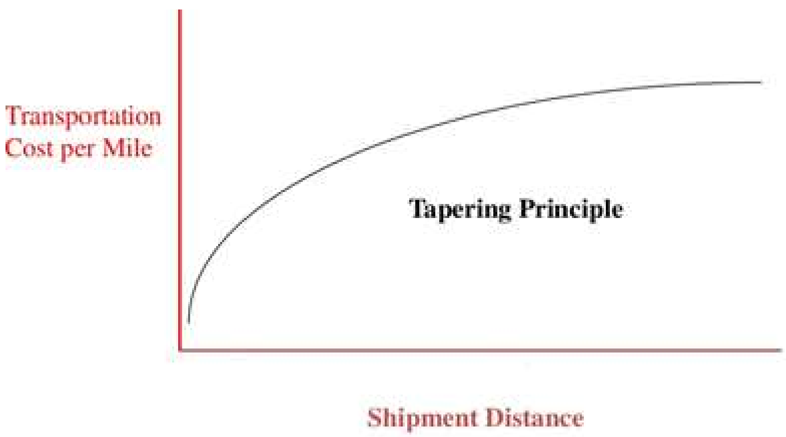


Figure 15:Economies of Distance (source: Shravanthi, 2016)

Distance adds variable costs in term of physical transport (labour, fuel, maintenance), but also in term of information transmission, since the different actors are mostly dispersed all around the world a high degree of communication and coordination is needed and the exchange systems must increase their complexity with different levels of information infrastructures. (Ghemawat, 2001)

The physical distance is recognised as having impact on all types of product both tangible and intangibles as well as on services. (Ghemawat, 2001)

In FCA the concept of distance is considered on the basis of the calculated transit time from the city of depart to the designed plant, the routes of transport are categorised in transit time classes on a day repartition, it means that one class is placed each 24 hours. We have 7 classes (0-24-48-72-96-120 and 144) but since the numbers of elements in each class, with the exception of the 72 hours class, decrease with the increase of the distance (as shown in table 6), to make a correct comparison, we have considered the elements over 72 hours as a unique class.

Table 5:Cluster Transit Time

TRANSIT TIME (H)	Number of Deliveries	Number of Group Product Deliveries
0	**15094**	**36048**
24	**9523**	**20598**
48	**19860**	**39089**
over 72	**11651**	**19561**
72	1301	2515
96	6120	11318
120	4055	5544
144	175	184
Total	**56128**	**115296**

Doing a unique group for all the route with a transit time longer than 72 hours we realise a one-way ANOVA with 4 levels of the factor (0, 24, 48 and over 72) and the results obtained are showed in the following output.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Cluster TT	3	2733	910,968	137,95	0,000
Error	56124	370608	6,603		
Total	56127	373341			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,56970	0,73%	0,73%	0,72%

The P-VALUE is equal to 0, so the null hypothesis must be rejected: not all the means are equal. More considerations can be done starting from the analysis of the confidence intervals and of the interval plot (figure 16).

Means

Cluster TT	N	Mean	StDev	95% CI
0	15094	0,1322	1,5444	(0,0912; 0,1732)
24	9523	0,2334	1,8962	(0,1818; 0,2850)
48	19860	-0,1253	3,2136	(-0,1610; -0,0895)
over 72	11651	-0,3910	2,8599	(-0,4376; -0,3443)

Pooled StDev = 2,56970

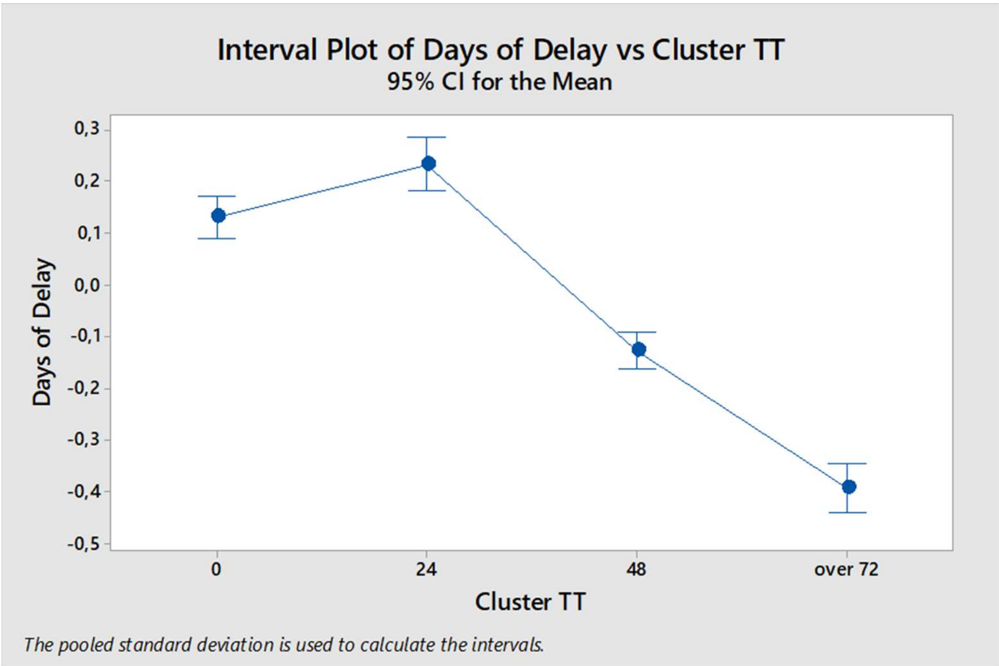


Figure 16: Interval Plot Transit Time (1)

The first level, that includes the shorter routes, presents the values closer to the 0 value, corresponding to the on-time delivery. Considering the other levels, initially increasing the distance the delays seems to increase but continuing to increase instead of having more delays we obtain early deliveries.

To better analyse this phenomenon of increase in early deliveries we do now the one-way ANOVA considering 7 levels of transit time (0;24;48;72; 96; 120; 144). In this case we have to pay more attention as the reduced number of observations for the last levels and so the different numerousness can in some way influence the results.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Transit time	6	3018	502,939	76,22	0,000
Error	56121	370323	6,599		
Total	56127	373341			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,56878	0,81%	0,80%	0,76%

The P-VALUE remain 0 so again the null hypothesis must be rejected, what can be seen (figure 17), excluding the first and last classes, is again a trend of the means toward earlier deliveries.

Means

Transit time	N	Mean	StDev	95% CI
0	15094	0,1322	1,5444	(0,0912; 0,1732)
24	9523	0,2334	1,8962	(0,1818; 0,2850)
48	19860	-0,1253	3,2136	(-0,1610; -0,0896)
72	1301	-0,1284	2,1468	(-0,2680; 0,0112)
96	6120	-0,3266	2,6411	(-0,3910; -0,2623)
120	4055	-0,5855	3,0713	(-0,6645; -0,5064)
144	175	-0,086	6,815	(-0,466; 0,295)

Pooled StDev = 2,56878

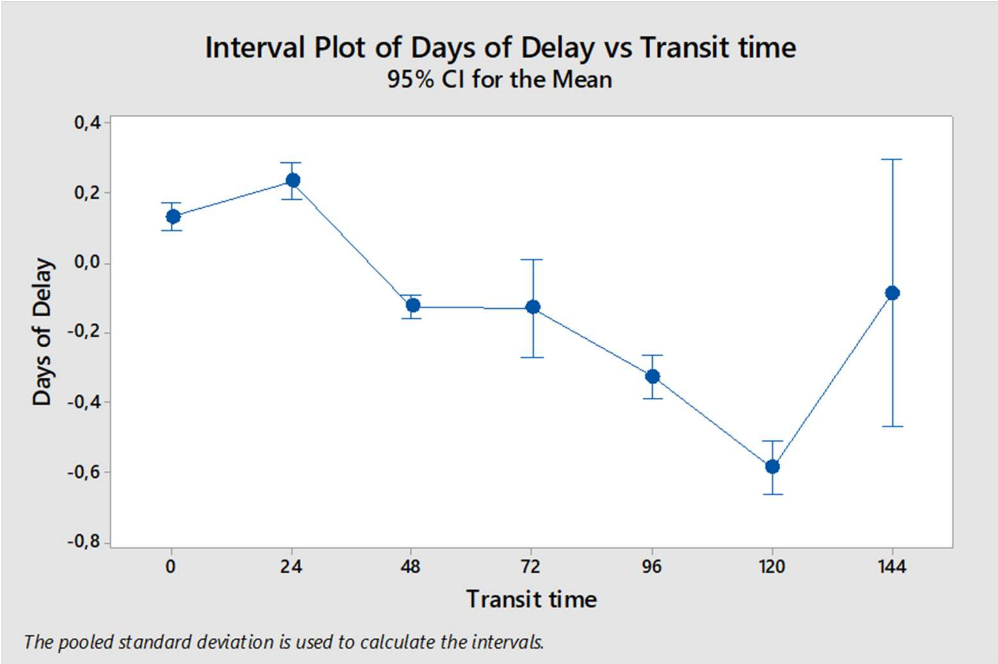


Figure 17:Interval Plot Transit Time (2)

In general, we can see that, independently from the value of the means, increasing the transit time and so the distance the standard deviation increases. This can be sign of the fact that increasing the distance the uncertain of the delivery grows.

What seems strange is the prevalence of the early deliveries, but we have to evaluate this phenomenon taking in consideration the fact that we are comparing the date of take in charge received from the plant with the date of estimated arrival received directly from the supplier. For the deliveries, the suppliers sign with the company an agreement, and in most cases is inserted a clause that impose to pay penalties for late deliveries, in this way, as the uncertain increase, the supplier is often pushed to postpone the estimated arrival date preferring to increase advances rather than have delays, the problem is that this effect is difficult to be quantifiable.

Suppliers region

A common evidence in the supplier's management is the fact that farther is the country with which do you want to collaborate harder will be to conduct the business. (Ghemawat, 2001)
Different confirmations are founded in the literature concerning the influence of the trade region on the efficiency of transport and for each different business environment is important to consider different aspects. (Javalgi & Ramsey, 2001)
When we speak about distance it must be considered that the distance is not only the kilometric one but can also be manifested on other dimensions like the cultural, the social, the administrative and the economic one. Each of these dimensions includes elements and factors to take into account, like the physical size of the country, the distances to borders, the topography, the transportation and communications infrastructures. (Ghemawat, 2001)
Geographical differences in markets are source of complexity (Vachon & Klassen, 2002).
Social and cultural factors play crucial roles in particular in a global context, where the lack of boundaries and the character of a global consumer amplify again the already discussed complexity. (Javalgi & Ramsey, 2001)
The cultural element must be considered in term of cultural issues and barriers like beliefs, languages and value systems, also the educational and technological skills level, if under a certain threshold, can become a barrier. (Javalgi & Ramsey, 2001)
If assumed as superficial and so not considered, from the management point of view, national differences in term of culture, legality, social norms, language and communication can inhibit trades. (Hornby, Goulding, & Poon, 2002) Many companies have done serious mistakes in this sense neglecting these issues, so it seems clear that they must somehow be treated.
The cultural aspect has an effect on technological innovations and entrepreneurial spirit and can create barriers to information sharing with the prevalence of different traditions also in term of habitual methods of trading (e.g. preferences for mail order or for the use of an EDI, methods of negotiating prices) (Javalgi & Ramsey, 2001)
Social factors include the organizations and the institutions, the method of resources distribution, the system of social infrastructure and the network of relation linked to. They influence the cost of doing business and the supplier's relationship, they drive the decision about how to select a supplier, the choose of the supplier's country, the development or not of a long-term relationship with a specific one. (Javalgi & Ramsey, 2001)

The economic dimension isn't less important, it influences the actors' behaviours in the business environment. The country economic development level can be used to assess the relationship between complexity and delivery performance. A first and evident difference is present between emerging and advanced economies.

In countries with an emerging economy, the lower competition lets the possibility to overlook some aspects and maintaining at the same time a good position in the market, in other words a company doesn't need to be the first in all the areas. For example, a company can put the focus on volume and cost aspects reducing the attention on quality or on customer responsiveness, they can increase the inventory and be less customer-oriented, but in every case have a competitive advantage sufficient to survive and to maintain the position in the market. The reduced competition conducts these companies to put less attention on some points and this can have a negative impact on quality and efficiency of transport and information and can create an increase in the variability of the performances. (Vachon & Klassen, 2002)

As already explained, to manage the processes on a global basis, the FCA manages the different geographical and markets areas with defined mechanisms. The group is organised under approximately 200 markets and each market, based on the geographical position, is included in one of the four commercial areas called regions.

In our case we will treat only the deliveries flows in the EMEA region (Europe, Middle East and Africa) and, as the major flow is the European one, the cultural differences are not so marked and so the impacts of the explained elements are not so easy to be recognised.

Once treated the cultural and social barriers is necessary to consider also the physical barriers like the lay of the land and the natural barriers, the infrastructural systems, the traffic flows and the customs.

Studies assess the dependence of transport costs and trade volumes on geography and infrastructures. A good level of infrastructures is important to permit to a country to be involved in the world economy, instead poor or deteriorated infrastructures and remoteness reduce the effectiveness and the quality of exchanges between countries impacting on the performances and in some cases isolating countries and reducing their possibility to participate in the global network. (Limão & Venables, 2001)

Speaking about national barriers and borders, recognised as influencing the frequency of spatial interaction (Stępniak & Piotr, 2016), we have to talk in particular about customs. The border's controls limit the circulation of peoples and goods and have a negative impact on the commercial trades. (13)

On this subject, dealing with the EMEA region, the signature of the Schengen agreements can be considered as an important step in the reduction of the border's controls and so in the reducing of the related delays.

The Schengen agreement leads to the creation of the Schengen Area that, derived from the same concepts behind the European Union, is a sort of free movement area in which internal border controls and limitations have been abolished. It is composed of 26 countries, where the majority are members of the European Union but not only (4 are Extra-UE). (14)

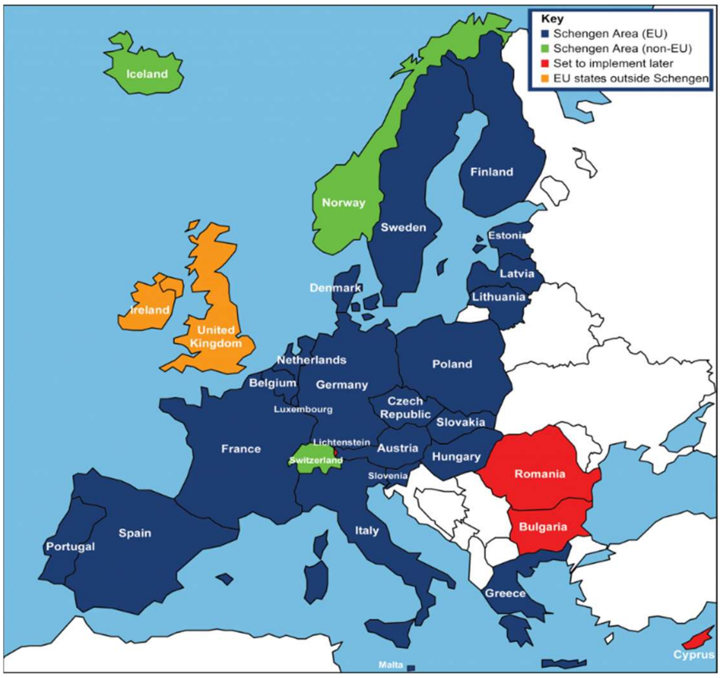


Figure 18:Schengen Area (source: differencebetween.net)

The Schengen area can be considered as a single state with not internal border checks but, as a consequence, with stronger external borders for external travellers entering. (15)

The existence of this area is an interesting aspect and have to be taken into account as the customs and border controls for entering into a country are elements adding uncertainty at transport level as it is impossible to know how much time will be spent at a customs.

A German study reveals that the passage between two Schengen countries is twenty minutes faster than the crossing of a non-Schengen country border (16) and Stępniak and Piotr recognise a visible negative impact on the waiting time on non-Schengen borders considered as having lower accessibility values. (Stępniak & Piotr, 2016)

From our data we have deliveries coming from 22 different countries, with the bigger part from European countries and in particular from Italy.

After a general explication on how the countries have been distinguished the exact division in classes is showed in the table 7 and 8, with the relative numerousness in term of delivery codes.

We start distinguishing the regions between Italy and International. Considered the high number of deliveries we divide again Italy in sub-zones. The used division for Italy is the classical one that consider the north, the centre and the south, but considering the higher flux of transport coming from Piemonte, the north is segmented again between north-east (Piemonte, Valle d'Aosta and Liguria) and north-west including the other regions of the north. (17)

Table 6:Italian Cluster

NORTH-WEST		NORTH-EAST		CENTRE		SOUTH	
Piemonte	16476	Lombardia	4651	Lazio	3859	Basilicata	1604
Valle d'Aosta	327	Emilia Romagna	1373	Abruzzo	2706	Campania	8112
Liguria	74	Veneto	558	Molise	1160	Puglia	372
		Trentino Alto Adige	116	Marche	771		
		Friuli Venezia Giulia	103	Toscana	471		
				Umbria	454		

Figure 19:Italian Division (source:lettera43.it)

The other countries, considered the previous studies, are divided between regions of the Schengen space and not to analyse the impact of the customs. The majority of the considered regions are included in the Schengen space so to obtain similar numerousness an ulterior segmentation has been realised following the division in regions and sub regions of the Geoschema of the United Nations realized by the United Nations Statistics Division (UNSD) that divides the Europe in 4 sub regions (eastern, southern, western and northern Europe). (18)

Table 7: International Cluster

Schengen							
Western Europe		**Eastern Europe**		**Southern Europe**		**Northern Europe**	
Austria	373	Czech Republic	1930	Malta	44	Sweden	53
Belgium	46	Hungary	718	Portugal	222		
France	1557	Poland	2719	Spain	803		
Germany	2837	Slovakia	410				
Netherlands	136						
Switzerland	81						
Extra-Schengen							
Bulgaria	99	Romania	669	Turkey	25		
Croatia	24	Serbia	138	United Kingdom	41		
Egypt	16						

The final scheme of the clusters used in the analysis, with the relative quantity of deliveries and different products, is showed in the following table (table 9).

Table 8:Cluster Region

REGIONS	Number of Deliveries	Number of Group Product Deliveries
INTERNATIONAL	**12941**	**22001**
Eastern Europe	5777	10277
Extra-Schengen	1012	1598
Northern Europe	53	107
Southern Europe	1069	2493
Western Europe	5030	7526
ITALY	**43187**	**93295**
Centre Italy	9421	21847
North-East Italy	6801	13230
North-West Italy	16877	34079
South Italy	10088	24139
Total	**56128**	**115296**

Concerning this factor, the first ANOVA analyses the relation with only two levels the one of the international deliveries and the one of the Italian deliveries.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Italy VS Others	1	1289	1289,05	194,46	0,000
Error	56126	372052	6,63		
Total	56127	373341			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,57466	0,35%	0,34%	0,34%

The P-VALUE is 0 so the means are not equal. As the Italian deliveries are the majority, we must take into account that the numerousness of the two classes are very different.

Means

Italy VS Others	N	Mean	StDev	95% CI
INTERNATIONAL	12941	-0,3272	2,8200	(-0,3715; -0,2828)
ITALY	43187	0,0326	2,4964	(0,0083; 0,0569)

Pooled StDev = 2,57466

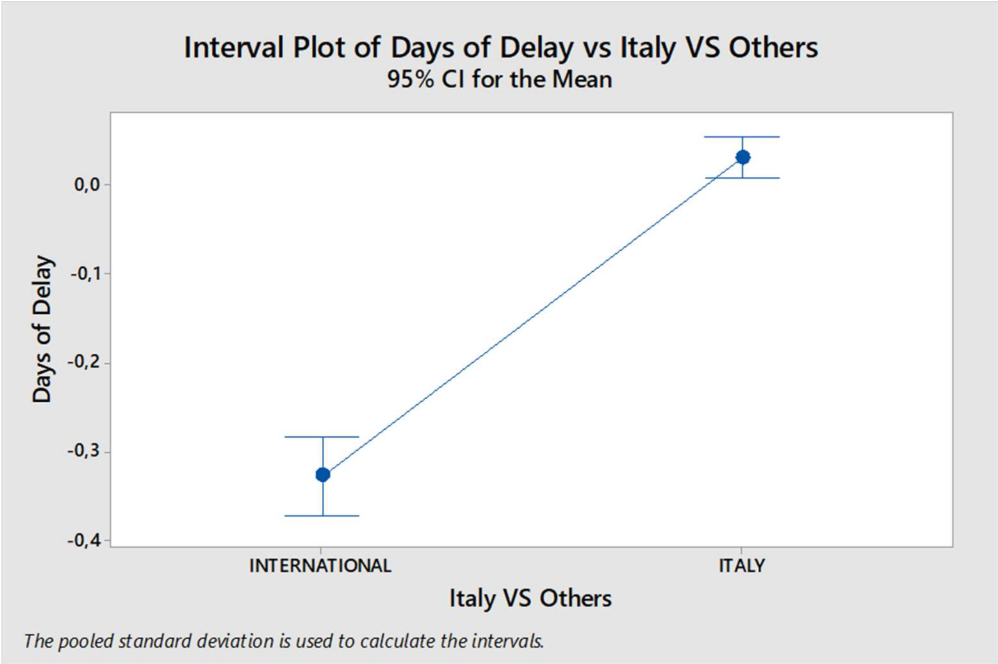


Figure 20:Interval Plot Region

The Italian deliveries are very near to the 0 instead the international one is moved on the early deliveries, maybe this is explained by the same mechanism considered for the transit time factor.

Confirmed the difference between the international and italian deliveries we'll go to see independently the deliveries from Italy and from foreign countries to improve our analysis.

Starting from Italy we consider 4 levels (Centre, North-East, North-West and South).

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Region Italy	3	892	297,390	47,87	0,000
Error	43183	268253	6,212		
Total	43186	269145			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,49239	0,33%	0,32%	0,31%

The P-VALUE is again 0, so not all the means of the different regions are equals.

Means

Region Italy	N	Mean	StDev	95% CI
CENTRE	9421	0,1095	1,2396	(0,0592; 0,1599)
NORTH-EAST	6801	0,1919	4,1248	(0,1326; 0,2511)
NORTH-WEST	16877	-0,1441	2,6542	(-0,1817; -0,1065)
SOUTH	10088	0,1491	1,3796	(0,1005; 0,1977)

Pooled StDev = 2,49239

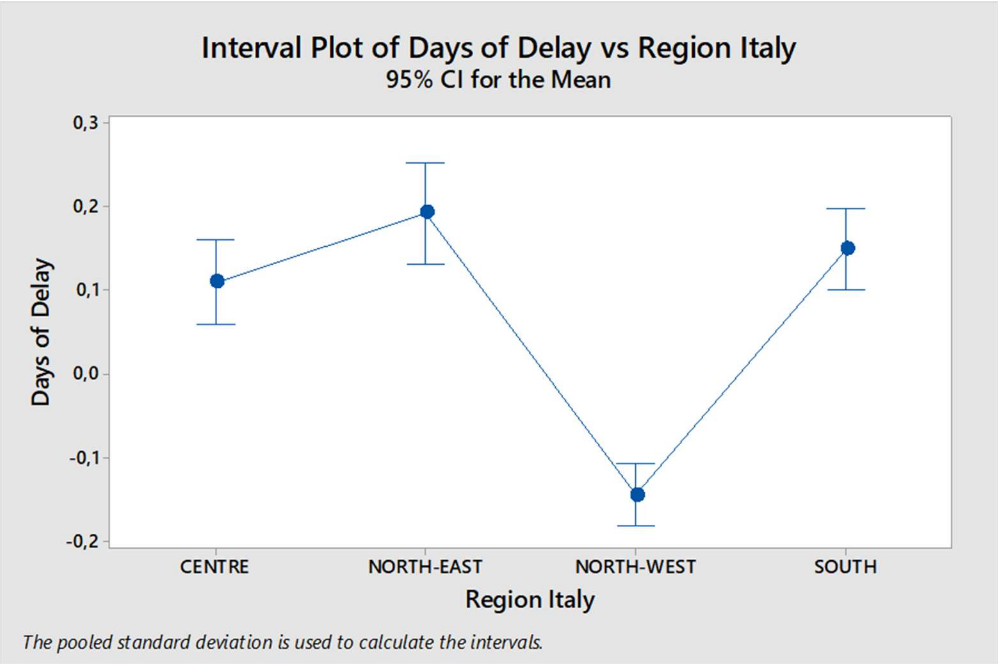


Figure 21:Interval Plot Region Italy

There is no gap between the confidence interval of the centre, the north-east and the south levels, the means are partially shifted to the delays but there aren't particular evidences. The level containing the north-west region is instead different and characterised by earlier deliveries.

The last analysis concerning the regions is the one about the foreign countries and, also in this case, we have 4 levels (Eastern Europe; Extra-Schengen; Southern Europe; Western Europe). The Northern Europe was not considered for the too low number of observations.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Cluster region	3	1095	364,871	46,28	0,000
Error	12884	101567	7,883		
Total	12887	102662			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,80770	1,07%	1,04%	1,00%

Also in this case the P-VALUE is 0, so the null hypothesis must be rejected.

Means

Cluster region	N	Mean	StDev	95% CI
Eastern Europe	5777	-0,5676	2,5822	(-0,6400; -0,4952)
Extra-Schengen	1012	0,499	3,870	(0,326; 0,672)
Southern Europe	1069	-0,1001	1,4366	(-0,2684; 0,0682)
Western Europe	5030	-0,2728	3,0148	(-0,3504; -0,1952)

Pooled StDev = 2,80770

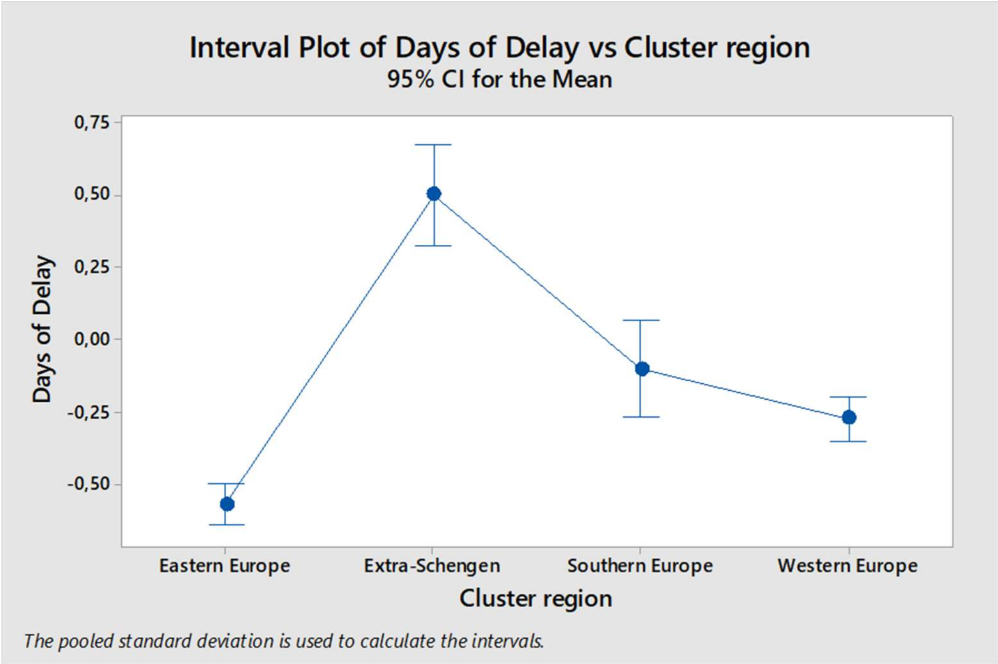


Figure 22:Interval Plot Region International

As expected, probably linked to the customs question already treated, the Extra Schengen level is characterised by more delays, for the Southern and Western levels the confidence intervals are not distinguished and the means are on -0,1 and -0,27, instead for the Eastern Europe more advances are registered maybe linked to the increased uncertainty derived from the fact that this class contains countries less economically developed .

Delivery quantity and frequency

Another element to consider is the size of the supplier, the size is used as a measure of the organization complexity and its growth increases the complicatedness of the management. (Vachon & Klassen, 2002)

In the use of an EDI we have seen that the size impacts as larger is the extend in which an EDI is used larger will be the advantages obtainable. (Vachon & Klassen, 2002)

Another good point is the fact that how much more is frequent the submission and shorter the horizon as the information will be better in term of quality and accuracy (Holweg, 2005), companies with an higher number and frequency of deliveries could increase the quality of information given concerning the date of estimated arrival by improving the previsions with the help of a major experience.

The size usually is not seen as directly related to the delivery performance but can influence it in different ways. What we want to verify is the balancing between the disadvantages derived from an increasing in complexity derived from a bigger size and the possible advantages and if it is possible to say that a supplier with more deliveries is more efficient and accurate despite the more complexity.
To evaluate the size of the supplier we have used two different measures, the first one is the delivery quantity, that measure how many deliveries have been send in the time frame considered independently from the frequency, the second one is instead the frequency that consider more the systematic deliveries, and answer to the questions: how often is send a truck? how much time elapses between two deliveries?
This two metrics have been measured using the number of deliveries registered from the FCA information system during the analysed timeframe.

Frequency

The delivery frequency can be a consequence of the supplier size, but also of the agreement based on the customers and logistics needs and specifications in term of physical volume, so that for example a bulk part supplier can show more frequent deliveries based on the volumes asked. (Holweg, 2005)
To evaluate it, we have started from the customers specifications, so from the time criteria used for the demand forecast to evaluate if a correspondence exists with the timing of delivery of suppliers. The timeframe used are usually a quarter, a month and a week, in our case we have verified that the majority of the suppliers send goods more than once a week and for this, going deeply, we have analysed the data on a daily basis creating 5 classes based on the means of the differences between two deliveries and grouped to having a similar number of supplier considered for each class.
The table 10 shows the division in cluster with the corresponding quantity for each one in term of number of suppliers, different deliveries and product.

Table 9: Cluster Frequency

FREQUENCY	Number of Suppliers	Number of Deliveries	Number of Group Product Deliveries
EACH 3-4-5 DAYS	91	889	1115
EACH TWO DAYS	105	2147	2792
LESS THAN ONCE A WEEK	88	342	355
ONCE A DAY	106	3993	6271
TWICE A DAY	273	48757	104763
Total	**663**	**56128**	**115296**

For the One-Way ANOVA 5 levels have been used based on the increasing frequency (once a week; each 3-4-5 days; each two days; less than once a day; twice a day).

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Cluster frequency	4	593	148,295	22,33	0,000
Error	56123	372748	6,642		
Total	56127	373341			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,57713	0,16%	0,15%	0,09%

The P-VALUE is 0, so the null hypothesis must be rejected and not all the different levels are equals.

Means

Cluster frequency	N	Mean	StDev	95% CI
EACH 3-4-5 DAYS	889	0,479	5,490	(0,310; 0,649)
EACH TWO DAYS	2147	0,0494	3,7917	(-0,0596; 0,1584)
LESS THAN ONCE A WEEK	342	0,725	8,394	(0,452; 0,998)
ONCE A DAY	3993	0,0836	3,3405	(0,0037; 0,1636)
TWICE A DAY	48757	-0,0808	2,2488	(-0,1037; -0,0579)

Pooled StDev = 2,57713

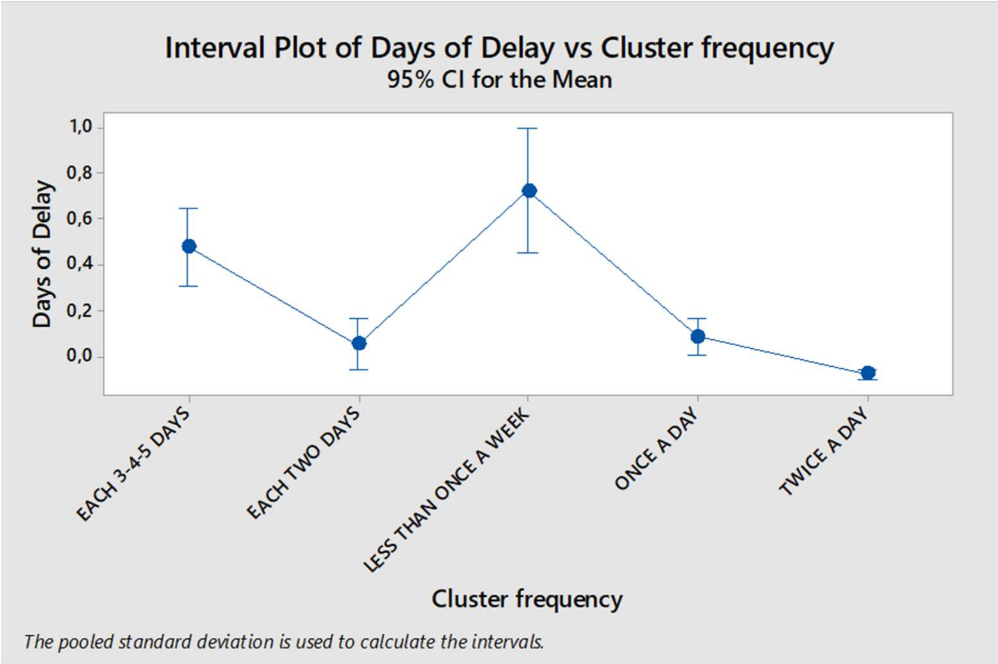


Figure 23:Interval Plot Frequency

In the case of the levels containing the suppliers with the major frequency of deliveries the means are closer to the 0 value and so the delays are very reduced, instead the number of delays increase for the other two categories (as the means are shifted to a higher value of the response days of delay). The class of the supplier delivering less than once a week and for this containing also the supplier with only occasional deliveries is the one with the higher means 0,7 and so the one that registers more delays.

In this case the hypothesis that when there is a major quantity of submissions (major frequency) and, in some sense, when the delivery process is seen almost as a routine there is an increase in the quality and accuracy of the prevision seems to be confirmed.

Quantity

To evaluate the size of an organisation is often used the number of personnel employed (Ahmad & Schroeder, 2001), an example is the use from the European Commission of the number of employed to define the small and medium-sized enterprises (SMEs), dividing the categories in classes, the micro companies with 10 employed or less, the small 50 or less, the medium 250 or less and the big with more than 250 employed. In our case we don't have the number of employees for each supplier, but we use this threshold levels as starting point to define the limits of our classes based, instead, on the number of deliveries. The first classes have been later adapted and increased in number to obtain classes with a similar number of suppliers and to have a number of classes coherent with the one of the frequency factor. The division can be seen in table 11.

Table 10:Cluster Quantity

QUANTITY	Number of Suppliers	Number of Deliveries	Number of Group Product Deliveries
HIGH	130	39533	81375
LOW	138	553	1061
MEDIUM	133	4168	8521
MIDDLE-LOW	130	1700	3340
UPPER-MIDDLE	132	10174	20999
Total	**663**	**56128**	**115296**

So, also for the frequency factor, the number of levels is 5 (high, low, medium, middle-low and upper-middle).

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Cluster quantity	4	621	155,318	23,39	0,000
Error	56123	372720	6,641		
Total	56127	373341			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,57704	0,17%	0,16%	0,12%

The P-VALUE is again 0, also in this case the null hypothesis must be rejected.

Means

Cluster quantity	N	Mean	StDev	95% CI
HIGH	39533	-0,0562	2,0453	(-0,0816; -0,0308)
LOW	553	0,468	6,657	(0,254; 0,683)
MEDIUM	4168	-0,0034	3,5494	(-0,0816; 0,0749)
MIDDLE-LOW	1700	0,408	4,283	(0,286; 0,531)
UPPER-MIDDLE	10174	-0,1517	3,1230	(-0,2017; -0,1016)

Pooled StDev = 2,57704

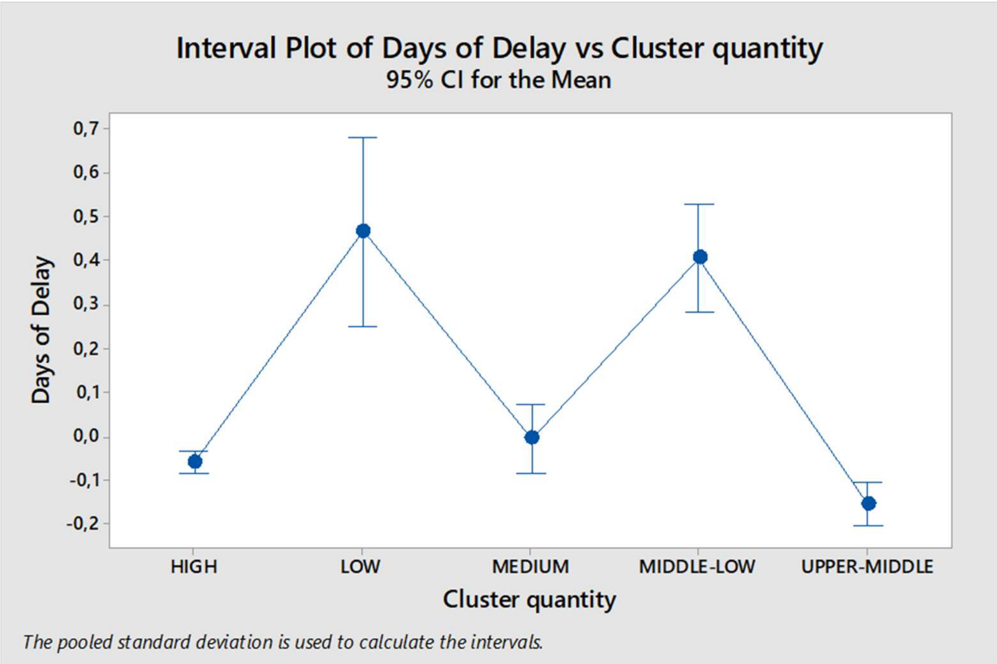


Figure 24:Interval Plot Quantity

The results showed are similar to the ones obtained with the frequency factor, the high, the upper-middle and the medium classes, the ones with the higher number of deliveries, are nearer to the 0 value and so characterised by less delays. The upper-middle class mean, with respect to the other two, is shifted a little more on negative values of delay so to a major number of early deliveries.

For the low and middle-low classes the means are similar and the confidence interval are almost overlapping, these two classes have a means around 0,4 so higher than the others (more delays).

Also in this case seems to be confirmed the fact that more deliveries drives to better results in term of numbers of delays.

Product Variety

Variety is defined as "the diversity of products that a production system provides to the marketplace" (Ulrich, 1995) and is considered as an element of competitiveness and as the answer to the increasing diversified demand of the market. (Medini & Boucher, 2015)
Increasing the product variety to align his products to the customers' needs the firms think to maximise the fit to the customer desires, but sometimes they don't consider the challenges in term of performance and operations arising from these decisions. (Salvador, Forza, & Rungtusanatham, 2002)
The first challenge is for sure linked to an augmented complexity.
The index of product variety and the number of components outside the SBU, with the size of the supply network already discussed, is used as a metric of management systems complicatedness. (Vachon & Klassen, 2002) The variety can be measured by the number of final product configurations sold to customers by the plant as each new configuration imposes additional constraints on the process, increases the range of decision to be taken as well as the number of interfaces to face (suppliers, customers, and competitors). (Ahmad & Schroeder, 2001)
Suppliers may experience diseconomies due to component variety, with potential negative impact on delivery times and inventory levels caused by less efficient and more expensive internal operations (Salvador, Forza, & Rungtusanatham, 2002)
An increased complexity, derived from more products diversity and customization, drives to more coordination problems and asks for more communication and can, consequently, conduct to worst delivery performances. (Ahmad & Schroeder, 2001)
The importance of the question about variety is confirmed again by the numerous researches conducted to find solutions to reducing his negative impacts in term of costs, complexity and performances: some examples are the use of commonality and modularisations or the use of TPL.
The use of commonality, creating product families with common components, modules and processes, is a way to gain advantages from the economies of scopes and to balance the

advantages and the disadvantages of an increased variety mainly in term of production. (Medini & Boucher, 2015)

The increasing use of a TPL can be considered as the researched answer, in term of logistics services, to the increasing request for variety from customers and the tendency to ask for aggregate products from different parts of the world and for different kind of goods in the same delivery, these elements are cause of a continuous growth of complexity, asking for more efforts and coordination and in this way affecting the transport performance. (Hertz & Alfredsson, 2003)

As seen the variety is a driver of complexity both for the production and for the delivery. The negative effect on the efficiency of the production processes is confirmed but have to be balanced with the gains derived from the wide offer perceived by the customer point of view. The variety seems to influence also the transport process, but this aspect has to be analysed more in detail. We will verify at what level the variety influences the transport process, a company having more than one product to deliver at the same place has more problems at the organisational level, more difficulty to follow it and more actors to deal with.

An added number of choices have to be taken like the decision to use the same delivery for different parts or a different delivery for each part.

From another point of view, although the negative effects, a gain can be obtained from scale economies linked to the different product specifications able to capture the spatial dimension (Winston, 1985) or the use of combinations of weight and volume to increase the density of products and maximise the use of the transport cubic capacity. (APICS, 2017)

The level of variety is an element to take under control, as well as the its effect can also be influenced and, in some cases, amplified by other factors what the outsourcing or the proximity of the suppliers (Salvador, Forza, & Rungtusanatham, 2002)

In our analysis, we start from the observation of how many different product codes are provided by the different suppliers, the minimum value, that is the one observed for a big part of the supplier, is one, only one product delivered, in this case we consider the variety as 0, so there isn't variety. Instead the maximum number of different product codes is 454.

From the examples in the literature we have defined 300 different products as a possible value of difference, the threshold value between low product variety and high product variety. On the other hand, is also underlined the importance of considering not only the level of variety independently but also the variety with respect to the total volume (Salvador, Forza, & Rungtusanatham, 2002).

Considering the 300 as threshold level we can say that our considered suppliers are mainly to be putted under the low product variety definition, but in every case a differentiation exists and so is necessary to find other criteria to define some classes.

To evaluate both the variety and the volume together, we have decided to create an index based on the ratio between the number of different product code for each supplier and the number of deliveries registered in the considered time frame. An independent class including all the supplier providing a single product has been maintained, as this class presents suppliers that don't face variety and so is held to be considered separately. Concerning the other elements, we have created 7 classes with different levels of variety, based on the created index, maintaining a similar number of suppliers for each class. The division with the relative numerousness can be seen in the following table (table 12).

Table 11:Variety Quantity

VARIETY	Number of suppliers	Number of Deliveries	Number of Group Product Deliveries
0 Variety	77	354	354
1-First Level of Variety	85	14637	19389
2-Second Level of Variety	86	10820	20770
3-Third Level of Variety	83	9274	19392
4-Fourth Level of Variety	83	7353	15559
5-Fifth Level of Variety	82	7200	17537
6-Sixth Level of Variety	82	4137	13226
High Variety	85	2353	9069
Total	**663**	**56128**	**115296**

The One-Way ANOVA has been realised with 8 levels (0 variety, first level of variety, second level of variety, third level of variety, fourth level of variety, fifth level of variety, sixth level of variety and high variety)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Cluster variety	7	420	60,002	9,03	0,000
Error	56120	372921	6,645		
Total	56127	373341			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,57780	0,11%	0,10%	0,05%

The P-VALUE is equal to 0, so at least one mean is not equal to the others and the null hypothesis must be rejected.

Means

Cluster variety	N	Mean	StDev	95% CI
0 VARIETY	354	0,494	7,332	(0,226; 0,763)
FIFTH LEVEL OF VARIETY	7200	-0,1479	2,8064	(-0,2075; -0,0884)
FIRST LEVEL OF VARIETY	14637	-0,1233	1,8654	(-0,1651; -0,0816)
FOURTH LEVEL OF VARIETY	7353	0,0129	3,1763	(-0,0460; 0,0718)
HIGH VARIETY	2353	-0,1398	4,4696	(-0,2440; -0,0357)
SECOND LEVEL OF VARIETY	10820	0,0536	1,8687	(0,0050; 0,1022)
SIXTH LEVEL OF VARIETY	4137	-0,0278	2,0946	(-0,1064; 0,0508)
THIRD LEVEL OF VARIETY	9274	-0,0389	2,7323	(-0,0914; 0,0135)

Pooled StDev = 2,57780

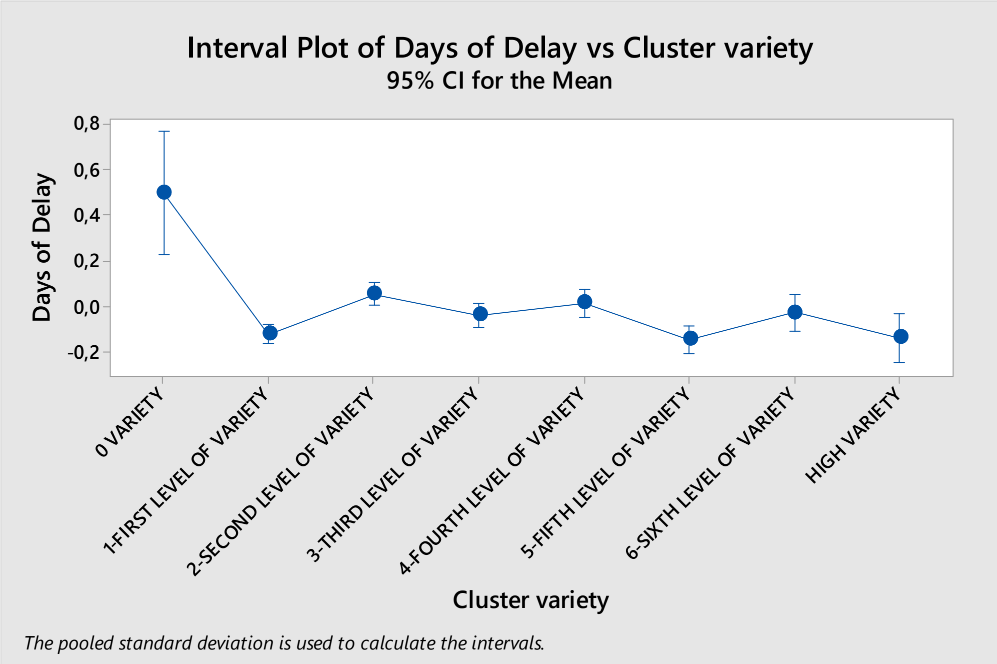


Figure 25:Interval Plot Variety

The means for the different levels of variety seems not so different, staying in a range of 0,20 between the minimum value of -0,1479 and the maximum of 0,0536, with confidence interval from -0,244 to 0,1. We can say that the delays are not so influenced from these levels. The only significant difference is the one between having or not having variety. The not having variety in the transport step, seems to impact negatively on the delivery performance more than the presence of variety for which little delays are registered and this result is different from the evidence founded in the production step. The negative effect for 0 variety suppliers can maybe be explained with a not optimal use of the transport volumes, a more variety in term of product can help in exploiting the spaces and volumes during the transport.

The same analyses, concerning the quantity, frequency and variety, have been realised also considering the single supplier level and can be founded in the appendix II, but are not been inserted here as the reduced number of suppliers, with respect to the deviation of the supplier average delays distribution from the normal has not been considered sufficient to justify the use of the central limit theorem.

3.4.2. Carried parts

Once defined as important factor the variety of products it seems obvious to go to evaluate the different impact of different types of product on the transport. We have though to consider this difference in term of cost, dimension, shape and production complexity making evaluation considering also the types of materials and the function of each product. The two analyses realised on the type of product and on the type of plant have the same purpose but at different levels and go to verify if the differentiation of products impacts on the transport and so on the on-time deliveries.

Part type

From the FCA documents, as from numerous articles, it is clear that the cost is a factor impacting at more levels, we have decided to consider it also in terms of differentiation of products during the transport beside the more intuitive differentiation on the base of weight and shape.

Firstly, the inventory costs are considered as having an interesting impact on transportation choice. (McGinni, 1979), the investment in advanced manufacturing technology (AMT) adoption and the value of purchased materials are recognised as a measure of product complicatedness. (Vachon & Klassen, 2002)

The level of transportability of a product is decided considering how it is priced, and on “whether profits, consumer surplus, or social welfare is maximized in selecting the transport rate” (Gronberg & Meyer, 1982), the firm has to decide how many resources to use to make the product more transportable. Some decisions in term of manufacture and packaging may increase the handling and reduce the cost for the transport. Some characteristics like collapsibility, removable parts or packaging products in durable containers can be taken into account, even if they increase the cost of manufacturing. (Gronberg & Meyer, 1982)

For the scope of our analysis we can overlook the question of the balancing between the transport costs and production costs, but we can see these types of questions as a confirmation of the hypothesis that a particular geometry or shape can influence the transport in term of cost but also in term of efficiency. What we want to see now is how this can influence the delivery performances.

The difference between assembled and unassembled parts, the size, the difference between parts easily packaged in functional way and parts with a particular shape difficult to be stocked, the easiness of loading and unloading are all elements to be considered.

The possibility to take advantage from the economies of scale increasing the load size, for example consolidating small loads into larger ones, creates a difference based on the ability to maximise the truck load, on the level of stowability of the products and more in general on the easiness of a product to optimize standard transport vehicle capacities. (APICS, 2017)

What is found in the FCA documentation confirms the criteria of differentiation that have been treated until now.

FCA divides products into product family and each region use a different division based on the necessity and the characteristics of the sold product. We have not only used the subdivision used in the EMEA region, but we have taken into consideration the different options used in the different regions, for example the division at the CPOS level (body, trim, engine, gear and transmission) used in NAFTA and LATAM and the budget concept used in EMEA. Starting from the FCA divisions and making some adjustment on the basis of the elements analysed before we have created the product classes starting from the drawing codes to do an analysis based on the dimension, the value and the complexity of the product. (APICS, 2017) (Valentini, 2010)

The defined classes are the following:

1. Engines and complex parts. This group includes the most expensive parts, starting from the complete engine and considering all the complex mechanics components linked to.
2. Pipes and cables. It considers the oblong elements: the first type more complex in term of dimension and weight, the second one in term of cost of components and from the electric/electronic point of view.
3. Internal parts, glasses and accessories. It includes the non-mechanical parts and the non-structural ones, they have a wide range of functions but are primarily based on a comfort and aesthetic purpose, they usually have different and particular shapes, but they don’t have too big dimensions.
4. Little mechanical components and common unassembled parts. It includes components of little and relative standard dimension, elements of easy production and low cost, like screw and nut.

5. Elements of aesthetic and refinishing in particular for the exterior part. It includes primarily paints, solvents, stickers and logos but also other simple components not in metal, not fragile and not heavy like rubber and elastic products.
6. External parts and big laminates. It includes the car-body and the structural skin parts, usually are metal parts with big dimensions.
7. Technology: the more technological and complex parts. It includes the more complex parts in term of electronic and software, usually characterised by a high cost. The majority is part of the optional elements and is usually seen from the customer point of view as added value for the car.

Table 12: Cluster Part Type

PART TYPE	SPECIFICATIONS	Number of Group Product Deliveries
1	Engine and complex parts	13061
2	Pipes and cables	21334
3	Internal parts, glasses and accessories	20294
4	Little mechanical components	22336
5	Elements of aesthetic and refinishing	12181
6	External parts and big laminates	18079
7	Technology	8011
Total		**115296**

The analysis has been run with 7 levels corresponding to the categories of parts explained before and indicated with the class number.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Cluster Product	6	1592	265,291	51,66	0,000
Error	115289	592063	5,135		
Total	115295	593655			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,26616	0,27%	0,26%	0,26%

The P-VALUE is 0, so not all the means are equals.

Means

Cluster Product	N	Mean	StDev	95% CI
1	13061	-0,1119	2,2881	(-0,1508; -0,0731)
2	21334	-0,0844	1,5030	(-0,1148; -0,0540)
3	20294	0,0076	2,4601	(-0,0235; 0,0388)
4	22336	-0,1529	2,6314	(-0,1827; -0,1232)
5	12181	0,1193	2,2034	(0,0790; 0,1595)
6	18079	0,1144	2,3223	(0,0814; 0,1475)
7	8011	-0,2671	2,2734	(-0,3168; -0,2175)

Pooled StDev = 2,26616

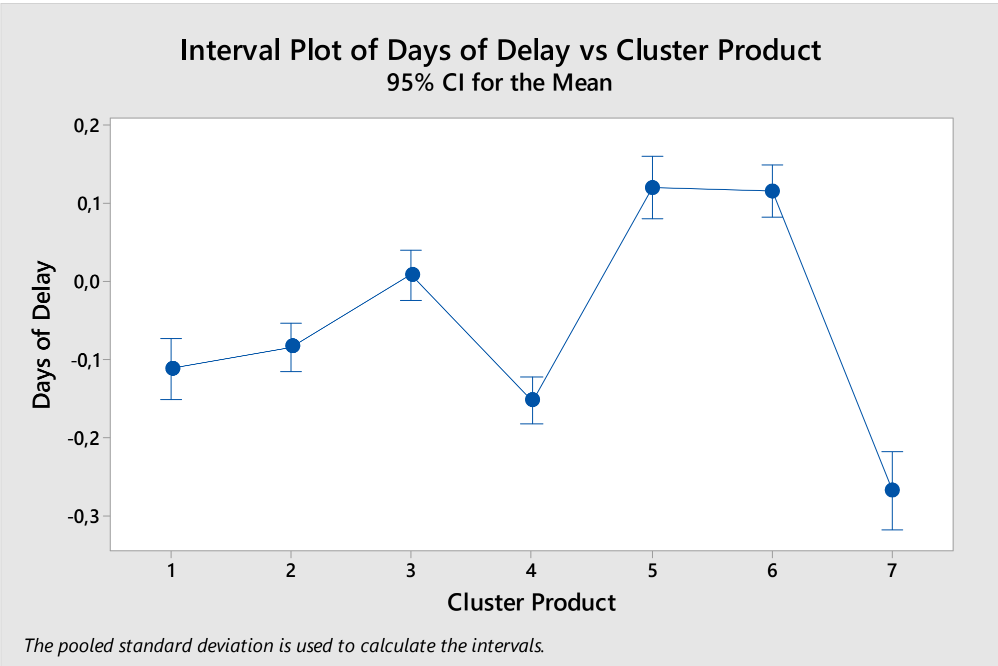


Figure 26: Interval Plot Product Type

Seeing the interval plot in figure 26 we register more delays for the classes 5 and 6.
The first contains elements of aesthetic and refinishing, where particular materials, like paints or solvents, can requires more attention in the loading or other have particular geometries

difficult to be managed. For the second one (external parts and big laminates) the result doesn't surprise, in fact in this class are included the more complex parts in term of sizes and geometries and also the heaviest, so problem in the loading can be frequents as well as the high weight can impose to the trucks a reduced speed. The third class (internal parts, glasses and accessories) is almost on the 0, this class includes in a certain sense the easiest parts in term of electric, electronic and software but also in term of loading (limited dimensions and reduced weights).
For the classes 1, 2 and 4 more early deliveries are registered but, as the advances are not excessive, we will consider them as not so meaningful.
For the class 7, that contains the elements of technologies, so the more complex in term of software and the more sophisticated and costlier, the higher number of early deliveries can be sign of a recognised phenomenon. For a more expensive and sensitive product is a common use to pay more attention on the transport steps because effects of deteriorations or destruction linked to a bad transport management or to a bad packaging can have a huge economic impact, for this in these cases more control is usually put during the transport, more direct routes are chosen, even if sometimes costlier, and this can also conduct to register early deliveries.

Plant Type:

The plants for which are the shippings are of different types, in terms of type of pieces produced and type of cars. In particular, we consider nine plants in the Italian region. In this case, with respect to the parts division, a high level of product aggregation is used to classify the plants types.
A first division is realised taking more in consideration the purpose of the final product, the plants are divided in mechanics and body on the base of their production, plants that produce subassemblies and plants that produce the final product.
On the other hand, we have used the concept of budget classes of the EMEA region to subdivide the body plants. In this way, we consider also the level of cost of the final product, dividing the plants on the basis of the realised model. In our case we have plants that produce 4 different models with different cost levels (see table 14).[1]

[1] The prices are be taken from (19) www.quattroruote.it/listino/

Table 13: Plants Production

CODE	PLANT	TYPE 1	TYPE 2	COST LEVEL	FINAL PRODUCT
M1	TORINO-Mirafiori Mechanics	Mechanics	Mechanics		Stamping and transmissions
M2	Termoli	Mechanics	Mechanics		Fuel engine FIRE and Multiair engine, engine GME and V6 for Alfa Romeo
M3	Verrone	Mechanics	Mechanics		Transmissions and gearbox
M4	Pratola Serra	Mechanics	Mechanics		Modular engine FIAT
B1	TORINO-Mirafiori Components	Body	Maserati		Maserati Levante
B2	Pomigliano-Gb Vico	Body	Fiat Panda	10000 €	Fiat Panda
B3	Piedimonte S.Germano	Body	Alfa Romeo	23500€ 46000 €	Alfa Romeo Giulietta, Alfa Romeo Giulia, Alfa Romeo Stelvio
B4	Melfi	Body	Fiat 500x Jeep Renegade	18000€ 21000 €	Fiat 500x, Jeep Renegade
B5	Grugliasco-Agap	Body	Maserati	70000€ 100000 €	Maserati Quattroporte, Maserati Ghibli

Table 14: Cluster Plant Type

PLANT TYPE	Number of Deliveries	Number of Group Product Deliveries
BODY	**49795**	**106929**
ALFA ROMEO	18683	40723
FIAT 500X- JEEP RENEGADE	19063	41705
FIAT PANDA	5292	10778
MASERATI	6757	13723
MECHANICS	**6333**	**8367**
MECHANICS	6333	8367
Total	**56128**	**115296**

Although the different numerousness (as showed in table 15), a first analysis has been realised considering only the two levels concerning the Body Plants and the Mechanics ones.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Plant type_1	1	19	19,295	2,90	0,089
Error	56126	373322	6,651		
Total	56127	373341			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,57905	0,01%	0,00%	0,00%

In this case the P-VALUE is bigger than 0,05 so the null hypothesis cannot be refused. Regarding the confidence interval in the interval plot (figure 27), we can see as the confidence interval of the mechanics class is widely larger than the body one, so also if the exact calculated value of the means deviates one from the other the null hypothesis cannot be refused.

Means

Plant type_1	N	Mean	StDev	95% CI
BODY	49795	-0,0437	2,2733	(-0,0664; -0,0211)
MECHANICS	6333	-0,1023	4,2799	(-0,1658; -0,0388)

Pooled StDev = 2,57905

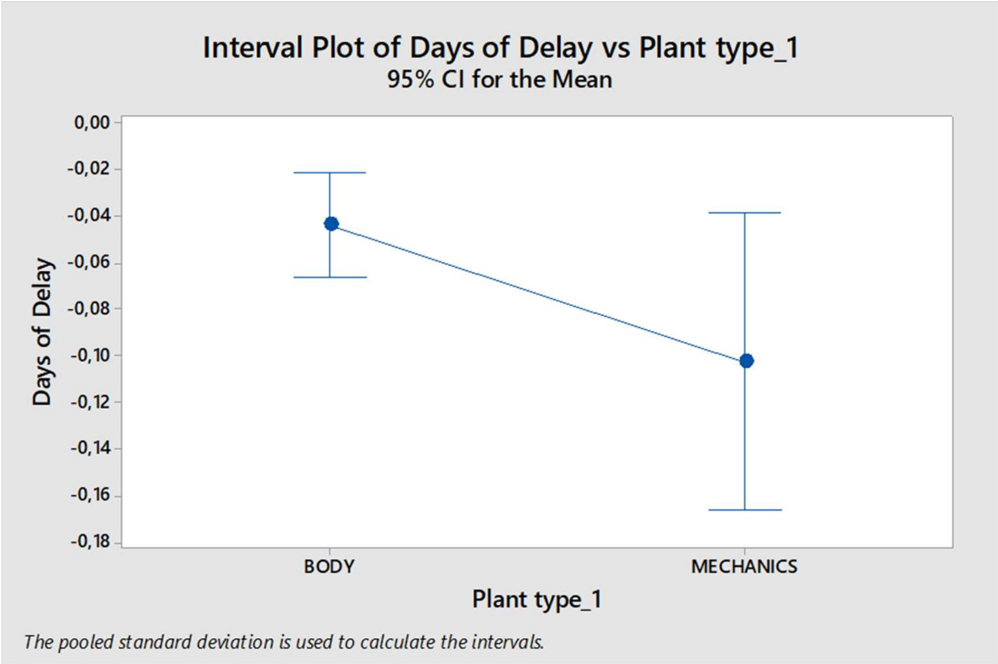


Figure 27: Interval Plot Plant Type (1)

The second analysis based on the plant type factor is realised with 5 levels having more similar numerousness (Alfa Romeo; Fiat 500x-Jeep Renegade; Fiat Panda; Maserati; Mechanics).

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Plant type	4	2297	574,232	86,86	0,000
Error	56123	371044	6,611		
Total	56127	373341			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,57124	0,62%	0,61%	0,59%

In this case the P-VALUE is equal to 0, so the null hypothesis must be rejected.

Means

Plant type	N	Mean	StDev	95% CI
ALFA ROMEO	18683	0,1078	1,9825	(0,0709; 0,1447)
FIAT 500X-JEEP RENEGADE	19063	-0,2964	2,5107	(-0,3329; -0,2599)
FIAT PANDA	5292	-0,0582	1,5901	(-0,1275; 0,0111)
MASERATI	6757	0,2617	2,6680	(0,2003; 0,3230)
MECHANICS	6333	-0,1023	4,2799	(-0,1656; -0,0390)

Pooled StDev = 2,57124

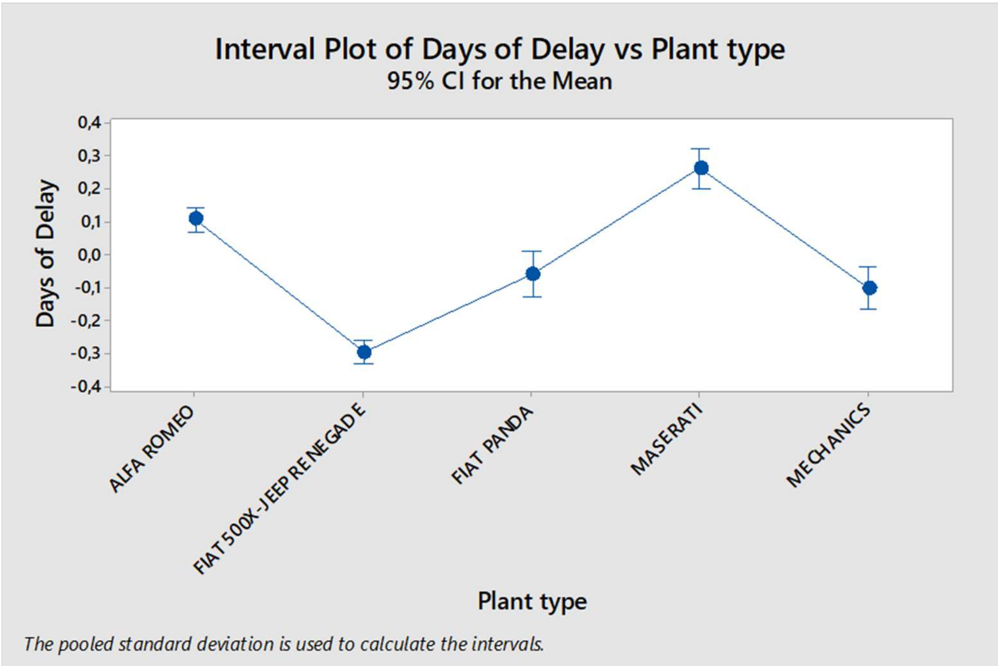


Figure 28: Interval Plot Plant Type (2)

From the interval plot (figure 28), we can see as the FIAT PANDA is the nearest to the 0 level and presents more on-time deliveries, this is the product with the lower level of cost and is a common car frequently sold with not a lot of optionals. Not so different from this first level are the mean and the confidence interval for the mechanics class, it includes some more early deliveries and is characterised by lower costs with respect to a final vehicle. The MASERATI mainly, but also the ALFA ROMEO group are more characterised by delays, between the models considered these two cars are the higher expensive ones, are models with more complex components and are usually sold with more optionals included with respect to the PANDA.

People buying this type of car are people able to spend more for their car so are usually less disposable to accept a standard model and they want a car more customised. The added quantity and complexity of the components needed for these types of vehicle can increase the general transport complexity and, in this way, can conduct to higher delays. The last class, the one including the FIAT 500X and the JEEP RENEGADE, is the one including the medium cost value vehicles and registers more early deliveries than all the others.

3.4.3. Transport mode (INCOTERM)

Talking about transports and physical deliveries is necessary to evaluate how each industry decides to manage the routes. Different options are possible, we have already cited the actual tendency to use third-party logistics providers. The majority of the suppliers are part of a third-party collection, a part delivers products using their own trucks and the last group uses a third-party as a mean for the deliveries. From another point of view different delivery schemes are possible: the direct delivery to a customer warehouse, the use of an interim one or the directly line-side delivery. (Holweg, 2005)

In-transit goods represent an investment for both buyers and sellers, but they are often under huge risks of damage or loss, so as the different managements change the responsibility during the transport is important to clearly define who owns the goods at a given time or location and who will pay the expenses incurred to transport the goods.

The concept of INCOTERM (International Commercial Terms) answers to these questions defining the ownerships and the responsibilities concerning the costs, the documentations and more in general the risks. (APICS, 2017)

In other words, an Incoterm is a contract that defines the delivery, the cost division and the management in term of risks transfer. The INCOTERM is recognised as unequivocal worldwide according to the Incoterms 2010 rules of the International Chamber of Commerce and can be classified, as detailed in the image below (figure 29), according to the defined terms on the basis of the growth in sellers' responsibilities. (INTERNATIONAL CHAMBER OF COMMERCE, 2010)

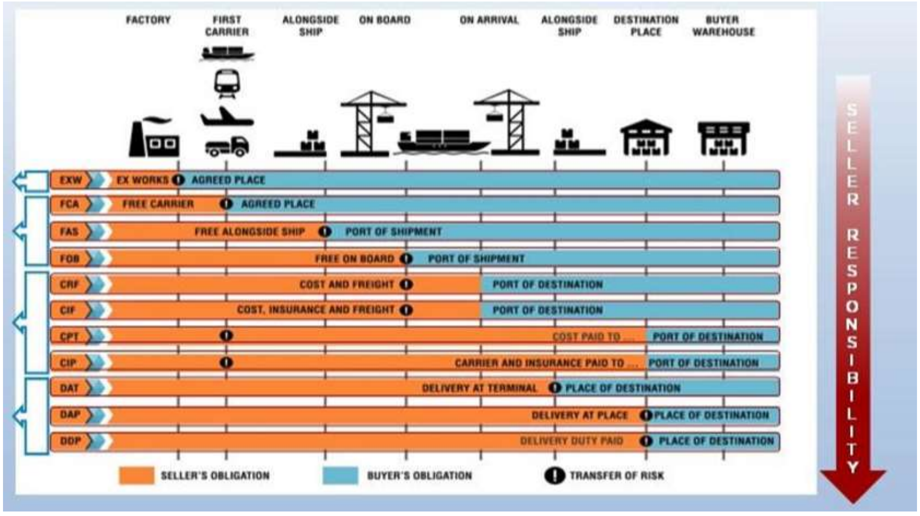


Figure 29:Incoterms (source:FCA documents)

The FCA system of transport all over the world is characterized by the upstream transport, that includes the raw materials and components deliveries toward the plants, and the downstream transport, the vehicle distribution to dealers. The first one is realised by external logistics services providers, put under contract by the company, or is directly managed by the suppliers; the second one uses the means of the own society of distribution or delegates the task to external transport providers engaged by the group. (FCA, 2013 Sustainability Report, 2014)

From the point of view of the FCA management of the EMEA region the deliveries can be organised under two modes: the FCA Incoterm and the DDP one.

FCA MODE-Free Carrier

The goods are considered as delivered by the seller as soon as they, authorised to export, are made available to the vector designated by the buyer in the agreed place. (INTERNATIONAL CHAMBER OF COMMERCE, 2010) The seller is responsible for preparing the export documentation and delivering the goods to the transporter. The buyer is responsible for all the other costs. (APICS, 2017)

In these cases, FCA uses the I-FAST Automotive Logistics S.r.l, a society of his own property, for the planning and the management of transports from the supplier to the designed plant. This society manages the complete transport and to organise the high volume of deliveries uses the help of some tools that starting from the demand planning are able to optimise the routes, the management of trucks' load and the utilisation of the transport capacity for each delivery balancing transport rates and costs and taking into account also the environmental impact of logistics operations.

DDP MODE- Delivered Duty Paid

The goods are considered as delivered by the seller as soon as they, authorised to import and not unloaded, arrive at the designed destination on a vehicle of any kind. (INTERNATIONAL CHAMBER OF COMMERCE, 2010) The seller detains the transport risks and pays for all the costs of shipping, the export documentation and any duties occurred before the designed destination is reached. (APICS, 2017)
In these cases, FCA can trace the goods only at the time when they are finally delivered toward the FCA plant, before the supplier can manage the products and his network in autonomy, choosing for example between a direct transport or a more complex system like a milk run, aggregating different product deliveries to maximise the load.
The number of deliveries and suppliers that use the FCA mode already represents a superior percentage in comparison to those with a DDP mode and the trend is toward an increasing in the I-FAST management of transport.

Table 15: Cluster Transport Mode

TRANSPORT MODE	Number of Deliveries	Number of Group Product Deliveries
DDP	7455	13232
IFAST	48673	102064
Total	**56128**	**115296**

For this factor we consider only two levels (table 16), the DDP incoterm and the FCA one, that is signed under the name IFAST that is the name of the company that manages the deliveries of FCA type.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Incoterm	1	14	14,035	2,11	0,146
Error	56126	373327	6,652		
Total	56127	373341			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,57907	0,00%	0,00%	0,00%

In this case the P-VALUE is 0,146, so bigger than 0,05 and the null hypothesis cannot be refused.

Means

Incoterm	N	Mean	StDev	95% CI
DDP	7455	-0,0099	3,5362	(-0,0685; 0,0486)
IFAST	48673	-0,0565	2,3990	(-0,0794; -0,0336)

Pooled StDev = 2,57907

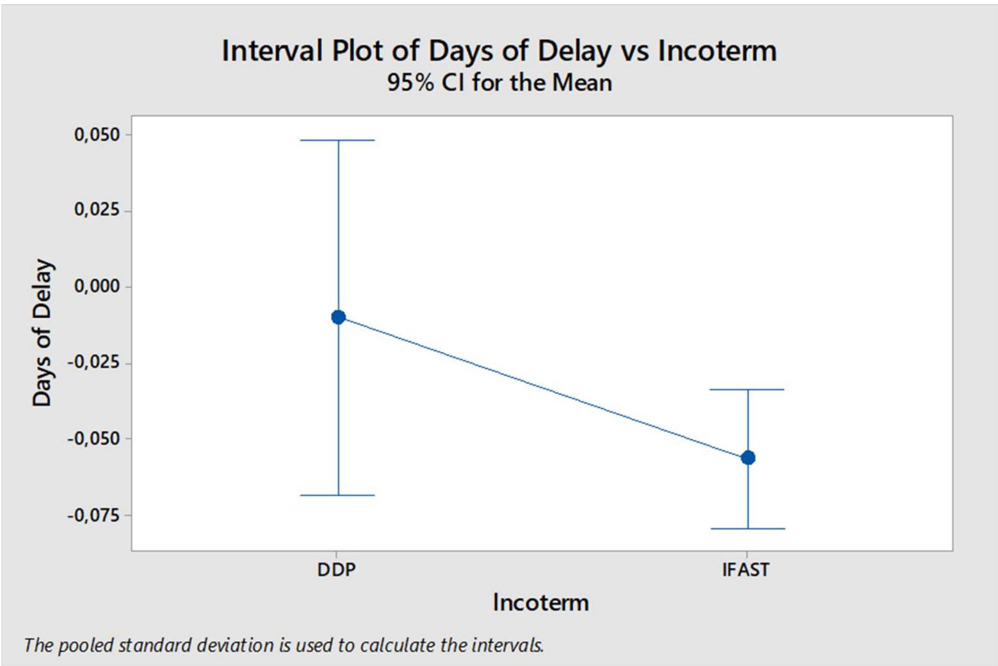


Figure 30:Interval Plot Transport Mode

Regarding the interval plot (figure 30), we can see that the confidence interval of the DDP class is widely larger than the I-FAST one and this is caused by the reduced number of elements going under the DDP class with regard to the ones in the I-FAST one. The different quantity of observations in the two levels drives to two crossing intervals, the means have different values but however are not so far each other. We have no ways to makes ulterior division to go deeply in the analysis of this factor, so we can only say that the null hypothesis cannot be rejected, we can't consider the means as different and confirm the assumption that the incoterm factor impacts on the delivery performances.

3.5. Results

Table 16:ANOVA Results

FACTOR	SUB-DIVISIONS	P-VALUE	NULL HYPOTESIS
DISTANCE		0	Refused
REGION	ITALY	0	Refused
	INTERNATIONAL	0	Refused
QUANTITY		0	Refused
FREQUENCY		0	Refused
VARIETY		0	Refused
PART TYPE		0	Refused
PLANT TYPE	BODY-MECHANICS	0,089	Accepted
	VEHICLE MODEL-MECHANICS	0	Refused
INCOTERM		0,146	Accepted

Looking at the obtained results, resumed in table 17, it is clear that the hypothesis that the considered factors influence the delivery performances are confirmed. The incoterm case is the only one that has to be refused as there aren't strong evidences on the difference between the DDP and the FCA mode. Another question to be discussed is the variety, where there is not a wide difference between the mean of the growing levels of variety but there is a huge difference concerning the 0 variety.

From the analysis of the region it emerges that the local deliveries register better results which confirms the effect that can derive from the presence of customs and borders. It is difficult to define a correct strategy to face this problem: the idea to give preference to the local suppliers seems to solve the issue, but goes against the actual market trend toward the globalisation. In any case these elements concerning the difference between countries have to be taken in consideration in the supplier selection but also in the supplier evaluation as overlooking this question can damage the extra-Schengen suppliers that have usually more to deal with the waiting time at the customs. Another point is the case of less economical developed countries that can be cause of more uncertainty in the deliveries.

Concerning the other factors, we can say that after a certain level an increasing supplier distance increases also the early deliveries. Instead, frequent and numerous deliveries give origins to better results, but on the other hand a reduction in the number of suppliers, having less actors doing more shipments each, can increase the risks. The complexity of the shipped part (dimension, shape, production cost) impacts at two levels, considering the part type but also the plant type.

The obtained results are in general in line with our expectation but what is unexpected is the presence of a big number of early deliveries. This phenomenon has to be taken into account while monitoring the KPI. Usually, and FCA is an example, in the evaluation of the targets for the on-time deliveries the advances are considered at the same way as if they were on-time. A lower impact is recognised to the advances with respects to the production while a delay is seen as a possible cause of stops in the production and of huge losses. The use of penalties to avoid productions stops conducts the suppliers to prefer to obtain more early deliveries with respect to a delay, so a major uncertainty brings the supplier to declare longer lead times to avoid late deliveries. To prevent this effect and to really test the quality of the information more attention must be put also to the early deliveries.

3.6. Limitations and future developments

The response considered is the difference between an estimated data obtained from the supplier (the "estimated date of arrival") and a data obtained from the plant (the "take in charge" date), so the realised analysis includes not only the physical causes influencing the deliveries but also the factors linked to the information quality and to the policies followed by the management of the suppliers. This study must be interpreted as an analysis of the delays with respect to the previsions, so as an evaluation of the forecast quality.

A further analysis should firstly eliminate the influence of the already explained advances effect for example doing an analysis in a system without differences of evaluation between advances and delays or using interview to assess the real impact of this phenomenon.

Considered the nature of the data, in some cases it has been impossible to define classes with the same numerousness and this could have influenced some results. In this regard, also the correlation between the different factors can be considered to increase the value of further researches. The focus on a single process has already allowed the isolation of the analysed system from the major influences, for example the production uncertainty, but more steps can be done in this sense.

The current study has been done on a daily basis, but as the systems becomes increasingly focused on the due date a more detailed analysis can be realised regarding the delays in terms of hours or turns. The number of on-time deliveries is already high and more and more companies require not only a delivery in a specific date but a delivery in a specific time of the day.

The database we've used concerns the only FCA trucks deliveries in the EMEA region for some Italian Plants, so a further analysis can be extended to the whole FCA network but also to other companies. Moreover, other causes not possible to evaluate starting from our data can be considered, like the quantity of parts for each delivery or the loading level of the trucks.

The analysis of deliveries realised only by trucks on road can be a limitation, the impact of the different mean of transport is important for the delivery performance. The air transport is often used for the urgent deliveries (a more expensive and rapid transport is taken more under control) while the naval transport is usually measured with a different metric and more delays are permitted (in some cases two days of delays is considered as an on-time delivery).

The extension to all the means of transport can gain importance if done in parallel with the extension to the global network.

The extension of the analysis not only to the EMEA region but to the entire FCA network strongly increases the complexity at the management level. The longer distances, the bigger cultural differences and also the higher difficulties in term of integration of the information systems play their role.

CONCLUSIONS

The work of this thesis follows the purpose to recognise and analyse the main causes at the basis of the transport delivery delays to understand how and in what measure they impact. From the results of the analysis the influence of the defined factors (the distance, the region, the quantity and frequency, the variety, the part and the plant type) has been confirmed.

This work tries to cover a gap in the literature as it realises a study directly on the causes linked only to the transport process and gives space to further studies. Some emerged evidences show the need for always more detail to really understand the mechanisms under the delivery problems starting from the data and not only from impressions and hypotheses.

Always considering the need for a holistic view in the analyses, the method used in this work starts from the opposite concept. In fact, it consists in the isolation of the considered process, in this case the transport one, to better understand the single mechanisms without the influences of the other processes and to permit later to return to the overall view with more consciousness of the different parts working to develop the total system.

In particular, the analysis uses different means to obtain better results, it consists in starting from the hypothesis obtained from the literature, looking at the evidences emerged from the data and searching the correspondences between the two also with the support of the experience derived from the practice.

The result is, in a certain sense, an analysis of the supplier issues made from customer's point of view. From another perspective, it permits to evaluate not only the suppliers but also the carriers and this is more important everyday, if we consider the increasing diffusion of TPL, to obtain the better performances from the transport process.

This work can impact on the data quality used in traceability processes or more in general on the estimation of the right delivery date. A good data quality can be an added value giving useful information on the delivery timing. A reliable information on the delivery can be used to calculate the material coverage for the plant considering also the travelling as available at the date of the expected arrival. This and the reduction not only of the delays but also of the early delivery can conduct to a decrease in the cost of inventory, indeed with a reliable delivery timing less safety stocks are necessary and the inventory doesn't need any more to be overblown to accommodate the early deliveries.

Sometimes knowing the causes is not sufficient to improve the results but, in every case, a major comprehension of the supplier's mechanisms and of their issues (ex. customs and part complexity) permits to obtain better and more significant KPI and to definitively let go of the idea of the relationship between suppliers and customers as an antagonistic one, where the more powerful impose his rules on the weaker, for an idea of a supplier relationship more and more transparent and collaborative that permits to define common goals and to use the co-working to find the optimal problems solutions.

All these considerations gain more importance considering the high complexity of the automotive network and components and drives to the fact that in this industry the supplier choice cannot be based on the only price factor anymore.

REFERENCES

Ackoff, R. (1971). Towards a system of systems concepts. *Management Science, 17*(11), 661-71.

Ahmad, S., & Schroeder, R. (2001). The impact of electronic data interchange on delivery performance Production and Operations Management. *10*(1), 16-30.

APICS. (2017). FCA Supply Chain Academy Foundation Modules.

Cai, J., Liu, X., Xiao, Z., & Liu, J. (2009). Improving supply chain performance management: A systematic approach to analyzing iterative KPI accomplishment. *Decision support systems, 46*(2), pp. 512-521.

Christopher, M., & Peck, H. (2004). Building the resilient supply chain. *The international journal of logistics management, 15*(2), 1-14.

Dearing, B. (1990). The Strategic Benefits of EDI. *The Journal of Business Strategy, 11*(1), 4-6.

FCA. (2014). *2013 Sustainability Report.* Retrieved from https://www.fcagroup.com/en-US/sustainability/overview/pubblicazioni/FiatDocuments/2013_sustainability_report.pdf#start

FCA. (2018). *2017 Annual Report.* Retrieved from https://www.fcagroup.com/en-US/investors/financial_regulatory/financial_reports/files/FCA_NV_2017_Annual_Report.pdf

FCA. (2018). *2017 Sustainability Report.* Retrieved from https://www.fcagroup.com/en-US/investors/financial_information_reports/sustainability_reports/sustainability_reports/FCA_2017_Sustainability_Report.pdf

FCA. (2018). *Supplier Management Principles.* Retrieved from https://www.fcagroup.com/en-US/sustainability/FiatDocuments/Supplier_Management_Principles.pdf

Galbraith , J. (1973). *Designing Complex Organizations.* U.K., London: Addison-Wesley.

Ghemawat, P. (2001). Distance still matters. *Harvard business review, 79*(8), 137-147.

Giunipero, L., & Aly Eltantawy, R. (2004). Securing the upstream supply chain: a risk management approach. *International Journal of Physical Distribution & Logistics Management, 34*(9), 698-713.

Gordon, S. (2005). Seven steps to measure supplier performance. *Quality progress, 38*(8), pp. 20-25.

Gronberg, T., & Meyer, J. (1982). Spatial Pricing and Its Effects on Product Transportability. *The Journal of Business, 55*(2), 269-280.

Harland, C., Brenchley, R., & Walker, H. (2003). Risk in supply networks. *Journal of Purchasing and Supply management, 9*(2), 51-62.

Hart, P., & Saunders, C. (1997). Power and trust: Critical factors in the adoption and use of electronic data interchange. *Organization science, 8*(1), 23-42.

Hertz, S., & Alfredsson, M. (2003). Strategic development of third party logistics providers. *Industrial marketing management, 32*(2), 139-149.

Holweg, M. (2005). An investigation into supplier responsiveness: Empirical evidence from the automotive Industry. *The International Journal of Logistics Management, 16*(1), 96-119.

Hornby, G., Goulding, P., & Poon, S. (2002). Perceptions of export barriers and cultural issues: the SME e-commerce experience. *Journal of Electronic Commerce Research, 3*(4), 213-226.

INTERNATIONAL CHAMBER OF COMMERCE. (2010). *Incoterms rules 2010.* Retrieved from https://iccwbo.org/resources-for-business/incoterms-rules/incoterms-rules-2010/

Javalgi, R., & Ramsey, R. (2001). Strategic issues of e-commerce as an alternative global distribution system. *International marketing review, 18*(4), 376-391.

Jüttner, U., Peck, H., & Christopher, M. (2003). Supply chain risk management: outlining an agenda for future research. *International Journal of Logistics: Research and Applications, 6*(4), 197-210.

Kaufmann, J., & Schering, A. G. (2014). Analysis of variance ANOVA.".

Kritchanchai, D., & MacCarthy, B. (1999). Responsiveness of the order fulfilment process. *International Journal of Operations & Production Management,, 19*(8), 812-833.

Lambert, D., & Cooper, M. (2000). Issues in supply chain management. *Industrial marketing management, 29*(1), 65-83.

Limão, N., & Venables, A. (2001). Infrastructure, Geographical Disadvantage, Transport Costs, and Trade. *The World Bank Economic Review, 15*(3), 451-479.

McGinni, M. (1979). Shipper Attitudes Toward Freight Transportation Choice: A Factor Analytic Study. *International Journal of Physical Distribution & Materials Management, 10*(1), 22-34.

Medini, K., & Boucher, X. (2015). Decision making support to steer offering variety during production planning. *Procedia CIRP, 30*, 486-491.

Park, S., & Hartley, J. (2002). Exploring the effect of supplier management on performance in the Korean automotive supply chain. *Journal of Supply Chain Management, 38*(1), pp. 46-53.

Peck, H. (2005). Drivers of supply chain vulnerability: an integrated framework. *International journal of physical distribution & logistics management, 35*(4), 210-232.

Sadraoui, T., & Mchirgui, N. (2014). Supply Chain Management Optimization within Information System Development. *International Journal of Econometrics and Financial Management, 2*(2), 59-71.

Salvador, F., Forza, C., & Rungtusanatham, M. (2002). Modularity, product variety, production volume, and component sourcing: theorizing beyond generic prescriptions. *Journal of operations management, 20*(5), 549-575.

Slack, N. (2005). The changing nature of operations flexibility. *International Journal of Operations & Production Management, 25*(12), 1201-1210.

Speranza, M. (2018). Trends in transportation and logistics. *European Journal of Operational Research, 264*(3), pp. 830-836.

Stępniak, M., & Piotr, R. (2016). From improvements in accessibility to the impact on territorial cohesion: the spatial approach. *Journal of Transport and Land Use, 9*(3), 1-13.

Thun, J.-H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. *International journal of production economics, 131*(1), 242-249.

Turner, K., & Williams, G. (2005). Modelling complexity in the automotive industry supply chain. *Journal of Manufacturing Technology Management, 16*(4), 447-458.

Tushman, M., & Nadler, D. (1978). Information processing as an integrating concept in organizational design. *Academy of management review, 3*(3), 613-624.

Ulrich, K. (1995). The role of product architecture in the manufacturing firm. *Research policy, 24*(3), 419-440.

Vachon, S., & Klassen, R. (2002). An exploratory investigation of the effects of supply chain complexity on delivery performance. *IEEE Transactions on engineering management, 49*(3), 218-230.

Valentini, R. (2010). *Automobili e Materiali.* Retrieved from www1.diccism.unipi.it: http://www1.diccism.unipi.it/Valentini_Renzo/es%20Metallurgia%20Meccanica/automotive.pdf

Vicario, G., & Levi, R. (2009). *Metodi statistici per la sperimentazione.* Società Editrice Esculapio.

Wilding, R. (1998). The supply chain complexity triangle: uncertainty generation in the supply chain. *International Journal of Physical Distribution & Logistics Management, 28*(8), 599-616.

Winston, C. (1985). Conceptual Developments in the Economics of Transportation: An Interpretive Survey. *Journal of Economic Literature, 23*(1), 57-94.

SITOGRAPHY

(1) https://blog.optimumdesign.com/on-time-delivery-defined

(2) http://www.leanmanufacture.net/kpi/ontimedelivery.aspx

(3) https://www.edibasics.com/what-is-edi/

(4) https://www.fcagroup.com/it-IT/group/history/Pages/default.aspx

(5) http://www.rainews.it/dl/rainews/articoli/Da-Fiat-ad-Fca-le-tappe-della-fusione-dal-2009-allo-sbarco-a-Wall-Street-b7f5960c-5429-473f-90f4-af9ed6cf0190.html

(6) https://www.fcagroup.com/it-IT/group/Pages/group_overview.aspx

(7) https://www.fcagroup.com/it-IT/media_center/fca_press_release/FiatDocuments/2018/july/Comunicazione_FCA.pdf

(8) https://www.fcagroup.com/it-IT/media_center/fca_press_release/FiatDocuments/2018/october/Calsonic_Kansei_e_Magneti_Marelli_Comunicato_Stampa.pdf

(9) https://www.wsw-software.de/en/news/?no_cache=1&tx_ttnews%5Btt_news%5D=75

(10) http://static.gest.unipd.it/~livio/PDF/PDF_CIVILE/Elementi%20di%20statistica%20descrittiva.pdf

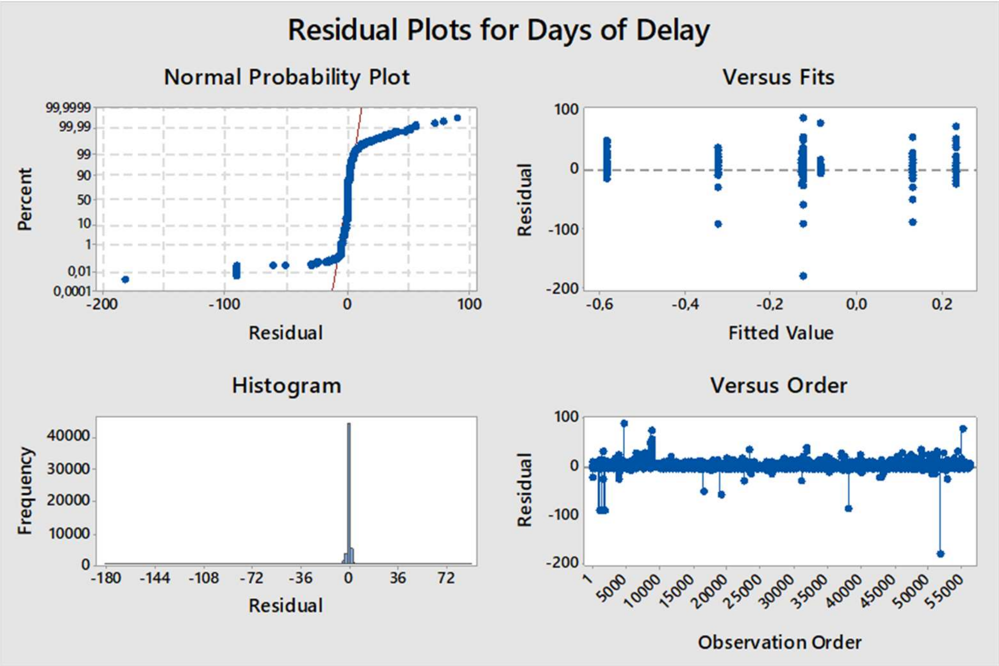
(11) https://support.minitab.com/en-us/minitab-express/1/help-and-how-to/graphs/probability-plot/interpret-the-results/all-statistics/probability-plot-with-normal-fit/

(12) https://towardsdatascience.com/understanding-the-central-limit-theorem-642473c63ad8

(13) http://www.europarl.europa.eu/news/it/headlines/eu-affairs/20180525STO04311/schengen-quali-sono-le-questioni-da-risolvere Controlli alle frontiere interne: quanto costano e a chi si rivolgono
(14) https://www.internazionale.it/notizie/2015/09/15/come-funziona-lo-spazio-schengen-mappa
(15) http://www.differencebetween.net/miscellaneous/politics/differences-between-schengen-countries-and-eu-countries/#ixzz5VntzWTRb
(16) http://classeuractiv.it/news/schengen-un-report-tedesco-minimizza-l-impatto-economico-di-un-eventuale-crollo-201604191210093894
(17) https://geograficamente.wordpress.com/2015/01/05/macroregioni-al-posto-delle-regioni-superare-al-piu-presto-le-obsolete-regioni-con-aree-territoriali-demograficamente-e-geomorfologicamente-omogene-e-il-progetto-macroregioni/
(18) https://unstats.un.org/unsd/methodology/m49/
(19) www.quattroruote.it/listino/

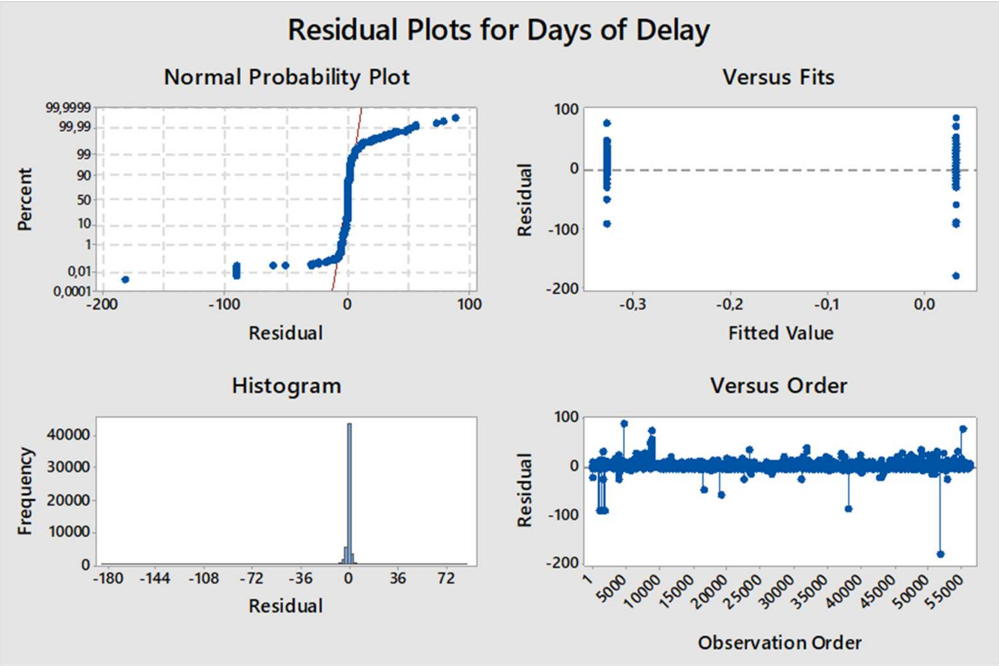
APPENDIX I: The residual value plots

Distance

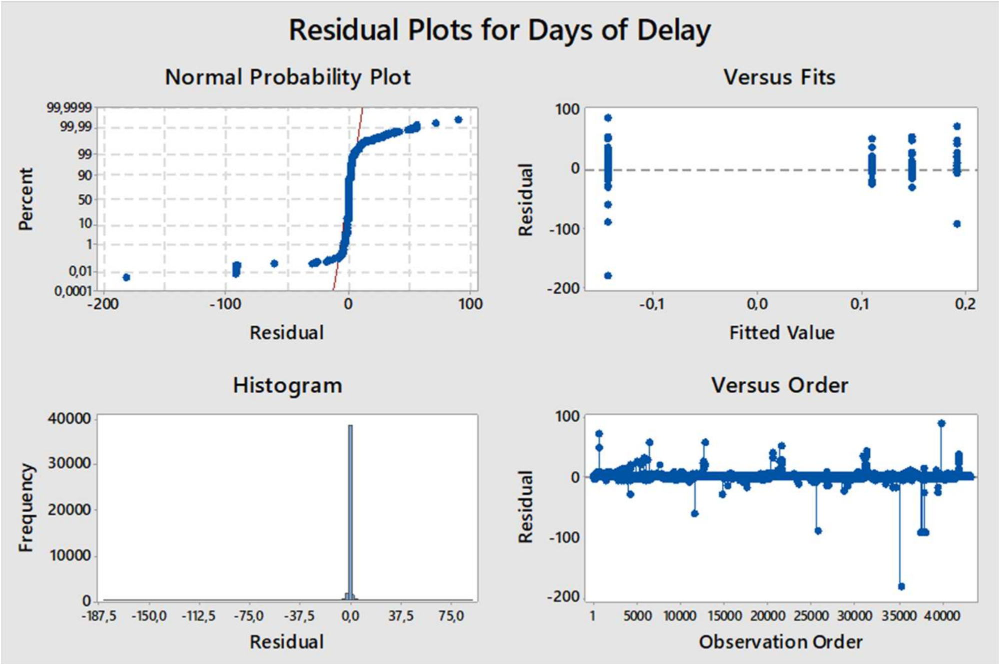


Region

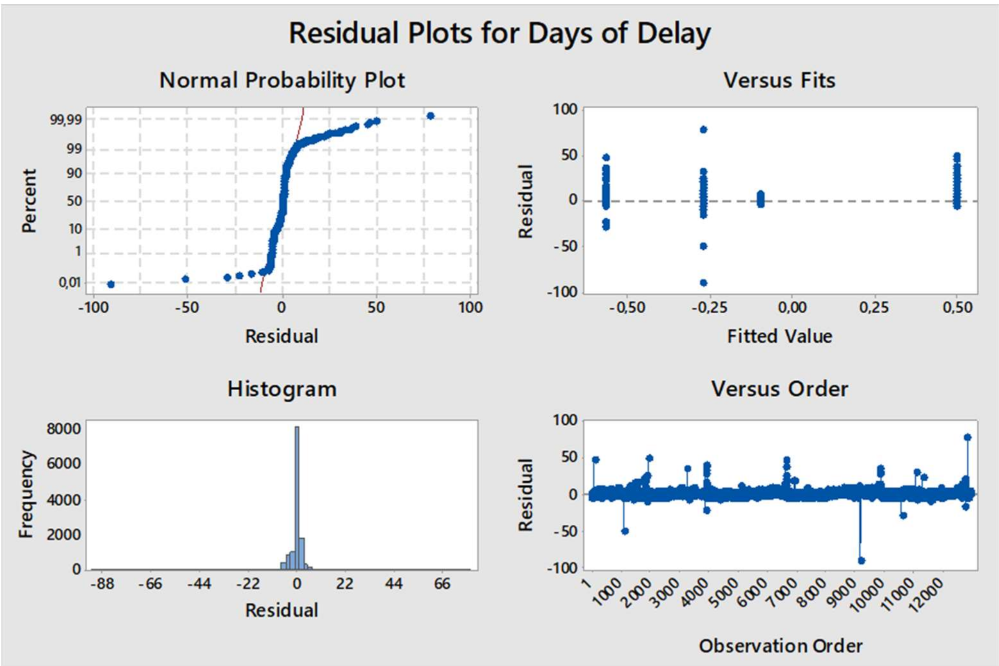
Italy VS Others



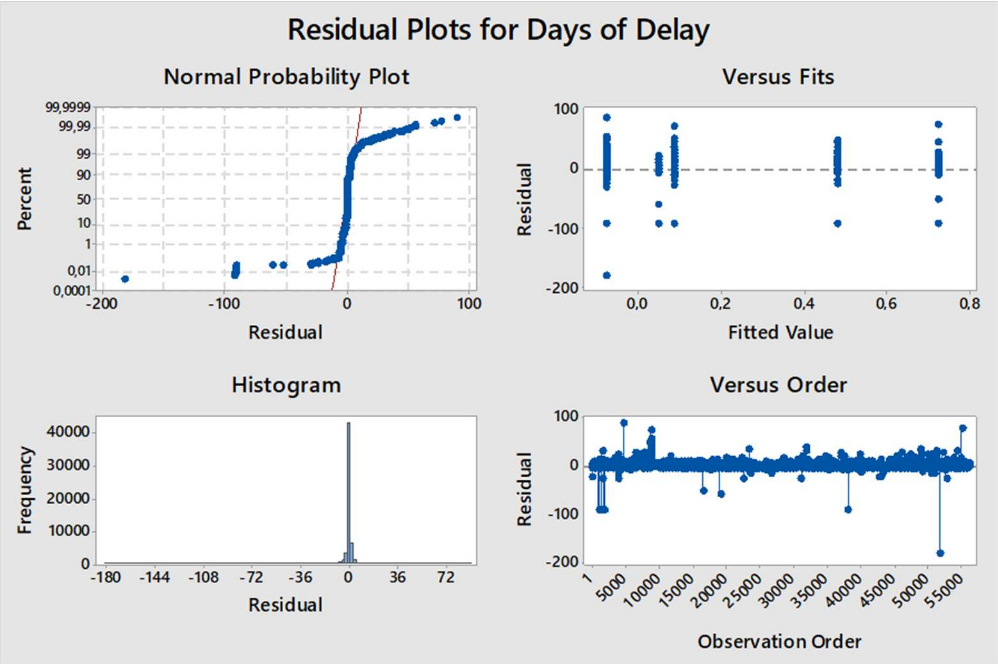
ITALY



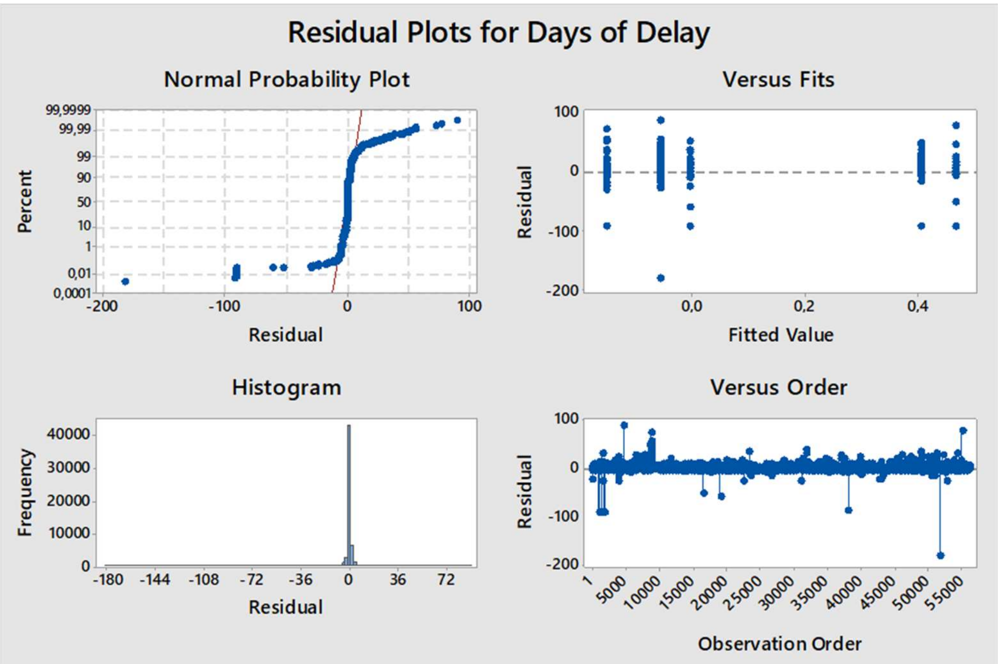
OTHER REGIONS



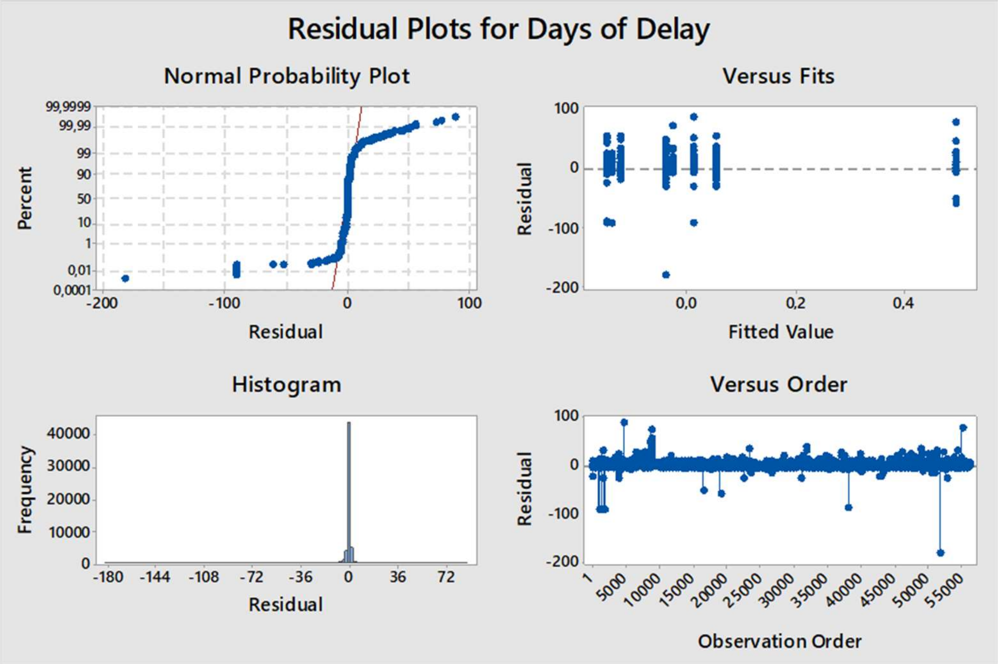
Frequency



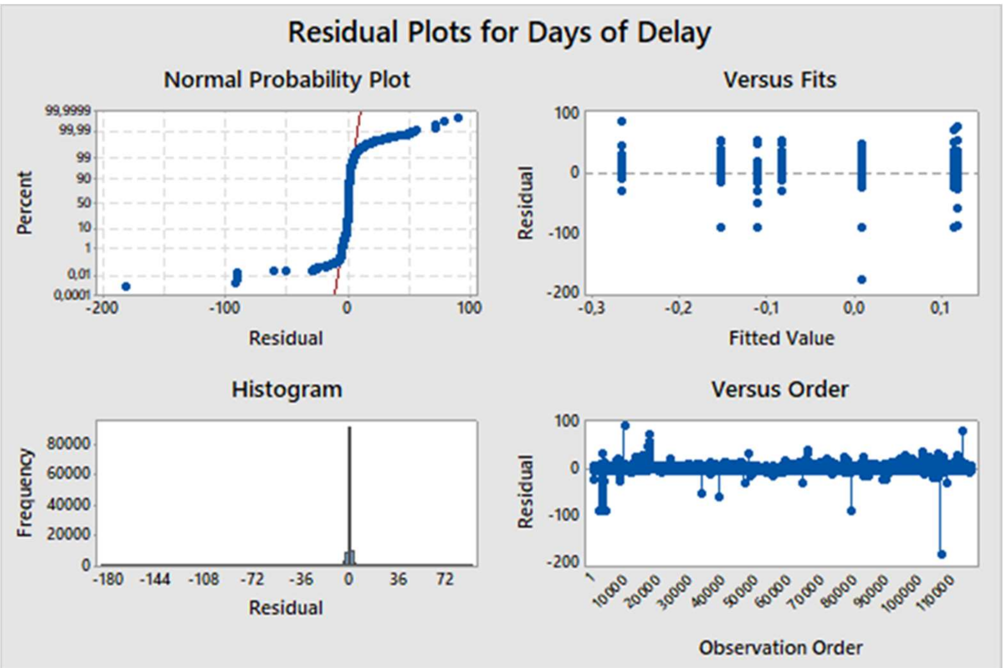
Quantity



Variety

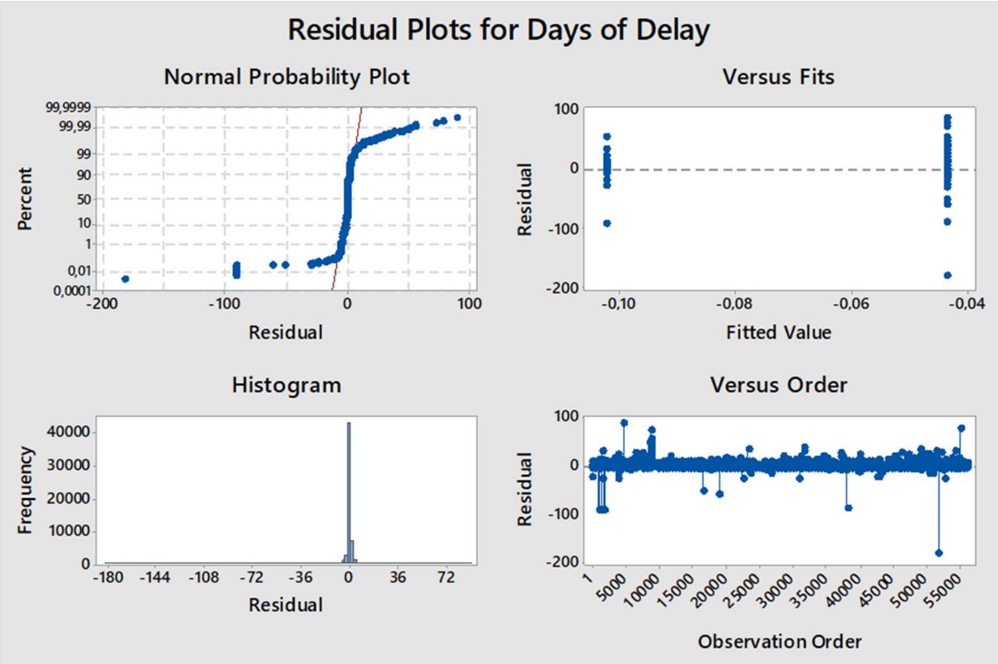


Part type

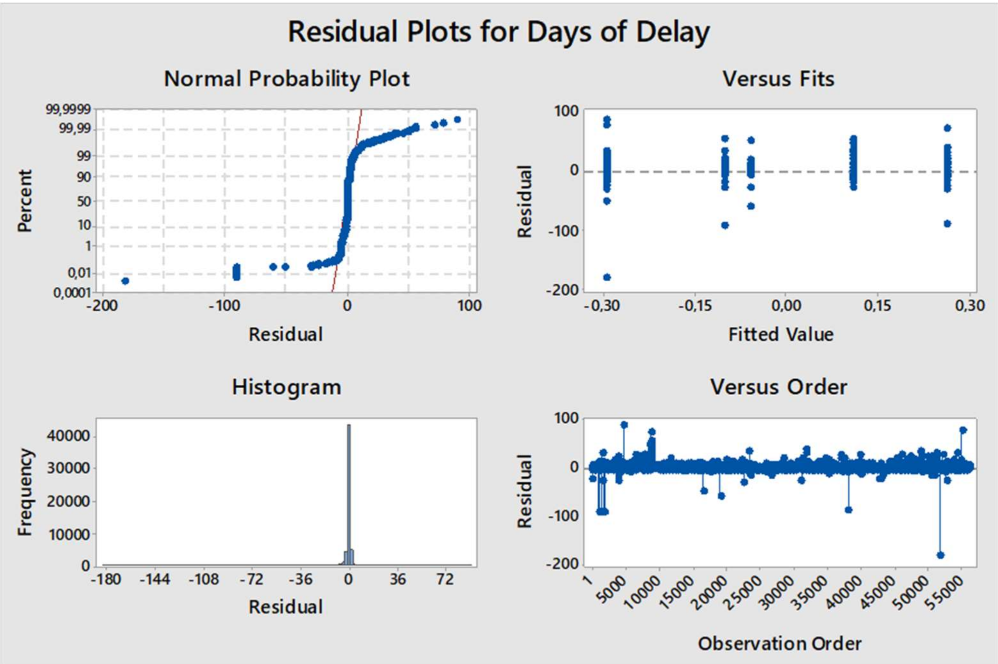


Plant type

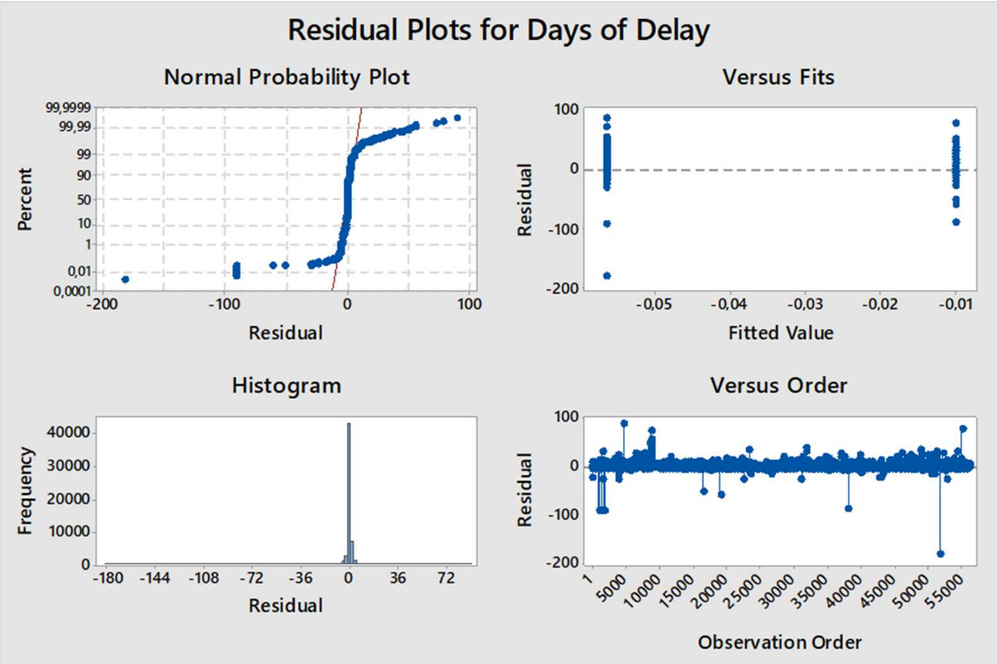
Body VS Mechanics



Model produced



Transport mode



APPENDIX II: The analysis on the supplier base

Frequency

Factor Information

Factor	Levels	Values
Cluster frequency	5	EACH 3-4-5 DAYS; EACH TWO DAYS; LESS THAN ONCE A WEEK; ONCE A DAY; TWICE A DAY

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Cluster frequency	4	106,6	26,64	1,96	0,100
Error	658	8961,9	13,62		
Total	662	9068,5			

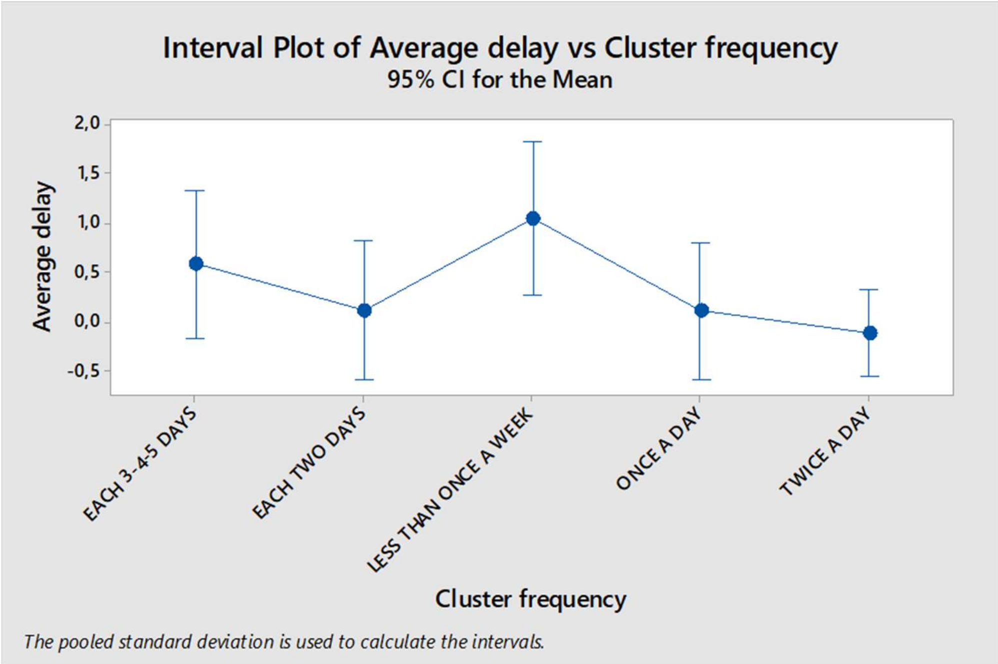
Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
3,69052	1,17%	0,57%	0,00%

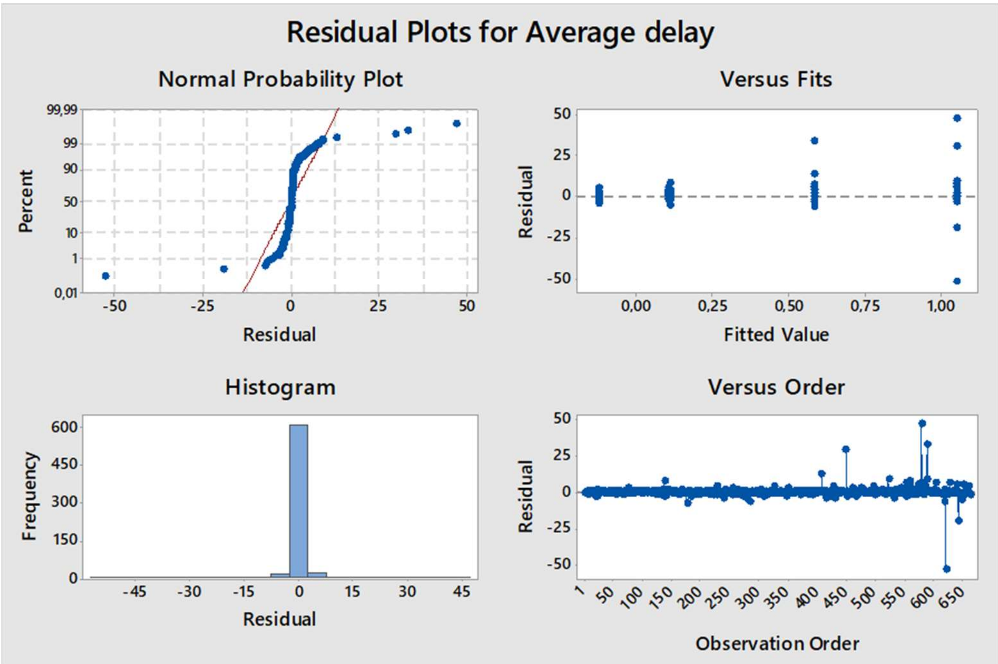
Means

Cluster frequency	N	Mean	StDev	95% CI
EACH 3-4-5 DAYS	91	0,581	4,168	(-0,179; 1,340)
EACH TWO DAYS	105	0,111	1,332	(-0,596; 0,818)
LESS THAN ONCE A WEEK	88	1,048	8,884	(0,276; 1,821)
ONCE A DAY	106	0,103	1,041	(-0,601; 0,807)
TWICE A DAY	273	-0,1215	0,9258	(-0,5601; 0,3171)

Pooled StDev = 3,69052



Interval Plot of Average delay vs Cluster frequency
95% CI for the Mean
Average delay
2,0
1,5
1,0
0,5
0,0
-0,5
EACH 3-4-5 DAYS
EACH TWO DAYS
LESS THAN ONCE A WEEK
ONCE A DAY
TWICE A DAY
Cluster frequency
The pooled standard deviation is used to calculate the intervals.



Residual Plots for Average delay
Normal Probability Plot
Percent
Residual
Versus Fits
Residual
Fitted Value
Histogram
Frequency
Residual
Versus Order
Residual
Observation Order

Quantity

Factor Information

Factor	Levels	Values
Cluster quantity	5	HIGH; LOW; MEDIUM; MIDDLE-LOW; UPPER-MIDDLE

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Cluster quantity	4	80,90	20,22	1,48	0,206
Error	658	8987,57	13,66		
Total	662	9068,46			

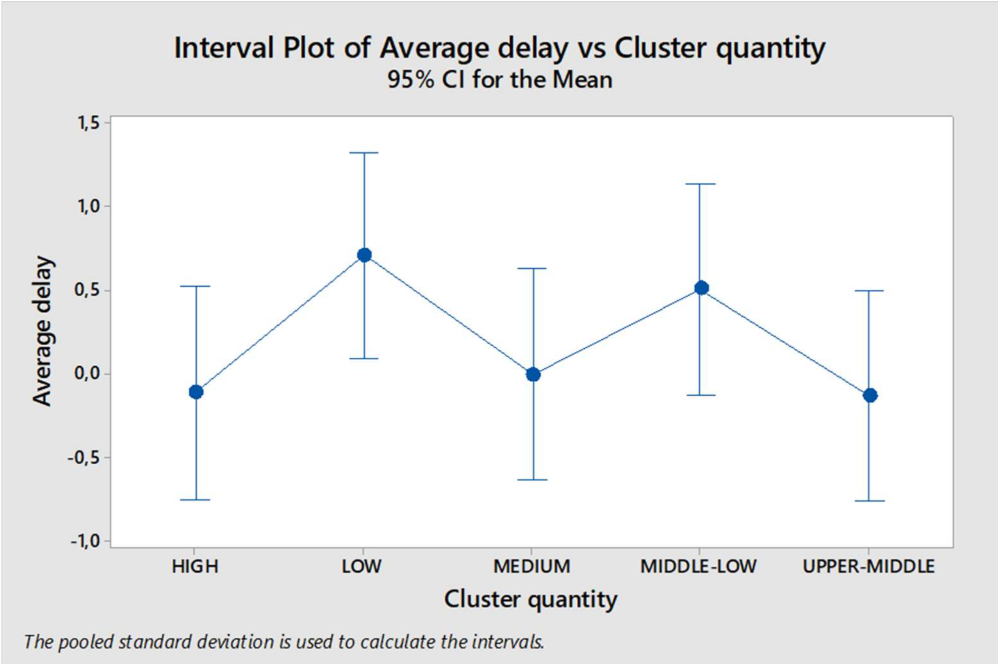
Model Summary

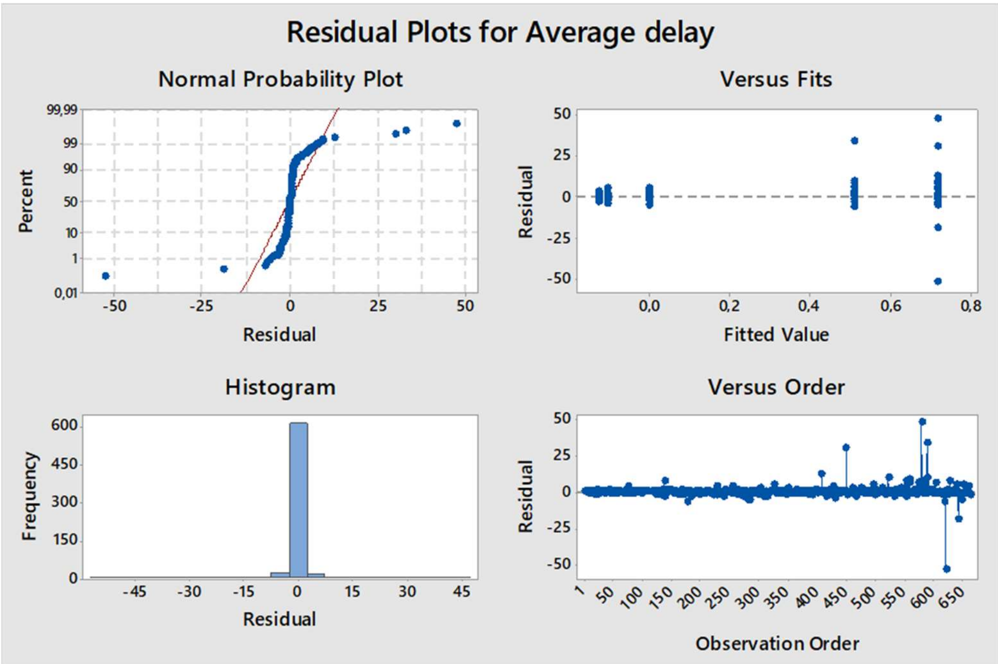
S	R-sq	R-sq(adj)	R-sq(pred)
3,69580	0,89%	0,29%	0,00%

Means

Cluster quantity	N	Mean	StDev	95% CI
HIGH	130	-0,1067	0,8383	(-0,7432; 0,5297)
LOW	138	0,716	7,195	(0,098; 1,333)
MEDIUM	133	0,001	1,173	(-0,628; 0,630)
MIDDLE-LOW	130	0,510	3,464	(-0,126; 1,147)
UPPER-MIDDLE	132	-0,1278	0,7555	(-0,7594; 0,5039)

Pooled StDev = 3,69580


Interval Plot of Average delay vs Cluster quantity
95% CI for the Mean
Average delay
1,5
1,0
0,5
0,0
-0,5
-1,0
HIGH
LOW
MEDIUM
MIDDLE-LOW
UPPER-MIDDLE
Cluster quantity
The pooled standard deviation is used to calculate the intervals.


Residual Plots for Average delay
Normal Probability Plot
Percent
Residual
Versus Fits
Residual
Fitted Value
Histogram
Frequency
Residual
Versus Order
Residual
Observation Order

Variety

Factor Information

Factor	Levels	Values
Cluster variety	8	0 VARIETY; FIFTH LEVEL OF VARIETY; FIRST LEVEL OF VARIETY; FOURTH LEVEL OF VARIETY; HIGH VARIETY; SECOND LEVEL OF VARIETY; SIXTH LEVEL OF VARIETY; THIRD LEVEL OF VARIETY

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Cluster variety	7	100,1	14,30	1,04	0,399
Error	655	8968,4	13,69		
Total	662	9068,5			

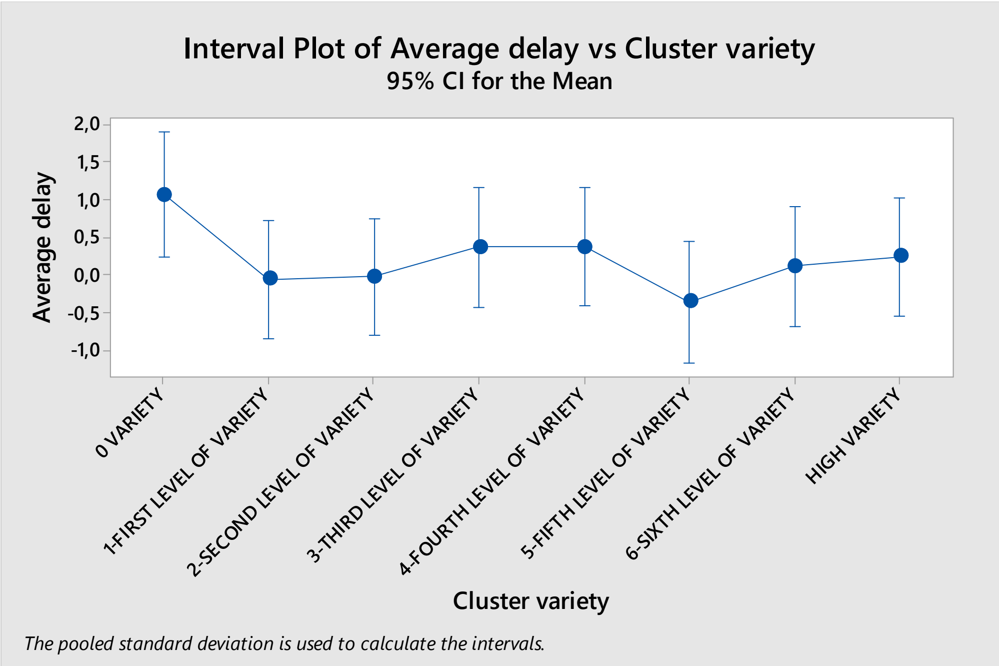
Model Summary

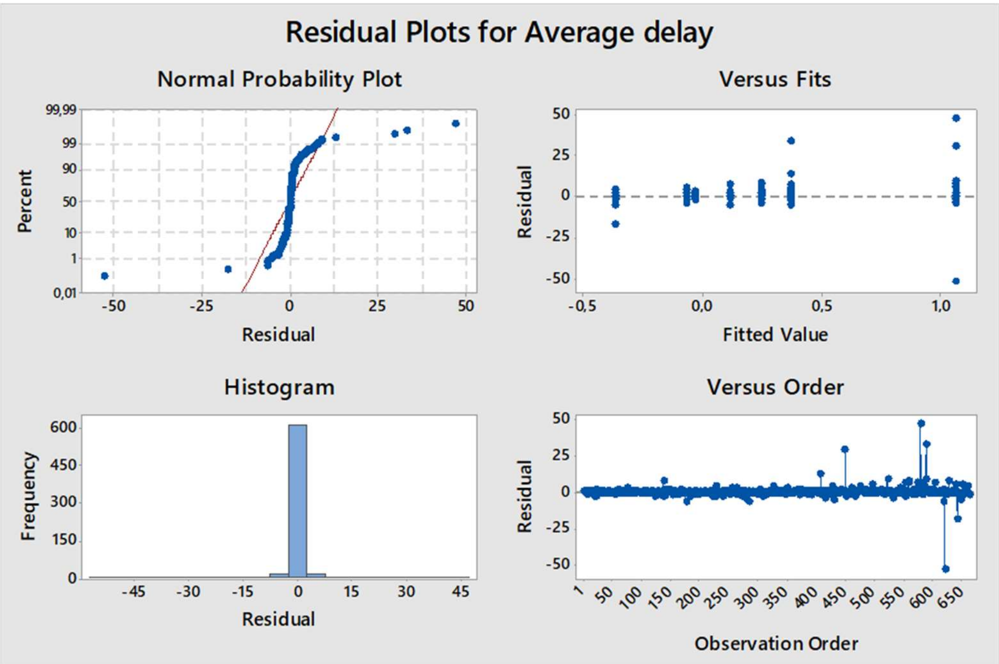
S	R-sq	R-sq(adj)	R-sq(pred)
3,70030	1,10%	0,05%	0,00%

Means

Cluster variety	N	Mean	StDev	95% CI
0 VARIETY	77	1,06	9,21	(0,24; 1,89)
FIFTH LEVEL OF VARIETY	82	-0,368	2,370	(-1,170; 0,435)
FIRST LEVEL OF VARIETY	85	-0,067	1,049	(-0,855; 0,721)
FOURTH LEVEL OF VARIETY	83	0,371	2,072	(-0,427; 1,168)
HIGH VARIETY	85	0,244	1,836	(-0,544; 1,033)
SECOND LEVEL OF VARIETY	86	-0,0326	0,7040	(-0,8161; 0,7509)
SIXTH LEVEL OF VARIETY	82	0,114	1,231	(-0,689; 0,916)
THIRD LEVEL OF VARIETY	83	0,366	3,787	(-0,431; 1,164)

Pooled StDev = 3,70030


Interval Plot of Average delay vs Cluster variety
95% CI for the Mean
Average delay
2,0
1,5
1,0
0,5
0,0
-0,5
-1,0
0 VARIETY
1-FIRST LEVEL OF VARIETY
2-SECOND LEVEL OF VARIETY
3-THIRD LEVEL OF VARIETY
4-FOURTH LEVEL OF VARIETY
5-FIFTH LEVEL OF VARIETY
6-SIXTH LEVEL OF VARIETY
HIGH VARIETY
Cluster variety
The pooled standard deviation is used to calculate the intervals.


Residual Plots for Average delay
Normal Probability Plot
Percent
Residual
Versus Fits
Residual
Fitted Value
Histogram
Frequency
Residual
Versus Order
Residual
Observation Order