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# **A metric to characterize major innovation sequences and its application in three industrial sectors: from random emergence to waterfall phenomena**

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## Abstract:

*Are Major innovations rare or frequent? Is there any relationship between major innovations? Do major innovations occur independently of the others? In order to answer these questions, we build a new tool of measuring major innovations sequences, based on Lancaster's approach to consumer theory. This new tool allows us to characterize major innovation sequences and its application in three industrial sectors (Mobile phone, Iron, Automobile).*

*The main results of our empirical work show that Major Innovations (MI) are not rare and reveal the existence of a relationship – with a chain reaction effect- between successive major innovations. This article treats especially major innovations and it focuses on characterizing the sequences and the increasing rhythm of major innovations.*

## **Introduction:**

The identification of innovation types and their influence on the marketplace is really an old problem (Schumpeter 1939), and there are a lot of features to characterize one single innovation (major, disruptive, breakthrough...) but very few measurements to characterize a sequence related to major innovations. These mentioned models would suggest measuring not only the type but also the frequency of innovations, and the relationship between innovations along a certain sequence.

More specifically, contemporary models consider that there is at least a form of continuous, incremental innovation. Our question is on contemporary innovation capabilities that support so-called "major" innovations (Veryzer 1998, O'Connor 2006) ie disruptive, breakthrough, or discontinuous innovation. Several scholars suggest that major innovations are rare and difficult to be measured. However, some scholars as the dynamic capabilities stream (Danneels, E. 2002, O'Connor, 2006), suggests that major innovations can be organized and structured within the firm. Major changes serve to develop firm competences and thus contribute to firm renewal over time. That means that major innovations are particularly important in the current dynamic environment. However, with this viewpoint, the frequency of major innovations is not studied (they are frequent or rare), also the degree of interdependency between different major innovations is indirectly treated (Danneels, 2002).

The purpose of this article is to develop new methodology to measure major innovations then to study the frequency and to clarify the interdependency between different major innovations.

The remainder of this paper is organized as follows: First, the literature is reviewed to show different researches' viewpoint over the major innovations, then to construct our hypothesis. Also to show the lack concerning the quantitative measurement of major innovations sequences. Then, the article explains the followed methodology and the results of our

empirical work. The hypotheses are tested on a three different sectors. The paper concludes with a summary; avenues for future research and managerial implications.

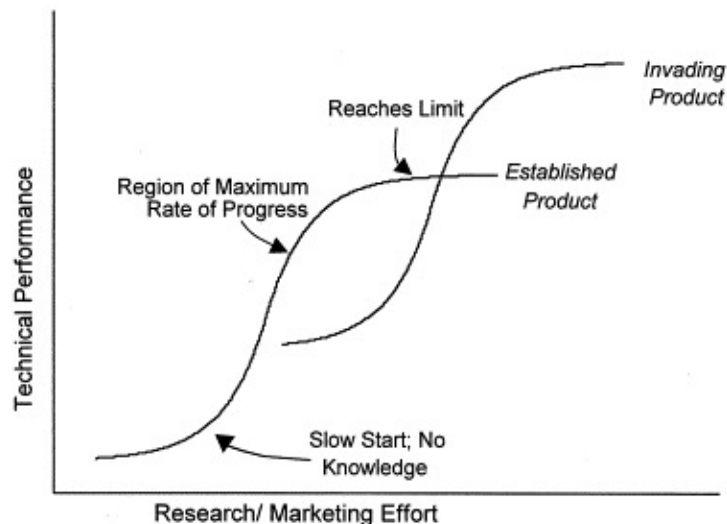
## 1. Major innovations sequences: Literature review and research questions

Several scholars suggested that major innovations are rare. Even during periods in which overall rates of change are high, there will be relatively few radical or major innovations. Major innovations usually occur independently of other major innovations. In other words, literatures suggest that there is no relationship between major innovations within a given sector.

### 1.1 Frequency of major innovations:

Several research works have suggested that major innovations are rare. According to Rothwell and Gardiner (1988), major innovation introduces a new type of product on the market, e.g. the jet engine versus piston engine or the personal microcomputer versus mainframe computer, then, this major innovation will be followed by a series of minor modifications (incremental innovations) until the introduction of other new type of product. Indeed, if we consider a new type of product as a reference to measure major innovations during time, the authors estimated that only 10% of all new innovations fall into the category of radical or major innovations and incremental innovations cover 90% of the remaining cases. That means that major innovations are rare. The punctuated equilibrium model of change confirms that long periods of small incremental change are disconnected by brief periods of discontinuous, major, radical change (Abernathy and Utterback 78; Tushman and Anderson 86; Rosenkopf and Tushman 95). Like a Darwinian theory, which discuss the notion of punctuated equilibrium, which means that such long periods of gradual change were interrupted periodically by massive discontinuities. In addition, Foster's works give a tool that can aid in the identification of radical innovations' behavior. This tool is the technology S-Curve introduced by him in 1986 (Figure.1).

Figure.1. Technology/Marketing S-Curve Phenomena (Adapted from Foster 1986)



The S-curve has been used to describe the origin and evolution of technologically radical innovations (Utterback and Abernathy, 1996; Utterback, 1996). This theory suggests that technological changes moves along an S-curve until technical limitations cause research effort,

time, and/or resource inefficiencies to result in diminishing returns. New innovations replace the old technology and a new S-Curve is initiated (see Figure.1).

In addition to the management and marketing literature concerning the scarcity of major innovations, economists were also interested in it. Lancaster (1966a) was aware of innovation and dedicated an important part of his work on this issue. He introduced the idea that goods are consumed for the characteristics that they possess, and he describes goods not merely as goods but takes them as an input to the consumption function, which gives in characteristics of goods as outputs; According to him, new goods could be regarded solely as a combination of existing characteristics in new proportions or as an improvement in the performance of certain characteristics. Lancaster’s model encompasses innovations, which are due to combinations of characteristics or to a performance improvement in the characteristics, and excludes the innovations, which could be due to the addition of characteristics that are not possessed by any existing good. According to Lancaster there is no revolutionary good that integrates characteristics, which are not possessed by any existing good (Lancaster, 1966a). That means that major changes are really rare.

These different viewpoints suggested that major innovations are rare and not frequent (Table.1 summarizes different viewpoints concerning the frequency of major innovations).

Table.1 Major/Radical innovations and different viewpoints:

<b>Authors</b>	<b>Innovations</b>	<b>Frequency</b>
<b>Lancaster 1966</b>	Revolutionary	Rare
<b>Tushman and Anderson 1986</b>	Discontinuous innovation	Not frequent
<b>Foster 1986</b>	Radical innovation	Not frequent
<b>Tushman and Anderson 1986</b>	Discontinuous/Radical	Rare
<b>Rothwell and Gardiner</b>	Major innovations	Rare
<b>Garcia and Calantone 2002</b>	Radical innovation	Extremely rare

This literature review allows us to construct the following hypothesis:

*Hypothesis 1 (H1): Major innovations are rare and not frequent.*

This first hypothesis is clearly confirmed by Lancaster’s approach, which suggests that each new good is solely a combination of existing characteristics. The punctuated equilibrium model also confirms the first hypothesis, because it suggests that long periods of small incremental change are disconnected by brief periods of major or radical change.

This article will test this hypothesis (H1), to answer the question: Are major innovations really rare?

Before doing our empirical tests, we noted that some scholars suggested that firms could implement special structures and organizations in order to increase the frequency of major innovations. This viewpoint considers that many firms compete by changing continuously, for example Intel, 3M, Apple; their ability to change is not limited. The technological discontinuities, and the continuous changes affect the firms’ organizational environment and require certain types of organizations structures. Many scholars showed that organizations structures which grouped different actors of the innovation process and which facilitate the communication between them could be particularly promising to follow the continuous change and to have repeated major innovations (Clark and Wheelwright, 1992). Brown and Eisenhardt (1997) describe organizations in which change is frequent, rapid and even endemic to the firm, this

perspective contrasts with many paradigms in organizational and strategic thinking, such as transaction cost economics, agency theory, and organization ecology, in which organizations are assumed to be static or nearly so. According to Godoe (2000), evidence from analysis of innovation in the telecom sector suggests that innovation regimes have provided a capability of coordination, direction and leadership in the creation of many of the radical technological innovations that have emerged in the sector. That means that major innovations could be coordinated. According to this point of view, we can think that major innovations could be organized and can be scheduled to be a part of the firms' strategy. That means that major innovations could be frequent and not rare.

### ***1.2 Interdependency and chain reaction effect between major innovations:***

Beyond the debate around the frequency of major innovations, the purpose of this article is to delineate the interdependency between major innovations; in other terms the relationship between new and past major innovations.

In contemporary innovation theory, the creation of incremental innovations is variously explained in terms of rational responses to markets, dynamics of technological regimes, radical innovations in contrast are explained in terms of serendipity, chance or haphazard scientific discoveries without any interdependency between them. However, building on the resource-based view of the firm, past research has emphasized leveraging firm competences to create successful products. That means that interdependency exists between past and future major innovations. The idea is to capitalize on what the firm does well. Lansiti and Clark 1994 found that building on past knowledge for current projects was related to successful product generations in the mainframe computer and auto industries. So building on the past is key to successful multiple new product innovation. Lansiti and Clark confirmed the fact that future innovations could benefit from the past innovations and the past knowledge.

In the other hand, economists as Aghion and Howitt (1992) were interested in the interdependency of innovations during the technological progress. According to them, Research firms are motivated by the prospect of monopoly rents that can be captured when a successful innovation is patented. But those rents in turn will be destroyed by the next innovation, which will render obsolete the existing intermediate good. This means that there is no interdependency between major changes and that new innovations destroy systematically the existing technology or goods. This viewpoint is contrary to the idea that interdependency between major innovations could exist and that old innovations could influence the appearance of a set of others new major innovations.

We have two different points of view concerning the interdependency between innovations. One viewpoint rejects the interdependency between major changes, because new innovations destroy the old ones, and the other point of view supports the idea that building new innovations on the past could be a key to successful innovations. So, is there any relationship between major innovations?

In order to answer this question, we should test the following hypothesis:

*Hypothesis 2 (H2): There is interdependency between major innovations. These major innovations create a chain reaction effect between them.*

This article focuses on the frequency and interdependency between major innovations and in order to reject or confirm the previous hypotheses, we need an adequate method to measure major innovations. The next part will debate the measurement of major innovations.

## **2. The measurement of major innovations:**

Several scholars were interested in the definition of innovations: incremental, continuum, breakthrough, really new, or radical and major innovations (Garcia and Calantone 2002). Different types of innovations were identified but the article's aim is to focus on major innovations and how they can be measured. What should be measured, the resources, or the results of the innovations' process? Measurement should be done within the firm or outside firms? Different scholars tried to answer these different questions concerning the measurement of innovations.

### ***2.1 Definition of innovations and the type of innovations wanted to be measured:***

Several literatures defined different types of innovations: "Incremental innovation", "Radical or major innovation" (Garcia and Calantone, 2002; Godoe, 2000; Veryzer, 1998), "Architectural or generational innovation", "Revolutionary innovation" (Abernathy and Clark, 1984), "Disruptive innovation" (Christensen, 2003).

The architectural innovation, it is defined as new technology that departs from established systems of production; Revolutionary innovation is defined as an innovation that disrupts and breaks established technical and production competence (Abernathy and Clark, 1984).

Incremental innovations can easily be defined as products that provide new features, benefits, or improvements to the existing technology, "An incremental new product involves the adaptation, refinement, and enhancement of existing products and/or production and delivery system" (Song and Montoya-Weiss, 1998). In contrast, radical innovation has been used to refer to products that involve dramatic departures from existent products or their logical extensions, it refers to a high degree of technological novelty and the company has to employ a new manufacturing process (Veryzer, 2000). Radical innovation is defined as the creation of a new line of business – New for both the firm and the marketplace (O'Connor 98).

Beyond all these different classifications of innovations, we are interested especially on the major innovations. According to O'Connor (2008) major innovation composed of both radical and really new innovation. How can we measure this type of innovation? O'Connor's definition suggests that major innovation is really new to the market or industry with the comparison of the existing things. If we take Lancaster's approach, in terms of characteristics, which are integrated to a good, major innovation will be the really new characteristics (not possessed by any existing good), which are embedded to this good. Hence, to measure major innovations we should measure new characteristics added to a given product.

The central idea of this article is to focus on major innovations and their quantitative measurement. That means that we are interested on the measurement of new characteristics of goods.

In order to capture major innovations sequences, we should have a detailed list of products' characteristics all over time. The product should be a reference, which allows us to capture major innovation on a given industry. However, how can we measure major innovations when the previous conditions are not available? For example, when we don't have a unique product reference. In the Sport sector, we find several product references because there is a universe of uses, and for each usage we can find a product reference. Hence, if we measure major

innovations with the sport shoes or with the sport bags we are not sure to measure major innovations of the whole sport sector.

## ***2.2 Different methods to measure the major innovations:***

The measurement of innovations remains very complicated and requires really complex tools. Several scholars measure innovations on different levels: Product or technology measures; financial or market measures; Patent or intellectual property measures (Griliches, 1990; Sanderson and Uzumeri, 1995; García-Morales et al 2008; Salomo, 2009).

The financial (Ratio of sales of new products to total sales, R&D spending), the organizational (Innovation activities), or patent measures (Number of patents, patents fees) are useful to measure the performance of innovations or the way in which teams can be organized to be innovative, or the performance of R&D activities. As seen before, we are interested on the measuring of major innovations through new characteristics. Indeed, financial or organizational measures couldn't capture these major innovations aspect. We can think that patent measures could capture major innovations, but patents reflect new technologies, we are not sure that they could be transformed to new characteristics with an economic effect on the market (new characteristics which help consumer to choose between different new products).

These measures are not adequate to measure major innovations in terms of new characteristics, which integrate a product reference.

There are researches, which used quantitative measurement to capture the major innovations on a given market. However there are only few researchers how try to construct quantitative measures to capture innovations. We will treat two examples: 1) Measurement of major innovation with specific magazines and groups of experts. 2) Measurement of major innovation with manufacturers' sales brochures.

The first methodology used by Salomo (2009), who measured innovation by capturing the major car's innovations (ABS, Daylight or rain sensors, aluminum chassis etc.); he used industry publications that target end consumers in the Automobile industry. His method is the use of Automobile magazines, which offer available data on new product launched over time. According to Salomo these conditions allow him to build a data set, which capture major innovations in the Automobile industry. These innovations are important to end consumers; they have an economic effect because these innovations have an influence on sales performance. Salomo's methodology requires the intervention of a number of experts who should verify and complete the list of innovations.

The second methodology was the one used by Sanderson and Uzumeri (1995) to capture variety and new features on personal portable stereos. They used manufacturer's sales brochures to obtain information on the design, new features and specifications of the whole market personal stereos models. The measurement of variety is interesting with this method.

These two methods are used to capture major innovations and variety (new products' characteristics and features). They are properly constructed, but they are not easily to duplicate. The intervention of experts to verify the major innovations' list can influence the objectivity of information, may be major innovations for a group of experts are not the same for an other group (what is new for one expert is not new for the others). In addition, Salomo chose a set of brands and set of categories of cars (small, medium) and then he captured major innovations of

these cars. The problem with this methodology is the choice of the adequate product references. How can be sure that with this set of cars we can capture major innovation on the automobile sector?

The second method captures manufacturer's viewpoint of new products' features. These characteristics could may be not have an economic effect on marketplace (consumers), it excludes the value for the end consumers.

The measurement of major innovations sequences requires a new method, which can capture new characteristics with an economic effect (consumption function); which can be easy to duplicate;

### ***2.3 New tool of measuring major innovation:***

The quantitative measurement of major innovations remains complicated. However this article try to bridge the gap by using a new tool of measuring the sequences of major innovations by following the Lancaster's viewpoint.

#### *2.3.1 Research approach:*

In his seminal work, Lancaster (1966b) introduced the idea that goods are consumed for the characteristics that they possess, and he describes goods not merely as goods but takes them as an input to the consumption function which gives in characteristics of goods as outputs; According to him, goods contain many properties, but he defines characteristics as properties that are relevant to consumers' choices (economic effect). As seen before, our method will follow this viewpoint to measure major innovations through the measurement of new characteristics.

As explained by Lancaster, the evaluation of the product characteristics is regularly made by consumer guides, which regularly make a synthesis of all existing products and compare them along well-identified characteristics that are considered to be critical in the consumer choice. In this perspective a major innovation can be identified by looking at the *emergence of new characteristics* used to evaluate the product on the market. Measurement of innovation in this case considers what the customer really wants to use or to consume; this methodology enables us to study only innovations that pass the "Market test" (Hayek, 1978) and that have economic values.

This paper used consumer guides, following the advice from Lancaster (1966a): "Organizations such as the consumers Union exist to provide more objective information on characteristics than is easily available elsewhere". Consumers union's missions are to test products, to inform the public, and to protect consumers. In fact, we based our empirical work on the test results from the tests that are carried out on consumer goods by the French Consumers Union, *Union Fédérale des consommateurs*. These results have been published periodically in *Que Choisir?* - The French equivalent of the American magazine Consumer Reports- since 1961. In these reports, attributes of goods are tested and they are tabulated with their technical values. A consumer would be more interested in the evolution of these technical values but we are interested in the evolution of the characteristics that are being tabulated. Therefore, for our research, characteristics that are given in a test report constitute our material.



### *2.3.2 Specification of the basic methodology: Strengths and weaknesses:*

Our New tool of the measurement of major innovations has both strengths and weaknesses.

#### Methodology's Strengths

The quantitative method of measuring major innovations using consumer guides, capture the characteristics with an economic value. Consumer guides are responsible for the selection of the right sample of products, which correspond to consumers needs on different market (TV, Mobile phone, Iron, Washing Machine etc.). They do different test and give consumers the right devices concerning the consumer goods and give a detailed list of characteristics of products, which help consumers' choice.

The consumer guides are independent organizations; they are not advertising for brands; in contrast they do tests on different brands to compare them.

With consumer guides we don't need to contact experts who can verify the list of characteristics. Consumer guides are a reachable source of information; give a detailed list of products' characteristics; every year we find products' tests (products from different brand); they give information, which correspond to consumers' need (economic value).

#### Methodology's Weaknesses

This method captures new product's characteristics not at the right time, because consumer guides do tests on the existing products (they are already on the market), indeed characteristics can be overdue. In addition, this method could not capture all new characteristics. For example, in the case of mobile phone, we capture 83 new characteristics during the period from 1996 to 2010, and may be in the reality there are more than 83 characteristics, but our objective with this method is to capture major innovations to show the sequences of them. So, in spite the fact that we capture lower bound of characteristics number we can reject our first hypothesis, and we can show that major innovations are frequent.

This methodology is strong and can measure the major innovations solely if we have what we call a product reference. For example on the market of mobile phone the product reference is mobile phone and we can measure the major innovations integrated each time to this product reference. However, this methodology becomes weak when we have a market with several product references like sport sector. We have several products reference because this sector is a universe of different uses. If we capture major innovations of shoes or bags sport we are not sure to capture major innovations of a whole sport sector. This method becomes weak also with a complex product like a car. In the consumer guides concerning car the list of characteristics is not tabulated like a mobile phone. So the measurement of major innovations in this case cannot use detailed characteristics. We will see in the following parts how we can extend this methodology to capture major innovations on car market.

This article focuses on a quantitative methodology, which allows us to characterize major innovation sequences and its application in three industrial sectors.

In the next part, this article analysis and exposes the main results concerning mobile phone and Iron. In these cases the list of characteristics is known and explicit within the consumer guides.

### **3. Data Analysis and Main results: Case n°1 – The list of characteristics is known and reachable.**

#### ***3.1 Data collection:***

In order to obtain empirical evidence to test our hypothesis, we needed a characteristics database. First, we selected two types of products: Mobile Phone and Iron. At the beginning of our work, our aim was to study goods that were very volatile in terms of innovation and others that have been on the market for a long time and that are stable in terms of innovation.

Second and after the choice of the reference products (Mobile phone and Iron), we based our empirical work on the test results from tests that are carried out on consumer goods by the French consumers Union, “ *Union Fédérale des consommateurs* ”. The results have been published periodically in “ *Que choisir?* ”. And finally, it is important to note that our aim is to show the sequences of major innovations, elsewhere the relationship between these innovations for a long time. That is the reason why, we should build characteristics database on the longest time period; from 1996 to 2010 for mobile phone and from 1962 to 2010 for Iron. We take the longest periods (over almost 50 years) to gain insight into the long-term dynamics of innovation discontinuities. To follow the evolution of characteristics on time we use the archives of “*Que choisir?*”.

We capture major innovations by measuring the number of new added line in the list of products’ characteristics each year. The characteristics are reachable because consumer guides provide the detailed list of products’ characteristics.

Basically the work shows that the method enables to characterize a sequence of major innovations: there are reliable data and reliable ways to analyze them.

#### ***3.2 Major innovations are frequent and not rare:***

Our empirical findings (Table.2) show that there are major innovations sequences. If we took Mobile Phone, since the first report in 1996 on mobile phones, the cumulative number of new characteristics has reached 83. The mobile phone cumulate new characteristics from “Display”, “Camera”, “Music” to “Bluetooth”, “GPS”, and “internet”, with this set of new characteristics, we can have more dynamic view of mobile phone. Mobile phone is not only the object which allows us to call people without being at home, but it becomes also camera, TV, personal computer... etc. We could think that mobile phone is very recent and volatile product, and this could be the main reason for the appearance of these new characteristics (83 since 1996 to 2010). However, we observe the same symptom concerning Iron. This product exists for a long time on marketplace and we thought that it is stable. Our database for irons contains information about 19 periods of product tests over almost 50 years. According to the database, cumulative number of characteristics of irons is 73 new characteristics. Iron cumulated new characteristics from “Safety”, “Teflon sole” to “Steam”, Comfort”, and “Cordless”, these major innovations show that iron is not solely an object for ironing clothes, but becomes an object, that take care of clothes.

Table.2 Number of consumer tests and total number of new characteristics by products

	<b>Mobile Phone</b>	<b>Iron</b>
<b>Period of time</b>	1996 - 2010	1962 - 2010
<b>Number of consumer guide surveys</b>	15	19
<b>Total number of new characteristics</b>	83	73
<b>Major innovations frequency (New characteristics per year)</b>	6	2,3

Over almost 50 years and in the two markets, these are usually newly added characteristics, this expansion in the characteristics space show the existence of major innovations on the marketplace. As seen before, many scholars noted that major innovations are rare. However, our results rejected the hypothesis 1 which suggests that major innovations are rare and we confirmed that major innovations are frequent. Major innovations are not rare; the frequency of major innovations (sequences of new characteristics. See Table.2) reaches until 6 new characteristics per year for mobile phone during 14 years (1996-2010) and 2.3 new characteristics per year for Iron during the whole given period (1962-2010).

Figure.2 shows the total number of new characteristics that are added to mobile phone from May 1996 to September 2010. The new characteristics added to product reference (6 new characteristics per year) are significantly high. We can see in that curve the number of characteristics, which are added to product reference (mobile phone) all over time. We noted that the first 14 new characteristics started on May 1996 are the first characteristics tabulated for mobile phone; they represent the starting point; there are no predecessor characteristics before these 14 mobile phone's characteristics. The first consumer guide's test on mobile phone was on May 1996. The appearance of new characteristics is frequent; we can see that every year new characteristics were added to the mobile phone. With these results, we can reject the first hypothesis. Major innovations are not rare.

Figure.2: Total Number of new Characteristics for Mobile Phone

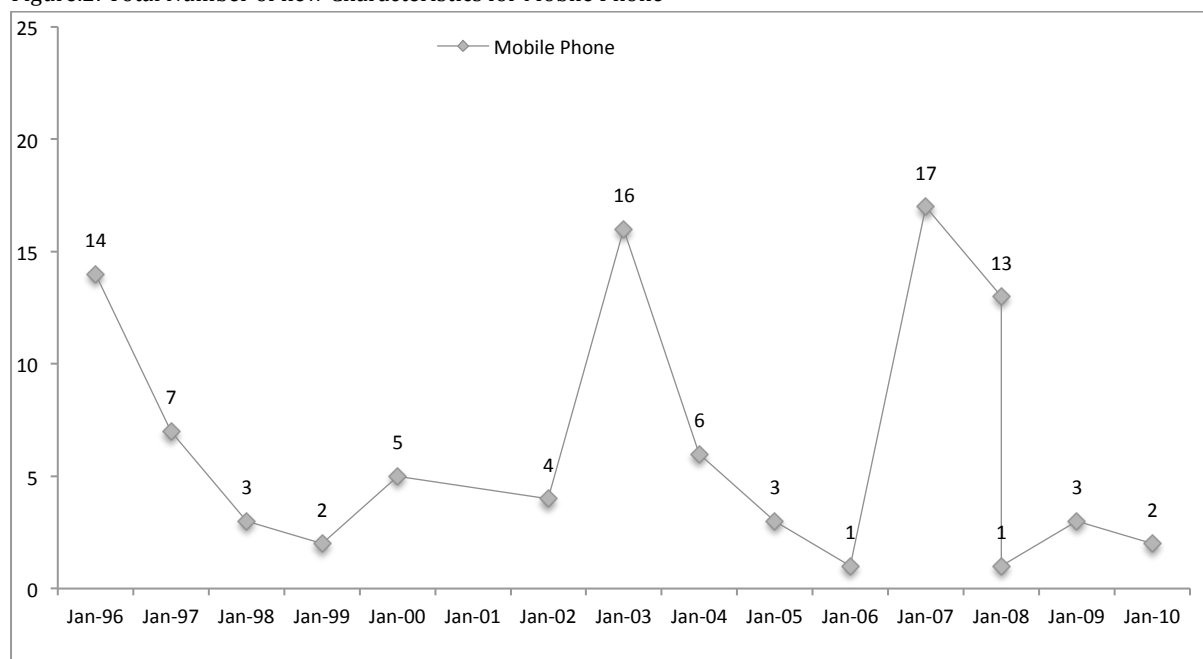


Figure.3 shows the total number of new characteristics that are added to Iron from December 1962 to May 2010. The frequency of changes is relatively high. We can see in that curve the number of characteristics, which starts on December 1962, sets of characteristics were usually added to the mobile phone all this given period. There is a continuous change. We noted that the first set of twelve characteristics is a starting point; then, this starting point is followed by the other sets of new characteristics.

Figure.3: Total Number of new Characteristics for Iron

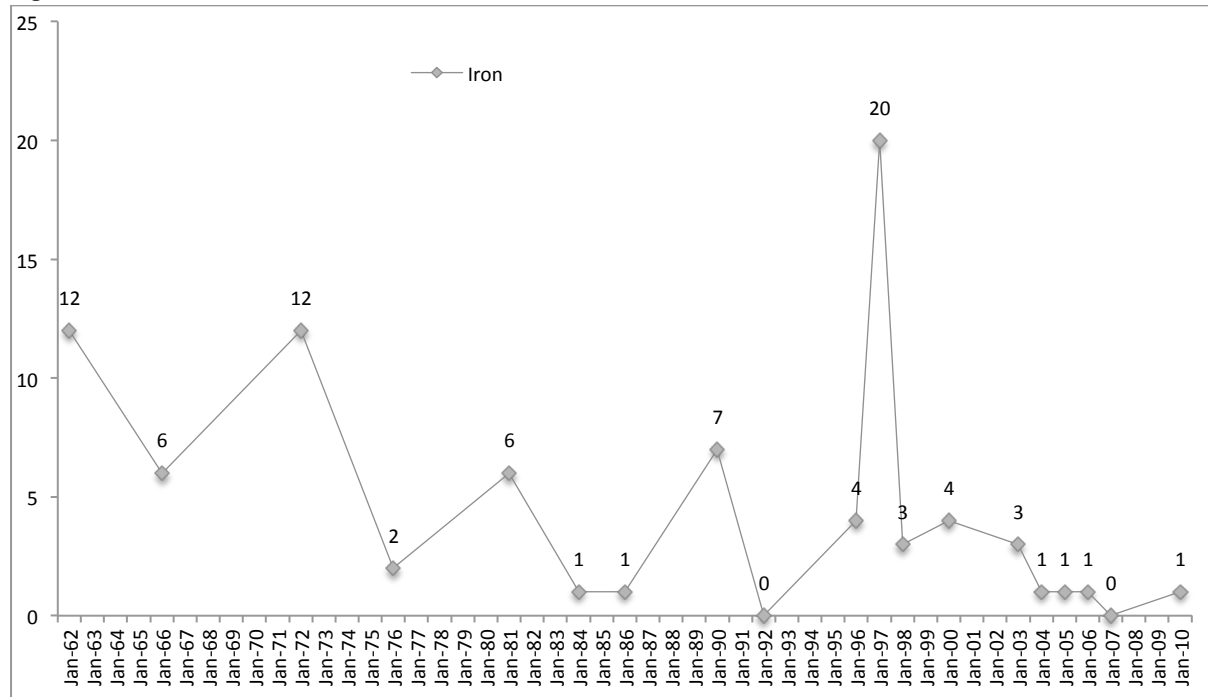
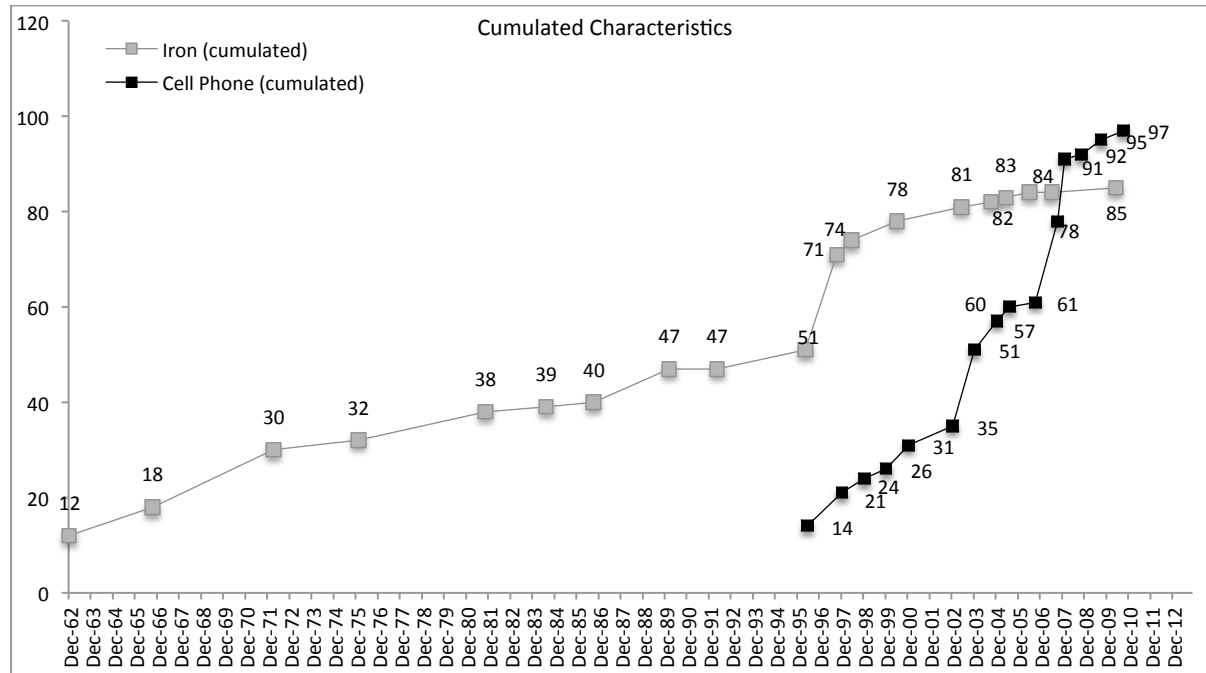


Figure.4 This curve represents the cumulated characteristics for mobile phone and Iron. Such new set of new characteristics is added to the old one and it represent dynamic of mobile phone and Iron sector. Major innovations are not rare and frequent; that means that the first hypothesis can be rejected. In these cases, major innovations are cumulated into the same product reference; new characteristics reflect the dynamic of the products reference (Mobile phone and Iron).

Figure.4: Total Number of cumulated characteristics – Mobile Phone and Iron



These empirical results reject the first hypothesis (H1). According to our results major innovations are repeated all over time, they are not rare and major innovations' sequences are frequent. The dominant design is revisited by the addition of a set of new characteristics on products. If we take the example of mobile phone, during the time the mobile phone become music, pictures, videos and Internet support. The product reference, which is mobile phone, has now different uses than before.

### 3.3 Chain reaction effect and Interdependency between major innovations:

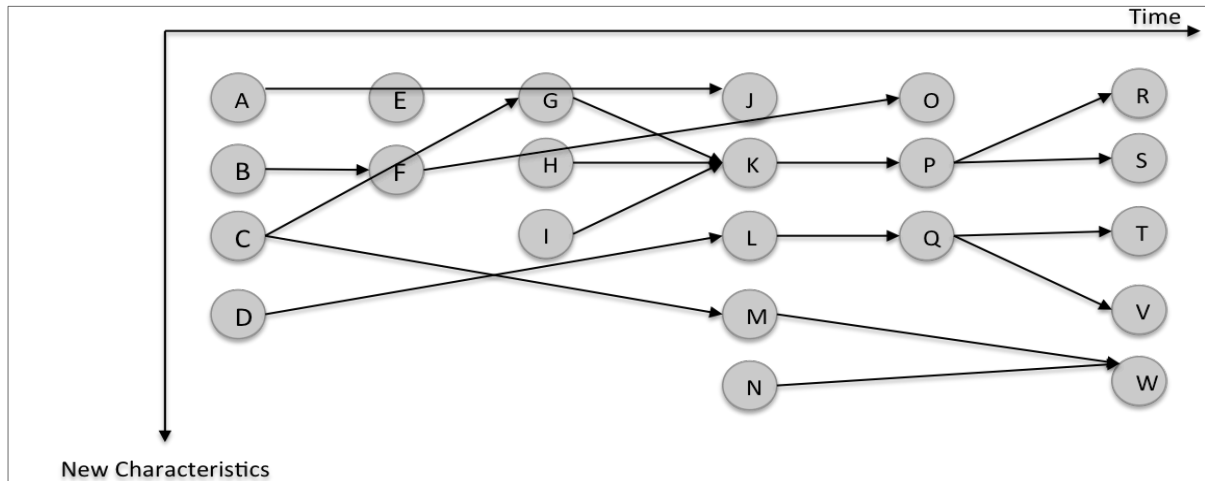
Our empirical studies show that major innovations are interdependent. We identify chain reaction processes that link certain newly emerging characteristics over time. That means that our results can confirm the second hypothesis (H2), which said that major innovations are interdependent. We use the term "Chain reaction" because old characteristics influence the appearance of new ones, like chain reaction in chemistry and physics fields. A chain reaction is a sequence of reactions where a reactive product or by-product causes additional reactions to take place.

The interdependency can be represented as a network of characteristics (Figure. 5). There is more than one type of relationship between major innovations. The interdependency can take a lot of time to be observed; also the interdependency can be build by chaining new characteristics.

Figure.5 summarizes the relationships between different major innovations all over time. Our results show that some new characteristics give, in fact, other new ones. The initial characteristics influence the appearance of a set of other characteristics. For example, here characteristic "B" influences the appearance of "F" and this one gives other new characteristic "O". That shows the interdependency and the chain reaction effect in the same time. In other hand, a set of characteristics could generate one new characteristic - "G", "H" and "I" influence the appearance of "K". However, one new characteristic can take a long time to generate other

new one or a set of new characteristics (example: “A” and “J”). We can find also, the situation, when new characteristic doesn’t generate other. It appears and stops like “E”. Characteristics follow different patterns and rhythm, but still confirming the interdependency between them all over time. The chain reaction effect can have different aspect and it depends on: the speed of appearance of new characteristics; the number of intermediate characteristics, which build the chain of characteristics.

Figure.5: Interdependency between major innovations and the chain reaction effect



Mobile Phone:

The evolution of the mobile phone is due to the evolutions of new characteristics. All over time, new characteristics have antecedent or influence the appearance of new ones.

Figure.6 summarizes the interdependency between different significant new characteristics. Such new set of characteristics played an important role in the evolution of added characteristics of mobile phone.

*Multi band* characteristic is about the frequency bands that mobile phones support. This characteristic is important when traveling. If a mobile phone supports a wide variety of frequency bands then the consumer can use his phone for roaming purposes. When the characteristic dual-band first added, it was new to the market but then it generated other new characteristics as tri-band technology.

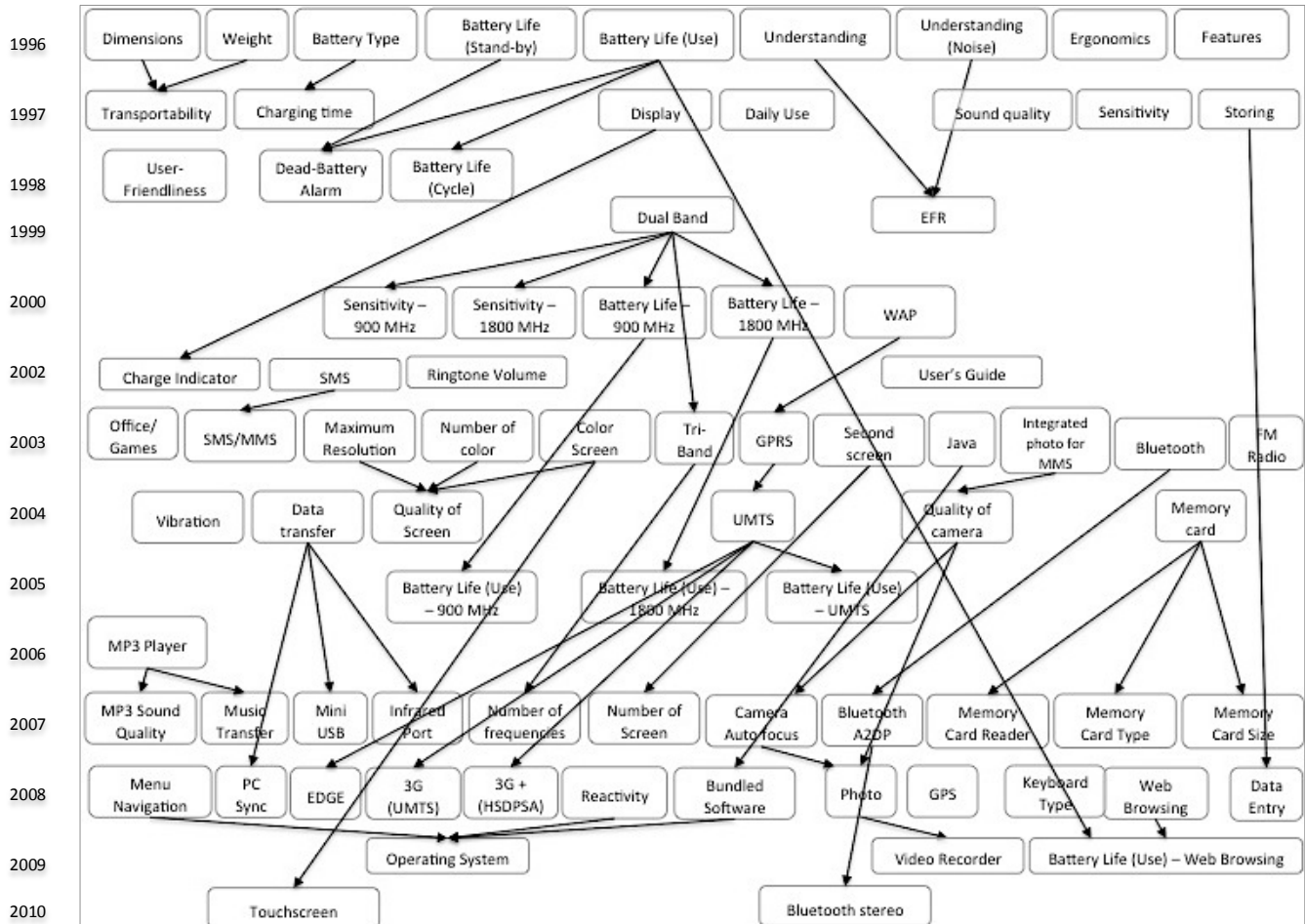
*Internet:* After the appearance of GPRS and UMTS on the list of characteristics, there has not been an immediate effect. Then these were followed by another characteristics Wi-Fi, which was in turn, was followed after a few years by other characteristics that are internet-related.

*Picture:* Camera was appeared on a list of characteristics, that is followed by many characteristics that all consumers notice and know how to use.

*Music:* When music player was first introduced to mobile phones, right after it was added MP3 sound quality and music transfer characteristics.

*Data characteristics:* Many data characteristics were added on the lists of mobile phone characteristics, and other new ones followed them. Data transfer - Mini USB, Memory Card - Size, Type.

Figure.6: Interdependency between major innovations and the chain reaction effect – Mobile Phone



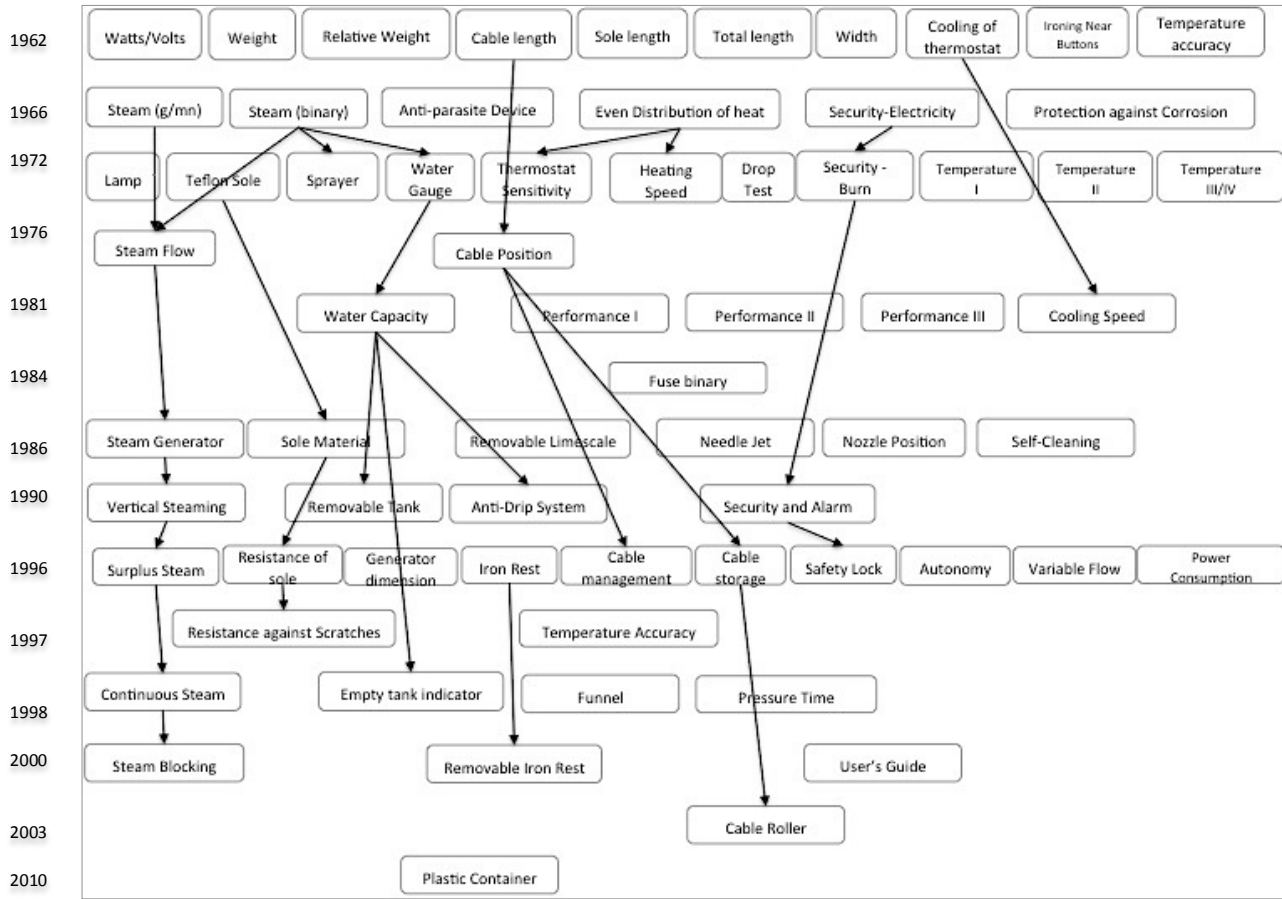
**Iron:**

The major change of the iron is due to the evolutions of new characteristics. All over time, new characteristics have antecedent or influence the appearance of new ones on long time period. Figure.7 summarizes the interdependency between different significant new characteristics.

*Steam characteristics:* Steam related characteristics are the most interesting ones. In fact, Steam introduced as one major new characteristic, which was bring some others until 1984 and six years later a new major characteristic as Steam Generator.

*Comfort characteristics:* They are around the characteristics about cables of irons, weight, care of laundry.

Figure.7: Interdependency between major innovations and the chain reaction effect – Iron



Our basic methodology with the known and the reachable list of characteristics, allows us to reject the hypothesis 1 (H1), and to confirm the idea that major innovations are not rare. Also to confirm the second hypothesis (H2) with the interdependency between the old and the new set of major innovations.

**4. Basic methodology’s extension: Data Analysis and Main results case n°2 – The list of characteristics is unknown and not reachable (Automobile)**

Some methodology’s weaknesses encourage us to extend our basic methodology in order to test our hypothesis in the case of complex product when the list of characteristics is unknown and aren’t tabulated in the consumer guides.

**4.1 Methodology’s extension and Data collection:**

As seen before, with complex product like car, consumer guides don’t give the list of new characteristics like mobile phone or Iron. Automobile is a complicated product with a huge number of sets of characteristics, which are integrated within different types of car (Small, medium, big etc.). With Lancaster viewpoint it was interesting to capture a set of characteristics, but it is no easy to do that with complex product, like an automobile. Indeed, we extent our basic methodology from set of characteristics to an other type of reference product. We measure major innovations by capturing the appearance of new car’s models or classes and capture the appearance of car’s trends.



The models of car (Sedans, Breaks, Roadster, Family cars etc.) integrated a huge set of characteristics, so when new category appears, it suggests that a new set of characteristics appears too. Major innovations are integrated within cars' models. In the addition to that, and in order to complete our method, cars trends are measured too.

Cars trends represent the new way or the new use of cars (Family, Sporty, Urban, fashion etc.). We noted that new trend influence the appearance of new models (Underlying the appearance of new set of characteristics).

We measure major innovations in this case, by extending our basic methodology from characteristics of products to other reference level of product. We measure the appearance of new models or classes of cars and trends. Consumers chose their car by regarding models and also by regarding sector trends.

In order to obtain empirical evidence to test our hypothesis in this case, we needed a categories and trends database concerning the Automobile. We used one of the most French known Automobile consumer guides, which is "L'Auto-journal", we use specially "Le guide de l'acheteur" (Consumer guide) to measure the appearance of new cars' models. We used the archives of this magazine from 1959 to 2011.

#### **4.3 Major innovations are not rare:**

Our database contains information about 15 periods of product guide surveys over almost 50 years; the cumulated new characteristics of Automobile are 20 new trends and 40 new categories (Table.3). These variables have an economic value for the consumers (as seen before). Automobile is no longer solely a means of transport, but becomes a living space, a communication object, and a fashion.

Table.3 Number of consumer tests and total number of new characteristics by type of the observable

<b>Types of the observable</b>	<b>Automobile</b>	
	Models/ Classes	Trends
<b>Period of time</b>	1959 - 2011	1959 - 2011
<b>Number of consumer guide surveys</b>	13	15
<b>Total number of new characteristics</b>	40	20
<b>Major innovations frequency</b>	1	0,5

Concerning the sequences of major innovations, we have found that during the given period, 1 new class or model appears each year, and in terms of trends, 1 new trend per two year appears during the same given period.

Figure.8 shows the sequences of major new trends (Low-cost, Eco-responsibility, sporty, Fashion, Family etc.) that are added to Automobile from 1959 to 2011. We can see in that curve the number of new trends of car added to the universe of trends; sets of characteristics were usually added to the Automobile all this given period. We noted that the first 8 trends are the starting point. There is a continuous change and major innovations represented by trends are frequent all over the time. That means that we can reject the first hypothesis (H1) in order to suggest that major innovations are not rare.

Figure.8: Total Number of new cars Trends

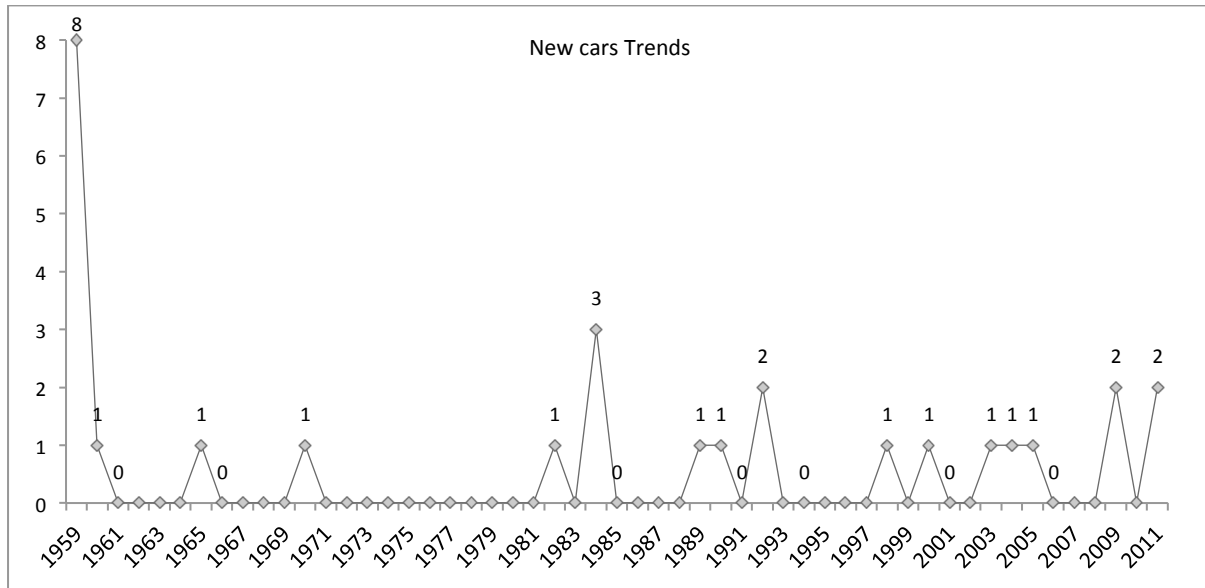
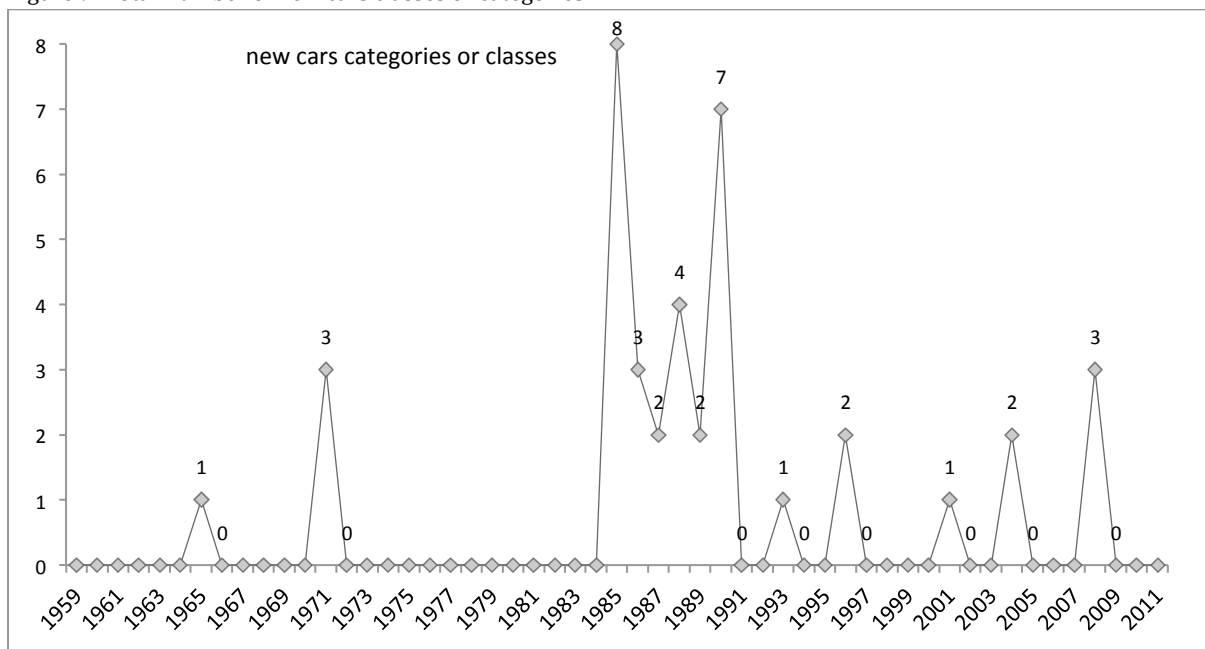


Figure.9 represent the sequences of major new car's models (Sedans, Breaks, Roadster, Family cars etc.) that are added to Automobile from 1959 to 2011. We can note that the number of models of car reached 40 new cumulated models during the given period; sets of characteristics were usually added to first model.

Figure.9: Total Number of new cars classes or categories



Our results with the basic methodology's extension reject also the first hypothesis and suggest that the major innovations follow ordered sequences all over time.

#### 4.4 Interdependency between major innovations

The results of our basic methodology's extension show that the characteristics concerning the automobile have two levels of interdependency. Trends of cars influence the appearance of new models. And new models influence the generation of others (see figure.10).

Our results show that major innovations could be expressed by the major changes in usefulness of cars (Low-cost, Eco-responsibility, sporty, Fashion, Family etc.) and models (Sedans, Breaks, Roadster, Family cars etc.).

Our results confirm the second hypothesis; Major innovations are interdependent. In the case of Automobile there are two levels of interdependency. The first level is between car's trends and car's models (see Figure.9.). The appearance of a set of new trends influences the appearance of new set of car's categories.

Figure.9: Interdependency between major trends and models – Automobile

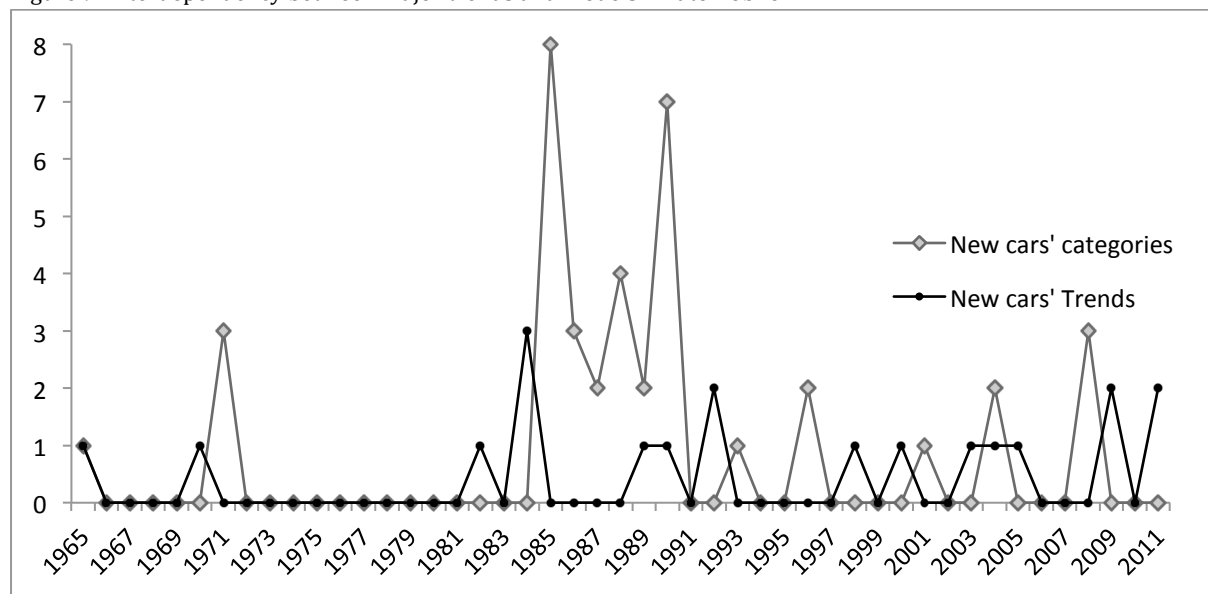


Figure.10 summarizes the interdependency and the chain reaction effect on automobile sector in terms of trends of cars.

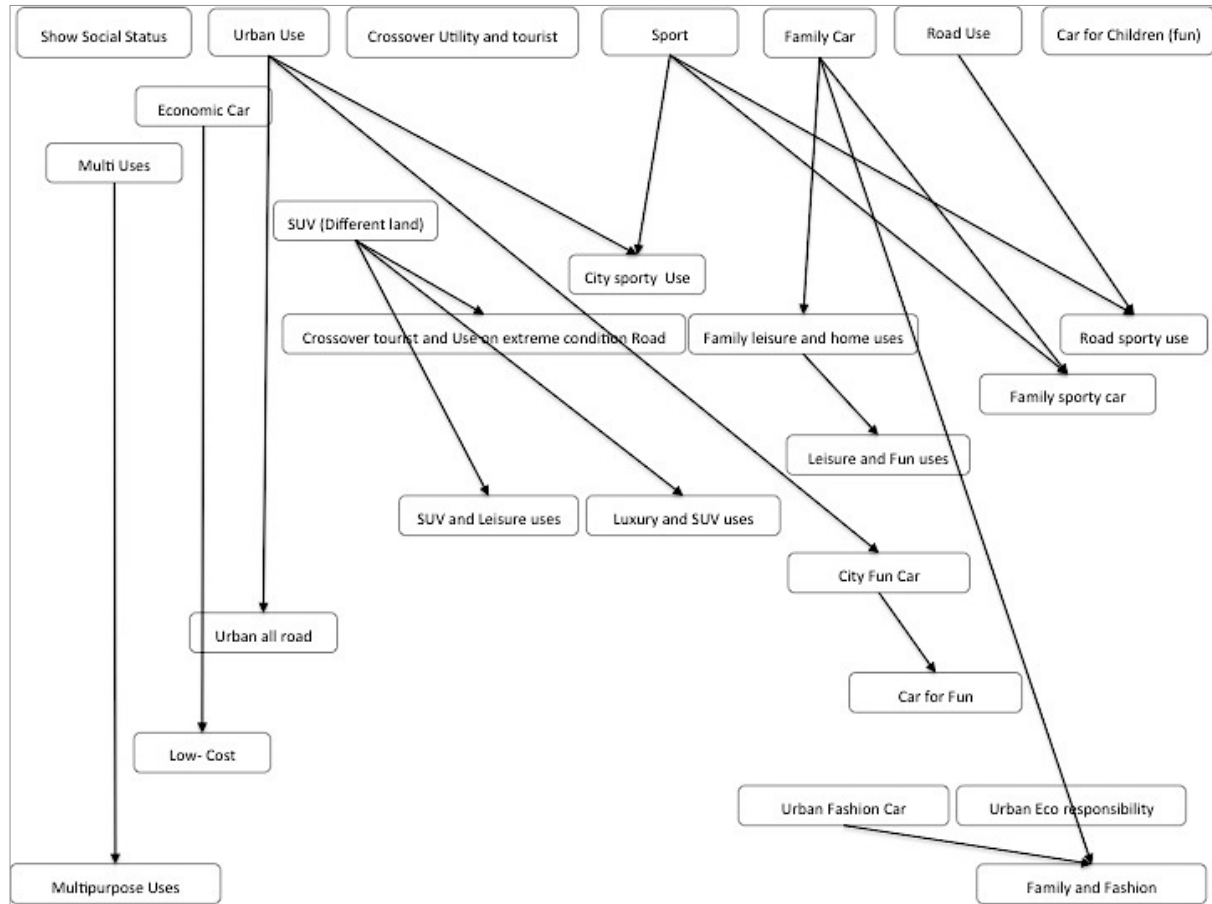
*Urban city:* Our results show that the urban uses evolve all over time. The appearance of the first trend "Urban use" influence the appearance of new others trends "City sporty use" and "Urban all Road"

*Family:* The family car trend evolved all over time and influence the appearance of other characteristics, which were in other type of car's uses like sporty, leisure and fashion characteristics.

*SUV:* SUV car evolves to be conducted on extreme condition land. This characteristics evolves all over time in order to generate other new characteristics like luxury, Leisure and urban. These characteristics were be mixed to SUV. Major changes were related to this category of car's uses.

*Eco responsibility:* New characteristic was related to car, it is eco responsibility. That means that this kind of characteristic let cars contain new technologies and innovations in order to respect the environment and to be eco responsible.

Figure.10: Interdependency between cars trends – Automobile



These results support the second hypothesis, and show the chain reaction effect and the interdependency between major innovations within a complex product. We could capture major innovations by measure the really new trends and models cars.

The extension of our basic methodology allows us to reject the first hypothesis and to confirm the second one. Major innovations are not rare and they are interdependent; Old innovations can influence the generation of a set of new characteristics.

## Conclusion and Future Research

This study contributes to innovation research - specially the measurement of major innovations- by providing a new tool to measuring major innovations sequences by regarding new characteristics, which are integrated to the product reference (Mobile phone, Iron, Automobile) on long time period (1959-2011). It studied innovation from the perspective to show that new characteristics were coming and expanding the characteristics space of different product, even if the most stable and old product on the marketplace as Iron or Automobile. In other words, this article suggests that major innovations are not rare all over time. This article shows also, contrary to several viewpoints, that major innovations could follow a chain reaction effect, because of the relationship between the succeeding major innovations (Old innovations influence the generation of new ones).

This article opens the debate around the dominant design of mobile phone, Iron or Automobile. The accumulation of major innovations within the products reference revisited the dominant

design of the products; for example, mobile phone became not solely a simple tool of communication, but also personal computer, agenda, Camera etc.

This article use database concerning three different products (Mobile Phone, Automobile and Iron), may be further research should duplicate our methodology on other different products or sector, first in order to reinforce and extend our methodology, second to study the frequency of the major innovations in multitude sectors and finally to study the different degree and types of interdependency.

This article analysis the appearance of new characteristics and the dynamic of different markets via major innovations; however it didn't treat the situation with markets without major innovations or really less innovations. Further research may try to answer the following question: Are sectors without major innovations dynamic? Do they have a continuum growth?

### **Implications for Management:**

These phenomena – frequency and chain reaction effect - suggest analyzing the adequacy of the organizational forms in the sector companies with the sequence of innovations in the sector. It helps to diagnose some inadequacies and to suggest some organizational changes. The tool would also allow monitoring the current dynamic of innovations in a given industrial sector and, occasionally, the shifts in these dynamics (changes in innovation regime).

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