Whether first, second and third generation maquiladoras exist, is it legitimate to wonder if first, second and third generation clusters can exist? This paper sustains that it is possible to identify qualitative differences in the electrical/ electronic autopart offshore cluster located in Chihuahua (north of Mexico). This lead us to identify different generation clusters, as well as different generation offshore plants.

The purpose of this document is to describe from a double perspective, the birth and evolution of the technological cluster located in Chihuahua. It reconstructs Packard Electric-Delphi’s (PE) evolutionary path as a primordial company, as well as harness technological trajectory. Throughout the text both histories are explained sometimes simultaneously, sometimes sequentially.

PE is denominated «primordial company» since regional and international production nets with enough capacity to induce specific evolutionary processes of the cluster are built around this enterprise. To reconstruct the company’s quantitative and qualitative history allows to link the

1 Email: alara@cueyat.uam.mx
3 A cluster is « a geographically dense group of companies and related institutions, belonging to a concrete field, joined by common and complementary features among them ». This concept allows to integrate a group of factors and realities that were separated. On one hand it allows to integrate: i) the sectors « similar » (vertical dimension) and the sectors « complementary » (horizontal dimension) ; ii) the institutions that provide knowledge, technologies, information, specialized infrastructure, etc. Porter M., Ser competitivo: Nuevas Aportaciones y Conclusiones, Ed. Deusto S.A., España, 1999.
4 It is pertinent to clarify that doesn’t exist a direct relationship between first generation offshore plants and first generation clusters. The distinction of first, second and third generation cluster, is trying to identify qualitative differences in their evolutionary process. Distinction that not necessarily correspond with the first, second and third generation offshore plants classification proposed by Carrillo and Hualde (1997).
5 «According to USITC harnesses are multiple isolated electric conductors assemblies which are assembled to terminal connectors, sockets and other wiring devices.» Carrillo J., R. Hinojosa and J. Waldam, «La industria de los arneses en México: Upgrading Downgrading Process?», 2000.
elements of the network into hierarchical relationships, where some firms are leaders but others simply followers (passive or active).

The methodology proposed can be synthesized as follows: Primordial companies, explain strongly the nature and direction of evolutionary processes in the cluster. To reconstruct the history of this cluster from the perspective of PE’s technological competition, allows to capture clearly the cluster’s qualitative history, for this reason PE’s evolution acquires a central place in this methodological approach. The «company» is defined as a space where resources are accumulated. A company and a cluster are organization forms where people and teams interact strategically, having their own interests and responding to coercions and incentives of economic, technological and organizational nature. What matters, is to reconstruct the internal nature of companies which don’t survive alone but inside clusters.

Chihuahua’s cluster is marked by the history (path dependence) of companies which decide to set up harness-assembler complexes in Ciudad Juárez. To capture the agglutination form and intensity of companies in Chihuahua, requires to discover the «identity» of these companies. A cluster is made up of companies which accumulate memory, not of anonymous or plane companies. Each company follows its own development and technological knowledge «accumulation» path. As Cantwell pointed out: «By extending its own network, each firm extends the use of its own unique line of technological development, and by extending it into new environments it increases the complexity of this development. The expansion of international production thereby brings gains to the firms a whole, as the experience gained from adapting its technology under new conditions feeds back new ideas for development to the rest of its systems».

The formation of the electrical/electronic (E/E) cluster of automotive parts located in Chihuahua, should be understood inside the PE’s integration/desintegration dynamics. This regional and international reconstruction process expresses: i) the accumulation of technological and organizational capabilities inside a firm; ii) the technological competition inside the sector; iii) that each company follows particular technological learning «paths» as well as own regional technological clusters formation (technological path); iv) that the integration/desintegration forms of firms are difficult and unstable processes, they depend on the difference between internal and external transactional costs.

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10 As Cantwell pointed: «Increasing internationalization of manufacturing production has helped to sustain technological competition between MNC’s multinationals»; Cantwell (1991:33).
There are three frequent given explanations about the transfer of harness-assembler companies to the north of Mexico. The first, of economic nature, (to take advantage of lower wage conditions) the second refering to unions and policies (labor force without fordist experiences and weak or null union organization) and finally the one that emphasizes incentive roles provided by regional organizations. It is necessary to complete this general explanation, to construct a specific explanation of PE’s particular history refering to its migration to Mexico’s north frontier.

Finally, as long as a great part of offshore companies which integrate this cluster are harness-assembler, it is convenient to understand the basic characteristics of harness technological trajectory. It is necessary to study the singular history of this device, that also has its own and distinguible identity. This approach to the analysis object (harness) demands systemic distinctions, of dynamic, quantitative and qualitative nature. It is necessary to overcome the harness static vision which design arose from a single attempt and forever. The original harness has been transformed with variable rhythms for almost a hundred years. As well as biological organisms are studied by their development and adaptation forms or their specialization and suffered mutations that lead them to form new populations and new identities; in the same way, it is necessary to distinguish the qualitative and quantitative changes in the harness’ history, which express that the harness of one period is not the same harness of another period, that the new functional, complexity or material attributes which arise in the harness’ trajectory, are forcing to add a distinctive name, for example; first, second and third generation harness. This document proposes a taxonomy which purpose is to distinguish different moments in the harness’ history. This taxonomy, also allows to construct the taxonomy of first, second and third generation cluster, associating each one of these moments with the harness development phases.

The document is structured as following: three moments are described in the history of PE: from 1973 to 1980 (section I); from 1974 to 1993 (section II) and finally from 1994 to 2000 (section III). Most of the text shows parallely to PE’s history, the reconstruction of harness’ history also in three moments (first, second and third generation harness).

PACKARD ELECTRIC (1890-1973)

The evolution of Packard Electric

Packard Electric (PE) was founded in 1890, 10 employees produced incandescent lamps and energy transformers in the plant located in Warren, Ohio. In 1901, PE started to produce
automotive cables. «The company started to make wire cables because they were unable to find a reliable supplier» In the following 30 years, PE turned into a technological leader in the production of automotive cables, diversifying its market and production lines later on.

In 1928 General Motors (GM) acquired PE’s cables division and four years later (1932), GM bought PE in its whole. Between 1932 and 1973, PE became one of the technological leaders in the production of automotive, military and electrical equipment cables. In the mid 1930’s, this enterprise had 500 employees who were able to produce two million and a half of ignition cables by day.

In the 1960’s, an increasing demand of harnesses and non-cooperative industrial relationships between managers and workers, created a confrontation culture inside the plant of Warren. «With the increase demands for production technological speed-ups, the 1960’s were a period of nominal unrest at PE. While there is no evidence of major strikes or disruptions of production, some in-plant actions, involving slowdowns and ‘soldiering’ were used by workers indicating their displeasure with working conditions». The rules from 1950 to 1960 settled down that «no more than two people were allowed to speak to one another at the same time, lunch time was limited to 20 minutes and two tables and chairs were provided».

From 1960 to 1973, big sales of automobiles, lead to increase PE’s internal labor market. In 1960, PE had 13,500 employees. Every year from 1962 to 1973, a thousand new workers were hired (Graphic 1). However, the demand of producing bigger volumes of harnesses was blocked by fordist industrial relationships at this plant but particularly due to the constitution of worker groups whom knowing that Warren was the unique harness supplier to GM, betted to the pressure and to maintain antagonistic relationships with the managers in order to obtain better labor and salary conditions. During this period, many labor categories were created what blocked the possibilities to share know-how besides hindering the quantitative and qualitative flexibility processes.

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14 It produced high tension ignition cables to PHIO Automobile Company.
15 Pound (1934:477) mentioned by Rubenstein (1992:116)
16 Actually it also produces cables for trucks, aeronautics and communication industry.
17 In 1940, PE was one of the first companies in developing: i) the use of plastic as an isolation device; ii) the successfully use of injection plastics processes to produce parts; iii) multiple and bulk head connectors; iv) flexible printed circuits dedicated to control panels, etc. Russo J., «Integrated Production or Systematic Desinvestment: The Restructuring of Packard Electric», Facing North / Facing South: A Multidisciplinary Conference on U.S.-Canadian-Mexican Relations and NAFTA, Michigan, May, 1994.
18 Russo (1994).
21 Businessweek, August 29, 1983.
PE’s management knew that there were a strong connection between the fact that Warren was the exclusive source of harnesses to GM and the intensity of the intra-firm conflict. The labor atmosphere were polluted by intense conflicts between the management and the union, such as; provisioning vulnerability, weak cooperation culture joined to antagonistic industrial relationships. «Poorly trained foremen and union commitmen constantly clashed over shop-floor issues. Because Packard was the sole source of wire harnesses for GM cars. Local 717 often won disputes over work practices and disciplines (..) There were many slowdowns, wildcat strikes, and «tea parties», a local tradition in which dozens of union officials would converge on a foreman, shouting, pushing, and generally intimidating him»22. «It was miserable», commented A. Lee Crawford who was the boss (foreman) of this plant in the 60’s. «We were adversaries, screaming and yelling at one another. We didn’t hire people to get involved. Even thinking wasn’t a criterion for employment. We assumed that the people didn’t really care about their work, but they did» 23. Beneath these conditions, in 1973, PE announced that the company would stop hiring and building plants in Warren. To continue ahead it was necessary to reconstruct a group of relationships inside and outside the company. Which were the reasons of the limited growth in this company?, what was the relation between these limits and the transformations of the harness´ technological trajectory?.

Harness’ Technological trajectory.

Three generations of harnesses are distinguished. The first one of simple harnesses (1900-1973). The second one, characterized by its rejuvenation, has its origin in the processes of convergence of the automotive industry with the electronic industry (1974-1993) and lastly, the third generation that in contrast to the second generation, it is not an independent system but a system integrated to the physical and functional parts of the automobile. It is the harness that is integrated inside a modular system (1994 - ahead).

First generation harnesses.

From the invention of T motor by Ford to the early 1900’s, were developed between 1910 and 1919 two harnesses: the electric light system and the electric ignition system. The electric system stayed relatively simple and stable from 1920 to 1950. In the period of 1950-1959 were developed and diffused a group of standards (as the 12 volts system24) linked with the electric system, such as the air conditioning system (1946-1954).

These facts brought modifications in the wiring highway. It was requesting more electric power for its operation and therefore a bigger quantity of harnesses25.

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23 Interview with Lee Crawford, Businessweek (1983).
From 1900 to 1973, wiring harnesses were characterized by:

1. The transmision of exclusively electric power. This means that it had a passive role, by the time it’s compare with current harnesses.
2. In a typical vehicle, wiring harnesses were formed by three brunches or wiring subsystems.
3. During this period, the fordist production system was the one that auto makers took as organization mode: big volumes of harnesses were produced so it was necessary to take advantage of scale economies, frequently in a single complex.
4. Wiring harnesses were relatively a simple device: a few of them (three harnesses), a few conectors and small extensions. It was possible to design manually wiring harnesses, this is, making up prototypes and testing whether or not its functional design was robust.
5. From 1900 to the early 1970’s, the production regimen of auto industry was determined by the capabilities to reach scale economies in each company. The market was not regulated by the demand but for the supply. In the market, therefore existed scarce variety and long life cycles of the product. Due to these conditions (stable product designs) there were also scarce variety of wiring harnesses.

**PE and the transition to second generation wiring harnesses production.**

At the end of the 60’s decade, the design of wiring harnesses was different, but until the 70’s, the use of electronic components was quickly spread through the auto industry due to the growing maturity of semiconductors and integrated circuits production. The wiring harness of the previous period had the unique function of transmitting electric power, in contrast second generation wiring harness also transmits information. Qualitative transformation of wiring harnesses because it isn’t any more a marginal component, it is now the «nervous system» of the vehicle. Qualitative and also quantitative transformation, because as long as the market was demanding more efficient energy-user vehicles as well as less polluting ones, automakers were lead to the design of more complex combustion systems. Two components synthesize the complexity of this qualitative change; the substitution of the carburetor into fuel injection systems and the incorporation of *trip computers*.

As long as the production and use of electronic components were maturing, the use of E/E systems in vehicles was being enlarged. The number of wiring harnesses grew from three to twelve as a result of the increasing E/E systems adopted.

The convergence of automotive and electronic industries caused to: i) the appearance of new functions and therefore new components, ii) the substitution of mechanical parts (old parts) into new E/E parts; iii) the combination of mechanical parts with E/E components. Quite variety

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27 In particular the market’s demand to improve security systems: air bags (front, lateral) that drove to incorporate E/E systems and more complex harnesses. Green (1999).
28 To average, twelve harnesses in a vehicle, in a deluxe one up to 18 or more. The tendency is the increase of these numbers because of the current technology based on copper.
of cables and wiring harnesses was required\textsuperscript{29} because of the growing number of (E/E) units, each one with different electric load and information demands.

Other factor that encouraged this transition was the fact that in the 70’s, GM’s goal, main PE’s client, was to increase the automobiles diversity. In order to this, the company adopted two strategies: on one hand introducing different platforms and on the other one, introducing different models with identical motors and platforms. In 1930, GM sold basically identical models and for this reason, it demanded to PE basically identical wiring harnesses. In 1950, GM had 5 divisions of automobiles, all of them used similar platform measures. In 1960, the GM’s cars dimensions exceeded 5.3 m of length. However, the competition with the European market, pressed GM to introduce compact automobiles, 1 meter shorter than conventional full-sized automobiles. As a result of the increasing imports of small-sized automobiles\textsuperscript{30}, North American companies decided to produce different platforms: 4.3 m; 4.7 m; 5 m, and more than 5.4 m of length. Additionally, during the 70’s the market and the competition led to create a more varied trucks spectrum so new segments of these were created: slight trucks, vans, utilitarian vehicles and finally the introduction of the minivan in the 80’s\textsuperscript{31}. These variations demanded different wiring harness dimensions so its complexity was notorious\textsuperscript{32}. In 1980, GM built its automobiles on 11 platforms, ascending to 14 in 1990. Each size platform demanded different dimensions of wiring harness.

The different strategies that were adopted in PE to evolve from the production of first generation of harness to the second generation are described next.

**PACKARD ELECTRIC (1974-1993)**

**Exclusive supplier and bilateral dependence**

In 1973 PE, was the primary source of wiring harnesses for GM. In case of contingency in the Warren plant, GM’s production could be paralyzed. «This was a source of concern for GM, PE’s parent corporation»\textsuperscript{33}. In the early 70’s, PE probably wondered itself the following: Which was the cost of supporting its production exclusively on a single plant?.

In the early 70’s, Warren faced the challenge of producing a bigger variety and improved quality of wiring harness in order to satisfy: i) an increasing heterogeneity of wiring harnesses used in a vehicle, ii) an increasing variation of models and variants in the same vehicles model, iii) the complexity of E/E systems, iv) the need to produce wiring harnesses with a more and more short life cycle as well as; v) smaller inventories.

PE’s organization pattern, successful as for reaching high scale economies and learning curves, had worked properly while: i) simple and non-varied harnesses were produced (three
harnesses), ii) the harness’ role was limited to transmit electric power and in case of damage it was relatively easy to detect where the flaw was; reason why quality had not become a fundamental parameter in those manufacture processes; iii) when it didn’t matter if reaching scale economies meant high rejection indexes, because its production was supported on great inventories. Any human error could be supported on this mattress (great inventories) that could absorb mistakes and on the whole anything came up during the production process.

Did necessary conditions exist to go on with the expansion of the harnesses production capacity in Warren?. As previously pointed, GM was concerned about having a single source of harnesses provisioning. Indeed, it was necessary to diminish the bilateral dependence by creating other plants or subcontracting a part of harnesses production with other companies, that meant the begining of the decentralization for wiring harnesses production.

This decentralization, became an imperative that expressed the necessity of settling down new harnesses production lines, some of them: i) technologically more complex and therefore demanding more closer cooperation processes between engineers and workers than the ones that were reached inside Warren; ii) whose production levels were altered by oscillations which was necessary to regulate with more flexible internal and external work markets; iii) in order to establish smaller internal transaction costs and efficiency in decision making; iv) in order to build different experimentation trajectories, so learning processes don’t decrease into a single option, neither stay associated with a single plant but multiple plants, consequently avoiding lock-in that could lead to development inside a technological learning paradigm.

Geographical decentralization and subcontracting

As a result of economic and technological competition, as well as labor tensions at the Warren plant, as mentioned before, in 1973 the company announced its harness production enlargement, but not in this same place. In that same year, PE built a new plant, in Clinton, Mississippi and in 1977 another one in Brookhaven, Mississippi. PE’s spatial reconstruction, was not an exclusive phenomenon; during the 70’s GM set up 10 new electric part supplier plants in the south and in the west of the country. At Warren, the union accepted that PE would create new companies beneath the conditional that UAW would organize those plants down its comanding. This situation led to weaken salary and labor conditions of PE’s biggest plant.

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34 Coordination Internal costs that were increased as the plants evolved to more complex harnesses production.
36 The Mississippi plants were organized (in 1979 and 1982) by the same union that it represented PE workers in Ohio. Helper (1998:308).
37 Delco Remy manufactures batteries in Anaheim, California; Olathe, Kansas; Fitzgerald, Georgia; and Laurel, Mississippi. Delco Remy begins outburst motors production and other electric components in Meridian, Mississippi and Albany, Georgia. Guide Lamp manufactures headlamps in Monroe, Louisiana. Rubenstein (1992:124).
38 UAW agrees not to hinder the construction of a plant in Alabama, where the workers could be paid at 6.50 per hour. In compensation, managers would not hindered to the union’s efforts to organize the plant. Helper (1998).
At the same time PE began to develop more opened relationships with other companies in order to diminish production costs through the use of non-qualified work force\(^{39}\).

Enterprises were attracted towards the south of the country by the readiness of non-qualified workers, weak or non-existing unions and relatively low wages\(^{40}\). From auto industry’s point of view, according to Rubenstein, this situation was «reflecting for the first time a spatial division of labor within the United States»\(^{41}\).

### Offshore plants

In 1975, PE opened an offshore plant exclusively for wiring harness assembly. Its name: Conductores y Componentes Eléctricos, located in Mexico, specifically in City Juárez, Chihuahua. This plant was paying one tenth of the wage payed at the Ohio’s plant\(^{42}\). The next four years, PE built four more plants in Ciudad Juárez. Between 1987 and 1993, PE built 12 additional plants in Mexico. In sume, 24 plants employing approximately 30,000 workers\(^{43}\).

This offshore plants were small-sized, on average each plant had 1250 workers, in contrast to Warren plant whose maximum employment level reached 13500 workers in 1973. It means that these last ones are on average ten times smaller. The modification of the optimum plant size, was a direct consequence of the need to produce more complex and varied harnesses with sensitive recurrent variations. Before using scale economies, PE’s purpose within Mexico’s offshore companies, was to create optimum plant sizes in order to face the demands of producing second generation harnesses, as well as to diminish the production and transaction costs.

It is legitimate to suppose that PE could have built at the north of Mexico large-sized plants just as Warren, but it didn't happen. PE rather bet to set up relatively small-sized plants, with just the bureaucratic structure needed to coordinate the process, as well as managers who interact easily with smaller groups of workers, improving constantly cooperation and technological learning processes. These conditions allowed to produce in each plant, specific lines of harnesses with economical, technological and administrative flexibility and efficiency.

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\(^{39}\) As long as the community opposed, PE failed in its attempts to create an employment program for the prisoners in Yazoo City, Mississipi. At the same time it stimulated the formation of subcontractors in Haiti. Russo J., «The Introduction of Team Programs and Competitive Manufacturing at GM Lordstown: An Historical Perspective», in Juárez-Babson (coord.), *Confronting Change-Auto labor and lean production in North America*, Benemérita Universidad Autónoma de Puebla/Wayne State University, p.p. 237-256, Mexico, 1998.

\(^{40}\) In the same region, (south of USA) were located small PE´s subcontractor plants which created different industrial relationships and mainly lower salaries due to union’s distance. Subcontractors companies located in the region mentioned before frequently pay less than minimum salary and were specialized in the production of small shipments for a sigle owner. In 1987, a northamerican company studied by Koido, had 15 integrated suppliers, and 42 independent ones who were distributed around Ohio, North Carolina and Mississipi. All these companies employed to more than 7000 people. Koido A., «U.S. – Japanese Competition and Auto Component Maquiladoras: The case of Wiring Harness Sector in the State of Chuihuahua» (mimeo), (s.f.).

\(^{41}\) Rubenstein (1992:121).

\(^{42}\) Helper (1998:308).

\(^{43}\) In the same year, were located in Mexico, the following PE’s competitor companies: United Technologies (10 plants), Yazaki (12); Murphi (1); Alcoa-Fujikura (4); L.T.T. (4); Chrysler (4), National Ind (3), y Molex (1). Carrillo J., R. Hinojosa y J. Waldam, «La Industria de los Arneses en México: Upgrading or Downgrading Process?», 2000.
Technological upgrading processes at PE´s offshore companies has been modified. Initially PE transferred, intensive labor processes. However, as long as offshore companies were accumulating capabilities and technological knowledge, PE transferred more complex processes. This technological learning dynamics is founded, in closer cooperation patterns between engineers and workers, as well as work force readiness to higher-quality production. Comparing Mexican and Northamerian PE´s plants, Helper observes: «This operation (maquiladora) was very impressive. A lot of incremental improvements has been made by both engineers and operators, with the result that components were readily available to the worker on the conveyor without stooping (...) Inventory was very low, and many procedures were in place to prevent defects»\(^{44}\). Intra-plant and inter-plant cooperation conditions that have led to higher quality levels; only one defective part in million in Mexico compared with 66 for Ohio operations\(^{45}\). PE´s offshore plants had begun an intense process of product engineering by the mid 80´s, in contrast the ones located in Ohio, began this process in the early 90´s\(^{46}\). The combination of management and labor efforts explain largely, those higher quality levels at offshore plants. This result also expresses PE´s capabilities for the creation of efficient plants from the logistics´ point of view. «Wherever, all of our plants work with JIT, as in cities as in small towns. Harnesses arrival take one day coming from Chihuahua´s rural areas and 18 days from Philippine. Harnesses shipments are still being very expensive and it is crucial made them in an efficient way»\(^{47}\).

The international labor division that PE was encouraging in 1983, meant for Warren union: «a more systematic integration of high skilled componentry production jobs in the Warren/Youngstown operation and so-called low skilled assembly jobs in Mexico»\(^{48}\). Relocation process that configures an international labor division where E/E components manufacture would remain in USA, as long as intensive in capital. The intensive segments in capital would not be relocated in the offshore plants by different reasons: i) «Packard Electric´s fear of political instability in Mexico, (ii) the loss of intellectual property associated with advanced production, and (iii) fears of future currency fluctuations» \(^{49}\).

This international labor division was being modified as long as wages earned by GM´s workers were decreasing. According to a Senior in Warren: «nobody is profitable at build-to (blue) print wiring, your margin is like a grocery store, just a few percentage points. Wiring is not perceived as hi-tech and has lots of labor content. So you´re a low-wage chaser, a continual chaser»\(^{50}\).

The migration process from USA to the north of Mexico was deepened everytime that PE´s managers pointed out that they were frustrated with the employees' envolving programs carried out in the 80´s and 90´s in Ohio, because: i) it didn't reduce costs, ii) PE was still paying

\(^{44}\)Helper (1998:318).
\(^{45}\)«There are many opportunities to create quality defects in the assembly process: by not inserting a lead into the connector far enough to establish an electrical connection». Helper (1998:307)
\(^{47}\)Carrillo (2000:18,19).
\(^{48}\)Russo (1994:12)
\(^{49}\)Russo (1994:10), subindexes are mine.
\(^{50}\)Gillet (1992), mentioned by Helper (1998:322).
high wages, iii) they perceived unions like a blockade to the changing process and therefore unable to recognize the market reality\textsuperscript{51}. Finally, another important factor; iv) Warren’s heavy bureaucratic structure that hindered the transition from first into second generation harness\textsuperscript{52}.

In 1996, PE’s managers announced the discharge of 1,800 positions which were dedicated to harnesses cutting. Those would be transferred Mexico. Later on, in november 1996, it was announced that BEC’s\textsuperscript{53} (Bussed Electrical Centers) for pickup trucks, would be transferred to Mississippi, losing with this 468 positions. PE’s first goal was to disappear the complex electric components area (BEC’s), where the best qualified workers were concentrated in. Secondly, to transfer complex harness assembly to the north of Mexico\textsuperscript{54}. As it is observed in graphic 1, employment level decreased year after year, form 13,500 employees in 1973 to only 7500 in 1997.

PACKARD ELECTRIC (1994-AHEAD)

Third generation wiring harnesses

From the 70’s to the early 90’s when an electronic component was introduced or improved, harnesses should be re-designed almost in its whole. In the late 80’s, Koido observed that: «Minor automobile model changes every year affect the wiring harness designs and lead to modifications in the production process. Moreover, small changes in some electronic parts can prompt changes in wiring harness design even in the middle of a car model year». Let’s think about frequently modifications in design and manufacture processes given the following complexity characteristics of automotive E/E systems: i) on average an automobile integrates 14 harnesses types, each one related to specific E/E components. A vehicle may require more than 40 electric subsystems\textsuperscript{55}. ii) Cable quantity varies according to the sorts of automobiles, it depends on the size of the motor: 800 cables for a 1,500 cm\textsuperscript{2} motor; 1,000 cables for the 2,000 cm\textsuperscript{2} one and 1,500 cables in the 2,500 cm\textsuperscript{2} motor\textsuperscript{56}. iii) Each harness uses around 100 different connectors types\textsuperscript{57}, exist in turn more than 200 terminals types\textsuperscript{58}. This complexity of E/E systems

\textsuperscript{51} Helper (1998:311)
\textsuperscript{52} GM’s different plants and divisions, which PE was part of, powerful and retrenched bureaucracies had been created. An internal report of GM, made in 1982 down (GM’s president) Roger Smith’s order, pointed out that GM’s bureaucracy «was virtually a swamp of moving sands as for procedures.» (..) To find a solution was easy, but its implantation was different history. It could take years. «Fifty thousand studies had to be developed to show which was the best solution. Then it had to go through ten different committees for its approval» (..) Too many negligences (..) Too many resistances to let intermediate managers to have initiative.» Thompson A. and A.J. Strickland (1994: 615).
\textsuperscript{53} BEC: Multiple switches are placed inside a box, in which wiring harness is inserted. Less intensive manpower process that it was invented by PE’s plant in Ohio.
\textsuperscript{55} Delphi Automotive Systems, 1999.
led automakers to: i) creating modular designs, ii) the substitution of copper by fiber optic and iii) developing multiplex systems. Modular designs and multiplex systems are the more important transformations in harness design and assembly, because both had led to stabilize the change processes. The main goal of modular designs is to develop flexible and change-opened harness architectures. This is the reason why whether or not many connections and harnesses can change. Approximately 80% of new designs are variations of previous designs. This result is explained by the simplification of: i) individual cables, ii) harness branches; iii) and control systems.

Modular architecture is based on a group of techniques that allow keeping 80% of the harness stable while the 20% remaining is changeable.

Modular designs have led to increase the proximity of: i) design and development centers of E/E components; ii) E/E component manufacture centers; iii) harness assembler plants.

Overall, modular designs have increased the intensity of communication skills between R&D, manufacture and assembly centers. This situation leads to perceive this new harness, from the point of view of its architecture (variability/stability) as a qualitatively different one, since it is compared with «unstable» second generation harness. The harness that emerges in the mid 90’s is also a third generation harness because it demands the concentration of suppliers and users linked by R&D centers whom are able to translate the heterogeneous and extensive needs of E/E system and part producers.

Packard Electric-Delphi, assembly plants and third generation clusters

After approximately 20 years when Packard Electric-Delphi created its first harness offshore plant in Ciudad Juárez, Chihuahua; Delphi set up in 1995 a research and development center (R&D) in the same city with an initial 150 million dollars investment. It is dedicated to produce E/E systems and components to a quite varied group of automakers. Fact that expressed in a successful way technological learning dynamic processes that took place inside PE’s offshore plants in Chihuahua.

Delphi’s technological capacity expansion process in Chihuahua took a direction that responded to diverse strategic purposes. To turn a design into a «dominant design» requires the presence of the company which impels the design, it must be present when and where assemblers find bottle necks or technological imbalances; so that production process continues without

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58 Lara A., «Cooperación y Competencia en la Construcción de Estándares», Universidad Autónoma Metropolitana-Xochimilco, Mexico, 2000b.
62 Lara A. «Arquitectura Modular y Administración de la Variabilidad: El caso del Sector Automotriz» Universidad Autónoma Metropolitana-Xochimilco, Mexico, 2000c.
interruptions. The company must be also present because it is interested in the appropriation of the information and knowledge that emerge from the conceptualization and solution of technological imbalances. The direction taken by the solutions to technological imbalances has enormous implications to create different technological trajectories in the companies of the cluster, as well to strengthen or to weaken the existing ones. At the same time, and as long as the strategy of the companies is to explode scale economies in new designs production of, and mainly to diffuse its designs or standards to remaining assemblers and suppliers, it is necessary to establish an efficient bridge in Chihuahua where the hugest concentration of companies linked to harnesses manufacture and assemble takes place. To implement this deep interaction process between suppliers and users demands rather high quality of human capital from those who gather technological information as from transmisors of it.

Delphi’s resources deployment from USA to Mexico, should be understood from the horizon of technological competition which is extremely intensified in the early 90’s with the launching of different models and versions of E/E automobiles ⁶³.

From 1995 to 1999 the center experienced increasing demand of products and services. For this reason in 1999 the company decided the expansion nearly double existing space to 40,500 m² dedicated for engineering, laboratory and prototype development ⁶⁴. While in 1995 it employed 850 people, towards 1999 the center employed 1600 engineers, technicians and support personnel ⁶⁵. In the year 2000 this center has 2000 engineers, 50 of those are linked to harness design and development ⁶⁶. While, there are 500 people employed on average in each Delphi’s engineering center, Delphi-Juarez employs four times this number. This center has been able to diminish, only in its first year of operation in 60% its total costs and in 20% its delivery time ⁶⁷. It has diverse activities of design and R&D linked to its six-division headquarter and at the same time with the environment; public and private institutions located in Chihuahua ⁶⁸.

CONCLUSION

In this paper, Packard Electric-Delphi’s history and harness technological evolution were reconstructed. In turn different histories emerge from this:

1. The first one, tells about the plant which met the power of a huge labor concentration: 13,500 workers in 1973 which little by little lost weight ending up with 7500 workers in 1997. There are different reasons behind the disintegration process of the plant in Warren, Ohio. Firstly, the conflict with rigid organization forms and weak cooperation

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⁶⁶ Carrillo, et. al. (2000)
⁶⁷ Carrillo y Hualde (1997).
between Warren’s engineers and workers. Secondly, the new organizational requirements of wiring harnesses manufacture. Second generation wiring harnesses demanded as individual as team higher commitment, attention and readiness in order to produce improved and reliable and high-quality harnesses. Weak cooperation between engineers and workers was an obstacle to reach these requirements and mainly to improve technological learning processes. The transition from first to second generation harnesses should be supported on horizontal and less hierarchical industrial relationships and because of the costs competition intensity in the auto industry, it should be supported on cheaper manpower.

2. The second one, presents to workers’ groups with scarce labor and union experience, organized in small plants, located in small and depressed towns of the south of USA. As a result of the agreement between PE and UAW, these plants were organized under similar rules, positions and salary segmentation as in Warren; in consequence they transferred to these plants the same sort of industrial relationships.

3. The third history; offshore plant’s workers and engineers creating more cooperative interaction forms, efficient and powerful forms in order to rationalize and to increase wiring harness manufacture processes. Added to the enormous salary breach that exists between USA and Mexico, PE and GM took a cost-saver decision which brough higher margins of competitiveness. But mainly, offshore plants represent a technological learning fertile social, economic and institutional field. It isn’t only an economic space, it is also a social space, constituted by thousands of workers who in many senses are highly able to create the cooperation forms demanded by wiring harness technological trajectory. Engineers and Mexican technicians are also an essential part to complete this successful technological competences accumulation process. After two decades of settling experiences at the PE’s offshore plant net as well as inside Chihuahua’s region, in 1995, Delphi set up in Ciudad Juarez a R&D center specialized in E/E systems and components.

4. PE’s migration to the south of USA and later on to Mexico, allows to identify the singular evolutionary processes of organizational and technological nature at the different regions where PE’s plants are located. When PE began operations with the form of offshore companies, it reconstructs a part of its history. In particular, the expectation of consolidating new industrial relationships, different to those existent at Warren. In 1975 when PE began with wiring harness assemblies in its new offshore plants; engineers and operation managers were provided by memory, as well as each one of the manufacture process actors.

5. Wiring harnesses assembled at offshore plants, are not the same harnesses (first generation) that traditionally had been assembled in USA, because this variated, complex an unstable wiring harness (second generation) was demanding higher quality levels and therefore self controled and cooperative workers. The transition to third generation wiring harness assemblies, multiplies this pressure as on workers as on engineers and managers.
6. The analysis of wiring harness technological trajectory is the fact that allows to identify the path of the harness qualitative and quantitative transformation and in this way to achieve an approach to the nature and evolution of clusters.

7. The distinctions built in this work about flowed and changing technological nature of harnesses, are useful to characterize the automotive parts cluster situated in Chihuahua. A cluster that produces first generation wiring harnesses is not the same than a cluster that produces second or third generation ones. So, during the second generation wiring harness production this cluster was structured around two demands; to elevate the quality of the harness assembly process and to improve the production and delivery rhythms, under just-in-time’s (JIT) logic. Later on, during the third generation wiring harnesses production, the cluster is densely guided to the production and assimilation of new designs of harnesses and E/E parts inside modular architectures of the automobile. The third generation cluster, is inside deeper and specialized interactions among plants, because modular design demands a geographical and social proximity to each participant of the production process. The transition of second into third generation wiring harnesses, is possible as long as a R&D «technological core» is built, it has the capabilities of joining and giving coherence and mainly of managing the order/variability processes of E/E systems. Visibility horizon therefrom is explained the importance of Chihuahua’s R&D center and its role inside the cluster located in this region.
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