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SUPPLIER PARKS AND AGENT-BASED TECHNOLOGIES AS EFFICIENT SOLUTIONS FOR COMPLEXITY MANAGEMENT IN AUTOMOTIVE INDUSTRY

Abstract

Due to their geographical dispersion and multi-national supply networks global supply chains are not able to manage logistics without proper technologies and organizational solutions. In the last two decades, few solutions have appeared which would change the traditional logistics management concepts. These include, but are not limited to, supplier parks (and their successors) and agent-based technologies. These concepts support implementing the BTO strategy in the automotive industry and help to manage complexity, especially in the area of variant management in the case of multi-variant products.

Keywords: software agents, supplier parks, automotive, complexity management

Introduction

The development of international business has resulted in a number of changes in the global market. Capital concentration, caused by a series of mergers and acquisitions, has led to the creation of transnational corporations (TNCs), which later transformed into network organizations. The technology development has simplified communication at a distance, which has allowed carrying on business simultaneously in different parts of the world. This development should be supported by process solutions (coordinating the order and performance of individual activities) and technical solutions to support them.

Network organizations, the latest stage in the evolution of network solutions, move operations to countries with less expensive factors of production. Processes of regional specialization, creating industrial monocultures, globalization of business and its fragmentation have started on the global market. Business ecosystems of network organizations, bringing together whole supply chains and elements of the external environment (e.g. competitors), due to their size, must be based on a smooth flow of data and apply the latest information technologies.

The development of information technologies and a growing role of intangible resources in shaping the competitive advantage of enterprises has led to the development of flexible forms of knowledge-based organizations (including flexible supply chains) that are focused on an effective use of knowledge as a critical resource, e.g. through diffusion of knowledge (see Table 1).

Today, companies pursue the concept of a learning organization closely related to the information society and knowledge-based economy concepts. Learning in such an organization is a continuous process, such as improvement of information and knowledge management. An organization may be called intelligent when it has reached a state of perfection as a result of learning processes. This entity is able to respond to changes in the environment and also understands and avoids shortcomings in its activities. The intelligence of an organization is described as a synergy effect of cooperation of the intelligence of its employees and various bits of functional intelligence.

The concept of 'fractal organization' means an independent business unit which has specific, certain objectives and its activity can be described as separate from other units. From this perspective, a fractal can be, for example, one of the organization departments (microfractal) or a whole organization (macrofractal). Microfractals are parts of the entire fractal organization (macrofractal). Global equity groups are macrofractals and subordinate subsidiaries – microfractals. However, the structure of capital relations in the global market is so complicated that there are often microfractals that are at the same time macrofractals for subsequent subsidiaries and subunits (one organization is both micro- and macrofractal). A virtual organization can be understood in many ways (as a network of interconnected computers between which there is a transfer of information; as an organization acting on the boundary between reality and fiction, etc.). Mostly, in the context of global market changes, it is defined as temporary cooperation of organizations that are separate but depend on each other, or as an organization functioning in the virtual environment only.

Those features can be achieved by stimulating the so-called smart growth, sustainable development and social inclusion. Information and communication technologies are expected to contribute to the acceleration of economic recovery and creating a 'knowledge-based economy' and 'sustainable digital future' (European Digital Agenda, 2015). It will be accompanied by the development of flexible manufacturing systems (FMS), supported by data communication networks and by robotics and automation of processes resulting in a pursuit of 'unpopulated factories'. The work will be intellectualised for both people and advanced IT solutions (Goban-Klas, 1999).

Table 1. Characteristics of today's transnational organizations

Organization type	Characteristics
Learning organization	– continuous learning – continuous process improvement – openness to criticism – flattened organizational structure – collective learning system – willingness to take risks – high innovation level – gaining new competencies – involving all staff in learning processes – delegation of power – expanded expert knowledge – management commitment – use of employee potential
Intelligent organization	– full internal information openness – investing in core competencies of professionals – focusing on multiplication of knowledge and exponentiation of convergence and synergy – organizational culture based on mutual respect, trust, willingness to co-operate with other employees in various configurations – IT infrastructure supporting communication in permanent and temporary teams – collaborative organizational forms (project organization, matrix organization) – creating innovative ideas through synergy of work of all team members (especially interdisciplinary teams) – full internal openness to sharing information – blurred boundaries between different types of information used, but also technologies, tools and information distribution channels (convergence) – pressure on multiplication of knowledge and competencies
Fractal (self-similar) organization	– structural, strategic and managerial similarity – freedom of decision-making – self-organization – self-optimization – system of objectives resulting from fractal targets – dynamism – orientation to create added value for the customer – developing synergy effects through fractal interaction – horizontal communication – removal of space-time barriers
Virtual organization	– task nature (project nature), dynamic project groups and virtual teams – intangible nature – a large role of the planning of communication processes and implementation of accompanying technologies – telecommuting (geographic dispersion of workers) – simultaneous use of modern communication techniques (Internet, Intranet and Extranet) – minimal possession and consumption of physical resources

Source: (own elaboration, referring to Kłak, 2010)

The main objective of this paper is to prove that supplier parks and agent-based technologies are ideas to help complexity management of logistics systems in an era of rapidly growing global network organizations in the automotive industry, one of the most dynamic and innovative sectors of the global economy. The secondary purpose is also to indicate these solutions as a support for building effective communication networks in supply chains in this sector, hence – logistics support of the primary (production) processes. The article is a typical review paper and contains the author′s viewpoint on the current state and role of supplier parks and agent-based technologies in the chosen industry. For this purpose, the author has used a literature review and critical analysis of the open source reports of the global research and consultant agencies. Firstly, the current state of the automotive industry is described. The next section presents the complexity management approach. Two following parts of the paper are focused on the two mentioned solutions, namely supplier parks and agent-based technologies. The last part concludes the paper.

1. Automotive industry

The automotive industry has shown high sensitivity to any fluctuations in the global economy for many years. Therefore, the greatest effort in this sector is put on reducing costs and increasing the innovation level in order to avoid the problems that occurred after the last global financial crisis. The size of assets held in the industry and the turnover generated are the reason why implementation of complex system solutions is needed to enable improvement of financial results in the long term. Stagnation of demand in the standard market segments can be seen mainly in the Triad, i.e. the US, Japan and Western Europe. In the early 21st century, the profitability of car sales decreased from 5.5% to 4% (Woźniak, 2011). The level of share of the BRIC countries (Brazil, Russia, India, China) in the industry production and in the creation of the production value of the industry has been constantly increasing since 2000, other developing countries have followed this trend. Additionally, other legal issues are introduced, mainly governing the safety of passengers and environmental protection. Increasing investments in product development can be noticed (coupled with growing changes in customer preferences) by more than 5% with car manufacturers (OEMs – Original Equipment Manufacturers) and 9% with suppliers, to which the risk of supply chain activities is shifted more often. The product life cycles are getting shorter, so the time for which the manufacturer introduces a new product on the market should also be shortened. In addition, the complexity of logistics and production systems is further intensified by a large variety of products, due to a diversity of customer requirements concerning the product attributes.

Providing good communication becomes the main goal for improving processes in network organizations, including supply chains. According to Woźniak (2011), the majority of electronic components in cars today do not originate from manufacturers, but from suppliers of subsequent tiers (Tier 2, Tier 3), what complicates the communication network design in the global supply chains. The share of electronic components in cars increases constantly. In the 1980s, the share of electronic solutions in cars was 16%, to increase to 25% in 2002 and 35% in 2010. It is expected to increase to 50% in 2020.

Therefore, communication in the supply chains of global corporations and mastering the product portfolio complexity will become the most important areas of logistics management in the industry in the forthcoming years. The following concepts can be realized to reduce the lead time and provide all kinds of flexibility in manufacturing systems:
– modularity of production;
– commonality of production;
– agent-based technologies;
– supplier parks.

2. Complexity management

The phenomenon of complexity in business ecosystems, built by global companies is a result of the impact of a number of internal and external factors (see Table 2). The most important internal factor have been an increase in the range of finished products offered to customers. The external factors that have shaped the long-term complexity of logistics systems are global macroeconomic volatility, volatility of raw material prices and the condition of the automotive sector (Marczyk, Czarnota, Gliński, 2014; Szmelter, 2017).

Notwithstanding the fact that complexity is described in the context of logistics management (Westphal, 2000; Baller, 2008; Mesjasz, 2014), there has been no universal, comprehensive definition of the term for over ten years. This is mainly due to the multidimensionality and ambiguity of the concept. For the purpose of this study the author's definition has been adopted stating that complexity is the number of states that are adopted by a system consisting of many components that interact with each other by building various types of single- or multi-directional relationships. The increase in complexity has its limits. In practice, each system has the so-called 'critical complexity' – a point beyond which the system cannot develop and further, it begins to totter. Then, it is necessary to introduce strategic changes to master complexity and in most cases – to limit it.

15% to 20% of the costs in the automotive industry depend on the product complexity. These, in turn, can be divided into the manufacturing area (30–40%), research and development (20–40%), logistics (10–20%), sales (10–20%) and procurement (5–10%) (Schoeller, 2009; Szmelter, 2017).

The system complexity is described in two dimensions – static and dynamic. The static dimension of complexity is its description at a given point in time (diversity), and the dynamic approach is considering this phenomenon over time (variability) (Westphal, 2000). Taking into account two characteristics of systems, namely, the dynamics of change and the diversity of components, four main types of systems can be distinguished. These system types are presented on Figure 1. Most logistics systems in the global automotive industry are systems in the upper right quadrant of the matrix.

Table 2. Major complexity drivers

Complexity driver dimension	Determined complexity area	Driver group	Drivers
External	Society complexity		Value changes
			Environmental awareness
			Legal factors
			Economic and environmental factors
			Political environment
			Sustainability
	Market complexity	Demand	Client expectation diversity
			Individualized demand
			Market dynamics
		Market competition	Number and strength of market players
			Market changes
			Competition dynamics
			Globalization
		Supply market	Supplier quantity
			Supplier diversity
			Variety of ordered materials
			Demand fluctuations
			Uncertainty of delivery dates and quality
Internal-external	Company complexity (connected with market and society)	Client structure	Quantity of clients and client groups
			Co-decision degree
			Heterogeneity of clients and client groups
		Products/Product range	Product structure
			Products and product variant quantity
			Frequency of new product launches and product mix changes
		Technology	Technological changes
			Availability of innovative technologies
			Innovation life cycle
Internal	Autonomous company complexity	Company objectives	Number and diversity of objectives reached simultaneously
			Dynamics of matching purposes to global market changes
			Timeliness of achievement of objectives
		Processes	Design and number of interconnection points in the process
			Degree of network density
			Degree of standardization
			Internal diversity and dynamics of the flow of inventories and financial and information resources

Complexity driver dimension	Determined complexity area	Driver group	Drivers
		Organization	Number of hierarchy levels
			Centralization degree
			Number of organizational units
		Structure	Number of distribution levels
			Number of warehouses, machinery, employees, etc.
			Vertical integration degree
			Communication systems

Source: (own elaboration based on: Giessmann, 2010)

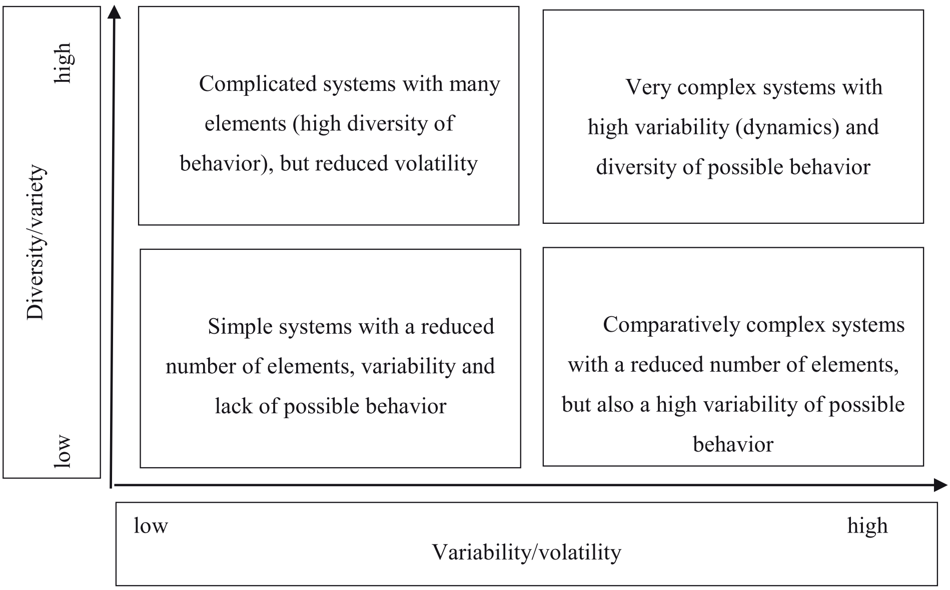

Figure 1. Types of systems with different complexity level
Source: (own elaboration based on: Krenn, Zsifkovits, 2007; Schoeller, 2009)

One of the dimensions of complexity is the product diversity. A distinction is made between internal and external variety. The external variety is a set of the same products in different variants to satisfy the customer. The more options to choose, the greater the chance of meeting the needs of all customers, and the higher the value delivered to the customer. The internal variety is determined by its external dimension and means a variety of processes and resources that are designed to meet the conditions of the external variety. Variant management should be designed to meet the external variety needs with the internal variety limited to a maximum at the same time (Zenner, 2006). It is part of complexity management, namely, the area is associated with a variety of products in the product portfolio of companies or capital groups.

The added value criterion in the automotive industry lies currently in meeting customer needs by offering a large variety of products that have the same functions but differ in details. An example of such a product differentiation concept is the Build-to-Order (BTO) strategy, which is reflected, *inter alia*, in the independent car design by the client in the configurator on the car (vehicle) manufacturer's website. The number of available product variants depends mainly on the segment in which the product is sold (see Table 3). Usually, car manufacturers allow the customer to select the preferred option from a few to a dozen or so kinds of options including the engine capacity, paint colour, type of rims, upholstery, dashboard and other parameters.

Complexity management of systems means activities aimed at (Szmelter, 2017):
- reducing complexity;
- mastering complexity;
- avoiding complexity.

Table 3. The number of standard variants offered in different car configurators of vehicle manufacturers

Model	Number of variants
Porsche Cayenne Tiptronic S	$2.53*10^{54}$
Audi A8 LWB	$6.67*10^{19}$
Volvo XC 60 Momentum	$1.65*10^{13}$
Ford All New Kuga	312004

Source: (own elaboration)

An important element of complexity management in logistics systems is the management of product variants. For this purpose, specific activities should be undertaken (Baller, 2008):
- determine the optimal number of product variants (which will satisfy the needs of customers without causing low profitability of the business at the same time);
- establish the principle of 'cleansing' the product portfolio in order to avoid product cannibalism;
- prepare a thorough analysis of costs (variant valuation);
- overcome the lack of information, resulting from incomplete and improper use of historical data about product variants.

Companies sometimes wrongly estimate the number of variants that will satisfy customer needs, so there is an excessively extended range of product variants. This situation takes place shortly after product launching. The optimum number of product variants can be estimated based on historical and forecast financial data, or analysis of costs and revenues. Too many product variants increase costs, while revenues are generated at the same level as in the case of smaller numbers of these variants. Therefore, such a number of variants should be established so as to ensure the highest possible profit from product sales. At the same time, an optimal number of variants may have different values and be in a certain range.

On the other hand, the increasing market competition requires that the product prices should be lowered, which is in conflict with offering an increasing number of product variants. Therefore, a conflict of objectives arises, which also poses a challenge for the automotive industry, in order to reconcile the expectations concerning the number of product variants with the increased competition and a high volume of production, i.e. economies of scale. Production management in this industry is linked strongly with modularization and commonality of production (Meyer, 2007; Renner, 2007; Krumm, Rennekamp, 2008). On the one hand, a finished product is not made of single parts, but entire assemblies of parts (components, modules), on the other hand – some parts are common for different product variants, and even for different products, included in the manufacturer's portfolio. Therefore, a synergy between products occurs, which is a result of the use of joint projects, products, parts, technologies and manufacturing concepts to manufacture various products.

System complexity in the automotive industry is not solely due to the multi-variant product portfolio. Intensification of globalization leads to a geographical dispersion of the supply chain components, including a diversity of the car manufacture location. In addition, except for the number of product variants, the complexity of a single product grows, resulting from the technological development and the dynamic phenomena of digitization of the social and economic life. Product life cycles are significantly shortened, not only by the technical development but also due to the growing customer expectations. All these factors affect the supply chains that need to meet the increasing competition in the global market. In view of the overlapping various complexity dimensions (complexity of processes, products, networks of relationships, etc.), the overall complexity is not growing at a linear but exponential pace.

Trade-off situations are common between the two spheres: purchasing with production and research and development, marketing and sales departments. The main challenge for people in charge of these areas is to reconcile innovation, complexity and profitability. The main activities that can make this possible are reduction of multi-variant products, price recalculation (based on Activity Based Costing), an increase in the commonality of products and the appropriate determination of the decoupling point (delayed customization, postponement strategy). First, there is a need to analyze the brands offered by the company in terms of strategic value and profitability. The analysis should also cover market segments, product portfolio and storage units. The weakest products which do not generate sufficient positive financial results should be eliminated from the product portfolio and replaced by new or already existing products, but requiring additional funding to increase sales and the market share. Sometimes, it can become profitable to leave in the portfolio products that have a high strategic value, but generate small profits. Then, the company should increase the prices to encourage customers to pay for the complexity maintained (this is called complexity visible to the customer, external complexity). In turn, internal complexity management focuses on building common platforms for products and commonality of their components, raw materials and production processes (including technology). The most effective strategies include simultaneous manufacture commonality and customization of products (postponement strategy). This helps to reduce the supply chain costs and eliminates the time required for research and product development, while providing the possibility of product differentiation. This solution allows minimizing the complexity and maintaining a high variability of products at the same time.

3. Supplier parks

The main determinant of the potential for complexity management of logistics systems is the ability to create flexible supply chains based on both mass production and order manufacturing. Howard, Miemczyk and Graves (2006) present the main dimensions of flexibility as the process, product and volume flexibility. The process flexibility includes the processes carried out in the whole value chain, also in the supply network. Integration of suppliers and their access to data on the actual demand will give a chance to build the process flexibility. The product customization must occur at a moment closer to the customer, which will ensure the product flexibility. The volume flexibility requires negotiations with employees and suppliers in order to reduce the dependence on the full capacity utilization.

One way to achieve the desired level of system flexibility is creation of supplier parks, located close to the OEM manufacturing plants. A classic example of such a park became the Dell plant in Limerick (Ireland) which operates exclusively on the BTO principle. It takes 5 to 7 days to deliver the product to the customer from the time of receiving a production order. The manufacturing facility maintains sufficient stocks for 4 hours of work on average, and orders are taken every 15 minutes (Davis, 2005).

A large distance between suppliers and customers has a negative impact on strengthening cooperation on joint production planning in relation to incoming customer orders. This means that any sudden changes in production mean significant financial losses that could be avoided if the provider were not far away. The main reason is the need to transport goods from the supplier to the customer. Therefore, supplier parks are one of the solutions to support implementation of the BTO strategy and optimizing the complexity management in the context of variant management.

Supplier parks are collections of different supplier manufacturing units located close to their customers. Howard, Miemczyk and Graves (2006) define supplier parks as a concentration of dedicated production, assembly, storage, carried out by suppliers or the service provider (third party) in close proximity (e.g. to 3 km) from the OEM (Chew, 2003; Szmelter, 2017). Parks are often described in the same way as industrial clusters, but this concept is much broader as it should not relate to the supply network of only one dominant recipient. However, it happens that recipients, and market competitors at the same time – run manufacturing plants close to each other and they have the same suppliers around them, simultaneously supporting competing companies.

In 2003 in Europe, there were 23 parks, centred around manufacturing plants of 8 automotive brands (VM-vehicle manufacturers): Ford, GM, Fiat, Peugeot, Renault, Seat, BMW and Volkswagen. All of them ranged from 7 to 24 suppliers (Howard, Miemczyk, Graves, 2006). Since that time a number of new units have been built, appearing to be subsequent at the planning stage, but there is no available data on the current number of those parks in Europe or worldwide. Experts expect an increase in the importance of the just-in-time (JIT) strategy in the material flow in the automotive industry, which undoubtedly will also be associated with the placement of supplier factories close to OEM plants. In addition, the development of information technology (e.g. self-steering technologies) will affect positively the creation of subsequent parks.

There are three types of supplier parks with respect to the BTO strategy, strongly connected with variant and complexity management: parks implementing this strategy, parks with the potential for its implementation, and those that have very low potential (Szmelter, 2017). The first group includes parks in which production is carried out on a large scale, and most of the value is created by suppliers. In their case, the park started operation aided with public funds, and these parks are not in direct neighbourhood of OEM plants (Volvo, Audi, Seat parks). In parks of this type activities are coordinated by the OEM (Volvo) or the logistics service provider (Seat). These parks enable the implementation of BTO because of the need for the production volume and the portfolio flexibility. Low start-up costs are an additional benefit. The potential inflexibility is reduced by advantageous relationships with suppliers.

Supplier parks with a BTO potential (for example GM) are usually small factories located near a major manufacturing plant of the same OEM. They are too small to support the BTO. The exist mainly due to the need for using free capacity or support a sister unit within Europe (GM). A location close to the OEM in such parks is due to the lack of financial support from government institutions. They have the potential to introduce JIT and late product configuration (both suppliers and the OEM), however, the low production scale is the reason why BTO practices are not in place there.

Parks with very low, limited potential (Ford and Jaguar) are also small, moreover, generally they do not have the support of the local administration in the form of financing the infrastructure and providing tax advantages. In the case of Jaguar there was no external financing, and initially the purpose of building the park was the production volume. The 12-hour lead-time eliminated the need to locate supplier plants next to this OEM factory. On the other hand, in the case of Ford, only one supplier located its unit near the OEM factory, for other potential suppliers the benefits of placing their units near the Ford facility were unclear.

Groups of suppliers cooperating with the OEM can form various types of associations with a diversified level of intensity (see Table 4).

The evolution of forms of supplier association types, especially supplier parks, developed strongly since the 90s of the twentieth century, led to the emergence of the multi-customer supplier parks concept that supports a number of car manufacturers located within a radius of 400 km from the park (Sihn, Schmitz, 2007). This is an 'intelligent' supplier structure in which factories of multiple vendors are located. This intelligence resides in increased productivity of this geographically concentrated structure compared to the dispersion of individual suppliers operating in isolation. Another feature of these parks are well-developed communication networks and automation of processes using self-steering technologies, particularly between Tier 1 suppliers and suppliers of subsequent tiers.

Every MCSP consists of (Sihn, Schmitz, 2007):

– suppliers which manufacturing components for several OEMs;
– one central logistic hub which is supported by one or more logistics service providers and includes logistics services for all suppliers in the park;
– one central production hub that supports the manufacturing processes for all suppliers (e.g. painting factories);
– one central park operator managing the park infrastructure.

Usually, the location of this type of parks depends on the transport potential of the region. Due to its remoteness from various OEMs, the integration between suppliers and car manufacturers depends on the means of transport, mainly trucks and trains, supporting the flow of goods. The logistics service provider is in turn responsible for the logistics operations, mainly delivery and distribution. The MCSP concept has been included in the strategies of BMW (KOVP concept – customer-oriented distribution and production process) and Daimler-Chrysler (pearl-chain concept).

Table 4. Types (levels) of supplier and OEM integration

Level of supplier and OEM integration	Characteristics	Examples
Automotive supplier community	Allocating production plants of suppliers (Tier 1and Tier 2) close to plants of their clients (OEM) One supplier can deliver for two recipients (two plants of one or many OEMs) Can be geographically dispersed	BMW Innovation Estate in Wackersdorf (Germany) Automotive Supplier Park Rosslyn (South Africa)
Supplier park	Result of cooperation of OEM and local government Mostly a cluster of Tier 1 suppliers near the campus of one OEM Suppliers produce modules, pre-assemble products which can be customized There is also logistics service provider (LSP) which for example assembles lamps The park is connected with a final assembly line of OEM by conveyor belts, tunnels or bridges	Seat car plant at Martorell near Barcelona (Spain) Audi Ingolstadt logistics Centre (GVZ) (Germany)
Supply centre	The centre is located next to the OEM manufacturing plant Structures and equipment are financed totally or partially by the OEM (and sometimes partially by the LSP) All suppliers and the LSP are tenants in a specific location (this it the reason for high flexibility for OEMs to change partners) Allows late product customization and automation for line side deliveries	BMW Werk Leipzig (Germany)
Condominium	Suppliers work in the same manufacturing plant as the OEM Suppliers locate their own equipment on the plant (in-house supplier assembly) Low buffer stocks Final assembly is controlled by OEM	Ford Industrial Complex at Camaçari (Brazil)

Level of supplier and OEM integration	Characteristics	Examples
Modular consortium	The highest level of supplier and OEM integration The whole assembly process is split into separable modules, each of them has assigned a responsible supplier Suppliers responsible for modules are responsible also for the finished product (car) All workers at the final assembly stage are hired by suppliers OEM is focused only on planning, engineering, control and administration. OEM tests the finished product only.	Volkswagen Truck and Bus in Resende (Brazil)

Source: (Howard, Miemczyk, Graves, 2006; Bennett, Klug, 2009)

Three main features of supplier parks contribute to reducing the logistics systems complexity:

– operational cost reduction;
– component inventory reduction;
– reduction of the time needed to plan and implement a production plan, also for production on order (BTO).

Additional advantages of such parks also include:

– lower transport costs, due to a well-designed and maintained road and rail infrastructure, lower labour costs in the park;
– synergy effects through the cooperation of people, but also intelligent IT solutions;
– knowledge sharing and benchmarking (knowledge-sharing networks).

No company today has all the knowledge necessary to design, improve and manufacture finished products in the automotive industry. The geographical dispersion of car production is mainly due to the existence of the global car model (world car) (Morris, Donnely, Donnely, 2003), to which manufacturing parts are brought from the same suppliers, but from different locations. It is called a design follow/follow sourcing strategy (Wassermann, 2009). However, the location of their manufacturing facilities close to the customer eliminates a number of risks associated with the transportation of parts at large distances. It is particularly beneficial when Tier 1, 2 and 3 suppliers locate their plants in close proximity. In such event, Tier 1 supplier, with which the OEM has placed the responsibility for the product, can locally control the manufacture of parts and components.

4. Agent-based technologies

With the development of information technologies, the systems engineering concept was developed, which focuses on the design of hardware and software in such a way as to integrate internal and external communication systems of organizations, including network organizations. In the automotive industry, as well as in other industries, agent technologies as well as self-steering concept

and embedded systems increase in importance. Automation of communication processes and the use of information systems engineering has resulted in a significant improvement in the functioning of the organization. Wassermann (2009) cites the following benefits already achieved in this area:
– 19% greater chance to achieve the financial objectives (profit) than the average in the industry;
– 4.4 times more embedded systems than in case of market competitors;
– 50% fewer defects in embedded systems than before the introduction of systems engineering;
– shortened product development time (time-to-market) by 25%.

The use of this kind of technology has increased productivity, e.g. by 20% in Volkswagen AG.

One of the elements of modern communication and convergence phenomena are agent-based technologies, which in recent years have been successfully used and developed in organizations, especially those with an international structure.

Thanks to the wireless technologies (e.g. Bluetooth, GPS, WiFi) and mobile devices that support them, it is possible to send and receive messages almost anywhere in the world. The growing processing power makes it possible to store large amounts of data, what allows building a hardware and software network to process these resources. The concept of Ambient Intelligence is closely related to these trends. It is needed to combine the so far existing technologies and equipment to create complex systems, smart grids, so that automation of activities will become possible (Stanek, Zadora, Żytniewski, Kowal, 2012). Devices that support these networks have inherent powerful processors and are able to connect to wireless networks. These solutions include:
– smart materials;
– microelectronic systems, sensor technologies;
– embedded systems;
– input/output device technology;
– ubiquitous communications;
– adaptive software;
– self-steering systems.

Self-steering in logistics can be joined to a group of other logistics management philosophies (e.g. electronic data interchange, integrated information systems, radio-frequency identification) that use technology development, contribute to mitigating the effects of high dynamics of modern logistics systems and enable the use of the potential that they generate. However, the use of modern technology makes sense, if it is possible to identify precisely specific goods (including the history of their development in the form of stored data and events related to the flow), their location and the status in the system (Fischer, 2012). The idea of this concept is based on intelligent software agents, specially designed computer programs that base on previously introduced parameters and control their own behaviour. They operate autonomously and are able to interact with other programs (with the use of the enterprise server or cloud computing). In independent decision-making, they base on information relating to the events in the real processes. Self-steering paradigm assumes independent decision-making at the level of logistics objects

(Szmelter, Woźniak, 2013), however, for these decisions prior targets and limits shall be determined (Freitag, Herzog, Scholz-Reiter, 2004). Each self-steering item takes into account its parameters and the associated similar entities, in order to set all the action in the most optimal way. Thus, the self-steering characteristic in logistic systems is decentralization of planning and control.

Two dimensions – decentralization and autonomy describe self-steering in logistics systems. Decentralization of planning functions and decision-making is good for large fluctuations of demand or unexpected disruption on the market or in the supply chain. Therefore, it means that the decisions connected with logistics objects are taken at their level. In turn, the second characteristic of the self-steering systems, namely autonomy, is based on independent decision making, which, however, is in a set of possible decisions. Specific intelligence is necessary to implement this type of actions. The degree of decentralization and autonomy indicates the degree of self-steering (Szmelter, Woźniak, 2014). The aim of logistics management should not become maximization of self-steering but an increase in the current self-steering level to the optimum. The level of complexity of a logistics system which consists of but is not limited to a variety of products and their quantity as well as the quantity and variety of the relationships in the logistics system of enterprises (logistics microsystem), supply chain (metasystem) and the economy (macrosystem) should be taken into account with the determination of such an optimum level. The aim of self-steering is to achieve a higher level of efficiency of the logistics system by overcoming the complexity of the existing system and the dynamics of the changes that occur therein.

Self-steering significantly improves the efficiency of the logistics system with increasing complexity. The usefulness of self-steering is verified by measuring the impact of different methods of self-steering to achieve levels of the logistic target volume with the increasing size of the structural complexity of the system. It is very important in the system to simulate real events, what is carried out before executing specific tasks. Thus, self-steering is very suitable for standard processes, often encountered in a given activity, but on the other hand, exceptional situations require intervention of a logistics specialist.

Self-steering is primarily based on intelligent agents – software that independently controls the behaviour of logistics objects on the basis of the previously introduced algorithms and control parameters. Self-steering in logistics consists primarily of process automation of control processes to the point in which logistics objects take some decisions on their own (these are the only decisions which affect them). One example of the application of this concept was implemented in the 2004–2008 ILIPT project, also known as the 5-Day Car program. The main objective of this project was to improve the indicators of planning in supply chains implementing the BTO strategy so that the car ordered by the customer reached him or her within 5 days from the time of placing the order.

The agent concept was created in the 1970s and it is based on the theory of AI (artificial intelligence). Its author is considered to be C.E. Hewitt who described the concept of intelligent, parallel concluding and decision-making IT system components (actors) (Jakiela, 2014). In the context of logistics systems such agents can be seen as interactive, self-contained, autonomous objects, carrying out logistics processes.

Software agents (softbots) are programs acting alone and reacting to environment changes in a similar way as humans. They consist of hardware and software architectures. They are able to communicate with people and other objects similar to them, therefore, they are reactive systems. After defining the task to be accomplished by the agent, it is able to tell which way of doing the task is the best (Jakiela, 2014).

Agents are goal-oriented, usually very complex (Wooldridge, 2002), pursue actively, constantly monitoring the variables that affect their decisions. They are able to quickly reconfigure a 'different way of thinking', if one or more of the variables have suddenly changed. What is more, they can select from the contradictory information that they often receive. Consequently, they are extremely flexible (Shirazi, Soroor, 2007). Normally they represent a specific department or position and they are able to perform one or more functions.

Softbots often take over price and other conditions of negotiations in supply chains, and they are also used for testing new network settings, new production line organisation, new software and many other issues (see Figure 2). Requirements for production materials are negotiated by the manufacturer (OEM) with suppliers, they, in turn, are conducting negotiations with their suppliers, and so on, throughout the supply chain. If the negotiations do not end with success, backward negotiation is made. In a situation where there are more bidders than the target number, the auction with the participation of softbots is carried out. Then the control parameters in the form of potential production, transport, storage, etc. and the financial scope of freedom are introduced by both the bidder and the buyer. If someone changes any of the control parameters, an immediate reconfiguration of other settings or even the entire supply chain is made (Müller, 2011). In every round of negotiations, the lower and upper price limits are introduced by both the supplier and the receiver. If one round is not completed with an agreement, the programs move to the next round of negotiating with new settings (Szmelter, Woźniak, 2014).

Agents can also be used in other situations, often requiring to take into account a large number of different variables, which would not be possible to do in a short time by a human. It is production forecasting and scheduling, calculations of material requirements, supply network design, scheduling of deliveries to customers that are often mentioned among such functions. However, the design process of this type of software is complex, as is the operation of solutions of this type. It is necessary to create algorithms that allow simulation and testing.

Agents allow connecting the already existing technologies in intelligent solutions, which are mainly based on synergy effects of the interaction of such technologies. The effects achieved by the use of agents are more far-reaching than traditional software types such as ERP, CRM and SCM. Therefore, development of agent-based technologies should be expected in the forthcoming years.

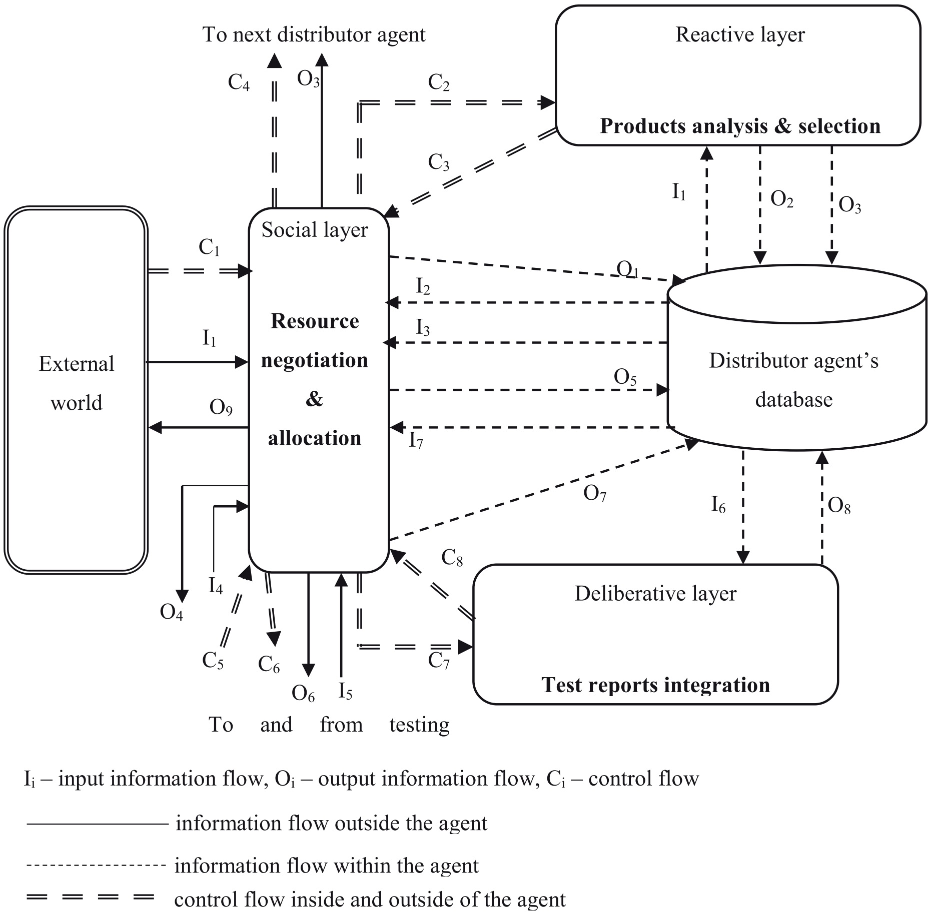

Figure 2. A view of the distributor agent
Source: (Dhavachelvan, Uma, Venkatachalapathy, 2006)

Conclusions

The development of global supply chains has presented many new challenges to logistics management. One of them is the complexity of logistics systems, being a result of, *inter alia*, high product variability and a rich product portfolio of vehicle manufacturers. In response to these challenges, a number of organizational and technological solutions have appeared to help companies to manage the complexity, so that they can help to reduce, control and limit it.

Supplier parks are a solution facilitating movement of goods in supply chains in the automotive industry. Placement of supplier factories close to their customers, the OEM, significantly contributes to the proper implementation of the BTO strategy, which is a solution to many problems associated with too many product variants.

The evolution of the parks in the past twenty years has contributed to the creation of many production sites with well-organized production, allowing customer orders to be fulfilled in a very short period of time.

The information flow in the parks, as well as in the entire supply chains in the automotive industry is supported by modern IT solutions, among which agent-based technologies have very high efficiency. Software agents allow quick decision making without human intervention, implementation of price negotiations, purchasing, planning and rescheduling of production in a very short time. In the future, artificial intelligence will be the basis of modern supply chains, not just in the automotive industry. The symptoms of this trend can be seen already today.

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