Systemic disruption and ambidextrous program management: The case of electric buses

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Technological developments (mainly digital), worldwide competition stemming from innovations and societal pressures on issues related to the environment has created a context where organizations are faced with major, sudden transitions. Relating the literature on innovation, ambidexterity and project management, this article describes these "systemic disruptions" and, using the concept of "ambidextrous program management", proposes the principles for coping with them. With the help of these concepts, a typical case of such a transition is analyzed, namely the electrification of the urban bus service in Paris. It helps clarify the issues raised by such transitions and the forms of project management capable of responding to them. An explanation is made about how these forms compare with the processes adopted since the 1990s to manage innovations in firms.

Disruption, systemic innovations, ambidexterity, the change of scales… management's terminology has, for several years now, been enlarged with many new ideas referring to the transformations that firms are now undergoing. Beyond fads, the concomitance of technological (mainly digital) opportunities and social pressure (related to environmental issues in particular) is creating a context that deeply alters the nature of the innovations that firms have to manage. This article seeks to accurately describe "systemic disruptions" and analyze how they require implementing new forms of organization, which we call "ambidextrous program management".(1)

After the first part of this article on what, in our opinion, are the original characteristics of these disruptions, an empirical case will be analyzed in transportation and mobility. For several years now, this sector has been a center of focus owing to the major changes experienced by the automobile industry, ranging from electric vehicles today to driverless vehicles tomorrow. This is not the only industry however. Urban transit is undergoing changes just as important. We shall examine the most ambitious program in Europe for deploying electric busses, namely the RATP's (Régie Autonome des Transports Parisiens, the greater Paris area's transit operator) electric bus program, which has characteristics that fully match those of a systemic disruption. We shall use to this case to suggest general principles for managing transformations of this sort.

Systemic disruptions

Systemic disruptions (VON PECHMANN 2014, VON PECHMANN *et al*. 2012) are transformations with five characteristics:

- the radical nature of the disruption;
- the scope of the disruption and its perimeter;
- the scale of the projects for handling it;
- the pace of the expected transition; and
- the necessity of making the transition while pursuing current activities.

Let us look more closely at these characteristics.

(1) This article has been translated from French by Noal Mellott (Omaha Beach, France). The translation into English has, with the editor's approval, completed a few bibliographical references. All websites were consulted in September 2020.

The most obvious is the RADICAL nature of the disruption. The switch from internal combustion engines to electric motors leads to questions about core business activities, which have been developed around transportation based on internal combustion engines. In the literature (DANNEELS & KLEINSCHMIDT 2001, CALANTONE *et al*. 2006, ABERNATHY & CLARK 1985), this is a first criterion for differentiating innovations: the contrast between an incremental innovation, which preserves the integrity of the existing system of design and manufacturing ("*design dominant*": ABERNATHY & UTTERBACK 1975 & 1978) and a radical innovation, which makes a break with the existing architecture and components.

The SYSTEMIC SCOPE (TEECE 1996, CHESBROUGH & TEECE 1996) of these changes means that they are being deployed in a wide range of business activities, beyond a single product over which the firm exercises (partial) control. The switch to electricity affects not just the design of an efficient vehicle; it also has implications about the new value chain for economically producing components (Batteries immediately come to mind), the infrastructure for doing so, the learning processes that users and operators must undergo (ranging from the individual customers who learn to drive the new electric vehicles to transportation management services, in particular transit authorities), and the modification of traffic regulations in urban areas (the goal being to decrease pollution and establish regulations about the emissions of vehicle fleets).

Managing systemic innovations is a major challenge since the firm involved has to adapt a whole ecosystem in order to transform the context so that its product can be efficiently used. For instance, the slow installation by public and private economic agents of stations for recharging batteries accounts for the difficulty of rolling out electric vehicles in most European countries.

Owing to this second characteristic, the companies most likely to make systemic innovations are mostly big firms well placed in their sector. They alone can push or pull their industrial and regulatory environments (TEECE 1996, CHESBROUGH & TEECE 1996). Apart from a few exceptions in California or China, this is outside the reach of startups.

The third important characteristic is the SCALE. To continue with examples from the mobility sector: prototypes of electric vehicles have existed for decades. What is now on the board are the changes needed for a massive rollout. The goal is no longer to deliver a proof of concept or to conduct a local experiment but, instead, to pass to a large-scale rollout "in real life". This scaling up has implications for making investments and overhauling manufacturing systems.

The fourth characteristic is the SPEED of the transition. Many of the programs on mobility conducted in recent years have set ambitious delivery dates that make it urgent to undertake major changes. The case of electric mobility is emblematic when we compare the acceleration of history since 2010 with the speed during the previous thirty years of changes in small, cautious steps at a slow pace.

The fifth characteristic is the PURSUIT OF CURRENT ACTIVITIES while managing the transition. A systemic disruption (which, as pointed out, is usually steered by major players in the sector) has to be managed without impairing current operations: "During renovation, the store will be open." This serves as the grounds of research on ambidextrous organizations (BEN MAHMOUD-JOUINI *et al*. 2007, DUNCAN 1976, TUSHMAN & O'REILLY 1996 & 1997 cited by BIRKINSHAW & GUPTA 2013). It has focused on how a single organization can carry on with business as usual while exploring the ways to cope with a systemic disruption.

Ambidextrous program management

The combination of these five characteristics accounts for the originality of the transition studied herein under the heading of "management of systemic disruptions". The globalization of the competition stemming from innovations and giant Chinese or American firms, the environmental emergency and the maturation of technological capacities during recent decades form a context favorable to the multiplication of such transitions.

These systemic disruptions challenge the processes of design and R&D that firms adopted during previous decades. Firms have long made efforts to develop their apacity for innovation. The landscape of industrial organizations has thus been deeply modified since the 1990s. The development and empowerment of project management (MIDLER 1993 & 1995), projects portfolio management (COOPER 1990), concurrent engineering (PRASAD 1996, SOBEK *et al*. 1999), multiple project management and the modularization of products (CUSUMANO & NOBEOKA 1998, MANIAK *et al*. 2014) have been conducive to the diversification of product lines thanks to the sharing of components and the distribution of innovation throughout the value chain. Innovation units now located upstream in the manufacturing process can explore possibilities (BEN MAHMOUD JOUINI 2015); and units of advanced engineering can use demonstrations to prove whether an innovation is valuable, help a new technology mature and prepare "riskless" solutions (MIDLER *et al*. 2012). Finally, the phase of development focuses on solutions that have been made feasible by optimizing the "golden triangle" of quality, costs and production time. These organizational models for design and their associated methods — "*concept knowledge*" (HATCHUEL & WEIL 2002, LE MASSON *et al*. 2006) and "*design thinking*" (BROWN 2009) upstream in the process along with concurrent engineering and computer-aided manufacturing (CHANG *et al*. 1991) downstream during development — have reshaped many firms. They are intended to rationalize the phases in a project upstream (exploration, prospecting, brainstorming and the maturation of innovative solutions) and then downstream (product development, speed, quality and costs). These design-based models effectively develop a flow of innovations (via dominant design) and protect (owing to the sequences and, thus, the compartmentalization they introduce) exploratory activities upstream in product development. A head-on competition between long-term, uncertain projects and short-term development projects would be fatal to the former, since the latter are by definition more profitable in the short run, and it would soon suck up a firm's financial resources (BOWER & CHRISTENSEN 1995, CHRISTENSEN 1997).

However these models have two limits for the management of systemic disruptions. On the one hand, key questions are not, given the compartmentalized division into sequences, addressed upstream; and this delays the actual attainment of the objectives set for the rollout of new products. Typically, systemic variables are seen as important only once the product is working in real life (VON PECHMANN 2014, VON PECHMANN *et al*. 2016), whence questions about how to switch to development on an industrial scale. These questions about scaling up are not usually addressed in "labs" (ALOCHET & MIDLER 2019). On the other hand, the innovation/development sequence (and compartmentalization) hampers the sharing of knowledge throughout the whole process, upstream and downstream, from those who develop products for tomorrow to those who prepare the solutions for the day after tomorrow.

Just as the concept of concurrent engineering modified the methods and organization of development engineering during the 1990s (CLARK & FUJIMOTO 1991), systemic disruptions lead to overhauling both the models of corporate organization and corresponding theories in the managerial sciences. Herein, we would like to contribute to this new model of ambidextrous program management. This form of program management has the following three specific characteristics, which make a break with projects portfolio management (PPM):

• First of all, ambidextrous program management is both strategic and complex. It is intended for managing a systemic disruption, as previously defined, in "megaprojects" (FLYVBJERG *et al*. 2003), like the Grand Paris Express (PRAGER 2019). Projects for developing electric mobility and driverless vehicles in the automobile industry have to raise billions of euros over several years. They represent a challenge for the industry's usual business-to-customer model, its technology and all players along the value chain.

• Secondly, this sort of program management involves multiple, heterogeneous projects (for new products, services, infrastructures, business models, ecosystems…) and objectives (exploratory or operational) with different horizons (short, medium or long terms). This heterogeneity is the reason for borrowing the word "ambidextrous" from authors who have defined it in strategy-making and the theory of organizations (TUSHMAN & O'REILLY 1996). This handling of a projects portfolio is different from traditional PPM, which compares projects classified in homogeneous categories (R&D, advanced engineering, product development) and tracks their advancement from one category to the next following regular reviews at "stage-gates" (COOPER 1990).

• Thirdly, the projects in an ambidextrous program are very interdependent and thus require special efforts of coordination. This accounts for the word "program" as defined in the literature on project management (ARTTO *et al*. 2009, MAYLOR *et al*. 2006). This sort of management tries to organize a concurrence in various aspects of the program in order to accelerate the scaling up to the global system (*e.g.*, by simultaneously working on the variables "infrastructure" and "vehicle" in a program on electric mobility: VON PECHMANN 2014), speed up the transfer of knowledge between projects of different sorts, and foster the pooling of solutions and shortcuts between processes up- and downstream in the "funnel of innovation", something that PPM with its categories cannot do.

Figure 1 depicts this passage from a classical sequence-based program to the concurrence fostered by a global program, as in the case of electric vehicles, where the mismatch between product development and the system of mobility was, from 2011 to 2014, a major

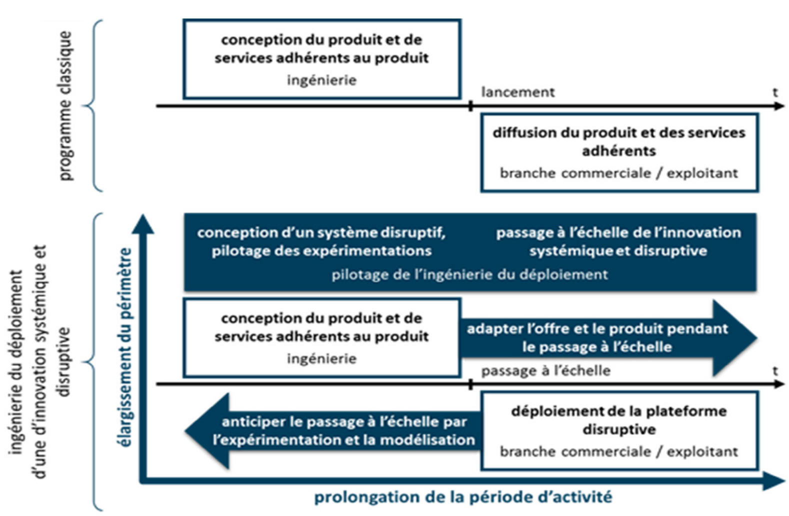

Figure 1: The rollout of a program for a systemic, disruptive innovation (VON PECHMANN 2014, VON PECHMANN et al. 2015)

impediment to this market's rapid growth (VON PECHMANN 2014). It is worthwhile adopting "rollout engineering" (VON PECHMANN 2014, VON PECHMANN *et al*. 2015) to simultaneously explore, prepare and implement the various aspects of such a transition. This can be done by detecting problems as best possible so as to find the best compromises for settling them.

To discuss an ambidextrous program and its principles, let us now examine a typical example, the RATP's Bus 2025 Program, a flagship for the rollout of electric busses in Europe and the world.[2]

The Bus 2025 Program

The initial challenge: A massive, sudden transition

In December 2013, Île-de-France Mobilités (IDFM, the transit authority for the Île-de-France Region, which includes Paris) made the decision to stop the RATP from acquiring nonhybrid diesel busses: "No procuration 100% diesel for the motorized rolling stock can be notified as of the current meeting." The IDFM's council also decided "to undertake actions for the transition of Île-de-France's fleet [of vehicles] toward a material that is all-electric or 'GNV Bio Gas'".[3] This decision forced the RATP to respond to what thus became an urgent situation. So, the transit operator switched to hybrid busses, a controllable technology not at odds with current operations. This switch represented a challenge because it had to be made massively and speedily. By 2019, the RATP had one of the biggest hybrid bus fleets in Europe, more than one thousand vehicles.

Though realistic in the short run, this choice entailed a transition. The extra costs for maintenance and a partial electrification of the drivetrain would hardly be offset by the savings on motor fuel over the life of a hybrid vehicle. Such vehicles were not, therefore, a lasting solution — a conclusion widely shared in the professional milieu. So, the RATP faced two possibilities: either continue operations as usual or undertake a radical transformation. Continuity meant natural gas, a familiar, industrially mature solution that could be applied in a way similar to the operation of diesel busses. The radical transformation would be to switch to electricity.

Pierre Mongin, CEO at the time, decided on a full transformation of the RATP's bus fleet, a decision that gave birth to the Bus 2025 Program. Publicly announced on 17 March 2014, this plan was extremely ambitious at the time. It aroused enthusiasm among users who take the bus but skepticism among several experts and manufacturers. Converting such a large bus fleet in such a short time to such an untried technology would be a major, even colossal, industrial challenge. Many voices were heard both in- and outside the RATP that expressed doubts about the program's feasibility. This program had all the characteristics of a systemic disruption, as previously defined.

Let us now see how this massive, sudden disruption is radically transforming the RATP's activities as a transportation operator and how this transformation reaches well beyond the firm's usual core activities.

[2] https://www.ratp.fr/groupe-ratp/newsroom/bus/bus-2025-lambitieux-plan-de-la-ratp-pour-un-parc-100-propre

[3] Minutes of the meeting of 11 December 2013, n°2013/548, of the Syndicat des Transports d'Île-de-France (STIF). At the time, the IDFM was called the Syndicat des Transports d'Île-de-France. In France, GNV (natural gas for vehicles) is the same gas distributed to households for heating or cooking. It is mostly methane.

Table 1: History and planning

11 December 2013	Decision by STIF (IDFM) to halt the purchase of diesel busses and to replace the oldest diesel vehicles with a large fleet of hybrid busses.
14 March 2014	The Bus 2025 Program presented to the RATP's governing board.
17 March 2014	The Bus 2025 Program officially announced.
17 August 2015	The TECV Act on the energy transition for green growth requires that at least 50% of busses have low emissions by 2020; and 100%, by 2025. Local authorities may designate low-emission zones (ZFE, formerly ZCR).
6 December 2016	STIF's decision: "*an objective for a clean bus fleet in 2025 in the most polluted urban zones*".
11 January 2017	The decree implementing the TECV Act: for the RATP, 50% of busses are to run on electricity or natural gas by 2020 and 100% by 2025.
11 October 2017	Under the Paris Climate Plan, the city of Paris announces the end of vehicles with internal-combustion engines by 2030, and reaffirms the end of diesel by 2024.
3 August 2018	Installations classified for the protection of the environment (ICPE): signature of the ministerial order with general specifications applicable to electric bus recharging stations.
End 2019	The first deliveries of electric busses at depots converted to electricity.
End fin 2020	The delivery of electric busses following a massive order for up to a thousand busses.
2025	The RATP's bus fleet will be 100% electric, natural gas or hybrid.

A radical technological shift in transportation services

The first rupture was, of course, to replace diesel or hybrid with electric (battery) busses. Hereafter, the phrase "electric bus" refers to a bus running on electricity from a battery, its horsepower coming 100% from the energy stored in the battery.

When the program was announced, 80 out of the RATP's 4500 busses were running on natural gas and 14 on electricity (respectively 2% and less than 0.5%). In 2013, 0.22% of busses in Europe were electric.[4] The Euro VI standard, which had just come into effect for trucks, required considerable investments from truck-builders, investments that would be amortized through the sales of vehicles with internal combustion engines. Outside China, electric-battery busses were mostly niche markets, such as urban shuttle services made up of vans or small busses (6-9.50 meters long). The shift from busses of a standard size (12 meters) to electric busses seemed far away. For public authorities (the regions and cities that organize public transit), operators and bus-makers, the reference point was diesel or eventually hybrid busses.

The switch from a diesel to an electric motor meant radically redesigning the bus as a product, since more than two tonnes of batteries d to be installed in a traditional bus, which, empty, weighs nearly twelve tonnes. Unlike private cars, where installation of the battery in the lower part of the chassis lowers the vehicle's center of gravity, a modern bus must have a low floor for facilitating passenger access. As a consequence, the batteries can only be installed in the back or on the roof. In other words, the bus's architecture has to be redesigned at the same time as its motor.

[4] Page 17, 3ibs (https://cordis.europa.eu/project/id/314334/reporting) D 23.1. These statistics do not take account of trolleys, which represented 1.2% of the European fleet. A trolley mainly relies on electric current from the cables suspended above the line.

A systemic disruption but without interrupting services

Like the shift to electric automobiles, which does not mean just replacing thermal with electric motors, the development of fully electric public transit services deeply alters all variables in the transportation system: busses, of course, but also the energy infrastructure, activities at maintenance depots, and processes for operating transit services (cf. Figure 2). The components in this system and their articulation have been stable for decades, owing to the dominant design model for busses with internal combustion engines (ABERNATHY & UTTERBACK 1975 & 1978). The shift to electricity means changing components and their articulation in the overall system.

Redesigning the energy infrastructure

Battery-charging stations has been recognized as the Achilles' heel of electric mobility. This holds for the Bus 2025 Program. Will the electricity grid be capable of charging the batteries of more than 3000 electric busses? When the program was launched, the answer was not evident. With approximately 200 busses per depot, each depot would have to receive about 10 MW of current — the average drawn per month in the winter by 10,000 households in France. Besides this question of capacity, connecting 17 electric bus depots to the grid is a major industrial project, necessitating approximately 100 km of trenches on public streets and highways.

Redesigning depots

A bus depot is a parking lot with white lines, a gasoline station and a building for maintenance work. Under the program, the depot has to be turned into an industrial center for charging batteries, a task that takes several hours. This means installing parking places with high-voltage stations and designing systems for distributing and transforming the electricity so that the batteries can be recharged in time. Recharging the batteries of 200 busses simultaneously with 10 MW in a space that, in the dense Parisian area, amounts to 500-700 apartments is not just a technical but also

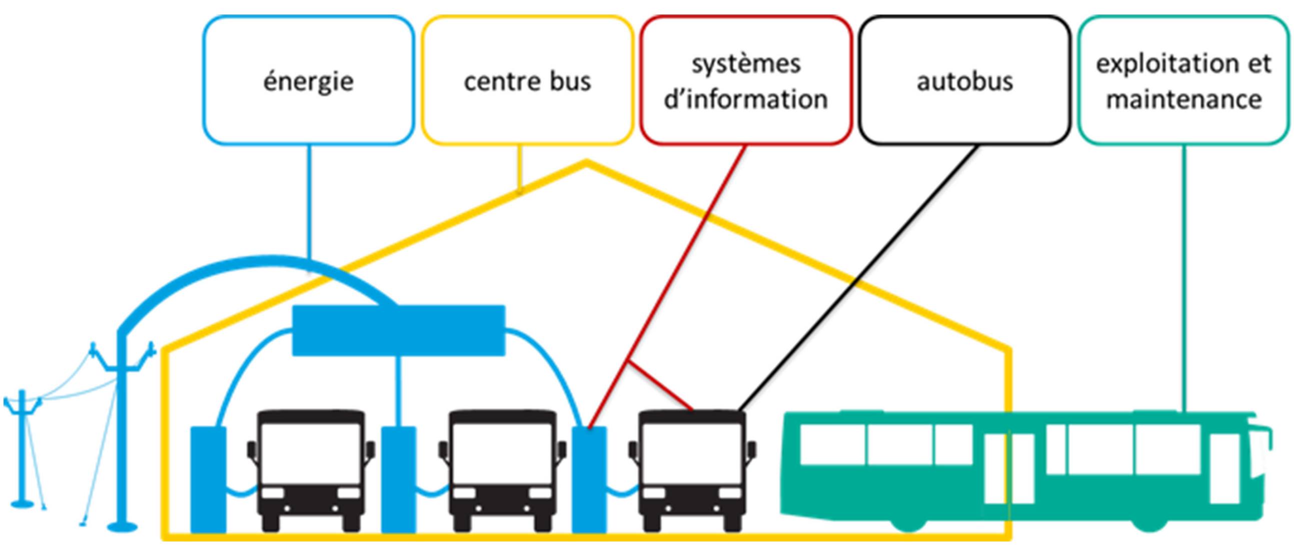

Figure 2: The principal finds of activity of an electric bus transportation system

a regulatory challenge. Regulations about installations "classified for the protection of the environment" (ICPE) did not foresee this case. They contain a section on small batteries (for elevators, for example) with rules that have to be followed when the current loaded is more than 50 kW. The consumption of electricity by a bus depot overshoots this ceiling 200 times. Following the regulations also implies major (but classical) construction works, such as the installation of sprinklers or protective barriers — on locations where installations often date back to the start of the 20th century. For instance, to store water for the sprinkling system, vats have to hold hundreds of cubic meters; and holes have to be dug for storage pools — a herculean task in a bus depot that remains in operation.

Redesigning current operations

The shift to electric vehicles brings along new conditions that have to be managed. Whereas the bus's autonomy is not a problem when it has a diesel engine, it has now become a parameter — the battery range or capacity — that has to be controlled. Reloading a bus's tank with diesel fuel took only a few minutes during the night, while the recharging of batteries has to be optimized in the organization of work at the bus depot. This restrictive factor could be loosened by increasing the number of busses in operation, but the program's objective is to have the RATP's bus fleet undergo the energy transition as is. The RATP thus started conducting in-depth studies of its current operations in 2016.

Till then, timetables for drivers as a function of bus services and under the conditions set in the contract with public authorities had been optimized for the number of drivers, the number of busses and drivers' working conditions. Could current operations be adapted? For example, can an electric bus driven all day long also be driven overnight? Till now, a diesel bus, if it had to be used right away, could be reloaded with fuel in three minutes. How to manage with an electric bus? How to be sure there will be enough time for maintenance, given that the bus cannot be recharging its battery during certain maintenance operations? How to be sure that the battery has been recharged adequately so that the bus, once back in service, can function (even if the current might have been cut awhile at the recharging station)? How to design bus services and assign busses so as to cope with contingencies during daily operations? These are questions that obviously have to be answered before launching the new electric bus transit system.

Overhauling the information system

For this transit system to operate, existing information systems have to be adapted to supervise the whole chain of operations: charging stations, battery ranges, the actual recharging of batteries…. Till now, the need for real-time information from a bus in service was limited to its geolocation, so that waiting times could be displayed. With the coming of the electric bus, the vehicle's autonomy has to be supervised in real time; and the bus has to relay technical information back to the command center. This real-time information has to be available all the time in the right format. These centralized data will have to be processed, aslo in real time, so as to have timely information about problems. These "real-time" requirements mean an organization capable of seeing to the operation of the whole information chain 24 hours a day. Furthermore, these data have to be stored for an *ex post* analysis, whence the need for storage space and, above all, the right analytical tools.

These important changes must be managed without jeopardizing existing infrastructures, roads, streets and bus services. This is the reason for ambidexterity: the program must be managed without interrupting existing operations and services.

Ambidextrous program management: Challenges and principles

How to manage systemic disruptions? We shall use the Bus 2025 Program to illustrate the principles that guide the organization of ambidextrous program management (MIDLER *et al*. 2019), namely:

- strategic flexibility;
- in-house learning processes related to a portfolio of heterogeneous projects with different time horizons;
- management of the ecosystem (partners, stakeholders, etc.) so that the transition will be a success;
- set up a governing structure to steer and coordinate the project; make choices for ensuring the ambidexterity of the transition, *i.e.*, invent and deploy the new transit service without jeopardizing current operations and services.

Strategic flexibility

In traditional project management, a project might be an element in a precise strategy. For instance, the classical projects portfolio management (PPM) basically organizes priorities among projects as a function of their alignment with the firm's strategy (assuming that it is stable).

In the management of the transitions described herein, there is a global vision, but the precise means and phases cannot be defined at the outset. An ambidextrous program is conducted in an ambiguous strategic context and must, therefore, be as flexible as necessary so as to make adjustments as projects advance. In the electric bus program, the initial goal of 100% electric by 2025 was, in 2014, trimmed down to a mix of 80% electric and 20% natural gas and then, at the end of 2017, on the basis of the findings of the studies conducted, again revised down to two thirds electric and one third natural gas.

This readjustment of the initial objectives has two consequences, as in all megaprojects (BEN MAHMOUD-JOUINI 2019). First of all, it proves that a "moment of truth" must be foreseen as soon as possible in order to adjust initial goals to precise, realistic objectives. Secondly, it means mastering communications with stakeholders and the general public so that these adjustments do not appear to be renouncements but, instead, normal actions in an emerging strategy (MINTZBERG & WATERS 1985), as it is honed thanks to the program.

Besides the problem of the size of the electric bus fleet, and given the program's systemic nature, the major options related to the architecture of mobility services — options that will determine subsequent developments — had to be frozen during this phase. One fundamental option was the decision to recharge batteries overnight in bus depots. Several other options existed, in particular, batteries could be recharged at the terminals of the bus line or at bus stops between terminals. For several reasons, the RATP decided on the depots. It wanted to preserve flexibility, a specific characteristic of the bus as a mode of transportation. A bus can flexibly alter its itinerary in case of street works; and a new bus line can be opened within a few weeks (compared with several years for railways). Furthermore, given a bus's relatively low daily mileage, busses can be acquired that have sufficient battery ranges. Furthermore, given the restrictions in a dense urban environment (with many historical monuments), it is often hard, even impossible, to set up recharging stations at terminals. Recharging batteries along the line or at the terminal would require parking time and simple access to the charging station — two conditions not always met in the greater Paris area. Finally, the batteries can be recharged at night with a current that produces fewer CO_2 emissions, while the electricity grid is more available.

Learning to conduct multiple, diverse projects with different prospects

How has the principle of coordinating heterogeneous projects with different time horizons been applied in the Bus 2025 Program?

Simulations of the feasibility of global options

The use of primarily qualitative methodologies of creativity (as in innovation labs) is of little worth for handling questions related to the large-scale operation of a complex system, such as running hundreds of vehicles in the greater Paris area. For this reason, the Bus 2025 Program launched, from the start, a series of actions for exploring the major obstacles to scaling its projects up.

Starting in early 2016, the RATP carried out simulations for recharging bus batteries. These simulations, which took account of the time busses run and of the time needed to recharge batteries, could be used to explore the variation of parameters, such as the power per bus needed for recharging. The results have been shared with Enedis (which distributes electricity) and RTE (which oversees the high-voltage grid in France) so that they can make medium-term plans for their grids.

Other simulations have focused on the operation of bus lines, or routes. A study, which will take several years, focuses on how to manage and recharge busses at the depot. It will gradually delve into all questions about the time an electric bus spends at the depot. The initial aim was to see whether sufficient time had been foreseen for recharging batteries. In-house teams will study how to optimize the assignment of busses to services so as to maximize the recharging period for each bus. In a partnership with a public research laboratory, this research will then shift to building a complete model of a bus depot. Studies of this sort are complicated, since they have to take account of the planned services at a depot, the time for recharging batteries there and other factors (such as parking space). They represent a completely new learning experience for the RATP that will help it develop an operational information system.

Experiments for a collective learning of new operations

At the end of 2015, the RATP also launched studies on the infrastructure in view of a first series of experiments on a line for an electric bus of standard size (12 meters). The 23 diesel busses on Line 341 will be converted to 23 electric busses to be recharged at the Belliard depot in le 18th arrondissement of Paris. This experiment sought to learn about several aspects of the transit system, in particular the distribution of current at the depot.

To benefit from the feedback from these studies, a second experiment was conducted at the end of 2016. It mainly sought to study the recharging of batteries at bus line terminals, but it will also test the systems of distribution foreseen for general use. It will help foresee the forms of organization needed for this generalization. In effect, the conversion of 17 bus depots in seven years time calls for major efforts. Since transit services have to continue throughout this period, any construction work will be carried out while the depots remain in operation. Besides construction equipment, approximately 200 busses will be entering and leaving each depot every day, all this in an extremely dense urban environment. Several teams have been formed to oversee the construction work on buildings and electric lines; and one team is to coordinate all players and current operations.

The first wave of experiments focused on converting Line 341 to electricity. Nearly all fields of engineering were involved: electricity, information systems, the building trades, operations and maintenance. The public administration paid close attention to this experimentation since it was, at the time, drafting regulations. Busses on loan were used in tests. These experiments have accelerated learning at the participating firms and in the RATP's engineering and current operation departments. Studies of several subsystems have been made to clearly specify the transit operator's needs and improve its understanding of electric bus systems.

A second phase of experiments tested the solutions worked out during the previous phase: electric heating in busses, their electric architecture, the organization of construction work at the depots, and the recharging of batteries at terminals as well as the supervision of this operation. These studies are increasingly systemic in view of building a model of all aspects of the operation of electric busses.

For the rollout phase, the RATP has chosen to gradually scale up skills and qualifications. Following a decision-making process involving major actors in the firm, a multicriteria analysis will rank the depots so as to give priority to those where it will be easiest to convert bus lines to electricity. This analysis will also take account of the construction work necessary for this conversion. Two new depots, partly predisposed for this, are going to be converted in advance. They will use busses (acquired under an intermediate bid) nearly a year before the rollout at the other depots. This rollout will take place gradually, thus bridging the transition between the phases of experimentation on location and massive deployment.

By the end of the second phase of experiments in 2018, the RATP was running 80 electric busses, half of them of standard size. By the end of the first subphase in the rollout (late 2019 and early 2020), nearly 160 electric busses will be in circulation. The rollout will intensify, with deliveries of up to 600 busses per year, an unprecedented pace for the firm.

Thanks to this engineering model for an ambidextrous rollout, all actors in the firm, in particular those who continue their usual activities, can be involved. While the program is under way, operations with diesel busses continue. The RATP will purchase its last hybrid bus and inaugurate two new depots. The experiments and thematic committees are forums of exchanges where those involved in the program regularly meet personnel from traditional occupations, exploration and current operations.

Managing the ecosystem

Although we have insisted on actions inside the firm, the systemic nature of the transformation requires implicating in the engineering model of the rollout all stakeholders outside the firm: bus manufacturers of course, the transit authority (IDFM) and operator (RATP), and the public entities (Enedis) in charge of regulating and distributing electricity.

The design and supply of electric busses

In 2014, European automakers had very little experience with electric busses. A few urban shuttle busses or vans (6-9.5 meters long) made up most of the electric fleet in Europe; the penetration rate was only 0.22%, while standard size busses (12 meters long) represented approximately 56% of the European and 85% of the RATP's fleet.[4] Only a few prototypes of electric busses produced in small series were in circulation. To test and stimulate the market, the RATP issued a first, experimental, invitation to bid in 2014. Its specifications stipulated a minimum autonomy of 120 km between recharges. Given the ceiling set at €20 million, this represented a small procurement operation for the RATP but an important market for electric busses. Bluebus, a subsidiary of the Bolloré Group, won the contract while pledging an autonomy of 180 km. Unlike some established vehicle-makers, this newcomer would make the busses from scratch so as to better take account of specifications for the batteries.

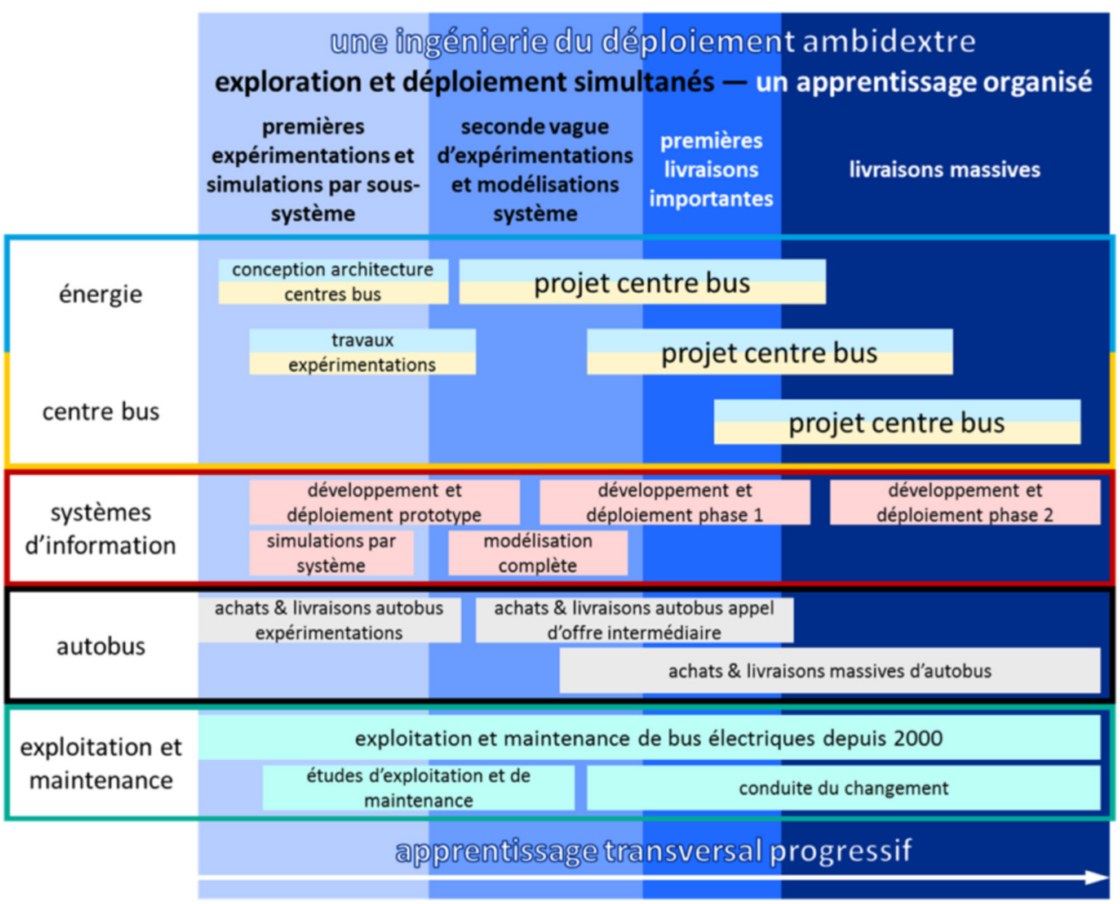

Figure 3: The engineering of an ambidextrous rollout of electric busses

Shortly afterwards, the RATP proposed to automakers worldwide to test electric busses, often with passengers, under operating conditions. Seven manufacturers from four countries (France, Spain, China and Poland) loaned vehicles for use on bus lines in Paris. These busses were equipped with devices for measurements. Tests started at the end of 2015 and lasted several months. All participants thus improved their technical knowledge of these vehicles and of the infrastructure, and better understood the operation of electric busses. These experiments created knowledge for engineering, for operators and for the companies that supplied the vehicles. Surveys at that time confirmed the validity of the switch to electric busses in Paris: most passengers preferred them, and drivers very much appreciated the calm, fluid driving.

As a signal of its determination, the RATP launched other invitations to tender for electric busses: an intermediate one in early 2017 for a total of €40 million, and a massive one in early 2018 for a maximum of €400 million with the goal of up to 1000 busses — the largest public procurement of electric busses in Europe.

Purchasing such large quantities of vehicles meant drafting lists of specifications. For this, the RATP's engineering department had to take account of all requirements, in particular, for the electric drivetrain. Successive invitations to tender and the experiments with loaned busses were crucial to the program. The experience gained by those involved and the exchanges upstream with manufacturers were essential for formulating with manufacturers realistic but ambitious demands. Let us take the example of heating, a critical point in an electric bus. Heating a bus used to be a nearly for-free operation, since the diesel motor produced heat that could be recuperated inside the bus. These exchanges with manufacturers would lead them to guarantee an acceptable temperature for both driver and passengers, while seeing to it that the bus could be driven the distance planned. New servomechanisms had to be designed specifically for these busses.

Given these massive invitations to bid, activities had to be reorganized in view of the volume of procurement. The teams that accept deliveries normally check whether the goods comply with specifications. They are used to handling about 300 busses per year (exceptionally up to 500). To be sure that it will be able to do without diesel busses by 2025, the RATP will have to take delivery of 600 (electric or gas-fueled) busses annually over a period of several years. The challenge is twofold: take delivery of an unprecedented number of new vehicles and see to the operation of the busses using a new technology and the interfaces with this new ecosystem.

Involving public authorities

Public transit naturally involves many public actors. A transformation like the Bus 2025 Program can be undertaken only in close cooperation with a large number of public authorities. Let us now discuss two of the roles played by these authorities in the program: the role of setting (and sticking to) a schedule for the energy transition and the role of regulatory guidance.

- Setting a calendar for the energy transition. Public authorities see to it that the timetable set for the Bus 2025 Program is kept. The history of this program is about ongoing interactions between the conditions imposed by authorities at various levels and the RATP's strategic decisions (*cf.* Table 1).

The first level of public authorities involved is regional, namely Île-de-France. The transit authority's decision to halt the procurement of diesel busses led the RATP to make the strategic decision to convert its fleet to electricity and natural gas.

At the state level, the TECV Act on the energy transition for green growth ratified, we might say, this strategic decision. Under its provisions, cities with more than 250,000 inhabitants are to acquire by 2020 at least 50% of busses with lower emissions and by 2025 100%.[5] It was probably easier to add these provisions since the RATP had already announced its decision to convert its fleet at a faster pace. This act has facilitated the rollout of electric bus programs. When a program is made mandatory under the law, it becomes less uncertain; and its implementation, more evident for actors, both internal and external. Thanks to this act, the Bus 2025 Program is no longer an isolated pilot experiment. The RATP is leading a large group of metropolitan areas that will be converting to electricity.

The state has also given cities a means for implementing the TECV Act: it allows local authorities to set up low-emission zones (ZFE). The city of Paris has taken advantage of this provision to keep the most polluting vehicles, including mass transportation vehicles, from entering the city. It has also announced its intention to gradually shorten the list of vehicles allowed to enter the city, the objective being to eliminate all diesel vehicles. Mayors in the neighboring communes belonging to the Greater Paris Metropolitan Area are planning similar restrictions. Although these announcements and decisions do not have an impact on the strategy for the Bus 2025 Program, which, as pointed out, has set very ambitious objectives, they do make it more legitimate. This most ambitious electric bus program in Europe now replies to a demand from local authorities. For this reason, not sticking to the schedule is out of question. Besides, those who head the program have had to contact stakeholders and explain to them that accelerating the implementation of such an ambitious program cannot be imagined.

- Regulatory guidance. Interactions with public authorities have been ongoing for the purpose of adapting the rules and regulations for public transit.

A positive point for the development of electric busses was Article R312-4 in the French Highway Code, which authorizes such vehicles to weigh a tonne more than the normal limit. An electric bus may legally weigh up to 20 tonnes with its passengers, compared with 19 tonnes for a diesel bus. Thanks to this, electric busses can be built and purchased that transport the same number of passengers as a diesel bus. In other

[5] Article L224-8 of the Environmental Code, created by Article 37 of the TECV Act on the energy transition for green growth. Act n°2015-992 of 17 August 2015 available at: https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000031044385.

countries, the 19-tonne limit has hampered the development of busses with electric batteries, since operators claim, rightly so, that they want to transport people instead of batteries.

Owing to its innovativeness, the Bus 2025 Program has made it necessary to rethink existing rules and regulations. For example, regulations about the workshops for recharging batteries were made for lead batteries, which can emit hydrogen if damaged. This is not the case for the modern lithium batteries installed in electric busses.

The public administration may decide to set up an "authorization-based" system when it is unable to draft general rules for a new field of technology. Operators will then have to show, case by case, that their installations are safe enough for property and people, in particular employees, neighbors and other third parties (such as firefighters). This procedure would add at least twelve months to the period for converting a depot (the time needed to conduct a mandatory public survey). Furthermore, it would raise costs significantly since models would have to be built for each depot. Foreseeing this risk, the RATP entered into contact with the administration in 2015 for the experiments at the Belliard depot. For approximately three years, the RATP and its partners have built models of how busses and batteries are used, and have carried out tests in certified centers to better understand how an electric bus can break down. This work led the administration to draft a set of regulations about electric bus depots. Enforced since August 2018, it has many more regulations than those for diesel busses. Nonetheless, thanks to it, the RATP can plan the rollout phase of its program on a stable basis without going through an authorization process.

Involving energy-providers

As of 2015, the RATP had contacts with the distributor of electricity, Enedis (ERDF at the time), to improve connections to the grid in bus depots and ascertain whether the grid had the capacity for recharging bus batteries. Owing to transit by rail (the Parisian and suburban subway systems, tramways), RATP's engineering department has a long experience with electricity and already had close ties with Enedis. Having its own system for distributing electricity in house, the RATP was already aware of the constraints and delays for public works on such a system. During the discussions planned with the energy-provider, the RATP asked for several scenarios of connections to be examined and for feasibility studies for each depot. The results are conclusive: the electricity grid in Île-de-France region has the capacity for recharging the RATP's electric vehicles. To provide for the continuity of public transit services, the RATP has opted for a double connection to the Enedis grid, since, in case of a single connection, a severed cable would halt operations at the depot for several days.

The first series of studies launched at the start of 2016 focused on the overall design of the electricity grid in bus depots. Several options were worked out; and each was then analyzed using the criteria of labor costs, geographical impact (in a dense urban environment with scarce space for busses), feasibility and maintainability. The solution selected will maximize the space for busses, and guarantee a high level of feasibility at a controlled cost.

Connecting 17 electric bus depots is, as pointed out, a major industrial challenge that entails digging approximately 100 km of trenches on streets and highways. To oversee these works and best optimize public expenditures by sharing the costs of handling mutual constraints, the presidents of the RATP and Enedis signed a partnership in early 2018.

A program team for orchestrating contextual ambidexterity

The Bus 2025 Program is a portfolio full of projects that have different purposes and involve different actors. Some projects explore possible scenarios; others will work out solutions for 2025; and still others, examine transitional procedures for passing from the current situation to future services of mobility. How to organize this transition without jeopardizing current operations? This is a key topic in research studies on organizational ambidexterity. The literature has pointed to three possible forms of organization.

STRUCTURAL AMBIDEXTERITY consists of separating the persons in charge of designing the solutions for handling a disruption (TUSHMAN & O'REILLY 1997), as in the case, for example, of the management of projects like Renault's Logan or Kid (JULLIEN et al. 2012, MIDLER et al. 2017). In contrast, CONTEXTUAL AMBIDEXTERITY is based on managing a transition while letting the firm's actors in their usual situation at the workplace but giving them the time to explore scenarios for the transition (GIBSON & BIRKINSHAW 2004). NETWORK AMBIDEXTERITY relies on actors outside the organization to make the rupture, actors (typically startups) who will be helped in their exploratory activities (by funding them or welcoming them in a firm's business incubator). Forms have emerged that combine these three models in innovation labs, which ever more big firms are setting up (BEN MAHMOUD JOUINI 2015).

The organizational options chosen by the RATP to articulate the Bus 2025 Program with the existing organization follows a model of contextual ambidexterity. These options give priority as much as possible to intimately associating the actors of the transformation with the system of operations in place.

- ORGANIZING THE PROGRAM hinges on the position of the "program team". In mid-2015, a division was created for the program within the rolling stock department (MRB) in charge of the purchase and maintenance of busses. This choice might come as a surprise in a firm where another department is devoted to major civil engineering projects; but it turned out to be judicious in many ways throughout the program.

To its advantage, the MRB is closer to current operations and maintenance, and under the deputy CEO in charge of transportation and maintenance. The purchase of busses, which represents the largest heading in the program's budget, is in his hands. This proximity with the program seems essential for mastering the new interfaces, while the proximity with current operations facilitates the leadership necessary for accompanying the move toward electric busses. However the MRB is oriented toward processes but has had little experience with projects. It has had to adapt to project management.

For these projects, several levels of steerage have been introduced. A steering committee meets every two months and reviews all projects in the portfolio. Alternating with these meetings are those of several select committees, which follow up on the projects in more detail. Finally, each project in the portfolio is subject to a semestrial review and assessment. At all these levels, the program director is present.

In all, the implementation of the electric bus program directly involves more than 150 people in the firm, without mentioning the more than 15,000 operatives, drivers and maintenance workers employed by the RATP or the persons concerned among subcontractors and suppliers.

- Governance. To involve as best possible all departments in the RATP and foresee the changes that will affect numerous persons in engineering, operations and maintenance, a governing structure was set up at the company level in early 2016.

Every three or four months, Comex, the executive committee (including the RATP's president), meets for about two hours to foresee and address major risks. In addition, regular steering committee meetings are held with the transit authority, IDFM, on various aspects of the program.

A form of governance has been set up in parallel by occupational field. Thematic committees meet every quarter or semester to discuss the program's main aspects: bus depots, current operations, maintenance, energy, etc. The results of the studies being conducted are diffused during these committee meetings. The major decisions made are recorded in the presence of the program director and the heads of occupational fields.

- Learning across the board. To respond to the challenge of conducting simultaneously the phases of exploration and rollout in both familiar and unknown fields, the RATP has set up two forums for pooling skills and capitalizing on the qualifications that gradually develop during the program.

The one is related to the full-scale experiments that involve nearly all occupational groups. The other forum is the thematic committees that, besides their role in governance, are also places for exchanges among experts (in particular about the studies to be carried out).

A model of ambidextrous program management

Systemic disruptions, like those described herein, are occurring in several sectors: sudden, radical, massive transitions that, with a perimeter much larger than the core business, concern diverse parties other than a firm's usual partners. These transitions have to be undertaken without jeopardizing the activities that currently bring in income. Behind these inevitable transitions, we often come upon factors related to: the urgency of climate-related issues, the upsurge in power of digital technology or the arrival of competitors who, like some American or Chinese firms, are to be dreaded because of their capacity for deploying innovations. Transitions of this sort call for organizations and innovation processes different from those that made firms excel in the 1990s, when innovations were managed via a rather stable approach, dominant design.

Herein the phrase "ambidextrous program management" refers to the key principles of a new model that seems better adapted to systemic disruptions. We have illustrated these principles in the case of the RATP's Bus 2025 Program, which, still under way, is coping with this sort of disruption. Since it has not yet entered history, we do not intend to prove that it will turn into a success story. Instead, we have sought to show that certain principles of organization can be rationally more coherent with the situation resulting from a systemic disruption than the processes currently used for innovations in firms. Let us now place this case in a general model of ambidextrous program management. On the basis of the Bus 2025 Program, Table 2 summarizes the reasons that ambidextrous program management can represent a relevant response to a systemic disruption.

Contextual or structural ambidexterity?

Obviously, the case of the RATP does not let us describe all forms of ambidextrous program management. The literature on ambidexterity proposes, as we have seen, contrasting forms, between contextual and structural ambidexterity, for implementing this sort of management in organizations.

The choice offer contextual ambidexterity might be made for two main reasons.

The first has to do with the program's position in the firm's strategy. As we have seen, this transition is both a proactive strategy by senior executives and a response to external factors. For sure, the energy transition will affect the whole system of bus transportation. As a consequence, the best strategy for accelerating the transition is to involve all actors as soon as

Table 2:	
Characteristics of systemic disruptions	***Characteristics of ambidextrous program management***
Radical nature of the disruption	— Identify the target for a global strategic transition. — Adjust the strategy while the program is under way as a function of the findings of the studies conducted.
Systemic dimension of the transition	— Regardless of the sort, perimeter or horizon of the projects, bring them all into a single program for managing the transition. — Implicate outside actors (public authorities, energy-providers, bus manufacturers, etc.) as soon as possible in carrying out the program.
The scale of the disruption	— Define phases of the program while gradually enlarging the perimeter of experiments in the field.
Speed of the transition	— Organize a program coordination for pooling learning experiences and accelerating the circulation of their results as widely as possible and for seeing to concurrent advances in the development of all components of the global system so that certain variables not become bottlenecks that slow down the program's efficient rollout.
Pursuit of current operations during the rollout	— Embed the program in current operations in order to anticipate problems and prepare actors for scaling up to the global level. — Rollout options ensuring the continuity of services (hybrid busses, the priority of sites for the rollout, etc.).

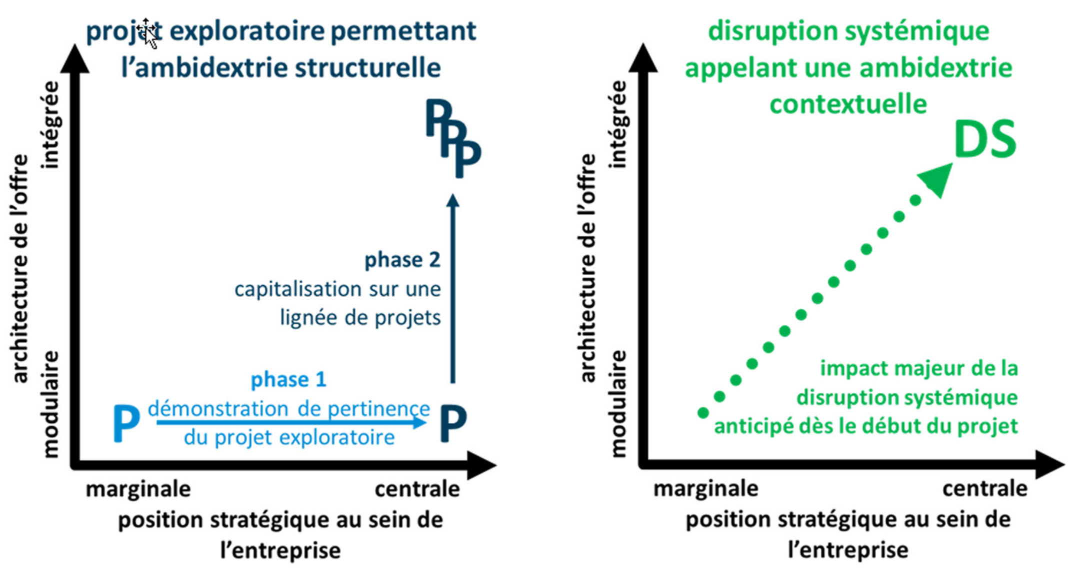

Figure 4: The organizational position of exploratory projects and systemic disruptions

possible. This situation differs from that of automakers (VON PECHMANN et al. 2015, MIDLER 2013), who have to fine-tune control over the speed of the transition toward electric vehicles as a function of less foreseeable external constraints. The full switch from internal combustion engines to electric motors in a short time would be, for global automakers, a senseless risk, since they are unable to anticipate the response of consumers and demands from regulators.

The second reason is related to the architecture of the firm's offer. Structural ambidexterity is based on the capacity to isolate the project from the firm's current operations. Electric busses have a major impact on several systems and processes in public transit companies. Beyond a few limited experiments, electric busses cannot, as shown, be introduced in the offer of services without redesigning the system. Running both electric and thermal busses might create operational conditions that the firm would like to minimize by speeding up the transition. The situation is often different in manufacturing firms, which can devote means of production to specific products and differentiate its sales policy by type of customer or market segment. In other words, the offer of public transit services is integrated whereas the offer of products is more modular (BALDWIN & CLARK 1997, VOSS & HSUAN 2009). Managing a transition in a modular context can be done using a model of structural ambidexterity, whereas an integrated offer favors contextual ambidexterity. Figure 4 depicts these two different configurations.

The choice of contextual ambidexterity has some disadvantages, as pointed out in the literature (GIBSON & BIRKINSHAW 2004): actors might not be available because they are busy with current operations; risk aversion might be strong if changes are made too suddenly; the qualifications might be wanting that are needed to design scenarios different from what already exists. To avoid these risks while benefitting from the advantages of contextual ambidexterity, a strong program function has been introduced for orchestrating the activities of the personnel who take part in the transition, without taking them out of their operational units. This choice is the opposite of the one made by certain automakers (*e.g.*, Daimler) in relation to the development of "autonomous" taxis (MIDLER *et al*. 2019). In this typical example of a systemic disruption, a separate, autonomous business unit is created to bring together hundreds or even thousands of persons representing the various sorts of expertise necessary for the transition; and various partners, technical firms or services of mobility are mustered around this unit so as to cover the full perimeter of providing services of mobility by autonomous taxi. This sort of ambidexterity is structural or mixed (BEN MAHMOUD JOUINI *et al*. 2007).

We cannot yet judge whether these choices are well-founded, since the transitions are still under way. We can, however, remark that these contrasting choices are coherent with the position of the actors behind the steering wheel. For the RATP, the transportation operator, the program has been centered on the integrity of the public transit system. The bus is a vehicle for providing a service, whence a management of the transition that closely associates product design with the offer of services. Automakers, on the other hand, see their autonomous vehicles as a new class of products, complementary to current product lines. These vehicles can thus be developed like a new product. For automakers, the operators of autonomous taxi systems are a supplementary layer, like the managers of vehicle fleets. Some automakers have incorporated in their strategy the possibility of becoming an operator in this new layer, while others seem satisfied with providing vehicles adapted to these specialized operators (like Uber or Waymo, a subsidiary of Google). In any case, their strategies, unlike the RATP's, do not have to take into account existing transportation services. They can, therefore, function in an autonomous structure and adopt a model of structural ambidexterity (the left of Figure 4).

Disrupted offers and customer services

What comes as a surprise in the transition described herein is that an actor is missing who is usually in the forefront of major transitions: the passenger/customer. Is the switch from internal combustion engines to electric motors so transparent for bus passengers that they take no notice of it? This absence is even more surprising since, at first sight, the question of whether customers will adopt electric vehicles was, and still is, a bottleneck in the massive rollout of private electric cars (VON PECHMANN et al. 2016). In this case, a section on a complicated but indispensable topic had to be incorporated in the program, namely the customer's learning experience so that they will be ready to purchase electric cars when the offer is made (VON PECHMANN et al. 2015). Nothing of this sort applies to the RATP's Bus 2025 Program. Although this transition is a disruption for the transportation provider, it does not radically alter the customer experience. The switch to electric vehicles is probably going to be positive for passengers, owing to the much quieter environment in the bus or more fluid mobility, but this situation is not at all comparable with the learning experience that a driver used to an internal combustion engine goes through when switching to an electric motor.

It is worthwhile to dwell on this comparison. The "value" created by the Bus 2025 Program is collective: improvement in air quality air in urban areas. Ultimately, cyclists behind the bus will benefit more than the passengers inside. Since the benefits are collective, it is coherent that public entities (the transit authority) cover the costs and oversee the necessary changes. In the case of private cars on the contrary, individuals pay the costs and learn how to manage an innovation and benefit from it. For this reason, considerable work is necessary to create, through innovative business models and services, an individual experience of electric mobility that will stimulate purchases by individuals.

Emergency management and the "golden triangle"

The Bus 2025 Program illustrates a transition with a schedule. Triggered initially, in December 2013, by the obligation to stop acquiring diesel vehicles by 2025, this timetable was at first a priority but became a deadline under the TECV Act. The economic question was no longer to choose between doing or not doing. It had to do with optimizing the rollout of this transition so as to minimize costs. The program's successive revisions (100%, then 80%, then two thirds of the fleet to be electric busses) and the massive invitation to tender (€400 million for 1000 electric busses) were significant decisions that showed that costs were a factor to be taken into account. The "golden triangle" of quality, costs and production time has to be optimized. The balance between the economics of this program and of the agenda might have been different had the possibility of a slower transition been explored.

Conclusion

We would like to end by raising questions about the opportunities related to these ways of managing a transition. Changing society through a continuous series of incremental stages definitely seems more reasonable than triggering a sudden, global transformation. But is this always possible? Why did the RATP speed up a massive energy transition rather than opt for a smoother transition? Why did plans for electric cars stall for thirty years until a few CEOs, more ambitious than the others, set a foot on the accelerator pedal? Why wait for the Olympic Games in Paris or another big event to start the Grand Paris Express program? The complexity of the latter can be criticized, but we waited decades in vain for it. The tempting answer is, of course, to point to the degree of maturity of the technology to be used and the growth of awareness. This argument is fallacious however. Scientific progress in electrochemistry was not the main factor that made electric mobility take off in 2011. The trigger was, instead, the ambitious industrial programs that attracted the interest of scientists from several disciplines to research in a field that had not previously caused much excitement.

Tartakover, a chess grandmaster, defined the main difference between strategy and tactics as follows: tactics is knowing, what to do when something is to be done whereas strategy is knowing what to do when there is nothing to do. The contemporary world invites us to modestly take stock of our collective capacity for strategy-making. This remark is in line with the conclusions of the studies made since the early 1990s on the concept of emergency management (RIVELINE 1991). In these studies, the sense of an emergency paradoxically emerges as an "*organizational binding force*" (MOISDON 1990) that forces us to transcend contradictions and find compromises between the different value systems and issues that coexist without direct confrontation during the usual operations of an organization. Rather than regretting a definite lack of foresight and preparedness for the transitions to come, the priority should be, in our opinion, to develop our tactical capacities for steering emergences in big programs with complex disruptions. This article is intended to help us learn and improve these capacities.

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