[illegible] PROJE[illegible]
[illegible]AGEMENT

[illegible]ier.com/locate/ijproman

Time-to-market vs. [illegible] Managing speed in Engineering, P[illegible]ement and Construction projects

Sihe[illegible]hmoud-Jouini [a,b,*], Christophe M[illegible] Garel [illegible]

[illegible]ersity Paris XI , 54 Bld Desgranges, 92[illegible]ce
[illegible]ole Polytechnique, 1 Rue Descarte[illegible]
[c] PRISM OEP – M[illegible]d Descartes, Cité Descartes, [illegible]4 Marne La Vallée Cedex 2, Franc[illegible]

Ab[illegible]tract

The time-to-mar[illegible] the comp[illegible]een innovative firms. Research [illegible] gineering has shown [illegible] a delay and as a[illegible]. Our concern in this paper is to [illegible] in the case of Engi[illegible]ction (EPC) projects, where a customer initially contra[illegible] contractor on the [illegible]nd delay. Is time-to-de[illegible]y a key factor? Does its re[illegible] petitive advantage [illegible]ontractor in EPC proje[illegible]ject speed a key variab[illegible] result from other [illegible]t define an analytical [illegible]terize a speed p[illegible] plement this mode[illegible]on projects developed b[illegible]l firm. A v[illegible] conclude by show[illegible]PD project speed man[illegible]

Keywords: Project [illegible]e-to-market; Time-to-deliv[illegible]
Concurrent engine[illegible]

1. Introduction[illegible]

Since the [illegible]nd of the 1980s, th[illegible] products [illegible] become a comp[illegible] larly i[illegible]kets where the [illegible] vant[illegible]h as in th[illegible] S[illegible] NPD pro[illegible] [illegible]value.

[illegible]cern i[illegible] [illegible]of [illegible] tion (EPC) proje[illegible] project fr[illegible]m a contractor.

Time[illegible]anagement in EPC pr[illegible] been [illegible]ed from two different[illegible]

[illegible] we implement this

[illegible]onding author. Te[illegible]

[illegible]addresses: sih[illegible]@poly.polytechnique.fr, [illegible]
[illegible]moud-Joui[illegible]
[illegible]-mlv.fr ([illegible]

0[illegible]$30[illegible]
doi:[illegible]6[illegible]

Table 1
Main characteristics of the studied projects

Project type	Duration	Place	Object of the contract – type of contract	Amount of contract
Construction of a railroad tunnel and bridge	26 months 22 months	England	Construction work Cost + fee contract	£100 million
Construction of two office buildings	16 months	France	Construction work Fixed price	30 million
Construction of civil engineering work on a highway	24 months	France	Construction work Unit price contract	10 million
Construction of four tunnels for extending a subway line	46 months	Hong Kong	Design and build Fixed price	87 million
Construction of a suspension bridge	24 months design 60 months work	Greece	Fixed price Build operate and transfer	585 million
Construction of an underwater tunnel	60 months	Northern Europe	Construction work	2 billion

concept for six major construction projects developed by a large, international contractor. [1] The criteria for choosing these projects were that they had to cover a variety of situations based on the following variables: type of work (building, road construction, etc.), type of contract (fixed price, unit price, incentive clauses, etc.), composition of the group in charge of the project (foreign partners, joint venture, etc.) and location of the project (domestic or international). In each case, a case study was drawn up and approved by the project participants. These case studies were based on an analysis of existing documentation, visits and interviews with a wide variety of those involved in the project at different hierarchical levels (project chief, design engineer, works clerk, general foreman, etc.) and in different organizations (customers, project manager, construction firm, etc.) (see Table 1).

The projects analysis shows that a firm can manage project speed by choosing a planned speed profile at the preparation stage of the project, and by driving an effective profile speed, which may differ from the planned one. The planned speed profile is chosen according to the strategy of the firm concerning the speed management. The effective profile is driven according to the terms of the contract, to the relationship between the customer and to the contractor and/or the importance of the time-to-delivery factor for them. We conclude by discussing the relevance of the NPD speeding up model in the case of EPC projects.

2. Time-to-market reduction in NPD projects

Time-to-market reduction is a competitive advantage for NPD projects Speeding up NPD projects can increase profit margins by reducing the cost and/or increasing the earnings. Time plays a role in these two ways of generating profit : reducing delay can reduce the cost by the reduction of the financial immobilisation [12], and can also, based on an economic analysis of *first mover advantage* [9], create value in markets where obsolescence is central.

Thus, concurrent engineering [4] is a project management method that reduces project delay particularly by using cross-functional teams early in the NPD process and by planning parallel activities on the same project (for example, marketing and engineering work). Midler [11] showed that more than overlapping the project phases, delay reduction lies in the management of the relation between them. He represents a project by two curves: a learning one representing increase in knowledge about the project and a decision-making one representing a reduction in the possibilities of action on the project. The first is a process (shown as a dashed line), where uncertainty about the project characteristics and its feasibility are gradually reduced; the second is a process of action (solid line), where the degree of freedom is steadily reduced as the irreversibility of decisions rises. Managing a project involves trying to resolve this dilemma : at the beginning of the project almost everything can be done but almost nothing is known; at the end, everything is known but almost no possible choices remain (see Fig. 1).

One might think that in order to reduce the delay of the project decisions must be made as quickly as possible. But at the beginning of the project, understanding is at too low a level and it serves no purpose to make hasty decisions. There is a risk of getting off on the wrong track, possibly resulting in costly and time-consuming modifications. Accelerating a project thus requires taking time at the beginning to explore and prepare project

[1] This research won the company's annual Innovation Award in the *Sharing Knowledge* category.

options as thoroughly as possible before deciding on them and putting them into practice. Then all the parameters need to be frozen in order to move towards almost automatic realization. Fig. 2 shows that increasing the average overall speed (i.e., reducing the overall deadline) involves expanding the initial phase, synchronizing the decision phases and drastically cutting the realisation phase.

This analysis points to three important issues:

- The model identifies two different processes, learning and implementation, that have to be managed from the speed point of view.
-

4. For whom the time-to-delivery reduction is a key factor in EPC projects?

We will study under which conditions it is interesting for the customer and for the contractor to reduce the time-to-delivery.

4.1. Time-to-delivery for the customer

The customer can consider the time-to-delivery in different ways.

4.1.1. Deadline and late penalties

Generally, the customer can fix a deadline with late penalties for the contractor if the deadline is not met. This situation is most frequently encountered in construction projects. It corresponds to a situation where the customer has no interest in seeing the work completed before the deadline set in the contract. He wants to have the project achieved exactly at the planned delay: not before and not after. This was the case with Hong Kong's four tunnels extending the subway line.

4.1.2. Incentive clauses

Delay reduction can be a profit-raising factor for the customer. In that case, he will insert incentive clauses into the contract. This is especially the case in the BOT (Build Operate and Transfer) projects where it is worth beginning the operation as soon as possible. In this case, a trade-off between the increase in costs because of the acceleration and the increase in profit because of early operation of the equipment is made by one global firm, which undertakes the development and the market risks, as in NPD projects. The customer manages the time-to-delivery in a dynamic way by latching onto opportunities and finding additional funds in order to accelerate the work and have the project ready in advance of the planned delay.

> This was the case with the office building project. The real estate developer wanted to take advantage of an opportunity for an extra year's lease, since he had found tenants interested in early occupation. He thus came up with significant additional funds to accelerate the work. This was attainable despite the large number of actors belonging to different organizations and because of the partner relation ship and mutual confidence built up over a succession of projects involving the same players. (This team, composed of a developer, engineering firms and construction firms, was on its third project together.)

Finishing early could also be of interest to the customer if this were to enable him to reduce his costs.

> It was the case of the railway tunnel project, which was a cost-plus-fees (8%) contract with bonus and penalty clauses. This scheme functioned as follows. If a compensation event that led to revising project targets occurred, it was necessary to inform the customer of the event within one month, propose arrangements for handling it, calculate the impact on costs, and negotiate an agreement for sharing the adjustments between the customer and the contractor in accordance with the following rules: if the costs fell below the estimate, the contractor received the costs plus a bonus on the difference from the estimate; if the cost was greater than the estimate, the contractor received only costs up to the estimated amount. The customer paid the contractor the additional costs after deduction of a penalty for exceeding the estimate.
> Soon after start-up, the tunnel was dug at a pace that was faster than estimated, gaining three months overall on the deadline initially set.

This project illustrates the fact that the time-to-delivery reduction yields to project cost reduction, under these conditions:

- the importance of a partnership contract [2] (with an open-book procedure), and the existence of a climate of mutual trust between the contractors and the customer, who was aware of the value of finishing the project early even if the infrastructure could not be put into operation right away;
- a phase of detailed and in-depth worksite preparation;
- the importance of a capacity for ongoing progress, which made it possible to make use of a learning strategy between the beginning and the end. This was made possible, in particular, by the location of the design on the worksite.

In conclusion, the customer can consider time as a resource, as in NPD projects.

4.2. Time-to-delivery for the contractor

In this section, we will study in particular the case of projects where the customer is not interested in reducing the delay. We can report to the section before, in case he is interested in.

One might imagine that an early completion relative to the initial schedule would enable the contractor to free up resources early. After balancing the gains with the cost of this acceleration, the contractor could be interested in a reduction of the time-to-delivery. But in EPC projects, the contract freezes the cost-delay-quality trade-off based on the project studies and worksite arrangements. This freezing is even more rigid when the contract includes time milestones that fix the main steps in the project. [3] Any change in this planning requires negotiation with the customer, who is often reluctant to accept any modifications out of fear that accelerating

[2] The two parts being governed by the same contract, including the same incentive clauses.

[3] Note that identifying contractual phases can play a very positive role by obliging the project team to complete steps that the latter might tend to neglect, with potentially harmful consequences.

the work could degrade the quality of the end product – unless, of course, the customer gains from the time-to-delivery reduction, which brings us back to the cases studied above.

So, it is unusual for the contractor to reduce the time-to-delivery. The contractor wants to avoid any urgent and costly changes in order to complete the project within the scheduled timeframe. This is particularly the case when the project encounters problems and does not take place according to the planned process. The contractor must analyse the reasons and take measures. In that case, the project might require modifications of design, methodology, organization and/or resources committed in order to meet the agreed-upon deadline. It is often possible to catch up to the initially scheduled speed with the additional allocation of resources (expanding the teams, working longer hours than scheduled) as well as by modifying the original jobsite arrangements, but this results in additional costs.

For instance, in the railroad bridge, the original organization of the works was to build sequentially from the east bank and then the west in order to reuse the tools and to exploit the learning acquired during the overall course. When it became clear that the bridge could not be completed within the deadline, not only were the initial design revised and the final deadline postponed, but it was also decided to shift to simultaneous construction from both banks resulting in doubling up on the tools and cutting the overall learning effect in half.

Such revisions inevitably necessitate negotiation and partnership relation with the customer.

For instance, in the underwater tunnel project the contractor quickly proposed changes in the design so as to significantly accelerate the pace of completing the tunnel segments. But the customer was not willing to accept the changes until it became apparent that, using the initial design, the tunnel would not become available within the set timeframe.

Therefore, the time-to-delivery reduction is not able to generate higher margins for contractors unless there is an initially flexible contract or a favourable climate for negotiation.

The role played by initial contract flexibility in customer negotiations is highlighted in the BOT bridge project. Here, the original commitment concerned a functional definition of the work, where "the only technical fixed point was the position of the pillars, due to geological tests that could not be redone."

A favourable situation for negotiation is found above all in relationships involving ongoing partnerships between the customer and contractor, like in the case of the building project.

In conclusion, the projects analysis shows that the aim of the contractor is to avoid costly changes. Time-to-delivery reduction for the contractor depends strongly on customer attitude, because it requires negotiation. Thus, contract flexibility and the relationship between the project actors are important. Without looking to reduce the time-to-delivery, the contractor in an EPC project must manage the time-to-delivery in order to:

- achieve it as fixed in the contract,
- reap his profit by controlling his costs in case of unanticipated events that may delay the project or force him to modify the project organization in a costly way,
- answer to the flexibility demand of the customer if he asks him to reduce the time-to-delivery.

In order to study the speed management in EPC projects, we propose the project speed profile concept, that we will define and apply to the projects studied.

5. Managing speed in EPC projects

We propose to break a project down into four basic phases: a preparation phase, an execution phase split between a transitory learning phase [14] and a permanent ongoing one and a back-up phase. Each of these phases has its own specific progression. We define the speed as the progression of the project achievement per unit of time, such as the number of *m* excavated in a tunnel per week or the number of floors built per week.

We can represent the speed of the project by the curve of Fig. 3, where the different phases with their specific progressions are distinguished. We will call this a speed profile or scheme.

Based on the six projects analysed, we will show that the contractor manages the project speed in two steps. First, during preparation of the project and anticipation of his profit, he plans to follow one planned speed profile. Then, as the project progresses, he drives the effective speed profile and reacts based on his previous expectations.

5.1. Planned speed profiles

During the bidding phase and contract negotiation, the contractor works on a planned speed profile in order

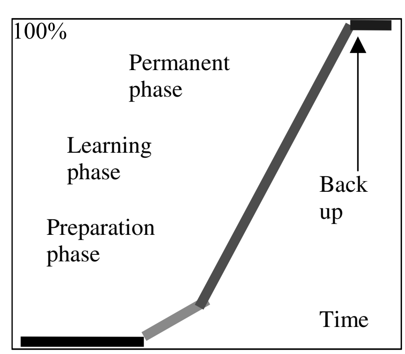
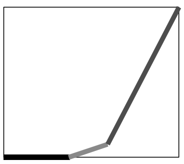
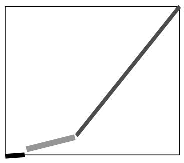
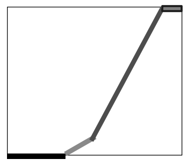
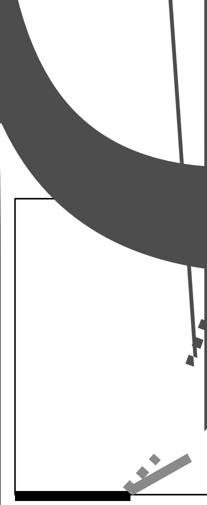


Fig. 3. Speed profile.

Table 2
Planned speed profiles

Industrial profile	Learning profile	Back-up profile
		



to anticipate his costs. He can choose between at least the three following planned speed profiles (see Table 2). These profiles reveal the resource deployment strategy of the contractor and the project organization he has anticipated.

In the first profile, the *industrial* one, the preparation and the design phase are emphasized. Several processes are tested during the preparation and the learning phases, and executed during the permanent one. The *industrial* speed profile was planned in the underwater tunnel and the bridge projects. This profile is termed *industrial* because the approach to speed is similar to that of NPD projects for industrial products, where the firm invests in studies and in-depth exploration before locking in and freezing the choices in an effort to obtain a return on the upstream phases. In the case of EPC projects, this preparation phase is based on a very detailed phase of estimates, risk analysis and alternative organizations because of the numerous unpredictable events that may take place.

The *learning* profile is more common in construction projects: the preparation phase is not long (becaus [redacted] generally the payments begin with the execution of [redacted] work). Optimisation of the processes is obtained a [redacted] long learning phase. Such was the profile of th [redacted] Kong tunnel.

In the *back-up* profile, the contractor ex [redacted] permanent phase than necessary in order [redacted] up that will absorb the unexpected [redacted] reorganizing the project. A margi [redacted] integrated into the planned profil [redacted]

For each of these planned [redacted] profiles are possible.

5.2. Effective speed pro [redacted]

During the pro [redacted] and has to drive [redacted] six constructi [redacted] effective sp [redacted]

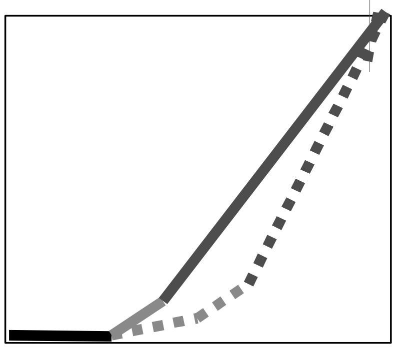
5.2.1. [redacted]

[redacted]

planned profile is reached be [redacted] (see Fig. 4). The learning pl [redacted] because of anticipated actio [redacted] preparation or pleasant surp [redacted] when excavating a tunnel, fo [redacted] tor can negotiate an early co [redacted] the customer who is intere [redacted] he can continue the proj [redacted] because of the learnin [redacted] permanent speed [redacted] one.

This was p [redacted] project and [redacted] than exp [redacted]

In [redacted] and [redacted] t [redacted]



5.2.3. *Difficult start-up and late convergence*

In this profile the difficulties of the learning phase spread to the permanent one and are responsible for the late beginning of this phase. In order to reach the planned delay, the permanent phase is accelerated with deleterious effects on the project cost because of reorganization and/or addition of resources (human or material).

The underwater tunnel project is an example of this profile.

Two factors are particularly relevant for these two latest profiles:

- the importance of confidence among the project partners, enabling the acceleration of learning throughout the project and confining breaking-in problems to the beginning of the project,
- the mobilizing impact of the final deadline ("going flat-out"). As the degree of urgency increases, difficult compromises can be worked out more rapidly than when significant deadlines are distant.

5.2.4. *Permanent catch-up*

In this profile the project encounters many difficulties at the beginning, and the permanent phase is constantly delayed. It is as if the project has no preparation and no learning phase. It is based essentially on the responsiveness of the actors. The course of the project is a succession of events to which the actors respond in an atmosphere of urgency and crisis.

This profile is illustrated both by the four tunnels project in Asia and the bridge in the railroad project (see Fig. 6).

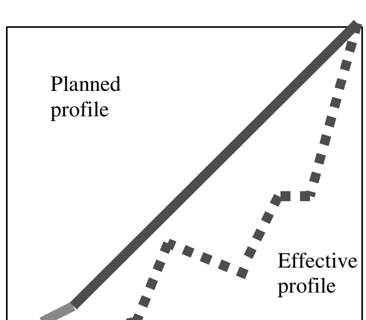


Fig. 6. Permanent catch-up profile.

6. From speeding up NPD projects to managing speed in EPC projects

Is the concurrent engineering model relevant for EPC projects? While it is true that in EPC projects the overlapping that characterizes the concurrent model cannot be implemented and projects generally follow a stage gate model, this does not mean that concurrent engineering is totally irrelevant in these projects. Some of its guiding ideas, such as anticipation and time management, could be very fruitful in EPC projects and could offer new ways to think about these projects. We will discuss the relevance of the concurrent model for EPC projects through the main characteristics of these projects: the three Cs, the Content, the Context and the Contract. These characteristics are usually designated by professionals as obstacles to any transfer of industrial management methods to the construction field. We will discuss the three C specifics in the case of the six project studied.

The content: The product is a prototype, a unique realisation, and there is not a volume-based production following development, as in auto-manufacturing, for example. But viewed in more detail, significant repetition can be identified in the components and the tasks, and learning can take place between the beginning and the end of the construction phase, resulting in time gain. Accordingly, adapting the product design in order to promote these repetitions can result in a speed-up of the project. In that case, the design phase can last longer and be considered an investment phase leading to significant learning and time gaining. The projects analysed illustrate these repetitions.

> The railroad tunnel reveals great repetition both in the excavating phase (about 2000 cycles) and in concreting (about 275 cycles).
> The BOT bridge is composed by four highly similar piles.

These repetitions can also be fostered by the preparation of the realization and by the constitution and deployment of the work teams.

The context: The product may have an impact on a large scale. Thus, many external actors, especially public ones, can interfere. The environment also can lead to unforeseeable events and substantial uncertainty (the local and regulatory context, geological and climatic contingencies, innovations in the structure and/or the construction process, etc).

The railroad tunnel benefits from good surprises concerning the geological conditions and the excavating was faster than planned.
On the other hand, the Hong Kong tunnels encountered hard geological conditions.

Emphasizing the importance of these contingencies means that anticipation and preparation must be combined with vigilance, responsiveness and ongoing learning. While it is unrealistic to think that all disturbances can be eliminated, the consequences they engender depend to a large extent on the managerial know-how developed to anticipate, detect and deal with them.

Even if the BOT bridge project occurs some problems in the beginning, it is the anticipation that permits to react rapidly and find other solutions. The accelerating of the work in the office building was not anticipated but the fact that actors had worked on several problems similar to the speeding up ones help them to find solutions.
It is probably because of a lack of anticipation and preparation of the explosive materials transport or the coordination with the design firm that the Hong Kong tunnels followed a permanent catch up profile.

We focus here on anticipation as an interactive and learning process rather than on the planning result.

The contract: The trade-off between specifications, cost and delay is frozen at the beginning of the project can. It can often, be optimised in the course of the project but it involves then many actors and necessitates lengthy negotiations. The interactive anticipation process described above needs to be supported by flexible contract and partner relationship.

We studied projects such as the BOT bridge, the office building or the railroad tunnel, where the time-to-delivery was reduced. In these projects, the contractor and the client considered time-to-delivery as one of the project parameters to be managed, representing a mean of action and not solely a cost to control. The speed profiles (difficult start-up with controlled convergence for the bridge and accelerated profile for the latest) show that the way to accelerate the project as a whole does not necessarily lie in cutting down the phases proportionally but in emphasizing some phases over others and structuring their interconnection differently. Managing project speed thus comes down to answer the following questions: How much time should be devoted to the exploratory and the design phases? When should construction work, a costly and irreversible phase, begins? What should the relationship be between the design phase and the construction phase?

These examples show also that, in EPC projects, the flexibility of the contract and the implicit relationship that it permits play a huge role in creating a win-win situation necessary to manage time as a resource and not solely as a cost.

7. Conclusion

The management of time in the projects was studied primarily for NPD projects from a time-to-market reduction perspective. Our goal in this paper was to promote greater understanding of project management by filling a gap concerning the management of time in EPC projects from a time-to-delivery perspective.

We have shown how the concurrent engineering model reduces time-to-market and speeds NPD projects. We discussed the importance of the time-to-delivery reduction for the customer and for the contractor. We showed that in EPC projects, customers can consider time as a resource and, in that case, they will encourage the contractor to reduce the project duration. But if they are not interested in early delivery, the contractor will generally go with the achievement of the delay fixed in the contract, reaping profit by controlling costs, particularly in the case of a required reorganization of the project. The reputation of the contractor consists of his ability to respect the time-to-delivery and to satisfy the customer when he asks to speed up some phases.

Based on an analysis of six projects, we distinguish different phases in a project : preparation, learning, ongoing and back-up, each having its own speed. These phases represent the global speed profile concept. The firm chooses a planned speed profile before the start of the project and then drives the effective speed profile according the planned one or in a different way in order to latch on the opportunities and react to surprises. Managing speed is choosing a planned profile corresponding to the speed strategy of the firm and then driving the course of the different phases and their connection. We characterized three types of contrasting planned profiles: the industrial, the empirical and the back-up one, and four speed effective profiles : the accelerating, the difficult start-up with controlled convergence and late one, and the permanent catch-up.

This depiction of the variety of possible speed profiles normally falls apart with general, over-simplified observations that treat speed as the simple result of other project dimensions. In contrast, our paper aims to show that, in EPC projects, time can be considered a resource and speed can be managed.

The goal in this paper was to remain within the framework of a structural analysis. In further research, a subsequent causal analysis might consider the contractor's ability to manage the planned and effective speed profiles. We could distinguish external aspects, such as relationships with the customer or the environment of the project, and internal ones, such as composition of the team, learning from past projects, product and process integration.

Subsequent research, which is already under way, will answer the following questions:

- How can project supervisors be trained in order to handle these aspects?
- How can lessons on good speed management practices be shared?
- How promote the development of partnership practices which seems to be the cornerstone for effective speed management?

Acknowledgements

We thank the referees, Jonas Söderlund and Florence Charue-Duboc for their fruitful comments.

References

[1] Brown SL, Eisenhardt KM. Competing on the edge. Cambridge: Harvard Business School; 1998.
[2] Callahan J, Moretton B. Reducing software product development time. Int J Project Manage 2001;19(1):59–70.
[3] Chelaka M, Abeyasinghe L, Greenwood DJ, Johansen DE. An efficient method for scheduling construction projects with resource constraints. Int J Project Manage 2001;19(1):29–46.
[4] Clark KB, Wheelwright SC. Revolutionizing product development: quantum leaps in speed, efficiency and quality. New York: Free Press; 1992.
[5] Clough R, Sears G. Construction project management. New York: Wiley; 1991.
[6] Cordero R. Managing for speed to avoid product obsolescence. J Product Innovation Manage 1991;8:283–94.
[7] Cova B, Hoskins S. A twin track networking approach to project marketing. Eur Manage J 1997;15(october):546–56.
[8] Dissanayaka S, Kumaraswamy M. Evaluation of factors affectinf time and cost performance in Hong Kong building projects. Eng Constr Architect Manage 1999;6(3):287–98.
[9] Lambkin M. Order of entry and performance in new markets. Strategic Manage J 1988;9(summer):127–40.
[10] Leu SS, Chen AT, Yan CH. A GA-based fuzzy optimal model for construction time-cost trade-off. Int J Project Manage 2001;19(1):47–58.
[11] Midler C. L'auto qui n'existait pas; Management des projets et transformation de l'entreprise. Paris: InterEditions; 1993.
[12] Rosenau MD. Speeding your product to market. J Consum Marketing 1988;5:23–40.
[13] Stalk Jr G, Hout TM. Competing against time. New York: Free Press; 1990.
[14] Thomas RH. Learning curve models of construction productivity. J Constr Eng Manage 1986;112(2).